ENVIRONMENT 2010

THE STATE OF THE ENVIRONMENT REPORT

VOLUME III

Risk Evaluation Reports

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Washington Environment 2010

State of Washington
October, 1989

Washington Environment 2010
State of the Environment Report
Volume III

Risk Evaluation Reports

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INTRODUCTION

This document is Volume III of a three volume State of the Environment Report and is a compilation of reports on the relative human health and/or ecological risks associated with 23 environmental threats in the state of Washington. These reports were generated in support of Washington Environment 2010, a long-range planning and public outreach initiative aimed at identifying - and ultimately addressing - the state's environmental priorities.

The first phase of Washington Environment 2010 involved the evaluation of the past, present, and likely future condition of the state's environmental resources, including analyses of the human health and ecological risks and economic damages associated with 23 threats to those resources. The results of the human health and ecological risk analyses are presented here. The draft results of the economic damages evaluation are presented separately in Appendix A. The limitations of this draft economic damages report are discussed in more detail on pages 6 and 7 of Volume I. Also, detailed characterization of the state's environmental resources (i.e. air, water, land, wetlands, fisheries, and wildlife) are presented separately in Volume II of the State of the Environment Report.

These papers were generated for Washington Environment 2010 by a Technical Advisory Committee (TAC) - which consisted of approximately 26 environmental professionals from various state agencies - with support from the project staff and various consultants. The TAC first identified and defined those environmental threats they considered to be of primary concern in the state. These reports represent the TAC's attempt to systematically gather and analyze the best available information on those threats.

When using this document, it is critical that the reader understand the context in which the analyses were prepared, and their major limitations:

- The analyses are intended to supplement rather than replace the judgement of environmental professionals and the general public in the environmental priority-setting process.

- It is important to note that these draft reports are intended to identify the major human health and ecological risks associated with the 23 environmental threats, and to highlight important differences among those threats <u>for the purpose of comparison</u>. Both the analytic approach and the data available to support that approach, are limited. Consequently, these reports are <u>not</u> intended to be comprehensive or precise. The results of these analyses should <u>not</u> be construed as accurate estimates of the absolute levels or risk associated with the various threats; rather, they should be viewed as rough approximations of the <u>relative magnitude</u> of these issues.

- It is also important to recognize that these reports were prepared within a short timeframe, and with limited resources. All of the analyses, then, are based on existing information; no original research was conducted.

- Finally, the limitations noted above, should be carefully considered prior to quoting or citing these reports.

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for
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EXECUTIVE SUMMARY

Ambient air pollution is a significant risk to human health and the environment in Washington State. Though impressive strides have been made in our effort to improve air quality over the past 20 years, the pressure on the air resource - the air that we breathe - will continue to grow as our population grows. This report presents the risks associated with ambient air pollution. Though the results are generally quantitative, they should only be considered rough estimates to be used in a comparative assessment of relative risk. In that context, we feel the results fairly reflect the threat to the air resource from ambient air pollution.

This study does not include impacts from pesticides, radon, acid rain, and indoor air pollution. These environmental threats were analyzed by other Environment 2010 technical advisory sub-committees.

The primary resource affected by air pollution is the ambient air. In addition, air pollution poses a significant threat to the land resource and the water resource from acid deposition, deposition of particulates and toxic aerosols, ozone depletion and global warming.

There are probably impacts on the wildlife resource from air pollution. Animal species are probably affected when a human health threshold is exceeded.

The human health risk results of this assessment agree with what we would expect intuitively - pollution is where the people are. "We have seen the enemy, and it is us" is an apt description of the air pollution problem in the state. From the gasoline we use to fuel our cars to the wood we burn in our fireplaces, the largest contributor to human health risks in the state is ourselves. For example:

- The entire population is at risk from elevated levels of ozone, a pollutant formed in the atmosphere when organic vapors (like gasoline) react with other pollutants and sunlight.

- Over 1,700,000 people live in areas that exceed the federal standard for carbon monoxide, virtually all of which comes from automobile tailpipe emissions.

- Nearly 1,400,000 people will be exposed to levels of fine particulates high enough to cause respiratory distress. Motor vehicles and woodstoves are the primary sources in most areas.

- Xylene and toluene, mostly from vehicle re-fueling, are emitted in sufficient quantities to potentially affect over 2 million people in urbanized areas throughout the state.

- Woodburning is the primary source of manganese emissions in the state. Our modeling shows that nearly 2 million people live in areas likely to be effected by elevated manganese levels.

It is clear from the lack of information about impacts on the environment from ambient air pollution (i.e. the Ecological Risks) that the threat to human health has been our principle concern. Few conclusions can be drawn from our ecological risk analysis, except to say that there is a very real need to study more closely the effects of air pollution on the ecology of the state. Our conclusions:

- There is evidence to indicate that elevated levels of ozone, experienced throughout the state, are probably damaging sensitive plant species. From our study of the probable impact on hardwood trees, we would speculate that similar damage is likely to occur in other plant species that have not as yet been studied.

- The impacts from toxic air pollutants are most likely very localized - in the areas of maximum impact from large point sources.

- Air pollution can significantly impact water ecosystems, especially in the "microlayer", that is the interface between the ambient air and the affected waterbody. The microlayer is a particularly important, and potentially sensitive, ecosystem suggesting the need for further analysis.

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WASHINGTON ENVIRONMENT 2010

Report on Environmental Threat from Ambient Air Pollution

I. Background

A. DEFINITIONS AND EXCLUSIONS

This report summarizes the risks to human health and the environment from ambient air pollutants. For the purpose of this report, ambient air pollution includes all forms of degradation of the ambient air resource, with the exception of radioactive pollutants (including radon), pesticides, and the secondary impact of acid deposition. Radon, radioactive releases and acid deposition are analyzed in other Environment 2010 Risk Reports. Note that ambient air does not include indoor air pollution, which is also analyzed elsewhere in the Environment 2010 report. Finally, risks from catastrophic releases (such as the Bhopal tragedy) are discussed in the Accidental Release portion of the Environment 2010 report.

B. RISKS FROM AMBIENT AIR POLLUTION

Virtually all valued resources are affected by excessive levels of some air contaminant. This report analyzes human health risks (both cancer and non cancer), ecological risks and the economic damages resulting from ambient air pollution.

Air pollution is a significant risk to human health and the environment in Washington State. One main reason for this is that air pollution, unlike hazardous waste or water pollution, cannot practically be contained once it is emitted. Thus, exposure to polluted air for the average individual who must work, travel, exercise, and otherwise move about is practically unavoidable. Some of the health risks associated with air pollution are lung diseases, such as chronic bronchitis and emphysema, cancer, neural disorders, asthma, and eye irritation. Environmental damages from air pollution include foliar damage, reduction in growth, alterations in reproductive capacity, and alterations in susceptibility to pests and pathogens. Air pollutants impact human health and the environment directly via inhalation and skin contact, and indirectly via the food chain from contaminants taken up through soil deposition and inhalation.

Hundreds of air pollutants are emitted from a wide variety of sources. Various heavy metals, volatile and other organic compounds, inorganic compounds, and particulate matter have been classified as air pollutants, causing acute and chronic cancerous and non-cancerous harm. Ambient air pollutants emitted from specific industrial sources such as smoke stacks are called point sources. Examples of major point sources in Washington are pulp mills, oil refineries, aluminum smelters, and electric utilities. Pollutants emitted from industrial facilities through leaking valves, spills, evaporation from tanks or holding ponds, or during material transfers are called non-point or area sources. Ambient air pollutants coming from home use of paints and solvents, construction site dust and painting, and slash burns are also considered non-point or area pollutants. Automobiles, trucks, trains, planes, and ships are classified as mobile sources of air pollution.

Ambient air pollutants can have localized impacts, that is, they only impact the area immediately surrounding their point of origin, or they can have area-wide impacts causing harm many miles from their point of origin. Carbon monoxide is an example of a pollutant that primarily has localized impacts; sulfur dioxide, because of its contribution to acid rain, and nitrogen dioxide because of its contribution to smog formation are examples of pollutants that have area-wide impacts.

Air pollution has long been recognized as a serious pollution problem. Several large industrial cities - Chicago, Cincinnati, Pittsburgh, and New York, passed smoke emission regulations as early as the latter part of the 19th Century. "Killer fogs" in Donora, Pennsylvania in 1948 and in London in 1952 focused national attention on the potential health hazards of air pollution, spurring increased legislative activity at the state and federal level to control air pollution. The first federal Clean Air Act was passed in 1963 and was substantially strengthened in 1970, giving the federal government, through the Environmental Protection Agency (EPA), the lead role in controlling air pollution. Washington State passed its version of the Clean Air Act in 1967 and has since incorporated the requirements of the federal Clean Air Act.

The federal Clean Air Act classified air pollutants as either criteria pollutants or non-criteria pollutants. Criteria pollutants are those pollutants commonly found throughout the country which pose the greatest overall threat to air quality. There are six critera pollutants: carbon monoxide, ozone, particulate matter, lead, nitrogen dioxide and sulfur dioxide. EPA has set ambient air quality standards for these pollutants. Non-criteria pollutants are those remaining air contaminants which can contribute to an increase in mortality or serious illness. EPA has established emission standards for very few non-criteria pollutants.

This report presents the risks associated with criteria and non-criteria pollutants separately.

II. Human Health Risks

A. DESCRIPTION OF ANALYTICAL APPROACH AND DATA SOURCES

1. Pollutants Analyzed and Their Effects

a. Criteria Pollutants

The reader is referred to Appendix 1 for a thorough discussion of the health effects from criteria air pollutants. The following is a summary of impacts from elevated pollutant levels:

CARBON MONOXIDE: impaired learning ability, reduced vigilance, decreased manual dexterity, headache, dizziness, lassitude and increase in angina pain.

OZONE: eye irritation, chronic bronchitis, emphysema, pulmonary edema.

PM10: asthma, pneumonia, bronchitis, lung cancer

SO2: respiratory symptoms, lung disease, increased frequency and severity of respiratory disease.

LEAD: visual, motor, perceptual and learning deficits, hyperactivity

b. Non-Criteria Air Pollutants

As noted previously, the list of non-criteria air pollutants is virtually endless. We have limited our analysis to a selected list of 24 pollutants and pollutant classes (e.g. dioxins, POMs) which represents only a fraction of the total number of compounds in the ambient air. The pollutant list was selected after review of the Six Month Study[7] list, the Region 10 Comparative Risk Study[1], the South Coast Air Quality Management District report[8], the Puget Sound Air Pollution Control Authority's toxic pollutant ranking[9] results, the Washington air toxics inventory (1984)[10], and the Washington Acceptable Ambient Level guideline (AALs)[11]. We also reviewed a study by Radian Corporation[12] of toxic emissions in Washington and considered all of the pollutants in their study for inclusion in this report. The pollutants we selected are the major ones identified in the ambient air for which there is health information. They are as follows:

Acetaldehyde	Arsenic
Asbestos	Benzene
Beryllium	Cadmium
Carbon Tetrachloride	Chloroform
Chromium (VI)	Dichloromethane
Dioxin 2,3,7,8 TCDD	Ethylene Dichloride
Ethylene Dibromide	Fluoride
Formaldehyde	Manganese
Mercury (Hg)	Nickel (Ni)
Nickel-Refinery dust	Perchloroethylene
Phenols	POMS (BaP)
Toluene	Trichloroethylene
Xylene	

Health effects from each of these 24 pollutants are listed in Appendix 2 (non-cancer effects).

Tables 1 ,2 and 3 below indicate the risk thresholds used by the committee for this comparative risk report. In addition, the source of the risk threshold is included for reference. The Tables are broken out according to type of risk - cancer risk from chronic exposures (Table 1), non-cancer risk from chronic exposures (Table 2), and non-cancer risk from acute exposures (Table 3).

Note in these tables that the AAL is inversely proportional to the unit risk factor times 10^{-6}. In words, the AAL is the pollutant concentration at which the increased risk is 10^{-6}, or one in a million over a 70 year period of suffering the applicable health impact.

Table 1
Cancer Risk Factors

POLLUTANT	Unit Risk Factor (URF) $(ug/m^3)^{-1}$	AAL= 10-6/URF (ug/m^3)	EVIDENCE CLASS
Acetaldehyde	$2.200x10^{-6}$	$4.500x10^{-1}$	B2, CRAVE
Arsenic	$4.300x10^{-3}$	$2.300x10^{-4}$	A, CRAVE
Asbestos	$2.300x10^{-1}$*	$4.348x10^{-6}$*	A, CRAVE
Benzene	$8.300x10^{-6}$	$1.200x10^{-1}$	A, CRAVE
Beryllium	$2.400x10^{-3}$	$4.200x10^{-4}$	B2, CAG
Cadmium	$1.800x10^{-3}$	$5.556x10^{-4}$	B1, CRAVE
Carbon Tetrachloride	$1.500x10^{-5}$	$6.700x10^{-2}$	B2, CRAVE
Chloroform	$2.300x10^{-5}$	$4.300x10^{-2}$	B2, CRAVE
Chromium (VI)	$1.200x10^{-2}$	$8.300x10^{-5}$	A, CRAVE
Dichloromethane	$4.700x10^{-7}$	2.130	B2, CRAVE
Dioxin 2,3,7,8 TCDD	$3.300x10^{-1}1$	$3.030x10^{-8}$	B2, CAG
Ethylene Dichloride	$2.600x10^{-5}$	$3.800x10^{-2}$	B2, CRAVE
Ethylene Dibromide	$2.200x10^{-4}$	$4.545x10^{-3}$	B2, CRAVE
Fluoride	N/A	N/A	N/A
Formaldehyde	$1.300x10^{-5}$	$7.692x10^{-2}$	B1, CRAVE
Manganese	N/A	N/A	N/A
Mercury (Hg)	N/A	N/A	N/A
Nickel (Ni)	N/A	N/A	N/A
Nickel-Refinery dust	$2.400x10^{-4}$	$4.167x10^{-3}$	A, CRAVE
Perchloroethylene	$5.800x10^{-7}$	1.720	B2, CAG
Phenols	N/A	N/A	N/A
POMS (BaP)	$1.700x10^{-3}$	$6.000x10^{-4}$	B2, CAG
Toluene	N/A	N/A	N/A
Trichloroethylene	$1.700X10^{-6}$	$5.900X10^{-1}$	B2, CAG
Xylene	N/A	N/A	N/A

* Asbestos concentrations given in fibers per ml

Reference:F. Hauchman/OAQPS 6/3/88. Unit risk estimates from Carcinogen Assessment Group (CAG) and verified by the Carcinogen Risk Assessment Verification Effort (CRAVE), except as indicated.

Assumptions: All chromium emissions are Chromium VI. 15% of POM emissions are Benzo(a)pyrene (BaP). 10% of Dioxin emissions are 2,3,7,8 TCDD

Table 2
NON-CANCER CHRONIC RISK THRESHOLDS

POLLUTANT	AAL ug/m3	SOURCE OF AAL	REF. DOSE mg/kg/day
Acetaldehyde	See acute		
Arsenic	Cancer	N/A	$1.4X10^{-3}$
Asbestos	Cancer	N/A	N/A
Benzene	Cancer	N/A	N/A
Beryllium	Cancer	N/A	$5.0X10^{-3}$
Cadmium	Cancer	N/A	$2.9X10^{-4}$
Carbon Tetrachloride	Cancer	N/A	N/A
Chloroform	Cancer	N/A	N/A
Chromium	Cancer	N/A	$5.0X10^{-3}$
Dichloromethane/MeCl	Cancer	N/A	N/A
Dioxins 2,3,7,8 TCDD	Cancer	N/A	$1.0X10^{-9}$
Ethylene Dichloride	Cancer	N/A	N/A
Ethylene Dibromide	Cancer	N/A	N/A
Fluoride	34.0	MASS,1987	Case by case
Formaldehyde	Cancer	N/A	N/A
Manganese	31.0	N.CAROLINA	N/A
Mercury (Hg)			$5.1X10^{-5}$
Alkyl Hg cpds	0.06	N.CAROLINA	N/A
Vapors	0.60	N.CAROLINA	N/A
Aryl and inorganic	0.60	N.CAROLINA	N/A
Nickel (Ni)	0.18	MASS,1987	$2.0X10^{-2}$
Perchloroethylene	Cancer	N/A	N/A
Phenol	52.0	MASS,1987	N/A
POMs (Benzo(a)pyrene	Cancer	N/A	N/A
Toluene	51.0	MASS,1987	N/A
Trichloroethylene	Cancer	N/A	N/A
Xylenes	59.0	MASS,1987	N/A

All AAL limits for noncarcinogens are 24 hour TWA. All limits for carcinogens are annual averages. MASS refers to the Massachusetts Chemical Health Effects Assessment Methodology (CHEM) Method to Derive Acceptable Ambient Limits. N. Carolina refers to proposed AALs by the North Carolina Department of Natural Resources and Community Development, 1987. Both states' AAL methods are characterized by a case by case review of the applicable occupational exposure limit and application of "adjustment factors" as appropriate to account for review findings. N. Carolina is used for chemicals without a MASS AAL.

Table 3
Acute Exposure Qualitative Effect Information

POLLUTANT	EFFECT	CONCENTRATION	SOURCE
Acetaldehyde	Acute irritant	15 ppm/15 min	N.C. AAL
Fluorides	Acute irritant & chronic toxicant; nosebleeding, nausea	0.25 mg/m3 1 hr.	N.C. AAL
Phenols	Acute irritant & acute systemic toxicant; toxicity to lungs, heart, liver, kidney	0.25 ppm 1 hr.	N.C. AAL
Toluene	Acute systemic chronic toxicant; reaction time prolongation & decrease in pulse rate; decrease systolic b.p.	15 ppm 15 min.	N.C. AAL
Xylene	Acute irritant & chronic toxicant	15 ppm/15 min	N.C. AAL

2. Methodologies for Estimating Risks from Criteria Pollutants

The basic approach to determining health risk from criteria air pollutants (particulate matter, carbon monoxide, ozone, lead, sulfur dioxide and nitrogen dioxide) by this project was to estimate the population living within areas which exceeded a risk threshold. Where possible, methods used in the EPA Region 10 Comparative Risk Project[1] were followed. Deviations from these methods are noted. One consistent difference is that we stated all non-cancer risks in terms of "number of people at risk" without regard to the duration of the event, whereas often the Region 10 analysis stated risk in terms of the number of days above a standard.

For a complete discussion of the risk thresholds and the resulting health impacts used in these methodologies, the reader is referred to Appendix 1. The severity of the impact in some cases is rated generally as either high or low, where high is ranked equal to or greater than 4 in the table provided in Appendix 12, and low when the ranking was 3 or less.

a. Particulate Matter

Particulate matter can be a health risk when fine particles (generally less than 10 microns in diameter) get past the body's natural defenses and penetrate deep into the lungs. We refer to these fine particles as PM10 (for particulate matter of 10 microns or less). Epidemiological studies have shown a link between elevated particulate levels and several health impacts including premature mortality and restricted activity days.

The following formula is derived from two studies, both of which were stated in terms of the annual arithmetic mean of total suspended particulate (TSP) levels. This formula was converted to one based on PM10 by assuming that 46% of TSP is PM10 (the national average TSP to PM10 ratio). This figure (46%) is generally consistent with data collected in Washington State.

$$\# \text{ people at risk} = \text{sum } [5.7\text{x}10^{-6} * (PM10_j - 40) * POP_j]$$

where:

$PM10_j$ = annual average PM10 in ug/m3 in location j
POP_j = total population in location j

The EPA Region 10 method for determining restricted activity days also relied on average annual concentrations of PM10. Intuitively, we do not feel it is accurate to assume that an area which does not average 40 ug/m3 (the annual average figure used by Region 10) has no days during which activity is restricted. Data for PM10 are broken out by areas with exceedances of the 150 ug/m3 24 hour standard, which is the threshold we will use in the following equation. We will use the 24 hour standard as a measure of the risk to sensitive people according to the following formula:

$$\# \text{ people at risk} = [\# \text{ sites with exceedance} * POP * F]$$

where:

POP = total population in locations with exceedances
F = fraction of population sensitive to elevated values

b. Carbon Monoxide

Carbon monoxide (CO) indirectly reduces the oxygen-carrying capacity of the blood. This is particularly a problem for people with heart or respiratory problems.

The Technical Advisory Committee (TAC) chose the federal 8 hour standard of 9 ppm as the threshold beyond which there is a health risk from CO. People with heart disease (approximately 10% of the population) are most susceptible to risk from elevated levels of CO. We therefore stated the risk from CO as high (severity rank 4 or greater) for those most susceptible, and low for the rest of the population.

people at risk (high) = .10 * sum [CO_j * POP_j]

people at risk (low) = .90 * sum [CO_j * POP_j]

where:

CO_j = site with at least one 24 hour exceedance
POP_j = number of people in area j with at least 9 ppm exceedance

At more elevated levels (15 ppm 8 hour average), effects include headaches, impaired coordination and impaired psychomotor function. These are impacts to all people living within the affected area and, for the purpose of this study, will be considered a high risk.

c. Ozone

Ozone is the primary component of photochemical oxidants, or what many refer to as smog. Ozone is formed in the ambient air from a photochemical reaction involving volatile organic compounds (such as gasoline vapors), oxides of nitrogen and sunlight. Because this chemical reaction is slow, elevated levels of ozone are often found many miles from urban centers, the source of the precursor pollutants. A number of health risks can be attributed to ozone, including chronic respiratory diseases and asthma.

The EPA Region 10 Comparative Risk Project Plan of Attack[2] (POA) cites studies by Chestnut and Rowe[3] and Chestnut et al.[4] which use the California standard of .10 ppm as a threshold level beyond which there are health related impacts (primarily asthma and restricted activity due to respiratory distress). While the federal standard is .12 ppm, there is considerable dispute about whether this standard actually protects against chronic respiratory problems. One study cited by Chestnut and Rowe[3] concluded that adverse health impacts were noted at .07 ppm. We chose the .10 California standard as being a middle of the road threshold.

To determine the number of people at high risk due to levels of ozone in excess of this risk based level, we will sum the risks to the population from both asthma and respiratory distress, both of which have a severity rank of 4. The Region 10 POA analyzes the number of days susceptible people are exposed to elevated levels of ozone. To estimate the number of people at risk from elevated levels of ozone, we simply sum the population exposed to levels in excess of .10 ppm, using the following formula:

people at risk = [# sites with exceedance * POP]

where:

POP = total population in locations with exceedances

In addition to the high risk associated with exceedances of .10 ppm, one hour values in excess of .05 ppm have been shown to cause headaches, a low risk. Since monitors throughout the state have shown exceedances of this threshold, we would conclude that the entire state population is at low risk from ozone exposure.

d. Lead

Lead affects different segments of the population in different ways. Affects include hypertension, IQ detriments and impacts the peripheral nervous system. Lead is also suspected as a carcinogen. Children are particularly at risk from elevated levels of lead.

The EPA Region 10 approach to estimating risk from lead is simply to assume that per capita risk estimates derived from studies of other urban areas would translate directly to Washington urban areas.[5] The TAC had no reason to believe the national estimates would differ from Washington State.

Studies show that different population groups are affected differently, and at varying levels, from elevated lead levels. Assuming Washington lead levels are consistent with those found nationally, we can estimate the number of people whose health is affected by elevated levels from the following simple formulas:

people at risk (low) = .0015 * urban population

people at risk (high) = .0020 * urban population

e. Sulfur Dioxide

Elevated levels of SO2 have been shown to cause a number of health effects, ranging from minor to severe. Our analysis will use two thresholds: .14 ppm/24 hour average (the NAAQS) for high risk to sensitive populations and low risk to the remainder of the population, and .08 ppm/24 hour average for low risk (increased frequency of asthma attacks). In the high risk case (.14 ppm), since the health effect is to aggravate respiratory problems affecting only an estimated 10% of the population (see similar discussion under carbon monoxide methodology), the number of people at risk can be determined using the following formula:

$$\# \text{ people at risk} = .10 * \text{sum } [SO2_j * POP_j] \text{ (respiratory)}$$

where:

$SO2_j$ = site with at least one 24 hour exceedance
POP_j = number of people in area j with at least one .14 ppm exceedance

For low risk,

$$\# \text{ people at risk} = \text{sum } (SO2_j * POP_j) \quad \text{(asthma)}$$

f. Oxides of Nitrogen

Nitrogen dioxide has not been monitored for a number of years in the state of Washington. The reason is simple - after years of monitoring in "worst case" locations it was determined that the NAAQS had never even been approached. We therefore will assume there is no risk from nitrogen dioxide.

<u>3. Methodologies for Estimating Risks from Non-Criteria (Toxic) Pollutants</u>

a. Definition

For the purpose of this analysis, we will use the term toxic air pollutants to mean all air contaminants except criteria air pollutants, which are covered above. With this definition we could generate a virtually endless list of pollutants to be analyzed. Clearly, a screening process is needed to identify the "riskiest" of these many pollutants. An explanation of how we chose which pollutants to analyze is included in section 1 above, "Pollutants Analyzed and Their Effects".

b. Methodologies

The various types of risks analyzed in this report require differing risk analysis methodologies, as described below. There are several ways to describe the risks from air toxics. Those that we chose to use were:

- Cancer risk to the maximum exposed individual, stated as a probability (e.g., $1x10^{-5}$, or one in 100,000);
- Cancer risk to overall population, stated as annual number of excess cancers;
- Non-cancer risk to maximum exposed individual, stated in terms of the number of people at risk;

- o Non-cancer risk/chronic, stated as number of people at risk (consistent with units for criteria air pollutants);
- o Non-cancer risk/acute, stated also as number of people at risk.

Estimate cancer risks to maximum exposed individual (MEI). Our approach was first to use a screening model (SCREEN) and to identify the maximum downwind concentration of each of the non-criteria pollutants on the target list . Modeling considered point parameters (e.g. stack heights, exit velocities). From our experience with screening models we concluded that running the model on the largest point source would suffice since concentrations drop off exponentially with distance from the source. Add to the modeled value a background concentration, assumed to be the contribution from area sources, determined as part of the effort to determine average concentrations (see methodology for determining cancer risk to overall population below). Since the screening model produced maximum hourly concentrations, we multiplied by 0.15 to estimate maximum annual concentrations. Multiplying the modeled maximum concentration estimates times 10^{-6} and dividing by the AAL results in an estimate of the probability of the MEI contracting cancer. It should be emphasized that this number is only theoretical, based on worst case assumptions layered on other worst case assumptions. It is however useful as a tool to compare relative risks, which is the purpose of this exercise.

Estimate cancer risk to overall population. Average concentrations were estimated based on county by county emissions and simple box modeling. The geographic area modeled was assumed to be smaller than the whole county (e.g., most of the population and emissions are confined to a significantly smaller area than the entire county). We chose 10% of the geographic area of the county.

Our box model assumes that emissions are uniformly emitted throughout the floor of the box and uniformly disbursed throughout the box volume. The "top" of the box is defined by an assumed mixing height, for which we used 900 meters.

The equation used to calculate average area concentration was as follows:

$$C = (Qa * x * 10^6)/(A * u * z_i)$$

where,

C = average concentration in ug/m3
Qa = average emission rate (g/sec)
A = 10% of area of county (meters^2)
x = length of box = $(A)^{.5}$ (meters)
u = average windspeed (m/sec)
z_i = average mixing height = 900 meters

In our analysis, we modified the above equation to account for wet and dry deposition, and atmospheric halflife (Hanna, 1982), as suggested in the Region 10 Plan of Attack[2] (David Sullivan, 1989). The above equation could be modified by dividing by the following factor:

$$(x/u) * (1 + (v_d/z_i) + L + (1/Tc))$$

where,

v_d = deposition velocity (m/sec)
L = scavenging coefficient (sec^{-1})
Tc = atmospheric residence time (sec)

Typical values for this expression range from 1 to 1.3, where the higher value would be found for pollutants particularly sensitive to scavenging (e.g. particulates), in rainy areas, and in large counties with relatively low average windspeeds. Given the uncertainties from many of our other estimates, we assumed constant scavenging, using 1.1 as the scavenging factor.

This approach might be expected to significantly underestimate actual monitored concentrations for several reasons. First, monitoring is ordinarily done in industrialized areas. Our model assumes all these emissions are spread over a large portion (10%) of the county. In addition, lateral movement of pollutants impacts adjoining "boxes". This impact is assumed to be zero in our model.

The number of excess cancers per million population is calculated by dividing the AAL for that compound into the average concentration.

<u>Estimate the number of people in the overall population at risk from non-cancer/chronic exposures.</u> Average concentrations were estimated based on county by county emissions and simple box modeling. The number of people at risk was determined by comparing average concentrations to non-cancer AALs. Where AALs are stated as 24 hour concentrations, the annual estimated concentration was multiplyed by 2.67 to give us a 24 hour AAL. People living in areas in which the AAL was exceeded by at least one pollutant were assumed to be "at risk". Since non-fatal health effects vary in their severity, a severity rating was included with the risk result summary in accordance with the severity ranking system provided in Appendix 12.

<u>Estimate the number of people at risk of non-cancer/acute affects.</u> Our approach here was the same as for non-cancer chronic health effects - model concentration, set a risk threshold and determine a health index. To estimate short term concentrations, we divided the box model results by 0.15 to obtain hourly concentrations and by 0.0375 for 15 minute concentrations.

4. Sources of Pollutants

Thirty pollutants or classes of pollutants were considered in this report (including both criteria and non-criteria pollutants). Primary sources of each pollutant are listed in Appendix 8: Major Sources of Pollutants.

5. Data Sources Used and Probable Bias

This study relied on data from a number of sources, some of which are considered accurate and up-to-date, others the best available under the circumstances. The individual data sources, the manner in which they were used, and their reliability (and probable bias, if known) are summarized below.

The ambient air monitoring database (SAROAD network) was used to estimate the concentrations of criteria pollutants statewide. Network design parameters dictate the spacial distribution of the network, based largely on characterizing ambient air quality in urban environments. Consequently, scaling up these discreet monitored values to statewide concentrations would likely bias the results towards the high end. However, since population densities are much smaller in rural areas, the resulting estimates of risk to the population would be affected only minimally. Average sampling bias by pollutant monitored, stated in terms of the 95% confidence interval, is listed below:

	AVERAGE ERRORS (% of Actual)		
POLLUTANT	MEAN	UPPER 95%	LOWER 95%
PM10	0.5	9.3	-8.2
CO	0.7	6.9	-5.6
Ozone	-0.1	7.0	-7.1
SO2	-0.1	7.0	-7.2
Lead	-4.5	5.3	-14.3

(Air Monitoring Data for 1987, 9/88)

The toxic air pollutant subset of the Washington Emission Data System (WEDS) was used to estimate the emission rates of point, area and vehicular sources statewide. Updated annually, this database is considered the most accurate assessment of emission rates available. There may be an overall negative bias based on the likelihood of errors of omission, without offsetting errors in commission (i.e., estimates of a known emission points are presumably without systematic bias, while there are undoubtedly emission points which are not accounted for in the database).

The WEDS database itself relies on data from a variety of sources. For example, emissions from motor vehicles are estimated based on vehicle populations within a given area, the miles traveled by those vehicles, and the average emission rate of the fleet. Each of these estimates is subject to error, but we are not aware of bias in either direction introduced by these individual databases. The same can be said of other emission estimates (e.g. woodstoves, fugitive dust, etc.) in the WEDS system.

Population data is used to determine the number of people exposed to a given concentration of pollutants. The most current population estimates were used in this study (census data and figures from the "Washington State Yearbook, 1987")[13]. We assume no bias in population figures used in this study.

Where we lacked current data on the ambient concentrations of criteria pollutants, especially in suburban areas with dramatic population growth, saturation studies (bag sampling) have been used to help us characterize the spacial distribution of pollutants throughout the study area. Where such data were relevant, we augmented SAROAD data with results from these studies. No bias is anticipated from the use of these data.

Two forms of modeling were used to estimate pollutant concentrations given pollutant emission rates (see WEDS above) - box modeling for average concentrations and dispersion modeling for maximum concentration estimates. Our approach to the box modeling should not result in a significant bias in either direction in terms of its estimate of average concentrations, however the approach itself is likely to underestimate both concentrations and risks in urban areas while overestimating concentrations in rural areas. The reason for this is that, in assuming emissions are evenly spread out throughout the county or a portion of the county and that the population is evenly distributed throughout the county, we are ignoring the fact that most of the population and emission sources generally congregate in relatively small geographic areas around industry. As noted in the methodology section, we have reduced the size of the box to 10% of the county to deal with this potentially significant error. Our modeling approach for estimating risks to the maximum exposed individual, on the other hand, tends to overestimate concentrations of individual pollutants from 2 to 4 times.

Meteorological data (windspeed, wind direction, mixing heights) are used in the models noted above. Significant measurement errors are known to exist at many of the sites used in the modeling, though there appears to be no systematic bias to these errors. Extrapolating a few monitoring sites to represent meteorological conditions throughout the state is also a source of significant error, again assumed to have no positive or negative bias.

In addition to the data sources listed above, non-criteria pollutant thresholds were derived from a number of studies and references. We were not able to assess the probable bias of each. Though the most current generally accepted thresholds were used, it should be noted that these tend to be worst case (or upper bound) values - that is, they tend to overstate risks.

6. Assumptions

EXPOSURE BOUNDARIES: Though Washington is blessed with an extensive criteria pollutant monitoring network, no ambient monitoring network can characterize pollutant levels at every street corner in every town throughout the state. Some assumptions must be made regarding how the limited number of monitoring sites describe pollution levels in areas where there is no monitoring.

Carbon monoxide is a very localized pollutant. An extensive monitoring network would be needed to completely describe levels which can vary dramatically from one street corner to the next. The state has performed a number of CO saturation studies (bag sampling studies) to help characterize the spacial distribution of CO in urban areas. In addition to SAROAD monitor exceedance areas (non-attainment areas), we have incorporated bag sampling results to expand the non-attainment boundaries where appropriate.

Ozone can be considered a regional pollutant in that often the highest values are found many miles from sources of the precursor pollutants, and can be in any direction from the sources. Our boundary assumption for ozone is to assume the few monitoring sites west of the Cascades represent ozone values throughout the Puget Sound basin from the Canadian to Oregon borders.

For SO2, lead and PM10, the TAC used the actual non-attainment boundaries.

POPULATION EXPOSURE: Air pollution does not respect boundaries used by census takers, making the task of identifying the number of people exposed to elevated levels difficult, at best. Our reference for population, the 1987 Washington Source Book[13], generally gives populations for cities and counties, plus a breakdown, by county, of the number of people residing in unincorporated and incorporated areas. After defining an exposure boundary (see above), our approach was to "scale up" the population of the incorporated cities within the boundary by the percentage of the county's population living in unincorporated areas. Though we admit that this is somewhat arbitrary, clearly some scale up is necessary. Future studies should use actual population grids to estimate exposed population.

MODELING: The basic assumption inherent in our non-criteria pollutant risk methodology is our assumption in modeling average concentrations that pollutant concentrations are homogeneous throughout a given area (for the purpose of estimating average lifetime exposure).

A Gaussian plume screening model was used to estimate risk to the maximum exposed individual (MEI). By their nature, screening models tend to overpredict concentrations by about a factor of 2 to 4.

Finally, we assumed that there were no synergistic effects from combining exposures to two or more pollutants.

7. Approach to Scaling Up

Scale-up is basically the same thing as data extrapolation and uncertainty factoring. It is a detailed description and rationale for how risk assessments for a complete database were developed based on a risk assessment from a subset of that data or how an uncertainty factor was added to that final risk assessment value.

Our need to scale up limited data to represent the entire state was minimal. Our approach to scaling up monitored criteria pollutant values was to assume that monitored data were indicative of concentrations throughout the area (see "Exposure Boundaries" above).

Average concentrations of non criteria pollutants were effectively scaled up by reducing the size of the box used in the model. Our rationale for doing so was that most of any given county's population and emission sources are congregated in a relatively small geographical area (see discussion above under Data Sources Used and Probable Bias).

8. Sensitivity analysis of alternative assumptions

A sensitivity analysis measures the impact that a change in value for one variable would have on an overall risk assessment. For example, for a given variable x in a risk assessment equation, you would calculate the equation using a range of values (1x, 9x, 100x) representing your widest range of possible values (1x, 100x), and your best estimate of the value of x (9x). Two types of variables warrant sensitivity analyses: those for which a high degree of uncertainty is involved in the determination of their value and those for which a change in value would cause a disproportionately large change in the overall risk assessment. The latter are the more important of the two to perform.

Sensitivity analysis is used to determine what affect the uncertainty of any value might have on the usefulness of overall risk assessment. For instance, a wide range of possible values for a given variable, made plausible because of a high degree of uncertainty or possible assumptions in calculating the variable, might have little affect on the overall risk value when plugged into the final equation. This large degree of uncertainty would diminish in importance due to its minor impact on the overall risk assessment.

On the other hand, even though a value calculated for a given variable might have a high degree of certainty associated with it, one might want to focus more attention on that variable because even a slight change in its value may make a large change in the overall risk assessment.

The following is a recap of data sources and assumptions used in our risk analyses, and a discussion of the sensitivity of each. Also included in this discussion of the sensitivity of data sources are the databases used to make these emission estimates. For example, estimates of motor vehicle emissions are based on the average emission rate the vehicle fleet operating in the area, the vehicle mix in the fleet (make, model, age, etc.), and the miles traveled by the vehicles in the area. Errors in databases such as these can result in significant errors in the estimated emissions of non-criteria pollutants (criteria pollutants rely on actual ambient monitoring data), noteworthy because motor vehicles are the primary source of many of the pollutants analyzed in this report. In a similar way, woodstove inventory and usage rate estimates are critical in our estimates of the concentrations of several of our target list of pollutants.

MONITORING DATA: Because our approach to determine non-cancer risks from ambient air pollution is to assume no risk below a risk threshold, any error that would result in an incorrect threshold classification (e.g., above the limit when it should have been classified below) will have a significant effect on our risk evaluation. This is only true at or near the risk threshold.

EMISSION INVENTORY DATA: For non-cancer risks, inventory errors when the modeled pollutant concentrations are at or near the risk threshold will have a dramatic effect on the risk evaluation. The same cannot be said for cancer risks, where the risk results are proportional to pollutant concentration.

POPULATION DATA: Since this is a comparative risk report, we expect any errors in the population exposed within a given area to be consistent with like errors in the risks estimated from other environmental threats. In terms of sensitivity, population errors should result in proportional risk errors.

MODELING: Our non-criteria pollutant risk methodologies rely heavily on mathematical modeling. Models can be very sensitive to assumptions and the reliability of certain input fields. For example, some models show exponential increases in concentration with decreasing windspeeds. Windspeed errors in this case would dramatically affect estimates of pollutant concentrations. To minimize the error in this potentially significant parameter, we used monitored county annual average windspeeds in our modeling.

RISK THRESHOLD ESTIMATES: In the same way as discussed above under ambient monitoring, we are assuming "all or nothing" risk thresholds for all non-carcinogens - that is, we assume no risk below our threshold, only at or above. Our approach of assuming homogeneous pollutant mixing is very sensitive to our assumed risk threshold. For example, if our modeled concentration of a given pollutant were .09 and our risk threshold .10, our conclusion would be no people are at risk. A small change in our risk threshold to .09 would result in the population of the entire area being at risk. Unfortunately, we do not have a great deal of faith in these assumed risk numbers, despite the sensitivity of our analysis to them.

The reader is referred to section C. below, Discussion of Uncertainty, for further discussion of the uncertainty or our analysis.

B. DESCRIPTION OF FINDINGS

Summarized below are the risks, presented for comparative purposes, resulting from ambient air pollution.

Table 4
Risks from Ambient Air Pollution in Washington

Threat: AMBIENT AIR POLLUTION

Human Health Risk		
Cancer MEI probability (risk of contracting)	10^{-3} to 10^{-2}	Chromium, Whatcom Co B(a)P, Pierce Co Trichloroethylene, King Co Dioxin, Stevens Co
Excess cancers (number of cancers)	2 - 150	
Non-cancer effects (# people at risk)	4+ million	severity 1-3 (O3)
	3+ million	severity 4-5 (O3)
	175,000	severity 6-7 (CO, PM10)
Significant Ecological Risks		
Animals	Fluoride at current levels may nave minor impacts on some animal species; air pollution may be significant polluter of Puget Sound microlayer	
Plants	Ozone in concentrations which have been monitored in the Cascades is likely damaging some tree species	
Other	Visibility degradation	
Economic Damages	<reserved>	

1. Summary of Human Health Risks

a. Criteria Pollutants

The following table summarizes the risks associated with exposure to criteria air pollutants in the ambient air. All the risks are listed with a severity rank since none are known carcinogens (lead is a suspected carcinogen). Each is a non-cancer/chronic risk, while some (e.g. CO) are known to have acute effects.

Table 5
Summary of Risks from Criteria Pollutants

POLLUTANT	# PEOPLE AT RISK*	SEVERITY	EFFECTS
Ozone	3,174,500	4	Asthma, chronic bronchitis
	4,420,000	3	Headaches from short term exposures
PM10	104	7	Mortality
	348,000	3	Respiratory distress from 24 hour NAAQS exceedance
CO	174,900	6	Aggravated angina
	1,574,000	3	Headaches and dizziness from short duration exposure to hi values
LEAD	8,000	6	Perceptual and learning deficits in children
	3,300	4	Hyperactivity, focus and other visual deficits
SO2	2,682	4	Increased respiratory infections
	26,815	4	Asthma

* does not include frequency of exposure to levels at which health impacts are assumed to occur (a measure of the probability of exposure to unhealthful levels

These risks can be summarized in low, medium and high terms as follows. Note that the same people are, in many cases, counted as "people at risk". We have not merely added the number of people at risk in each category, which would give the absurd result in the case of low risk (severity 1-3) of having more people at risk than reside in the state. Instead, the total number of people at risk from the worst case pollutant is stated, followed by an indication of the pollutant.

Total # people at risk,	severity 1-3 :	4,420,000	(O3)
	severity 4-5 :	3,174,500	(O3)
	severity 6-7 :	174,900	(CO)

As noted in Table 5, the "number of people at risk" figure does not indicate the probability that on any given day residents within a given area might be exposed to levels above the assumed threshold, or the number of days per year a given area exceeds the threshold. Unfortunately, time constraints did not allow us to do a cmplete anlaysis of this issue.

As a first approximation of the fréquency of exposure, we assumed that as the nubmer of days above a threshold increased people are exposed to this additional day. For exmaple, if 1000 people are at risk at least one day per year, then 750 would be at risk twice per year, 563 three times per year, and so on. The idea here is that though the entire state population may be at risk of a given health impact from exposure to ozone, that exposure may only be for one day in half the state while there may be 20 or more exceedances affecting a much smaller population. Based on this assumption, the number of people at risk at least 5 times per year would be about 25% of the total given in Table 5, while only 5% would be exposed 10 times or more.

b. Non-Criteria Pollutants

The health risks from non-criteria air pollutants can be both cancer and non cancer, chronic and acute.

CANCER RISKS: Of the 24 non-criteria pollutant and pollutant classes studied in this report, 17 are cancer risks. Risks are generally higher in areas with high population density. Significant sources in urban areas include motor vehicles (products of combustion, asbestos brake and clutch linings) and woodstoves. Emissions from both of these source categories are directly related to population density. Further, the higher the population density, the more people are exposed.

Table 6
Summary of Cancer Risks

Number of Excess Cancers		Best Guess	15
		Upper Bound	150
		Lower Bound	2
Highest MEI Risks	10^{-2} - 10^{-3}	B(a)P in Pierce Co.	
		Chromium in Whatcom Co.*	
		Chloroform in Clark Co.	

* This risk is likely to be overstated since we assumed all chromium to be hexavalent (most potent)

NON-CANCER RISKS: Of the seven non-criteria pollutants which are not considered carcinogens, three (mercury, nickel and fluoride) are primarily from point sources, while the other 4 come principally from vehicular sources and wood burning.

Table 7
Summary of Non-Cancer Risks

POLLUTANT	# PEOPLE AT RISK*	SEVERITY	POSSIBLE EFFECTS
Fluoride	-0-	2	Sclerosis of the bones
Manganese	1,937,200	4	Upper respiratory disease
Mercury	-0-	4	Damage to central nervous system, kidneys
Nickel	-0-	4	Lung disease
Phenol	1,891,600	4	Lung, heart, liver and kidney damage
Toluene	2,573,000	3	Central nervous system effects
Xylene	1,309,800	4	Teratogenic & liver effect

* does not include frequency of exposure to levels at which health impacts are assumed to occur (a measure of the probability of exposure to unhealthful levels)

Finally, the non-cancer acute effects of non-criteria pollutants were analyzed and none were found to exceed the short duration risk threshold.

2. Detailed Summary of Estimated Risk

a. Criteria Pollutants

CARBON MONOXIDE: Table 8 below lists the population residing within areas that have experienced exceedances of the carbon monoxide standard. Not all the population exposed to these unhealthful levels reside within the incorporated city limits listed above. Our population estimates are scaled up to include estimated population exposed to unhealthful values by multiplying the city figures given above by the percentage of the county's total population that is unincorporated to the county's total population[13]. To these population figures, we will apply the formulas described in the Methodology section of this report (Section II. A. 2. b.) to calculate the number of people at risk. The scaled up values are as follows:

Table 8
Carbon Monoxide - Populations Within
Areas Exceeding Standard

City	County	Ratio**	Population	Scaled Up Population
Seattle	King	.41	488,200	688,362
Everett	Snohomish	.55	59,470	92,178
Tacoma	Pierce	.59	158,900	252,651
Bellnghm*	Whatcom	.48	46,380	68,642
Olympia*	Thurston	.60	28,990	46,384
Bellevue	King	.41	81,770	115,296
Yakima	Yakima	.51	49,590	74,881
Spokane	Spokane	.46	172,700	252,142
Bremerton	Kitsap	.73	33,420	57,817
Vancouver	Clark	.72	42,740	73,513
Pullman*	Whitman	.20	22,530	27,036
	Total =		1,184,696	1,748,902

* - based on results from bag sampling studies
** - ratio of unincorporated to total county population

people at risk (low) = .9 * 1,748,902

= 1,574,000 people (Headaches, dizziness)

people at risk (high) = .10 * 1,748,902

= 174,900 people (Aggravated angina)

LEAD: Statewide, there are two areas with elevated values of lead due to point source emissions:

	Quarterly Ave
Harbor Island	1.82 ug/m3 (1986)
2555-13th Ave.S.W.	1.53 ug/m3 (1985)

There are few, if any, residences on Harbor Island. However, people do commute to and through this area. Our estimate of the population exposed to elevated levels of lead from point sources is 3,500 people.

As noted in the discussion of methodology for estimating risks from lead, two simple formulas are used:

people at risk (low) = .0015 * urban population

and,

people at risk (high) = .0020 * urban population

Assuming 50% of the state's population resides in urban areas,[13] and adding 3500 people at risk int he Harbor Island non-attainment area to the high risk total,

people at risk (high) = .0020 * 2,210,000 + 3500

= <u>8000 people</u> (learning disabilities)

people at risk (low) = .0015 * 2,210,000

= <u>3300 people</u> (visual impairment)

SULFUR DIOXIDE: The sulfur dioxide (SO2) standard is exceeded in one area. The 24 hour standard for SO2 is .14 ppm. The area that exceeded the standard was Port Angeles (at .16 ppm). The population exposed is assumed to be the city population factored by the ratio of unincorporated to total county population (see discussion above), or 17,300 * 1.55 = 26,815. Assuming 10% of the population is susceptible to lung disease:

people at risk (respiratory infections) = .10 * 26,815

= <u>2,682 people</u>

The number of people at low risk (asthma) is the sum of people residing in areas with exceedances of .08 ppm. Other than the Pt. Angeles site noted above, there were no sites with .08 ppm 24 hour exceedances.

people at risk (asthma) = <u>26,815 people</u>

PARTICULATE MATTER: The PM10 standard is exceeded in several areas in the state - the Puget Sound basin has two areas with exceedances of the 50 ug/m^3 standard: the Tacoma Tide Flats and the Duwamish industrial area. Both areas are greater than 50 annual arithmetic mean. Areas in the Puget Sound basin with 24 hour exceedances include, in addition to the Tacoma tide flats and Duwamish, Kent and most of Seattle CBD. In Eastern Washington, the Spokane CBD reports annual averages from 50-75. Other areas with annual average exceedances in Eastern Washington include Yakima (78) and Wallula (57). These areas also exceed the 24 hour standard. Finally, Lacey in Thurston County exceeds the 24 hour standard. We will again adjust population estimates upwards to account for those people living within areas that exceed the standard, but who do not live in incorporated cities (see discussion under CO above). We will assume the following population exposures for these areas:

Table 9
Populations Within Areas Exceeding
the 24 Hour PM10 Standard

City	County	Ratio	Population	Scaled Up Population
Seattle	King	.41	488,200	688,362
Tacoma	Pierce	.59	158,900	252,651
Lacey/Oly*	Thurston	.60	44,620	70,816
Kent	King	.41	28,620	40,354
Yakima	Yakima	.51	49,590	74,881
Spokane	Spokane	.46	172,700	252,142
Wallula	W.Walla	.32	2,000*	2,640
Clarkston	Asotin	.54	6,730	10,364
	Total =		951,000	1,392,200

* - estimate

Twenty four hour exceedances of the 150 ug/m3 standard have been shown to cause respiratory declines in children, estimated to be 25% of the population. Therefore, the number of people at risk from particulate matter, based on exceedances of the 24 hour standard is as follows:

people at risk = .25 * 1,392,200

= 348,000 people (respiratory distress)

Using the Region 10 formula[2] to determine annual deaths from PM10 based on annual average values exceeding 40 ug/m^3, the number of people at risk is computed from:

$$\# \text{ people at risk} = \text{sum } [5.7 \times 10^{-6} * (PM10_j - 40) * POP_j]$$

where:

$PM10_j$ = annual average PM10 in ug/m3 in location j
POP_j = total population in location j

Areas exceeding 40 ug/m^3, and their (adjusted) populations are listed below:

Table 10
Estimate of Additional Deaths in Areas
Exceeding Annual Average 40 ug/m^3 PM10

City	Annual Avg (ug/m3)	Population	Scaled Up Population	Annual Deaths
Seattle	46	488,200	688,362	24
Tacoma	48	158,900	252,651	12
Bellnghm*	45	46,380	68,642	2
Yakima	78	49,590	74,881	16
Spokane	75	172,700	252,142	50
Kent	43	28,620	40,354	1
Wallula	57	2000	2,640	<1
	Total =	946,390	1,379,700	105

* - based on results from bag sampling studies

Note that maximum values are reported for areas with more than one monitoring site

Using the formula above for number of people at risk from annual average exceedances,

people at risk = 105 people (mortality)

OZONE: Based on ambient monitoring data, augmented by special study sampling, we feel there is virtually no area west of the Cascade crest that does not exceed .10 ppm at least once each year. The entire population of each of the effected counties is therefore assumed to be effected due to elevated levels of ozone. The health effects include asthma (severity=4), respiratory distress during active exercising (severity=3), headaches (severity=3), chronic bronchitis (severity=4) and eye irritation (severity=2). Longterm exposure can aggravate angina (severity=6), however most ozone episodes in the northwest are short duration events.

The population residing within the geographic area described above (basically, west of the Cascades from the Canadian to Oregon borders) is assumed to be at risk from elevated ozone levels. County populations were taken from the 1987 Washington State Yearbook (OFM)[13].

Table 11
County Populations Affected by Elevated Ozone Levels

Clark	205,000
Cowlitz	78,900
Island	50,600
King	1,361,700
Kitsap	164,500
Lewis	56,800
Pierce	530,800
San Juan	8,900
Skagit	69,000
Skamania	7,800
Snohomish	381,600
Thurston	142,200
Whatcom	116,700
Total =	3,174,500

people at risk (medium) = 3,174,500 people (asthma, bronchitis)

In addition, as noted in the methodology, there is a risk of headaches and respiratory distress during periods of exercise from relatively low levels (0.05) of ozone. A review of recent monitoring data[18] indicates that these levels are experienced throughout the state.

people at risk (low) = 4,420,000 people (headaches, resp distress)

b. Non-Criteria Pollutants

Cancer risk to MEI. The following table presents maximum modeled concentrations, the county in which the maximum was found, and the resulting cancer risk to the MEI for each pollutant studied. The probability was determined by dividing the modeled concentration by the AAL times 10^6. For more information on the modeling method used to determine MEI risks, refer to Section II.A.3.b. Maps showing the distance from sources to the point at which the risk is less than 10^{-6} are provided in Appendix 13.

Table 12
Cancer Risk Probability to MEI

POLLUTANT	AAL (ug/m3)	MODELED CONCENTRATION	AREA	MEI CANCER PROBABILTY
Acetaldehyde	$4.5x10^{-1}$	1.43	Pierce Co.	$3.2x10^{-6}$
Arsenic	$2.3x10^{-4}$	0.031	Benton Co.	$1.3x10^{-4}$
Asbestos	$4.4x10^{-6}$*	0.003	Urban areas	$6.8x10^{-4}$
Benzene	$1.2x10^{-1}$			
Benzo(a)Pyrene	$6.0x10^{-4}$	4.9	Pierce Co.	$8.2x10^{-3}$
Beryllium	$4.2x10^{-4}$	$6.4x10^{-3}$	Lewis Co.	$1.5x10^{-5}$
Cadmium	$5.6x10^{-4}$	$3.8x10^{-3}$	Lewis Co.	$6.9x10^{-7}$
Carbon Tetr	$6.7x10^{-2}$			
Chloroform	$4.3x10^{-2}$	2250	Clark Co.	$5.8x10^{-3}$
Chromium	$8.3x10^{-5}$**	0.548	Whatcom Co.	$6.7x10^{-3}$
Dichl'methane	2.1	912	King Co.	$4.3x10^{-4}$
Dioxin	$3.0x10^{-8}$	$6.0x10^{-5}$	Stevens Co.	$2.0x10^{-3}$
Ethylene Dich	$3.8x10^{-2}$	25.4	King Co.	$6.7x10^{-4}$
Ethylene Dibro	$4.5x10^{-3}$			
Formaldehyde	$7.7x10^{-2}$	3.27	Pierce Co.	$4.3x10^{-5}$
Nickel	$4.2x10^{-3}$			
Perchloroeth.	1.7			
Trichloroeth.	$5.9x10^{-1}$	1079	King	$1.8x10^{-3}$

* concentrations expressed in fibers per cc
** assumes all chromium as hexavalent (most potent)

Though actual risk estimates are limited and most are preliminary, these estimates are consistent, in an order of magnitude sense, with those few risk analyses that have been done.

Note that in the above table several values are omitted for modeled concentration. Our modeling in these cases showed that the distance to the theoretical one in a million risk was less than one kilometer. We can assume for each of these pollutants that our MEI cancer probability would have been less than one in a million.

Cancer Incidences. To estimate the excess number of cancers from exposure to toxic air pollutants, we estimated the average annual concentration of each of the targeted pollutants within each county. The results of this modeling are presented in Appendix 9: Modeled Concentrations. Comparing these results to published monitoring data, our concentrations appear to be low by about one to two orders of magnitude. Though some of this can be attributed to emission inventory errors (conservative factors and errors of omission), most of this difference should be expected given the fact that most monitoring is done in industrialized areas. We tested this by modeling those conditions that can be expected to produce higher values. The results are presented in Appendix 10 and are summarized below.

Table 13
Order of Magnitude Comparison
of Monitored vs Modeled Values

POLLUTANT	MONITORED VALUES[14,7]	MODELED KING CO AVERAGE	MODELED KING CO MAXIMUM	MODELED PIERCE CO AVERAGE	MODELED PIERCE CO MAXIMUM
Arsenic	10^{-3}	10^{-5}	10^{-3}	10^{-5}	10^{-4}
Chromium	10^{-2}	10^{-4}	10^{-2}	10^{-5}	10^{-3}
Benzene	10^{+1}	10^{0}	10^{+2}	10^{0}	10^{+1}
Nickel	10^{-3}	10^{-3}	10^{-1}	10^{-3}	10^{-2}
B(a)P	10^{-3}	10^{-9}	10^{-7}	10^{-4}	10^{-2}

We are comfortable with our modeled average values based on this test in that modeling using these worst case assumptions did produce values that are comparable to those found from monitoring in worst case areas. Benzo(a)pyrene in King County appears to be an exception (modeled concentration 10-9, modeled 10-3). King County risk estimates from benzo(a)pyrene will be based on monitored values.

The number of excess cancers was determined by using the method described in Section II.A.3.b. The annual cancers are determined by dividing 70 years into the total number of cancers for all pollutants. Average modeled concentrations of all targeted pollutants are presented in Appendix 9, and lifetime excess cancers in Appendix 11. A summary of the excess cancers by pollutant follows:

Table 14
Lifetime Excess Cancers

POLLUTANT	70 YEAR EXCESS CANCERS	ANNUAL EXCESS CANCERS
Acetaldehyde	1.17	negl
Arsenic	2.75	negl
Benzene	221.3	3.2
Beryllium	1.03	negl
Cadmium	0.20	negl
Chloroform	8.36	0.12
Chromium	26.50	0.38
Dichloromethane/MeCl	0.17	negl
Dioxins 2,3,7,8 TCDD	827.10	11.8
Ethylene Dichloride	0.19	negl
Formaldehyde	14.40	0.21
POMs (Benzo(a)pyrene)	16.40	.23
Trichloroethylene	0.72	negl
TOTAL*...	1100	16

* estimates are plus or minus an order of magnitude

Non-Cancer Chronic Risks. The maximum concentrations from the previous section were used to determine whether or not worst case conditions would likely result in exceedances of the risk thresholds for non-cancer pollutants. In a number of cases, exceedances were modeled. Table 15 lists all for which the hazard index (modeled exposure divided by AAL) exceeded 0.5. Note that in table 15, the modeled concentration is the maximum concentration using the worst case assumptions multiplied by 2.67 to account for the AAL being stated as a 24 hour average.

Table 15
Non-Cancer Chronic Risks from Toxic Air Pollutants

POLLUTANT	ACCEPTABLE LIMIT (AAL)	24 HOUR (ug/m3)	HAZARD INDEX	COUNTY	POPULATION	RANK
Manganese	3.1E+01	5.5E+01	1.77	CLALLAM	29000	4
		2.1E+01	0.69	CLARK	195800	4
		3.5E+01	1.13	COWLITZ	80500	4
		2.8E+01	0.89	GRAYS HARBOR	66800	4
		3.9E+01	1.26	JEFFERSON	16600	4
		3.7E+01	1.21	KING	1309800	4
		2.3E+01	0.74	LEWIS	56700	4
		2.4E+01	0.78	PACIFIC	17800	4
		4.4E+01	1.43	PIERCE	501300	4
		1.6E+01	0.51	SKAGIT	64900	4
		1.7E+01	0.56	SKAMANIA	8100	4
		2.0E+01	0.63	SNOHOMISH	353400	4
		2.0E+01	0.65	SPOKANE	347600	4
		1.6E+01	0.51	THURSTON	129100	4
Mercury	6.0E-02	4.3E-02	0.72	LEWIS	56700	4
Phenols	5.2E+01	2.6E+01	0.51	CLALLAM	29000	4
		3.6E+01	0.69	CLARK	195800	4
		8.6E+01	1.66	COWLITZ	80500	4
		2.8E+01	0.54	GRAYS HARBOR	66800	4
		5.4E+01	1.04	KING	1309800	4
		6.8E+01	1.31	PIERCE	501300	4
		4.9E+01	0.95	SNOHOMISH	353400	4
		3.8E+01	0.73	SPOKANE	347600	4
		4.6E+01	0.88	STEVENS	29500	4
Toluene	5.1E+01	5.1E+01	0.99	CLALLAM	29000	4
		9.1E+01	1.77	CLARK	195800	3
		5.1E+01	1.00	COWLITZ	80500	3
		3.4E+01	0.66	GRAYS HARBOR	66800	3
		3.3E+01	0.65	ISLAND	45200	3
		3.4E+01	0.67	JEFFERSON	16600	3
		2.9E+02	5.59	KING	1309800	3
		8.0E+01	1.57	KITSAP	156800	3
		3.1E+01	0.62	LEWIS	56700	3
		2.6E+01	0.52	PACIFIC	17800	3
		3.9E+01	0.76	PIERCE	501300	3
		2.8E+01	0.56	SKAGIT	64900	3
		8.4E+01	1.66	SNOHOMISH	353400	3
		8.0E+01	1.56	SPOKANE	347600	3
		6.1E+01	1.20	THURSTON	129100	3
		3.0E+01	0.59	WHATCOM	109900	3
		3.1E+01	0.60	YAKIMA	175000	3
Xylene	5.9E+01	8.8E+01	1.49	KING	1309800	4
		3.4E+01	0.58	PIERCE	501300	4

Non-Cancer Acute Risks. Our comparison of modeled data to acute exposure risk thresholds was negative - that is, maximum concentrations did not appear to even approach the risk thresholds.

C. DISCUSSION OF UNCERTAINTY

The uncertainty of the risks presented above range from "somewhat uncertain" to "a somewhat educated guess". Sources of error, and therefore uncertainty, can be divided into two categories - actual measurement errors and estimation errors. Generally, measurement errors will be smaller than estimation errors, especially where estimations are based on "best professional judgement" and anecdotal information. Unfortunately, many of the pollutants analyzed in this report are not routinely sampled in the ambient air.

Risk thresholds are often based on short term, high dose studies on laboratory animals. How to translate the results of such studies to human health risk thresholds has been the subject of much controversy, and should be viewed as a source of considerable uncertainty.

Where actual monitored data were used to estimate ambient concentrations (primarily criteria pollutants), we have a high degree of confidence in our scaling up of these values to represent statewide concentrations (see discussion in Section 7. above, Approach to Scaling Up). A great deal of work has been done setting health-based standards for criteria pollutants, however the extent to which the standard allows for an "adequate margin of safety", and how such a policy might affect the risk numbers presented in this report is unclear. Some overstatement of risk is likely.

Where our estimation of area pollutant concentration relied on a combination of inventory estimates and modeling, our uncertainty is much greater than for monitored/scaled up estimates. Coupled with the uncertainty associated with the risk thresholds used for non-criteria pollutants, we can do little more than characterize our estimates as soft numbers with a dash of best professional judgement thrown in. With the exception of the risk thresholds themselves, we are not aware of any systematic bias. We would caution, however, that the error band of the numbers used (primarily emission rates and modeling) ranges from significant to very large, and severely limit how the resulting risk numbers should be used. In summary, the results should only be used in comparison with risks from other media derived using similar assumptions.

Where monitored data were missing, an attempt was made to compare modeled estimates with monitoring results from other states and cities. Where significant differences were found, and those results were likely to affect the resulting risk estimates, we analyzed the reason for the differences and used as our estimate the value we felt was more likely to represent what we would find if monitoring were done.

D. SUMMARY OF HUMAN HEALTH RISKS FROM AMBIENT AIR POLLUTION

1. Cancer Risks

Many toxic air pollutants are known or suspected carcinogens. Though concentrations of many of these pollutants tend to be very small, some are quite potent. In the worst case, our analysis indicates that the chance of contracting cancer due to a single pollutant may be as high as eight in 1000 over a 70 year lifetime. In reality, the probability may have been considerably higher had we determined the additive synergistic impacts of all the pollutants studied. Such an analysis could not be completed given the time constraints of this project.

Our best estimate of the total excess cancers due to air pollution is 15 annually, with those living in urban areas most likely to be victims. Though this result compares favorably with other studies, we would say our uncertainty is an order of magnitude in each direction - i.e., from 2 to 150 with 15 as our best guess.

2. Non-Cancer Risks

There is virtually no place to hide from unhealthful levels of air pollution in the state of Washington, with ozone, CO and PM10 being the most pervasive. Adding to the risks from criteria air pollutants are varying risks from several toxic air pollutants. Areas affected by more than one pollutant (discounting low level exposures to ozone) include:

* King County - ozone, PM10, CO, manganese, phenol, toluene, xylene
* Pierce County - ozone, PM10, CO, manganese, phenol
* Thurston County - ozone, PM10, toluene
* Snohomish County - ozone, CO, toluene
* Whatcom County - ozone, CO
* Clark County - ozone, CO, toluene
* Yakima County - CO, PM10
* Spokane County - CO, PM10, toluene
* Kitsap County - ozone, CO
* Cowlitz County - manganese, phenol, toluene

3. Trends

Air pollution has been regulated in Washington state for more than 20 years. During that time, air pollution control technology has improved remarkably, especially in the control of criteria air pollutants from point sources. And that stands to reason since our efforts in the beginning focused on controlling the six criteria pollutants.

It seems, however, that the more we know about the science and chemistry of air pollution, the more problems we find - toxics, acid precipitation and chlorofluorocarbons, for example. A great deal of energy is going into these "non-criteria" pollutant control efforts, as well it should.

Unfortunately, we cannot really afford to sit back and bask in our criteria pollutant control successes. Though the rate of emissions from nearly all major sources is lower today than it ever has been, that lower rate is being more than offset by population growth and our ever increasing energy demand.

The trend is a confusing one. We can only guess at the extent to which growing population will outstrip our improvements in controlling emission rates. More than likely, major emission reductions will have to be found in significant source categories (e.g. motor vehicles, woodstoves) or we can expect to see a trend towards higher and higher pollution levels, with corresponding increases in both human health and ecological risks.

III. Ecological Risks

In this section, we will explore the risks ambient air pollution present to the ecosystem (basically the universe of elements in the environment not made by man), excepting risks to human health, analyzed above. The basic limitation of this assessment was the limitation of studies relating endpoint effects to ambient levels of air pollutants. Most of these studies have focused on human health effects.

As we did with our discussion of human health risks, we separated criteria air pollutants and non-criteria pollutants in this report, again because the data sources on which we based our analyses were quite different.

A. CRITERIA AIR POLLUTANTS

1. Methodology

Of the six criteria air pollutants, ozone is the most likely to be of concern from an economic damage point of view. Although SO2 and nitrogen oxides are primary contributors to acid precipitation, these risks will be covered under the acid deposition 2010 threat report.

This methodology will, for the most part, follow that used by Region 10 in their Comparative Risk Project.[2] Any differences will be noted along with an explanation. Our analysis followed the following four steps:

Step 1: <u>Define the threshold value.</u> There is some disagreement among experts as to what ozone concentration and averaging times are most appropriate as the threshold beyond which forest damage will occur. In this step, we will define this threshold and the amount of damage expected when the level is exceeded. The Region 10 study used .10 ppm hourly maximum to represent a 5% damage.

Step 2: <u>Determine the sensitivity of the resource.</u> Elevated levels of ozone have been shown to reduce the productivity of some tree species, while having little effect on others. In this step, we will determine which tree species in Washington are susceptible to ozone and to what extent. Fifty four references are included in the RCG/Hagler report[16], and are repeated in our Appendix 4.

Step 3: Estimate volume of sensitive species. The Region 10 study[2] estimated species volume using the Renewable Resource Evaluation project of the USDA Forest Service. We will use these data for our study unless a more accurate or current database can be found.

Step 4: Summarize ambient ozone levels relative to threshold. Data covering the growing season (May - October) from all permanent monitoring sites should be summarized for the last 5-10 years. The Region 10 study assumed no damage east of the Cascade crest. Based on aircraft studies there is reason to question this assumption. We will reassess this issue based on a review of these studies.

2. Threshold Values and Their Effects

Our selection of risk thresholds and species sensitivity were based on a number of references cited in "Pollutants Analyzed and Their Effects" under Criteria Pollutants above. The search for one appropriate statistic which will adequately characterize ozone exposures to vegetation in regards to vegetation response (sensitivity) is at best frustrating. Numerous exposure-response studies report ozone exposures as means, however, the averaging times can be peak hourly, daily, weekly, monthly or seasonal means. None of these statistics adequately characterized the relationship between concentration, exposure duration, and the interval between exposures and plant responses. The selection of the appropriate statistic to represent ozone exposures to forest ecosystems is unresolved. While many investigators have suggested the use of long term seasonal mean exposures, others have pointed out that the use of the mean minimizes the importance of peak concentrations by treating low-level longterm exposures with the same weight as high concentration short-term exposures (U.S. EPA, 1987)[17].

Under natural conditions, exposure to 0.08 ppm ozone for 12 to 13 hours per day are sufficient to injure Ponderosa pine (Taylor, 1973). Subtle effects of ozone by sublethal exposures (0.06 ppm) characteristic of chronic oxidant pollution involve interference of the normal physiological and biochemical processes (Pell, 1974). This includes reduced yield, closure of stomates, genetic abnormalities, reduced reproductive yield and other species-specific responses (Heck and Brandt, 1977).

On the ecosystem level, oxidant-induced shifts in species composition away from the dominant populations have been observed in the San Bernardino Mountains of California (Miller et al, 1969). The effect on species composition and biomass can lead to altered nutrient cycling and energy relationships in terrestrial communities and altered hydrology and water quality in the drainage basin (Taylor, 1980).

After a review of the available literature and with the aforementioned caveats in mind, it was decided that four hour exposures of 0.07 ppm ozone or greater would cause 5% injury in sensitive species, four hours at ≥ 0.15 ppm would affect intermediate species, four hours at ≥ 0.25 would affect tolerant species. Summaries of key references that led us to use these criteria can be found in Appendix 4.

Within the time constraints of this project, we were only able to fully analyze the effects of one criteria pollutant on the environment - ozone. Specifically, we focused on the impact of ozone on Washington tree species, as summarized below.

3. Volume of Sensitive Species in Washington

Olympic Peninsula Region

Although there are several sensitive and intermediate species, low concentrations of ozone make it unlikely that any damage or productivity decline is occurring in this region. Below is a list of sensitive and intermediate species and the quantities found in this region. (1)

Softwoods	Millions of Cubic Feet	% of Total Softwoods
-Sensitive Species		
Western White Pine	15	0.12
-Intermediate Species		
Douglas Fir	4218	33.08
-Species with insufficient information to rank:		
Western Red Cedar	819	6.42
Pacific Silver Fir	762	5.98
Alaska Cedar	18	0.14
Subalpine Fir	2	0.02

Hardwoods	Millions of Cubic Feet	% of Total Hardwoods
-Sensitive Species		
Black Cottonwood	44	2.35
Oregon Ash	23	1.23
Oregon White Oak	1	0.05
-Species with insufficient information to rank:		
Red Alder	1610	85.96
Pacific Madrone	13	0.69

Critical Assumptions: Only one monitoring site exists in this region. This site, Pt. Angeles, was used to characterize ozone concentrations for the entire region.

Puget Sound Region

Softwoods	Millions of Cubic Feet	% of Total Softwoods
-Sensitive Species		
Western White Pine	9	0.07
-Intermediate Species		
Douglas Fir	4986	38.22
Noble Fir	93	0.71
-Species with insufficient information to rank:		
Western Red Cedar	1171	8.98
Pacific Silver Fir	2263	17.34
Alaska Cedar	80	0.61
Subalpine Fir	34	0.26

Hardwoods	Millions of Cubic Feet	% of Total Hardwoods
-Sensitive Species		
Black Cottonwood	193	7.78
Oregon Ash	29	1.17
Western Paper Birch	47	1.89
-Species with insufficient information to rank:		
Red Alder	1726	69.57
Pacific Madrone	29	1.17

Critical Assumptions: The combination of several ground monitoring sites and the aerial reconnaissance performed in 1988 help to characterize this region more thoroughly than the other three regions. However, according to Basabe's data, Ecology is not monitoring in the areas of highest ozone concentrations.

Southwest Washington Region

Softwoods	Millions of Cubic Feet	% of Total Softwoods
-Sensitive Species		
Western White Pine	60	0.43
Ponderosa Pine	33	0.23

-Intermediate Species

Douglas Fir	7271	51.59
Noble Fir	284	2.02
White Fir	7	0.05

-Species with insufficient information to rank:

Western Red Cedar	542	3.85
Pacific Silver Fir	1499	10.64
Alaska Cedar	10	0.07
Subalpine Fir	66	0.47
Western Larch	11	0.08

-Sensitive Species	Millions of Cubic Feet	% of Total Hardwoods
Black Cottonwood	44	2.35
Oregon Ash	23	1.23
Oregon White Oak	1	0.05

-Species with insufficient information to rank:

Red Alder	1610	85.96
Pacific Madrone	13	0.69

Critical Assumption: Very little monitoring has been done in this region. Characterization of ozone concentrations are extrapolated from one site within the region (Vancouver), one site outside the region (Pack Forest) and aerial reconnaissance. The geographical relationship of the eastern half of the region, especially the northeastern portion to the typical pollutant sources and pollutant routes, further strengthens the assumption that concentrations occur which could effect at least the sensitive species present.

Eastern Washington Region

Softwoods	Millions of Cubic Feet	% of Total Softwoods
-Sensitive Species		
Western White Pine	192	1.12
Ponderosa Pine	3160	18.47
-Intermediate Species		
Douglas Fir	5960	34.83
Noble Fir	8	0.05

-Species with insufficient information to rank:

Western Red Cedar	456	2.66
Pacific Silver Fir	552	3.23
Alaska Cedar	32	0.19
Subalpine Fir	641	3.75
Western Larch	1507	8.81
Whitebark Pine	21	0.12
Subalpine Larch	1	0.01

Hardwoods	Millions of Cubic Feet	% of Total Hardwoods
-Sensitive Species		
Black Cottonwood	52	21.67
Oregon White Oak	13	5.42
Western Paper Birch	71	29.58
Quaking Aspen	87	36.25
-Species with insufficient information to rank:		
Red Alder	10	4.17

Critical Assumptions: Data for the characterization of this entire region is taken from only one site within the region (Spokane) and one site near the western border of this region (Stampede Pass). It is difficult to extrapolate from such a limited data set to such a large region. It is reasonable to postulate however, that possible source areas within the region other than Spokane do not produce enough emissions to cause ozone concentrations high enough to effect even sensitive species, except on a rare occasion. Of much greater concern would be the transport of ozone from Western Washington into and beyond the east slope of the Cascades.

A last cautionary note: Although high concentrations of ozone are not likely in this region, nearly all (93%) of the hardwood species volume occurring here fall under the sensitive category. Under moderately high ozone conditions, the overall effect to the hardwood species population could be far greater than in other regions.

A map of the regions used in this analysis can be found in Appendix 5.

4. Summary of Risks from Criteria Air Pollutants

The data reviewed indicates that ozone levels throughout the state are sufficiently high to damage sensitive tree species. It is probably a reasonable assumption that other plant species are effected by similar ozone levels. We would also suggest that, given the evidence of human health risks, at similar levels other animal species are at risk due to elevated ozone values throughout the state. Though we believe these are reasonable theories, we were not able to find scientific evidence supporting these conclusions.

Intensity of Impact: Plant injury by ozone has been observed in several different regions affecting a wide range of vegetation including leafy vegetables, grains, coniferous and deciduous trees. Ozone enters the leaves of plants through the stomata during normal gas exchange and reacts with moist cells causing injury or death of cells (National Research Council, 1977).

Visible effects of trees include:

- Stipple, fleck and chlorosis (abnormal absence or deficiency of green pigment) on upper leaf surface, premature death or senescence in broad leafs.

- Brown or tan necrotic (pathological death of living tissue) needle taps and chlorotic mottling of needling in conifers.
(Heck & Brandt, 1977)

"Emergence tip burn" disease of eastern white pine is a well documented effect of photochemical oxidants in the northeast United States (Berry and Ripperton, 1963, Kelley et al, 1979). Concentrations of 0.06 - 0.25 ppm ozone are sufficient to produce tip burn symptoms and primary root die back in response (Berry & Ripperton, 1963; Costonis, 1970). Other susceptible eastern species include larch, hemlock and pine varieties while red pine, firs and spruces show greater tolerance.

Reversibility

There has been no documented report of ozone caused forest injury in Washington. However, monitoring data suggest that injury may be occurring in the Puget Sound Area. Ozone caused forest damage may be difficult to reverse if successional changes occur due to variable sensitivity of vegetation. These changes could result in alteration of animal habitat and other function and structural changes in the ecosystem.

Scale

Ozone damage is likely to be concentrated in forested areas downwind and to the east of urban centers in western Washington. Ozone damage is not likely on the Olympic Peninsula or in Eastern Washington.

Sensitivity

To determine the sensitivity ranking of tree species occurring in Washington, we relied on the EPA document by RCG/Hagler Bailly, Inc. (6/88)[16]. This risk assessment document lists species occurring in Region 10 and ranks them in tabular form based on available literature. This table, followed by the references they used and any additional references we used, is included in Appendix 4. Please note that there are many species for which there is insufficient information to determine a sensitivity ranking.

Trend

Western Washington ozone concentration are strongly influenced by summer weather patterns. The weather between 1986-1988 was unusually hot and dry, resulting in ozone concentrations which were higher than normal and make assessing future trends difficult. However, as population continues to grow ozone in some forested areas will increase. In addition, Basabe's data suggest there are much higher concentrations in western Washington than historical ground monitoring has indicated.

Productivity

Though this analysis was limited to the effect of ozone on trees, we expect there are other plant species in Washington equally as sensitive. Trees are an important part of the economy, sociology, history and culture of the citizens of Washington, the Evergreen State. Trees are an essential part of the ecosystem of the region, and, simply put, could not be replaced.

Uncertainty

The lack of adequate monitoring sites outside the Puget Sound area provides a measure of uncertainty to this analysis. (See critical assumptions for each region.) However, the dominant uncertainty is the limited understanding of the response of forest ecosystems and native tree species to ozone exposure. This has limited our ability to establish credible thresholds and estimate the response of forests to varying exposure levels.

B. NON-CRITERIA AIR POLLUTANTS

1. Methodology

There is limited information on the impacts of toxic air pollution on the ecology. Consequently, in their Comparative Risk Project[2], the Region 10 work team responsible for non-criteria air pollutant risks relied mostly on anecdotal information coupled with information compiled from a literature review conducted by a private consultant. The consultant's work resulted in a listing of LD50 values, sub-acute toxicity thresholds and concentrations of metals known to impact several species of plants and wildlife.

In addition to these three studies cited in the Region 10 Report, analysts reviewed a number of studies dealing with ecological effects from air pollutants. The general approach included the following four steps:

Step 1: Review literature to determine which toxic air pollutants are known to cause ecological damage.

Step 2: Develop a target list of compounds which have known impacts and that are inventoried in our toxics database.

Step 3: Estimate concentrations using modeling done for non-criteria health impacts analysis.

Step 4: Estimate risks. Risks will not necessarily be stated in common units, but our ultimate desire to compare risks across media should be remembered. In lieu of quantitative results, qualitative statements such as "Dibenzobadstuff emissions are likely to impact certain tree species in North Cascades National Park" will still convey an important message.

2. Analysis of Assumptions and Uncertainties

Our uncertainty of the risks presented above range from "somewhat uncertain" to "a somewhat educated guess". Sources of error in estimating pollutant concentrations, and therefore uncertainty, can be divided into two categories - actual measurement errors and estimation errors. Generally, measurement errors will be smaller than estimation errors, especially where estimations are based on "best professional judgement" and anecdotal information. Unfortunately, many of the pollutants analyzed in this report have not been sampled in the ambient air.

The reader is referred to the discussion of uncertainty under the Human Health Risk section of this report for more discussion regarding our uncertainty of pollutant concentrations. In addition, we note the paucity of studies in the literature dealing with the subject of environmental effects from air pollution. With so little work having been done in this area, we are somewhat skeptical of the few risk thresholds referred to in this report.

Most of the studies cited in this report were conducted in the field under ambient conditions. However, several controlled lab studies are included to give an idea of potentially lethal levels associated with certain pollutants. These studies do not simulate exposure patterns experienced in the wild, but because metals accumulate in the body over time, the results obtained under lab conditions are relevant. One study conducted off the coast of Rhode Island determined lethal concentrations of Cd, Ni and Mg to softshell clams (see Appendix 3 for breakdown). Another study found that high levels of heavy metals in aquatic environments can cause behavioral changes and death in toad tadpoles. However, it is unlikely that deposition from the air could cause levels to rise high enough to see these effects but deposition could be a significant contributor near point sources.

Laboratory studies conducted on lab rats are generally not included because of the uncertainty involved in extrapolating this data to correlate with wild animals. One study however is included because it studied the effects of PAH's specifically through inhalation. They found that repeated exposure of 180 ppm resulted in liver damage. The conclusions drawn here should be applicable for any small mammal with similar respiratory system.

3. Literature Review

A literature search and a phone survey were conducted to determine the effects of toxic air pollutants on the environment in Washington. This approach revealed that there has been very little analysis of toxic pollutants in Washington or for that matter, nationwide. There have been quite a few studies done to determine the levels of specific pollutants (Heavy Metals in particular) but these have not been extended to evaluate what negative effects are associated with these levels.

4. Target List of Compounds

To maintain continuity between this and the Human Health portion of this comparative risk report, we have concentrated on the same target list of pollutants in each. It seems that the only pollutant for which there has been any significant amount of research done which was not analyzed in this report is lead. Future studies should include a full analysis of lead.

5. Estimate of Concentrations

The reader is referred to Appendix 10 which tabulates maximum modeled concentrations of the 24 targeted pollutants. Unfortunately, most of the studies we reviewed did not indicate what endpoint could be expected at given concentrations.

6. Detailed Summary of Findings

Ecological effects from exposure to six toxic compounds or classes of compounds (e.g. heavy metals) were found in an extensive literature search. A tabular summary of these studies can be found in Appendix 7, and a summary of the findings of each study cited can be found in bibliography form in Appendix 3.

Three impacts were described in the Region 10 report: the effects of fluoride emissions from aluminum plants on livestock, on honey bees, and the possible contribution of toxic air pollutants to pollution of the Puget Sound microlayer (the top 50 micrometers). Fluoride from aluminum reduction facilities was found to reduce growth of Douglas fir and cause tooth problems in moles, shrews and white-tail deer. Washington State regulates fluoride emission at a level that protects both livestock and plants.

Fluoride and arsenic in sufficient concentrations can kill honey bees. Other research disputes the fact that levels found typically in the state are sufficient to kill bees. 19

Cadmium from zinc smelters and other environmental non-point sources was shown to cause kidney damage to white-tail deer, shrews and voles, in addition to showing a tendency to increase in concentration in edible vegetables.

Heavy metals (e.g. nickel) can cause death to softshell clams and behavioral changes and death to toad tadpoles.

Polynuclear aromatic hydrocarbons (PAH's) were shown to cause decreased hatching of sole eggs and to reduce the growth rate of algae in Puget Sound.

Finally, carbon tetrachloride was shown to cause chronic liver damage in laboratory rats.

7. Summary of Risks from Non-Criteria Air Pollutants

Overall, it seems that most of the studies have been on heavy metal deposition. In high concentrations metals can have a negative impact on animal life while their presence in plants poses potential danger as the metals accumulate in the plant tissue and are passed up the food chain. The exception was the effects of Fluoride on Douglas Fir near an aluminum plant in Whatcom County which caused growth reduction up to 70%. No effects were found from environmental levels of Cadmium in vegetables and plants in general and studies on Arsenic and Mercury in Burmudagrass revealed no effects to the evolution of CO2. Cadmium ingested by small mammals was found to cause kidney and liver damage of varying degrees depending upon dose and age. Fluoride caused tooth wear and mottling but no conclusions were drawn as to what this means. Again, it should be noted that Washington State regulates fluoride emission at levels which protect both livestock and plants.

Two studies done on the Puget Sound microlayer deserve special note. The microlayer is ecologically important as a nursing ground for the egg and larvae stages of a variety of fish and shellfish. One study found that fluoranthene, one of the PAH's deposited by industry near Commencement Bay caused significant growth reduction in algae. The algae are extremely adaptable and are able to recover to full rates of growth within 4 days. The other study, conducted by the University of Oregon found that deposited PAH's significantly cut down on the hatching of sole eggs.

C. TRENDS

The reader is referred to the discussion of trends under the human health portion of this report.

V. References

1 EPA Region 10 Comparative Risk Project, 1988

2 EPA Comparative Risk Project Plan of Attack, 1988

3 Chestnut, L.G., Rowe, R.D. and Ostro, B.D. 1987. Santa Clara Criteria Air Pollutant Benefit Analysis. Draft report.

4 Chestnut, L.G., T.N. Neithercut, and B.D. Ostro. 1987. The Health Effects Associated With Lead in Gasoline and Drinking Water in Metro-Denver. Draft report.

5 Hunt, W., Raoro, R., Curran, T. and Muntzz, J. 7/84. Estimation of Cancer Incidence Cases and Rates for Selected Toxic Air Pollutants Using Ambient Air Pollution Data. Report by PEDCo.

7 EPA, 1985. Air Toxics Problem in the United States: An Analysis of Cancer Risks for Selected Pollutants (a.k.a. the Six Month Study)

8 South Coast Air Quality Management District Report

9 Puget Sound Air Pollution Control Authority - Toxic Air Database

10 Washington Department of Ecology Emission Data System (WEDS)

11 Washington Department of Ecology Guidelines for Acceptable Ambient Limits

12 Radian Report

13 Washington State Yearbook, 1987

14 Woodstove Study (PSAPCA U.W.)

16 RCG/Hagler, Bailly Inc. 2/06/88. Regional and State Comparative Risk Project: Ecological Risk Assessment.

17 EPA 1987 Review of the National Air Quality Standards for Ozone Preliminary Assessment of Scientific and Technical Information. OAQPS Draft Staff Paper. Strategies and Air Standards Division, RTP, N.C.

18 Washington State Air Monitoring Data for 1987. 9/88 Washington Department of Ecology.

19. Mayer, D.F., Lunden, J.D., and Weintsein, L.H. Evaluation of Fluoride Levels & Effects in Honey Bees. 2/87. For: Environmental Entomology.

APPENDIX 1
HEALTH EFFECTS OF CRITERIA POLLUTANTS

Carbon Monoxide (CO)

At lower COHb (carboxyhemoglobin - CO bound to hemoglobin) levels there is evidence of neurobehavioral effects: impaired learning ability, reduced vigilance, decreased manual dexterity, impaired performance of complex tasks, disturbed sleep activity. There is suggestive though not conclusive evidence that drivers in fatal auto accidents often have elevated COHb levels. 10)

Acute effects of increasing CO exposure include a sequence of: headache, dizziness, lassitude, flickering before the eyes, ringing in the ears, nausea, vomiting, palpitations, pressure on the chest, muscular weakness, collapse, coma and death.

CO at 5-10 ppm has been shown to cause subtle physiological behavioral, motor and intellectual changes.

The body reacts to hypoxic stress (increased COHb formation) by increasing cardiac output and blood flow to critical tissues such as brain and myocardium. Individuals with cardiovascular disease are particularly susceptible to increasing COHb levels.

COHb levels as low as 5% has been shown to cause a significant increase in angina pain and decrease in exercise tolerance are noted in patients with advanced coronary disease.

Chronic exposure to CO, resulting in COHb levels as low as 5%, causes damage to the cardiovascular system, including increasing the rate of cerebrovascular accidents, decreasing auditory threshold sensitivity, increasing neuroretinitis and causing optic nerve atrophy. The significance of these effects at low continuous exposure levels is controversial. 11)

Ozone (O3)

Ozone, a highly toxic, biologically reactive gas, is a major component of photochemical smog.

Acute exposure to ozone causes pulmonary edema and epithelial necrosis and induces lesions in the terminal bronchioles and centroacinar alveoli.

Long-term exposure is associated with chronic bronchitis, bronchiolitis, pneumonitis and emphysema. Patients with angina appear to be more susceptible to O3 toxicity ; extensive exercise may increase pulmonary and cardiovascular symptoms in such individuals.

O3 may increase the formation of nitrosamines in the atmosphere or alter the pulmonary metabolism of inhaled PAH, thus influencing the carcinogenic potential of other inhaled carcinogens. 12)

Fine Particulates (PM10)

Human exposure to high particulate levels is associated with increased incidences of asthma, pneumonia and bronchitis as well as lung cancer. Inhaled particles may promote lung-cancer development even though they are deposited at a different time or route than the pulmonary carcinogen. Uptake and retention of chemical carcinogens adsorbed onto the surface of particles may be enhance by the particles themselves. In EPA's staff assessment of epddemiological studies, they found that small declines in lung function in children possible at 140 ug/m3. 13),14)

Sulfur Dioxide (SO2)

The toxicity of SO2 is enhanced when inhaled with particulate aerosol.

WHO (World Health Organization) suggests a threshold of 100-150 ug/m3 SO2 as 24 hour mean, 40-60 ug/m3 smoke as annual mean. Epidemiologic studies do not indicate that the concentration of sulfates is a more important air pollution variable than total particulates suspended as smoke as an annual mean. 15)

The following threshold values are from references 16) and 17):

SO2 at 1500 ug/m3 (.52 ppm 24 hour average) and SPM (suspended particle matter measured as a soiling index of 6 COH or greater) = increased mortality may occur.

SO2 at 750 ug/m3 (.25 ppm) and up with smoke at a concentration of 750 ug/m3 = increased daily death rate may occur.

SO2 at 715 ug/m3 (.25 ppm) with particulate matter = sharp rise in illness for patients over age 54 with severe bronchitis may occur.

SO2 at 600 ug/m3 (.21 ppm) with smoke concentration of 300 ug/m3 = patients with chronic lung disease may experience accentuation of symptoms.

SO2 at 500 ug/m3 (.11 ppm) with low particulate levels = increased hospital admissions of older persons for respiratory disease may occur.

SO2 at 105-265 ug/m3 (.037-.092 ppm) with smoke concentration of 185 ug/m3 = increased frequency of respiratory symptoms and lung disease may occur.

SO_2 at 120 (.046) with smoke concentration of 100 ug/m3 = increased frequency and severity of respiratory diseases in school children may occur.

Lead

The lead TLV is 150 ug/m3 air concentration. A TLV (Threshold Limit Value) is set by the American Conference of Government Industrial Hygienists for occupational exposure to various airborne materials based on continuous exposure 8 hours/day, 5 days/week. 18)

TLVs are not necessarily indicators of toxicity - does not take into account sensitive groups or interactions with other agents that may enhance toxicity. They do consider factors such as eye and respiratory tract irritation, and provide nearly complete protection.

Healthy adults absorb about 10% of ingested inorganic lead, while young children may absorb as much as 50%. The blood-brain barrier to lead uptake is not as well developed in children, making them more susceptible to brain damage from lead poisoning. Low to moderate blood lead levels in children have been associated with visual, motor, perceptual and learning deficits and with hyperactivity.

The following thresholds are from reference 19):

30 ug/100ml - highest safe blood level for children less than 5 years of age

60-80 ug/100 ml - mild toxic effects at this blood level in children

120 ug/100 ml - clear-cut central nervous system effects at this blood level in children

300 ug - normal daily intake of lead in the diet

600 ug lead daily (lifetime exposure) - has not resulted in toxicity

2500 ug lead daily (4 year exposure) - damage in humans

3500 ug lead daily (two months exposure) - toxicity developed

For children there is some research (unclear - but can't be discounted) that lead in the bloodstream in ranges of 15-30 ug/dl (deciliter - a blood lead measurement = ug/100ml) effects ability to focus, and behavioral performance. Lead in airborne dust has been shown to be a problem - windblown dust carries lead. 20)

Nitrogen Dioxide (NO2)

Nitrogen dioxide is damaging to alveolar macrophages, seriously impairing phagocytosis, interferon production and antibactericidal capability. Prolonged impairment of pulmonary clearance of inhaled particles is seen following exposure to NO2 levels that produce permanent histological lesion in the lungs.

Acute exposure to NO2 results in dyspnea, bronchospasm, cough, headache, tachycardia and chest pain. Bronchitis and bronchiolitis, with persistent cough, bronchiolitis obliterans or progressive deterioration and pneumonia may follow sub-acute exposure to NO2.

The following threshold values are from reference 21):

NO2 at .5 ppm and below - little or not direct effect on. pulmonary function, even in. sensitive populations like. asthmatics

The national ambient air quality standard (NAAQS) for NO2 is 100 ug/m3 (.5 ppm). Los Angeles is the only urban·region in US that regularly exceeds the standard.

NO2 may increase the formation of nitrosamines in the atmosphere or alter the pulmonary metabolism of inhaled PAH, thus influencing the carcinogenic potential of other inhaled carcinogens. (p. 132)

References

10) Review of the National Ambient Air Quality Standards for Carbon Monoxide, US EPA, Office of Air and Radiation, Office of Air quality Planning and Standards, Research Triangle Park, North Carolina 27711, Sept. 5, 1985, p. 17.

11) Toxicological Aspects of Energy Production, Charles L. Sanders, Batelle Press, Columbus, Richland, p.139-140.

12) Toxicological Aspects of Energy Production, Charles L. Sanders, Batelle Press, Columbus, Richland, p.129-132.

Toxicological Aspects of Energy Production, Charles L. Sanders, Batelle Press, Columbus, Richland, p.121-125.

14) 40 CFR Chapter 1 (07/01/88 edition)
Subchapter C - Air Programs
Part 50 - National Primary and Secondary Ambient Air Quality Standards.

15) G. Ericsson and P. Camner. 1983. Health effects of sulfur oxides and particulate matter in ambient air. Scand. J. Work Environ. Health 9:1-51. (this is a sub-reference)

16) National Air Pollution Control Administration (NAPCA), 1970. Air quality criteria for sulfur oxides. AP-50, Washington, D.C., NAPCA. (this is a sub-reference)

17) Toxicological Aspects of Energy Production, Charles L. Sanders, Batelle Press, Columbus, Richland, p.134-137. (this is the primary reference for information on this page)

18) Toxicological Aspects of Energy Production, Charles L. Sanders, Batelle Press, Columbus, Richland, p.115-116.

19) Toxicological Aspects of Energy Production, Charles L. Sanders, Batelle Press, Columbus, Richland, p.164-168.

20) EPA Criteria for Lead Vol. IV, EPA-600/8-83/028df June 1986, p. 13-32 - 13-40.

21) Toxicological Aspects of Energy Production, Charles L. Sanders, Batelle Press, Columbus, Richland, p.127-128.

APPENDIX 2
NON-CANCER HEALTH EFFECTS FROM NON-CRITERIA POLLUTANTS

Acetaldehyde: See acute

Arsenic: Short term high dose effects of muscle cramps, facial edema, gastrointestinal damage, vomiting, blood disorders, cardiovascular effects and skin disorders. Chronic ingestion hyperpigmentation and keratinization of skin, typically leading to skin cancer. Short term inhalation exposure: perforation of nasal septum and inflammation of upper respiratory tract. Long term inhalation associated with increased incidence of lung cancer in smelting industry workers (1).

Asbestos: A human carcinogen via oral and inhalation routes, causing cancer of the lung, pleura peritoneum, bronchus, and oropharynx (2).

Benzene: A human carcinogen, poison. A central nervous system narcotic and locally irritating (2).

Beryllium: Chronic inhalation can cause berylliosis, a fibrotic lung disease. Associated with an increased incidence of lung cancer (1).

Cadmium: Inhalation of fumes and dusts affects mainly the respiratory system and kidneys. Increased incidence of lung and prostate cancer in workers. Oral poison causes rapid GI discomfort so less absorbed (1,2).

Carbon Tetrachloride: Potential human carcinogen. Teratogenic. Damages human central nervous system, pulmonary and GI tract (2).

Chloroform: Suspected human carcinogen. Systemic, central nervous system (2).

Chromium: Toxicity related to valence with hexavalent corrosive and irritating. Chronic inhalation exposure to Chrome VI include ulceration and perforation of nasal septum, chronic rhinitis and pharyngitis. Inhalation associated with increased incidence of lung cancer (1).

Dichloromethane: Suspected human carcinogen. Narcosis, affects CNS and blood picture (2).

Dioxins 2,3,7,8TCDD: Potent animal carcinogen, probable human carcinogen. Oral exposure associated with chloracne, wasting syndrome, liver and immune system damage. Other dioxin isomers thought to be less toxic though few studys (1).

Ethylene Dichloride: Suspected human carcinogen. CNS hazard via inhalation. Also headache, mental confusion depression fatigue, lung edema (2).

Ethylene Dibromide: Suspected human carcinogen.

Fluoride: Chronic F poisoning or fluorisis. Sclerosis of the bones (2). Acute irritation.

Formaldehyde: Probable human carcinogen. Highly irritating to eyes skin and respiratory tract. Hypersensitivity possible. Allergan (2).

Manganese (Mn): Upper respiratory disease. Mn compounds induce Parkinsonian symptoms (2,3).

Mercury (Hg): Damage to central nervous system and kidneys (1).

Nickel (Ni): Nickel refinery dust and subsulfide are known human carcinogens. Inhalation effect on lung (1).

Perchloroethylene: Suspected human carcinogen. Acute intoxication involves nervous system (2).

Phenols: Acute systemic toxicant to lungs heart liver kidney. Acute irritant.

POMs/Benzo(a)pyrene: Major compounds of concern of polycyclic organic matter are the carcinogenic polycyclic aromatic hydrocarbons (PAH). Benzo(a)pyrene is the most studied and is a suspected human carcinogen (4).

Toluene: Central nervous system effects (2).

Trichloroethylene: Suspected human carcinogen. Damage to liver and other organs from chronic exposure (2).

Xylene: Acute irritant. Teratogenic and liver effects in animals.

APPENDIX 3
BIBLIOGRAPHY OF STUDIES ON THE EFFECTS
OF TOXIC AIR POLLUTANTS ON THE ENVIRONMENT

Taylor, Ronald & Felix A. Basabe, 1984; Effects of Fluoride on Douglas Fir, Environmental Pollution (Series A) 33:221-235

Study done in Whatcom County on the effects of Fluoride emissions from the Intalco Aluminum plant on Douglas Fir. Findings indicated up to 70% growth reduction occurs with F concentrations >300 mg/kg. Those trees nearest Intalco with levels >100 mg/kg experienced a mean growth of 40%; those trees 0-8 km from the source showed a growth reduction of 33%, those trees >8km showed a reduction of 14%; and the Pre-Intalco growth reduction was 11%. Other findings showed that the effects of SO2 and HF are additive.

Sakata, T et al, Chronic Liver Injury in Rats by Carbon Tetrachloride Inhalation, Bulletin of Environmental Contamination and Toxicology, 38:959-961

Controlled lab experiment pumped CCl4 into chamber at concentrations of 180 ppm. The rats became comatose after 15 minutes of exposure. They recovered completely after the source was removed. Repeated exposure for 8 weeks caused chronic liver injury with modular liver surface and extensive fibrosis.

Riznyk, Raymond et al, Short-Term Effects of PAH's on Sea-Surface Microlayer Phytoneuston, Bulletin of Environmental Contamination and Toxicology 38:1037-1043.

Study done on Puget Sound at Sequim Bay. Studies have shown that the microlayer contains 10-1000 times the concentration levels of metals and organic matter than the underlying water. Tanks set up in the Bay with a constant flow of seawater into them. Introduced Fluoranthene into microlayer - found that 1 mg/l caused low growth rates but the algae was able to fully recover after 4 days. Concluded that algae has the ability to fully recover from initial exposures repeatedly.

Zurera, et al, 1987, Lead and Cadmium Levels in Edible Vegetables, Bulletin of Environmental Contamination and Toxicology 38(5):805-812.

Effects from airborne lead and cadmium were associated with plants characterized by edible leaves and soft stalks, and tubercles & roots. Cd levels found = .008 for chard, .068

for parsley mg/kg fresh weight. Conclusions stated that no detrimental effects to the vegetables were found and the levels did not constitute a human health risk.

Fleischer, Michael, et al, Environmental Impact of Cadmium: A review by the Panal on Hazardous Trace Substances, May 1974, Environmental Health Perspectives 7:253-323.

Brief statement that no toxic effects occur in "plants". The danger comes from their ability to absorb Cd from soil and air and pass it along to people.

Sileo, L, and W.N. Beyer, 1985 Heavy Metals in White-tail Deer Living Near a Zinc Smelter in Pennsylvania, Journal of Wildlife Diseases 21(3);289-296

Sited the National Academy of Sciences (1980) findings that in many species of deer a Cd accumulation level of 2000 ppm wetr weight in the kidney cortex is associated with tubular damage. White-tail deer at the Pennsylvania site had levels approaching this. Also found that Cd accumulates with age in the kidney.

McKinnon, J. Glynn, et al, Heavy Metal Concentrations in Kidneys of Urban Gray Squirrels, Environmental Pollution Agency

Study done in Jacksonville FL. Average atmosphere concentration of Cd <0.001 ug/m3. Source was unknown but pathways are both dietary and pulmonary (not water). Did not give levels but found that levels accumulated over time.

Suttie, J.S. dt al, Effects of Fluoride Emissions from a Modern Primary Aluminum Smelter of a local Population of White-tail Deer (odocoileus virginianus), Journal of Wildlife Diseases 23(1):135-143.

Alcoa smelter was in operation from 1980-1983 at 100% capacity. It was equipped with BACT. Fluoride emissions were 200-250 kg F/day or 182,000 metric tons/year. Pre-smelter F levels were low at 50 ppm for fawns and 200-300 ppm for 2-1/2 year olds and older. Found that F exposure decreased rapidly as distance form smelter increased. Concluded that adverse impact on deer was minimal but there was a 5-fold increase in F concentration in bones of various aged deer. Tooth mottling was also found. Animals downwind from the stack had twice the skeletal F content of those in other areas.

Khangarot, B.S. & P.K. Ray, Sensitivity of Toad Tadpoles, Bufo

Melanostictus, to Heavy Metals, Bulletin of Environmental Contamination and Toxicology, 38:523-527.

The main source for Heavy metals are discharges from industry and mining. This was a lab study. Conclusions were that at higher concentrations (Hg) behavioral changes, including surfacing, increased erratic body movement and loss of equilibrium occured at 1-4 hours of exposure. At lower concentrations, behavioral changes were noted only before death.

Levels found were: Hg-LD50 at 12h: .068; at 96h: .0436 mg/l
Cd-LD50 at 12h: 22.42; at 96h: 8.18 mg/l
Ni-LD50 at 12h: 61.41; at 96h: 25.32 mg/l
Cr-LD50 at 12h: 74.25; at 96h: 49.29 mg/l

Eisler, Ronald, Acute Toxicities of Selected Heavy Metals to the Softshell Clam, mya arenaria, USEPA

Study done off the coast of RI.

Levels found were: Cd-LC50 at 48h: 3.4; at 96h: .85;
at 168h: .15 mg/l
Cd-LC100 at 48h: 15; at 96h: 1.5
at 168h: 1.5 mg/l
Mg-LC0 >300 mg/l
Ni-LC0 > 50 mg/l

Beyer, W. Nelson, Metal Contamination in Wildlife Living Near Two Zinc Smelters, Environmental Pollution 38:63-86.

Found no toxic effects from Cd although the test animals were mostly young. Since Cd accumulates over time this could skew the study significantly. The highest concentration was found in the shrews at 4.8 mg/kg dry weight. Cited a previous study which found that levels of 28 mg/kg dry weight caused kidney damage (proteinuria).

Wang, De-Shin, R.W. Weaver, and J.R. Melton, Microbial Decomposition of Plant Tissue Contaminated with Arsenic and Mercury, Environmental Pollution (Series A), 34:275-282.

Common burmudagrass was grown outdoors in pots. Plant tissue contaminated with Hg and As was added to the soil to see what effects these metals have on CO2 evolution. Relatively high concentrations were used: As=90, Hg=50 ug/g soil. Concluded that there was no toxic effect on CO2 evolution.

Walton, K.C., Fluoride in Moles, Shrews and Earthworms Near an Aluminum Reduction Plant, Environmental Pollution Vol. 34

Found that Fluoride concentrations were highest within 1 km of the plant. At 15 km moles showed toothwear with the mean concentration at 1294 ug/g (range=42-3125 ug/g). Shrews showed toothwear with concentrations at 1404 ug/g (range=82-86000 ug/g). No other effects from Fluoride were noted. Compared to earlier studies done with foxes in the same area they noted that it does not seem to pass up through the food chain. Foxes had approximately the same concentrations as the rodents therefore foxes were not accumulating F from the rodents they eat. This is probably due to the fact that the bones pass through their digestive tract.

Andrews, S.M., M.S. Johnson and J.A. Cooke, Cadmium in Small Mammals from Grassland Established on Matalliferous Mine Waste, Environmental Pollution (Series A) 33:153-162

Studied field voles and common shrews for cadmium levels and effects. Findings indicated levels in their bones as follows:
Control Voles: 0.88 ug/g dry weight
Exposed Voles: 1.84 "

Control Shrews: 1.19 ug/g dry weight
Exposed Shrews: 52.7 "

Concentrations found in their food sources are as follows:
Vole Diet concentrations: 4.7 ug/g dry weight
Shrew Diet concentrations: 23.2 "

Voles are herbivores while shrews have a voracious appetite for lower invertebrates - beetles, arancae, worms, opiliones. Effects from these levels of exposure included significant kidney damage and some liver damage. Other studies have found these effects from exposures at lower concentrations than these.

While this study was conducted on a site contaminated from tailings etc. from an old mine, the results can be applied to Cd intake through airborne deposition and digestion.

Peterson, Todd, Honeybees as Monitors of Industrial Pollution; The Work of Dr. Jerry Bromenshenk, A-Way With Waste, 2nd Ed. Department of Ecology, 1985 pp 188-190.

Study done with Puget Sound region Beekeepers. Found LD50 levels of Arsenic = 3 ppm inside the hive. Lethal Fluoride levels were measured to be LD50 = >100 ppm inside the hive. The gathering and storage methods of Honeybees tended to magnify F levels .

APPENDIX 4

SENSITIVITY OF WESTERN TREE SPECIES TO OZONE

The following table was excerpted from the 1988 EPA Region 10 Comparative Risk Assessment Project.

Table 2

Sensitivity of Western Tree Species to Ozone

(1=tolerant; 2=intermediate; 3=sensitive; 0-insufficient information to rank)

Species	Ozone Sensitivity	Source
Douglas-fir (*Pseudotsuga menziesii*)	2	5,8,9, 21,27,31
Big Cone Douglas-fir (*Pseudotsuga macrocarpa*)	2	28,30
Redwood (*Sequoia sempirvirons*)	1	9
Giant Sequoia (*Sequoiadendron giganteum*)	1	9,21,27, 30,31
Ponderosa pine (*Pinus ponderosa*)	3	1,2,3,5 6,7,8,9 11,12,16, 17,21.22, 23,25,26, 27,28,29, 30,31,32 33,34,35, 36,37,38 39,44,45 46,49,51, 52,53,54
Jeffrey pine (*Pinus jeffreyi*)	3	1,2,9,11, 21,25,27, 28,29,30, 31,33,34, 35,38,39, 44,49
Sugar pine (*Pinus lambertiana*)	1	9,11,21, 25,26,27, 29,30,31, 33,34,35
Western white pine (*Pinus monticola*)	3	15,21,27, 30,31
Lodgepole pine (*Pinus contorta*)	1	5,9
Coulter pine (*Pinus coulteri*)	2	9,11,21, 27,30,31

Table 2 -- Continued

Sensitivity of Western Tree Species to Ozone

(1=tolerant; 2=intermediate; 3=sensitive; 0-insufficient information to rank)

Digger pine (*Pinus sabiniana*)	1	9
Knobcone pine (*Pinus attenuata*)	2	9,21,27 30,31
Bishop pine (*Pinus muircata*)	1	*
Whitebark pine (*Pinus albicaulis*)	1	*
Single leaf pinyon pine (*Pinus monophylla*)	0	
Limber pine (*Pinus flexilis*)	1	15
Foxtail pine (*Pinus balfouriana*)	0	
White fir (*Abies concolor*)	2	5,9,21,23, 25,26,27, 28,29,30, 31,33,34, 35,48,52, 54
Red fir (*Abies magnifica*)	2	30
Grand fir (*Abies grandis*)	1	*[9]
Bristlecone pine (*Pinus aristata*)	0	
Englemann spruce (*Picea engelmannii*)	1	*[9],[15]
Brewer spruce (*Picea breweriana*)	1	*[9],[15]
Mountain hemlock (*Tsuga mertensiana*)	1	*[5],[9], [15]
Western hemlock (*Tsuga heterophylla*)	1	*[5],[9] [15]

Table 2 -- Continued

Sensitivity of Western Tree Species to Ozone

(1=tolerant; 2=intermediate; 3=sensitive; 0-insufficient information to rank)

Incense cedar (<u>Calocedrus</u> <u>decurrens</u>)	2	9,21,23, 25,26,27, 28,29,30,31,34,35
Port-Orford-Cedar (<u>Chamaecyparis</u> <u>lawsoniana</u>)	0	
Western Red Cedar (<u>Thuja</u> <u>plicata</u>)	0	
California nutmeg (<u>Torreya</u> <u>californica</u>)	0	
Pacific yew (<u>Taxus</u> <u>brevifolia</u>)	1	*[5],[9]
Western juniper (<u>Juniperus</u> <u>occidentalis</u>)	1	5,9
Cypress (<u>Cupressus</u> spp.)	0	
Alaska yellow cedar (<u>Chamaecyparis</u> <u>nootkatensis</u>)	0	
Sitka spruce (<u>Picea</u> <u>sitchensis</u>)	1	*[9]
Santa Lucia fir (<u>Abies</u> <u>venusta</u>)	0	
Short red fir (<u>Abies</u> <u>magnifica</u> var. <u>shastensis</u>)	2	*[30]
Noble fir (<u>Abies</u> <u>nobilis</u>)	2	*[30]
Monterey pine (<u>Pinus</u> <u>radiata</u>)	3	9,21,27, 31
California juniper (<u>Juniperus</u> <u>californica</u>)	0	
Utah juniper (<u>Juniperus</u> <u>californica</u> var. <u>utahensis</u>)	0	
Pinyon pine (<u>Pinus</u> spp.)	0	

Table 2 -- Continued

Sensitivity of Western Tree Species to Ozone

(1=tolerant; 2=intermediate; 3=sensitive; 0-insufficient information to rank)

Red Alder (*Alnus rubra*)	0	
Ash (*Fraxinus* spp.)	3	*[9]
Aspen (*Populus tremuloides*)	3	4,9,18, 47,48,50
Oregon ash (*Fraxinus oregona*)	3	*[9],[14]
Black cottonwood (*Populus trichocarpa*)	3	9,13,40 41,42,43
Bigleaf maple (*Acer macrophyllum*)	1	*[5],[9], [14]
California black oak (*Quercus kelloggii*)	2	23,35,38, 29,33
Coast live oak (*Quercus agrifolia*)	0	
California white oak (Valley oak) (*Quercus lobata*)	3	*[9]
Canyon live oak (*Quercus chrysolepis*)	0	
Interior live oak (*Quercus wislizenii*)	0	
Oregon white oak (Garry oak) (*Quercus garryana*)	3	*[9]
Tanoak (*Lithocarpus densiflorus*)	0	
Blue oak (*Quercus douglassii*)	0	
California laurel (*Umbellularia californica*)	0	

Table 2 -- Continued

Sensitivity of Western Tree Species to Ozone

(1=tolerant; 2=intermediate; 3=sensitive; 0-insufficient information to rank)

Giant chinquapin (Golden chinquapin) (*Castanopsis chrysophylla*)	0	
Madrone (*Arbutus menziesii*)	0	
Pacific dogwood (*Cornus nuttallii*)	2	*[9]
Sycamore (*Platanus racemosa*)	3	[14],[19], [20]
White Alder (*Alnus rhombifolia*)	0	
Water birch (*Betula occidentalis*)	1	*[5],[9]
Engelmann oak (*Quercus engelmannii*)	0	
California buckeye (*Aesculus californica*)	2	*[5]
Fremont cottonwood (*Populus fremonti*)	2	*[5],[9]
Eucalyptus (*Eucalyptus* spp.)	0	
Walnut (*Juglans* spp.)	1	*[9],[14]
Apple (*Malus* spp.)	0	
Cherry (*Prunus* spp.)	3	9,10,24, 47
Willow (*Salix* spp.)	0	

Ranking base on close phylogenetic relationship to species with known sensitivity.

☐ reference dealing with sensitivity of related species.

Table 2 -- Continued

Sensitivity of Western Tree Species to Ozone

(1=tolerant; 2=intermediate; 3=sensitive; 0-insufficient information to rank)

References

1. Allison, J. 1982. Evaluation of ozone injury on the Stanislaus National Forest. Forest Pest Management Report 82-07. U.S.F.S. Pacific Southwest Region. San Francisco, CA. 7p.

2. Allison, J. 1984. An evaluation of ozone injury to pines in the El Dorado National Forest. U.S.D.A. Forest Service, Pacific Southwest Region, Forest Pest Management, San Francisco, CA. 84-16.

3. Asher, J.E. 1956. Observation and theory on "X" disease or needle dieback. File Report. Arrowhead Dist., San Bernardino National Forest, CA.

4. Berrang, P. et al. 1986. Natural selection for ozone tolerance in Populus tremuloides. Can. Jour. For. Res. 16(6): 1214-1216.

5. Bialobok, S. 1984. Controlling atmospheric pollution. In M. Treshow (ed.) Air Pollution and Plant Life. J. Wiley and Sons, N.Y. pp. 451-478.

6. Coyne, P.I. and G.E. Bingham. 1982. Variations in photosynthesis and stomatal conductance in an ozone-stressed ponderosa pine stand: light response. Forest Science 28(2): 257-273.

7. Davis, D.D. 1977. Response of ponderosa pine primary needles to separate and simultaneous ozone and PAN exposure. Plant Disease Reporter 61(8): 640-644.

8. Davis, D.D. and F.A. Wood. 1972. The relative susceptibility of eighteen coniferous species to ozone. Phytopathology 62: 14-19.

9. Davis, D.D. and R.G. Wilhour. 1976. Susceptibility of woody plants to sulfur dioxide and photochemical oxidants. Final Report. Terrestrial Ecology Branch. Corvallis Environmental Research Laboratory, Oregon. No. EPA/600/3-76/102, 83 pp.

10. Davis D.D. et al. 1981. Susceptibility of tree and shrub species and response of black cherry foliage to ozone. Plant Disease 65(11): 904-907.

Table 2 -- Continued

Sensitivity of Western Tree Species to Ozone

(1=tolerant; 2=intermediate; 3=sensitive; 0-insufficient information to rank)

11. Evans, L.S. and P.R. Miller. 1972. Comparative needle anatomy and relative ozone sensitivity of four pine species. Can. Jour. Botany 50(5): 1067-1071.

12. Evans, L.S. and P.R. Miller. 1975. Histological comparison of single and additive O_3 and SO_2 injuries to elongating Ponderosa Pine needles. Amer. Jour. Bot. 62(4): 416-421.

13. Furukawa, A, et al. 1983. Inhibition of photosynthesis of poplar species by ozone. Jour. Jap. For. Soc. 65(9): 321-326.

14. Genys, J.B. and H.E. Heggestad. 1978. Susceptibility of different species, clones and strains of pine to acute injury caused by ozone and sulfur dioxide. Plant Dis. Reptr. 62: 687-691.

15. Jensen, K.F. 1973. Response of nine forest tree species to chronic ozone fumigation. Plant Dis. Reptr. 57: 914-917.

16. Karenlampi, L. 1986. Relationship between macroscopic symptoms of injury and cell structural changes in needles of ponderosa pine exposed to air pollution in California. Annales Botanici Fennici 23(3): 255-264.

17. Karhu, M. and S. Huttunen. 1986. Erosion effects of air pollution on needle surfaces. Water, Air, and Soil Pollution 31: 417-423.

18. Karnosky, D.F. 1975. Genetic variation in response of trembling aspen. (Populus tremuloides Michx) leaves and catkins to sulfur dioxide and ozone. Dissertation Abstracts International 36(3): 997.

19. Kress, L.W. 1978. Growth impact of O_3, NO_2, and SO_2 singly and in combination on two maternal lines of American Sycamore. Proceedings of Amer. Photopathology Soc. 4:120.

20. Kress, L.W. et al. 1982. Growth impact of O_3, NO_2, and/or SO_2 on Plantanus occidentalis. Agriculture and Environment 7(3/4): 265-274.

21. McBride, J.R. and P.R. Miller. 1987. Responses of American Forests to Photochemical Oxidants. In T.C. Hutchinson (ed.) Effects of Atmospheric Pollutants on Forests, Wetlands, and Agricultural Ecosystems. Springer-Verlag, NY. pp. 217-228.

Table 2 -- Continued

Sensitivity of Western Tree Species to Ozone

(1=tolerant; 2=intermediate; 3=sensitive; 0-insufficient information to rank)

22. McBride, J.R., et al. 1975. Impact of air pollution on the growth of ponderosa pine. Calif. Agric. 29(12): 8-9.

23. McBride, J.R., et al. 1985. Effects of oxidant air pollutants on forest succession in the mixed conifer forest type of Southern California. Proceedings of the Air Pollutants Effects Forest Ecosystems Symposium. May 8-9, 1985. St. Paul, MN. pp. 156-167.

24. McClenahen, J.R. 1979. Effects of ethylene diurea and ozone on the growth of tree seedlings. Plant Disease Reporter 63(4): 320-323.

25. Miller, P.R. 1973a. Oxidant damage to conifers on selected study sites, 1972. In O.C. Taylor (ed.) Oxidant Air Pollutant Effects on a western Coniferous forest ecosystem. Statewide Air Pollution Research Center. Riverside, CA. pp. III-1 to III-20.

26. Miller, P.R. 1973b. Oxidant-induced community change in a mixed conifer forest. Advan. Chem. Ser. 122: 101-117.

27. Miller, P.R. 1973c. Susceptibility to ozone selected western conifers. Abstr. Int. Congr. Plant Pathol. 2nd. Abstract No. 0579.

28. Miller, P.E. 1977. Oxidant Dose-Canopy Response Subsystem. In O.C. Taylor (ed.) Photochemical oxidant air pollution effects on a mixed conifer forest ecosystem. Final Report. Statewide Air Pollution Research Center. Riverside, CA. pp. 38-64.

29. Miller, P.R. 1984. Ozone effects in the San Bernardino National Forest. In Air pollution and the productivity of the Forest. Symposium held Washington, D.C., Oct-4 and 5, 1983 [Edited by Davis, D.D. et al. Arlington, Virginia, U.S.A.; Izaak Walton League of America.]

30. Miller, P.R. and J.R. McBride. 1973. In O.C. Taylor (ed.) Oxidant Air Pollutant Effects on a Western Coniferous forest ecosystem. Task B Report. Statewide Air Pollution Research Center. Riverside, CA. pp. A-1 to A-36.

31. Miller, P.R. and J.R. McBride. 1975. Effects of air pollutants on Forests. In J.B. Mudd and T.T. Kozlowski (eds.) Response of plants to air pollution. Academic Press. NY. pp. 196-236.

Table 2 -- Continued

Sensitivity of Western Tree Species to Ozone

(1=tolerant; 2=intermediate; 3=sensitive; 0-insufficient information to rank)

32. Miller, P.R. et al. 1963. Ozone injury to the foliage of ponderosa pine. Phytopathology 53: 1072-1076.

33. Miller, P.R. et al. 1982. Oxidant air pollution effects on a western coniferous forest ecosystem. Environmental Research Brief. EPA-600/D-82-276. Environmental Research Laboratory, Corvallis, OR. 10p.

34. Miller, P.R. et al. 1983. Sensitivity of selected western conifers to ozone. Plant Disease 67(10): 1113-1115.

35. Ohmart, C.P. and C.B. Williams, Jr. 1979. The effects of photochemical oxidants on radial growth increment of five species of conifers in the San Bernardino National Forest. Plant Disease Reporter 63(12): 1038-1042.

36. Parmeter, J.R. Jr. and P.R. Miller. 1968. Studies relating to the cause of decline and death of ponderosa pine in southern California. Plant Disease Reporter 52: 707-711.

37. Parmeter, J.R. Jr. et al. 1962. A chlorotic decline of ponderosa pine in southern California. Plant Disease Reporter 46: 269-273.

38. Pronos, J. and D.R. Vogler. 1981. Assessment of ozone injury to pines in the Southern Sierra Nevada, 1979/1980. Forest Pest Management Report 81-20. U.S.F.S. Pacific Southwest Region. San Francisco, CA. 13p.

39. Pronos, J.D. et al. 1978. An evaluation of ozone injury to pines in the southern Sierra Nevada. U.S.D.A. Forest Service, San Francisco, CA. 78-1. 12 p.

40. Reich, P.B. and J.P. Lassoie. 1984. Effects of low level of O_3 exposure on leaf diffusive conductance and water use efficiency in hybrid poplar. Plant, Cell and Environment 7(9): 66-668.

41. Reich, P.B. and R.G. Amundson. 1985. Ambient levels of ozone reduce net photosynthesis in tree and crop species. Science, U.S.A. 230(4725): 566-570

42. Reich, P.B. and J.P. Lassoie. 1985. Influence of low concentrations of ozone on growth, biomass partitioning and leaf senescence in young hybrid poplar plants. Environmental Pollution 39(1): 39-51.

Table 2 -- Continued

Sensitivity of Western Tree Species to Ozone

(1=tolerant; 2=intermediate; 3=sensitive; 0-insufficient information to rank)

43. Reich, P.B. et al. 1984. Reduction in growth of hybrid poplar following field exposure to low levels of O_3 and (or) SO_2. Can. Jour. Bot. 62(12): 2835-2841.

44. Richards, B.L., Sr. et al. 1968. Ozone needle mottle of pines in southern California. J. Air Pollut. Contr. Ass. 18: 73-77.

45. Tingey, D.T. et al. 1976. The effect of chronic ozone exposures on the metabolite content of ponderosa pine seedlings. For. Sc. 22(3): 234-241.

46. Townsend, A.M. and L.S. Dochinger. 1982. Relative sensitivity of pine species to ozone. Journal of Arboriculture 8(7): 186-188.

47. Treshow, M. 1970. Ozone damage to plants. Environ. Pollut. 1:155-161.

48. Treshow, M. and D. Stewart. 1973. Ozone sensitivity of plants in natural communities. Biol. Conserv. 5:209-214.

49. Wallner, D.N. and M. Fong. 1982. An analysis of ozone injury to ponderosa and Jeffrey pines in Sequoia and Kings Canyon National Parks. Resources Management. Sequoia and Kings Canyon National Parks. Three Rivers, CA.

50. Wang, D. et al. 1986. Effects of ambient ozone on the productivity of <u>Populus tremuloides</u> Michx. grown under field conditions. Canadian Journal of For. Res. 16(1): 47-55.

51. Williams, W.T. 1983. Tree growth and smog disease in the forests of California: case history, ponderosa pine in the Southern Sierra Nevada. Environmental Pollution 30(1): 59-75.

52. Williams, W. and N. MacGregor. 1976. Oxidant-induced air pollution damage to forest trees in the southern Sierra Nevada mountains of California. Proc. Amer. Photopath. Soc. 2:120.

53. Williams, W.T. and J.A. Williams. 1986. Effects of oxidant air-pollution on needle health and annual-ring width in a ponderosa pine forest. Environmental Conservation 13(3): 229-234.

54. Williams, W.T. et al. 1977. Air pollution damage to the forest of the Sierra Nevada mountains of California. Jour. Air Pollution Control Association. 27(3): 230-234.

Additional References Used for Effects/Sensitivity Assessment

- Basabe, F. A., R. L. Edmonds and T. Larson 1989 "Regional Ozone in Southwest British Columbia and Western Washington" Draft. To be presented at the JAPCA annual meeting, Anaheim, CA, June 25-30.

- Basabe, F. A. 1989, - Personal Communication

- Berry, C. R. and L. A. Ripperton, 1963, O3, A Possible Cause of White Pine Emergence Tipburn." Phytopathology 53, pp 552-557.

- Costonis, A. C. 1970, "Acute Foliar Injury of Eastern White Pine Induced by SO2 and O3," Phytopathology 60, pp994-999.

- James, R. L., F. W. Cobb, P. R. Miller and J. R. Parmeter, 1980. "Effects of Oxidant Air Pollution on The Suseptibility of Pine Roots to Fommes Annosus". Phytopathology, Vol 70, No. 6, pp 560-563.

- Miller, P. R. and A. A. Millecan, 1971. "Extent of Oxidant Air Pollution Damage to Some Pines and Other Conifers in California," Plant Disease Reporter 55, pp 555-559.

- National Research Council, 1977. Committee on Medical and Biological Effects of Environmental Pollutants, Ozone and Other Photochemical Oxidants, National Academy Press, Washington D.C.

- Pell, E. J., 1974, "Impact of O3 on the Bioenergetics of Plant Systems," Air Pollution Effects of Plant Growth. M. Dugger, ed. Washington D.C., American Chemical Society, ACS Symposium Series, No. 3, pp106-114.

- RCG/Hagler Bailly Inc., 1988, "Regional State Comparative Risk Project. Ecological Risk Assessment. Problem Area: Criteria Air Pollutants, Damage Category: Ecological Effects". Rcg/Hagler Bailly Inc.

- Reich, P. B., 1983, "Effects of Low Concentration of Ozone on Net Photosynthesis, Dark Respiration and Chlorophyll Contents in Aging Hybrid Poplar Leaves", Plant Physiology, Vol. 73, pp 291-296.

- Skelly, J.M., S. F. Duchelle and L. W. Kress, 1979. "Impact of Photochemical Oxidant Air Pollution on Eastern White Pine in the Shenandoah, Blueridge Parkway and Great Smokey Mountains National Parkls", National Parks Proceedings II, Conference on. Scientific Research in National Parks. San Francisco, CA

- Taylor, O.C., ed. 1980, "Photochemical Oxidant Air Pollution Effects on a Mixed Conifer Forest Ecosystem", Final Report. Corvallis, OR; US EPA, Office of Research and Development,; EPA-600/3-80-002, 169p.

- Taylor, O.C., ed. 1973, "Oxidant Air Pollution Effects on a Western Coniferous Forest Ecosystem." Task B Report, Riverside, CA; University of California, Air Pollution Research Center.

- Tingey, D. T., 1985, "Perspectives In Environmental Botany, Chapter I: Effects of O3 on Vegetation," ed. D. N. Rao, K. J. Ahmad, Mohd Yunus and S. N. Singh, Print House (India) 5, Tej Bahadur Sapru Marg, Lucknow U. P. (India)

- U.S. Environmental Protection Agency, 1987, Review of the National Air Quality Standards for Ozone Preliminary Assessment of Scientific and Technical Information. OAQPS Draft Staff Paper, Strategies and Air Standards Division, Research Triangle Park, NC

- Van Haren, F. J., 1985, "Ozone Concentrations in Some Forested Areas of Western Washington". Washington State Department of Ecology, Air Program Report.

- Van Haren, F. J., 1987, "Characterization of Ozone at Four Rural Sites in Western Washington", Washington State Department of Ecology, Air Program Report.

- WA Department of Ecology, 1986, "Washington State Air Monitoring Data for 1985", WDOE 86-8

- WA Department of Ecology, 1987, "Washington State Air Monitoring Data for 1986", DOE 87-20

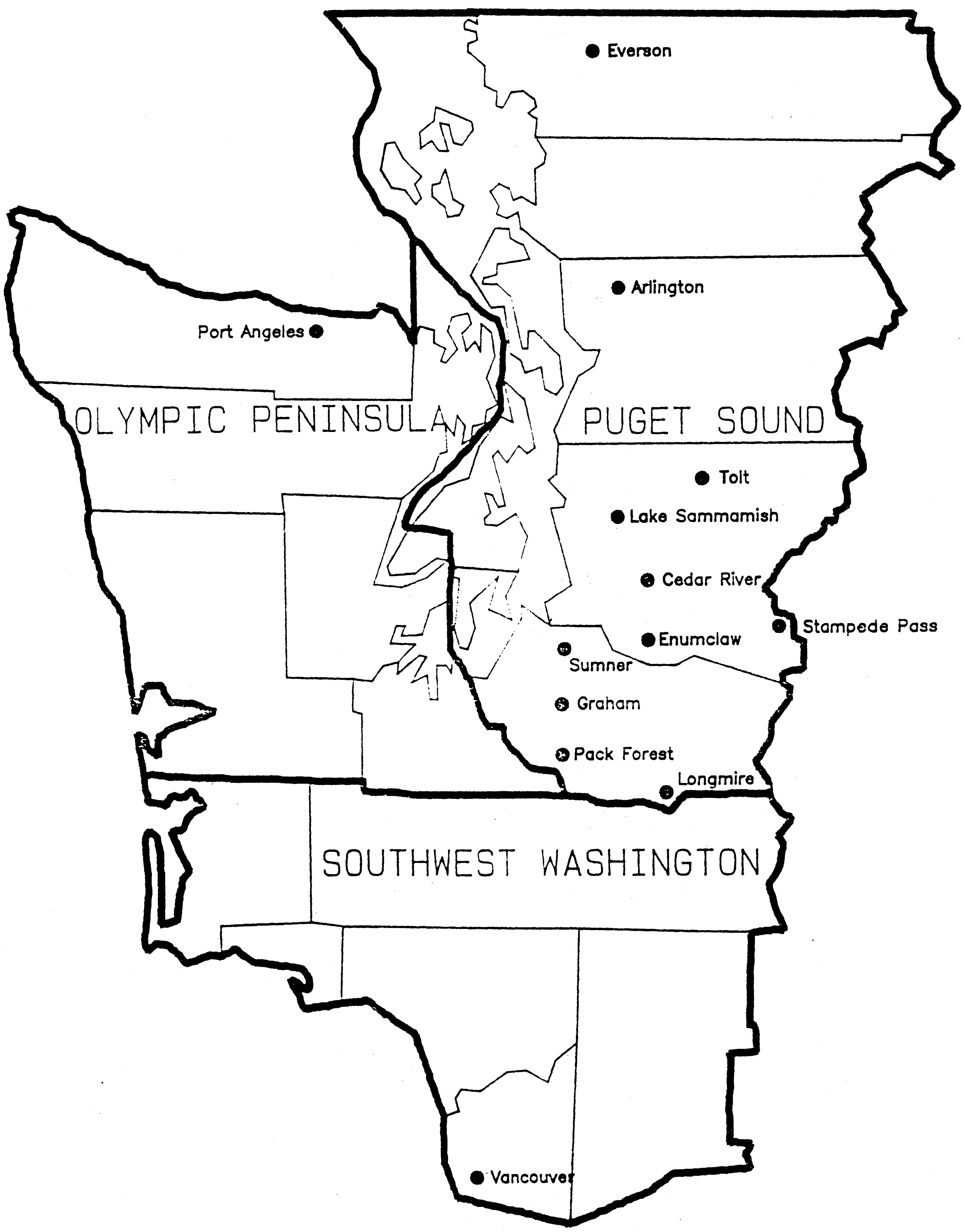
- WA Department of Ecology, 1988, "Washington State Air Monitoring Data for 1987", DOE 88-22

- Wilhour, R. G., 1970, "Influence of O3 on White Ash (Fraxinus Americanus)." Ph.d. thesis, PA State University, University Park, PA, 91 p.

Appendix 5

Site by Site Summaries of Elevated Ozone Levels

Regions of Western Washington Showing Ozone Monitoring Sites



2010 ECOLOGICAL ASSESSMENT - OZONE

Summary of Events > .07 ppm and > 4 hrs. Duration

1987

Site	No. of Events	Total Hours	1-Hr. Max	Comments
Everson	3	14	.09	
Arlington	3	16	.08	
Enumclaw	17	94	.14	
Pack Forest	20	115	.11	
Longmire	10	53	.11	
Graham	6	33	.10	
Port Angeles	0	--	.07	
Lake Sammamish	10	48	.11	
Sumner	5	26	.11	Discontinued for season on 6/307

1986

Site	No. of Events	Total Hours	1-Hr. Max	Comments
Arlington	6	28	.08	
Enumclaw	7	45	.12(2)	No data 7/23-9/1; ends 9/23
Pack Forest	28	199	.14	
Longmire	6	31	.10	
Graham	11	64	.11	
Spokane	5	29	.09	Monitoring ends 9/9
Port Angeles	0	--	.06	
Vancouver	9	50	.10	
Lake Sammamish	16	87	.13	
Sumner	6	29	.10	No data 4/1-7/18
Kent	2	10	.08	
Firwood	3	14	.10	

1985

Site	No. of Events	Total Hours	1-Hr. Max	Comments
Arlington	6	31	.11(3)	
Tolt	10	58	.10	
Enumclaw	5	22	.10	Monitoring begins 8/11
Pack Forest	22	158	.13	
Graham	4	21	.10	No data 6/28-7/31
Spokane	4	19	.08(4)	
Port Angeles	0	--	.06	No data 6/25-8/14
Vancouver	6	36	.10	
Lake Sammamish	12	70	.12	
Sumner	12	74	.10	
Kent	2	8	.09	
Firwood	4	21	.09	

APPENDIX 6
MISCELLANEOUS STANDARDS FOR CRITERIA AIR POLLUTANTS

National Ambient Air Quality Standards (NAAQS) 1)

SO2 - .03 ppm (80 ug/m3) - annual arithmetic mean
.14 ppm (365 ug/m3) - maximum 24 hour concentration not to be exceeded more than once per year. (Part 50.4)

PM10 50 ug/m3 annual
150 ug/m3 - 24 hour average concentration. (Part 50.6)

CO - 9 ppm - 8 hour average concentration not to be exceeded more than once per year
35 ppm - one hour average concentration not to be exceeded more than once per year. (Part 50.8)

O3 - .12 ppm (235 ug/m3) - standard attained when expected number of days per calendar year with maximum hourly average concentrations above .12 ppm is equal to or less than 1. (Part 50.9) (see Appendix H)

NO2 - .053 ppm (100 ug/m3) - annual arithmetic mean. (Part 50.11)

Lead - 1.5 ug/m3 - maximum arithmetic mean averaged over a calendar quarter. (Part 50.12)

Washington State Standards

Washington State standards are all identical to the NAAQS except that we have no lead standard, and our SO2 standards are more strict.

SO2
.02 ppm - annual average
.10 ppm - 24 hour average
.25 ppm - one hour average
.40 ppm - one hour average not to be exceeded more than twice in seven days

Puget Sound Air Pollution Control Authority Standards

PSAPCA standards are identical to Washington State's except for

SO_2 - they have two additional standards.

SO_2	.10 ppm - 24 hour average - short term never to be exceeded 1.00 ppm - 5 minute average not to be exceeded more than once in eight hours

Oregon Standards

Oregon standards are identical to the NAAQS, except that they have no lead standard. 2)

Idaho Standards

Idaho standards are identical to the NAAQS, except that they have no lead standard. 3)

California Standards 4)

SO_2 -	.02 ppm - annual average .10 ppm - 24 hour average
PM10 -	30 ug/m3 - annual geometric mean (not arithmetic mean like NAAQS) 50 ug/m3 - 24 hour average
CO -	6 ppm - 8 hour average for Lake Tahoe area only - due to concerns about CO effects at high altitudes 20 ppm - one hour average
O_3 -	.09 ppm - one hour average
NO_2 -	.25 ppm - one hour average
Lead -	1.5 ug/m3 - 30 day average

Canadian National Standards 5)

Canadian national and provincial standards are divided into two designations:

A - which is to protect pristine and rural areas for long term without deterioration

B - acceptable goal to protect majority of population and the environment

SO2

A - 150 ug/m3 (.06 ppm) - 24 hour average
B - 300 ug/m3 (.11 ppm0 - 24 hour average

A - 30 ug/m3 (.01 ppm) - one year average
B - 60 ug/m3 (.02 ppm) - one year average

03

A - 100 ug/m3 (.05 ppm) - one hour average
B - 160 ug/m3 (.08 ppm) - one hour average

A - 20 ug/m3 (.01 ppm0 - one year average
B - 30 ug/m3 (.02 ppm) - one year average

CO

A - 15000 ug/m3 (13 ppm) - one hour average
B - 35000 ug/m3 (31 ppm) - one hour average

A - 6000 ug/m3 (5 ppm) - 8 hour average
B - 15000 ug/m3 (13 ppm) - 8 hour average

NO2

A - none
B - 400 ug/m3 (.212 ppm) - one hour average

A - none
B - 200 ug/m3 (.106 ppm) - 24 hour average

A - 60 ug/m3 (.031 ppm) - one year average
B - 100 ug/m3 (.053 ppm) - one year average

PM10

No standards for PM10 at this time. In development.

Lead

No standards for lead at this time. In development.

British Columbia Standards 5)

SO2

A - 450 ug/m3 (.17 ppm) - one hour average
B - 900 ug/m3 (.34 ppm) - one hour average

A - 375 ug/m3 (.14 ppm) - three hour average
B - 655 ug/m3 (.25 ppm) - three hour average

A - 160 ug/m3 (.06 ppm) - 24 hour average
B - 260 ug/m3 (.10 ppm) - 24 hour average

A - 25 ug/m3 (.01 ppm) - one year average
B - 75 ug/m3 (.03 ppm) - one year average

03

Same as national standards.

CO

A - 14300 ug/m3 (12 ppm) - one hour average
B - 28000 ug/m3 (24 ppm) - one hour average

A - 5500 ug/m3 (5 ppm) - 8 hour average
B - 11000 ug/m3 (10 ppm) - 8 hour average

NO2

Same as national standards.

PM10

No standards for PM10 at this time. In development.

Lead

A - 4 ug/m3 - 24 hour average
B - 4 ug/m3 - 24 hour average

A - 2 ug/m3 - one year average
B - 2 ug/m3 - one year average

Definitions, Acronyms and other References

NAAQS - Nationsl Ambient Air Quality Standard - set by EPA for the general population

TLV - Threshold Limit Value - set by American Conference for Governmental Industrial Hygienists for a 40 hour/week exposure (the minimum exposure dose that produces significant adverse effects)

STL - Short Term Limits - set by American Conference for Governmental Industrial Hygienists - maximal limit for periods not to exceed one hour

EEL - Emergency Exposure Limit - set by Committee on Toxicology of the National Academy of Sciences - short term exposure limit thought not to cause disability or interfere with an emergency task 6).

References

1) 40 CFR Chapter 1 (07/01/88 edition) Subchapter C - Air Programs Part 50 - National Primary and Secondary Ambient Air Quality Standards

2) Lloyd Kostow, 03/07/89, Oregon DEQ, Portland, OR, 1-503-229-5187.

3) Martin Bauer, 03/07/89, Idaho Air Quality Bureau, Boise, ID, 1-208-334-5839.

4) Bill Sessa, 03/08/89, California Air Resources Board, Sacramento CA, 1-916-322-2990.

5) Barid Manna, 03/09/89, British Columbia Ministry of Environment, Victoria, BC, 1-604-387-9957.

6) Toxicological Aspects of Energy Production, Charles L. Sanders, Batelle Press, Columbus, Richland, p.115.

APPENDIX 7
SUMMARY OF EFFECTS FROM TOXICS ON THE ENVIRONMENT

Pollutant	Fluoride
Source	Aluminum smelter
Transport/Exposure Pathways	Deposition
Ecosystem Affected	Douglas Fir
Endpoints or Effects	Growth Reduction (up to 70%)
Comments	

Pollutant	Fluoride
Source	Aluminum smelter
Transport/Exposure Pathway	Ingestion
Ecosystem Affected	White-tail Deer
Endpoints or Effects	Mottled teeth, Increased concentration in bones
Comments	Adverse impact was found to be minimal

Pollutant	Fluoride
Source	Al Reduction Plant
Transport/Exposure Pathways	Deposition/Ingestion
Ecosystem Affected	Moles, Shrews, Earthworms
Endpoint or Effects	Toothwear
Comments	Not passed up through food chain since bones pass through digestive system

Pollutant	Cadmium
Source	Zinc Smelters
Transport/Exposure Pathways	Ingestion
Ecosystem Affected	Shrews
Endpoints or Effects	Kidney Damage
Comments	

Pollutant	Cadmium
Source	Environments Non-Point Source
Transport/Exposure Pathways	Leaves, soft stalks
Ecosystem Affected	Edible Vegetables (parsley, chard, etc)
Endpoints or Effects	None to plants but accumulation does occur
Comments	Potential to pass it up the food chain

Pollutant	Cadmium
Source	Environmental Non-point sources
Transport/Exposure Pathways	Deposition through leaves
Ecosystem Affected	Plants in general
Endpoints or Effects	None to plants
Comments	Potential to pass it up the food chain

Pollutant	Cadmium
Source	Zinc Smelters
Transport/Exposure Pathways	Ingestion
Ecosystem Effected	White-tail Deer
Endpoints or Effects	Tubular damage to kidney
Comments	

Pollutant	Cadmium
Source	Metalliferous mine residue
Transport/Exposure Pathways	Ingestion
Ecosystem Affected	Shrews and voles
Endpoints or Effects	Kidney & liver damage
Comments	Contamination due to mining leftovers but is applicable to atmospheric deposition.

Pollutant	Arsenic, Mercury
Source	Controlled Exposure through contaminated leaves added to soil
Transport/Exposure Pathway	Adsorption
Ecosystem Affected	Common Burmudagrass
Endpoints or Effects	No effects to CO2 evolution
Comments	

Pollutant	Heavy Metals (Cd, Ni, Mg)
Source	Controlled Exposure - deposition to water
Transport/Exposure Pathway	Deposition
Ecosystem Affected	Softshell Clams
Endpoints or Effects	Death
Comments	

Pollutant	Heavy Metals (Cd, Ni, Hg, Cr)
Source	Controlled exposure - deposition to water
Transport/Exposure Pathways	Deposition
Ecosystem Affected	Toad tadpoles
Endpoints or Effects	Behavioral Changes & Death
Comments	Unlikely to find levels this high from deposition alone

Pollutant	Arsenic, Fluoride
Source	Industry
Transport/Exposure Pathways	Honey Gathering (deposition)
Ecosystem Effected	Honeybees
Endpoints of Effects	Death
Comments	Study done on Puget Sound

Pollutant	PAH's
Source	Industry
Transport/Exposure Pathways	Deposition
Ecosystem Affected	Algae in Puget Sound microlayer
Endpoints or Effects	Growth rate reduction
Comments	Full recover and adaptation occured within 3-4 days

Pollutant	Carbon Tetrachloride
Transport/Exposure Pathways	Inhalation
Ecosystem Affected	Lab Rats
Endpoints of Effects	Chronic liver damage
Comments	

Pollutant	PAH's
Source	Unknown, (possibly coal burning)
Transport/Exposure Pathway	Deposition
Ecosystem Affected	Sole eggs in Puget Sound Microlayer
Endpoints or Effects	Decrease in hatching
Comments	Study done by U of Oregon. Cited in Steve Nicholas' 2010 report

Appendix 8
Major Sources of Pollutants

Pollutant	Significant Sources	Em. T/yr
Carbon Monoxide	Motor vehicles	1,858,413
	Off road transportation	255,230
	Primary aluminum	260,240
Ozone (VOC emissions)	Motor vehicles	194,976
	Other area sources	104,176
Sulfur Dioxide	Electric Utilities	68,695
	Small boilers	29,554
	Industrial boilers	20,672
Particulates	Motor vehicles	112,001
	Other area sources	35,797
	Slash burns	15,719
Acetaldehyde	Wood Comb: Fireplaces	1212.660
	Woodfired Boilers	496.825
	Forest Fire	177.400
	Agricultural Fire	158.000
Arsenic	Coal fired Boilers	9.160
	Coal Comb (R+C+Ins)	1.070
	Forest Fire	0.033
	Agricultural Fire	0.029
Benzene	Nat Gas (R+C+Ins)	44612.000
	Nat Gas (Ind)	19572.000
	Hwy Veh (Gasoline)	5237.000
	Slash Burning	2008.000
Benzo(a)pyrene	Aluminum Ore: Electo-reduction	15.030
Beryllium	Coal fired Boilers	4.226
	Coal Comb (R+C+Ins)	1.130
Cadmium	Coal fired Boilers	2.470
	Solid Waste Disposal	0.291
	Coal Comb (R+C+Ins)	0.071
	Sewage Sludge Incineration	0.027
Chlorform	Sulfite Pulping	1874.970
	Sulfate(Kraft) Pulping	1858.700
Chromium	Solid Waste Disposal	4.325
	Sewage Sludge Incineration	3.150
	Coal Comb (R+C+Ins)	1.990
	Oil fired boilers	1.597

Major Sources of Pollutants (cont'd)

Pollutant	Significant Sources	Em. T/yr
Dichloromethane	Point Sources	1035.000
Dioxins	Wood fired Boilers	0.077
	Wood Comb: Woodstoves	0.035
	Wood Comb: Fireplaces	0.030
Ethylene Dichloride	Point Sources	9.000
Fluorides	Aluminum Ore: Electro-red	1388.000
	Point Sources	46.000
Formaldehyde	Wood Comb: Fireplaces	2599.000
	Wood fired boilers	993.650
	Wood Comb: Woodstoves	471.000
Manganese	Slash Burning	3734.000
	Wood Comb: Woodstoves	981.000
	Wood Comb: Fireplaces	866.000
	Wood fired boilers	613.000
Mercury	Coal fired boilers	1.028
	Solid Waste Disposal	0.065
Nickel	R/D Oil Comb (Comm+Ind)	47.250
	Oil fired boilers	34.090
	Oil Comb (R)	12.800
	Coal Comm (R+C+Ins)	1.620
Phenols	Wood fired boiler	4140.000
	Wood Comb: Woodstoves	1962.218
	Wood Comb: Fireplaces	1732.370
Polycyclic Organic Matter	Primary prod aluminum	1177.000
	Wood Comb: Woodstoves	539.600
	Slash Burning	212.990
Toluene	Hwy Veh (Gasoline)	11087.000
	Slash Burning	2867.000
	Point Sources	1301.000
Trichloroethylene	Point Sources	1225.000
Xylene	Hwy Veh (Gasoline)	3044.300
	Point Sources	882.000
	Service Sta Tnk Refueling	530.000

APPENDIX 9

ANNUAL AVERAGE MODELED CONCENTRATIONS

The attached tables are the results of modeling pollutant concentrations in Washington counties using the modeling method described in Section II.A.2.b. Emission data from the 1989 update of the Department of Ecology's toxic emission database were used with one exception. Our comparison of POMs model concentrations were considerably under monitored values. Consequently, we estimated POM emission rates by assuming that 15% of total POMs is B(a)P. Th 15% figure was based on a recent study by Larson, et al (reference on the Kin County table). The reader will find that B(a)P values are 15% of POMs.

PARAMETERS USED IN MODELING

COUNTY	AREA (sq. miles)	POPULATION	AVG ANNUAL WINDSPEED
ADAMS	1894	13100	5.0800
ASOTIN	633	17000	5.7400
BENTON	1722	113400	6.3600
CHELAN	2926	21713	6.4500
CLALLAM	1753	29000	7.8000
CLARK	627	195800	6.0200
COLUMBIA	860	4000	5.7400
COWLITZ	1144	80500	5.8600
DOUGLAS	1839	22800	5.0800
FERRY	2202	6000	3.7800
FRANKLIN	1260	36700	6.3000
GARFIELD	713	2400	5.7400
GRANT	2680	48600	5.0800
GRAYS HARBOR	1910	66800	5.9200
ISLAND	212	45200	6.7200
JEFFERSON	1805	16600	7.8000
KING	2131	1309800	4.5500
KITSAP	393	156800	4.5500
KITTITAS	2320	25100	6.4500
KLICKITAT	1908	16200	6.2200
LEWIS	2449	56700	4.9100
LINCOLN	2306	9600	7.1900
MASON	962	31900	5.9200
OKANOGAN	5301	30900	5.0800
PACIFIC	908	17800	11.0900
PEND OREILLE	1402	8800	3.7800
PIERCE	1676	501300	4.2600
SAN JUAN	179	8100	6.7200
SKAGIT	1735	64900	5.5200
SKAMANIA	1672	8100	6.2200
SNOHOMISH	2098	353400	6.4600
SPOKANE	1758	347600	7.1900
STEVENS	2481	29500	3.7800
THURSTON	714	129100	4.9100
WAHKIAKUM	261	3800	11.0900
WALLA WALLA	1267	47900	5.7400
WHATCOM	2126	109900	5.5200
WHITMAN	2166	40400	7.1900
YAKIMA	4271	175000	6.2200

ANNUAL AVERAGE MODELED CONCENTRATIONS

---------------------------------- COUNTY=ADAMS ----------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	6.1E-03	.	6.1E-03
Arsenic	2.0E-06	.	2.0E-06
Benzene	9.6E-02	.	9.6E-02
Benzo(a)pyrene	0.0E+00	.	0.0E+00
Beryllium	1.5E-06	.	1.5E-06
Cadmium	2.5E-07	.	2.5E-07
Chromium	9.6E-06	.	9.6E-06
Dichloromethane	.	1.7E-03	1.7E-03
Dioxins	0.0E+00	.	0.0E+00
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	7.6E-03	.	7.6E-03
Manganese	6.7E-03	.	6.7E-03
Mercury	6.2E-07	.	6.2E-07
Nickel	8.4E-05	.	8.4E-05
POMs	0.0E+00	.	0.0E+00
Phenols	1.3E-02	.	1.3E-02
Toluene	3.5E-02	2.3E-03	3.7E-02
Trichloroethylene	.	2.3E-03	2.3E-03
Xylene	1.3E-02	1.7E-03	1.5E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=ASOTIN --------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	5.9E-03	3.3E-04	6.2E-03
Arsenic	6.9E-06	.	6.9E-06
Benzene	6.8E-02	.	6.8E-02
Benzo(a)pyrene	9.2E-10	.	9.2E-10
Beryllium	7.4E-06	.	7.4E-06
Cadmium	4.5E-07	.	4.5E-07
Chromium	1.6E-05	.	1.6E-05
Dichloromethane	.	3.5E-03	3.5E-03
Dioxins	0.0E+00	5.2E-08	5.2E-08
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	1.3E-02	6.7E-04	1.4E-02
Manganese	2.6E-02	1.4E-03	2.7E-02
Mercury	1.6E-07	.	1.6E-07
Nickel	8.4E-05	.	8.4E-05
POMs	6.2E-09	.	6.2E-09
Phenols	1.8E-02	2.8E-03	2.0E-02
Toluene	6.0E-02	4.4E-03	6.4E-02
Trichloroethylene	.	4.4E-03	4.4E-03
Xylene	1.6E-02	3.5E-03	1.9E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=BENTON ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	2.3E-02	.	2.3E-02
Arsenic	8.8E-06	1.0E-03	1.0E-03
Benzene	1.2E+00	.	1.2E+00
Benzo(a)pyrene	0.0E+00	.	0.0E+00
Beryllium	9.5E-06	2.5E-06	1.2E-05
Cadmium	5.8E-07	2.5E-06	3.1E-06
Chromium	4.0E-05	1.2E-05	5.3E-05
Dichloromethane	.	1.4E-02	1.4E-02
Dioxins	9.7E-07	.	9.7E-07
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	5.0E-02	1.1E-04	5.0E-02
Manganese	3.0E-02	6.9E-06	3.0E-02
Mercury	2.3E-07	7.5E-05	7.5E-05
Nickel	8.2E-04	2.3E-04	1.0E-03
POMs	0.0E+00	.	0.0E+00
Phenols	6.0E-02	.	6.0E-02
Toluene	1.4E-01	1.7E-02	1.6E-01
Trichloroethylene	.	1.6E-02	1.6E-02
Xylene	4.7E-02	1.2E-02	5.8E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=CHELAN ---------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	3.9E-03	5.5E-03	9.4E-03
Arsenic	2.8E-06	.	2.8E-06
Benzene	3.0E-01	.	3.0E-01
Benzo(a)pyrene	1.4E-08	1.2E-04	1.2E-04
Beryllium	2.9E-06	.	2.9E-06
Cadmium	2.2E-07	.	2.2E-07
Chromium	1.2E-05	9.4E-07	1.2E-05
Dichloromethane	.	1.8E-03	1.8E-03
Dioxins	1.8E-07	8.5E-07	1.0E-06
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	8.4E-02	8.4E-02
Formaldehyde	7.6E-03	1.1E-02	1.9E-02
Manganese	2.0E-02	2.3E-02	4.3E-02
Mercury	2.0E-07	.	2.0E-07
Nickel	1.7E-04	1.9E-05	1.9E-04
POMs	9.3E-08	8.0E-04	8.0E-04
Phenols	1.0E-02	4.6E-02	5.6E-02
Toluene	1.1E-01	2.6E-03	1.1E-01
Trichloroethylene	.	2.2E-03	2.2E-03
Xylene	3.1E-02	1.8E-03	3.3E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=CLALLAM ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	5.2E-03	1.6E-02	2.1E-02
Arsenic	2.7E-06	.	2.7E-06
Benzene	3.7E-01	.	3.7E-01
Benzo(a)pyrene	2.0E-08	.	2.0E-08
Beryllium	2.6E-06	.	2.6E-06
Cadmium	2.3E-07	.	2.3E-07
Chloroform	.	9.8E-02	9.8E-02
Chromium	1.7E-05	5.1E-06	2.2E-05
Dichloromethane	.	2.7E-03	2.7E-03
Dioxins	2.0E-07	2.4E-06	2.6E-06
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	8.9E-03	3.2E-02	4.0E-02
Manganese	2.7E-01	2.5E-02	2.9E-01
Mercury	3.1E-07	.	3.1E-07
Nickel	6.6E-04	1.0E-04	7.6E-04
POMs	1.3E-07	.	1.3E-07
Phenols	1.4E-02	1.3E-01	1.4E-01
Toluene	2.7E-01	3.5E-03	2.7E-01
Trichloroethylene	.	3.1E-03	3.1E-03
Xylene	2.3E-02	2.3E-03	2.5E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=CLARK ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	8.4E-02	6.4E-03	9.1E-02
Arsenic	2.0E-06	.	2.0E-06
Benzene	2.2E+00	.	2.2E+00
Benzo(a)pyrene	1.3E-08	.	1.3E-08
Beryllium	1.1E-05	.	1.1E-05
Cadmium	1.2E-06	2.3E-05	2.4E-05
Chloroform	.	9.5E-01	9.5E-01
Chromium	7.9E-05	3.2E-03	3.2E-03
Dichloromethane	.	4.1E-02	4.1E-02
Dioxins	3.4E-06	9.9E-07	4.4E-06
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	7.8E-02	7.8E-02
Formaldehyde	1.6E-01	1.5E-02	1.8E-01
Manganese	1.3E-01	1.3E-02	1.5E-01
Mercury	2.3E-06	2.3E-06	4.5E-06
Nickel	2.8E-03	9.8E-03	1.3E-02
POMs	8.5E-08	.	8.5E-08
Phenols	1.9E-01	5.4E-02	2.5E-01
Toluene	5.7E-01	5.2E-02	6.3E-01
Trichloroethylene	.	4.8E-02	4.8E-02
Xylene	1.5E-01	3.5E-02	1.8E-01

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=COLUMBIA ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	2.3E-03	.	2.3E-03
Arsenic	6.7E-06	.	6.7E-06
Benzene	4.5E-02	.	4.5E-02
Benzo(a)pyrene	0.0E+00	.	0.0E+00
Beryllium	7.0E-06	.	7.0E-06
Cadmium	4.9E-07	.	4.9E-07
Chromium	1.6E-05	.	1.6E-05
Dichloromethane	.	7.6E-04	7.6E-04
Dioxins	0.0E+00	.	0.0E+00
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	3.0E-03	.	3.0E-03
Manganese	1.8E-02	.	1.8E-02
Mercury	3.6E-07	.	3.6E-07
Nickel	6.3E-05	.	6.3E-05
POMs	0.0E+00	.	0.0E+00
Phenols	5.2E-03	.	5.2E-03
Toluene	2.2E-02	7.6E-04	2.3E-02
Trichloroethylene	.	7.6E-04	7.6E-04
Xylene	3.8E-03	7.6E-04	4.6E-03

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=COWLITZ ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	3.7E-02	6.3E-02	1.0E-01
Arsenic	9.1E-06	8.9E-04	9.0E-04
Benzene	1.6E+00	.	1.6E+00
Benzo(a)Pyrene	.	4.6E-03	4.6E-03
Benzo(a)pyrene	1.3E-07	6.4E-04	6.4E-04
Beryllium	6.2E-06	2.2E-06	8.5E-06
Cadmium	1.3E-06	2.2E-06	3.5E-06
Chloroform	.	2.4E-01	2.4E-01
Chromium	6.8E-05	4.4E-05	1.1E-04
Dichloromethane	.	1.3E-02	1.3E-02
Dioxins	6.5E-07	9.7E-06	1.0E-05
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	1.2E-01	1.2E-01
Formaldehyde	5.0E-02	1.3E-01	1.8E-01
Manganese	2.3E-01	1.7E-02	2.5E-01
Mercury	3.4E-06	6.7E-05	7.0E-05
Nickel	2.3E-03	8.5E-04	3.2E-03
POMs	.	3.1E-02	3.1E-02
POMs	8.8E-07	4.3E-03	4.3E-03
Phenols	7.4E-02	5.4E-01	6.1E-01
Toluene	3.5E-01	1.6E-02	3.6E-01
Trichloroethylene	.	1.5E-02	1.5E-02
Xylene	6.1E-02	1.1E-02	7.2E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=DOUGLAS ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	5.3E-03	.	5.3E-03
Arsenic	2.2E-06	.	2.2E-06
Benzene	5.4E-02	.	5.4E-02
Benzo(a)pyrene	0.0E+00	.	0.0E+00
Beryllium	2.4E-06	.	2.4E-06
Cadmium	1.5E-07	.	1.5E-07
Chromium	9.8E-06	.	9.8E-06
Dichloromethane	.	3.5E-03	3.5E-03
Dioxins	2.9E-07	.	2.9E-07
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	1.1E-02	.	1.1E-02
Manganese	7.9E-03	.	7.9E-03
Mercury	5.3E-08	.	5.3E-08
Nickel	1.4E-04	.	1.4E-04
POMs	0.0E+00	.	0.0E+00
Phenols	1.6E-02	.	1.6E-02
Toluene	1.1E-02	4.1E-03	1.5E-02
Trichloroethylene	.	4.1E-03	4.1E-03
Xylene	4.1E-03	2.9E-03	7.0E-03

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=FERRY ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	1.9E-03	3.1E-03	5.0E-03
Arsenic	8.6E-08	.	8.6E-08
Benzene	1.2E-02	.	1.2E-02
Benzo(a)pyrene	7.3E-08	.	7.3E-08
Beryllium	5.0E-08	.	5.0E-08
Cadmium	7.3E-09	.	7.3E-09
Chromium	2.0E-06	.	2.0E-06
Dichloromethane	.	7.2E-04	7.2E-04
Dioxins	0.0E+00	4.8E-07	4.8E-07
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	3.8E-03	6.2E-03	1.0E-02
Manganese	4.7E-03	1.3E-02	1.8E-02
Mercury	3.6E-08	.	3.6E-08
Nickel	5.3E-05	.	5.3E-05
POMs	4.9E-07	.	4.9E-07
Phenols	5.3E-03	2.6E-02	3.1E-02
Toluene	1.5E-02	1.4E-03	1.6E-02
Trichloroethylene	.	1.4E-03	1.4E-03
Xylene	4.2E-03	7.2E-04	4.9E-03

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------- COUNTY=FRANKLIN -------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	1.3E-02	.	1.3E-02
Arsenic	3.5E-06	.	3.5E-06
Benzene	3.3E-01	.	3.3E-01
Benzo(a)pyrene	0.0E+00	.	0.0E+00
Beryllium	3.0E-06	.	3.0E-06
Cadmium	3.8E-07	.	3.8E-07
Chromium	1.8E-05	.	1.8E-05
Dichloromethane	.	5.1E-03	5.1E-03
Dioxins	5.7E-07	.	5.7E-07
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	2.1E-02	.	2.1E-02
Manganese	1.4E-02	.	1.4E-02
Mercury	8.0E-07	.	8.0E-07
Nickel	2.3E-04	.	2.3E-04
POMs	0.0E+00	.	0.0E+00
Phenols	2.8E-02	.	2.8E-02
Toluene	7.4E-02	6.3E-03	8.0E-02
Trichloroethylene	.	6.3E-03	6.3E-03
Xylene	2.8E-02	4.6E-03	3.3E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=GARFIELD ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	1.2E-02	.	1.2E-02
Arsenic	5.6E-06	.	5.6E-06
Benzene	2.2E-02	.	2.2E-02
Benzo(a)pyrene	1.0E-08	.	1.0E-08
Beryllium	3.8E-06	.	3.8E-06
Cadmium	8.1E-07	.	8.1E-07
Chromium	2.2E-05	.	2.2E-05
Dichloromethane	.	8.3E-04	8.3E-04
Dioxins	0.0E+00	.	0.0E+00
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	5.6E-03	.	5.6E-03
Manganese	2.7E-02	.	2.7E-02
Mercury	2.2E-06	.	2.2E-06
Nickel	5.1E-05	.	5.1E-05
POMs	7.0E-08	.	7.0E-08
Phenols	1.8E-02	.	1.8E-02
Toluene	2.9E-02	8.3E-04	3.0E-02
Trichloroethylene	.	8.3E-04	8.3E-04
Xylene	3.8E-03	8.3E-04	4.6E-03

ANNUAL AVERAGE MODELED CONCENTRATIONS

COUNTY=GRANT

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	9.3E-03	.	9.3E-03
Arsenic	2.0E-06	.	2.0E-06
Benzene	2.9E-01	.	2.9E-01
Benzo(a)pyrene	0.0E+00	.	0.0E+00
Beryllium	1.9E-06	.	1.9E-06
Cadmium	1.8E-07	.	1.8E-07
Chromium	1.1E-05	.	1.1E-05
Dichloromethane	.	5.8E-03	5.8E-03
Dioxins	4.9E-07	.	4.9E-07
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	1.8E-02	.	1.8E-02
Manganese	1.3E-02	.	1.3E-02
Mercury	2.7E-07	.	2.7E-07
Nickel	1.8E-04	.	1.8E-04
POMs	0.0E+00	.	0.0E+00
Phenols	2.6E-02	.	2.6E-02
Toluene	6.4E-02	7.3E-03	7.1E-02
Trichloroethylene	.	6.8E-03	6.8E-03
Xylene	3.7E-02	4.9E-03	4.2E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

---------------------------- COUNTY=GRAYS HARBOR ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	1.5E-02	1.9E-02	3.4E-02
Arsenic	3.3E-06	.	3.3E-06
Benzene	5.9E-01	.	5.9E-01
Benzo(a)pyrene	9.9E-08	.	9.9E-08
Beryllium	3.1E-06	.	3.1E-06
Cadmium	3.0E-07	.	3.0E-07
Chloroform	.	3.5E-01	3.5E-01
Chromium	3.3E-05	1.8E-06	3.5E-05
Dichloromethane	.	7.9E-03	7.9E-03
Dioxins	7.4E-07	2.9E-06	3.6E-06
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	2.9E-02	3.7E-02	6.7E-02
Manganese	1.7E-01	2.5E-02	1.9E-01
Mercury	4.6E-07	.	4.6E-07
Nickel	1.6E-03	3.7E-05	1.6E-03
POMs	6.6E-07	.	6.6E-07
Phenols	4.2E-02	1.6E-01	2.0E-01
Toluene	2.3E-01	1.0E-02	2.4E-01
Trichloroethylene	.	9.4E-03	9.4E-03
Xylene	3.7E-02	6.9E-03	4.4E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

COUNTY=ISLAND

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	0.0E+00	.	0.0E+00
Arsenic	4.2E-06	.	4.2E-06
Benzene	3.0E-01	.	3.0E-01
Benzo(a)pyrene	0.0E+00	.	0.0E+00
Beryllium	4.5E-06	.	4.5E-06
Cadmium	2.7E-07	1.5E-04	1.5E-04
Chromium	1.9E-05	6.6E-05	8.5E-05
Dichloromethane	.	1.4E-02	1.4E-02
Dioxins	0.0E+00	.	0.0E+00
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	1.4E-03	2.7E-06	1.4E-03
Manganese	4.4E-06	2.1E-04	2.2E-04
Mercury	9.1E-08	3.3E-05	3.3E-05
Nickel	2.3E-04	4.4E-05	2.8E-04
POMs	0.0E+00	.	0.0E+00
Phenols	0.0E+00	.	0.0E+00
Toluene	1.9E-01	1.8E-02	2.1E-01
Trichloroethylene	.	1.7E-02	1.7E-02
Xylene	5.9E-02	1.2E-02	7.0E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=JEFFERSON ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	3.2E-03	4.0E-03	7.2E-03
Arsenic	1.1E-06	.	1.1E-06
Benzene	2.6E-01	.	2.6E-01
Benzo(a)pyrene	1.2E-08	.	1.2E-08
Beryllium	9.7E-07	.	9.7E-07
Cadmium	1.3E-07	.	1.3E-07
Chromium	6.8E-06	1.5E-06	8.4E-06
Dichloromethane	.	1.5E-03	1.5E-03
Dioxins	0.0E+00	6.1E-07	6.1E-07
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	4.7E-03	8.0E-03	1.3E-02
Manganese	2.1E-01	1.9E-03	2.1E-01
Mercury	2.7E-07	.	2.7E-07
Nickel	2.4E-04	3.1E-05	2.7E-04
POMs	7.8E-08	.	7.8E-08
Phenols	7.5E-03	3.3E-02	4.1E-02
Toluene	1.8E-01	1.9E-03	1.8E-01
Trichloroethylene	.	1.9E-03	1.9E-03
Xylene	8.9E-03	1.2E-03	1.0E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------- COUNTY=KING -------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	2.4E-01	.	2.4E-01
Arsenic	1.5E-04	.	1.5E-04
Benzene	1.6E+01	.	1.6E+01
Benzo(a)pyrene	1.1E-08	.	1.1E-08
Beryllium	1.6E-04	.	1.6E-04
Cadmium	1.0E-05	.	1.0E-05
Chromium	6.7E-04	.	6.7E-04
Dichloromethane	.	2.0E-01	2.0E-01
Dioxins	8.8E-06	.	8.8E-06
Ethylene_Dichloride	.	5.5E-03	5.5E-03
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	5.2E-01	.	5.2E-01
Manganese	3.4E-01	.	3.4E-01
Mercury	4.7E-06	.	4.7E-06
Nickel	1.2E-02	.	1.2E-02
POMs	7.1E-08	.	7.1E-08
Phenols	5.0E-01	.	5.0E-01
Toluene	2.4E+00	2.5E-01	2.6E+00
Trichloroethylene	.	2.3E-01	2.3E-01
Xylene	6.4E-01	1.7E-01	8.1E-01

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=KITSAP ---------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	6.7E-02	.	6.7E-02
Arsenic	2.1E-05	.	2.1E-05
Benzene	1.7E+00	.	1.7E+00
Benzo(a)pyrene	4.9E-10	.	4.9E-10
Beryllium	2.2E-05	.	2.2E-05
Cadmium	1.4E-06	.	1.4E-06
Chromium	1.1E-04	.	1.1E-04
Dichloromethane	.	5.5E-02	5.5E-02
Dioxins	3.5E-06	.	3.5E-06
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	1.4E-01	.	1.4E-01
Manganese	1.2E-01	.	1.2E-01
Mercury	7.2E-07	.	7.2E-07
Nickel	1.4E-03	.	1.4E-03
POMs	3.3E-09	.	3.3E-09
Phenols	2.0E-01	.	2.0E-01
Toluene	6.7E-01	6.8E-02	7.3E-01
Trichloroethylene	.	6.5E-02	6.5E-02
Xylene	2.0E-01	4.7E-02	2.4E-01

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=KITTITAS ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	8.9E-03	.	8.9E-03
Arsenic	9.7E-06	.	9.7E-06
Benzene	1.3E-01	.	1.3E-01
Benzo(a)pyrene	1.0E-08	.	1.0E-08
Beryllium	9.5E-06	.	9.5E-06
Cadmium	8.3E-07	.	8.3E-07
Chromium	2.6E-05	1.5E-07	2.6E-05
Dichloromethane	.	2.5E-03	2.5E-03
Dioxins	2.1E-07	.	2.1E-07
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	1.1E-02	7.2E-07	1.1E-02
Manganese	3.0E-02	8.7E-08	3.0E-02
Mercury	1.1E-06	.	1.1E-06
Nickel	1.4E-04	3.1E-06	1.4E-04
POMs	6.7E-08	.	6.7E-08
Phenols	1.9E-02	.	1.9E-02
Toluene	5.6E-02	3.3E-03	5.9E-02
Trichloroethylene	.	2.9E-03	2.9E-03
Xylene	1.3E-02	2.1E-03	1.6E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=KLICKITAT ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	3.1E-03	3.9E-03	7.0E-03
Arsenic	2.9E-07	.	2.9E-07
Benzene	1.7E-01	.	1.7E-01
Benzo(a)pyrene	3.8E-08	1.7E-03	1.7E-03
Beryllium	3.0E-07	.	3.0E-07
Cadmium	2.4E-08	.	2.4E-08
Chromium	3.9E-06	.	3.9E-06
Dichloromethane	.	1.9E-03	1.9E-03
Dioxins	0.0E+00	6.0E-07	6.0E-07
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	1.6E-01	1.6E-01
Formaldehyde	6.6E-03	7.8E-03	1.4E-02
Manganese	2.3E-02	1.5E-02	3.8E-02
Mercury	1.4E-08	.	1.4E-08
Nickel	5.7E-05	.	5.7E-05
POMs	2.5E-07	1.2E-02	1.2E-02
Phenols	9.0E-03	3.3E-02	4.2E-02
Toluene	4.5E-02	2.4E-03	4.7E-02
Trichloroethylene	.	2.4E-03	2.4E-03
Xylene	9.9E-03	1.4E-03	1.1E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

--------------------------------- COUNTY=LEWIS ---------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	1.3E-02	2.0E-03	1.5E-02
Arsenic	3.2E-05	2.5E-03	2.5E-03
Benzene	4.4E-01	.	4.4E-01
Benzo(a)pyrene	8.8E-08	.	8.8E-08
Beryllium	3.4E-05	2.2E-03	2.3E-03
Cadmium	2.2E-06	1.3E-03	1.3E-03
Chromium	7.7E-05	1.7E-04	2.5E-04
Dichloromethane	.	7.4E-03	7.4E-03
Dioxins	5.3E-07	3.1E-07	8.4E-07
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	2.0E-02	5.9E-03	2.6E-02
Manganese	1.9E-01	2.5E-03	1.9E-01
Mercury	1.5E-06	3.6E-04	3.7E-04
Nickel	4.1E-04	1.3E-04	5.4E-04
POMs	5.8E-07	.	5.8E-07
Phenols	3.2E-02	1.7E-02	4.9E-02
Toluene	2.6E-01	9.5E-03	2.7E-01
Trichloroethylene	.	8.9E-03	8.9E-03
Xylene	4.0E-02	6.3E-03	4.6E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=LINCOLN ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	5.5E-03	.	5.5E-03
Arsenic	3.0E-06	.	3.0E-06
Benzene	3.2E-02	.	3.2E-02
Benzo(a)pyrene	0.0E+00	.	0.0E+00
Beryllium	2.4E-06	.	2.4E-06
Cadmium	3.6E-07	.	3.6E-07
Chromium	1.2E-05	.	1.2E-05
Dichloromethane	.	7.4E-04	7.4E-04
Dioxins	0.0E+00	.	0.0E+00
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	4.5E-03	.	4.5E-03
Manganese	5.0E-03	.	5.0E-03
Mercury	8.2E-07	.	8.2E-07
Nickel	5.5E-05	.	5.5E-05
POMs	0.0E+00	.	0.0E+00
Phenols	1.0E-02	.	1.0E-02
Toluene	2.0E-02	1.1E-03	2.1E-02
Trichloroethylene	.	1.1E-03	1.1E-03
Xylene	6.8E-03	7.4E-04	7.6E-03

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------- COUNTY=MASON -------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	9.9E-03	6.3E-03	1.6E-02
Arsenic	2.1E-06	1.3E-04	1.3E-04
Benzene	2.1E-01	.	2.1E-01
Benzo(a)pyrene	3.9E-08	.	3.9E-08
Beryllium	2.0E-06	3.2E-07	2.4E-06
Cadmium	1.9E-07	3.2E-07	5.0E-07
Chromium	1.8E-05	3.8E-06	2.1E-05
Dichloromethane	.	5.6E-03	5.6E-03
Dioxins	7.0E-07	9.7E-07	1.7E-06
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	1.9E-02	1.3E-02	3.2E-02
Manganese	6.8E-02	2.6E-04	6.9E-02
Mercury	2.7E-07	9.5E-06	9.7E-06
Nickel	3.2E-04	5.0E-06	3.2E-04
POMs	2.6E-07	.	2.6E-07
Phenols	2.8E-02	5.2E-02	8.0E-02
Toluene	1.2E-01	7.0E-03	1.3E-01
Trichloroethylene	.	6.3E-03	6.3E-03
Xylene	2.6E-02	4.9E-03	3.1E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=OKANOGAN ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	3.2E-02	2.5E-03	3.5E-02
Arsenic	6.9E-06	.	6.9E-06
Benzene	7.9E-02	.	7.9E-02
Benzo(a)pyrene	9.4E-08	.	9.4E-08
Beryllium	1.8E-06	.	1.8E-06
Cadmium	1.5E-06	.	1.5E-06
Chromium	4.4E-05	.	4.4E-05
Dichloromethane	.	2.8E-03	2.8E-03
Dioxins	1.7E-07	3.8E-07	5.6E-07
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	1.9E-02	5.0E-03	2.4E-02
Manganese	4.0E-02	2.2E-04	4.0E-02
Mercury	5.2E-06	.	5.2E-06
Nickel	1.7E-04	.	1.7E-04
POMs	6.3E-07	.	6.3E-07
Phenols	5.2E-02	2.1E-02	7.3E-02
Toluene	7.2E-02	3.5E-03	7.5E-02
Trichloroethylene	.	3.1E-03	3.1E-03
Xylene	1.5E-02	2.1E-03	1.7E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=PACIFIC ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	4.6E-03	2.5E-04	4.8E-03
Arsenic	4.0E-06	.	4.0E-06
Benzene	1.0E-01	.	1.0E-01
Benzo(a)pyrene	2.2E-08	.	2.2E-08
Beryllium	3.9E-06	.	3.9E-06
Cadmium	3.4E-07	.	3.4E-07
Chromium	1.2E-05	.	1.2E-05
Dichloromethane	.	1.5E-03	1.5E-03
Dioxins	0.0E+00	3.8E-08	3.8E-08
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	6.5E-03	5.0E-04	7.0E-03
Manganese	8.9E-02	1.0E-03	9.0E-02
Mercury	4.4E-07	.	4.4E-07
Nickel	7.1E-05	.	7.1E-05
POMs	1.5E-07	.	1.5E-07
Phenols	1.1E-02	2.1E-03	1.3E-02
Toluene	9.6E-02	2.3E-03	9.9E-02
Trichloroethylene	.	1.9E-03	1.9E-03
Xylene	1.0E-02	1.5E-03	1.2E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

--------------------------- COUNTY=PEND OREILLE ----------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	4.6E-03	1.2E-03	5.9E-03
Arsenic	1.8E-06	.	1.8E-06
Benzene	7.1E-02	.	7.1E-02
Benzo(a)pyrene	4.3E-08	.	4.3E-08
Beryllium	1.6E-06	.	1.6E-06
Cadmium	1.8E-07	.	1.8E-07
Chromium	9.6E-06	5.6E-04	5.7E-04
Dichloromethane	.	1.8E-03	1.8E-03
Dioxins	0.0E+00	1.9E-07	1.9E-07
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	7.3E-03	2.5E-03	9.8E-03
Manganese	7.2E-03	5.2E-04	7.7E-03
Mercury	3.2E-07	.	3.2E-07
Nickel	7.6E-05	.	7.6E-05
POMs	2.8E-07	.	2.8E-07
Phenols	1.1E-02	1.0E-02	2.2E-02
Toluene	3.0E-02	2.7E-03	3.3E-02
Trichloroethylene	.	2.7E-03	2.7E-03
Xylene	8.9E-03	1.8E-03	1.1E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=PIERCE ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	1.3E-01	4.2E-02	1.7E-01
Arsenic	4.2E-05	.	4.2E-05
Benzene	5.3E+00	.	5.3E+00
Benzo(a)Pyrene	.	2.1E-03	2.1E-03
Benzo(a)pyrene	2.8E-08	.	2.8E-08
Beryllium	4.4E-05	.	4.4E-05
Cadmium	3.0E-06	.	3.0E-06
Chloroform	.	5.0E-02	5.0E-02
Chromium	2.1E-04	2.2E-05	2.3E-04
Dichloromethane	.	9.1E-02	9.1E-02
Dioxins	5.5E-06	6.5E-06	1.2E-05
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	7.8E-02	7.8E-02
Formaldehyde	2.7E-01	8.4E-02	3.6E-01
Manganese	3.4E-01	9.2E-02	4.3E-01
Mercury	2.4E-06	.	2.4E-06
Nickel	4.8E-03	4.4E-04	5.3E-03
POMs	.	1.4E-02	1.4E-02
POMs	1.8E-07	.	1.8E-07
Phenols	3.0E-01	3.6E-01	6.7E-01
Toluene	2.7E-01	1.1E-01	3.8E-01
Trichloroethylene	.	1.1E-01	1.1E-01
Xylene	2.6E-01	7.7E-02	3.4E-01

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=SAN JUAN --------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	4.4E-03	.	4.4E-03
Arsenic	6.5E-07	.	6.5E-07
Benzene	4.0E-02	.	4.0E-02
Benzo(a)pyrene	0.0E+00	.	0.0E+00
Beryllium	7.0E-07	.	7.0E-07
Cadmium	4.3E-08	.	4.3E-08
Chromium	7.0E-06	.	7.0E-06
Dichloromethane	.	2.8E-03	2.8E-03
Dioxins	0.0E+00	.	0.0E+00
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	9.6E-03	.	9.6E-03
Manganese	5.5E-03	.	5.5E-03
Mercury	1.4E-08	.	1.4E-08
Nickel	1.1E-04	.	1.1E-04
POMs	0.0E+00	.	0.0E+00
Phenols	1.1E-02	.	1.1E-02
Toluene	5.0E-02	4.3E-03	5.4E-02
Trichloroethylene	.	2.8E-03	2.8E-03
Xylene	1.5E-02	2.8E-03	1.8E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=SKAGIT ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	1.7E-02	2.6E-03	1.9E-02
Arsenic	4.2E-06	.	4.2E-06
Benzene	9.4E-01	.	9.4E-01
Benzo(a)pyrene	2.0E-08	.	2.0E-08
Beryllium	4.1E-06	.	4.1E-06
Cadmium	3.7E-07	.	3.7E-07
Chromium	2.5E-05	6.0E-05	8.5E-05
Dichloromethane	.	8.9E-03	8.9E-03
Dioxins	8.3E-07	3.9E-07	1.2E-06
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	3.2E-02	3.6E-02	6.8E-02
Manganese	1.1E-01	1.1E-02	1.2E-01
Mercury	5.3E-07	.	5.3E-07
Nickel	2.8E-04	1.2E-03	1.5E-03
POMs	1.3E-07	.	1.3E-07
Phenols	4.6E-02	2.1E-02	6.7E-02
Toluene	2.0E-01	1.1E-02	2.1E-01
Trichloroethylene	.	1.1E-02	1.1E-02
Xylene	4.7E-02	7.8E-03	5.5E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=SKAMANIA ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	2.3E-03	2.0E-03	4.3E-03
Arsenic	2.9E-06	.	2.9E-06
Benzene	6.8E-02	.	6.8E-02
Benzo(a)pyrene	6.5E-08	.	6.5E-08
Beryllium	3.0E-06	.	3.0E-06
Cadmium	2.2E-07	.	2.2E-07
Chromium	8.7E-06	.	8.7E-06
Dichloromethane	.	1.0E-03	1.0E-03
Dioxins	0.0E+00	3.0E-07	3.0E-07
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	3.7E-03	3.9E-03	7.7E-03
Manganese	1.1E-01	2.4E-03	1.2E-01
Mercury	2.0E-07	.	2.0E-07
Nickel	4.6E-05	.	4.6E-05
POMs	4.4E-07	.	4.4E-07
Phenols	5.8E-03	1.6E-02	2.2E-02
Toluene	9.9E-02	1.5E-03	1.0E-01
Trichloroethylene	.	1.0E-03	1.0E-03
Xylene	4.7E-03	1.0E-03	5.7E-03

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=SNOHOMISH ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	4.7E-02	2.2E-02	6.8E-02
Arsenic	2.0E-05	.	2.0E-05
Benzene	1.8E+00	.	1.8E+00
Benzo(a)pyrene	5.1E-09	.	5.1E-09
Beryllium	2.1E-05	.	2.1E-05
Cadmium	1.4E-06	.	1.4E-06
Chloroform	.	2.0E-01	2.0E-01
Chromium	8.2E-05	3.2E-04	4.0E-04
Dichloromethane	.	3.8E-02	3.8E-02
Dioxins	2.4E-06	3.3E-06	5.7E-06
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	1.0E-01	4.5E-02	1.4E-01
Manganese	8.9E-02	3.7E-02	1.3E-01
Mercury	8.0E-07	.	8.0E-07
Nickel	2.0E-03	7.4E-03	9.4E-03
POMs	3.4E-08	.	3.4E-08
Phenols	1.4E-01	1.8E-01	3.2E-01
Toluene	5.0E-01	4.7E-02	5.4E-01
Trichloroethylene	.	4.5E-02	4.5E-02
Xylene	4.5E-02	3.2E-02	7.7E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=SPOKANE ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	9.1E-02	1.5E-04	9.1E-02
Arsenic	1.1E-04	.	1.1E-04
Benzene	3.1E+00	.	3.1E+00
Benzo(a)pyrene	5.5E-09	.	5.5E-09
Beryllium	1.2E-04	.	1.2E-04
Cadmium	8.3E-06	.	8.3E-06
Chromium	2.9E-04	8.4E-08	2.9E-04
Dichloromethane	.	3.6E-02	3.6E-02
Dioxins	3.4E-06	2.4E-08	3.4E-06
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	2.0E-01	2.0E-01
Formaldehyde	1.6E-01	3.1E-04	1.6E-01
Manganese	1.2E-01	1.3E-05	1.2E-01
Mercury	6.5E-06	.	6.5E-06
Nickel	2.0E-03	7.5E-06	2.0E-03
POMs	3.6E-08	.	3.6E-08
Phenols	2.2E-01	1.3E-03	2.2E-01
Toluene	4.2E-01	4.5E-02	4.6E-01
Trichloroethylene	.	4.3E-02	4.3E-02
Xylene	1.4E-01	3.1E-02	1.7E-01

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------- COUNTY=STEVENS -------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	9.3E-03	5.7E-02	6.6E-02
Arsenic	4.0E-06	.	4.0E-06
Benzene	2.3E-01	.	2.3E-01
Benzo(a)pyrene	6.2E-08	.	6.2E-08
Beryllium	4.0E-06	.	4.0E-06
Cadmium	3.2E-07	.	3.2E-07
Chromium	1.5E-05	2.4E-07	1.5E-05
Dichloromethane	.	4.8E-03	4.8E-03
Dioxins	3.4E-07	8.8E-06	9.1E-06
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	1.8E-02	1.1E-01	1.3E-01
Manganese	1.5E-02	1.3E-02	2.8E-02
Mercury	3.5E-07	.	3.5E-07
Nickel	2.0E-04	4.9E-06	2.0E-04
POMs	4.2E-07	.	4.2E-07
Phenols	2.6E-02	4.8E-01	5.0E-01
Toluene	7.1E-02	6.1E-03	7.7E-02
Trichloroethylene	.	6.1E-03	6.1E-03
Xylene	2.2E-02	4.1E-03	2.6E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=THURSTON ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	4.3E-02	1.9E-03	4.5E-02
Arsenic	3.0E-05	.	3.0E-05
Benzene	1.5E+00	.	1.5E+00
Benzo(a)pyrene	2.8E-08	.	2.8E-08
Beryllium	3.2E-05	.	3.2E-05
Cadmium	2.0E-06	.	2.0E-06
Chromium	8.9E-05	.	8.9E-05
Dichloromethane	.	3.1E-02	3.1E-02
Dioxins	1.9E-06	2.9E-07	2.2E-06
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	9.0E-02	3.7E-03	9.4E-02
Manganese	1.3E-01	4.5E-03	1.3E-01
Mercury	8.8E-07	.	8.8E-07
Nickel	1.2E-03	.	1.2E-03
POMs	1.9E-07	.	1.9E-07
Phenols	1.1E-01	1.6E-02	1.2E-01
Toluene	4.8E-01	3.9E-02	5.2E-01
Trichloroethylene	.	3.7E-02	3.7E-02
Xylene	1.5E-01	2.6E-02	1.8E-01

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=WAHKIAKUM ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	1.1E-03	.	1.1E-03
Arsenic	5.0E-08	.	5.0E-08
Benzene	9.1E-03	.	9.1E-03
Benzo(a)pyrene	3.7E-09	.	3.7E-09
Beryllium	5.0E-08	.	5.0E-08
Cadmium	0.0E+00	.	0.0E+00
Chromium	2.3E-06	.	2.3E-06
Dichloromethane	.	7.1E-04	7.1E-04
Dioxins	0.0E+00	.	0.0E+00
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	2.3E-03	.	2.3E-03
Manganese	1.6E-03	.	1.6E-03
Mercury	0.0E+00	.	0.0E+00
Nickel	4.9E-05	.	4.9E-05
POMs	2.5E-08	.	2.5E-08
Phenols	3.2E-03	.	3.2E-03
Toluene	1.1E-02	7.1E-04	1.2E-02
Trichloroethylene	.	7.1E-04	7.1E-04
Xylene	3.9E-03	7.1E-04	4.6E-03

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=WALLA WALLA ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	2.4E-02	6.9E-03	3.1E-02
Arsenic	2.1E-05	1.3E-04	1.5E-04
Benzene	5.6E-01	.	5.6E-01
Benzo(a)pyrene	0.0E+00	.	0.0E+00
Beryllium	0.0E+00	3.1E-07	3.1E-07
Cadmium	1.9E-06	3.1E-07	2.2E-06
Chloroform	.	2.8E-01	2.8E-01
Chromium	6.2E-05	1.7E-06	6.4E-05
Dichloromethane	.	7.5E-03	7.5E-03
Dioxins	6.3E-07	1.1E-06	1.7E-06
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	3.2E-02	1.4E-02	4.5E-02
Manganese	2.4E-02	6.3E-03	3.1E-02
Mercury	2.6E-06	9.4E-06	1.2E-05
Nickel	4.5E-04	3.2E-05	4.8E-04
POMs	0.0E+00	.	0.0E+00
Phenols	4.9E-02	5.8E-02	1.1E-01
Toluene	9.6E-02	9.4E-03	1.1E-01
Trichloroethylene	.	8.8E-03	8.8E-03
Xylene	2.9E-02	6.3E-03	3.5E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=WHATCOM ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	3.0E-02	1.1E-02	4.1E-02
Arsenic	1.2E-05	.	1.2E-05
Benzene	1.3E+00	.	1.3E+00
Benzo(a)pyrene	7.0E-09	.	7.0E-09
Beryllium	1.3E-05	.	1.3E-05
Cadmium	8.8E-07	8.3E-05	8.3E-05
Chloroform	.	1.6E-01	1.6E-01
Chromium	4.8E-05	2.0E-03	2.1E-03
Dichloromethane	.	1.4E-02	1.4E-02
Dioxins	1.3E-06	1.7E-06	3.0E-06
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	6.2E-02	5.6E-02	1.2E-01
Manganese	7.3E-02	1.8E-02	9.1E-02
Mercury	6.4E-07	1.8E-05	1.9E-05
Nickel	8.2E-04	1.9E-04	1.0E-03
POMs	4.7E-08	.	4.7E-08
Phenols	8.0E-02	9.3E-02	1.7E-01
Toluene	2.1E-01	1.7E-02	2.3E-01
Trichloroethylene	.	1.6E-02	1.6E-02
Xylene	6.5E-02	1.2E-02	7.6E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------- COUNTY=WHITMAN -------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	7.8E-03	.	7.8E-03
Arsenic	7.3E-06	2.5E-04	2.6E-04
Benzene	1.7E-01	.	1.7E-01
Benzo(a)pyrene	0.0E+00	.	0.0E+00
Beryllium	7.4E-06	6.3E-07	8.0E-06
Cadmium	5.7E-07	6.3E-07	1.2E-06
Chromium	2.0E-05	3.6E-06	2.4E-05
Dichloromethane	.	3.8E-03	3.8E-03
Dioxins	3.8E-07	.	3.8E-07
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	1.2E-02	1.3E-05	1.2E-02
Manganese	9.7E-03	1.8E-06	9.7E-03
Mercury	6.2E-07	1.9E-05	1.9E-05
Nickel	1.1E-04	4.4E-06	1.1E-04
POMs	0.0E+00	.	0.0E+00
Phenols	1.9E-02	.	1.9E-02
Toluene	3.9E-02	4.6E-03	4.4E-02
Trichloroethylene	.	4.6E-03	4.6E-03
Xylene	1.3E-02	3.1E-03	1.6E-02

ANNUAL AVERAGE MODELED CONCENTRATIONS

------------------------------ COUNTY=YAKIMA ------------------------------

POLLUTANT	AREA SOURCES (ug/m3)	POINT SOURCES (ug/m3)	TOTAL (ug/m3)
Acetaldehyde	2.5E-02	6.2E-03	3.1E-02
Arsenic	4.2E-05	.	4.2E-05
Benzene	9.0E-01	.	9.0E-01
Benzo(a)pyrene	8.6E-08	.	8.6E-08
Beryllium	4.5E-05	.	4.5E-05
Cadmium	3.0E-06	.	3.0E-06
Chromium	1.0E-04	2.2E-07	1.0E-04
Dichloromethane	.	1.4E-02	1.4E-02
Dioxins	9.4E-07	9.6E-07	1.9E-06
Ethylene_Dichloride	.	0.0E+00	0.0E+00
Fluorides	.	0.0E+00	0.0E+00
Formaldehyde	4.4E-02	1.2E-02	5.6E-02
Manganese	3.5E-02	8.6E-03	4.4E-02
Mercury	2.0E-06	.	2.0E-06
Nickel	7.5E-04	4.4E-06	7.5E-04
POMs	5.7E-07	.	5.7E-07
Phenols	6.5E-02	5.2E-02	1.2E-01
Toluene	1.9E-01	1.7E-02	2.1E-01
Trichloroethylene	.	1.6E-02	1.6E-02
Xylene	6.1E-02	1.2E-02	7.2E-02

APPENDIX 11

MODELED EXCESS CANCERS
BASED ON 70 YEAR EXPOSURE

---------------------------- POLLUTANT=Acetaldehyde ----------------------------

COUNTY	POPULATION	TOTAL (ug/m3)	ACCEPTABLE LIMIT (AAL)	EXCESS CANCERS
ADAMS	13100	6.1E-03	4.5E-01	0.00
ASOTIN	17000	6.2E-03	4.5E-01	0.00
BENTON	113400	2.3E-02	4.5E-01	0.01
CHELAN	21713	9.4E-03	4.5E-01	0.00
CLALLAM	29000	2.1E-02	4.5E-01	0.00
CLARK	195800	9.1E-02	4.5E-01	0.04
COLUMBIA	4000	2.3E-03	4.5E-01	0.00
COWLITZ	80500	1.0E-01	4.5E-01	0.02
DOUGLAS	22800	5.3E-03	4.5E-01	0.00
FERRY	6000	5.0E-03	4.5E-01	0.00
FRANKLIN	36700	1.3E-02	4.5E-01	0.00
GARFIELD	2400	1.2E-02	4.5E-01	0.00
GRANT	48600	9.3E-03	4.5E-01	0.00
GRAYS HARBOR	66800	3.4E-02	4.5E-01	0.01
ISLAND	45200	0.0E+00	4.5E-01	0.00
JEFFERSON	16600	7.2E-03	4.5E-01	0.00
KING	1309800	2.4E-01	4.5E-01	0.70
KITSAP	156800	6.7E-02	4.5E-01	0.02
KITTITAS	25100	8.9E-03	4.5E-01	0.00
KLICKITAT	16200	7.0E-03	4.5E-01	0.00
LEWIS	56700	1.5E-02	4.5E-01	0.00
LINCOLN	9600	5.5E-03	4.5E-01	0.00
MASON	31900	1.6E-02	4.5E-01	0.00
OKANOGAN	30900	3.5E-02	4.5E-01	0.00
PACIFIC	17800	4.8E-03	4.5E-01	0.00
PEND OREILLE	8800	5.9E-03	4.5E-01	0.00
PIERCE	501300	1.7E-01	4.5E-01	0.19
SAN JUAN	8100	4.4E-03	4.5E-01	0.00
SKAGIT	64900	1.9E-02	4.5E-01	0.00
SKAMANIA	8100	4.3E-03	4.5E-01	0.00
SNOHOMISH	353400	6.8E-02	4.5E-01	0.05
SPOKANE	347600	9.1E-02	4.5E-01	0.07
STEVENS	29500	6.6E-02	4.5E-01	0.00
THURSTON	129100	4.5E-02	4.5E-01	0.01
WAHKIAKUM	3800	1.1E-03	4.5E-01	0.00
WALLA WALLA	47900	3.1E-02	4.5E-01	0.00
WHATCOM	109900	4.1E-02	4.5E-01	0.01
WHITMAN	40400	7.8E-03	4.5E-01	0.00
YAKIMA	175000	3.1E-02	4.5E-01	0.01

LIFETIME EXPOSURE RISK				1.17

--------------------------- POLLUTANT=Arsenic ---------------------------

COUNTY	POPULATION	TOTAL (ug/m3)	ACCEPTABLE LIMIT (AAL)	EXCESS CANCERS
ADAMS	13100	2.0E-06	2.3E-04	0.00
ASOTIN	17000	6.9E-06	2.3E-04	0.00
BENTON	113400	1.0E-03	2.3E-04	0.50
CHELAN	21713	2.8E-06	2.3E-04	0.00
CLALLAM	29000	2.7E-06	2.3E-04	0.00
CLARK	195800	2.0E-06	2.3E-04	0.00
COLUMBIA	4000	6.7E-06	2.3E-04	0.00
COWLITZ	80500	9.0E-04	2.3E-04	0.31
DOUGLAS	22800	2.2E-06	2.3E-04	0.00
FERRY	6000	8.6E-08	2.3E-04	0.00
FRANKLIN	36700	3.5E-06	2.3E-04	0.00
GARFIELD	2400	5.6E-06	2.3E-04	0.00
GRANT	48600	2.0E-06	2.3E-04	0.00
GRAYS HARBOR	66800	3.3E-06	2.3E-04	0.00
ISLAND	45200	4.2E-06	2.3E-04	0.00
JEFFERSON	16600	1.1E-06	2.3E-04	0.00
KING	1309800	1.5E-04	2.3E-04	0.86
KITSAP	156800	2.1E-05	2.3E-04	0.01
KITTITAS	25100	9.7E-06	2.3E-04	0.00
KLICKITAT	16200	2.9E-07	2.3E-04	0.00
LEWIS	56700	2.5E-03	2.3E-04	0.62
LINCOLN	9600	3.0E-06	2.3E-04	0.00
MASON	31900	1.3E-04	2.3E-04	0.02
OKANOGAN	30900	6.9E-06	2.3E-04	0.00
PACIFIC	17800	4.0E-06	2.3E-04	0.00
PEND OREILLE	8800	1.8E-06	2.3E-04	0.00
PIERCE	501300	4.2E-05	2.3E-04	0.09
SAN JUAN	8100	6.5E-07	2.3E-04	0.00
SKAGIT	64900	4.2E-06	2.3E-04	0.00
SKAMANIA	8100	2.9E-06	2.3E-04	0.00
SNOHOMISH	353400	2.0E-05	2.3E-04	0.03
SPOKANE	347600	1.1E-04	2.3E-04	0.17
STEVENS	29500	4.0E-06	2.3E-04	0.00
THURSTON	129100	3.0E-05	2.3E-04	0.02
WAHKIAKUM	3800	5.0E-08	2.3E-04	0.00
WALLA WALLA	47900	1.5E-04	2.3E-04	0.03
WHATCOM	109900	1.2E-05	2.3E-04	0.01
WHITMAN	40400	2.6E-04	2.3E-04	0.05
YAKIMA	175000	4.2E-05	2.3E-04	0.03

LIFETIME EXPOSURE RISK				2.75

---------------------------- POLLUTANT=Benzene ------------------------------

COUNTY	POPULATION	TOTAL (ug/m3)	ACCEPTABLE LIMIT (AAL)	EXCESS CANCERS
ADAMS	13100	9.6E-02	1.2E-01	0.01
ASOTIN	17000	6.8E-02	1.2E-01	0.01
BENTON	113400	1.2E+00	1.2E-01	1.14
CHELAN	21713	3.0E-01	1.2E-01	0.05
CLALLAM	29000	3.7E-01	1.2E-01	0.09
CLARK	195800	2.2E+00	1.2E-01	3.57
COLUMBIA	4000	4.5E-02	1.2E-01	0.00
COWLITZ	80500	1.6E+00	1.2E-01	1.08
DOUGLAS	22800	5.4E-02	1.2E-01	0.01
FERRY	6000	1.2E-02	1.2E-01	0.00
FRANKLIN	36700	3.3E-01	1.2E-01	0.10
GARFIELD	2400	2.2E-02	1.2E-01	0.00
GRANT	48600	2.9E-01	1.2E-01	0.12
GRAYS HARBOR	66800	5.9E-01	1.2E-01	0.33
ISLAND	45200	3.0E-01	1.2E-01	0.11
JEFFERSON	16600	2.6E-01	1.2E-01	0.04
KING	1309800	1.6E+01	1.2E-01	170.6
KITSAP	156800	1.7E+00	1.2E-01	2.27
KITTITAS	25100	1.3E-01	1.2E-01	0.03
KLICKITAT	16200	1.7E-01	1.2E-01	0.02
LEWIS	56700	4.4E-01	1.2E-01	0.21
LINCOLN	9600	3.2E-02	1.2E-01	0.00
MASON	31900	2.1E-01	1.2E-01	0.06
OKANOGAN	30900	7.9E-02	1.2E-01	0.02
PACIFIC	17800	1.0E-01	1.2E-01	0.02
PEND OREILLE	8800	7.1E-02	1.2E-01	0.01
PIERCE	501300	5.3E+00	1.2E-01	22.09
SAN JUAN	8100	4.0E-02	1.2E-01	0.00
SKAGIT	64900	9.4E-01	1.2E-01	0.51
SKAMANIA	8100	6.8E-02	1.2E-01	0.00
SNOHOMISH	353400	1.8E+00	1.2E-01	5.33
SPOKANE	347600	3.1E+00	1.2E-01	8.98
STEVENS	29500	2.3E-01	1.2E-01	0.06
THURSTON	129100	1.5E+00	1.2E-01	1.62
WAHKIAKUM	3800	9.1E-03	1.2E-01	0.00
WALLA WALLA	47900	5.6E-01	1.2E-01	0.22
WHATCOM	109900	1.3E+00	1.2E-01	1.22
WHITMAN	40400	1.7E-01	1.2E-01	0.06
YAKIMA	175000	9.0E-01	1.2E-01	1.31

LIFETIME EXPOSURE RISK				221.3

------------------------- POLLUTANT=Benzo(a)pyrene -------------------------

COUNTY	POPULATION	TOTAL (ug/m3)	ACCEPTABLE LIMIT (AAL)	EXCESS CANCERS
ADAMS	13100	0.0E+00	6.0E-04	0.00
ASOTIN	17000	9.2E-10	6.0E-04	0.00
BENTON	113400	0.0E+00	6.0E-04	0.00
CHELAN	21713	1.2E-04	6.0E-04	0.00
CLALLAM	29000	2.0E-08	6.0E-04	0.00
CLARK	195800	1.3E-08	6.0E-04	0.00
COLUMBIA	4000	0.0E+00	6.0E-04	0.00
COWLITZ	80500	5.2E-03	6.0E-04	0.71
DOUGLAS	22800	0.0E+00	6.0E-04	0.00
FERRY	6000	7.3E-08	6.0E-04	0.00
FRANKLIN	36700	0.0E+00	6.0E-04	0.00
GARFIELD	2400	1.0E-08	6.0E-04	0.00
GRANT	48600	0.0E+00	6.0E-04	0.00
GRAYS HARBOR	66800	9.9E-08	6.0E-04	0.00
ISLAND	45200	0.0E+00	6.0E-04	0.00
JEFFERSON	16600	1.2E-08	6.0E-04	0.00
KING	1309800	6.4E-03	6.0E-04	13.97
KITSAP	156800	4.9E-10	6.0E-04	0.00
KITTITAS	25100	1.0E-08	6.0E-04	0.00
KLICKITAT	16200	1.7E-03	6.0E-04	0.05
LEWIS	56700	8.8E-08	6.0E-04	0.00
LINCOLN	9600	0.0E+00	6.0E-04	0.00
MASON	31900	3.9E-08	6.0E-04	0.00
OKANOGAN	30900	9.4E-08	6.0E-04	0.00
PACIFIC	17800	2.2E-08	6.0E-04	0.00
PEND OREILLE	8800	4.3E-08	6.0E-04	0.00
PIERCE	501300	2.1E-03	6.0E-04	1.79
SAN JUAN	8100	0.0E+00	6.0E-04	0.00
SKAGIT	64900	2.0E-08	6.0E-04	0.00
SKAMANIA	8100	6.5E-08	6.0E-04	0.00
SNOHOMISH	353400	5.1E-09	6.0E-04	0.00
SPOKANE	347600	5.5E-09	6.0E-04	0.00
STEVENS	29500	6.2E-08	6.0E-04	0.00
THURSTON	129100	2.8E-08	6.0E-04	0.00
WAHKIAKUM	3800	3.7E-09	6.0E-04	0.00
WALLA WALLA	47900	0.0E+00	6.0E-04	0.00
WHATCOM	109900	7.0E-09	6.0E-04	0.00
WHITMAN	40400	0.0E+00	6.0E-04	0.00
YAKIMA	175000	8.6E-08	6.0E-04	0.00

LIFETIME EXPOSURE RISK				16.40

---------------------------- POLLUTANT=Beryllium ----------------------------

COUNTY	POPULATION	TOTAL (ug/m3)	ACCEPTABLE LIMIT (AAL)	EXCESS CANCERS
ADAMS	13100	1.5E-06	4.2E-04	0.00
ASOTIN	17000	7.4E-06	4.2E-04	0.00
BENTON	113400	1.2E-05	4.2E-04	0.00
CHELAN	21713	2.9E-06	4.2E-04	0.00
CLALLAM	29000	2.6E-06	4.2E-04	0.00
CLARK	195800	1.1E-05	4.2E-04	0.01
COLUMBIA	4000	7.0E-06	4.2E-04	0.00
COWLITZ	80500	8.5E-06	4.2E-04	0.00
DOUGLAS	22800	2.4E-06	4.2E-04	0.00
FERRY	6000	5.0E-08	4.2E-04	0.00
FRANKLIN	36700	3.0E-06	4.2E-04	0.00
GARFIELD	2400	3.8E-06	4.2E-04	0.00
GRANT	48600	1.9E-06	4.2E-04	0.00
GRAYS HARBOR	66800	3.1E-06	4.2E-04	0.00
ISLAND	45200	4.5E-06	4.2E-04	0.00
JEFFERSON	16600	9.7E-07	4.2E-04	0.00
KING	1309800	1.6E-04	4.2E-04	0.50
KITSAP	156800	2.2E-05	4.2E-04	0.01
KITTITAS	25100	9.5E-06	4.2E-04	0.00
KLICKITAT	16200	3.0E-07	4.2E-04	0.00
LEWIS	56700	2.3E-03	4.2E-04	0.30
LINCOLN	9600	2.4E-06	4.2E-04	0.00
MASON	31900	2.4E-06	4.2E-04	0.00
OKANOGAN	30900	1.8E-06	4.2E-04	0.00
PACIFIC	17800	3.9E-06	4.2E-04	0.00
PEND OREILLE	8800	1.6E-06	4.2E-04	0.00
PIERCE	501300	4.4E-05	4.2E-04	0.05
SAN JUAN	8100	7.0E-07	4.2E-04	0.00
SKAGIT	64900	4.1E-06	4.2E-04	0.00
SKAMANIA	8100	3.0E-06	4.2E-04	0.00
SNOHOMISH	353400	2.1E-05	4.2E-04	0.02
SPOKANE	347600	1.2E-04	4.2E-04	0.10
STEVENS	29500	4.0E-06	4.2E-04	0.00
THURSTON	129100	3.2E-05	4.2E-04	0.01
WAHKIAKUM	3800	5.0E-08	4.2E-04	0.00
WALLA WALLA	47900	3.1E-07	4.2E-04	0.00
WHATCOM	109900	1.3E-05	4.2E-04	0.00
WHITMAN	40400	8.0E-06	4.2E-04	0.00
YAKIMA	175000	4.5E-05	4.2E-04	0.02

LIFETIME EXPOSURE RISK				1.03

POLLUTANT=Cadmium

COUNTY	POPULATION	TOTAL (ug/m3)	ACCEPTABLE LIMIT (AAL)	EXCESS CANCERS
ADAMS	13100	2.5E-07	5.6E-04	0.00
ASOTIN	17000	4.5E-07	5.6E-04	0.00
BENTON	113400	3.1E-06	5.6E-04	0.00
CHELAN	21713	2.2E-07	5.6E-04	0.00
CLALLAM	29000	2.3E-07	5.6E-04	0.00
CLARK	195800	2.4E-05	5.6E-04	0.01
COLUMBIA	4000	4.9E-07	5.6E-04	0.00
COWLITZ	80500	3.5E-06	5.6E-04	0.00
DOUGLAS	22800	1.5E-07	5.6E-04	0.00
FERRY	6000	7.3E-09	5.6E-04	0.00
FRANKLIN	36700	3.8E-07	5.6E-04	0.00
GARFIELD	2400	8.1E-07	5.6E-04	0.00
GRANT	48600	1.8E-07	5.6E-04	0.00
GRAYS HARBOR	66800	3.0E-07	5.6E-04	0.00
ISLAND	45200	1.5E-04	5.6E-04	0.01
JEFFERSON	16600	1.3E-07	5.6E-04	0.00
KING	1309800	1.0E-05	5.6E-04	0.02
KITSAP	156800	1.4E-06	5.6E-04	0.00
KITTITAS	25100	8.3E-07	5.6E-04	0.00
KLICKITAT	16200	2.4E-08	5.6E-04	0.00
LEWIS	56700	1.3E-03	5.6E-04	0.13
LINCOLN	9600	3.6E-07	5.6E-04	0.00
MASON	31900	5.0E-07	5.6E-04	0.00
OKANOGAN	30900	1.5E-06	5.6E-04	0.00
PACIFIC	17800	3.4E-07	5.6E-04	0.00
PEND OREILLE	8800	1.8E-07	5.6E-04	0.00
PIERCE	501300	3.0E-06	5.6E-04	0.00
SAN JUAN	8100	4.3E-08	5.6E-04	0.00
SKAGIT	64900	3.7E-07	5.6E-04	0.00
SKAMANIA	8100	2.2E-07	5.6E-04	0.00
SNOHOMISH	353400	1.4E-06	5.6E-04	0.00
SPOKANE	347600	8.3E-06	5.6E-04	0.01
STEVENS	29500	3.2E-07	5.6E-04	0.00
THURSTON	129100	2.0E-06	5.6E-04	0.00
WAHKIAKUM	3800	0.0E+00	5.6E-04	0.00
WALLA WALLA	47900	2.2E-06	5.6E-04	0.00
WHATCOM	109900	8.3E-05	5.6E-04	0.02
WHITMAN	40400	1.2E-06	5.6E-04	0.00
YAKIMA	175000	3.0E-06	5.6E-04	0.00

LIFETIME EXPOSURE RISK				0.20

ATTACHMENT 1

RANKING OF SPECIFIC NON-CANCER HEALTH ENDPOINTS

SPECIFIC ENDPOINTS	SCORE (1-7)
Cardiovascular	
- unspecified	
- increased heart attacks	7
- aggravation of angina	5-6
- increased blood pressure	4
Developmental	
- fetotoxicity	6
- abnormal ossification (see teratogenicity)	
- low birth weight	4
- teratogenicity	7
Hematopoietic	
-unspecified	
- decreased heme production	4
- bone marrow hypoplasia	5
- impaired heme synthesis	4
- methemoglobinemia	5
Immunological	
- unspecified	
- herpes	1
- allergic reactions	3
- increased infections	4
Kidney effects	
- unspecified	
- tubular degeneration	5
- dysfunction	3
- hyperplasia	3
- hypertrophy	3
- atrophy	4
- necrosis	6

SPECIFIC ENDPOINTS	SCORE (1-7)
Liver effects	
- unspecified	
-hepatitis A	5
-jaundice	4
-increased weight	3
-increased enzymes	2
-necrosis	6
Mutagenicity	
-unspecified	
-cytogenetic	4
-heriditary disorders	7
Neurotoxic/Behavioral	
- unspecified	
- retardation	7
- reduced corneal sensitivity	2
- retinal disorders	4
- visual aging	2
- AChe inhibition	5
- learning disabilities	6
- neuropathy	6
- decreased sensory perception	3
- irritability	3
- tremors	4
- convulsions	6
- sensory irritation	2
Reproductive	
- unspecified	
- post implantation losses	4
- testicular degeneration	4
- spermatocyte damage	4
- decreased testicular weight	3
- uterine hypoplasia	3
- aspermia	6
- increased resorptions	4
- giant cell formation	2
- increased spontan. abortions	5

WASHINGTON ENVIRONMENT 2010

INDOOR AIR POLLUTANTS OTHER THAN RADON

I. Background

A. Indoor Air Pollutants Other Than Radon

B. Indoor concentrations of most air pollutants are considerably higher than outdoor concentrations of these pollutants. Research indicates that people spend approximately 90% of their time indoors, resulting in greater health risks from exposure to air pollution indoors than outdoors (Turiel, 1985). People most susceptible to the risks of pollution, including the aged, the ill, and the very young, spend nearly all of their time indoors. Even if indoor air pollutant concentrations are low, they may still make a substantial contribution to time-weighted pollutant exposures (Spengler & Sexton, 1983). The major sources of indoor air pollution include pollutant transport from outdoor air, interior pollutant sources, and inadequate ventilation (Meyer, 1983). Indoor pollution sources release gases or particles into the air and include such broad categories as combustion sources, building materials and furnishings, occupants and their activities, and household cleaners and maintenance products (EPA, 1988a). Common indoor air contaminants include carbon monoxide, carbon dioxide, nitrogen dioxide, infectious agents (bacteria and fungi), non-organic particulate matter, formaldehyde, trace organic compounds, allergens, asbestos, and smoke.

C. The types of risks analyzed in this report are confined to human health risks. The risks identified for indoor air problems would include those posed to Washington residents from their lifetime exposures to indoor air pollutants in residences, nonindustrial occupational environments, and public buildings. The human health risk analysis process addresses acute, chronic, and carcinogenic endpoints.

D. Increasing interest in the quality of the indoor environment is in part a result of efforts to reduce ventilation for energy conservation. Approximately 20-50% of energy consumed nationwide is for space-heating and cooling (NRC, 1981). Reducing ventilation in residential and commercial buildings can be a cost-effective method to achieve energy conservation, but concentrations of indoor air contaminants may increase as a result. The relative importance of any single source depends on how much of a given pollutant it emits, how many compounds are emitted, and how hazardous those pollutants are. Some sources release pollutants continuously (e.g., building materials or furnishings), while others result in only intermittent pollution based on their application or use (e.g., smoking or using gas appliances) (EPA, 1988a). As many as 30% of new and remodelled buildings may have indoor air quality problems (EPA, 1988c). Indoor air quality problems potentially involve thousands of substances, and any attempt to focus attention on six or seven representative pollutants omits a substantial portion of the indoor air problem. Due to the tremendous complexity, variety, and significant unknowns, an adequate assessment of "total health risk" posed to individuals from indoor air pollutants is impossible to achieve.

II. Human Health Risks

A. Air contaminants come in contact with the skin and eyes, and may be absorbed into the body through the skin, respiratory tract, or gastrointestinal system, and then transported to the rest of the body (Walsh et al., 1984). Some contaminants produce adverse health effects after contact with susceptible tissue. Health effects vary depending on the contaminant's chemical and/or biological properties, concentration, and duration of exposure to the contaminant as well as the particular sensitivity of the person exposed (EPA, 1987a). At higher concentrations, some pollutants have known carcinogenic, allergenic, respiratory or other physiologic effects. Except for some contaminants that cause irritation, the evidence of direct or important health damage at reported concentrations is not well established. The imprecision in air pollution health effects data may be due partly to varying concentrations of indoor air pollutants (NRC, 1981).

Many limitations prevent completion of an adequate quantitative health risk assessment of Washington indoor air pollution problems. The most limiting factor to an extensive assessment is the lack of exposure data in the state. Additionally, even on a national level, dose-response information for most indoor air pollutants is poorly developed, because adverse human health effects are reported at exposures to concentrations far below occupational standards or other "threshold" levels. Most indoor air related problems are multidisciplinary in nature, and involve complex relationships among ventilation systems, air pollutant concentrations, human response variations, and some psychological factors (Wallace, 1986). A major barrier for assessment of indoor air quality is the absence of standardized methods for sampling and analyzing indoor air. In Washington state, as on the federal level, no single agency has accepted responsibility for indoor air quality concerns, which has resulted in a lack of data compilation and resource concentration. This assessment is, of necessity, a more qualitative assessment of an unknown, but likely small, percentage of the indoor air problem in Washington State.

This assessment will focus on a few of the myriad compounds identified as common indoor air pollutants. These compounds are believed to be the most common sources of adverse health effects attributable to indoor air contamination exposure in this state. They include: environmental tobacco smoke, benzo(a)pyrene, nitrogen dioxide, volatile organic compounds (including p-dichlorobenzene, tetrachloroethylene, and carbon tetrachloride), formaldehyde, asbestos, and biological organisms. Other compounds associated with indoor air pollution, such as pesticides, will not be considered in this assessment primarily because the frequency of their occurrence in nonindustrial buildings in Washington State is unknown.

Environmental Tobacco Smoke. Environmental tobacco smoke is the major source of indoor air particulates (NRC, 1981). Smoke is generated from incomplete combustion, and is a complex mixture of gases and particulates, including carbon monoxide, nitrogen oxides, and organic compounds. Many of the substances released by burning tobacco are known or suspected carcinogens. To date, 43 chemicals in tobacco smoke have been determined to be carcinogenic, including tobacco-specific nitrosamines. Adverse health effects of mainstream smoke in tobacco smokers have been well documented (Surgeon General, 1979). One out of three adults smokes cigarettes, with the typical smoker smoking 32 cigarettes daily (Repace & Lowrey, 1985). Smoking is responsible for approximately 30% of all cancer deaths nationwide, 21% of deaths from coronary heart disease, 18% of stroke deaths, and 82% of deaths from chronic obstructive pulmonary disease (Surgeon General, 1989). The inhalation of sidestream and exhaled smoke by nonsmokers, termed passive smoking, may result in increased resting heart rate and blood pressure, carboxyhemoglobin, decreased respiratory capacity, ischemic heart disease, and induce allergic reactions (Repace & Lowrey, 1980). Nonsmokers in the U.S. are exposed to an estimated 0 to 14 mg of tobacco tar daily, with an average exposure of 1.4 mg (Repace & Lowrey, 1985). Risk estimates of lung cancer deaths nationwide among non-smokers exposed to environmental tobacco smoke range from 500 to 5,000 annually (EPA, 1988c).

Benzo(a)pyrene. Benzo(a)pyrene is a component of tobacco smoke and combustion appliance gases. It is one of hundreds of polycyclic aromatic hydrocarbons released during the combustion of wood or other organic substances. Benzo(a)pyrene is carcinogenic and is considered an index of general polycyclic aromatic hydrocarbon concentrations. The compound attaches to small particles that are inhaled deeply into the lung, and may cause acute or chronic tissue irritation.

In a study of indoor air components in 38 buildings in the Pacific northwest, concentrations of benzo(a)pyrene were positively correlated to respirable suspended particle concentrations, with a maximum benzo(a)pyrene concentration of 9.67 ng/m^3, considerably above the U.S. ambient urban concentration of 2 ng/m^3 (Turk et al., 1989). The nonsmoking average benzo(a)pyrene concentration in all buildings in this study was 0.4 ng/m^3 and the smoking average was 1.1 ng/m^3, clearly demonstrating the effect of smoking on airborne concentrations of this carcinogen.

The use of fireplaces or woodstoves appears to have a more profound effect on the benzo(a)pyrene concentrations in indoor air. Sample benzo(a)pyrene concentrations include 4.7 ng/m^3 during several days of woodstove use and 11.4 ng/m^3 during fireplace use (Quraishi & Todd, 1987).

Nitrogen Dioxide. The adverse health effects of nitrogen oxides are generally attributed to nitrogen dioxide, which is a respiratory irritant at low concentrations and may cause pulmonary edema and chronic lung function impairment. Asthmatics experience problems from short-term exposures to nitrogen dioxide at 0.3 ppm and greater (NRC, 1981). Sources of nitrogen dioxide include tobacco smoking, kerosene heaters, gas-burning appliances, and the outdoor air. Homes with gas stoves, kerosene heaters, or unvented gas space heaters have much higher levels of nitrogen dioxide than outdoor air, while homes without combustion appliances generally have about half the level of nitrogen dioxide in outdoor air (EPA, 1988a).

Volatile Organic Compounds. Sick building syndrome has been linked to buildings with very low volatile organic compound (VOC) concentrations, at orders of magnitude lower than levels of concern for any one pollutant (EPA, 1987b). Among the more common VOC's detected in indoor air include benzene, p-dichlorobenzene, xylenes, styrene, tetrachloroethylene, and carbon tetrachloride (Wallace, 1987). Benzene and xylenes are components of fuels and their presence in indoor air may be attributed to recent excursions to gas stations, or vehicles in attached garages that lack appropriate ventilation. Styrenes are associated with many plastics found in consumer items. P-dichlorobenzene is found in room deodorizers and moth crystals. Tetrachloroethylene and carbon tetrachloride are dry cleaning agents, and are thought to volatilize from clothing retrieved from dry cleaning establishments. Some of these compounds are considered carcinogenic, and low dose exposures to many of them may result in headaches or sensory irritation. Wallace (1987) determined the lifetime cancer risk of exposure to indoor VOCs in urban areas to be 5×10^{-4}, while the risk in non-metropolitan areas was calucated at half that amount.

In September 1988, EPA (1988d) released the results of two studies of indoor air quality that focused on VOCs. Buildings chosen for study included those where people spend long periods of time, such as schools, nursing homes, hospitals, and office buildings. New buildings were monitored at completion of construction and some months later for comparisons of VOC levels. Data from this study indicated that air levels of VOCs emitted by new building materials appear to decrease between one and two orders of magnitude in the first weeks to months following completion of construction. More importantly, people in buildings where renovation or refinishing work is occurring can be exposed to very elevated levels of toxic chemicals. Monitoring data for 28 chemicals were reported, but reference doses or cancer potency factor information is available for only 11 of the examined pollutants. Because over 300 VOCs have been detected in non-industrial indoor air, and risk estimates are calculated for only 5, the risk estimates reported in EPA's study likely capture only a fraction of the total risk posed by VOCs indoors. Assuming that VOC concentrations in Washington buildings do not differ from those in the EPA study, and that all residents of Washington are exposed to VOCs in schools, offices, or other buildings for 8 hours a day, a range of annual cancer cases for the state can be calculated (Table 1).

Formaldehyde. Of all the pollutants recognized as being important to the quality of indoor air, none has raised public concern more than formaldehyde, because of its acute health effects and irritant properties. Long term exposure studies have shown formaldehyde to have mutagenic activity in a variety of microorganisms and produce nasopharyngeal carcinomas in rats and mice (Spengler & Sexton, 1983). Formaldehyde effects on the nervous system are not well understood, though psychological and neurophysiological effects have been reported at levels of 1500 mg/m^3. Effects include subtle changes such as short-term memory loss, increased anxiety, and slight changes in adaptation to darkness. Concentrations as low as 0.2 mg/m^3 can be irritating to the skin, eyes, and mucous membranes (DOE, 1982). Higher concentrations (3 to 12 mg/m^3) may cause headaches, nausea, dizziness, vomiting, coughing, pulmonary edema, and skin rash. Sensitivity and chronic irritation may develop with repeated exposure to formaldehyde (Turiel, 1985). Formaldehyde may trigger asthmatic attacks or produce an allergic response by forming a hapten-protein complex (Godish, 1981). People with lung diseases or impaired immune systems, the elderly, and children may be particularly affected by this pollutant (EPA, 1988c).

Formaldehyde is a colorless gas with a pungent odor, and is a product of combustion and a component of many consumer products. A ubiquitous compound, it is used as a preservative in cosmetics, toiletries, and food contact substances. Over 50% of the formaldehyde produced today is used in the production of resins used as bonding or laminating agents and as adhesives in wood products, or for modifying the properties of paper or cloth, or as foam insulation in the sidewalls of houses (Walsh et al., 1984). High temperature and humidity induce the breakdown of the foam and resins, leading to offgassing of formaldehyde. Incomplete combustion of natural gas, tobacco and other combustibles may add to the formaldehyde levels of indoor air (Versar, 1986). Versar (1986) determined that average indoor air levels for formaldehyde in conventionally constructed homes was 75 mg/m^3. Formaldehyde levels in indoor air will be greatest when the building is new or newly remodelled, and will decrease over time as the gas is released from building materials. Additionally, human exposures tend to be greatest during winter months when windows and doors are closed, preventing dilution with outside air. Winter formaldehyde levels of 876 homes in the Pacific Northwest averaged 124 mg/m^3 (Reiland et al., 1988). This study also demonstrated a 20% reduction in airborne formaldehyde levels in a 12-month period, leading the authors to suggest that dwelling age is the principle factor in predicting formaldehyde levels.

Because of extensive use of formaldehyde-emitting wood products in construction and increased air tightness of newer mobile homes, residents of such units may experience relatively high exposures to free formaldehyde. Since 1985, HUD has permitted only the use of plywood and particleboard that conform to specified formaldehyde emission limits (500 mg/m^3) in the construction of prefabricated and mobile homes (HUD, 1984). Prior to instituting this construction standard, many mobile homes were constructed with materials containing high levels of formaldehyde, but emissions in these older units should be significantly reduced at this time. Recent data indicate that the HUD targeted concentration of formaldehyde in manufactured homes may not be adequate to protect home occupants from discomfort and other effects of exposure (Ritchie & Lehnen, 1987).

Asbestos. Asbestos is a mineral fiber that has been incorporated in a variety of building materials and textiles to impart insulation and fire-retardant properties. In buildings, asbestos containing materials commonly include sprayed on insulation of building supports and ceilings, ceiling tiles, vinyl tile adhesive, pipewrap and furnace insulation, asbestos shingles, millboard, and textured paints (EPA, 1988a). The use of asbestos containing materials in construction is waning due to federal bans on the use and manufacture of such products, though other materials such as automobile brake linings continue to contain asbestos. Elevated concentrations of airborne asbestos occur after such materials are disturbed by remodelling activities such as cutting or sanding, or from damage due to water or vibration. Even with normal aging, materials may deteriorate and release asbestos fibers in clumps or clouds of dust (EPA, 1988c). EPA measured asbestos concentrations from 9 to 1950 ng/m^3, with average concentrations of 217 ng/m^3 in schools visibly contaminated with asbestos (1987). Outside air averaged 14 ng/m^3 at these sites.

The association of pleural and pulmonary abnormalities with asbestos exposure was reported as early as 1935 (Anton-Culver et al., 1989). Inhalation of asbestos fibers can result in lung cancer or mesothelioma (cancer of the lining of the chest or abdominal cavities) several years after exposure has ceased. Asbestosis, an irreversible scarring of the lung, is a noncancerous condition associated with occupational exposure to asbestos. There is an exposure-response relationship between cumulative asbestos exposure and prevalence rates of pleural plaques as identified by chest radiographs of shipyard workers (Anton-Culver et al., 1989). Although the pathogenic mechanism of pleural plaques is unknown, such lesions are considered to be strong indicators of previous asbestos exposure.

Biological Organisms. A variety of biological material is present in indoor environments. Biological contaminants have directly led to many deaths as well as the expenditure of millions of dollars in lost time and productivity (Morris, 1986). These contaminants have a wide range of biological activities involving inflammatory, hemodynamic, and immunological responses. Inhalation of aerosols of these substances is a primary mechanism of contagion of upper respiratory diseases. Pollen, molds, dust mites, bacterial endotoxins, chemical additives, animal dander, fungi, algae, and insect parts are known indoor biological contaminants. Sources of these materials include pets, detergents, humidifier and air-cooling fluids, growth of molds and fungi on ductwork and other surfaces, and insect infestations (EPA, 1988a). Building ventilation systems and equipment can impact the concentrations of biological organisms in occupied spaces (Morris, 1986). Temperature and humidity are very important for many indoor aeroallergens. Higher temperatures and relative humidity enhance growth of molds, algae, and dust mites (Turiel, 1985). Reduced ventilation and increased use of recirculated, untreated air may concentrate many of these materials, and prolonged exposure may cause sensitization.

The pollutants chosen for this assessment do not illustrate the entire indoor air pollution problem, but were selected for the following reasons:

1. The pollutant has been associated with adverse human health effects in case studies or current literature.

2. The pollutant is commonly found in indoor environments at concentrations that may adversely affect human health.

3. Some exposure and/or dose information is available on the pollutant.

The exposure data utilized in the assessment are not specific to Washington State. Statewide data on indoor air exposures are negligible, and better data have been collected elsewhere in the nation. Human activity patterns and exposures are assumed to be similar to subjects cited in other studies. Variations in such data may exist from state to state, but the imprecision, uncertainty, and error inherent in available data reduce the effect of such differences. Washington census data has been used to determine the number of individuals affected by specific sources, when available, including the prevalence of smokers, number of homes with woodstoves and fireplaces (Jenkins, 1986), and number of mobile homes.

Cancer risk assessments were performed for the following pollutants:

1. Environmental tobacco smoke
2. Benzo(a)pyrene
3. Volatile organic compounds
4. Formaldehyde
5. Asbestos

The cancer risk estimates are based on potency estimates developed by EPA's Carcinogen Assessment Group. Because of the uncertainties in the data used to develop the estimates, the estimates are best utilized to determine the relative relationships among the various pollutants and exposure types, and cancer risks.

Lack of adequate data have made it impossible to separate acute from chronic health effects, so all noncancer health effects are summarized together. Qualitative health assessments were performed for the following pollutants:

1. Environmental tobacco smoke
2. Nitrogen dioxide
3. Volatile organic compounds
4. Formaldehyde
5. Biological organisms

The assessments outline the expected adverse health effects as well as the numbers of Washingtonians potentially affected. Noncancer effects are "scored" on the basis of the severity of the health effect as determined by the EPA's National Comparative Risk Project ranking (1987b).

B. Cancer risk assessment findings demonstrate the relative importance of the various indoor air pollutants that were examined in relation to cancer risk (Table 1). Because of the extensive assumptions and extrapolations made on the extremely limited data to arrive at the risk numbers, the estimates should not be used out of the context of this paper. Comparison of the various cancer risks indicate that exposure to environmental tobacco smoke would result in the greatest increased incidence of cancer among the pollutants examined (64 to 321 cases annually). Exposures to VOCs and formaldehyde appear to result in relatively high cancer risks as well (16 to 33, and 7 to 66 cases annually, respectively). Personal air exposure data was used for determining the cancer risk for VOCs rather than indoor air sampling data (Wallace, 1986). Since people spend approximately 90% of their time indoors and indoor air is generally more contaminated than outdoor air, these estimates primarily reflect indoor air exposure. Benzo(a)pyrene and asbestos exposure would result in few cases of excess cancer in Washingtonians, based on estimated exposure conditions.

The acute and chronic health risk assessment is summarized in Table 2 and illustrates the number of persons at risk of exposure to concentrations of pollutants which may be associated with adverse health effects. Generally, the number of affected individuals is not known, but it is possible to compare the estimated numbers of affected individuals or extensiveness of the problem for some of the pollutants. For most indoor air quality complaint investigations, a source of the problem is more likely to be identified than the specific pollutant(s) causing the adverse health effect. Additionally, factors relating to the building design and ventilation system influence the severity of any problems that are identified (Godish, 1986).

Potentially, the entire state population (4,565,000 individuals) may be exposed to volatile organic compounds emanating from such diverse items as plastics, bonding compounds, wood products, dry cleaned items, cleaning compounds, and smoking tobacco. Health effects associated with exposure to these compounds vary depending upon the compound itself, the size of the dose, and the duration of the exposure. Generally, the effects associated with exposure to low levels of VOCs are sensory irritation and headaches, which are ranked at 3 and 2 by EPA (1987b) as specific non-cancer health endpoints. An estimated 2,830,300 persons are exposed to environmental tobacco smoke at home with health effects endpoints of allergic reactions (3) and respiratory impairment (4), though other respiratory disorders, low birth weights (5) and mortality from ischemic heart disease (5) may be associated with environmental tobacco smoke (Repace & Lowrey, 1985). Relatively high formaldehyde exposure may occur to 274,731 mobile home residents, resulting in headaches (3), sensory irritation (2), and pulmonary edema (6). Additionally, other persons who are exquisitely sensitive to formaldehyde and energy efficient home dwellers may develop adverse health effects. The numbers of such individuals affected as well as their exposure levels are unknown. Asthmatics (124,440 in Washington state) may have increased severity of symptoms when exposed to either nitrogen dioxide or biological organisms. Residents of homes with gas cooking facilities may also be affected by increased levels of nitrogen dioxide, resulting in respiratory irritation (3), and impaired pulmonary function (4).

C. Valid measures of exposures of humans to pollutants over time are necessary to classify accurately their exposure status. This type of data was essentially not available to develop the risk assessment estimates. Additionally, exposure to an agent may be associated with other possible determinants of risk (confounding variables). In determining risk of exposure to indoor air contaminants, relevant confounding variables are unknown or difficult to measure. This is a particular problem in the interpretation of studies in which the relative risks are not large. In the rare cases where knowledge of the concentrations of the environmental pollutants in indoor air are known, there is a general lack of information on the magnitude of intake of, or contact with, the contaminated air per unit of time. Duration and frequency of exposures to indoor air contaminants are frequently unavailable, and are necessary components of an exposure assessment. Because of the relatively large number of assumptions and inferences made to complete the risk assessment, uncertainties are rampant in the risks identified in this report.

D. Although numbers of cancers have been calculated, such numbers are hypothetical. Little or no epidemiological data associating human cancer with the selected contaminants at the concentrations to which humans are exposed is available. Individual cancer risk can be relatively high, with passive smoking responsible for the majority of expected additional cancers.

Many individuals may have a relatively high risk of noncancer health risks from exposure to indoor air pollutants. Complaints of irritation and discomfort associated with exposure to indoor air pollutants should not be minimized because of the varying sensitivity of individuals exposed to such compounds. Unfortunately, such indoor air complaints cannot be separated from those associated with other factors. Indoor air related problems must be addressed with related issues such as ventilation, individual sensitivity, and human activity patterns. It is important to note that it is normal for some percentage (approximately 20%) of building occupants to experience symptoms associated with indoor air pollution exposure, and that occupant complaints may also result from an illness contracted outside the building, acute individual sensitivity, job-related stress or dissatisfaction, or other pyschosocial factors (EPA, 1988a; 1988b).

Three basic strategies have been identified for control of indoor air pollution: source removal, dilution, and air cleaning. The appropriate strategies to be used, either separately or in combination, must be selected with respect to other considerations, such as acoustic, thermal, economic, and energy conservation (NRC, 1981). Control of pollutants by removal, if sources are properly identified, provides the most effective and least expensive approach (in the long run) to the mitigation of an indoor air quality problem (Godish, 1986). When possible, mobile pollutant sources should be utilized when the least number of people would be exposed, such as interior painting during non-working hours. Building materials in new or remodeled areas should be allowed to off-gas pollutants under high ventilation conditions prior to occupancy. Air exchange by infiltration, exfiltration, natural ventilation, and mechanical ventilation may reduce indoor contaminants if the outdoor replacement air contains lower concentrations than the indoor air (DOE, 1982). Increasing ventilation rates can often be a cost-effective means of reducing indoor pollutant levels (EPA, 1988b). Ventilation is not the most important parameter affecting observed pollutant concentrations, since source strengths, which likely vary from building to building, are often the determining factor in pollutant concentrations (Turk et al., 1989). Filtration can be utilized for both particulate and gaseous contaminants. Such systems are expensive to install and maintain, and impose a decrease in volumetric flow rate of the ventilation system.

Regulatory controls of pollutants may be accomplished by product bans, labelling requirements, minimum performance standards, public awareness programs, and housing-related regulations (DOE, 1982). The adoption of indoor air quality standards by trade and professional associations could result in changes in the design and construction industry. At the present, it remains unclear who is responsible for residential indoor air quality and what controls will be developed and implemented. Precedents established through the courts may determine what minimum indoor air quality controls must be included in residential and other non-industrial structures, including public buildings.

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Table 1. Cancer Risk Estimates

Pollutant	Exposure Conditions	Incidence
Environmental Tobacco Smoke	Exposure (0.45-2.27 mg tar/day) at home for 62% population	64-321 cases/yr
	Average exposure (1.4 mg tar/day) at work and home for 62% population	198 cases/yr
Benzo(a)pyrene	462,806 households with woodstoves/inserts used for 3 to 6 months (456 to 912 hrs) at 4.7 ng/m^3 per day	4-7 cases/year
	462,806 households with fireplaces used for 3 to 6 months (273 to 547 hrs) at 11.4 ng/m^3 per day	5-10 cases/year
Volatile Organic Compounds	4,565,000 people exposed to average conditions based on TEAM study	16-33 cases/year
Formaldehyde	274,731 mobile home residents exposed to HUD mobile home formaldehyde standard (500 ug/m^3) and average level (525 ug/m^3)	22-23 cases/yr
	274,731 mobile home residents exposed to low to high levels (150 - 1500 ug/m^3)	7-66 cases/yr
	4,036,153 residents of conventional homes exposed to average formaldehyde levels (75 ug/m^3)	42 cases/yr
	4,036,153 residents of conventional homes exposed to low to high levels (7-4350 ug/m^3)	4-2445 cases/yr
Asbestos	986,745 children aged 5-19 exposed to average levels (200 ng/m^3) and a range (10-1950 ng/m^3) of asbestos for 200 days @ 8 hrs/day where 10% of student area in school contains asbestos and 66% of surface area is damaged	Mesothelioma: Avg - 1 case/yr Rng - <1 to 11 cases/yr Lung cancer: Avg - 1 case/yr Rng - <1 to 6 cases/yr

Table 2. Acute and Chronic Health Effects

Pollutant	Health Effects (Endpoint Ranking)	Estimated # Persons @ Risk
Environmental Tobacco Smoke	Allergic reactions (5), Respiratory impairment (4), Low birthweight (5), Ischemic heart disease (5)	- 2,830,000 at home (MEI) - population exposed occupationally unknown, due to workplace smoking restrictions
Nitrogen Dioxide	Respiratory irritation (2), Impaired pulmonary function (4), Increased susceptibility to infections	- 154,940 in homes with gas cooking utilities (MEI) - 124,440 asthmatics with increased severity of symptoms
Volatile Organic Compounds	Headaches (3), Eye, respiratory irritation (2)	- up to 4,565,000, depending on specific contaminant
Formaldehyde	Headaches (3), Eye, respiratory irritation (2), Pulmonary edema (6), Pneumonia	- 274,731 mobile home residents (MEI) - Unknown number of sensitive individuals
Biological Organisms	Allergic rhinitis (3), Bronchial asthma (4), Hypersensitivity pneumonitis (4), Infection	- 124,440 asthmatics with increased severity of symptoms (MEI) - Unknown number of sensitive individuals

BIBLIOGRAPHY

Anton-Culver, H., B. D. Culver, and T. Kurosaki. 1989. An epidemiologic study of asbestos-related chest X-ray changes to identify work areas of high risk in a shipyard population. Appl. Ind. Hyg., 4:100-110.

Godish, T. 1981. Formaldehyde and building-related illness. J. Environ. Health, 44(3):116-121.

Godish, T. 1986. Indoor air pollution in offices and other nonresidential buildings. J. Environ. Health, 28(8):190-195.

Jenkins, P. G. 1986. Washington wood smoke: emissions, impacts, and reduction strategies. WA Dept. of Ecology, Olympia, WA.

Meyer, B. 1983. Indoor air quality. Addison-Wesley Publishing Co. Inc., Reading, MA.

Morris, R. H. 1986. Indoor air pollution: airborne viruses and bacteria. Heating/piping/air cond., Feb. 1986, pp. 79-89.

National Research Council (NRC). 1981. Indoor pollutants. Nat. Acad. Press, Washington, DC.

Quraishi, T., & J. Todd. 1987. Effects of domestic wood-burning on indoor air quality - an overview. In: Proceedings of the 4th International conference on indoor air quality and climate. Inst. for Water, Soil and Air Hyg. West Berlin. 17-21 August 1987.

Reiland, P., M. McKinstry, and P. Thor. 1988. Final formaldehyde testing results for the residential standards demonstration program. Office of Energy Resources, Bonneville Power Administration.

Repace, J. L., & A. H. Lowrey. 1980. Indoor air pollution, tobacco smoke and public health. Science, 208:464-472.

Repace, J. L., & A. H. Lowrey. 1985. A quantitative estimate of non-smokers' lung cancer risk from passive smoking. Environ. Int., 11:3-22.

Ritchie, I. M., & R. G. Lehnen. 1987. Formaldehyde-related health complaints of residents living in mobile and conventional homes. Amer. J. of Publ. Health, 77:323-328.

Spengler, J. & K. Sexton. 1983. Indoor air pollution: a public health perspective. Science, 221:9-17.

Surgeon General. 1979. Smoking and health--a report of the surgeon general. HEW (PHS) Report No. 79-50066.

Surgeon General. 1989. Reducing the health consequences of smoking: 25 years of progress (executive summary). MMWR 1989:38 (suppl. no. S-2).

Turiel, I. 1985. Indoor air quality and human health. Stanford Univ. Press, Stanford, CA.

Turk, B. H., et al. 1989. Indoor air quality in commercial buildings - volume 1: measurement results and interpretation. Bonneville Power Administration. Report No. DOE/BP-12921-4, April 1989.

U.S. Department of Energy (DOE). 1982. Indoor air quality handbook. Sandia National Laboratories, Albuquerque, NM.

U.S. Department of Housing and Urban Development (HUD). 1984. Part 3280 - manufactured home construction and safety standards, subpart 308 - formaldehyde emission controls for certain wood products. 49 FR 32011, August 9, 1984.

U.S. Environmental Protection Agency (USEPA). 1987a. EPA indoor air quality implementation plan; Appendix A: preliminary indoor air pollution information assessment. Report No. EPA/600/8-87/014.

U.S. Environmental Protection Agency. 1987b. Unfinished business: a comparative assessment of environmental problems. Appendix II, non-cancer work group. EPA, Office of Policy Analysis, Washington, D.C., February 1987.

U.S. Environmental Protection Agency. 1988a. The inside story--a guide to indoor air quality. Report No. EPA/400/1-88/004.

U.S. Environmental Protection Agency. 1988b. Indoor air facts no. 4: sick buildings. EPA Public Info. Ctr., Washington, D.C., July 1988.

U.S. Environmental Protection Agency. 1988c. Environmental progress and challenges: EPA's update. Report No. EPA/230/07-88/033.

U.S. Environmental Protection Agency. 1988d. Indoor air in public buildings, volume I and volume II. Report Nos. EPA/600/6-88/009A and EPA/600/6-88/009B.

Versar, Inc. 1986. Formaldehyde exposure in residential settings: sources levels, and effectiveness of control options. Final report. EPA contract no. 68-02-3968.

Wallace, L. 1986. Estimating risk from measured exposures to six suspected carcinogens in personal air and drinking water in 600 U.S. residents. Presented at Annual Meeting of Air Pollution Control Association, June 22-27, 1986.

Wallace, L. 1987. The total exposure assessment methodology (TEAM) study: summary and analysis: volume 1. Report No. EPA/600/6-87/002A.

Walsh, P., et al. 1984. Indoor air quality. Addison-Wesley Pub. Co., Inc., Reading, MA.

THE STATE OF THE ENVIRONMENT REPORT

VOLUME III
Part 3

Risk Evaluation Reports for Radioactive Releases

ENVIRONMENT 2010

State of Washington
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RELEASES FROM RADIOACTIVE WASTES/RADIOACTIVE MATERIALS HUMAN HEALTH RISKS

Background

The section reviews the causes of human health risk associated with the presence of radioactive materials in the environment. The sources receiving attention were selected for several reasons including the prevalence and mobility of a particular type of radioactive waste within the state of Washington, the regulatory and political attention received, the availability of information on each, and the potential for an individual to be unknowingly exposed. The sources of potential radiation exposure and the associated facilities reviewed in this section are:

- the radioactive components of "mixed" hazardous wastes resulting from nuclear materials production
- commercial nuclear power operations
- high-level nuclear waste storage sites
- low-level nuclear waste storage and disposal sites
- transuranic waste storage and disposal sites
- radioactive effluents from nuclear medicine, laboratory, and radiopharmaceutical facilities
- uranium mill tailings disposal sites
- other licensed users of radioactive materials.

Risks associated with radiation exposure due to diagnostic medical procedures,or naturally occurring radioactive isotopes will not be considered. Indoor radon and non-ionizing radiation receive thorough reviews in other sections. Radiation exposures received as part of an individual's occupation can be several orders of magnitude higher than those received by the public but are limited to a much smaller population. Because of the limited populations in the occupational exposure category and because there is an assumed benefit to the informed persons receiving these types of exposures, (salary), occupational exposure will not be addressed in this section.

Long-term continuous exposure to relatively low levels of radiation is commonly termed chronic exposure. The health endpoints of chronic radiation exposure are usually described in terms of the number of cancers caused, or genetic or teratogenic defects occurring within a given population.

An assumption being made in this section is that there are no sources of environmental radiation sufficiently large enough to cause prompt, acute radiation exposure effects.

Acute effects are seen when large doses (hundreds of rem) are received by humans over a short time frame. Although various facilities and activities within the state are capable of producing such doses to the public under accidental conditions, those low probability events will not be considered here.

However, the exposures that could result from negligence or loss of institutional control over the radioactive materials and sources reviewed in this section might be substantial. This leads one to conclude that monitoring and regulatory controls are important in assuring that future doses to the public are minimized. Under certain accident conditions there is a high potential for large localized public exposures. Emergency preparedness around these activities should receive increased attention based on the potential severity of the impacts.

Health impacts associated with anxieties imposed on the public from the perception of risks associated with nuclear facilities and radioactive wastes are also not considered in this evaluation. Some studies have shown that these types of impacts exist, but because they are difficult to quantify and very little information is available for Washington populations, this section only acknowledges their possibility and doesn't attempt to identify or evaluate any associated risks.

Analytic Approach and Data Sources

Radiation doses will be estimated and listed as dose equivalents. These are units of radiation dose normalized to their potential for biological harm based on the nature of the radiation and the biological endpoint under consideration. The units used in this report are the rem, or the millirem, (one one-thousandth of a rem).

Throughout this report, site specific data were used when available. Reported national data were utilized where local information was lacking, and where they were judged to be representative of the local condition.

Various nuclear related activities in the state can lead to radioactive releases to the environment, with the potential for subsequent doses to surrounding populations. These activities are divided into: 1) nuclear weapons storage and atmospheric testing; 2) operation of nuclear navy facilities; 3) operation of the defense production facilities on the Hanford Reservation; 4) commercial nuclear energy production; 5) uranium mining, milling, and tailings disposal; 6) commercial low-level waste disposal; and 7) other radioactive material uses.

Nuclear defense activities may lead to radiation exposures through several different routes. Historically, nuclear weapons were tested in the atmosphere by several nations, including the USA and the USSR, principally in the 1950's and 1960's. Atmospheric testing by those major nations ended in 1963 with the establishment of an atmospheric weapons testing ban. However, some nations such as the Peoples Republic of China were not parties to that ban and continued to test in the atmosphere. The current estimate of the dose contributed from fallout is less than one mrem per year. This is a reduction from the dose received by the U.S. population in the early 1960's of about 4 mrem per year and amounts to less than 0.5% of the dose annually received from natural sources of exposure. Assuming that atmospheric testing continues to diminish, the dose contribution should follow the same trend.

The state also has several federal facilities designed to hold, store, and ship nuclear weapons. The presence of weapons at these facilities is classified information, but it would be reasonable to assume that some inventory exists in the state at any time. Those weapons contain various radioactive materials and thus have the potential to cause some dispersal of that material under non-detonating accidental conditions. Under normal transport and storage conditions the dose to the public can be considered as negligible.

Nuclear reactors are used to power naval vessels. The region has a number of nuclear powered submarines home based at Bangor, on the Hood Canal. Washington also has a naval shipyard in Bremerton which deals with nuclear powered vessels. The normal operation of these vessels and the associated maintenance activities cause trace releases of radioactive contamination to the environment. The environment around these facilities is surveyed and monitored by Department of Defense employees, and periodically by the Environmental Protection Agency and state agencies. The maximum dose to any member of the public has been estimated by the federal government to be less than one mrem/year, and the total dose to the population at less than one person-rem. The average public individual dose has been rounded to zero.

Potential impacts associated with historic activities on the federal Hanford Reservation have recently been receiving a great deal of scrutiny after previously classified information was released, revealing past radionuclide emissions at levels millions of times greater than those emitted by the facility today. This section will not attempt to estimate health risks associated with past Hanford operations. There are two major scientific efforts underway to quantify those risks. One study, called the Hanford Environmental Dose Reconstruction Project is attempting to provide dose estimates for various groups of people who in the past, lived and worked around the Hanford site. The other major study is reviewing the occurence of thyroid disease in populations surrounding the federal reservation to determine if the thyroid disease incidence rate is higher than expected and related to early Hanford emissions. The state of Washington is involved in both of those efforts.

The cleanup of wastes resulting from past Hanford operations is also a top priority of the associated state and federal agencies for many reasons. Those reasons include technical issues such as potential negative effects on human health and the environment and long-term loss or restriction of land use. Additionally, there are social/ethical considerations supporting cleanup that result from the need for a remedy to the impacts the state has suffered as part of its contribution to the national defense. Although these wastes are receiving increasing regulatory attention, years of work will be involved in developing the necessary technologies for the identification and assessment of the long-term risks they present. Additionally, the goal of Hanford clean-up is to reduce the potential for environmental degradation and health impacts that might occur over the next several hundred years. This report only looks forward to the year 2010 and does not attempt to quantify health, ecological, or other unknown risks over that extensive time period.

Radioactive waste resulting from the production of defense related nuclear materials has lead to public exposures through several environmental pathways. The Hanford Site, which is operated by the U.S. Department of Energy, is a major national site used in the production and processing of defense nuclear materials. The various industrial facilities located on the site emit radionuclides to the environment during normal operating conditions.

The site also contains a major fraction of the nation's high level, low level, and transuranic waste inventories. Most of these wastes exist as "mixed", or containing a hazardous chemical component as well as the radioactive. Most of the low-level and transuranic wastes have been disposed of with few environmental controls, in shallow trenches or directly to the soil column. The radiological impacts to human health from current operations have received a great deal of attention in recent years and dose estimates are routinely made available to the public.

The U.S. Department of Energy estimates that the dose via all pathways to a hypothetical maximally exposed member of the public as a result of 1987 Hanford operations is less than 0.05 mrem per year. The Hanford effective dose to the surrounding population (adding the doses to an average individual from all sources, then multiplying by the number of people in the area) for 1987 was about 4 person-rem. Both of these dose estimates are about 50% lower than the values estimated for 1986. These reductions can be attributed to a decrease in the release rates for radionuclides to the environment due to the curtailed operations of the production reactor and the reprocessing plant.

Washington state has several facilities which have served as components of the nuclear fuel cycle. Uranium mining and milling in the northeast part of the state has resulted in two large areas containing radioactive mill tailings. The state also has one operating commercial reactor on the Columbia River near Hanford, and is involved in the monitoring and emergency response activities for a second in Oregon. Finally, there is a commercial low-level waste disposal facility which receives radioactive wastes from nuclear reactors, medical laboratories, the armed forces, and industrial operations.

Portland General Electric Company is the operating utility for a 1,130 MWe pressurized water reactor located on the Oregon side of the Columbia River, three miles northwest of Kalama, WA. The plant is owned by the utility in conjunction with the Eugene Water and Electric Board and the Pacific Power and Light Company. The Trojan reactor first achieved criticality on December 15, 1975. In 1987, Trojan's dose contribution to the maximally exposed individual was estimated at less than 1 mrem/year, and the total population impact is about 0.2 person-rem/year.

The Washington Public Power Supply System operates the WNP-2 reactor near Richland, WA. This reactor is a 1,135 MWe boiling water reactor that became operational in January 1984. In 1987, WNP-2's dose contribution to the maximally exposed individual was estimated at less that 1 mrem/year, and the total population dose was about 0.25 person-rem/year.

Uranium mining occurred at several locations in the state but the two largest mines are located on the Spokane Indian Reservation near Wellpinit, WA. Commercial processing of the ore took place at two nearby mills which produced radioactive tailings waste that cover about 250 acres. The tailings piles range in depth from several feet to over ten feet and are in both lined and unlined impoundments. Both the mine and mill sites contain an inventory of uranium decay products which can be dispersed as particulates or as radon gas. These contaminants could potentially impact nearby populations through ingestion, inhalation, or degradation of local water quality. Historically, radiation releases and the subsequent exposures to nearby populations have been below existing standards. The contribution to population dose is probably negligible due to low population densities surrounding the sites. Currently attention is being given to the closure and decommissioning of both facilities, which will further reduce the potential for offsite exposures. Current dose estimates to individuals or populations surrounding these facilities are not available although monitoring data continues to be collected and reviewed by the facility owners and the state. The mills have not been operating for the past 5 - 7 years and regulatory agencies do not require an annual assessment of doses while they remain in a shutdown mode. Dose estimates were last calculated during 1982 - 1983 for exposure to isotopes of radium, thorium, and uranium. These estimates for the residents living nearest to the two mill resulted in whole-body doses that were less than one millirem per year.

US Ecology Inc. operates the commercial low-level radioactive waste facility on the Hanford Reservation. The state leases 1,000 acres of the reservation from the federal government and in turn sub-leases 100 acres to US Ecology for this purpose. This disposal site has been in operation since 1965. Due to the location of the facility near the middle of the Hanford Reservation, and the semi-arid hydrogeological setting, dose contributions from normal operations to the nearest residents of the area are currently negligible. Longer term effects of site degradation are under evaluation today.

There are about 300-400 licensed users of radioactive materials in the state. This category includes university researchers, nuclear medicine physicians, industrial radiographers and others. They receive regulatory oversight from both state and federal agencies. Although the potential exists for large exposures to workers or individual members of the public due to negligence on the part of the licensed user or during an accident situation, normal operating conditions typically result in population exposures and subsequent risks to human health that are negligible.

The doses noted above and on previous pages were tabulated in Table 1. The equivalent whole body doses were used in calculating cancer mortality estimates. Due to a lack of specific information on gonad doses and the low estimated whole body doses, the risks associated with genetic or teratogenic damage were not evaluated in this section.

A body of international information exists for estimating risks due to radiation exposure. The cohorts studied include survivors of the atomic bombing of Japan, and other groups including individuals who received exposures from various medical procedures.

It is important to realize that the cancer risk numbers generated here are only estimates. Numerous studies have demonstrated that exposure to high levels of radiation is carcinogenic and many difficulties exist in designing research studies that can accurately measure the small increases in cancer cases due to low exposures to radiation, as compared to the normal rate of cancers. There is still uncertainty and a great deal of controversy with regard to estimates of radiation risk at low levels of exposure. The numbers used here result from studies involving high doses and high dose rates, and they may not apply to doses at the lower levels of exposure. The Nuclear Regulatory Commission (NRC) and other agencies both in the United States and abroad are continuing extensive long-range research programs on radiation risk from low exposures.

Some members of the National Academy of Sciences (NAS), Biological Effects of Ionizing Radiation Advisory Committee and others feel that the risk estimates used in this review are higher than would actually occur, and represent an upper limit on risk. Other scientists believe that the estimates are low and that the net risk could be higher. However, the values used in these estimates are considered by many to be the best available that the public can use to make an informed decision concerning the acceptance of the risks associated with radiation exposure.

This report uses a risk estimate derived from the no threshold, linear quadratic extrapolation published by the NAS in 1980. The NAS estimates that the lifetime risk of cancer mortality induced by x-rays or gamma radiation, expressed as units of excess deaths per million exposed, per rem of dose, ranges from 67 to 226. To be conservative in our risk estimates the upper value of 226 cancer deaths/million exposed/rem of exposure will be used.

Findings and Conclusions

Several conclusions can be drawn from this risk analysis. Although not specifically addressed, exposure to natural radioactive isotopes (average annual exposure is from 80 - 100 mrem per year without radon) is the primary contributor to population dose in Washington. The average effective dose equivalent due to radon varies by geographical location, but is around several hundred mrem per year for residents of the state.

Radiation exposure associated with nuclear waste facilities, nuclear defense facilities, nuclear fuel cycle components and other users of radioactive materials are at least several orders of magnitude less than those associated with naturally-produced isotopes. No member of the public routinely receives doses which could cause acute effects, except for exposures that might be received under accidental conditions, or through inadequate industrial controls at nuclear sites.

These data are estimates and contain uncertainties. The estimates are as accurate as possible given the available information, and do not contain intentional large conservative biases for an average member of the population. The cancer risk estimates deal only with whole body exposures to x-rays and gamma rays. Those estimates were not intended to be used in evaluating the risks associated with exposures to other types of radioactive particles. Radioactive wastes that emit alpha and beta radiation are found among the radioactive materials and wastes described in this section. However, injuries resulting from exposure to these other types of radioactive material are usually associated with either their ingestion or inhalation. Exposures of the public due to ingestion and inhalation from the sources considered here are probably very limited under normal conditions.

The total annual population dose associated with fallout is the largest listed in Table 1, because all 4 million state residents are assumed to be exposed to it.

Table 2 presents annual cancer risk estimates and the resulting cancer mortalities that are predicted for affected populations. The cancer risk estimates are presented on an annual basis. To obtain a lifetime risk estimate,(assuming constant conditions), the annual estimate can be multiplied by the number of years an individual would receive a particular type of exposure. Total lifetime risks (70 years) are also presented in Table 2.

The population considered as part of the population dose estimate for defense production facilities in the state included everyone within an 80 kilometer radius of the various Hanford facilities, and ranged from 260 to 340 thousand people. The assumption is that this population includes all individuals potentially affected by any of the exposure pathways.

All doses were calculated using the most recent data available. Assuming that existing institutional controls still exist, that technology associated with the use of radioactive materials improves, and that progress is made to cleanup existing waste sites, then future exposure to state populations should continue to decrease through the year 2010.

TABLE 1

RADIATION DOSE ESTIMATES
(ANNUAL BASIS)

Radiation Dose Source	Average Individual Dose(mrem)	Maximum Exposed Individual(mrem)	Population Dose (person-rem)
Nuclear weapons testing	<1	<1	<4,100
Nuclear navy facilities	<1	<1	<1
Hanford defense production facilities	<0.05	<0.05	4
Commercial nuclear reactors			
Trojan	<1	<1	0.2
WNP-2	<1	<1	0.25
Uranium mining and milling	<1	<1	<1
Commercial low level waste disposal	<1	<1	<1
Other uses of radioactive materials	<1	<1	<1

The value <1 was used to indicate estimates which resulted in a range of values from near zero up to, but not including, one millirem per year.

TABLE 2

HEALTH IMPACTS AND RISK ESTIMATES

Potential Dose Source	Maximum Annual Cancer Deaths in Affected Populations	Maximum Lifetime Cancer Deaths in Affected Populations	Maximum Individual Risk (annual)	Maximum Individual Risk (70 year)
Atmospheric weapons testing	0.9	65	$<10^{-6}$	$<10^{-4}$
Nuclear Naval Facilities	<0.1	<1	$<10^{-6}$	$<10^{-4}$
Hanford Defense Production Facilities	<0.1	<0.3	$<10^{-7}$	$<10^{-6}$
Commercial Nuclear Reactors	<0.1	<1	$<10^{-6}$	$<10^{-4}$
Uranium Mining and Milling	<0.1	<0.1	$<10^{-7}$	$<10^{-6}$
Commercial Low-level Waste Disposal	<0.1	<0.1	$<10^{-7}$	$<10^{-6}$
Other Users of Radioactive Materials	<0.1	<0.1	$<10^{-7}$	$<10^{-6}$

RELEASES FROM RADIOACTIVE WASTES/RADIOACTIVE MATERIALS ECOLOGICAL RISKS

Background

This section reviews potential ecological risks associated with the presence of radioactive materials in the environment. For the purposes of this review, ecological risks are defined as any impacts from radioactive contamination that adversely affect species, biotic communities, and ecosystem structure or function. Economic impacts and health risks related to the presence of radioactive contaminants in areas of the state are reviewed in separate sections. The major potential radiation sources within the state include:

- nuclear weapons testing and storage
- nuclear naval facilities
- defense production facilities at Hanford
- commercial nuclear energy reactors
- uranium mining and milling
- commercial low-level waste disposal
- other radioactive material users

Description of Analytical Approach

The approach used in this evaluation adopts the assumption that long-term ecological risks due to radioactive materials in the environment are primarily limited to the concern for the ecosystem as a potential route to humans for health-effects stresses. This assumption is in agreement with the 1986 evaluation done by Harwell and Kelly of Cornell University for the EPA Comparative Risk Project. Although very local accidental releases can result in ecologically significant doses, only those releases of radioactive contaminants under non-accident conditions are considered here.

The number of sites where major sources of radioactive wastes or materials exist in the environment are limited. The Hanford Reservation has several facilities where radioactive materials are handled on a daily basis and large quantities of radioactive wastes are generated, stored and disposed. Therefore, this review will focus on what is considered to be one of the most significant potential sources of radioactive contamination in the state, the Hanford Reservation. At the outset, it was determined that if the review showed that Hanford represents a significant ecological risk, then other major facilities in the region should also be examined. Other potential sites which may present future impacts to ecological systems include the naval shipyard at Bremerton, the proposed naval homeport in Everett, and the commercial nuclear reactors. However, these impacts are not expected to be severe under normal operating conditions.

Findings

Summary

Ecological risks from nuclear facilities or nuclear wastes are expected to be localized around their sources. The Hanford Site has an extensive monitoring program in place that provides some information on ecological impacts sources have on the existing environment. There are also environmental monitoring programs in operation on and around the site for the commercial reactor (WNP-2) and for state oversight. Current monitoring programs have not demonstrated widespread ecological impacts associated with present-day operations.

Estimated Risks

Animal species potentially affected by activities on the Hanford site include waterfowl, upland game birds and various terrestrial mammals. Wildlife have access to several areas near facilities that contain various concentrations of radionuclides produced by on-site facilities. Deer, fish, game birds, waterfowl, and rabbits were all sampled during 1987 as biological indicators of environmental contamination. Results of these analyses were used in the calculation of the potential dose to humans from food pathways. These results were similar in magnitude to those observed in recent years. The dose that would result from the consumption of these animals, even at the maximum radionuclide concentrations measured in 1987, was well below applicable standards for human exposure and contributed only slightly to the estimated 0.05 mrem dose to the maximum exposed individual..

Assuming that waste inventories do not significantly increase, and that existing wastes continue to be removed from the site, or disposed in a secure manner, then the expected ecological risk should decrease through the year 2010. However, the lack of adequate attention to the existing waste volumes would serve to degrade the local environment and potentially impact existing biotic systems.

Transport of radionuclides occurs through the air, groundwater and surface water. Contact with air and surface waters are assumed to be the most significant pathways posing ecological risk. Possible effects to local ecosystems due to chronic exposure to radiation include mutations, cancer, and reproductive, developmental or immunological abnormalities. All could be manifest in declining populations, but to date no population declines have been attributed to Hanford. Table 1 presented below presents estimated ecological effects from the wastes on-site and some 1987 data on waste volumes and radioactive content.

TABLE 1

Exposure Source	Ecosystem Affected	Effects	1987 Waste Characteristics
Air (inhalation,and direct contact)	terrestrial	none measurable	There were significant decreases in all radioisotopes released compared with 1986 values except for tritium (1986 = 60 Ci and 1987 = 70 Ci) and radon-220 (1986 = 4 Ci and 1987 = 5Ci) Atmospheric releases included about 74,000 Ci of krypton-85, 0.0002 Ci of strontium-89,90, and 0.0034 Ci of plutonium isotopes
Water (ingestion, direct contact)	Columbia River (includes input from groundwater)	none measurable	The total volume of liquid wastes discharged in 1987 was 5.5 billion gallons. These wastes contained 2,000 Ci of tritium, 0.4 Ci ruthenium-106, and less than 1.3 Ci of plutonium. All releases were significantly below the levels of 1986.
Solid wastes (ingestion, inhalation, direct contact)	terrestrial	none measurable (may be small localized effects)	The total volume of solid wastes disposed in 1987 was about 21,500 cubic meters of low level wastes and about 60 cubic meters of transuranic wastes. These wastes are either already disposed or are being stored on-site. Large volumes of high-level, low-level and transuranic wastes from past operations have also been stored or disposed on-site and remain as part of the total inventory.

Risk Criteria Evaluation

Intensity of impact - The impact of radioactive contaminants on the structure and/or function of the ecosystem at the species or habitat level could be significant if the levels of exposure are high enough. However, the areas and opportunities available at Hanford for those types of exposures are limited.

Reversibility of impact - The reversibility of impacts to species, biotic systems, and ecosystem structure is dependent on the level of exposure received. Concentrations of radioactive contaminants in the systems will decrease with time once the source of exposure is controlled or removed. The reversibility will depend on many factors that restrict the future introduction of contaminants to the environment or cause those contaminants to be removed. A list of these factors includes; the effectiveness of control measures taken in the disposal of wastes, the adequacy of storage facilities, future waste disposal practices and the physical/biological characteristics of the biotic system affected and the isotopes present.

Sensitivity of the ecosystem/species affected - Several rare, threatened, and endangered species reside on or around the Hanford Reservation. Increasing numbers of bald eagles have been counted along the Hanford Reach since the 1970s. The increase in wintering eagles is attributed to the increasing amounts of autumn-spawning chinook salmon. The Hanford Reach also supports the only mainstream chinook salmon spawning habitat on the Columbia River. This population is maintained by a combination of natural spawning and artificial propagation.

The Western Canadian Goose, Ring-billed gulls, California gulls, Forster's terns and the Great Blue Heron all make use of existing habitats to nest and reside.

There are also two rare plant species which occur along the Hanford Reach of the Columbia. One is the Columbia River milk vetch (Astragalus columbianus), which has a very limited geographic distribution in the vicinity of the Priest Rapids Dam. The other is a local variety of yellow cress (Rorippa calycina) which is also a plant of limited geographic distribution. It grows in the Hanford Reach at the water's edge within the zone of fluctuating water levels.

The Hanford Reservation consists mostly of undeveloped land that supports native vegetation. Public access is restricted, the site is free from agricultural practices, and is essentially free from livestock grazing and the shooting of wildlife. This type of land use has favored populations of native wildlife that use the habitats found along the Columbia. In 1977, the Hanford Reservation was designated a National Environmental Research Park to be used as an outdoor laboratory for ecological research purposes, and to preserve the diversity of native populations of plants and animals.

Trend of impacts - In this analysis we continue to hold to the assumption that the primary ecological risk of concern is the potential pathway biotic systems provide for human exposure. So, the environmental concentrations of radioactive materials in plant and animal species and the inclusion of those species in the human food pathway would have to be of sufficient magnitude to result in a dose to humans before this impact could be considered significant. Current measured concentrations in Hanford wildlife are too low to cause a significant dose to the maximally exposed individual. Assuming that waste disposal volumes decrease and that disposal and storage sites continue to receive regulatory attention, the impacts will continue to decrease through the year 2010.

Scale of impact - The scale of potential impact is localized to the Hanford Reservation which is about 570 square miles.

Uncertainty of analysis - Uncertainty in this problem area is moderate. The design of the Hanford monitoring program should receive careful review to determine if it is adequate in detecting ecological impacts if they indeed exist. The monitoring programs are designed primarily to determine environmental concentrations of radioactive contaminants and have a secondary use as indicators of potential ecological impacts. Resource constraints did not allow for that level of critical review in this report.

Structure of Risk

Radiation risks on the Hanford Reservation are associated with specific sites such as nuclear reactors, reprocessing operations, waste storage sites, and waste disposal areas. Currently, eight of the older reactors are awaiting decommissioning. A ninth production reactor (N-reactor) is being prepared for cold standby status. The single existing reprocessing facility will continue to operate into the early to middle 1990's and then will probably shut down as all existing stockpiles of irradiated fuel will be processed. As cleanup activities on the Hanford Reservation continue, wastes currently stored will either be shipped offsite or will be disposed of onsite.

At a major site, such as Hanford, populations of organisms at risk can be divided between those in contact with onsite sources and those offsite. Monitoring of onsite wildlife indicates that there have been increases in body burdens for some of those populations. Pathways for the intake of the radioactive contaminants include direct contact or ingestion of liquid or solid wastes and plant materials contaminated by those wastes. Offsite populations are exposed primarily through the air and through surface water. No measurable significant effects are currently noted for offsite populations.

REFERENCES

Battelle Pacific Northwest Laboratories, Environmental Monitoring at Hanford for 1987, PNL-6464, May 1988

Cember, H., Introduction to Health Physics, 2nd ed., Pergamon Press, New York, 1983

Dawn Mining Company, 1982 Annual Environmental Monitoring Report, May, 1983.

National Academy of Science, The Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980, National Academy Press, Washington D.C., 1980

Naval Nuclear Propulsion Program, Environmental Monitoring and Disposal of Radioactive Wastes from U.S. Naval Nuclear Powered Ships and Their Support Facilities, Report NT-88-1, Feb. 1988

Nucleon Lectern Associates, The Health Physics and Radiological Health Handbook, Bernard Shleien and Michael Terpilak, eds. 1984

Portland General Electric Company, Radiological Environmental Monitoring Report, PGE-1006-87, April 1988

Rickard, W.H., and D.G. Watson, Four Decades of Environmental Change and Their Influences Upon Native Wildlife and Fish in the Mid-Columbia River, Environmental Conservation 12:241-248

Washington Public Power Supply System, Supply System Nuclear Plant No.2 Annual Environmental Operating Report, 1987, WPPSS, April 1988

Western Nuclear Inc., 1983 Annual Environmental Monitoring Report, July, 1984.

Westinghouse Hanford Company, Effluent Releases and Solid Waste Management Report for 1987: 200/600/1100 Areas, WHC-EP-0141, May, 1988

Westinghouse Hanford Company, Westinghouse Hanford Company 100 Areas Environmental Releases For 1987, WHC-EP-0165, July, 1988

Westinghouse Hanford Company, Westinghouse Hanford Company Effluent Report for 300 and 400 Area Operations for Calendar Year 1987, WHC-SP-0385, February, 1989

THE STATE OF THE ENVIRONMENT REPORT

VOLUME III
Part 4

Risk Evaluation Reports
for
Indoor Radon

ENVIRONMENT 2010

State of Washington
October, 1989

This report was prepared by Jonathan Lesser, Richard Byers, and Jeff Weber of the Washington State Energy Office on behalf of the Radiation Subcommittee of the Environment 2010 project.

Sources of Radon

Radon is a radioactive gas produced by the decay of radium, which occurs naturally in varying amounts in almost all soil and rock. Radium can be found in high concentrations in soils and rocks containing uranium, granite, shale, phosphate wastes, and pitch blende. When radon gas is released, it percolates up through soils and rocks into the atmosphere. More permeable soils and highly fractured rock represent larger pathways for the radon to escape from the earth.

In outdoor air, radon concentrations are extremely low. However, when it enters a building through small gaps and cracks, radon can accumulate. The gas can be trapped by the building and become concentrated. Radon can also emanate from building materials used (e.g., masonry), or enter a building through piped in drinking water or natural gas. The vast majority of indoor radon, however, is believed to enter buildings through contact of basements or foundations with underlying soils. Indoor radon levels are therefore strongly dependent on the radon content of soils, or rock on which a building is built, the pathways available for radon migration in these soils and rock, and on the construction characteristics of foundations, or basements (e.g., cracks exposed to soil). Indoor radon concentrations will also depend, to a more limited degree, on the ventilation characteristics of a building.

A variety of procedures have been developed to inhibit radon entry into buildings (e.g. foundation sealing, sub-slab ventilation) in areas where soil source strength is high. These procedures, taken together with well-designed mechanical ventilation systems, have proven to be effective at preventing, or mitigating, high levels of indoor radon concentration.

Radon and Ecological Risk

No risk to ecology exists from radon, since outdoor radon concentrations are all extremely low.

Radon and Health Risk

Because radon is chemically inert, it is not retained by most body tissues and poses little direct health risk. However, as radon decays, radioactive by-products, known as radon progeny, are formed. These can electrostatically adhere to dust particles in the air. When inhaled, these radon progeny are deposited in the air passages of the lungs and emit alpha particles that can damage lung tissue and, after long term exposure, lead to lung cancer. Current evidence suggests that smokers are at a much higher risk from radon exposure than are non-smokers. (However, this report will not investigate the additional risks to smokers.)

The relationship between inhaled radon progeny and lung cancer is well documented for both laboratory animals and humans. In the last century, Harting and Hesse (1879) first recognized the lung cancer hazard faced by underground miners. Studies by Chameaud and colleagues in France during the late 1960s and early 1970s confirmed that radon progeny alone induced tumors in rats. Current risk estimates from radon exposure are based on epidemiological studies of miners, particularly uranium miners, exposed to relatively high levels of radon in their work underground.

Exposure to radon is usually expressed in working level months (WLM). The working-level (WL) is a unit of radon concentration introduced by the uranium industry and is defined as an atmosphere contaminated with 100 pico curies per liter (pCi/l) of radon gas in equilibrium with its daughters. One WLM equals exposure to one WL for one month. One WLM equals the exposure a miner receives during one month of work (about 170 hours) in a working-level environment. The Environmental Protection Agency (EPA) has established a 4 pCi/l average annual reading as a guideline for maximum indoor radon concentrations in houses and advises that action be taken to reduce radon concentrations when they exceed this level. (Indoor radon concentrations can vary greatly throughout the year, increasing in winter and decreasing in summer.)

This report estimates the health risk from radon exposure in houses by 1) estimating the average indoor radon concentration, 2) multiplying that concentration by the total population exposed and, 3) multiplying the total obtained in Step 2) by the estimated health risk factor. Since exposure faced by miners in the working environment differs significantly from that experienced by the average person in a home, several assumptions are necessary to estimate exposure rates in homes. First, this report, in agreement with EPA, assumes that the residential population is home about 75 percent of the time, and is thus exposed to radon levels in the home about 540 hours per month (as opposed to the 170 hours per month that miners are exposed to radon in their working environment). Second, the breathing rate of a working miner is assumed to be about twice that of an average adult at home.

Third, this report adjusts the concentration of radon progeny as a function of radon gas concentration in order to reflect typical home environmental conditions. As radon progeny are formed from radon, they in turn decay into other isotopes. If the rate of formation and decay of the radon progeny is exactly equal, 100 pCi/l of radon would exist in equilibrium with one working level of radon progeny. However, other processes (such as attachment of decay products to the walls or floor) tend to remove some radon progeny from the air before they disintegrate, so equilibrium is never reached. Based on simultaneous measurements of radon and its progeny, the EPA has found that the equilibrium fraction averages about 0.5. Therefore, a ratio of 200 pCi/l of radon to one WL of radon progeny is fairly typical for residential environments, though most homes have average annual radon concentrations far below 200 pCi/l. (The EPA action level of 4 pCi/l is therefore equivalent to 0.02 WL.)

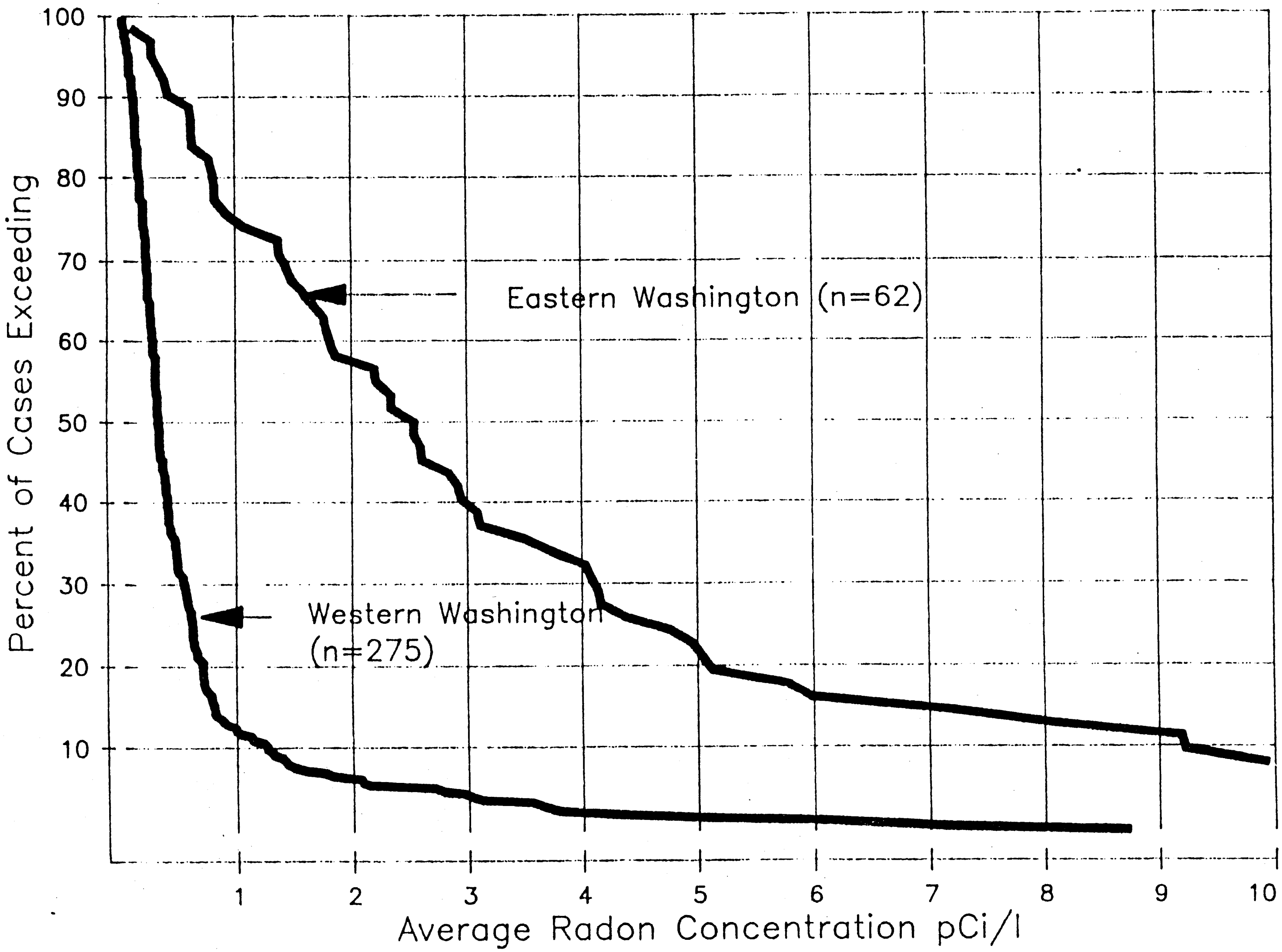
Using these adjustments, data on population levels, and estimates of measured radon concentrations in Washington counties, the population exposure is estimated. Assessment of the health risk associated with population exposure relies upon published estimates relating lung cancer deaths to lifetime exposure levels to radon. EPA reports that the risk from lifetime radon exposure equals 350 additional lung cancer deaths per million WLMs. This estimate, which EPA took from the BEIR IV report, is subject to uncertainty. Other studies estimate that the excess lung cancer mortality rate from lifetime radon exposure ranges from 130 - 730 deaths per million WLM. Consequently, estimates of future lung cancer mortality due to lifetime indoor radon exposure in Washington homes are subject to uncertainty.

Further complicating estimates of lung cancer mortality is the geographic variability of radon contamination. For example, a Washington Energy Office study monitored 345 homes throughout the state for a 12 month period, and showed that indoor radon concentrations in Eastern Washington tended to be higher than those in Western Washington. Figure 1 shows the results of the study. Of the 62 homes monitored in Eastern Washington, over 30 percent were found to have radon concentrations exceeding the EPA guideline of 4 pCi/l. Of the 275 homes monitored in Western Washington, however, only about 5 percent were found to have concentrations greater than 4 pCi/l. Of the 62 homes monitored in Eastern Washington, two-thirds were in Spokane County.

In a study conducted by the Bonneville Power Administration, mean household radon levels at the county level were reported. As calculated by the Environmental Agency and shown in Table 1, 14 counties had average radon levels less than 1 pCi/l, 8 counties had radon levels between 1-2 pCi/l, 1 county had a radon level between 2-3 pCi/l, and 2 counties had levels exceeding 3 pCi/l. Fourteen counties did not have any homes monitored. These counties, however, account for less than 10 percent of current population in the state.

Household-specific exposure levels can vary greatly even in counties that report generally high radon concentrations, depending on the porosity, or gas migration pathway characteristics of the underlying soil. Also, population mobility increases the uncertainty associated with estimates of mortality, since many people may not live in homes with high average radon concentrations their entire lives.

Figure 1



Twelve—month radon concentrations by zone (alpa track detector)

Note: Of the number of observations in Eastern Washington, two-thirds are in Spokane County.

Table 1

Mean Residential Radon Concentrations
by County

County	1988 Population	Mean Concentration(pCi/l)
Adams	14,000	N/A
Asotin	17,400	N/A
Benton	104,100	1.38
Chelan	49,700	1.43
Clallum	54,400	0.74
Clark	214,500	1.30
Columbia	4,100	N/A
Cowlitz	80,500	0.54
Douglas	24,100	1.34
Ferry	6,100	2.40
Franklin	35,500	1.13
Garfield	2,500	N/A
Grant	49,500	N/A
Grays Harbor	63,400	0.49
Island	53,400	0.43
Jefferson	18,600	0.48
King	1,413,900	0.67
Kitsap	177,300	0.76
Kittitas	25,000	1.70
Klickitat	16,600	0.88
Lewis	57,400	0.92
Lincoln	9,800	N/A
Mason	36,800	0.59
Okanogan	31,900	N/A
Pacific	17,600	0.84
Pend Oreille	9,100	N/A
Pierce	547,700	1.60
San Juan	9,600	0.30
Skagit	66,800	N/A
Skamania	8,000	4.30
Snohomish	409,500	0.49
Spokane	354,100	6.50
Stevens	30,200	N/A
Thurston	149,300	0.55
Wahkiakum	3,500	1.31
Walla Walla	48,300	N/A
Whatcom	117,200	N/A
Whitman	39,200	N/A
Yakima	180,000	N/A

Sources: OFM, Forecasting Division; BPA Report #10, EPA Draft Report on Risk Assessment of Radon for Region X.

Assessment of Health Risk in 1988 and 2010

The general methodology used to estimate the annual rate of cancer deaths induced from exposure to radon in residential environments in Washington state follows:

1. Determine population exposure in 1988 and 2010 in counties with available data. The source of the radon exposure data is BPA Report No. 10, Radon Monitoring Results from BPA's Residential Weatherization Program. This report presents the arithmetic average radon concentration for each of the counties in which measurements were obtained. It should be noted that arithmetic averages of skewed sample distributions (such as measured air pollutant concentrations) may overestimate typical exposure. The geometric mean, or median concentration, would better represent typical exposure in these counties. However, estimation of total population exposure is necessary to assess total health risk and for this purpose the arithmetic average is correctly used.

   Forecasts of population by county are from the Office of Financial Management, 1988 Population Trends for Washington State. Total exposure equals the average county wide exposure level times the forecast population. The result is an estimate of person times pCi/l in counties with radon exposure data.

2. Convert this figure to total WLMs. This is done by dividing the result in Step 1 by the estimate of 200 pCi/l/WLM to reflect the ratio of radon progeny to radon gas concentrations in residences.

3. Convert to total WLMs per year. Because the residential population is expected to be home approximately 540 hours per month, while miner's respiration rates are assumed to be twice the rate of the residential population, conversion to WLM per year is done by multiplying the estimate in Step 2 by (540/170)*(1/2)*12, or about 19.1

4. Assuming that radon exposure levels in counties that did not report data to the BPA study equal the mean exposure rate for those counties that did, total statewide WLM/year is extrapolated using the ratio of total forecast state population to forecast population in the reporting counties. Counties for which average concentration data are not available include Adams, Asotin, Columbia, Garfield, Grant, Lincoln,

Okanogan, Pend Oreille, and Skagit. These counties account for about 12 percent of the states projected population in 2010. This extrapolation is not likely to significantly bias the statewide risk assessment. An average concentration in the unmeasured counties that differed by 50 percent from the average in the measured counties would only introduce a 6 percent error in the statewide risk assessment. This is well within the uncertainty in the relationship between exposure and lung cancer risk.

5. Finally, expected lung cancer deaths per year in 1988 and 2010 attributable to radon exposure equals the estimate in Step 4 divided by the estimated deaths per million WLM/year. Since estimates of lung cancer deaths depend critically on the assumed death rate per million WLM/year, sensitivity results will be presented.

Risk Assessment Findings

The available data indicate that, in the year 2010, statewide residential exposure to radon will be 730,493 WLM/year. Even though the highest reading reported by BPA in Report No. 10 was over 100 pCi/l, the mean exposure in the reporting counties was only slightly more than 1 pCi/l. Only about 3 percent of the monitored homes reported exposure levels greater than 4 pCi/l, the level that represents the current EPA indoor radon action guideline.

Table 2 presents the expected additional lung cancers statewide in 1988 and 2010 based on alternative estimates of deaths per million WLM. The predictions for 2010 do not take into account any controlling factors, such as testing and mitigation, that can be applied to the housing stock. Thus, the 2010 estimates may represent upper bounds on additional lung cancer deaths.

Total estimated deaths per year in Washington will depend critically on epidemiological estimates of deaths per million WLM. Therefore, alternative estimates on deaths per million WLM were used to develop a range estimate. As a result, total expected statewide deaths could range from between 78-441 per year in 1988, and 100-559 per year in 2010 due to residential radon exposure. The BEIR IV study is the latest and most comprehensive study. Therefore, its estimates can be used for comparative purposes with other environmental threats.

Table 2

Forecast Additional Lung Cancer Deaths
in Washington State Due to Lifetime Radon Exposure

Source	Estimated Deaths per Million WLM	Deaths per Year 1988	Deaths per Year 2010[d]
BEIR[a] IV (1987)	350	210	268
NCRP[b] (1984)	130	78	100
BEIR III (1980)	730	441	559
UNSCEAR[c] (1977)	200 - 450	121 - 272	153 - 345

[a] National Research Council, Committee on the Biological Effects of Ionizing Radiation
[b] National Council on Radiation Protection and Measurements
[c] United Nations Scientific Committee on the Effects of Atomic Radiation
[d] Prediction for 2010 only assumes a chnage in population. Differences in housing stock or in level of effort made to mitigate radon in existing structures was not considered.

Summary of Key Issues and Findings

- Radon exposure in homes is strongly dependent upon underlying soil and geological characteristics. To a lesser extent, radon exposure also depends on the characteristics of the home. Consequently, exposure and risk are not uniformly distributed across the state. Available data indicate that average indoor radon concentrations tend to be higher in counties east of the Cascade mountains than in counties west of the range.

- Using indoor radon concentration data collected in Washington homes and standard assumptions taken from EPA and the uranium mining industry concerning exposure rates, the annual rate of lung cancer mortality induced by lifetime radon exposure in homes is estimated to range between 78-441 in 1988, and 100-599 in 2010. It is reasonable to assume that the majority of this health risk occurs in those areas of the state where the source strength of radon in the soils and geology is highest.

- The health risk associated with exposure to radon progeny in homes has been estimated from data obtained from mining environments. In general, radon concentration in these environments is greater than in homes. Consequently, extension of the uranium mining epidemiological findings to residential environments involve a number of assumptions and extrapolations. All of these contribute to the uncertainty surrounding assessment of health risk due to radon exposure in Washington homes.

References

Byers, R., "Thermabilt Performance Monitoring: Analysis of Energy Use, Ventilation Rates, and Indoor Air Quality Testing," Washington State Energy Office, April 1988.

Chameaud, J., R. Masse, and J. Lafuma, "Influence of Radon Daughter Exposure at Low Doses on Occurrence of Lung Cancer in Rats," Radiation Prot. Dosimetry 7:385-388, 1984.

Harting, F., and W. Hesse, " Der Lungenkrebs, die Bergkrankeit in den Schneeberger Gruben," Veirteljahrsschr. f. Gerichtl, Med. u. Offentl. Gensundheitswesen 30:296-309; 31:102-132, 313-337, 1879.

National Council on Radiation Protection and Measurements (NCRP), "Exposures from the Uranium Series with Emphasis on Radon and Its Daughters," NCRP Report #77, Washington, D.C., National Council on Radiation Protection and Measurements, 1984.

National Research Council, Committee on the Biological Effects of Ionizing Radiation (BEIR) "Health Risks of Radon and Other Internally Deposited Alpha-Emitters," Washington:National Academy Press, 1988.

______, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," Washington: National Academy Press, 1980.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), "Sources and Effects of Ionizing Radiation," Report E.77.IX.1, New York: United Nations, 1977.

United States Dept. of Energy, Bonneville Power Administration, "Radon Monitoring Results from BPA's Residential Weatherization Program," Report #10, January 1988.

THE STATE OF THE ENVIRONMENT REPORT

VOLUME III
Part 5

Risk Evaluation Reports for Nonionizing Radiation

ENVIRONMENT 2010

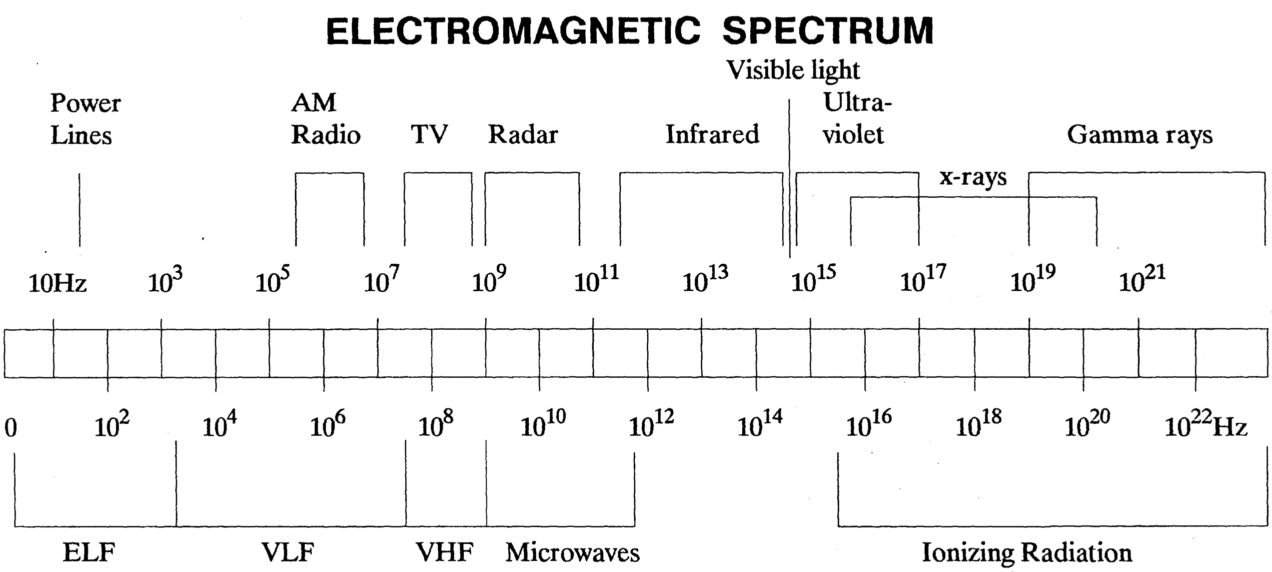
State of Washington
October, 1989

NONIONIZING RADIATION

I. BACKGROUND

Nonionizing radiation comprises a major portion of the electromagnetic spectrum. See Figure 1. Nonionizing radiation, by definition, includes lower frequencies ultraviolet, visible light, and infra-red as well as microwave, radar, television, radio,

FIGURE 1

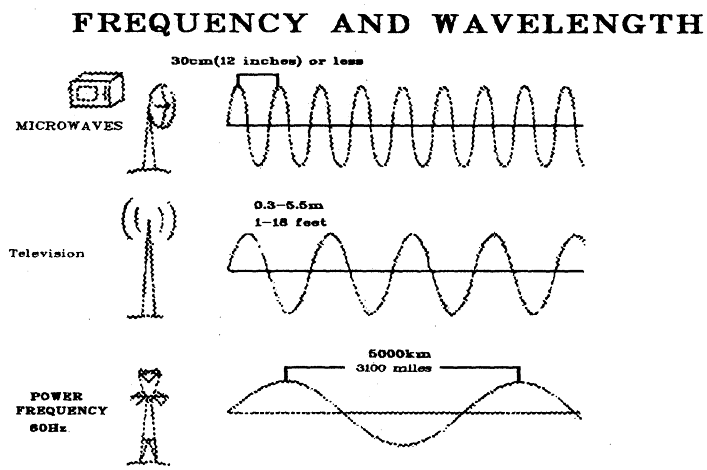


and power line frequencies. This report focuses on the two major components of the nonionizing electromagnetic spectrum which potentially impact the general public: Radio frequency and transmission power line frequency.

The energy from shorter wavelength, higher frequency fields such as radio frequency are absorbed more readily by biological material and can produce heating (as applied, for example, in microwave ovens). In contrast the extremely long wavelength at 60 Hertz (cycles per second) allows the transfer of only minute amounts of energy. See Figure 2. Transmission lines are a very poor transmitting antenna. The low frequency power is not radiated away as happens with high frequency television or radio transmitters. Because of the long wavelength and low frequency, transmission lines do not radiate energy comparable to microwave or radio and television antennas.

Risks associated with occupational exposures will not be considered for the

FIGURE 2



Washington Environment 2010 Report. This exclusion also applies to exposures to nonionizing radiation received inside a facility (within the fence line) other than a residence. This effectively excludes several portions of the nonionizing spectrum (such as infared and ultraviolet) which are primarily associated with workplace exposures. Concern over video display terminals (VDT) use is also excluded since this is predominately a workplace phenomenon. Use of tanning beds is now discouraged but never-the-less represents an individual choice relating to ultraviolet exposure. Increases in ultraviolet exposures as a result of ozone depletion is another matter. However, the impact of ozone depletion is included in another report and will not be separately addressed here.

This report will look at human health risks and ecological risks only.

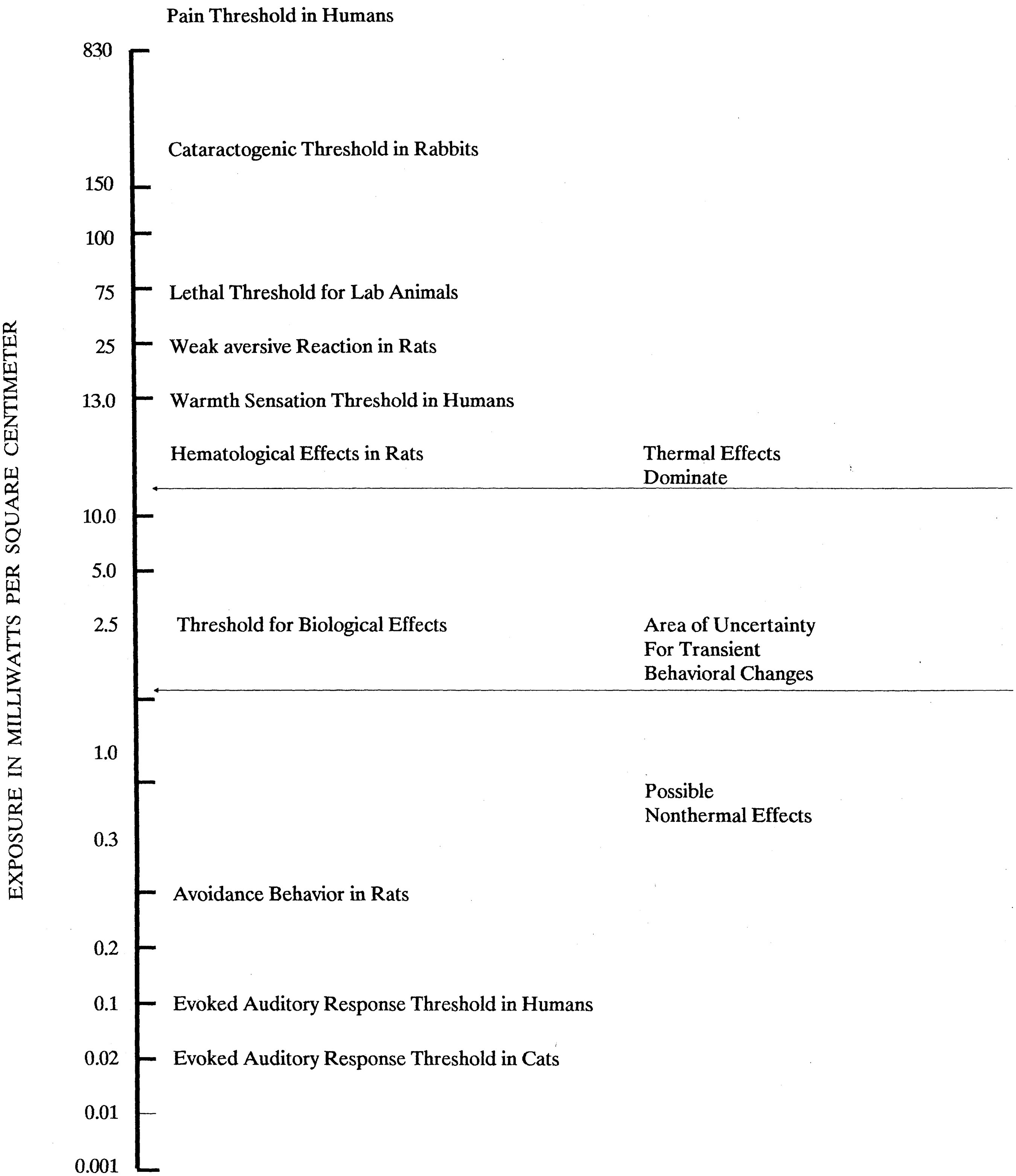
II. HUMAN HEALTH RISKS

A. Analytical Approach and Data Sources

A review of several summary documents was undertaken to determine existing monitoring data and potential risks. The known effects of nonionizing radiation are summarized in Figure 3. Radio frequency radiation absorption depends on a number of variables including wavelength, orientation of the body to the incident electromagnetic field, electrical characteristics of the body tissues at specific frequencies and intensity of the radiation. Localized heating or nonuniform absorption can occur in humans because the complex tissue structure absorbs energy differently in different parts of the body. Two

FIGURE 3

EFFECTS OF NONIONIZING RADIATION



Adapted from "Population Exposure to VHF Broadcast Radiation in the Seattle and Portland Metropolitan Area", U.S. EPA 1979.

kinds of effects on humans exposed to radio frequency radiation are usually discussed: Thermal effects from high level exposure and possible low-level or "nonthermal" effects. Thermal effects include warmth sensations, sweating, fatigue, headaches, cataract formation and death. Thermal effects are those which produce a mesurable temperature rise in body tissue and normally occur from radiation with power densities above ten milliwatts per square centimeter. This is the level set for the advisory standard for occupational exposure issued by the Occupational Safety and Health Administration. The American National Standards Institute applies a safety factor of 10 to the specific absorption rate above while biological effects are assumed to begin, and derives a power density of one milliwatt per square centimeter in the frequency range which affects humans most. The Natural Council on Radiation Protection and Measurements has recommended an exposure standard of 0.2 milliwatts per square centimeter for general population exposure.

Low-level effects are a subject of controversy. The effects of exposure to one milliwatt per square centimeter or less have not been well documented. While a portion of absorbed radio frequency radiation is always degraded to heat there are scientists who believe that some low-level effects as a result of nonthermal events (those which occur without an increase in tissue temperature). Their views are based on animal research and statistical studies of worker's exposure histories and medical records. These effects are considered to be mainly central nervous system effects. Symptoms attributed to low-level nonthermal exposure include headache, weariness, dizziness, irritability, emotional instability, partial loss of memory, loss of appetite, cardiovascular effects, blood chemistry changes, changes in respiration and possible genetic effects. Cancers have not been attributed to radiofrequency radiation although some unconfirmed animal research would indicate a possible connection. While many scientists are skeptical of the conclusions of these low-level effects, there has been little research conducted in the U.S. to validate the effects reported from long-term exposures to low-level microwave and radiofrequency radiation.

Transmission power lines are in a different portion of the electromagnetic spectrum than radiofrequency. Electrical power lines operating at low frequency, long wavelength, produce both electrical fields and magnetic fields. High power transmission lines typically produce electric fields on the order of 9,000 volts per meter. The electrical field from a transmission line rapidly gets weaker as one leaves the line right of way. In comparison, the electric field created by wiring in appliances in the home may be only a few volts per meter. Close to electrical appliances, levels are higher (for example near an electric blanket the field may range between 240 volts per meter at one foot away from the blanket to 10,000 volts per meter near the heating wires).

Although electric discharges (shocks) associated with electric fields are well understood and largely controllable, questions have been raised as to whether there are long-term biological effects of electric fields. Electric fields such as those produced by transmission lines and electrical appliances induce weak currents and electric fields in people and animals. These currents and fields are too small to be felt other than by hair stimulation. Some scientists believe these fields are potentially harmful and that long-term exposures to 60 Hertz fields should be minimized. Based on hundreds of studies over more than 20 years, the bulk of scientific evidence indicates that typical exposures to electric fields pose no health hazard. This subject remains controversial however because some studies have found effects withuncertain biological significance. It is not possible to conclude scientifically that there is zero risk associated with long-term electric field exposures. There is also renewed interest in magnetic fields.

A magnetic field is produced whenever electric current flows in a wire. The magnetic field beneath a transmission line is very weak compared to localized magnetic fields near common household appliances. Alternating current magnetic fields induce electric currents and electric fields in organisms and objects. However, the internal currents and fields induced by a transmission line magnetic field are even weaker than those produced by the electric field. Because of this, long-term effects were not of concern until recently. However, several recent reports have suggested a possible association between occupational and residential exposure to alternating current magnetic fields and an increased risk of lymphoreticular tumors such as childhood leukemia. The evidence for such an association is weak and studies are underway to obtain more definitive information on this subject.

B. Findings

Information on exposure levels to radio frequency and to 60 Hertz transmission line is available. However, quantitative health impacts based upon that level of exposure is not.

For instance, in the Seattle metropolitan area it is estimated that 99.81 percent of the population is exposed to less than one microwatt per square centimeter of radio frequency energy and only .001 percent of the population is exposed to more than ten microwatts per square centimeter. Several proposed communication towers in and near downtown Seattle are projected to increase localized power densities inoccupied areas from average values of 20 microwatts/cm^2 (maximum 46 microwatts/cm^2) to projected values around105 uW/cm^2 with a maximum near 120 uW/cm^2. No information on the size of the exposed population was provided. However, if we assume the Seattle metropolitan exposure of 0.001% applies statewide to both radiofrequency and transmission powerlines and further assume a 10 fold safety margin, then the size of the population exposed to more than the lowest levels of radiation would be 456 people based on the 1988 statewide population. A projected doubling at the usage of electricity along with population growth would potentially expose 1,202 people annually by the year 2010. Given the political climate regarding radiation exposure it is unlikely that exposures to ionizing radiation would increase and, in fact, higher towers and "right of way" clearance are likely to decrease individual exposures. Because of this lack of hard information on risk impact it is not possible to critically evaluate this threat to the human environment. Additional research is necessary to judge the health risk from nonoccupational uses of nonionizing radiation.

III. ECOLOGICAL RISKS

A. Analytical Approach and Data Sources

Many studies have been conducted to investigate the possible effects of transmission power lines on plants, insects, wildlife and livestock. In contrast, studies of radiofrequency radiation appear to focus on laboratory animals and cell cultures rather than systems or subject matter which could represent an ecological risk. Overall, the results appear either inconclusive or no effects were discerned for seed germination, plant growth, movement of large mammals, fertility or milk production. However, there appear to be effects for honey bees. Hives placed directly under high voltage transmission lines exhibited decreased colony weight gains, increased irritability and mortality, and poor over winter colony survival. However, these effects were most likely caused by frequent shocks experienced by the bees while inside the hives and this can be prevented by grounding the hive. The magnetic field appeared to have no effect on bee colonies. Also, trees growing in the vicinity of power lines will exhibit a "self pruning" effect as a result of electrical discharges due to an induced current at branch tips. In general, low-level electric and magnetic fields do not appear to pose a quantifable ecological risk and there is little basis for determining qualitative effects.

B. Findings

As with human health risks, there is little consistent information on the nature of the impact and any quantitative assessment of the effect. Given the limited exposure to the ecological environment and the apparent absence of impact, it is unlikely that even the most optimistic growth of the communications and electric power industries would produce levels of nonionizing radiation capable of causing signficant harm to the nonhuman members of the environment.

IV. REFERENCES

"Population Exposure to VHF Broadcast Radiation in the Seattle and Portland Metropolitan Areas", Edward Cowan and Richard A. Tell, July 1979, U.S. Environmental Protection Agency, Region X.

Electrical and Biological Effects of Transmission Lines: A Review, Jack M. Lee, Jr., et.al, June 1986, U.S. Department of Energy, Bonneville Power Administration.

"Environmental Study of Telecommunications Facilities, Seattle", Office for Long-Range Planning, City of Seattle December 1987.

Biological Effects of Radiofrequency Radiation, Joe E. Elder and Daniel F. Cahill, September 1984. US EPA.

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EXECUTIVE SUMMARY

Threat Definition
We know that the chemistry of the atmosphere is changing rapidly. Scientific theory predicts that these changes will result in global warming due to the greenhouse effect of certain gases, particularly carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons, as well as other species. This warming will include other climate changes which are expected to have profound effects on agriculture, forestry, ecosystems, sea level, water resources, energy use, transportation, and many other aspects of human life.

The implications of ozone depletion are less well researched than those of climate change. It is known that the effects will be mostly related to human health issues, principally skin carcinomas and melanomas, cataracts and other eye diseases, and immune system effects. Ecological implications are also anticipated.

General Analytic Approach
Risks were evaluated by reviewing the literature and summarizing the anticipated scenarios for Washington state.

Direct Effects
Average annual temperature in the Pacific Northwest is projected to increase by 3° to $5^{\circ}C$ with a doubling of carbon dioxide. No analyses of seasonal variation are known to have been prepared. Greater temperature increases are expected for the Columbia basin than for western Washington.

Precipitation is generally expected to increase by as much as 25 to 25%, although seasonal variation could result in less precipitation at some times of the year. Due to the projected increase in temperature, more precipitation will fall as rain than does now, thus lessening the winter show pack.

In general, peak streamflows are expected to occur earlier in the season, likely shifting from a spring snow melt runoff peak to a winter precipitation runoff peak.

A sea level rise by 2100 of 1.8 feet to 11.3 feet is predicted to occur due to global warming of the oceans (and thus expansion) as well as the melting of snow and ice. Global sea level rise (G) must be adjusted for local vertical land movement (V) to determine local relative sea level rise (R) such that $R = G - V$. Subsidence in Puget Sound will aggravate global sea level rise; uplift along the ocean coast will moderate sea level rise.

The annual average total ozone column has decreased 2-3% between 53 degrees South and 53 degrees North from October, 1978, to October, 1985, or about 0.35% annually. In the mid latitudes (30 degrees north to 64 degrees north) of the northern hemisphere, ozone decreased 1.7% to 3% between 1969 and 1985, depending on the latitude. Over Washington state, the total decrease is believed to be about 2.2% (OTP, 1988). Between 40 degrees north and 52 degrees north, wintertime ozone has decreased by 4.7%.

Human Health
It is difficult to predict specific regional impacts of global warming on human health. Global warming may provide new geographic areas suitable for the survival and increase of certain disease organisms, thus increasing the potential for incidence of those diseases in Washington. Concurrently, climate change may either increase or decrease the variability of weather patterns within the state. Climate variables (heat waves, excessively cold spells, heavy rains and warm or cold fronts) all affect human health, whether directly or through effects on disease bearing or causing organisms.

With a 1% decrease in upper atmospheric ozone, we can expect a 2% increase in UVB (wavelengths from 280-320 nm) exposure. UVB light is a major factor in human skin cancers, particularly basal and squamous cell carcinomas and malignant melanomas. While rarely fatal, a 3-6% increase in these common skin cancers can be reliably predicted for each 1% decrease in ozone.

High cumulative exposure levels of UVB radiation significantly increase the risk of cortical, or lower inner quadrant of the lens, cataract formation. While still statistically inconclusive, evidence is accumulating that solar radiation is responsible for some of deteriorative changes leading to macular degeneration. Pterygium is a degeneration of the epithelial conjunctiva, or scar tissue on the inner surface of the eye extending from the conjunctiva to the cornea; they are the most common result of ocular overexposure to UV radiation and prove costly due to the large numbers of patients requiring surgery.

Agriculture
In a study for the Environmental Protection Agency the economic effects of changes in crop yields and water availability arising from projected long-term changes in climate associated with a doubling of CO_2 was measured. For the Pacific states (California, Oregon, Washington), under the assumption that CO_2 enhances crop yields, researchers predicted an increase in land used for agriculture from eight to 13 percent. Irrigated acreage could either increase or decrease by about six percent, depending on whether the GISS or the GFDL model is used. Gross revenues from agriculture in the Pacific region could increase by as much as 30 percent. However, there remain questions about the availability of irrigation water.

According to research conducted by the Environmental Protection Agency's National Crop Loss Assessment Network, one of the major pollutants that causes crop yield losses is ozone (either tropospheric or atmospheric). Tropospheric ozone pollution has a direct adverse effect on crop yields. Stratospheric ozone depletion causes increases in UV radiation which causes crop yield declines.

Energy
Washington has the largest hydropower generating system in the nation, producing 30 percent of all hydropower in the US. Thus, the region relies on year-round hydropower production, which makes the nature and timing of precipitation as important as the quantity.

Washington's hydropower system is driven by water from rain runoff, snow melt runoff, or through controlled reservoir releases. On the Columbia/Snake system, snow-melt runoff accounts for about 85 million cubic feet of water per year, or 60 percent of the annual flow through the rivers' hydroelectric power system (fifty year average as measured at the Dalles Dam. For this reason, an increase in regional temperature could have more impact on the hydropower system than an increase in precipitation. A decrease in snowfall would lead to a smaller snowpack, although the snowpack most important to the power system -- in southern British Columbia, Montana and Idaho -- could be less affected than the southern Cascades. With an increased average temperature and reduced snowfall, large water volumes could be available during a short winter period, forcing hydropower operators to serve winter demand and fill reservoirs at the same time.

Precipitation, evaporation, and wind changes would likely have little effect on the demand for electricity. But a rise in average temperature could increase the severity and length of the summer cooling season, increasing electricity demand. That same average temperature increase could produce a milder and shorter winter heating season, decreasing electricity demand. It is unclear whether the net result would be an increase or decrease in total electricity demand.

Washington's energy system has not yet been analyzed in detail with respect to possible climate changes from the greenhouse effect. However, preliminary analysis reviewed in this report suggests that an increase of 4.5 degrees C in the Northwest could have significant impacts on electricity supply and demand. These impacts on the supply and demand balance could be economically beneficial or detrimental to Washingtonians.

Fisheries
The effect the increased ultraviolet radiation will have on marine phytoplankton (free-floating microscopic plants) is of major concern. Marine algae are a major sink for carbon dioxide, slowing the rate of global warming. At the same time, phytoplankton are very sensitive to UV light. Increases in UV may decrease phytoplankton production and/or change the species composition. Since phytoplankton are the basis for most ocean food chains, these changes could have profound effects on the food available and the types and quantities of fish production occurring in the ocean.

Under the present conditions, Washington state is located at the southern extremity of the range of several commercially and recreationally important species. If the Washington climate changes to resemble northern California's, the ranges of all of these species may undergo a northward shift, with populations of fish such as the salmon species dwindling or disappearing in Washington state and other species appearing.

Shifts in the timing and volumes of runoff are expected to have substantial adverse effects on salmon productivity.

Sea level rise is expected to have adverse effects on species such as Surf Smelt and Pacific Herring which spawn on intertidal beaches, and on Pink and Chum Salmon which make extensive use of shallow intertidal areas for rearing.

Forestry

Experimental data on plant seedlings shows that increased carbon dioxide in the atmosphere will increase the optimum temperature for photosynthesis, and at least partially compensate for increases in heat stress and decreases in site water balance, thus mitigating the effects of global warming. The extent to which mature trees respond to increased carbon dioxide in the atmosphere is unknown, and remains key to determining the long range impact of global warming on Washington Forests.

While the direct effects of increased temperature and decreased water availability may be mitigated by higher levels of atmospheric carbon dioxide, the ability of tree shoots and seedlings to meet their chilling requirements in an overall warmer climate may be substantially reduced. Without sufficient time below a certain temperature, tree species such as Douglas-fir could be eliminated from coastal areas in Washington state. For those tree species whose chilling requirements can be met in the projected climate scenario, their distribution in the lower elevations is not expected to change. For most species, the upper elevation limit of their range is projected to rise. A consequence of this shift could be a reduction in subalpine meadows and subalpine tree species in most mountain ranges.

The secondary and tertiary effects of doubled carbon dioxide and global warming are not known, however certain adverse effects relating to forest fire frequency and plant communities are possible.

Sea Level Rise

Sea level rise is generally expected to drown existing coastal wetlands, and where the topographic gradient permits, cause wetlands to migrate inland. Computer modeling of wetlands inundation in Washington state has produced mixed results -- in some areas there will be wetlands and uplands loss; in other areas wetlands are expected to actually increase in extent. More extensive modeling and field verification is necessary.

Storm surges, the flooding induced by wind stresses and the barometric pressure reduction associated with major storms, will be aggravated by sea level rise in areas of low gradient offshore slopes such as southwest Washington's ocean coast. Rising sea level is accompanied by a general recession of the shoreline due to inundation or erosion. Puget Sound bluff and cliff shorelines are in dynamic equilibrium with sea level; accelerated sea level rise is therefore expected to increase the rate and severity of shoreline erosion and landsliding. Under certain circumstances sea level rise is expected to aggravate sea water intrusion; sea water intrusion of fresh water aquifers is presently a problem in Island and San Juan counties and at some locales along Hood Canal due to groundwater withdrawals for domestic use. A rising sea level will tend to force upward the water table in low lying coastal areas causing an increased duration of flooding due to impeded drainage and higher recovery costs; decreased effectiveness of soils for onsite sewage disposal and the need to resort to more costly alternatives; increased corrosion of underground utilities and storage tanks leading to more frequent replacement schedules and recovery costs of ground water contamination by leaking underground storage tanks; inundation of coastal underground waste sites leading to a leaching of pollutants into the groundwater and the resultant recovery and cleanup costs; impediments to agriculture due to water logged soils leading to drainage costs or abandonment. Coastal drainage systems will function less efficiently.

Trends
It is, of course, impossible to discuss trends in the context which this topic is defined for other Environment 2010 risks. The thrust of global warming and ozone depletion warnings from the scientific community is that these processes will fundamentally alter existing environmental trends and/or accelerate the rates of existing trends to levels not known to have ever occurred.

Uncertainty
While there is good agreement in the scientific community regarding the global and generalized effects of global warming and ozone depletion, there is substantially less certainty regarding regional or specific effects. This report presents an overview of the current state-of-the-knowledge. National and international research programs are expected to provide information on specific effects within the next decade. The availability of better regional predictions is dependent on the availability of enhanced computer technology for civilian applications which does not appear likely.

1. BACKGROUND

This report summarizes information about the anticipated effects of global warming and ozone depletion upon Washington state. Global warming is caused by the addition of greenhouse gases to the atmosphere. Ozone depletion is caused by the addition of chlorofluorocarbons (CFCs) to the atmosphere; CFCs are also greenhouse gases.

Of necessity, these analyses differ from other Environment 2010 analyses. First, the pollutants involved are generally benign; it is the impact pathways which they set in motion that are the problems. Second, the pathways are complex and interrelated. The effects of greenhouse gas emissions, for example, lie with an impact chain which begins with global warming, which causes other climatic changes, e.g. precipitation, storm pattern, etc. changes, which cause ecologic effects, and thus human health and economic impacts. Third, the time scale involved is profoundly different. The effects of water pollution, for example, are often immediate and obvious. The effects of greenhouse gases emitted in past decades are only now being tentatively detected, and the impacts are not yet conclusive.

Global warming and ozone depletion is characterized by a high degree of uncertainty, and a high degree of risk if we (society) are wrong in our assessment. Funtowitz & Travetz (1985; in Gerlach & Rayner, 1988) characterized three kinds of science and decision making: (1) consensual (applied) science, (2) clinical consultancy, and (3) total environmental assessment. Consensual science is characterized by low decision making stakes, high consensus in professional circles, and large amounts of data and therefore certainty; most *2010* topics are consensual science issues. Clinical consultancy issues are characterized by uncertainty and considerable decision stakes, but are ones in which professional expertise is still a useful guide. When decision stakes and uncertainty are high, the process is permeated by qualitative judgements and value commitments; global warming and ozone depletion are just such "total environmental assessment" issues.

The implications of global warming and ozone depletion and the associated risks are none the less real; the scenarios for both are based on the laws of physics and chemistry.

Also, the full implications of global warming and ozone depletion are just now becoming apparent; it is also becoming apparent that our knowledge is incomplete, and that new knowledge is usually "bad news." Throughout the preparation of this report, the principal author was frequently frustrated to discover yet another aspect of the issue had just been announced in the scientific news media such as *Science News, Eos,* or *Ocean Science News*. The reader should be aware, then, that this report is totally lacking in a discussion of the adverse implications of climate change for air quality; information on comprehensive air quality modeling results was just becoming available in May, 1989 as this report was nearing completion. The sections on fish and agriculture suffer for a lack of information on seasonal stream flow characteristics; limited information on modeling of a Yakima Basin watershed became available in July, 1989. Information on sea level rise scenarios has been available since at least 1983; quantitative information on Washington's coastal zone resources sufficient to develop quantitative impact analyses is lacking, however. This report is as accurate as it can be; within a few months many portions of it will likely be obsolete.

1.1 Characterization of Threat

The future climate will likely be radically different from present conditions. We know that the chemistry of the atmosphere is changing rapidly. Scientific theory predicts that these changes will result in global warming due to the greenhouse effect of certain gases, particularly carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons, as well as other species. This warming will include other climate changes which are expected to have profound effects on agriculture, forestry, ecosystems, sea level, water resources, energy use, transportation, and many other aspects of human life.

1.1.1 Climate Change

The greenhouse effect results from the trapping of radiant energy in the lower atmosphere by greenhouse gases (Figure 1.1). Most, but not all ultraviolet (UV) radiation is filtered by the stratospheric ozone layer, and some penetrates the troposphere (lower atmosphere). Visible radiation penetrates the troposphere and is reflected from the surface of the earth as infrared (IR) radiation. IR radiation does not penetrate the troposphere, and thus is trapped, warming the Earth. Without the greenhouse gases, the Earth's surface would be approximately 30^{o}C cooler than it is, thus prohibiting life as we know it. If Earth had a carbon dioxide atmosphere as does Venus and Mars (95-98% CO_2), Earth's average surface temperature would be about 290^{o}C.

There is good agreement in the scientific community that:

* Carbon dioxide and other greenhouse gases are accumulating in the atmosphere.
* As these gases accumulate, they will cause a gradual increase in global average temperature; an effective doubling of CO_2 will occur as early as 2030.
* An effective doubling of CO_2 will eventually cause global average temperature increases of at least 1.5^{o}C and no more than 4.5^{o}C; the delay may be as much as 60 years.
* With this gradual warming will also come changes in wind, rainfall, and other climatic patterns.
* There will be substantial regional variability. In general, temperature increases will be greater in the polar latitudes and lesser the equatorial latitudes; some areas may be cooler than at present.

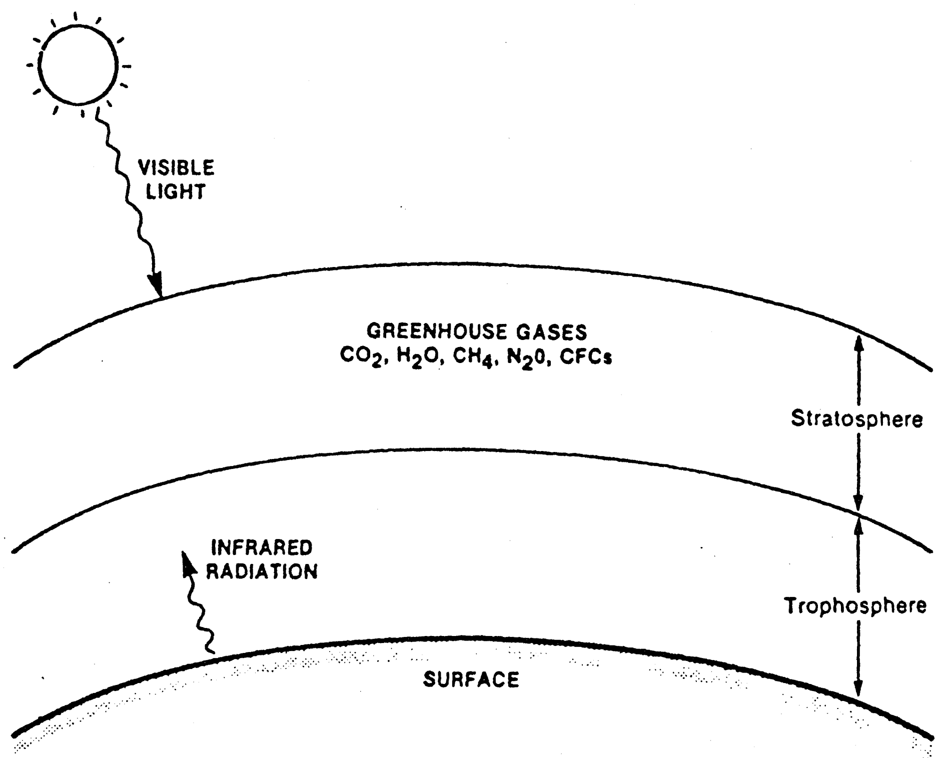

Figure 1.1 Global energy balance and the greenhouse effect.

* Global precipitation will increase; regional precipitation may increase or decrease.
* Sea level will rise due to warming and expansion of the oceans plus ice and snow melt; most scenarios lie in the range of 0.5 to 2.0 meters increase by 2100.

1.1.2 Ozone Depletion

Stratospheric ozone depletion is caused by both simple and complex chemical reactions. Many of the destructive reactions are dependent upon the presence of chlorine or bromine radicals. Chlorofluorocarbons (CFCs) are the principal supplier of these radicals.

The implications of ozone depletion are less well researched than those of climate change. It is known that the effects will be mostly related to human health issues, principally skin carcinomas and melanomas, cataracts and other eye diseases, and immune system effects. Ecological implications are also anticipated.

1.2 Types of Risks Analyzed

The Global Warming and Ozone Depletion Subcommittee identified five principal areas in which global warming could have significant effects upon Washington state: agriculture, energy, fisheries, forestry, and sea level rise. Ozone depletion will primarily affect human health, although effects are also anticipated for the composition of the Puget Sound phytoplankton and the fisheries industry.

Human health risks are diffuse. Global warming will cause increased heat stress and disease; introduction of insect disease vectors due to ecological changes; and injuries and deaths due to an increased frequency and intensity of flooding caused by sea level rise. Ozone depletion and the resulting increase in ultraviolet radiation will cause an increased incidence of malignant melanoma and other less malignant skin cancers, ocular damage such as cataracts, and immune system disruptions.

Ecological impacts will be reflected as economic impacts: agricultural crops and the agricultural economy; energy supply and demand; fisheries and the sports, commercial, and Tribal harvests; and forestry and the forest industry. Sea level rise will cause economic losses or costs due to flood damage, property loss due to inundation or erosion, and public and private protective measures.

Ecological risks will ensue from changes to climate (temperature and precipitation), hydrology, and sea level rise, with resultant effects on primary productivity (plant growth rates), ecosystem composition, and the life cycles, ranges and migration patterns of animals. Little is known about this latter issue, and is therefore not addressed by this analysis.

1.3 Causes of Global Warming and Ozone Depletion: Major Pollutants and Sources

Earth's atmosphere is composed mostly of nitrogen (78%) and oxygen (20%), with small amounts of argon (1%) and carbon dioxide (0.03%), and trace amounts of other gases including neon, helium, methane, ozone, and nitrogen oxides. Greenhouse gases are any molecules with three or more atoms. Atmospheric nitrogen and oxygen molecules each have two atoms. The principal greenhouse gas, carbon dioxide, accounts for approximately 50% of the current greenhouse effect. The secondary gases account for the remaining greenhouse effect, principally methane (20%), chlorofluorocarbons (CFCs; 15%), nitrous oxide (10%) and ozone (5%). The following discussion of greenhouse gases is summarized from Hansen, et al. (1987, 1984a), Watson (1989), and Hoffman & Wells (1987) except as noted.

When the National Science Foundation released its first report on global warming (Charney, et al., 1979), the analyses were based on a doubling of carbon dioxide which was expected to occur sometime during the second half of the 21st century. Since then, the importance of the other greenhouse gases has become better known. Global warming analyses now include consideration of all the greenhouse gases, but generally speak in terms of an "effective doubling" of carbon dioxide, that is, a doubling of greenhouse gas effect due to the combined effect of carbon dioxide plus the other greenhouse gases. The phrase "effective carbon dioxide doubling" is often represented as "$2XCO_2$" in the technical literature, and present conditions as "$1XCO_2$." An effective doubling of carbon dioxide is now expected as early as 2030.

1.3.1 Carbon Dioxide

The principal anthropogenic source of carbon dioxide (CO_2) is the burning of carbon fuels (coal, petroleum, and natural gas). About 20% of the carbon dioxide increase is attributed to deforestation, principally in the equatorial regions. The sources of carbon dioxide by fuel source and function in the United States and Washington state are summarized in Table 1.1. The global sources of carbon dioxide are depicted in Figure 1.2. In Washington state, the principal source of carbon dioxide emissions is the burning of petroleum products for transportation (Table 1.1).

Pre-industrial atmospheric carbon dioxide concentrations were about 280 ppm. Since accurate, modern measurements were begun in 1958, concentrations have increased from approximately 315 ppm to approximately 350 ppm. Carbon dioxide emissions from Washington state constitute 1% of the North American total, which in turn constitutes about 27% of the global total (Figure 1.2).

Carbon dioxide also plays a part in stratospheric ozone formation. Increased levels of CO_2 cause a decrease in stratospheric temperature (as opposed to greenhouse warming in the troposphere) with a resulting increase in ozone production.

Table 1.1. Carbon dioxide sources by fuel type and function.

Source	United States	Washington state
Fuel Type		
Coal	33%	14%
Oil	49%	65%
Natural Gas	18%	9&
Wood	<1%	12%
Function		
Industry	24%	24%
Buildings	12%	14%
Electric Utilities	33%	14%
Transportation	31%	48%

Source: Electrical Power Research Institute in: Watson (1989).

* * * * * * * *

1.3.2 Methane

Nearly fifty percent of methane (CH_4) is derived from biological respiration, principally rice growing and sheep and cattle production. Overall, the sources are estimated to be: rice paddies, 28%; ruminants (cows, sheep, etc.), 20%; biomass burning, 19%; swamps and marshes, 11%; coal mining, 8%; natural gas, 8%; and other biogenic sources, 6% (Scientific Committee on Problems of the Environment, 1986:167).

Atmospheric concentrations of methane are increasing at a rate of about 1% a year principally due to increasing rice production in equatorial areas and increased ruminant herding globally. Washington state is not likely to be a major contributor to methane emissions.

Methane can also reduce the rate at which chlorine radicals destroy stratospheric ozone, and can also be responsible in part for the formation of tropospheric ozone.

1.3.3 Chlorofluorocarbons

Chlorofluorocarbons (CFCs) are a class of substances which are doubly an environmental problem. In the troposphere (lower atmosphere) they act as a greenhouse gas. Rising to the stratosphere, they release their chlorine atoms through photochemical reactions with UV radiation and other atmospheric chemicals. If not bonded to other agents within the stratosphere, chlorine radicals will react with odd-atom oxygen molecules (O and O_3) to produce molecular oxygen (O_2), thereby depleting the ozone (O_3) layer and reducing its ability to filter ultraviolet radiation.

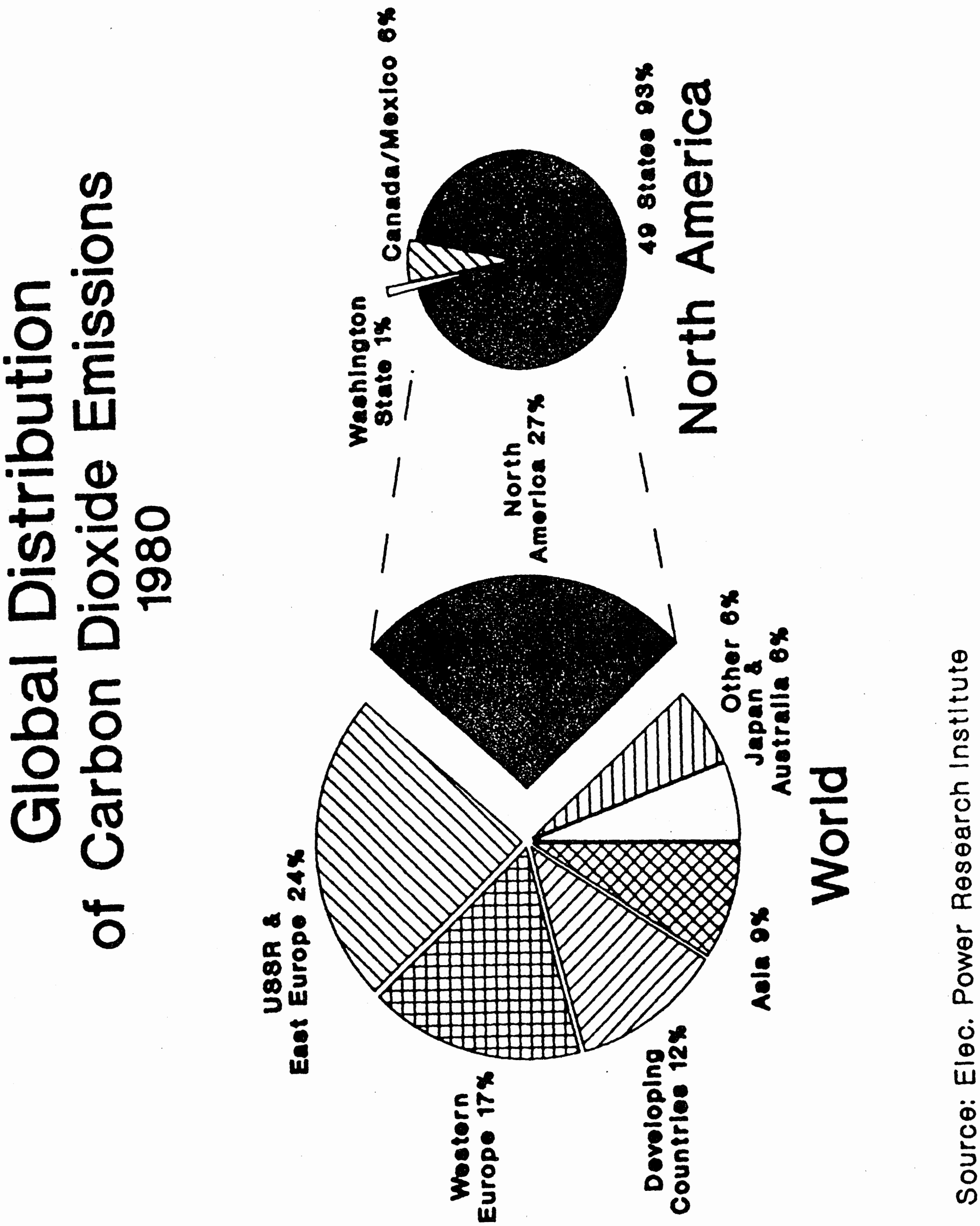

Figure 1.2 Global distribution of carbon dioxide emissions, 1980.

CFCs have no natural source; all CFCs are manufactured. They are used as aerosol propellants, solvents, blowing agents for insulating foams, and in a number of other industrial processes. CFCs are well suited to many industrial processes because of their stability: they are nontoxic, nonflammable, and virtually indestructible. These desirable industrial properties are environmentally troublesome; decreases in CFC emissions will not result in a corresponding decrease in atmospheric CFC concentrations for decades. CFCs have a residence time in the environment of at least 100 years.

Since the 1970s, CFCs have been increasing in the atmosphere at an average annual rate of 5 percent.

1.3.4 Nitrous Oxide

The major sources of nitrous oxide (N_2O) are fossil fuel combustion and fertilizer denitrification. Fossil fuel combustion is estimated to produce 20 - 30% of nitrous oxide emissions, with fertilizers and natural sources contributing the remainder. Like CFCs, nitrous oxide is long lived in the environment and therefore not susceptible to rapid reductions in concentration with reductions of emissions. Their residence time is estimated to be 100 to 175 years. Nitrous oxide also can form nitric acid in the stratosphere, which, under appropriate conditions, can neutralize atomic radicals capable of depleting the ozone layer.

In recent decades nitrous oxide concentrations have been increasing at an average annual rate of 0.2%.

1.3.5 Other

Other substances which have been identified as very small contributors to global warming include nitrogen compounds, sulfur compounds, fully fluorinated species, chlorocarbons, brominated and iodated species, hydrocarbons, aldehydes, and tropospheric ozone (Hoffman & Wells, 1987).

Two minor classes of ozone depleting chemicals include halons and methylchloroform and carbon tetrachloride.

Halons are used primarily in fire extinguishing systems and in the computer industry. While their volume of use is smaller than other ozone depleting chemicals, their bromine radicals are far more effective at ozone destruction. No feasible substitute for the fire fighting chemicals currently exists. Their release into the atmosphere, however, can be contained more easily than other chemicals. Most major releases occur during training for firefighting and testing of equipment, rather than during actual fire-fighting activities. The simple processes of equipment redesign and changes in testing or training practices can greatly minimize halon release into the atmosphere.

Methylchloroform and carbon tetrachloride represent 13% of the ozone depleting chemicals released into the lower atmosphere. (Amicus, Summer 88) While very effective at breaking ozone into smaller molecules, these chemicals are less stable than other halocarbons, break down quickly and, therefore, have a shorter destructive residence time in the stratosphere.

1.3.6 Cumulative Effects

Global warming is caused by the cumulative effect of the entire class of greenhouse gases and an array of human activities. Carbon dioxide receives the greatest attention in the popular press, but it now accounts for just 50% of the greenhouse effect. The estimated residence times and concentrations of greenhouse gases in 1980 and 2030 are summarized in Table 1.2. The less abundant greenhouse gases, however, are much more effective than carbon dioxide at radiative forcing, or warming. A chlorofluorocarbon molecule, for example, is approximately 20,000 times as effective as is a carbon dioxide molecule (see Table 1.3).

It is important to remember that these processes are all interconnected, and in the final analysis none can be viewed as a separate issue. Also, it is important to remember that many of the greenhouse gases have residence times in the atmosphere of hundreds of years (Table 1.2).

In recent months, the scientific literature has begun to emphasize the close causal relationships between global warming, ozone depletion, and acid precipitation. In the future, we can expect to find that the causes of each phenomenon are more closely related than now commonly realized.

Table 1.2 Estimates of the Abundance of Trace Chemicals in the Global Atmosphere of Years 1980 and 2030.
Source: Ramanathan, Cicerone, Singh and Hiehl (1985)

Chemical Group	Chemical Formula	Dominant Source*	Dominant Sink*	Estimated Average Residence Time (τj)	Year 1980 Global Average Mixing Ratio (ppb)+	Year 2030 probable global average concentration: Probable Value	Year 2030 probable global average concentration: Probable Value	Remarks (also see text for details)
Carbon Dioxide	CO_2	N.A	O	2	339×10^3	$450 \times 10_3$	--	Based on a 2.4% per year increase in anthropogenic CO_2 release rates over the next 50 years
Nitrogen Compounds	N_2O	N.A	S(UV)	120	300	375	350 - 450	Combustion and fertilizer sources
	NH_3	N.A	T	0.01	<1	--	--	Concentration variable and poorly characterized
	$(NO+NO_2)$	N.A	T(OH)	0.001	0.05	0.05	0.05 - 0.1	Concentration variable and poorly characterized
Sulfur Compounds	CSO	N.A	T(O.OH)?	I(?)	0.52	0.52	--	Sources and sinks largely unknown
	CS_2	N.A	T	I(?)	<0.005	<0.005	--	Sources uncharacterized
	SO_2	A(?)	T(OH)	0.001	0.1	0.1	0.1 - 0.2	Given the short lifetime the global presence of SO_2 is unexplained
	H_2S	N	T(OH)	0.001	<0.05	<0.5	--	
Fully Fluorinated Species	CF_4(F14)	A	I	>500	0.07	0.24	0.2 - 0.31	Aluminum industry a major source
	C_2F_6(F116)	A	I	>500	0.004	0.02	0.01 - 0.04	Aluminum industry a major source
	SF_6	A	I	>500	0.001	0.003	0.002- 0.05	
Chlorofluoro-carbons	$CClF_3$(F13)	A	S(UV).I	400	0.007	0.06	0.04 - 0.1	All chlorofluorocarbons are of exclusive man-made origin. A number of regulatory actions are pending. The nature of regulatory actions are pending. The nature of regulations and their effectiveness would greatly affect the growth of these chemicals over the next 50 years
	CCl_2F_2(F12)	A	S(UV)	110	0.28	1.8	0.9 - 3.5	
	$CHClF_2$(F22)	A	T(OH)	20	0.06	0.9	0.4 - 1.9	
	CCl_3F(F11)	A	S(UV)	65	0.18	1.1	0.5 - 2.0	
	CF_3CF_2Cl(F115)	A	S(UV)	380	0.005	0.04	0.02 - 0.1	
	$CClF_2CClF_2$(F114)	A	S(UV)	180	0.015	0.14	0.06 - 0.3	
	CCl_2FCClF_2(F113)	A	S(UV)	90	0.025	0.17	0.08 - 0.3	
Chlorocarbons	CH_3Cl	N(O)	T(OH)	1.5	0.6	0.6	0.6 - 0.7	Dominant natural chlorine carrier of oceanic origin
	CH_2Cl_2	A	T(OH)	0.6	0.03	0.2	0.1 - 0.3	A popular reactive but non-toxic solvent
	$CHCl_3$	A	T(OH)	0.6	0.01	0.03	0.02 - 0.1	Used for manufacture of F22; many secondary sources also exist
	CCl_4	A	S(UH)	25-50	0.13	0.3	0.2 - 0.4	Used in manufacture of fluorocarbons; many other applications as well
	CH_2ClCH_2Cl	A	T(OH)	0.4	0.03	0.1	0.06 - 0.3	A major chemical intermediate (global production=10 tg/yr); possibly toxic

Table 1.2 Estimates of the Abundance of Trace Chemicals in the Global Atmosphere of Years 1980 and 2030.
Source: Ramanathan, Cicerone, Singh and Hiehl (1985) (continued)

Chemical Group	Chemical Formula	Dominant Source*	Dominant Sink*	Estimated Average Residence Time (τj)	Year 1980 Global Average Mixing Ratio (ppb)+	Year 2030 probable global average concentration: Probable Value	Probable Value	Remarks (also see text for details)
	CH_3CCl_3	A	T(OH)	8.0	0.14	1.5	0.7 - 3.7	Non-toxic, largely uncontrolled degreasing solvent
	C_2HCl_3	A	T(OH)	0.02	0.005	0.01	0.005- 0.02	Possibly toxic, declining markets because of substitution to CH_3CCl_3
	C_2Cl_4	A	T(OH)	0.5	0.3	0.07	0.03 - 0.2	Possibly toxic; moderate growth due to substitution to CH_3CCl_3
Brominated and iodated species	CH_3Br	N	T(OH)	1.7	0.01	0.01	0.01 - 0.02	Major natural bromine carrier
	$CBrF_3$(FI3BI)	A	S(UV)	110	0.001	0.005	0.003- 0.01	Fire extinguisher
	CH_2BrCH_2Br	A	T(OH)	0.4	0.002	0.002	0.001- 0.01	Major gasoline additive for lead scavenging; also a fumigant
	CH_2I	N	T(UV)	0.02	0.002	0.002	--	Exclusively of oceanic origin
Hydrocarbons CO, H_2	CH_4	N	T(OH)	5-10	1650	2340	1850 - 3300	A trend showing increase over the last 2 years has been identified
	C_2H_6	N	T(OH)	0.3	0.8	0.8	0.8 - 1.2	Predominantly of auto exhaust origin
	C_2H_2	A	T(OH)	0.3	0.06	0.1	0.06 - 0.16	No trend has been identified to date
	C_3H_8	N.	T(OH)	0.03	0.05	0.05	0.05 - 0.1	No trend has been identified to date
	CO	N.A	T(OH)	0.3	90	115	90 - 160	No trend has been identified to date
	H_2	N.A	T(SL.OH)	2	560	760	560 - 1140	
Ozone	O_3 (Tropospheric)	N	T(UV, SL,O)	0.1-0.3	F(Z)**	12.5%		A small trend appears to exist but data are insufficient
Aldehydes	HCHO	N	T(OH,UV)	0.001	0.2	0.2	--	Secondary products of hydrocarbon oxidation
	CH_3CHO	N	T(OH,UV)	0.001	0.02	0.02	--	1980 concentration estimated from theory

*N - Natural; A - Anthropogenic; O - Oceanic; S - Stratosphere; UV - Ultraviolet Photolysis; T - Troposphere; OH - Hydroxyl radical removal; I - Ionospheric and extreme UV and electron capture removal; SL - Soil sink

+These concentrations are integrated averages; for chemicals with lifetimes of 10 years or less, significant latitudinal gradients can be expected in the troposphere; for chemicals with extremely short lifetimes (0.001-0.3 years) vertical gradients may also be encountered

**Varies from 25 ppbv at the surface to about 70 ppbv at 9 km. The concentration was increased uniformly by the same percentage from the surface to 9 km.

***These values are not used in the present assessment.

Source: Ramanathan, Cicerone, Singh, and Kiehl (1985)

Table 1.3 Radiative forcing for a uniform increase in trace gases.

Compound	Radiative Forcing °C/ppb
carbon dioxide CO_2	0.000004
methane CH_4	0.0001
nitrous oxide N_2O	0.001
chlorofluorocarbons	
CFC-11	0.07
CFC-12	0.08
CFC-13	0.10
Halon 1301	0.10
fluorinated species	
F-116	0.08
F-14	0.04
chlorocarbons	
carbon tetrachloride CCl_4	0.05
$CHCl_3$	0.04
CH_2Cl_2	0.02
CH_3Cl_3	0.01
sulfur dioxide SO_2	0.01

Source: Ramanathan, et al., 1985.

* * * * * * * *

1.4 Climate Change

1.4.1 Analytic Approach

Global climate predictions, or more accurately, scenarios, are based on General Circulation Models (GCMs). Five GCMs have been developed, four American and one British. The American GCMs are: the GISS model developed by James Hansen's team at NASA's (National Aeronautics and Space Administration) Goddard Institute for Space Studies, New York City; the GFDL model developed by the Princeton University Geophysical Fluid Dynamics Laboratory for the National Oceanic and Atmospheric Administration (NOAA); the OSU model developed by Michael Schlesinger's team at the Department of Atmospheric Sciences, Oregon State University; and the ORNL model developed at Oak Ridge National Laboratory, Oak Ridge, Tennessee.

General Circulation Models do not have sufficiently fine resolution to produce consistent regional scenarios. The grid or cell compartments used in GCMs are a few hundred miles on a side, usually covering an area larger than the state of Washington (see Figure 1.3). A stack of cells represents the atmosphere. Each cell is assigned a set of single values to represent temperature, precipitation, etc., at a particular time. Each GCM uses a different cell size and makes different assumptions about global climate interactions.

Thus, the GCMs, while in good general agreement as to global average temperature changes, show less agreement, and occasional disagreement as to regional climate change patterns. Therefore, the following discussion of climate change in Washington state and surrounding areas should not be taken as anything more than a general indication. Also, remember that these are scenarios, not predictions.

It now appears that there is a lag time of about 60 years between the introduction of greenhouse gasses to the atmosphere and any resultant temperature increases (Schlesinger, 1989).

Our scenarios for the effects of global warming in the Pacific Northwest rely on interpretations of the GCMs as cited in our text. The US EPA *Report to Congress* (Smith & Tirpak, 1988) depicts scenarios based on the GISS, GFDL, and OSU GCMs.

1.4.2 Uncertainty

While there is good agreement in the scientific community as to the likelihood of global warming and climate change, there are dissenting opinions. Arguments are made by some scientists that the global circulation models which are used to predict global climate change do not adequately model either cloud cover, or oceanic heat or carbon dioxide absorption. Their arguments contend that these factors could act as negative feedback, lessening or negating the generally accepted effects of global warming. However good these arguments are intellectually, good evidence to the contrary abounds.

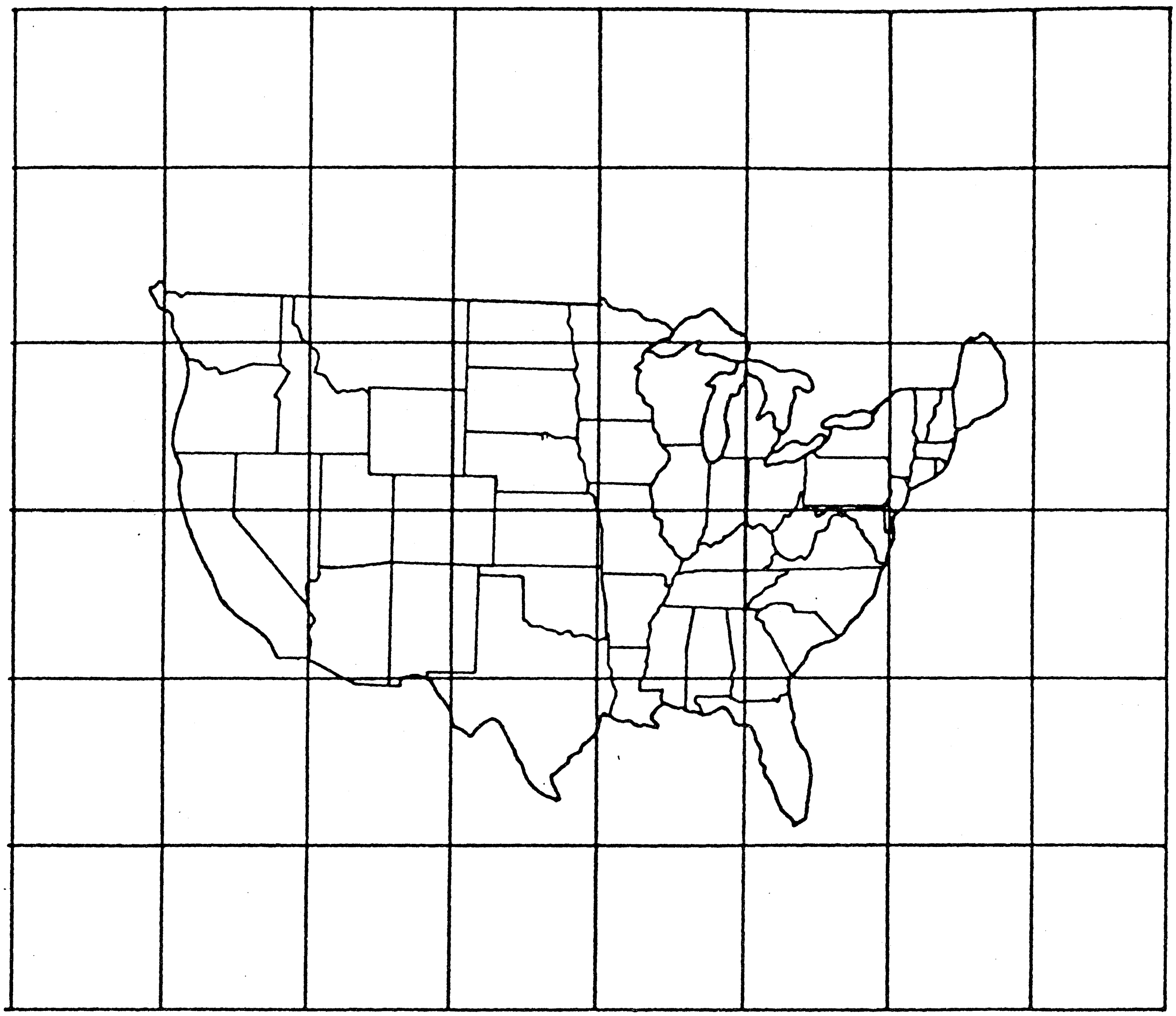

Figure 1.3 GISS Model of the United States.

One common argument is that the oceans will absorb the excess carbon dioxide from the atmosphere, thus mitigating anthropogenic disruption of the global carbon cycle. This is true, but the rate of carbon dioxide emission to the atmosphere appears to be vastly greater than the oceanic uptake capacity. Lapenis and Rampino (1989) modeled a set of these factors including seawater alkalinity and biological calcium carbonate fixation in the ocean. According to model calculations, atmospheric carbon dioxide concentrations will rise to a maximum of 750 ppm (for the average emission scenario), and then will decrease to 450 ppm over 2,000 to 2,500 years. The remaining excess carbon dioxide in the atmosphere would be neutralized in about 15 to 20,000 years.

Another ongoing debate has questioned the role of planetary cloud cover in global warming models (GCMs). All researchers and modelers agree that clouds play a role in global climate; the debate is whether they act more to cool the planet or to warm it. A recently published (May, 1989) article reports that, based on NASA satellite experiments, clouds presently cool the planet more than they heat it (Ramanathan, Barkstrom & Harrison, 1989). The NASA program, Earth Radiation Budget Experiment (ERBE) was begun in the mid-1980s; data has been processed for four months: April, July, and October 1985, and January 1986. The data for July 1985, for example, show that the long-wave radiative forcing was 30.1 W/m^2 while the shortwave cloud forcing was -46.7 W/m^2. This is interpreted to indicate a net cloud forcing of -16.6 W/m^2, and therefore a cooling effect. Because long wave length and short wave length radiative forcing is produced by different kinds of clouds, there remain questions as to the net effects under global warming scenarios because it is not certain what kind of cloud would be produced under climate change conditions.

Possibly the best indication of certainty is the effects of increased carbon dioxide in the atmosphere found in ice cores retrieved from polar ice caps. The Vostok ice core records analyzed by Barnola et al. (1987) show an excellent correlation between carbon dioxide and global average temperatures over the last 160,000 years (see Figure 1.4). Approximately 20,000 ypb (years before present) an increase in carbon dioxide from 200 to 250 ppm was accompanied by an increase in temperature of about 10^{o}C. Approximately 150,000 ybp an increase in carbon dioxide from 190 to 280 ppm was also accompanied by an increase in temperature of about 10^{o}C.

Debates also occur as to whether global warming has already begun. As reported by the popular press, these debates are often misinterpreted as being debates over whether global warming will occur.

In June, 1988, James E. Hansen, a global climate modeler and director of NASA's Goddard Institute for Space Studies (GISS) testified before Congress that he was 99 percent certain that the predicted greenhouse warming had begun. (Then recent temperatures had so exceeded the norm that there was only a 1% probability of such an occurrence; Hansen interpreted the converse 99%

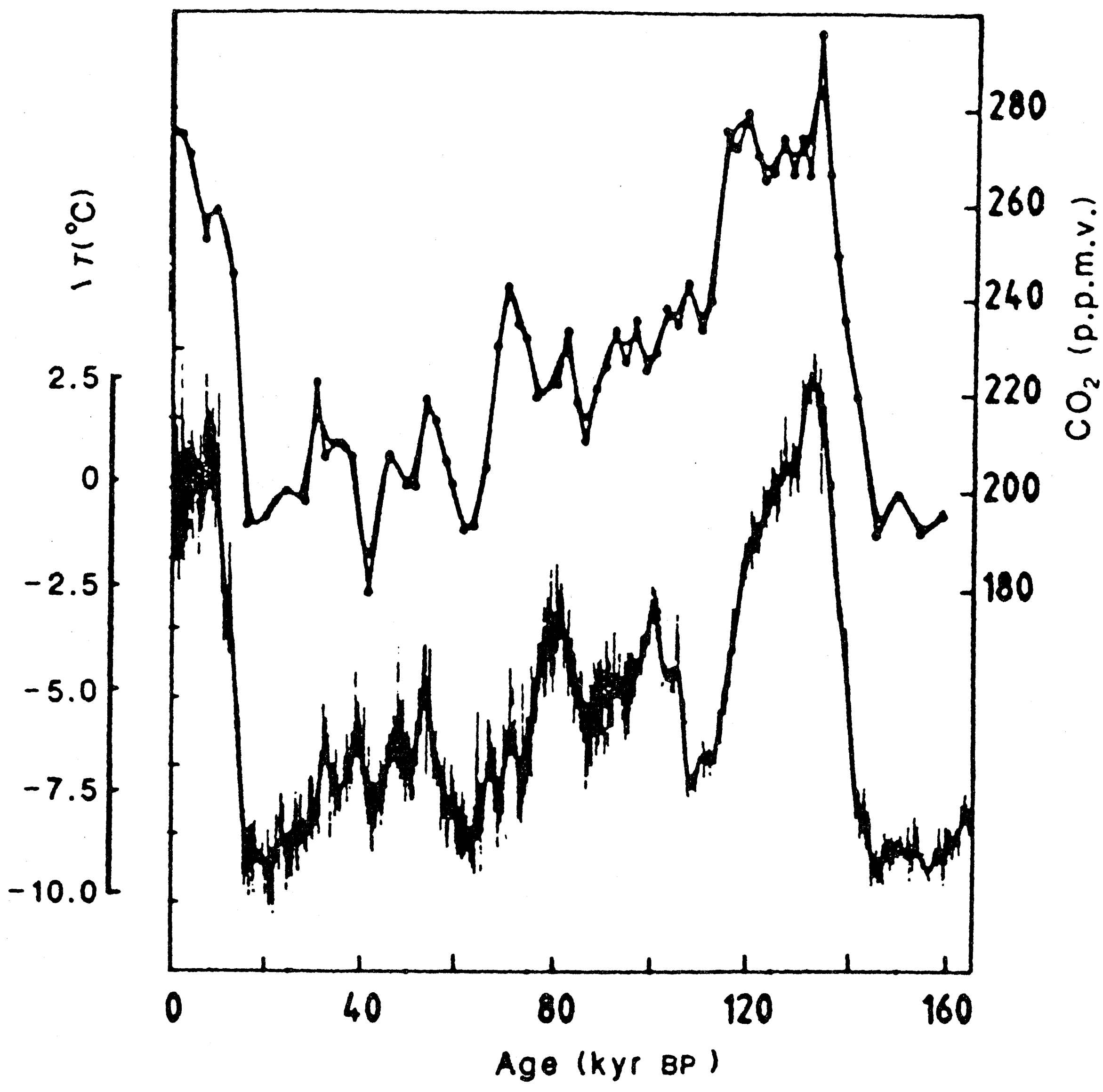

Figure 1.4 Carbon dioxide levels and temperature over the last 160,000 years. From Vostok 5 Ice Core (Barnola, et al., 1987).

probability to indicate the likelihood of greenhouse warming.) He went on to state that the global average temperature had increased significantly over the past century, and that part of the increase could be attributed to human activities which introduced greenhouse gases to the atmosphere. Since then other climatologists have joined Hansen, while yet others have publicly disagreed. Hansen's statements were often misinterpreted, claiming that he had attributed the 1988 heat wave and drought solely to global warming (Monastersky, 1989a).

There is no debate whether the record shows an increase in global average temperature over the past century; the global record clearly shows an increase of 0.5 to 0.7°C. Some scientists assert that the increase is due solely to the urban heat island effect. Most weather stations were established adjacent to a population center. As these areas urbanized, they enveloped the weather stations. Urban areas have been shown to be warmer and to have more precipitation than nearby rural areas, thus leading to climatic records showing artificially altered conditions. The urban heat island effect accounts for some (up to 0.3°C) but not all of the global average temperature increase; the residual (0.3 to 0.4°C) can still be attributed to greenhouse warming (Lettenmaier, 1989; Monastersky, 1989a).

1.4.3 Temperature

Average annual temperature in the Pacific Northwest is projected to increase by 3° to 5°C with a doubling of carbon dioxide. There appears to be general agreement that temperature increases will be similar for the Pacific Northwest and Northern California. Existing average annual temperature and precipitation data for selected locations in Washington is shown in Table 1.4.

Existing average annual temperature and precipitation data for selected locations in Washington is shown in Table 1.4.

GISS Model Hansen et al. (1984) mapped global warming based on their GISS model and show a 4°C increase for coastal Pacific Northwest and northern California, with the temperature gradient increasing to the east and south. The expected increase in summer temperatures for the Pacific Northwest is 4.4°C (Adams, Glyer & McCarl, 1988). For an east Cascades basin, temperature increases range from 3°C during summer to 6°C during winter (Vail & Lettenmaier, 1989). Temperature increase scenarios for California (Smith & Tirpak, 1988) indicate an annual average of 4.7°C, with a winter change of 4.9°C, and a summer change of 4.8°C.

GFDL Model Gibbs and Hoffman (1987) used the GFDL model to map changes in mean annual temperature for the United States and indicate a 4.1 to 5°C increase for the Washington, Oregon, California, and western Nevada cells. At a finer level of detail, Gibbs and Hoffman worked with National Climate Center climate division data to project mean annual temperature increases in this area for Leverenz & Lev (1987). In this detailed work, they projected >5°C

Table 1.4 Existing average annual temperature and precipitation at representative locations in Washington state.

Location	Temperature °F	Temperature °C	Precipitation in/year	Precipitation mm/day
Aberdeen	50.3	10.2	84.54	5.90
Vancouver	41.7	5.4	39.00	2.71
Sequim	49.3	9.6	16.81	1.12
Seattle	40.8	4.9	38.94	2.71
Kennewick	53.6	12.0	7.49	0.52
Spokane	47.8	8.8	17.19	1.20

Source: Phillips, 1965.

* * * * * * * *

increases for the Columbia Basin, 3-5°C increases for the Cascades, and <3°C increases for coastal and Puget Sound Basin portions of Washington. The expected increase in temperatures for the Pacific Northwest is 4.5°C (Adams, Glyer & McCarl, 1988). Temperature increase scenarios for California (Smith & Tirpak, 1988) indicate an annual average increase of 4.4°C, with a winter increase of 4.2°C, and a summer increase of 4.3°C. For an east Cascades basin, temperature increases range from 4°C to 6°C throughout the year (Vail & Lettenmaier, 1989).

OSU Model For an east Cascades basin, temperature increases range from 1°C during winter to 4°C during summer (Vail & Lettenmaier, 1989). Temperature increase scenarios for California (Smith & Tirpak, 1988) indicate an annual average increase of 2.3°C, with a winter increase of 3.0°C, and a summer increase of 2.2°C.

1.4.4 Precipitation

Precipitation projections for Washington are more variable than temperature scenarios. In general, the GISS model predicts a 29% increase, and the GFDL model predicts a 1.7% increase. Due to the projected increase in temperature, more precipitation will fall as rain than does now, thus lessening the winter show pack.

GISS Model In the Pacific Northwest, average annual precipitation is predicted to increase by 23 percent (Adams, Glyer & McCarl, 1988). For an east Cascades basin, precipitation changes range from a 20 to 30% increase throughout most of the year to a 25% decrease during the autumn, with an apparent 25% net increase (Vail & Lettenmaier, 1989). Precipitation change scenarios for California (Smith & Tirpak, 1988) indicate an annual average increase of 0.28 mm/day, with a winter increase of 0.45 mm/day, and a summer increase of 0.30 mm/day.

GFDL Model Gibbs and Hoffman (1987) used the GFDL model to map changes in mean annual precipitation for the United States and indicate an increase of 11 to 30% for Washington, Oregon, northern California, the northern Great Basin, and the Northern Rocky Mountains cells. In the Pacific Northwest, average annual precipitation is predicted to increase by 1.7 percent (Adams, Glyer & McCarl, 1988). For an east Cascades basin, precipitation changes range between 25% increases to 35% decreases throughout the year with a slight apparent net increase (Vail & Lettenmaier, 1989). Precipitation change scenarios for California (Smith & Tirpak, 1988) indicate no substantial change on an annual basis, with a winter increase of 0.25 mm/day, and no substantial change on a summer season basis.

OSU Model For an east Cascades basin, precipitation changes range from a 0 to 25% increase throughout most of the year to a 25% decrease during the autumn with an apparent slight net increase (Vail & Lettenmaier, 1989). Precipitation change scenarios for California (Smith & Tirpak, 1988) indicate an annual average decrease of 0.10 mm/day, with a winter increase of 0.12 mm/day, and a summer decrease of 0.35 mm/day.

1.5 Hydrology

No comprehensive hydrologic projections have yet been developed for Washington state or the Pacific Northwest. Lettenmaier (1989) is developing hydrologic scenarios for two watersheds in the Yakima River basin and has presented preliminary findings (Vail & Lettenmaier, 1989). Hartman (1988) summarized the literature and has offered a scenario for Washington which hypothesizes more total precipitation, but dryer summers, with the Cascade snow line approximately 1,850 feet higher than present.

As noted in Section 1.4.3, more precipitation is expected to fall as rain than does now, thus lessening the winter show pack. A corollary of this is the expectation that higher average temperatures will lead to higher snow lines in the mountains. The cumulative effect of these factors will be increased winter stream flows in all streams, and decreased delayed runoff during the summer in snow pack fed streams.

Vail & Lettenmaier's (1989) evaluation of the effect of global warming on the American River watershed of the Yakima Basin used three GCMs; all indicated a shift in the hydrograph to the left, that is, from a May - June peak runoff (approximately 40 inches), to an earlier runoff peak. The GISS scenario shows a January peak runoff (approximately 50 inches); the GFDL scenario a December peak (approximately 35 inches) with a secondary peak in March (approximately 30 inches); and the OSU scenario an April peak (approximately 35 inches). In general, all scenarios indicate higher flows between November and April, and lower flows between May and August.

It is likely, therefore, that the hydrograph of all snow fed streams will shift to the left. Streams not fed by snow melt may also experience lower summer flows if summer precipitation decreases. These conditions are similar to those now caused by development in urban areas (see Canning, 1988) whereby cumulative increases in impervious surface increases winter runoff and decreases ground water recharge, thus decreasing summer delayed runoff.

1.5.1 Decreased Summer Stream Flow

During the relatively dry summer season, most, if not all, stream flow results from (1) the seepage of ground water into streams and ponds or (2) snow melt. Regardless, summer stream flows are delayed runoff from winter storms. In many western Washington areas, summer low flows are now so reduced from what was the norm under predevelopment conditions that the fisheries productivity of the stream is adversely affected. Late summer flows may be insufficient for returning salmon to ascend the stream to spawning locations. In extreme cases summer stream stagnation results in the death or diminished growth of salmon eggs or young in the gravel or rearing pools of the stream (Canning, 1988). Precipitation changes due to global warming will aggravate this situation.

1.5.2 Increased Winter Stream Flow

The size of a streambed -- its width and depth -- is created by the one and one-half- to two-year recurrence interval flow volume. Flows larger than the one and one-half- to two-year volume top the stream banks and flow overland on the floodplain. If global warming results in a steadily increasing winter runoff volume, it is inevitable that the stream bed and banks would be continually scoured as the stream enlarged itself to accommodate the larger flows. Bed scour is destructive of salmon spawning habitat. Bank scour leads to unstable bank conditions. Additionally, increased runoff will contribute to an increased frequency and volume of flood flows (Canning, 1988).

These conditions are presently occurring in western Washington due to urbanization (Canning, 1988) and can be illustrated with some research results from the Bellevue NURP studies on Kelsey Creek. Kelsey Creek drains an area of 3,200 hectares (7,910 acres). The majority (78%) of the watershed is now urbanized; the remainder (22%) is parkland or undeveloped. The shift in flood flow hydrology for Kelsey Creek from the 1960s to the 1970s is summarized in Table 1.5. With the increasing urbanization and coverage by impervious surface which occurred during those decades, the streamflow volume resulting from the 100-year storm doubled. Under natural conditions, the 100-year storm produced a relatively predictable 100-year flood flow in Kelsey Creek. Under urbanizing conditions, however, the 100-year storm produces increasingly larger 100-year flood flow volumes.

Table 1.5. Flood frequency estimates, Kelsey Creek, Bellevue.

Recurrence Interval, years	Annual Probability, per cent	Flow Rates, m^3/s 1962-70	Flow Rates, m^3/s 1971-80
1.01	99	3.68	4.33
1.25	80	4.79	6.68
2.0	50	6.63	11.36
5.0	20	6.43	10.85
10	10	6.97	12.32
25	4	7.56	14.13
50	2	7.99	15.41
100	1	8.38	16.68

Source: Pitt & Bissonnette, 1984: 37.

Another way of looking at the data in Table 1.5 is to say that what was formerly the 100-year flood flow volume (8.38 cubic meters per second), now occurs every year or two, with an average recurrence interval of about 1.5 years. That is, the former 100-year flood flow volume is now the 1.5-year flow volume in Kelsey Creek. These increases in flood flow frequency and volume in turn cause additional adverse impacts to streams. Increased winter precipitation and runoff will simply aggravate these existing trends.

1.6 Sea Level Rise

1.6.1 Analytic Approach

This evaluation of sea level rise summarizes the findings of a detailed preliminary evaluation of the implications of sea level rise for Washington state (Canning, 1989) prepared by the Shorelands and Coastal Zone Management Program, Washington Department of Ecology. Other recommended information sources include Barth & Titus (1984), Hoffman, Keyes & Titus (1983), National Research Council (1987), and Titus (1988). Quantitative damage estimates for Washington state in dollars or land losses have not yet been developed.

1.6.2 Sea Level Rise Scenarios

Accelerated sea level rise is one secondary effect of an altered greenhouse effect. Global sea level rise is estimated to have been in the range of 10 to 15 cm during the past century (Fairbridge & Krebs, 1962; Barnett, 1984). Presently, 1.2 mm/yr is the generally accepted rate for predictive modeling (Park, et al., 1988; Titus, 1988). Moffat & Nichol (1988) determined a global sea level change of 0.0039 ft/yr (1.2 mm/yr) for San Francisco Bay.

Sea level rise is predicted to occur due to global warming of the oceans (and thus expansion) as well as the melting of snow and ice. The factors which are thought to control future sea level rise are summarized in Table 1.6. These factors are the basis for sea level rise scenarios developed by the US Environmental Protection Agency and summarized in Table 1.7. The low range scenarios were developed using the low assumptions, and the high range scenarios, the high assumptions. The US EPA researchers further assumed that it is possible but unlikely that either extreme scenario (high or low) would occur. Therefore, two mid-range scenarios were developed. In recent years, most sea level rise scenarios have fallen into the range 0.5 to 2.0 meter rise by 2100 (see Figure 1.5).

Other scenarios are offered which go far beyond the US EPA predictions. One scenario postulates a collapse of the West Antarctic ice shelf, resulting in a sea level rise of about 20 feet over a few hundred years. There is evidence for this having occurred approximately 150,000 years ago, but the evidence for sufficient future global warming is not convincing to a majority of climatologists. The most radical theory envisions a complete melting of the Greenland and Antarctic ice caps, resulting in a sea level rise of about 200 feet. There is little scientific support for this scenario.

Global sea level rise (G) must be adjusted for local vertical land movement (V) to determine local relative sea level rise (R) such that $R = G - V$. Uplift moderates or negates sea level rise; subsidence aggravates sea level rise. Although global climate change may alter the mass of the planet, thus producing latitudinal differences in sea level rise rates, presently only uniform global sea level rise is modeled (Titus, 1988).

Relative sea level change in Washington state will result from the combined effects of vertical land movement and global sea level rise. Subsidence in Puget Sound (1 - 2mm/yr; 0.3 - 0.6ft/century) will aggravate global sea level rise; uplift along the ocean coast (1 - 1.6mm/year; 0.3 - 0.5ft/century) will moderate sea level rise (Lyles, Hickman & Debaugh, 1988; Holdahl, Faucher & Dragert, nd).

Vertical land movement patterns in western Washington are not well understood. Ecology's Shorelands and Coastal Zone Management Program is conducting a review of the scientific literature which is expected to be completed by late 1989.

Table 1.6 Summary of high and low assumptions used to estimate sea level rise by US Environmental Protection Agency.

Factor	Assumption: Low	Assumption: High
Population Growth	All scenarios assumed the world will reach zero population growth by 2075.	
Productivity Growth	2.2% per year; decreases to 1.7% by 2100.	3.5% per year; decreases to 2.2% by 2100.
Energy Technology	Best estimate; nuclear costs halved arbitrarily.	Best estimates.
Unexpected Additions To Fossil Fuel Base	None.	None.
Energy Conservation	All countries move toward high efficiency (60% improvement in energy efficiency).	
Fraction Airborne Carbon Dioxide	53%	ORNL Model; 60% increases to 80%.
Nitrous Oxide	0.2% per year growth.	0.7% per year growth.
Chlorofluorocarbons	Emissions increase 0.7% of 1980 level per year.	Emissions increase 3.8% of 1980 level per year.
Methane	1% per year growth.	2% per year growth.
Temperature Sensitivity	1.5°C for CO_2 doubling.	4.5°C for CO_2 doubling.
Heat Diffusion of Ocean	1.18 cm_2/sec	1.9 cm_2/sec
Glacial Discharge	Equal to thermal expansion.	Twice thermal expansion.

Source: Hoffman, Keyes & Titus, 1983.

* * * * * * * *

Table 1.7 Scenarios for future sea level rise developed by US Environmental Protection Agency. (Centimeters *Feet*)

Scenario	Year 2000	2025	2050	2075	2100
High	17.1 *0.6*	54.9 *1.8*	116.7 *3.8*	211.5 *6.9*	345.0 *11.3*
Mid-range High	13.2 *0.4*	39.3 *1.3*	78.9 *2.6*	136.8 *4.5*	216.6 *7.1*
Mid-range Low	8.8 *0.3*	26.2 *0.9*	52.6 *1.7*	91.2 *3.0*	144.4 *4.7*
Low	4.8 *0.2*	13.0 *0.4*	23.8 *0.8*	38.0 *1.2*	56.2 *1.8*
Current Trends	2.0-3.0 *0.1*	4.5-6.8 *0.1-0.2*	7.0-10.5 *0.2-0.3*	9.5-14.3 *0.3-0.5*	12.0-18.0 *0.4- 0.6*

Source: Hoffman, Keyes & Titus, 1983.

Note 1: The values projected by US EPA in this table are absolute sea level rise predictions. The base year is 1980. To apply these values to a particular local area requires consideration of local subsidence or uplift. Subsidence will produce a greater relative sea level rise; uplift will produce a lesser relative sea level rise.

Note 2: Subsequent to developing these scenarios, Hoffman et al. refined their computations, and now feel that the "mid-range low" scenario is most probable (Barth & Titus, 1984:16). The low and high scenarios, however, remain as the outer limits of what is reasonably possible during the next century.

* * * * * * * *

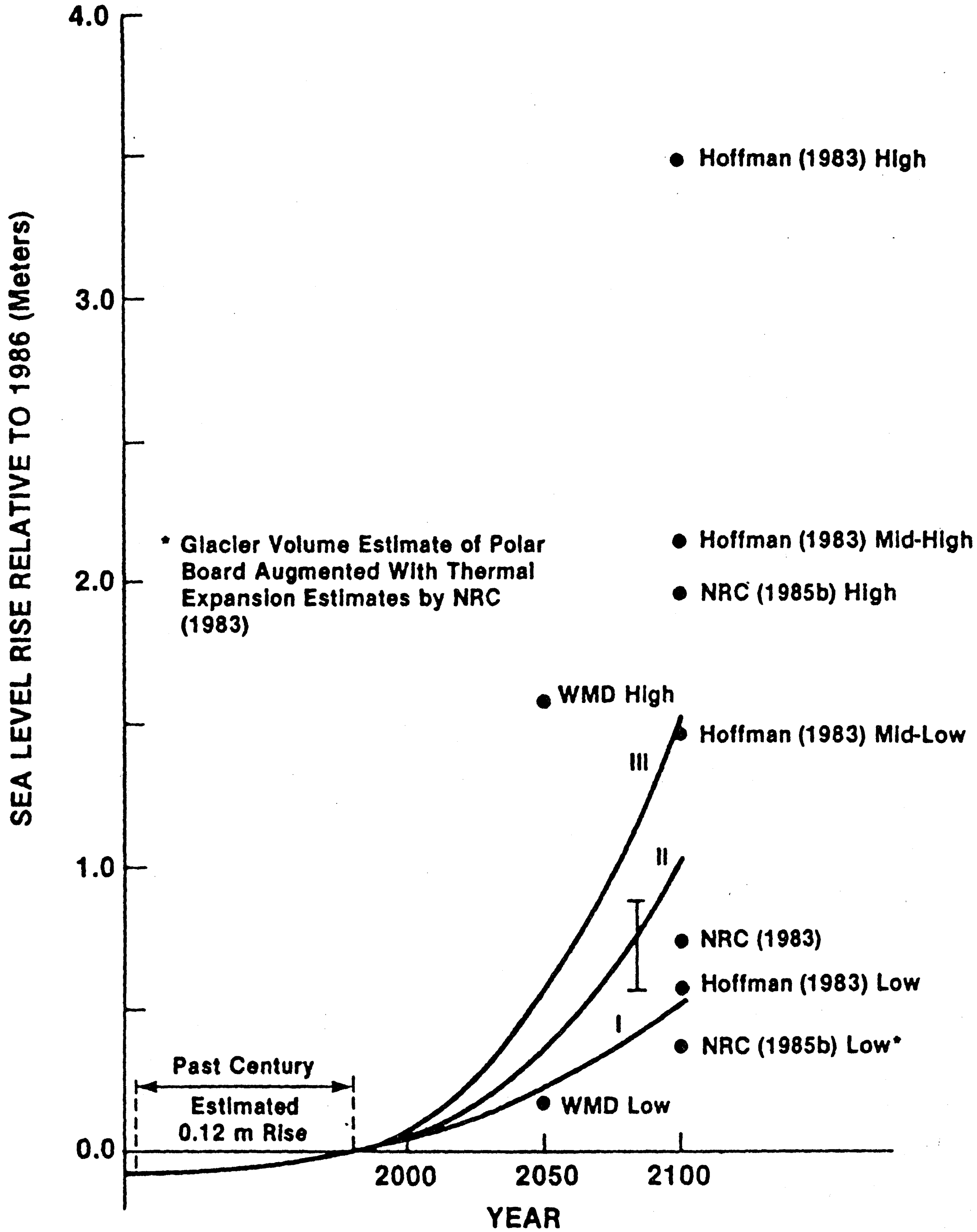

Figure 1.5 Estimates of future sea level rise. Source: Titus, 1988.

1.7 Ozone Depletion

1.7.1 Analytic Approach

Three networks have been primarily responsible for ozone monitoring during the past two decades. The Nimbus 7 Solar Backscatter Ultraviolet (SBUV) Satellite and the Total Ozone Mapping Spectrometer (TOMS) have provided continuous global records of the total atmospheric ozone column since October of 1978. This data is not entirely reliable due to the gradual degradation of satellite equipment. Results from SBUV and TOMS have, therefore, been normalized by coordinating with measurements from the groundbased Dobson network in the Northern Hemisphere. During the past three years, more accurate measurements have been obtained by actual aerial collection and monitoring of stratospheric gases by regular flights of specially equipped airplanes.

An Ozone Trends Panel (OTP) was formed with representatives from the National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), United Nations Environment Program (UNEP), Western Meteorological Organization (WMO), and the Federal Aviation Administration (FAA). Their March, 1988, report to Congress stresses "undisputed evidence that atmospheric concentrations of source gases important in controlling stratospheric ozone levels continue to increase on a global scale because of human activities." Their report states the annual average total ozone column has decreased 2-3% between 53 degrees South and 53 degrees North from October, 1978, to October, 1985, or about 0.35% annually. In the mid latitudes (30 degrees north to 64 degrees north) of the northern hemisphere, ozone decreased 1.7% to 3% between 1969 and 1985, depending on the latitude. Over Washington state, the total decrease is believed to be about 2.2% (OTP, 1988). Between 40 degrees north and 52 degrees north, wintertime ozone has decreased by 4.7%. The actual numbers were not accurately predicted by previous models because atmospheric models do not include ice in their reaction schemes; ice clouds appear to bind chemicals which in turn are not available to neutralize ozone destroying radicals.

1.7.2 Chemical Breakdown Mechanisms

Ozone is the triatomic form (O_3) of oxygen (O_2). While rare in the troposphere, its presence in small but crucial amounts in the stratosphere protects the earth from damaging ultraviolet radiation. The amount of ozone present varies with latitude, temperature and sunlight and is a result of a balance between ongoing processes that produce and destroy this substance. Its formation is influenced by solar activity, the presence of certain chemicals in the atmosphere, and meteorological conditions. Normally, ultraviolet (UV) light may break molecular oxygen (O_2) into two particles of atomic oxygen (O) *(1)*. One atom of O joins with an O_2 molecule to form the triatomic ozone and, additionally, the stratosphere is warmed by the absorption of the UV radiation *(2)*. Concurrently, UV rays also break ozone into smaller molecules *(3) or (4)*.

(1) UV + O_2 --> O + O + heat

(2) O + O_2 --> O_3

(3) UV + O_3 --> O + O_2 + heat

(4) UV + O + O_3 --> O_2 + O_2 + heat

While these two reactions *(3) (4)* normally fluctuate within a narrow range of equilibrium, the steadily increasing presence of man-made chemicals in the atmosphere appears to destabilize the balanced chemical reactions with the rate of ozone destruction currently exceeding the rate of ozone formation.

Chemicals effective at reducing the ozone layer are dominated by halocarbons. All include a carbon (C) atom surrounded by a combination of chlorine (Cl), bromine (Br), or fluorine (Fl) atoms. These chemicals are very stable until bombarded by ultraviolet radiation, at which point they release chlorine and bromine radicals which react with the surrounding odd oxygen molecules (O, O_3), converting them to molecular oxygen (O_2) *(5)*.

(5) Cl + O_3 --> Chlorine monoxide (ClO) + O_2

Chlorine and bromine monoxides (ClO, BrO) already present in the atmosphere or formed by this reaction are also capable of attacking odd oxygen molecules and converting them into molecular oxygen, thereby further depleting the ozone layer and reverting back into the original radicals, capable of further ozone depletion *(6) (7)*.

(6) ClO + O --> Cl + O_2

(7) ClO + O_3 --> Cl + O_2 + O_2

Other radicals which also appear to fit this catalytic cycle include chlorine monoxide dimers ($(ClO)_2$), hydroxyl (OH) and hydroperoxy (HO_2); more research is necessary to delineate all possible pathways of chemical ozone reduction. The presence of free nitrogen, hydrogen chloride and water in the atmosphere reduce the ability of bromine and chlorine molecules to attack ozone. If present in sufficient quantities, free nitrogen, hydrogen chloride and water neutralize the destructive radicals and prevent them from attacking ozone. If these chemicals are incorporated into stratospheric ice clouds, they are unavailable to neutralize the destructive radicals.

2. ECOLOGICAL RISKS

This section addresses the ecological implications of greenhouse induced climate change and ozone depletion. The ecologic implications of ozone depletion are not yet well studied; most efforts have addressed human health issues. The potential ecologic effects of climate change have been better addressed by ecologists, but only in a generalized manner.

2.1 Analytic Approach

Ecologic risks were evaluated by reviewing the literature and summarizing the anticipated scenarios for Washington state. The state-of-the-art in climate change and ozone depletion impacts analysis is not yet quantitative due to the uncertainties of the exact natures of the secondary, tertiary, etc., impacts. There is still little or no information specific to Washington state or even the Pacific Northwest. The implications of this for *Environment 2010* is that is not possible to conduct quantitative analyses for Washington state, in fact even qualitative discussions are often difficult. Quantitative capabilities are probably at least five years in the future.

2.2 Climate Change

There is not yet any published speculation on the effects of global warming on the natural systems of Washington state. The rate of temperature increase projected is unprecedented, and we are limited by our imagination as to the consequences. In general we can expect a migration of plant communities, and the animal communities associated with then, north in latitude and upward in elevation. Whether the plant communities will be able to migrate rapidly enough to keep up with climate change is speculative and of concern. The following excerpt from a memorandum report by the lead author (DJC) illustrates the kind of unexpected consequences global warming will have for Washington.

> On December 14, 1988 the Pacific County Planning Department convened a work shop to discuss recent findings on the status of *Spartina alterniflora* in Willapa Bay. Twenty eight attendees represented various federal, state, and local government agencies, academic interests, and local aquaculturists.
>
> *Spartina alterniflora*, Smooth Cordgrass, is a species native to the Atlantic Coast. First introduced to Willapa Bay in c. 1895, it appears to have been held in check by the relatively cool summer climate in western Washington. During the 1980s, *Spartina* has noticeably colonized larger areas; the expansion is attributed to the abnormally warmer summer temperatures of this decade.

If recent abnormally warm conditions continue, *Spartina* is predicted to expand from its present 680 acres to 31,000 acres -- 66% of the total intertidal mudflats of Willapa Bay -- by 2025. *Spartina* is more invasive in Willapa Bay than in its native habitat where a barnacle limits its range to above mean sea level, and insect predators limit its vitality within its range. In Willapa Bay *Spartina* grows from about the 3 foot tide level (2.5 feet below mean sea level) to the upper limits of the mud flats, and has no predators (Sayce, 1988).

The ecological implications of a *Spartina* invasion are the replacement of the native, mid-tide, diverse, mudflat habitat and associated species with a high intertidal *Spartina* monoculture. *Spartina* colonies eventually succeed to a high intertidal *Salicornia* marsh when sedimentation raises the marsh elevation above the tidal range in which *Spartina* competes most effectively.

The economic implications of a *Spartina* invasion is the loss of habitat for rearing and holding oysters, the principal aquaculture business in Willapa Bay.

An invasion of Willapa Bay, and other estuarine areas of Washington, could be the first documented ecologic effect of global warming in the state.

Intensity The intensity of impacts will, of course, vary in the different ecological communities in Washington state. Some communities will likely be little affected. As illustrated above, the impacts could be profound in other instances.

Reversibility There appears to be about a 60 year lag between the introduction of greenhouse gases and the resultant global warming; we are therefore committed to at least 60 years of global warming.

Scale Impacts can be expected across the entire state. Effects will be most noticeable along the edges of distinct ecologic communities.

Sensitivity Ecologic impact studies of climate change typically show address the northward movement of plant communities or ranges of species. In the Northwest, elevation controls community and species location as much as does latitude. Therefore, community and species migration will be both northward and to higher elevations.

Trend There are not yet any measurable trends, therefore it is not yet possible to speak in terms of trends.

Productivity/Uniqueness Unique plants will be most affected by climate change. Unique plants which, in Washington, are at the northern extent of their range will likely increase in extent and abundance. Unique plants which, in Washington, are at the southern extent of their range will likely decrease in extent and abundance or be extirpated in Washington.

Uncertainty Until better information on climate change in Washington has been developed, and until plant ecologists examine the issue with respect to Washington, no quantitative or species-specific analyses will be possible.

2.3 Sea Level Rise

National studies on the ecological effects of sea level rise are largely limited to wetlands, and then only to inundation and migration. This section reviews the ecological effects on wetlands and fish dependent on shallow water and intertidal habitats. The national literature also addresses changes in estuarine salinity, but we are not as yet able to discuss this issue for Washington's estuaries.

Intensity The intensity of the ecologic effects of sea level rise are variable and uncertain as yet for Washington state -- the requisite studies to sensitize national trends to local conditions have not yet been done.

Reversibility There appears to be about a 60 year lag between the introduction of greenhouse gases and the resultant global warming; the lag between global warming effects and corresponding sea level rise is not yet known. We are therefore committed to at least 60 years of accelerated sea level rise, and likely more. For all practical purposes, sea level rise is irreversible.

Scale The effects of sea level rise will be measurable along all marine and estuarine shorelines of the state. The ecologic implications will vary from place to place depending on the sensitivity of the local community.

Sensitivity Because marine and estuarine communities are inherently formed and regulated by salinity and the frequency and duration of daily tidal inundation, any change in sea level will have profound effects in the location of these communities. If they are unable to migrate inland, they will be eliminated.

Trend The existing sea level rise trend will be accelerated in coming decades; as noted, the most likely sea level rise scenario id a rise of approximately five feet by 2100.

Productivity/Uniqueness The habitats most affected by sea level rise, coastal wetlands, are both unique and highly productive.

Uncertainty Sea level rise is considered to be the most certain of the side effects of global warming. The degree and rate of sea level rise is, however, debated.

2.3.1 Wetlands Modification and Inundation
Sea level rise is generally expected to drown existing coastal wetlands, and where the topographic gradient permits, cause wetlands to migrate inland. Freshwater wetlands backing salt marshes may be converted to salt marsh. Coastal wetlands backed by developed lands will be prevented from migration by protection of the developed uplands (Titus, 1988). Initial computer modeling of the effect of sea level rise on selected Washington coastal wetlands predicted net gains in coastal wetlands (Armentano, Park & Cloonan, 1988), but the modeling assumptions appear to have been incomplete. The model has been enhanced, and the modeling of the Pacific coast is being rerun. The selection of coastal sites for the second modeling (5 sites in Puget Sound) was done by random sampling (Park, pers. comm.); because wetlands in Puget Sound are not randomly dispersed, but rather are clumped, therefore the results of this modeling, too, must be evaluated. The principal areas at risk are river deltas and estuaries plus nonestuarine coastal wetlands.

Intensity Whether a coastal wetland would be able to migrate inland, would be prevented from migration by topography, or be prevented from migration by existing or future development is site specific and not yet known on a broad scale. Where wetlands are able to migrate, it is likely that the newly established wetland would be smaller than before.

Reversibility Wetlands loss to sea level rise is irreversible.

Scale The extent of wetlands loss has not yet been studied quantitatively; Ecology's Shorelands and Coastal Zone Management Program proposes to inventory and evaluate coastal wetlands relative to sea level rise during the next few years.

Sensitivity Because marine and estuarine wetlands are inherently formed and regulated by salinity and the frequency and duration of daily tidal inundation, any change in sea level will have profound effects in the location of these communities. If they are unable to migrate inland, they will be eliminated.

Trend There is no existing quantitative information on the alteration of wetlands by present and recent sea level rise.

Productivity/Uniqueness Coastal wetlands are both unique and highly productive.

Uncertainty It is certain that wetlands will be affected by sea level rise; there is a high degree of uncertainty as to exactly how specific wetlands will be affected.

2.3.2 Fish and Shellfish
Surf Smelt (*Hypomesus pretiosus*) spawn through out Puget Sound, particularly in the South Sound, southern Hood Canal, Liberty Bay, and northern Saratoga Passage. Spawning occurs throughout the

year in the upper intertidal below mean higher high water (MHHW). Preferred spawning substrates range from coarse sand to pea gravel (Penttila, 1978).

Pacific Herring (*Clupea harengus pallasi*) spawn throughout Puget Sound, particularly in southern Hood Canal, Dabob Bay, Port Orchard Inlet and Liberty Bay, northern Saratoga Passage and Skagit Bay, and the Straight of Georgia. Their range is from Alaska to San Francisco Bay. The spawning period extends from January through early June. Eggs are deposited on marine vegetation in the intertidal and upper subtidal (Meyer & Adair, 1978).

Salmon (*Oncorhynchus* spp), particularly Pink (*O. gorbuscha*) and Chum (*O. keta*) juveniles use shoreline shallows as migratory and rearing areas to feed and escape larger predator fish (FWTC, 1970).

With rising sea level, the loss of some intertidal and shallow subtidal habitat can be expected. In some areas, upland property owners will react to sea level rise by raising existing bulkheads or building new bulkheads where none are now needed. In other areas, naturally occurring steep banks and bluffs will inhibit maintenance of shoreline intertidal and shallow intertidal habitats (see Section 4.6.3).

Intensity The loss of upper intertidal spawning habitat will occur at select location throughout the greater Puget Sound system; not all Surf Smelt and Pacific Herring spawning locations have been identified. The intensity of the loss of shallow water habitat and resultant effects on salmon will depend on the rate at which shoreline bulkheading and other similar environmentally undesirable practices take place.

Reversibility For all practical purposes the process is irreversible.

Scale See *Intensity* above.

Sensitivity The species affected are highly sensitive the effects; they have evolved to use the specific habitats for spawning or rearing.

Trend The effect of existing sea level rise is undocumented.

Productivity/Uniqueness No comment.

Uncertainty It is certain that intertidal and shallow water habitats will be affected by sea level rise; there is a high degree of uncertainty as to exactly how specific sites or locales will be affected.

2.4 Ozone Depletion

The ecological effects of ozone depletion are less well studies than are the human health effects. This section discusses interrelations of tropospheric ozone depletion with greenhouse climate change, plus some observed effects of increased UV radiation on Antarctic invertebrates.

Intensity The intensity of effects for Washington state is presently unknown.

Reversibility Ozone depletion is reversible on a scale of decades to centuries.

Scale Effects will occur state wide.

Sensitivity The sensitivity of Washington's ecosystems to UV radiation increases due to ozone depletion is as yet unknown.

Trend There is no existing data on which to base a trends analysis.

Productivity/Uniqueness No comment.

Uncertainty No comment.

2.4.1 Climate

The existing ozone layer screens out more than 99% of the incoming ultraviolet energy between 230 and 320 nanometers in wavelength and reradiates energy in the infrared wavelengths. This radiation of infrared light produces heating in the upper stratospheric layers and promotes vertical stability of the stratosphere. In the troposphere, heating occurs in the bottommost layers and the hot air constantly rises, forcing vertical instability and resulting climate changes. As the ozone layer decreases, the stratosphere cools, possibly changing the vertical temperature distribution and circulation of the stratosphere. Question still exists as to what this will mean for global warming and global climate disruptions.

2.4.2 Invertebrates

Fisheries are dependent upon the phytoplankton and micro organisms present in local waters. Studies in Antarctica indicate increased UV radiation may significantly alter the biologic diversity of similar species in the Pacific Northwest.

Larry Weber, a postdoctoral fellow at Texas A & M University has been studying crustacea and phytoplankton in Antarctica. Phytoplankton are the base of the marine food web. They convert inorganic compounds such as phosphorous and silica into organic plant matter, providing food for herbivorous zooplankton and krill which, in turn, are the major food source for larger free swimming animal life. Weber found that phytoplankton were two to four times more productive when UV light was excluded from their water. Increased UV radiation decreased the productivity of all types of phytoplankton, bringing about decreased photosynthesis, changes in protective pigment colorations, and significant shifts in species populations within the algal community (El-Sayed, 1988).

Further up the food web, studies in Puget Sound have shown that increased UV radiation decreases the activity, development rates, and survival rates of shrimp, shrimp-like crustaceans and crab larvae. Death rates in copepods are greatly increased while the fecundity in survivors is severely limited. Benthic organisms are often killed on exposure to excess UV radiation while egg development is retarded. Complex interrelations between water depth, mixing of water layers, seasonality of UV exposure, organism behavioral response, and the ability of each organism to repair damage should lead the scientific community to great caution in making predictions for Puget Sound (El-Sayed, 1988).

3. HUMAN HEALTH RISKS

This section discusses the potential human health effects of climate change, sea level rise, and ozone depletion. Quantitative analysis was not deemed appropriate.

3.1 Analytic Approach

Human health risks were evaluated by reviewing the literature and summarizing the anticipated scenarios for Washington state. The state-of-the-art in climate change and ozone depletion impacts analysis is not yet quantitative due to the uncertainties of the exact natures of the secondary, tertiary, etc., impacts.

3.2 Climate Change

It is difficult to predict specific regional impacts of global warming on human health. Current literature studies are limited by the fact that, until recently, human health problems created by regional climate change were considered less likely, and therefore examined less, than those created by rapid variations in weather. No reason existed to study changing climate in a specific region. This section (3.2) is summarized from White & Hertz-Picciotto (1985).

Therefore, in order to understand how climate change might affect Washington state, we can only describe some of the already known influences of climate and interrelated problems on human health. First, what changes in human health may be created by an increase in overall temperature? Second, what health burdens may be brought about by a variability in weather conditions.

An increase in overall temperature can change endemic disease currently evident within a region or state. Bacteria, viruses, allergens and fungi are distributed throughout the atmosphere and soils. They are affected by atmospheric conditions; temperature, precipitation, humidity, sunlight and wind contribute to their dispersal and survival. While some disease organisms are currently limited in their survival ranges, climate change could vary the areas in which they are prevalent and responsible for disease. Similarly, in vector-borne viral, ricketsial and bacterial diseases, the hosts of an organism may find their range or habits modified, causing the disease to become established out of historic endemic regions. Global warming may therefore provide new geographic areas suitable for the survival and increase of disease organisms. Washington state could find it necessary to increase costs associated with specific disease treatment or with increased control of disease vectors.

Concurrently, climate change may either increase or decrease the variability of weather patterns within the state. Climate variables (heat waves, excessively cold spells, heavy rains and warm or cold fronts) all affect human health, whether directly or through effects on disease bearing or causing organisms. Increased humidity adds to the human susceptibility to disease in cold weather and, in hot weather, aids survivability of many pathogenic organisms. Extreme temperatures, while modified by humidity, challenge the body's thermoregulatory system. Chronically ill, elderly and infant populations have difficulty acclimatizing to rapid, prolonged changes in temperature and exhibit increased mortality and morbidity during heat and cold waves. Individuals with otherwise healthy thermoregulatory systems may likewise suffer increased mortality or morbidity due to overexposure to temperature extremes. The question for Washington state revolves around whether the climate will become more consistent or whether Washington will experience increased variability in weather.

3.3 Sea Level Rise

Storm surges, the flooding induced by wind stresses and the barometric pressure reduction associated with major storms, will be aggravated by sea level rise in areas of low gradient offshore slopes (National Research Council, 1987) such as southwest Washington's ocean coast. In general, higher sea levels will provide a higher platform for coastal flood waters to inundate low lying areas. The magnitude of the problem has yet to be evaluated. The most susceptible areas are those mapped by FEMA (Federal Emergency Management Agency) as Velocity Zones, although other lowlying coastal areas are also at risk.

Death and injury often results from coastal flooding. Comprehensive information, however, is not compiled. Limited information on deaths and injuries due to coastal flooding is compiled by the Federal Emergency Management Agency and the Emergency Services Division, Washington Department of Community Development. This information is not in a form which readily enables analysis, therefore it is not possible to report on existing death and injury rates due to flooding, let alone future rates under sea level rise.

3.4 Ozone Depletion

3.4.1 Skin

Stratospheric ozone effectively absorbs ultraviolet radiation between the wavelengths of 200 to 320 nanometers. With a 1% decrease in upper atmospheric ozone, we can expect a 2% increase in UVB (wavelengths from 280-320 nm) exposure. UVB light is a major factor in human skin cancers, particularly basal and squamous cell carcinomas and malignant melanomas (Scheibner, et al, 1986). Increased exposure to all UV light is related to an increased risk of developing such skin cancers (Armstrong, et al, 1988).
Basal and squamous cell carcinomas are the most common cancer found in the United States with 400,000 to 500,000 cases reported

each year (Koh, 1989). They typically occur on sun exposed body sites of fair skinned Caucasians. Their incidence increases with increased age and cumulative lifetime exposure to sunlight (Scotto, et al, 1988). While rarely fatal, a 3-6% increase in these common skin cancers can be reliably predicted for each 1% decrease in ozone (Hoffman, 1987).

Malignant melanomas are the ninth most common form of cancer, with their incidence rising at a faster rate (93% increase during last 8 years) than any cancer except male lung cancer (Kripke, 1988a). Mortality from these cancers is also increasing with 6000 deaths out of an estimated 27,300 cases reported in 1988 (Koh, 1989). They result from UV induced cellular damage which, under laboratory conditions, contributes to both their induction and subsequent growth. They occur throughout the body and appear related not only to lifetime total sun exposure but also to acute episodes of sun exposure or sunburn (Kripke, 1988a). Research now indicates some relationship between malignant melanomas and UV induced damage to the immune system. A 1% decrease in ozone can be predicted to cause a 1-1.5% increase in malignant melanomas (Hoffman, 1987).

3.4.2 Eyes

UV radiation is suspected of contributing to three types of ocular changes. Biochemical descriptions of such changes have yet to be thoroughly explained and further research is in progress.

High cumulative exposure levels of UVB radiation significantly increase the risk of cortical, or lower inner quadrant of the lens, cataract formation (Taylor, et al, 1988). This type of cataract is common in the tropics. A recent study of Chesapeake Bay fishermen provides information indicating that a doubling of the cumulative UVB exposure increased the risk of cortical cataract by a factor of 1.60 with a 95% confidence interval (Taylor, et al, 1988). Age related macular degeneration involves progressive deterioration of the outer layers in the center of the retina. The process is irreversible and untreatable. High energy visible and UV photons have been shown to produce this type of molecular damage by a photochemical mechanism (Young, 1988). While still statistically inconclusive, evidence is accumulating that solar radiation is responsible for some of deteriorative changes leading to macular degeneration.

Pterygium is a degeneration of the epithelial conjunctiva, or scar tissue on the inner surface of the eye extending from the conjunctiva to the cornea. Such scars commonly grow across the cornea and pupil and must be surgically removed. They are the most common result of ocular overexposure to UV radiation and prove costly due to the large numbers of patients requiring surgery (Prendergast, 1989).

3.4.3 Immune System

Limited information exists on the actual connection between excess UV exposure and disease. Only recently have changes in immunofunctions after UV exposure been studied in detail. The significance of such immune changes on the incidence of skin cancers and human infectious diseases is, as yet, undetermined (Kripke, 1988b). Laboratory research so far indicates three perturbations in immune response, occurring both locally in irradiated skin and systemically at sites distant from the area of irradiation (Kripke, 1988a).

First, a population of immune cells called Langerhans cells resides in the skin and initiates immune responses to foreign substances so they can be recognized and destroyed by white blood cells. UV radiation alters the Langerhans cells morphologically and decreases their numbers, destroying the skin's capability to respond to foreign substances or infective organisms (Kripke, 1988a).

Second, the white blood cells, named T-lymphocytes, can themselves be affected by UV radiation. Their role is to help regulate the function of other disease fighting lymphocytes. Two types of T-lymphocytes, helper and suppressor cells, have currently defined roles in the immune system. T-helper cells augment the response of disease fighting lymphocytes while T-suppressor cells limit the response of disease fighting lymphocytes. Increased exposure to UV light greatly increases the systemic proportion of T-suppressor cells in relation to T- helper cells with a resulting decrease in the immune system's ability to fight disease. This change in T-cell ratios is expected to bear a role in the appearance of malignant melanoma on sites distant from sun exposed body surfaces. The suppressed immune response may also affect other infectious diseases such as herpes and parasitic infections (Kripke, 1988b).

Cellular DNA can also be directly damaged by exposure to UV radiation. Increased spontaneous cellular mutations and a decreased ability to repair damage created by either UV exposure or disease processes may have an as yet undetermined effect on human health (Kripke, 1988a).

4. ECONOMIC RISKS

A relatively large body of scientific and technical literature exists on the effects of climate change and sea level rise on economic sectors, and less so for ozone depletion. For the most part, however, this literature is national or global in scope. The US Environmental Protection Agency's *Draft Report to Congress* on *The Potential Effects of Global Climate Change on the United States* (Smith & Tirpak, 1988) makes an initial attempt to address regional studies on the effects of climate change and sea level rise for California, the Great Lakes region, the Southeast, and the Great Plains. Global Warming and Ozone Depletion authors and analysts had varying success in finding studies specific to the Pacific Northwest or Washington state.

This section addresses the effects of climate change on agriculture, energy, fisheries, and forestry in separate subsections. The agriculture and fisheries discussions also address ozone depletion. The sea level rise subsection addresses flooding, coastal geophysical effects, wetlands, sea water intrusion and coastal water tables, and coastal drainage systems. Economic analyses are contained in a separate chapter.

4.1 Analytic Approach

Economic risks were evaluated by reviewing the literature and summarizing the anticipated scenarios for Washington state. The state-of-the-art in climate change and ozone depletion impacts analysis is not yet quantitative on a regional basis due to the uncertainties of the exact natures of the secondary, tertiary, etc., impacts. The information specific to Washington state or the Pacific Northwest is still generalized. The implications of this for *Environment 2010* is that is not possible to conduct quantitative analyses for Washington state, although semiquantitative discussions are often possible. Quantitative capabilities are probably two to five years in the future.

4.2 Climate Change, Ozone Depletion and Agriculture

The effects of climate change on agriculture are complex, and not all factors have as yet been taken into account in the available studies upon which this report is based. Increased temperatures will tend to shift crops zones north, requiring crop substitutions by farmers. Increased temperatures will increase plant evapotranspiration and water stress, but the accompanying higher carbon dioxide levels will cause plants to use water more efficiently. The net effect will depend on the availability of soil moisture and/or irrigation water, both of which are matters of uncertainty for Washington state.

Additionally, plants respond to increased carbon dioxide with increased growth rates in two fundamentally different ways; they are characterized, for this purpose, as C3 or C4 plants. C4 plants (e.g. soybean, wheat, cotton) show little response to carbon dioxide increases above 340 ppm, while C3 plants (e.g. corn) show considerable increase in growth. Thus C4 crops afflicted by C4 weeds would be at a disadvantage. Again, this is a poorly explored area of concern.

In summary then, the following discussion should be considered preliminary.

4.2.1 Agriculture, the Greenhouse Effect, and Ozone Depletion

As the greenhouse effect increases the average temperature, changes the magnitude and frequency of precipitation, and ultimately alters the hydrology in Washington, the nature of agricultural production could change. Similarly, depletion of the ozone layer could have a significant impact on agriculture. Agricultural researchers have only recently begun to explore the potential impacts from global warming and ozone depletion (Adams & McCarl, 1985; Decker, Jones & Achutuni, 1986; Kopp, et al, 1985; Adams, 1989). These efforts have been focused at the national level, with only passing effort to disaggregate results to a particular region. Thus, the following discussion relies heavily on the national work.

4.2.2 Impacts from Climate Change

In a study for the Environmental Protection Agency, Adams, Glyer, and McCarl (1988) measured the economic effects of changes in crop yields and water availability arising from projected long-term changes in climate associated with a doubling of CO_2. According to the base case of Adams, Glyer, and McCarl, the aggregate net loss in economic welfare to the US could range from $6 billion to $33 billion annually. To test the sensitivity of the results, the authors used a range of climate scenarios from both the GISS and GFDL climate models, assumptions about the structure of US agriculture over the next 70 years, and scenarios on crop yield and water availability.

In addition, Adams, Glyer, and McCarl combined estimates of long-term changes in technology, food demand, and the potential yield-enhancing effects of CO_2 with the assumptions of the base case. These factors serve to moderate the economic consequences of a doubling of CO_2, such that the aggregate change in economic welfare to the US ranges from a slight increase in economic welfare to a net loss of about $10 billion.

Regionally, Adams, Glyer, and McCarl find that, with a doubling of CO_2, crop production will decrease in southern areas and increase in northern and western areas. The authors predict that the changes in temperature and precipitation would work to increase irrigated acreage because of a corresponding increase in the comparative advantage of irrigated versus dryland yields and a projected rise in commodity prices that would make irrigated production more economically feasible.

For the Pacific states (California, Oregon, Washington), under the assumption that CO_2 enhances crop yields, Adams, Glyer, and McCarl predict an increase in land used for agriculture from eight to 13 percent. Irrigated acreage could either increase or decrease by about six percent, depending on whether the GISS or the GFDL model is used. Gross revenues from agriculture in the Pacific region could increase by as much as 30 percent.

As Adams, Glyer, and McCarl indicate, it appears that climate change will not bring a food security issue for the US, since the production capacity of US agriculture is adequate to meet domestic needs even under extreme climate changes. The authors note that their study does not address the effects of climate change on global agricultural production, which could modify patterns of agricultural trade.

Rather, this study suggests that climate change will portend major adjustments in resource and environmental quality. In the agricultural sector, a climate change could induce shifts in crop pest and disease infestations. Expansion of irrigation and shifts in regional agricultural production patterns could imply more competition for water resources, a larger potential for ground and surface water pollution, loss of wildlife habitat, increased soil erosion, and changes in the structure of local economies.

4.2.3 Impacts from Ozone Depletion

According to research conducted by the Environmental Protection Agency's National Crop Loss Assessment Network, one of the major pollutants that causes crop yield losses is ozone (either tropospheric or atmospheric). By modeling the response of plants to different levels of ozone and adjusting for variations in growing seasons and levels of moisture stress, researchers have developed a mathematical relationship between ozone and crop yield.

In a 1989 study, Adams estimated the change in economic welfare in the US attributable to alternative levels or standards of tropospheric ozone. This change ranges from an increase of $808 million annually for a 10 percent reduction in ozone to an increase of $2.7 billion annually for a 40 percent reduction, or about three to five percent of gross crop value in the US The gains of a reduction in ozone accrue to both producers and consumers. For scenarios that reduce ozone from 10 to 40 percent, about 25 percent of the increase in economic welfare accrues to producers and 75 percent accrues to consumers. These levels of increase might be reduced somewhat, depending on the nature of federal agricultural price and supply programs that are in effect.

Similarly, in 1988 Adams and Rowe estimated the change in economic welfare in the US attributable to the depletion of stratospheric ozone. In this case, the depletion directly affects crop yield adversely, but also serves to increase the amount of tropospheric ozone, which then decreases crop yields further. According to Adams and Rowe, if stratospheric ozone is reduced by 15 percent, that will give rise to a 13 percent increase in tropospheric ozone. Both of these effects together would decrease the economic welfare to the US by about $2.6 billion annually.

4.3 Climate Change and Energy

4.3.1 The Greenhouse Effect and Energy in Washington State

Global warming will likely affect Washington's energy system primarily by changing the balance of electricity supply and demand, although an increase in temperature could also affect the demand for other forms of energy used for space heating and cooling. Even a small amount of atmospheric warming could conceivably change many climate variables -- such as surface and air temperatures, evaporation rates, precipitation levels, and wind patterns -- that will in turn have a major effect on weather-dependent electricity sources such as wind, solar, and especially hydropower.

Washington has the largest hydropower generating system in the nation, producing 30 percent of all hydropower in the US (Edison Electric Institute, 1988). In 1987, that represented 94 percent of the electricity generated in the state, and 109 percent of the electricity consumed. (Washington state is a net exporter of electricity.) States that could supply Washington with electricity also generate a significant amount of electricity with weather-dependent systems. Oregon, California, Montana, and Idaho produce 45 percent of the nation's hydropower (Edison Electric Institute, 1988). Hydropower represents approximately 90 percent of the electricity produced in British Columbia, which has developed but one-third of its hydropower potential (B.C. Hydro, 1988).

In the Northwest, unlike other regions of the country, hydropower primarily supplies the base demand for electricity, rather than the peak demand. Thus, the region relies on year-round hydropower production, which makes the nature and timing of precipitation as important as the quantity. Major weather changes could have a significant impact on hydropower production in and around Washington state. However, it is unclear whether those changes in electricity supply, when coupled with weather-induced changes in electricity demand, would produce either a more or a less favorable energy environment in Washington.

4.3.2 Effects on Electricity Supply

Washington's hydropower system is driven by water from rain runoff, snow melt runoff, or through controlled reservoir releases. However, on the major hydropower river system in Washington -- the Columbia/Snake river system -- reservoirs at full capacity represent only 32 percent of the annual average flow of the river (fifty year average as measured at the Dalles dam). As it is operated now, the Columbia/Snake hydropower system relies heavily on snow melt and reservoir water to produce power during the dry summer and fall seasons. Reservoir water also produces power to meet power demand during the winter. Excess rain runoff and snow melt runoff from early spring to midsummer refills the reservoirs. Hydropower systems on other Washington rivers operate similarly.

On the Columbia/Snake system, snow-melt runoff accounts for about 85 million cubic feet of water per year, or 60 percent of the annual flow through the rivers' hydroelectric power system (fifty year average as measured at the Dalles Dam, as estimated by the US Army Corps of Engineers, Pacific Northwest Division.) The Bonneville Power Administration estimates that roughly each million cubic feet of water above the Dalles dam represents approximately 1.1 billion kilowatt hours of electricity generation (Columbia Basin average as estimated by Bonneville Power Administration, Power Planning Division).

For this reason, an increase in regional temperature could have more impact on the hydropower system than an increase in precipitation. As mentioned in sections 1.4.2 and 1.4.3 of this report, both the GISS and GFDL models forecast Northwest temperature increases of approximately 4.5 degrees Centigrade (C). The relatively low altitude of Northwest mountain ranges and the already mild climate suggest that a fair amount of snow is produced very close to the rain/snow margin, especially during early and late winter. Although no study has yet assessed the sensitivity of Northwest snowfall to long-run temperature changes, an average increase of 4.5 degrees C could reduce snowfall in the region.

A decrease in snowfall would lead to a smaller snowpack, although the snowpack most important to the power system -- in southern British Columbia, Montana and Idaho -- could be less affected than the southern Cascades. A reduction in snowpack could significantly change the way the hydroelectric system is operated and has implications for stream flow predictability. At present, operators estimate future water supply and fill reservoirs as needed to meet winter demand. During a dry year with little snowfall, the hydropower system uses little water from reservoirs in order to ensure a sufficient supply of water for winter power production.

With an increased average temperature and reduced snowfall, large water volumes could be available during a short winter period, forcing hydropower operators to serve winter demand and fill reservoirs at the same time. Reservoirs could be drafted during the summer and fall, with no assurance that next winter's rains would be sufficient to meet electricity demand. It is unclear whether a change in the hydrology would lead to fewer or more unplanned non-generating reservoir releases, which affect the total supply of water available for electricity generation. The change in the predictability of stream flows appears to be the clearest impact of a temperature increase. It is not clear whether that impact would be a benefit or a cost to the state's hydropower system. The GISS model predicts an evaporation increase of 17 percent and a precipitation increase of 23 percent, while the GFDL forecasts increases of 10 and 2.7 percent. The GISS model also predicts that the increase in precipitation will occur during all seasons. If this proves true, the hydropower system could rely less on drawing water from reservoirs during the summer and fall.

4.3.3 Effects on Electricity Demand

Precipitation, evaporation, and wind changes would likely have little effect on the demand for electricity. But a rise in average temperature could increase the severity and length of the summer cooling season, increasing electricity demand. That same average temperature increase could produce a milder and shorter winter heating season, decreasing electricity demand. It is unclear whether the net result would be an increase or decrease in total electricity demand.

Air conditioning currently accounts for only about one percent of the total electricity used by the Northwest residential sector and about nine percent of the total electricity used by the Northwest commercial sector. Space heat accounts for about 25 percent of the total electricity used by the Northwest residential sector and 28 percent of the total electricity used by the commercial sector (Northwest Power Planning Council, 1986).

In 1981, the Bonneville Power Administration measured the weather-sensitivity of peak and average electricity demands during the winter. For the Northwest as a whole, the estimated response to temperature change was about 270 and 262 megawatts per degree Fahrenheit (F) for peak and average demands. Thus, according to the BPA study, an increase in average temperature of 4.5 degrees C could result in a regional decrease in winter of as much as 2,193 megawatts of peak demand and 2,124 megawatts of average demand, or about 12 percent of the region's total demand in each case (Bonneville Power Administration, 1981).

In 1988, the Environmental Protection Agency studied changes in US electricity demand from climate change using the GISS, GDFL and OSU models. According to this study, the Northwest could experience a decrease in net (heating decrease and cooling increase) average electricity demand from zero to five percent and a decrease in peak electricity demand from zero to ten percent.

In a forthcoming report, Dr. Joel Loveland of the University of Washington's School of Architecture estimates changes in electricity demand for six types of buildings due to global warming. He finds increases in Northwest residential air conditioning demand and decreases in residential heating demand that will likely produce no net change in residential demand. However, increases in commercial air conditioning demand of 40 to 75 percent will likely far outweigh the reduction in commercial heating demand. Overall, Loveland estimates an increase in net demand for electricity such that the highest seasonal demand for electricity in the Northwest will shift to the summer.

In general, it is difficult to calculate the effect of a change in heating or cooling requirements, since many Washington structures operate close to a 55 degree F balance point (the temperature at which a building shifts its requirements between heating or cooling). As a result, even a small change in average temperature could cause a large change in electricity demand.

It is reasonable to expect that Washington's share of any change in electricity demand would be proportional to the change experienced by the Northwest region as a whole. In absolute terms, Washington residents and businesses account for about 70 percent of the Northwest's total electricity demand. Thus, most of the increase or decrease in regional demand would occur in Washington.

Although about 50 percent of Washington single family homes, nearly all multiple family dwellings, and 70 percent of businesses use electricity for space heat, those that heat with oil or natural gas could also experience a reduction in demand for heating energy due to an average increase in temperature.

4.3.4 Energy Policy Considerations

Washington's energy system has not yet been analyzed in detail with respect to possible climate changes from the greenhouse effect. However, preliminary analysis reviewed in this report suggests that an increase of 4.5 degrees C in the Northwest could have significant impacts on electricity supply and demand. These impacts on the supply and demand balance could be economically beneficial or detrimental to Washingtonians.

If climate changes influence the supply and demand balance such that demand exceeds supply, the region will need to rely on demand-management strategies, development of renewable resources, and possibly additional high-cost, large-scale thermal resources. Certain types of thermal resources -- such as those from fossil fuels -- might be even more costly than they are today, in order to prevent the emission of CO_2 or other greenhouse gases. In an extreme scenario, certain types of fossil fuel generation could be banned entirely, which might serve to raise the cost of the remaining types of thermal generation. Thus the economic impacts to Washington could be negative, due to an increased cost of electricity.

On the other hand, if climate changes influence the supply and demand balance such that demand remains below supply over the long-run, (particularly due to a reduction in winter demand which is not offset by a decrease in winter supply), then the region may not need to develop new electricity resources solely due to changes in climate. In this case, the economic impacts to Washington could be positive, due to a decreased cost of electricity and increased revenues from the sale of power to the Southwest.

The Northwest will likely continue to rely on its extensive hydropower base of electricity over the long run. If changes in climate work to decrease the amount of surface water, policy issues regarding the competing uses of water could continue to be the focus of intensive debate. The priority of using rivers to produce hydroelectricity, as opposed to using the water for agriculture, municipal and industrial uses, or fisheries, could also affect the supply and demand balance, and the total cost, of Washington's electricity system.

4.4 Climate Change, Ozone Depletion and Fisheries

4.4.1 Introduction

Experts are in general agreement that changes will occur due to the greenhouse effect and the ozone layer depletion although the magnitude of events and the time frame are difficult to assess. Some of the fairly drastic changes hypothesized include: an increase in average annual atmospheric temperature of 2-4°C (potentially making Washington's climate similar to northern California), changes in the rainfall patterns (sharp increases or decreases), an increase in sea surface temperatures of 1-2°C, and a significant rise in sea level (see Section 1.6).

Prediction of the climatic, oceanographic and radiation consequences which will result from the global warming trend and depletion of the ozone layer is difficult. Translation of those effects into changes in fish or shellfish production is even more speculative. While we do not have accurate predictions about the fishery related consequences, we have many questions and concerns relating to these two phenomena.

Given the very speculative nature of this discussion, the scenarios should not be taken as actual predictions of the consequences of ozone layer depletion or the global warming trend. In some cases, the possible results described may represent "worst case" consequences; in others they may be underestimates of impacts.

4.4.2 Ozone Depletion

We currently have several "holes" in the ozone layer. Further depletion of the ozone layer is predicted to cause an increase in the amount of ultraviolet radiation reaching large areas of the surface of the earth.

Our questions and concerns relating to the depletion of the ozone layer involve a wide variety of resources. As the amount of ultraviolet radiation reaching the earth's surface increases, the fish resources most vulnerable to impact are probably marine species. Virtually all shellfish resources of commercial and recreational importance have larvae and, often, eggs which float at or near the surface of the water for days or weeks during development. This is also true for a variety of marine fish species including the flatfish (such as English sole and halibut) and rockfish. These resources are extremely vulnerable to changes in the surface layer of the ocean (often referred to as the "micro-layer"). As increased ultraviolet radiation penetrates the surface of the water column, eggs and larvae of fish and shellfish are likely to suffer extreme damage. We do not have information on the range of vulnerability to damage. Certain species may be more resistant and come to predominate as a result.

The effect the increased ultraviolet radiation will have on marine phytoplankton (free-floating microscopic plants) is of major concern. Marine algae are a major sink for carbon dioxide, slowing the rate of global warming. At the same time, phytoplankton are very sensitive to UV light. Increases in UV may decrease phytoplankton production and/or change the species composition. Since phytoplankton are the basis for most ocean food chains, these changes could have profound effects on the food available and the types and quantities of fish production occurring in the ocean.

4.4.3 Climate Change

In relationship to the greenhouse effect, we can hypothesize potential consequences for resources we manage based on the present differences in fish populations between Washington and northern California, the effects of the 1988 drought, and historic changes during El Ninos (periods of ocean warming). In some cases, there may be both positive and negative potential consequences to the same species and the net effect can not be predicted.

Under the present conditions, Washington state is located at the southern extremity of the range of several commercially and recreationally important species. Pacific cod and pink salmon are examples of resources which are not found south of Washington state. We are also close to the southern end of chum salmon and razor clam range. The ranges of Coho and Chinook extend south into northern California although runs of these species have been weak in California in recent years. Pink shrimp populations are weak, at best, in northern California. If the Washington climate changes to resemble northern California's, the ranges of all of these species may undergo a northward shift, with populations of fish such as the salmon species dwindling or disappearing in Washington state and other species appearing. This prediction assumes that climate is the factor limiting the ranges of these species. If their occurrence is tied to some other factor such as the present pattern of ocean upwelling, other patterns of abundance might result.

Some confirmation of the probability of these major shifts in populations is available by looking at the observations during historic El Nino events and during the recent drought years in the Pacific Northwest. While there has not always been a proven link between the changes observed and the oceanic and climatic conditions, the observations are still of some interest in this discussion.

During past El Nino events, a number of sub-tropical species appeared off the coast of Washington. These included large numbers of bonito (tuna) as well as some non-commercial species. Ghost shrimp, a species which causes problems for oyster growers, underwent a major increase during a past El Nino. Other typical Washington species did not fare well during the recent El Nino event. The reproduction of the Pacific cod was depressed, and the razor clam populations may have been adversely affected. Chinook and Coho produced in the Columbia and coastal systems had reduced marine survival during this period.

The 1988 drought conditions are thought by some to be possible evidence of the effects of global warming. The drought has undoubtedly had a negative effect on Coho and Chinook production. Both Coho and Chinook salmon depend on freshwater streams for rearing for all or part of their first year of life. With the decrease in streamflows, there is less area available for juveniles to rear and the numbers produced decline. In addition, both of these species must migrate upstream as adults to deposit their eggs. During extremely low-flow conditions, upstream migration may become impossible for adults, especially Chinook which spawn in the early fall before winter rains. While the adults may find a place to deposit their eggs in the downstream areas, egg survival may be poor and the upstream area will go unused for juvenile rearing, further reducing production.

By comparison, the consequences for pink chum and Sockeye salmon could be quite different. Pink, chum and Sockeye salmon production has often been limited by high winter flows which scour the eggs out of the gravel before they hatch. If the greenhouse effect produced mild winters with moderate flows (as during the past few drought years), these species might benefit. On the other hand, if winter storms increased with the global warming, freshwater production of these species might also decrease. As noted above, any fresh water change in production might be masked by changes in marine survival due to changes in ocean currents and upwelling patterns.

A side-effect of the drought is the increased demand for fresh water for agriculture, industry and population centers. We already have competition for fresh water between salmon resources and human uses. This competition could be intensified if drought conditions were more common in the future.

Current hydrologic scenarios (see Section 1.5) suggest a substantial shift in the timing of peak runoff of snow fed streams from spring to winter. Stream flows will be greater from November through April, and less from May through August. These changes are expected to have substantial adverse effects on the productivity of salmon. Spawning and deposition of eggs which occurs during late fall and early winter will be subjected to greater stress due to higher, more turbulent flows. Young salmon now migrate out to the ocean on the spring freshet (peak Flow) which is expected to occur during the winter under global warming scenarios further stressing reproductive success. Overall, salmon productivity is expected to be substantially lowered. These is archeological evidence for similar conditions and effects during the Hypsithermal (8,000 to 5,500 ybp) and Little Climatic Optimum (1,050 to 700 ybp) (Chatters, 1989).

4.4.4 Sea Level Rise

To consider the effects of a potential rise in sea level, we must look at the physical changes which will result from the rise as well as the probable response of both people and fish life to these changes. If there is a significant rise in sea-level many intertidal areas will be under water. Many flat intertidal areas would become steep shorelines as the rising water moves farther shoreward. The owners of many facilities built along the water (ports, housing areas, etc.) will be interested in measures to protect their property. Protection measures proposed may include construction of vertical bulkheads, large landfills at the site of existing docks or piers, and diking of developed areas. All of these measures entail filling in or loss of the shallow water areas now being used for juvenile fish rearing. Even those areas which are simply flooded by the rising sea level will change drastically. The resulting steeper intertidal areas would have limited intertidal beach available for rearing fish. Intertidal spawners such as the surf smelt might have no usable habitat left.

In addition to the effects of such responses to the rise in sea level, the changes in the shoreline and the increase in water depths may affect other resources directly. For example, nearly all the oyster production in the state occurs in the intertidal areas. Inundation of historic oyster grounds could decrease the capacity of these areas for growing oysters and reduce the state's oyster production considerably.

4.5 Climate Change and Forestry

The major climate changes expected in a global warming scenario are:

1. Increased average annual temperature by 3° to 5°C;
2. Increased mean winter monthly temperatures;
3. Static or slightly increased total precipitation; and
4. Increased evaporation relative to precipitation during the spring and summer growing seasons

The impact of these climatic changes on the growth and health of forests is dependent on the plants' reaction to these stresses in combination with a carbon dioxide-loaded atmosphere. Experiments on seedlings suggest that a doubling of atmospheric carbon dioxide may mitigate or compensate for many of the direct and indirect stresses produced by changes in temperature and precipitation. What is not known is the extent to which mature trees respond like seedlings, nor how the specific impacts and compensating effects work synergistically.

Additionally, forest scientists are just coming, in recent decades, to understand the symbiotic relationships between forest trees, fungi, and microbial communities. Theoretical research on the effects of climate change on forest trees has focused on a few trees of high commercial value; little effort has as yet been directed at climate change and forest ecology.

4.5.1 Increased Average Annual Temperature

Heat Stress on Plants The optimum temperature for photosynthesis increases by approximately $5^{o}C$ in an atmosphere with double the present level of carbon dioxide. Thus, within the range of projected temperature increase, elevated levels of carbon dioxide will compensate for higher temperatures without unduly stressing the plants.

Overheated Soil Air temperature is not as significant as soil moisture, color and texture in the development of lethal soil temperatures. And shading is an important mitigating factor. For these reasons, heat girdling of seedlings is not projected to increase significantly with the projected global warming.

4.5.2 Increased Mean Winter Monthly Temperatures

In regions of summer drought or at high altitudes with short growing seasons, synchronization of germination and shoot growth with seasons depends on trees or seeds receiving sufficient winter chilling (Lavender, 1981; Campbell, 1978 in: Leverentz and Lev, 1987). Scientists do not agree on the length of time and degrees of temperature required for sufficient chilling. One study (Copes, 1983 in: Leverentz and Lev, 1987) suggests that Douglas fir will not survive in areas where the mean monthly temperatures do not drop below $9.3^{o}C$. Under the Copes scenario, Douglas fir will meet chilling requirements and maintain or increase (up slope) its range in western Washington, and decrease its range in eastern Washington. Lavender (1988) reported that Douglas fir has a chilling requirement of 12 to 14 weeks at about $5^{o}C$. Given a projected mean winter temperature increase of 5^{o} to $7^{o}C$ (which is higher than the 3^{o} to $5^{o}C$ projection in this report), Lavender predicts that Douglas fir will be eliminated from productive forest stands at least below 1000 feet in elevation. If mean monthly temperatures do not drop below $7^{o}C$, a figure intermediate between those cited by Copes and Lavender, it is projected that Douglas fir will be eliminated from lower elevation sites along the entire West Coast of the US, in the Willamette Valley of Oregon, and in the Sierra Range of California (Leverentz and Lev, 1987)

For those tree species whose chilling requirements can be met in the projected climate scenario, their distribution in the lower elevations is not expected to change. For most species, the upper elevation limit of their range is projected to rise. A consequence of this shift could be a reduction in subalpine meadows and subalpine tree species in most mountain ranges.

4.5.3 Static or Slightly Increased Precipitation

Total precipitation in Washington state is expected to stay the same or increase slightly, however more of the precipitation may fall in the winter months and in the form of rain instead of snow. The combined effect of increased temperatures and less rainfall in the growing season (spring and summer) is projected to change the site water balance -- precipitation minus evaporation.

4.5.4 Increased Evaporation Relative to Precipitation in the Growing Season

Using the projected precipitation increase (11 to 30 %) reported in Gibbs and Hoffman (1987), and changes in evaporation calculated for a warmer climate, Leverenz and Lev (1987) estimated changes in site water balance for the western United States. Their data suggest a general drying of the summer climate in Washington due to increased evaporation in the warm months. In areas like coastal Washington which have a relatively high summer rainfall increased evaporation is not likely to affect the areas ability to support tree growth even in a warmer climate (Leverentz and Lev, 1987).

Plant response to decreasing site water balance is mitigated by doubling the available carbon dioxide. Assuming that a doubling of atmospheric carbon dioxide may more than compensate for a decreased site water balance of less than 25% and completely compensate for a decreased site water balance ranging from 25 to 50%, Leverentz and Lev (1987) project that the distribution of conifers in Washington will not change substantially as a result of changes in precipitation and evaporation. However, if a doubled concentration of carbon dioxide can only compensate for a 25% decrease in site water balance, then almost the entire West is projected to become drier and major shrinkages of forest zones are projected as species move up slope almost everywhere.

4.5.5 Secondary and Tertiary Effects

The secondary and tertiary effects of doubled carbon dioxide and global warming are not known, however the following effects are possible.

* It is possible that rapid leader elongation may predispose trees to wind damage.

* Warmer, wetter autumns may prevent "hardening off" leaving trees more vulnerable to frost damage.

* Increased CO2 might cause earlier flowering and increased seed production due to the increase in ratio of carbon to ni-

trogen (Kramer and Sionit, 1987)

* Woody plants may require more nitrogen and in some areas more phosphorus to obtain maximum benefits from the CO_2 increase (Kramer and Sionit, 1987)

* Tolerance to air pollution could increase due to partial closure of stomata in response to increased levels of CO_2

* Increased potential for wildfire is projected due to less spring and summer precipitation, and increased winter runoff.

* A drier climate and increased water stress are likely to increase attacks by boring insects (Kramer and Sionit, 1987).
* Rising carbon dioxide levels could alter the type and magnitude of pest problems (Sandenburgh, et al., 1987)

* Competition with shrubs or grass may substantially change and severely restrict natural regeneration in some areas.

* The possibility of competition from angiosperms is unknown, but may be severe in an atmosphere of doubled carbon dioxide.

* Conifers have fixed growth and may suffer in relation to plants with free growth.

* In general, the competitive capacity of C3 relative to C4 plants should be increased by increasing concentrations of CO_2. However, all forest trees have the C3 carbon pathway, and the differences in competitive capacity among species are likely to be smaller among trees in forests than in communities of annual plants (Kramer and Sionit, 1987).

4.5.6 Genetic Adaptation to Global Change

According to Kellison and Weir (1987) one generation of genetic engineering will not be long enough to make a species more adaptable to global change. However, since in every generation the best survive, the preferred course of action will be to maintain genetic diversity which is greater within a stand of trees established from genetically improved seed than it is in a natural stand (Kellison and Weir, 1987). This strategy will be made possible by the shift from harvesting of old growth natural forests to establishing and tending younger-planted forests which is nearing completion in the Douglas fir region. Management of plantations on a site-by-site basis should allow future managers to adjust more quickly to local climate changes (Woodman, 1987).

4.6 Sea Level Rise

The National Research Council (1987) Committee on Engineering Implications of Changes in Relative Mean Sea Level reached the following conclusions and recommendations:

* The risk of accelerated mean sea level rise is sufficiently established to warrant consideration in the planning and design of coastal facilities.

* Accelerated sea level rise would clearly contribute toward a tendency for exacerbated beach erosion.

* Retreat is the most appropriate response in areas with a low degree of development; protection of developed areas is financially and fiscally feasible.

* Defensive or mitigative strategies are site specific and cannot be developed nationwide on the basis of a blanket generalization or comprehensive legislation.

There has been a relatively great effort exerted nationally to address the effects of sea level rise since about 1983, and therefore there is an abundant literature. In 1988, the Shorelands and Coastal Zone Management Program, Washington Department of Ecology, began an investigation of the implications of Sea level rise for Washington state. Current project plans should result in the identification of policy response alternatives in 1990, and specific knowledge of impacts beginning in 1991. The following discussion represents the current state-of-the-knowledge.

4.6.1 Storm Surges and Flooding

Storm surges, the flooding induced by wind stresses and the barometric pressure reduction associated with major storms, will be aggravated by sea level rise in areas of low gradient offshore slopes (National Research Council, 1987) such as southwest Washington's ocean coast. In general, higher sea levels will provide a higher platform for coastal flood waters to inundate low lying areas. The magnitude of the problem has yet to be evaluated. The most susceptible areas are those mapped by FEMA (Federal Emergency Management Agency) as Velocity Zones, although other lowlying coastal areas are also at risk.

Property often results from coastal flooding. Comprehensive information, however, is not compiled. Limited information on property due to coastal flooding is compiled by the US Army Corps of Engineers, the Federal Emergency Management Agency and the Emergency Services Division, Washington Department of Community Development. This information is not in a form which readily enables analysis, therefore it is not possible to report on existing property damage rates due to flooding, let alone future rates under sea level rise.

Economic implications also include the protection by levees and sea walls of at-risk areas, where financially and technically feasible. Retreat and abandonment may be necessary in areas where the cost of protection exceeds the value of the property and facilities.

4.6.2 Sandy Coast Shoreline Retreat
Rising sea level is accompanied by a general recession of the shoreline due to inundation or erosion (National Research Council, 1987). Most susceptible are sandy, unconsolidated shorelines such as that of southwest Washington. The coast of southwest Washington accreted rapidly between the late 19th century and the 1970s (Phipps & Smith, 1978). During the past ten years accretion has greatly diminished on the Long Beach Peninsula and chronic erosion occurs between North Head and the Columbia River (Phipps, 1989). As accelerated sea level rise overwhelms uplift on the ocean coast, erosion will likely become more widespread. The entire southwest coast of Washington is at risk. Economic implications include the protection by beach nourishment or armoring of at risk areas where financially and technically feasible. Retreat and abandonment may be necessary in areas where the cost of protection exceeds the value of the property and facilities.

4.6.3 Bluff and Cliff Erosion and Landsliding
Puget Sound bluff and cliff shorelines are in dynamic equilibrium with sea level. As sea level has risen during the present interglacial period, the toe of bluffs and cliffs has retreated such that the toe has remained approximately a foot above mean higher high water (Downing, 1983). Existing shoreline erosion and land sliding is attributed to recent sea level rise (Terich, 1987). Accelerated sea level rise is therefore expected to increase the rate and severity of shoreline erosion and landsliding. The degree of risk is site specific and largely a function of local geology and soils characteristics. Economic implications include loss of real property and the need to retreat from high risk coastal sites.

4.6.4 Wetlands Modification and Inundation
Economic implications include the loss of primary and secondary productivity leading to adverse effects on fish productivity and thus losses to sports, Tribal, and commercial harvests.

4.6.5 Sea Water Intrusion
Sea water intrusion of fresh water aquifers is presently a problem in Island and San Juan counties and at some locales along Hood Canal due to groundwater withdrawals for domestic use. Under certain circumstances sea level rise is expected to aggravate sea water intrusion (National Research Council, 1987). Whether this would be a significant problem in Washington is debatable, and requires further research. Economic implications could include the need to drill deeper wells, the need to import water from inland source, and limitations on the ability to develop coastal margins for lack of potable water.

4.6.6 Water Table Rise
A rising sea level will tend to force upward the water table in

low lying coastal areas (National Research Council, 1987). Areas such as the Long Beach Peninsula and the Ocean Shores peninsula presently have water tables at or near the surface most of the year. Similar conditions exist at Puget Sound river deltas and their associated river valleys. For example, flooding and drainage is presently a documented problem in the lower Skokomish valley and delta due partly to a high water table (Canning, Randlette & Hashim, 1987). High risk areas include, in addition, the low lying margins of Grays Harbor and Willapa Bay. Economic implications include: an increased duration of flooding due to impeded drainage and higher recovery costs; decreased effectiveness of soils for onsite sewage disposal and the need to resort to more costly alternatives; increased corrosion of underground utilities and storage tanks leading to more frequent replacement schedules and recovery costs of ground water contamination by leaking underground storage tanks; inundation of coastal underground waste sites leading to a leaching of pollutants into the groundwater and the resultant recovery and cleanup costs; impediments to agriculture due to water logged soils leading to drainage costs or abandonment.

4.6.7 Coastal Drainage Systems

Urban storm drainage systems are designed to minimize flooding by storing and conveying storm water runoff from the 10- or 25-year (10% or 4% probability) storm event (Canning, 1988). The effectiveness of coastal drainage systems also depends on storm water infiltration to the ground and upon the slope of the "hydraulic head" or difference in elevation between the head of the drainage area and the discharge into marine waters. Sea level rise will diminish infiltration drainage (Section 4.6.6) and the hydraulic head (Titus, et al., 1987).

Increases in precipitation (Section 1.4.3) will increase the intensity of the 10- and 25-year storm events, and thus the flow volumes of the resultant stream flow. Continued urbanization will increase the resultant stream flow for a given storm event. Increases in storm intensity and/or runoff cause streambed scour and damage to fishery habitat (Section 1.4.4; Canning, 1988).

Titus et al. (1987) reviewed two case studies (Fort Walton Beach, Florida; Charleston, South Carolina) of sea level preparedness, precipitation increase preparedness, and storm drainage design.

The Charleston case study showed that urban coastal communities that plan to overhaul or build coastal drainage facilities can consider the risk of future sea level rise and climate change like any other risk. It is possible to insure the studied Grove Street watershed against the potential future retrofit cost of $2,410,000 that would be required as the result of a 30 cm (12 inch) rise in sea level by spending and additional $260,000 today to improve the system. Whether or not this insurance is worth buying depends on one's assessment of the probability of the sea rising or precipitation increasing.

5. REFERENCES CITED AND CONSULTED

Adams, R.M. 1989. Estimated economic consequences of ozone on agriculture: Some evidence from the US in: *Atmospheric ozone research and its policy implications.* Elsevier Science Publishers, Amsterdam.

Adams, R.M. 1988. *Estimated economic consequences of ozone on agriculture: Some evidence from the US.* Corvallis Environmental Research Laboratory, US Environmental Protection Agency, Corvallis, Oregon.

Adams, Richard M., J. David Glyer & Bruce A. McCarl. 1988. *The economic effects of climate change on U. S. agriculture: A preliminary assessment.* Corvallis Environmental Research Laboratory, US Environmental Protection Agency, Corvallis, Oregon.

Adams, R.M. & B.A. McCarl. 1985. Assessing the benefits of alternative oxidant standards on agriculture: The role of response information. *Journal of Environmental and Economic Management* 12:264-276.

Adams, R.M. & R.D. Rowe. 1988. *The economic effects of stratospheric ozone depletion on US agriculture: A preliminary assessment.* Corvallis Environmental Research Laboratory, US Environmental Protection Agency, Corvallis, Oregon.

Armentano, Thomas V., Richard A. Park & C. Leslie Cloonan. 1988. Impacts on coastal wetlands throughout the United States. pp 87-128 in Titus, James G. (ed). 1988. *Greenhouse effect, sea level rise, and coastal wetlands. (EPA-230-05-86-013)* US Environmental Protection Agency, Washington.

Armstrong, Bruce K. 1988. Epidemiology of malignant melanoma: Intermittent or total accumulated exposure to the sun. *Journal of Dermatologic Surgery & Oncology* 14(8):849.

Barnett, T.P. 1984. The estimation of "global" sea level change: A problem of uniqueness. *Journal of Geophysical Research* 89(C5):7980-7988.

Barnola, J.M. D. Raymond, Y.S. Korotkevich & C. Lorius. 1987. Vostok ice core provides 160,000 year record of atmosphereic CO_2. *Nature* 32:408-414.

Barth, Michael C. & James G. Titus (eds). 1984. *Greenhouse effect and sea level rise.* Van Nostrand Reinhold Co., New York.

B.C. Hydro. 1988. *Twenty-Year Resource Plan.*

Bonneville Power Administration. 1981. *Effect of Temperature and Wind Velocity on Northwest Power Pool Loads.* Economic and Utility Studies Branch, Bonneville Power Administration.

Brown, Lester R. & John E. Young. 1988. Growing food in a warmer world. *World Watch* Nov/Dec, 1988: 31-35.

Campbell, R.K. 1978. Regulation of bud burst timing by temperature and photoregime during dormancy. In: C.A. Hollis (ed). *Proceedings of the Fifth North American Forest Biology Workshop.*

Canning, Douglas J. 1989. *Sea level rise in Washington state: State-of-the-knowledge, impacts, and potential policy issues.* Shorelands and Coastal Zone Management Program, Washington Department of Ecology, Olympia.

Canning, Douglas J. 1988. *Urban runoff water quality: Effects and management options (Shorelands Technical Advisory Paper No. 4).* Shorelands and Coastal Zone Management Program, Washington Department of Ecology, Olympia.

Canning, Douglas J., Lisa Randlette, and William A. Hashim. 1987. *Skokomish River Comprehensive Flood Control Management Plan: Preliminary Draft Plan.* Shorelands & CZM Program, Washington Department of Ecology, Olympia.

Charney, Jules, et al. 1979. *Carbon dioxide and climate: A scientific assessment.* National Academy of Sciences Press, Washington.

Chatters, James C. 1989. *Proxy evidence for changes in past climate and hydrology of the Columbia River basin.* Presentation, Effects of Global Warming on the Water Resources of the Columbia River Basin workshop, Battelle Conference Center, Seattle, Washington, 19 April 1989.

Copes, D.L. 1983. Failure of grafted Douglas-fir planted at Monterey, California. *Tree Planters Notes* 34:9-10.

Decker, W.L., V.K. Jones & R. Achtuni. 1986. *The impact of climate change from increased atmospheric carbon dioxide on American griculture.* U.S. Department of Energy publication DOE/NBB-0077.

Dover, J.S., et al. 1989. Cutaneous effects and therapeutic uses of heat with emphasis on infrared radiation. *Journal of American Academy of Dermatology* Feb, 1989:278-286.

Downing, John. 1983. *The coast of Puget Sound: Its processes and development.* University of Washington Press, Seattle.

Dudek, Daniel J. 1988. *Global atmospheric change and domestic forest resources (statement before the Senate Committee on Energy and Natural Resources, September 19, 1988).* Environmental Defense Fund, New York.

Earth System Sciences Committee. 1988. *Earth system science: A closer look.* National Aeronautics and Space Administration, Washington.

Edison Electric Institute. 1988. *Statistical Yearbook of the Electric Utility Industry.*

Ehrlich, Paul R. and Anne H. 1977. *Ecoscience: Population, Resources, Environment.* W.H. Freeman & Co., San Francisco.

El-Sayed, Sayed. 1988. Fragile life under the ozone hole. *Natural History.* Oct 1988:72-80.

English, D.R., et al. 1985. Cutaneous malignant melanoma and flourescent lighting. *Journal of the National Cancer Institute* 74:1191-1197.

Fish and Wildlife Technical Committee. 1970. *Puget Sound and adjacent waters study, Appendix XI: Fish and wildlife.* Puget Sound Task Force of the Pacific Northwest River Basins Commission.

Flavin, Christopher. 1988. The Heat Is On. *World Watch* Nov/Dec, 1988:10-20.

Funtowicz, S.O. & J.R. Ravetz. 1985. Three types of risk assessment: A methodological analysis. in: C. Whipple & V. Covello (eds). *Risk analysis in the private sector.* Plenum, New Tork.

FWTC - see Fish and Wildlife Technical Committee.

Gerlach, Luther P. & Steve Rayner. 1988. *Managing global climate change: A view from the social and decision sciences.* Oak Ridge National Laboratoes publication ORNL/6390.

Gibbs, Michael J. & John S. Hoffman. 1987. An approach for generating climate change hypotheticals given limitations in current climate models. pp 91-111 in: William E. Shands & John S. Hoffman (ed). 1987. *The greenhouse effect, climate change, and U.S. forests.* The Conservation Foundation, Washington, D.C.

Gribben, John E. 1982. *Future weather and the greenhouse effect.* Delacorte Press/Eleanor Friede, New York.

Fairbridge, R.W. & W.S. Krebs, Jr. 1962. Sea level and the southern oscillation. *Geophysical Journal* 6:532-545.

Hansen, J. et al. 1988. Global climate changes as predicted by Goddard Institute for Space Studies three-dimensional model. *Journal of Geophysical Research* 93:9341-9364.

Hansen, J. et al. 1987. Evidence for future warming: How much and when? pp 57-76 in: Shands, William E. & John S. Hoffman (eds). 1987. *The greenhouse effect, climate change, and U.S. forests.* The Conservation Foundation, Washington, D.C.

Hansen, J. et al. 1984a. Climate sensitivity to increasing greenhouse gases. pp 57-77 in: Barth, Michael C. & James G. Titus (eds). 1984. *Greenhouse effect and sea level rise.* Van Nostrand Reinhold Co., New York.

Hansen, J. et al. 1984b. Climate sensitivity: Analysis of feedback mechanisms. *In* J. E. Hansen & T. Takahashi (ed.), *Climate processes and climate sensitivity.* American Geophysical Union, Washington, D.C.

Hart, John. 1989. *Global warming: An overview.* Presentation to the Northwest Power Planning Council, 9 February 1989.

Hartman, Dennis. 1988. *Greenhouse effect: Its causes and possible impacts on the environemnt.* Greenhouse Effect Briefing, December 15, 1988, Olympia, Washington. Sponsored by Association of Northwest Gas Utilities.

Hoffman, John S., Dale Keyes & James G. Titus. 1983. *Projecting future sea level rise: Methodology, estimates to the year 2100, and research notes. (EPA 230-09-007)* US Environmental Protection Agency, Washington.

Hoffman, J.S. (ed). 1987. *An assessment of the risks of stratospheric modification.* US Environmental Protection Agency, Washington.

Hoffman, John S. & John Bruce Wells. 1987. Past and projected changes in greenhouse gases. pp 19-41 in: William E. Shands & John S. Hoffman (ed). 1987. *The greenhouse effect, climate change, and U.S. forests.* The Conservation Foundation, Washington, D.C.

Holdahl, S.R., F. Faucher & H. Dragert. n.d. *Contemporary vertical crustal motion in the Pacific Northwest.* unpublished mss.

Houghton, Richard A. & George M. Woodrell. 1989. Global climate change. *Scientific American* 260(4):36-44.

Jacobson, Jodi L. 1989. Swept away. *World Watch* Jan/Feb, 1989: 20-26.

Kellison, R.C. & R.J. Weir. 1987. Breeding strategies in forest tree populations to buffer against elevated atmospheric carbon dioxide levels. pp 285-294 in: William E. Shands & John S. Hoffman (ed). 1987. *The greenhouse effect, climate change, and U.S. forests.* The Conservation Foundation, Washington, D.C.

Koh, H.K., et al. 1989. Screening for melanoma/skin cancer: Theoretic and practical considerations. *Journal of American Academy of Dermatology* Feb. 1989:159-172.

Kopp, R.J., W.J. Vaughn, M. Hazilla, & R. Carson. 1985. Implications of environmental policy for U.S. agriculture: The case of ambient ozone standards. *Journal of Environmental Management* 20:321-331.

Kramer, Paul J. & Nasser Sionit. 1987. Effects of increasing carbon dioxide concentration on the physiology and growth of forest trees. pp 219-246 in: William E. Shands & John S. Hoffman (ed). 1987. *The greenhouse effect, climate change, and U.S. forests.* The Conservation Foundation, Washington.

Kripke, Margaret L. 1988a. Impact of ozone depletion on skin cancers. *Journal of Dermatological Surgery and Oncology* 14(8):853-856.

Kripke, Margaret L. 1988b. Address, Annual Academy of Dermatology Meeting, San Diego, California, December, 1988.

Lapenis, A.G. & M.R. Rampino. 1989. The response of pelagic sedimentation to anthropogenic CO_2 emissions. *Eos* 70(15):293.

Lavender, D.P. 1988. Forestry Task Force told how global warming could affect Douglas-fir growth. Remarks made to Western States Legislative Forestry Task Force, Portland, Oregon; December 12, 1988.

Lavender, D.P. 1981. *Environment and shoot growth of woody plants.* Forest Research Laboratory Publication, School of Forestry, Oregon State University, Corvallis.

Lettenmaier, Dennis. 1989a. *Effect of global warming on Pacific Northwest hydrology.* Presentation to the Northwest Power Planning Council, 9 February 1989.

Lettenmaier, Dennis, Thain Yew Gan & David R. Dawdy. 1989. *Interpretation of hydrologic effects of climate change in the Sacramento - San Joaquin rivers.* Presentation, Effects of Global Warming on the Water Resources of the Columbia River Basin workshop, Battelle Conference Center, Seattle, Washington, 19 April 1989.

Leverenz, Jerry W. & Deborah J. Lev. 1987. Effects of carbon dioxide-induced climate changes on the natural ranges of six major commercial tree species in the western United States. pp 123-155 in: William E. Shands & John S. Hoffman (ed). 1987. *The greenhouse effect, climate change, and U.S. forests.* The Conservation Foundation, Washington, D.C.

Lyles, Stephen D., Leonard D. Hickman, Jr. & Henery A. Debaugh. 1988. *Sea level variations for the United States, 1855 - 1986.* National Oceanic and Atmospheric Administration, Rockville, MD.

Monastersky, Richard. 1989a. Looking for Mr. Greenhouse. *Science News* 135(14):216-217+221.

Monastersky, Richard. 1989b. Global change: The scientific challenge. *Science News* 135(15):232-235.

McElroy, Michael & R. J. Salawitch. 1989. Changing composition of the global stratosphere. *Science* February 10, 1989: 763-770.

Meyer, John H. & Robert A. Adair. 1878. *Puget Sound Herring surveys, including observations of the Gulf of Georgia SAC - Roe fishery, 1975-1977.* US Fish & Wildlife Service, Olympia, Washington.

Moffatt and Nichol, Engineers. 1988. *Future sea level rise: Predictions and implications for San Francisco Bay.* San Francisco Bay Development and Conservation Commission, San Francisco.

Moore, Lewis T. & Richard H. Ives. 1988. *Temporal meteorologic and hydrologic changes: Prospects and potential effects on irrigation (paper presented at the US Committee on Irrigation and Drainage Conference, 14-15 September 1988, San Diego, California).* US Bureau of Reclamation.

National Research Council. Committee on Engineering Implications of Changes in Relative Sea Level. 1987. *Responding to changes in sea level: Engineering implications.* National Academy Press, Washington.

Northwest Power Planning Council. 1986. *Northwest Conservation and Electric Power Plan.*

Penttila, Dan. 1978. *Studies of the Surf Sment* Hypomesus pretiosus *in Puget Sound.* Washington Department of Fisheries Technical Report No. 42.

Park, Richard A., Manjit S. Trehan, Paul W. Mausel, & Robert C. Howe. 1988. *The effects of sea level rise on U.S. coastal wetlands.* Holcomb Research Institute, Butler University, Indianapolis.

Pfau, R.G., Antoinette F. Hood & W.L. Morison. 1986. Photoageing: The role of UVB, solar-simulated UVB, visible and psoralen UVA radiation. *British Journal of Dermatology* 114:319-327.

Phillips, Earl L. 1965. *Climates of the states: Washington. (Climatography of the United States No. 60-45)* US Department of Commerce Weather Bureau.

Phipps, James B. 1989. *Coastal accretion and erosion in southwest Washington: 1977 - 1987.* Shorelands and Coastal Zone Management Program, Washington Department of Ecology, Olympia.

Phipps, James B. & John M. Smith. 1978. *Coastal accretion and erosion in southwest Washington.* Washington Department of Ecology, Olympia.

Pitt, Robert and Pam Bissonnette. 1984. *Bellevue urban runoff program: Summary report.* Bellevue Storm and Surface Water Utility, Bellevue, Washington.

Prendergast, Dr. William. Opthamology Lecture. Portland, OR. March 1989.

Picolo, M.C., G.M. Perillo, C.G. Ramon & V. Didio. 1988. Outbreaks of asthma attacks and meteorological parameters. *Annual Yearbook of Allery* 60(2):107-110.

Ozone Trends Panel. 1988. *Report to Congress.* National Aeronautics & Space Administration, Washington.

Ramanathan, V., Bruse R. Barkstrom & Edwin F. Harrison. 1989. Climate and the Earth's radiation budget. *Physics Today* 42(5):22-32.

Ramanathan, V., R.J. Cicerone, H.B. Singh & J.T. Kiehl. 1985. Trace gas trends and their potential role in climate change. *Journal of Geophysical Research* 90(D3):5557-5566.

Sandenburgh, Robin, Carol Taylor & John S. Hoffman. 1987. How forest products companies can respond to rising carbon dioxide and climate change. pp 247-258 in: William E. Shands & John S. Hoffman (ed). 1987. *The greenhouse effect, climate change, and U.S. forests.* The Conservation Foundation, Washington, D.C.

Sayce, Kathleen. 1988. *Introduced cordgrass,* Spartina alterniflora Loisel. *in saltmarshes and tidelands of Willapa Bay, Washington.* US Fish and Wildlife Service contract # FWSI-87058(TS).

Scheibner, A. et al. 1986. Effects of exposure to ultraviolet light in a commercial solarium on Langerhans cells and melanocytes in human epidermis. *Australian Journal of Dermatology* 27: 35-41.

Schlesinger, Michael. 1989. *Global warming: Magnitude and timing.* Presentation to the Northwest Power Planning Council, 9 February 1989.

Scientific Committee on Problems of the Environment. 1986. *The greenhouse effect, climate change, and ecosystems.* Wiley & Sons, New York.

Scotto, J., G. Cotton, F. Urbach, D. Berger & T. Fears. 1988. Biologically effective ultraviolet radiation: Surface measurements in the United States. *Science* 239: 762-4.

Shands, William E. & John S. Hoffman (eds). 1987. *The greenhouse effect, climate change, and U.S. forests.* The Conservation Foundation, Washington, D.C.

Shea, Cynthia Pollock. 1989. Mending the Earth's shield. *World Watch* Jan/Feb, 1989: 27-34.

Smith, Joel B. & Dennis A. Tirpak (eds). 1988. *The potential effects of global climate change on the United States (Draft report to Congress: Executive Summary; Vol 1: Regional Studies; Vol 2: National Studies).* US Environmental Protection Agency, Washington, D.C.

Sulman, F.G. 1984. The impact of weather on human health. *Review of Environmental Health* 4(2):83-119.

Taylor, H.R., S.K. West, F.S. Rosenthal, & B. Munoz. 1988. Effect of ultraviolet radiation on cataract formation. *New England Journal of Medicine* 319:1429-33.

Terich, Thomas A. 1987. *Living with the shore of Puget Sound and the Georgia Strait.* Duke University Press, Durham.

Titus, James G. (ed). 1988. *Greenhouse effect, sea level rise, and coastal wetlands. (EPA-230-05-86-013)* US Environmental Protection Agency, Washington.

Titus, James G. 1986. Greenhouse effect, sea level rise, and coastal zone management. *Coastal Zone Managemetn Journal* 14 (3):147-171.

Titus, James G. et al. 1987. Greenhouse effect, sea level rise, and coastal drainage systems. *Journal of Water Resources Planning and Management* 113(2):216-227.

US Environmental Protection Agency. 1987. *Unfinished business: A comparative assessment of environmental problems.* US Environmental Protection Agency, Washington.

US EPA - see US Environmental Protection Agency.

Vail, Lance & Dennis Lettenmaier. 1989. *Preliminary interpretation of climate change: Implications for tributary of the Yakima River.* Presentation, Effects of Global Warming on the Water Resources of the Columbia River Basin workshop, Battelle Conference Center, Seattle, Washington, 19 April 1989.

Watson, Richard. 1989. *Regional culprits: Sources of greenhouse gases.* Presentation to the Northwest Power Planning Council, 9 February 1989.

Watson, R.T., M.J. Prather & M.J. Kurylo. 1988. *Present state of knowledge of the upper atmosphere: An assessment report.* National Aeronautics & Space Administration, Washington.

White, Margaret R. (ed). 1985. *Characterization of information requirements for studies of CO2 effects: Water resources, agriculture, fisheries, forests and human health.* US Department of Energy document DOE/ER-0236.

White, M.R. & I. Hertz-Picciotto. 1985. Human health: Analysis of climate related to health. pp 171-206 in: White, Margaret R. (ed). 1985. *Characterization of information requirements for studies of CO2 effects: Water resources, agriculture, fisheries, forests and human health.* US Department of Energy document DOE/ER-0236.

Woodman, James N. 1987. Potential impact of carbon dioxide-induced climate changes on management of Douglas fir and Western Hemlock. pp 277-284 in: William E. Shands & John S. Hoffman (ed). 1987. *The greenhouse effect, climate change, and U.S. forests.* The Conservation Foundation, Washington, D.C.

Young, R.W. 1988. Solar radiation and age-related macular degeneration. *Survey of Opthamology* 32: 252-69.

THE STATE OF THE ENVIRONMENT REPORT

VOLUME III
Parts 7 and 8

Risk Evaluation Reports
for
Point Source
Discharges to Water
and
Nonpoint Source
Discharges to Water

ENVIRONMENT 2010

State of Washington
October, 1989

EXPLANATORY NOTE

The Washington Environment 2010 report on point- and nonpoint-source discharges to water is divided into three sections, reflecting divisions in the expertise and data bases on these environmental threats:

- First is a section on the ecological risks associated with discharges to surface waters (lakes, rivers, streams, coastal waters, and estuaries). This includes separate discussions of point-source disharges (such as industrial pipe discharges) and nonpoint-source discharges (such as agricultural run-off).

- Next is a section on the human health risks associated with both point- and nonpoint-source discharges. Please note, however, that this section focuses on the health risks related to swimming in contaminated water or eating contaminated fish and shellfish; the health risks related to drinking water contamination from both point- and nonpoint-sources are discussed in detail in the drinking water contamination report located elsewhere in this volume.

- Last is a section on the risks associated with point- and nonpoint-source discharges to groundwater.

Environmental Threats Related to Point and Nonpoint Source Discharges To Water.

ANALYTICAL APPROACH AND DATA SOURCES.

General Approach: The general approach was one of using the best information readily available to team members. Information was acceptable if it could be used in its current condition or if important components were available or could be extracted. Unsynthesized information and data could not be considered because of time constraints associated with the 2010 project.

Environmental threats associated with both point and nonpoint pollution were divided into major sources. Each major source was then fractioned into individual categories. The resulting categories should be interpreted somewhat broadly as they were chosen to represent a class of activities. The groupings are also a good compromise between finer detail and extreme broadness. The concerns and the considered major sources are detailed in the Environmental Threat Definitions (See Appendix).

Methods:
The 305-b report (Ecology, 1988a) and its founding Water Body Tracking System (WBTS) (Ecology, 1989d) database were used extensively by most team members. It represents the best compiled information available to date. It must be understood that the only a fraction of the Washington's surface waters re contained in the database and were therefore assessed. The 305-b report utilized both historical and current water quality data. Current information, collected within the last five years, was used preferentially and discussed as "monitored". "Evaluated" information included data older than five years and single grab sample data. The 2010 effort utilized and gave equal weight to information from both categories. The waters of the state and the database coverage are broken into four categories; Coastal (100 %), Estuaries (71.8 %), Rivers and Streams (11.4 %), and Lakes (25.5 %). In many cases, data are present for a given waterbody because an earlier investigation evaluated suspected problems. This is most true for "Lakes" and "Rivers and Streams". This fact alone precludes scaling with any certainty. Therefore, none of the impacts are scaled for the rest of the state. Both, the inability to scale and the data coverage relative to the total waters were of great concern to reviewers.

Water quality impacts or use impairment follows the definition used in the water resource characterization portion of this report. Specifically:

> "Beneficial uses", refers to the attainment of the Clean Water Act goals of a water body being fishable and swimmable.
>
> "Impaired", refers to a water body which does not, or only partially support the Clean Water Act goals.
>
> "Threatened", refers to a water body which currently meets CWA goals, but is in danger from adjacent activities and may slip into the "Impaired" category.

Impaired and threatened categories were combined for the purposes of 2010. The logic being that threatened waters today, could likely be impacted in 2010 if the control programs are not begun now.

Ranking: Threats were given a relative priority based on a number of factors. The relative priority was accomplished using:

o information available in the 305-b report and the WBTS system

o severity and reversability of a risk, using the Cornell Panel Information (Harwell and Kelly, 1986)

o the regulatory history of control programs and probable trends, e.g., a new program may need more resources than an established one.

o the relative size or scale of a threat, either geographically or the magnitude was evaluated using best professional judgement

o best professional judgement

SUMMARY OF FINDINGS

The key findings for both nonpoint and point source discharges to water are included in Tables 1 and 2, and depicted in Figure 1. The threats associated with agricultural activities represented the area of highest concern in the nonpoint source category. Combined sewers, stormwater, and runoff affected the largest amount of Washington,s waterways. These two categories also do not have extensive management programs in place today and will be of greatest concern in the year 2010.

As discussed above, the relative priority is the rating assigned to each of the major sources in consideration of severity, extent, reversibility, biological impact, probable trends, the status of regulatory activity, and best professional judgement. The uncertainty associated with each of the estimates included here may be very high. Understanding that the numbers will be used to quantify risk, they should be taken as worst-case conditions. Ideally, the numerical estimates are a relative means to focus attention on future programmatic direction and efforts.

NONPOINT DISCHARGES TO WATER

Nonpoint source water pollution is typically defined as pollution that is not discharged through pipes. It can originate from large diffuse sources or from more confined and localized areas. The delivery mechanism is the overriding variable. Therefore nonpoint pollutants are generally carried by some agent, e.g., runoff, groundwater, and wind, or just enter waters because of proximity to the source, e.g., landslides from unstable slopes, direct animal access, and introduction of boating wastes. Some sources of nonpoint pollution are not discussed here, having been identified as a specific threat to be addressed separately in the 2010 effort. Spills, for example are being handled in the Accidental Release component. The complete 2010 threat definition list should be consulted to find the appropriate section for a nonpoint pollutant source not included in this section. Additionally, the definition of nonpoint source pollution has undergone recent change. Runoff confined to pipes and ditches generally labelled as nonpoint sources are now regulated as point sources.

The pollutants associated with nonpoint sources include all of the constituents/concerns included in the point source threat definition. Concentrations and impacts range from minimal to severe. Relative to point source controls, nonpoint pollution is highly variable because very few treatment options are in place and any control practices are somewhat newly implemented.

The ecological risks for both point and nonpoint pollution are very similar and in many cases inseparable. Both are related to population growth and development pressure; as they increase, so does the potential for impact. The prime population growth/development areas in Washington will experience the most impact. These areas also have the greatest opportunity for responsible growth and can minimize the impact which occurs.

DETAILED SUMMARY OF ESTIMATED NONPOINT SOURCE RISKS

AGRICULTURE

Agricultural nonpoint discharges result from various activities associated with both crop and animal production. Pollution from agricultural activities is highly variable, depending on both environmental factors, such as precipitation and runoff, as well as land treatment practices such as row cropping and manure management. A variety of nonpoint pollutants including fecal bacteria, nutrients, sediment, organic chemicals and pesticides, and salts result from the diverse agricultural practices in Washington State.

Crop production (irrigated, non-irrigated, and specialty crops) introduces pollutants by disturbing the soil and increasing runoff, removing vegetative cover, and increasing nutrients and other chemicals through the application of fertilizers, pesticides, and herbicides. Major water quality concerns related to crop production are pesticides/herbicides, sedimentation and turbidity, and increased nutrients.

Animal production activities can cause increased stream pollution by employing inadequate waste management systems in animal confinement areas, increasing runoff and erosion due to overgrazing pasture lands, improperly applying manure to fields, and allowing animals unlimited access to streams where they can trample vegetation and damage streambanks. Aquaculture, fish rearing pens in marine and freshwater, present nutrient problems to the water column and can affect benthos below. Major concerns related to animal production are bacteria (fecal coliform), sedimentation and turbidity, increased nutrients, salts ammonia, herbicides (aquaculture), and habitat distruction due to shoreline vegetation removal and erosion.

Table 3 relates the percentage of waterbody impairment of rivers/streams, lakes, and estuaries assessed statewide due to various agricultural practices.

Each concern resulting from agricultural practices leads to a variety of endpoint effects. The concerns and their associated impacts are listed below (Puget Sound Water Quality Authority (PSWQA) 1988; Harwell and Kelly, 1986).

Bacteria: Major sources are animal operations and manure in fields. Bacteria introduction to surface waters reduces recreational usage, increases treatment costs for drinking water and creates human health hazards via direct exposure and indirect exposure (i.e. bioaccumulation in shellfish consumed by humans). Shellfish growing areas have been decertified for commercial harvest as a result of agriculture related bacterial contamination. Level of impact for all waterbody types is moderate and will have a relatively short term effect (one year) if corrected, but if high loadings occur (i.e. sludge beds), longer term impacts may be seen (1 to 10 years).

Nutrients (nitrogen and phosphorus): Major sources of nutrients are fertilized fields, animal operations, and sedimentation. Nutrients, though needed in certain quantities by all organisms, can cause algal blooms on a scale larger than normal, and promote unwanted plant growth. Toxic algae blooms can affect health of swimmers and aesthetic qualities of waterbodies, reduce quality of public water supplies, lower dissolved oxygen and affect fish, thereby enhancing survival of less desirable fish species. In lakes, ecosystem impacts can range from medium to high, depending on the current nutrient status, and can take 1 to 100 years to correct. Streams and rivers, on the other hand, have low-to-medium ecological impacts from nutrient loading, and may take 1 to 10 years to correct. This is due to mixing and transport mechanisms in moving waters. Estuarine impacts can be high as a consequence of nutrients, but will vary due to water residence time and relative additional riverine contributions; reversibility is 1 to 10 years.

Sedimentation/Siltation: Increased sedimentation decreases light transmission through water which decreases primary productivity and obscures sources of food, habitat, hiding places, and nesting sites. Sedimentation can also directly affect respiration, decrease survival rates of fish eggs thus population size and species composition, increase drinking water filtration costs, destroy habitat by siltation of spawning grounds or feeding areas for aquatic organisms, limit growth of aquatic plants, increase temperature of surface water layer, and decrease oxygen supply for supporting aquatic life. Sediments successfully carry organic chemicals including pesticides, Impacts on lakes are low and primarily affect the ecosystem as a result of reduced sunlight from the suspended sediment throughout the water column and nutrient addition. Impacts on streams and rivers are high, usually as a result of smothering benthos and habitat change. Impacts on estuaries are moderate and depend on the natural turbidity of the given area of concern. Reversibility for lakes, rivers/streams, and estuaries is anywhere from 1 to 10 years. Major sources are all the agricultural practices listed in Table 3.

Pesticides and herbicides: Impacts include: hindrance of aquatic plant photosynthesis; lowering organisms resistance and increasing susceptibility to other environmental stresses; lower reproduction success; lower respiration, growth, and development in aquatic species; reduce food supply; destroy habitat; kill non-target organisms (including fish) if chemical is released into the aquatic environment before degradation; and increase cancer risks in fish and related organisms (some pesticides/herbicides are carcinogenic and mutagenic). Some indirect effects include, threats to nearshore aquatic dwelling animals (i.e. birds, muskrats), and creation of human health hazards from consumption of contaminated fish and/or water. Impact levels for lakes, rivers and streams, and estuaries are high and are a concern as a potential threat to humans. Intensity and duration of the ecological effects are functions of toxicity, persistence, fate-transport, partitioning, and bioaccumulation of the chemical at hand. Reversibility can range from less than 1 to 1000 years, depending on the above criteria for the chemical. Major sources are crop production (all types), pasture and range lands, and aquaculture.

Salts: Impact levels can be high for rivers and lakes. Inorganic salts are leached from the soil and usually enter surface waters through irrigation return flows. Once soils are contaminated, the duration of the condition likely ranges from 1 to 100 years. The ecological affect of increased ionic strength is not well defined (may cause some species shift). The major impact is associated with water reuse. High dissolved inorganic solids preclude irrigation use and makes the water

Table 3. Percentage of assessed waterbodies impaired or threatened by agricultural activities in Washington State. (Source: Ecology 1988b).

	LAKES	RIVERS/STREAMS	ESTUARIES
Irrigated Crop	25.5*	15.1	0.03*
Non-irrigated Crop	0.09**	0.1-18.9 +	ND
Specialty Crop	ND++	ND	ND
Pasture/Range land	6.3**	20.0	10.4
Animal Holding Areas & Feedlots	ND	16.7	7.7
Aquaculture	4.3	ND	0.09
Agriculture Total	28.0-49.0	42.7	10.7

Assumptions: While some causes or sources may only affect part of an impaired segment, they are applied to the total impaired size for the purposes of generating summary reports. This tends to over-represent the total size affected by some cause and source categories.

These values include not fully supported and threatened categories as well as not supporting categroy; this is done for projection purposes.

Percentages are not additive, thus should not be summed to get a total impact. Cumulative impacts listed here (Agriculture Total) have been summed and do not represent double counted figures.

The ND values do not necessarily mean there are no impacts as a result of a particular practice; ND means there are no data.

Total rivers and stream miles in the state = 40,492 miles
Total assessed = 4621 miles

Total lake acreage in the state = 613,582 acres
Total assessed = 156,518
21% of assessed lake acreage defined in the 305(b) report represents Lake Chelan (33,104 acres)

Total estuary square mileage = 2943.6 sq. miles
Total assessed = 2114 sq. miles

* This value mostly represents Lake Chelan. See text.
** This is an estimated value
\+ 1988 305(b) Report gives impacted area as 0.1%, whereas the 1988 EPA-Risk Assessment gives 18.9% based on the 1986 305(b) Report. Likely falls somewhere between.
++ ND = No Data

undesirable for potable supply.

Dissolved oxygen (DO) and biochemical oxygen demand (BOD): Impacts are high on lakes, rivers/streams, and estuaries and result primarily from sedimentation, and organic and nutrient loading. Reversibility of the problem is 1 to 100 years for lakes, rivers/streams, and estuaries.

The following values are derived from Ecology 1988a and 1988b documents and the WBTS data base program (Ecology, 1989d), and have assumptions that coincide with the percentages listed in Table 3. Net agricultural impacts on rivers/streams, lakes, and estuaries were obtained from Ecology 1988b and the WBTS program and are not double counted figures. The subcategorized sources of impairment values are taken from the 1988 305(b) Report (Ecology 1988a) as well as the WBTS program; these values cannot be added for cumulative impacts. Because the waterbodies investigated tended to be on the polluted end of the scale with respect to pristine, especially in the lake analyses, the percentages may represent a worst case condition. Of the rivers and streams assessed, (11.4% of total statewide), 42.7% are impacted as a result of all agricultural practices. Primary agricultural sources are pasture and range lands, which is responsible for 20.0% of assessed rivers/streams impairment. Animal holding areas ranked second, with 16.7% of rivers and streams impaired.

Twenty eight percent (28.0%) (Ecology 1988b; 1989d) to 49.4% (Environmental Protection Agency (EPA), 1987) of the assessed lakes (25.5% of total) are impacted by agriculture. Primary agricultural impacts are from irrigated agriculture, causing 25.5% of the assessed lake impairment. The lake acreage assessed largely represents Lake Chelan, which was the subject of intensive surveys, and sits in the irrigated cropland belt. Therefore, the state's lakes impacted due to agriculture is based primarily on the impairment of Lake Chelan and may not be representative of the whole state. The real value could be higher or lower and impairment may be from other sources as well.

About 10.7% of assessed estuaries (71.8% total were assessed statewide) are impacted from agricultural pollutants (Ecology 1988b). Ten and four-tenths percent (10.4%) are impacted because of pasture and range lands, the primary agricultural source problem for estuaries. This data may be subjective due to intensive sampling in some areas.

According to employment projections for Washington State in the year 2010, agriculture will have made a small decline, therefore, this report assumes land use with respect to agriculture will remain the same as 1989. Many of the waterbodies studied were/are water quality concerns and may be representing the polluted end of the water quality range. Furthermore, some have had intensive surveys conducted which may focus on one particular region of concern, therefore all source problems may not be identified. It is however, safe to assume that agricultural nonpoint source pollution needs to be better controlled. The observed impacts are significant and irreversible in some cases. Streams/rivers and lakes surrounding high agricultural areas will benefit from additional protective measures. Estuaries don't appear to be directly suffering significant impacts from agriculture, but can be affected by impacted rivers and streams. Sources of pollution in Puget Sound and impact assessment is detailed to a greater length in the State of the Sound Report 1988 (PSWQA 1988).

Nonpoint pollution from agricultural activities can be controlled and significantly reduced by use of best management practices (BMPs) (PSWQA 1988). Examples of best management practices include contour farming, nutrient and pesticide management systems, pasture management, runoff control, limiting animal access to streams, and revegetating unstable stream banks. Voluntary implementation of BMPs is increasing throughout the Puget Sound area by both commercial and noncommercial farms, and improved water quality has been found in some areas where the majority of land owners are employing some form of BMPs; however, the overall effectiveness of these programs has been limited in the past by inadequate funding and too little attention to noncommercial farms (PSWQA 1988). Erosion controls are also helping, but little quantified information exists on program effectiveness (Daly, 1989, personal communication).

SILVICULTURE

Typical logging and forest management/practices have been linked to water quality problems, nonpoint pollution, and habitat degradation. These include road construction, maintenance, and abandonment; site preparation; clearcut and partial cut practices; removal of streamside vegetation; herbicide and pesticide spraying; and debris management. Altered stream sedimentation processes and rates are one of the larger water quality concerns resulting from many of these practices. Specifically, mass wasting from unstable slopes, physical disturbance, and road building all increase erosion and/or sedimentation in surface waters. Increased sediment loads can alter spawning habitat and actually cause physical damage to fish. The perturbation associated with logging and slash burning increase nutrient release from the watershed. Sensitive waters may experience enrichment. Temperature alterations due to the removal of streamside vegetation are also suspected of lessening fish production. Less is known about pesticide, herbicide, and fertilizer use and resulting long-term impacts, although short-term toxicity can result from all three compound classes. Hydrographic modification can cause significant perturbation and is being discussed under that particular threat.

Sivicultural impact intensity can range from slight to complete habitat alteration. Toxicity from forest chemicals and turbidity (solids) likely have short-term impacts (less than a year); whereas, modifications of habitat, temperature, hydrographic regime, and large organic debris loading rates take several years to correct. Extensive streambed siltation and its impact to the fishery, especially in lower gradient waterways, may never recover without some remedial action. The scale of the potential impact is also variable and relates to the acreage cut. Cumulative effects, which are suspected in large logged watersheds, are poorly understood, but are a major concern.

Fifty three percent (53 %) of the land in Washington consists of forest and alpine areas, of which 17.6 million acres are in commercial production. Eastern Washington harvest volumes have been very constant over the last 30 years and will likely remain at today's levels through 2010. Western Washington harvest volumes have been increasing slightly, representing 80 to 85 percent of the total volume. The industry appears to be reseeding about 95 percent of what is cut annually (OFM, 1987). This implies that harvest will be sustained at some level through the year 2010. However, the amount of harvestable timber will be on the decline in the future. Public sentiment, concern over losing habitat, and forest lands lost to urbanization will all ultimately affect the land available for sustained harvest. Forest production is estimated to decrease about 10 percent from levels today (Bergvall, personal communication). Employment projections for 2010 similarly indicate a decline of 12.5 percent in the lumber industry workforce (BPA/NWPPC, 1988). This estimate likely includes the effect of automation and more efficient harvest methods.

The WTBS (Ecology, 1989d) provides an estimate of the impact associated with sivilculture related activities. These have been combined for purposes here. The rivers are the most affected (5.2 percent); whereas, estuaries, lakes and coastal waters range from 2 percent to no impacts. Groundwater quality impacts are not expected.

CONSTRUCTION

Nonpoint discharges resulting from construction includes highway/road/bridge construction and maintenance, land development, vegetation removal, and aquatic/marine construction activities (dredging, channelization, and shoreline modification). Highway, road and bridge maintenance is also discussed in Runoff. A variety of nonpoint concerns including hydrocarbons, metals, contaminated particles, sedimentation and erosion, organic chemicals, debris, nutrients, and habitat alteration result from the diverse construction practices in Washington.

The most serious environmental concern with respect to construction activities appears to be vegetation removal, especially of riparian (shoreline) vegetation and erosion. For the purposes of this report, riparian vegetation removal is considered as a separate construction activitiy.

Dredging and channelization, where subaquatic or submarine sediments are displaced and either moved to a new location in the aquatic/marine environment or removed and put in a fill area, can pose serious threats to the ecosystem. Open water dumping of dredged material can bury bottom-dwelling organisms and resuspend and redistribute contaminated sediments to relatively clean areas. Guidelines for dredge spoils disposal are presently being developed and evaluated (PTI, 1989) to minimize impacts by the Puget Sound Dredged Spoils Analysis (PSDDA).

Runoff from roads and equipment used in construction can introduce metals, hydrocarbons, and other toxic substances to aquatic environments, potentially impacting the organisms of the receiving areas. These impacts may pose threats to human health via bioaccumulation. Table 4 relates the percentage of waterbody impairment attributable to construction activities in evaluated rivers and streams, lakes, and estuaries.

Impacts

Each pollutant resulting from construction practices leads to various endpoint effects, some more severe than others. The concerns and associated impacts are listed below (PSWQA 1988; Harwell and Kelly 1986).

Sedimentation/Siltation: See discussion under Agriculture.

Nutrients: (nitrogen and phosphorus): See discussion under Agriculture.

Metals and toxic chemicals including toxic organics: In lakes and streams, ecosystem effects will be high, whereas in estuaries, impacts are high but uncertain. Metals persist in sediments, but toxicity tends to be less than organic toxicities. Metals may be less bioavailable, and metal accummulation is less likely to occur as the toxic is transferred through the trophic chain. The intensity and duration of any effect is a function of toxicity, persistence, fate-and-transport, partitioning, and bioaccumlation rates. Reversibility for all waterbody types ranges from 1 to 1000 years. Contaminated particles washoff into roadside ditches and storm drains, and dredging and channelization activities which relocate contaminated sediments and possibly disperse them into the water column during open water dumping. Rivers, though usually not the source of contaminants, carry them to lakes and estuaries,

Habitat Alteration: Habitat alteration and destruction will have certain high impacts on lakes, rivers/streams, and estuaries. Depending on the extent of the disturbance, reversibility can be

Table 4. Percentage of assessed waterbodies impaired by construction activities in Washington State. (Source: Ecology 1988b)

	LAKES	RIVERS/STREAMS	ESTUARIES
Highway/Bridge & Road Construction	ND*	0.5	ND
Highway/Road Maintenance	ND	1.0	1.0
Land Development	18.6	7.1	0.4
Vegetation Removal (Riparian)	5.0	18.1	2.1
Shoreline Modification	0.4	9.4	2.0
Channelization	0.4	3.4	ND (Dredging)
Dredging	0.06	3.8	0.3+
Construction Total	19.1	22.1	4.1

Assumptions: See assumptions listed in Table 3. in the Agriculture section.

* ND = No Data, Included in Runoff

\+ Dredging in the marine environment poses hazards due to multiple transport mechanisms that can carry contaminated materials to shores and pristine areas. This value is likely underestimated.

anywhere from 1 year (minor disruption i.e. short term and small scale dredging efforts) to more than 1000 years (major destruction i.e. filling wetland areas). Habitat impacts can affect aquatic organisms such as plankton and fish as well as shoreline and aquatic birds and mammals. Main endpoint concerns are spawning and brooding areas.

As mentioned before under Agriculture, scaling is difficult due to sampling bias (waterbodies sampled tended to be at the polluted end of the scale), and data availability. Total impacts from cumulative construction activities were derived from the WBTS program mentioned in the Agriculture Section of this report. These values were categorized to only include construction activities listed here and do not include urban runoff. The subcategorized construction sources of impariment values are taken from the 1988 305(b) report (Ecology 1988a) and the WBTS program. These values represent some double counting and do not equal the total impacted area. As a result separate categories may be over estimated.

Of the rivers and streams assessed (11.4% of total statewide), 22.1% are impaired as a result of construction activites. Primary sources of impacts are from riparian vegetation removal and shoreline modification. Best estimates for lakes indicate that of the 25.5% assessed, 19.1% are impaired by construction nonpoint sources. Primary construction sources of impacts are from vegetation removal, shoreline modification, and land development. This value appears to be most affected by Lake Union data.

Of the assessed estuaries (71.8% total statewide), 4.1% were impaired as a result of construction activites. Again, as with rivers and lakes, vegetation removal appears to be the primary source of concern. Dredging activity showed low impacts; however, impacts are not well documented and are likely higher than current estimates show. Currently, the Puget Sound Dredged Disposal Analysis (PSDDA) program is evaluating dredging related impacts and ways of controlling them.

naive assumption re: growth management

Due to available funding; which will be inadequate to meet the projected road construction needs of the state, county and local areas, it is unlikely major new roads will be built except for four pending projects mentioned in the Transportation Improvements section of the 2010 report. Most efforts will be restricted to maintaining existing roadway networks, completing the Interstate system, and undertaking capacity improvements as funds permit. Thus, it is assumed that road/bridge/highway construction will increase at fairly low rates through to the year 2010, at about 5-10%. Land development and building construction (including houses) was not quantified in the employment projections for this report, thus current growth rates for Washington are assumed for 2010.

Construction nonpoint sources are not well quantified. Due to the limitations of the current knowledge of ecological impacts from construction, current levels of contribution to nonpoint sources represent a worst case scenario.

Monitoring efforts such as PSDDA will help evaluate impacts and contributions of dredging to water quality problems. Further controls need to be placed on riparian vegetation removal and shoreline modification activites.

RUNOFF

Runoff occurs when the precipitation rate exceeds the soil infiltration rate. Infiltration rates are slowest when soils are very tight, saturated with water, frozen, or covered with impervious surfaces. Water has the ability to dissolve pollutants and physically carry contaminated particles and sediments to the receiving environment. Therefore runoff quality is a function of adjacent land uses. As a result, contamination can occur with all classes of pollutants, and the intensity of any impact ranges from slight to severe. Runoff is also a factor in several specific source-related impacts. For example contaminated runoff is associated with spills, industrial sites, agricultural activities, hazardous waste sites, and municipal combined sewer overflows and storm sewers. Impacts are all being included under the specific source. Similarly, detailed source evaluations within the Nonpoint Threat implicitly include runoff effects in the respective assessment. As a result, the Runoff category only evaluates impact from one general source; on-site wastewater disposal systems.) ?

On-site wastewater disposal systems are used by about 30 percent of Washington's population. There are an estimated 575,000 systems in place today. In many cases they are the only alternative for residents in some parts of cities and most suburban and rural settings. The ratio of homes using on-site systems to sewers is decreasing (Ecology, 1988c).

Working properly, on-site systems treat wastewaters reasonably well and pose little environmental threat. Population density, proximity to sensitive aquifers, soil type, and soil saturation all potentially affect the acceptability of on-site systems. Systems located in overly tight or saturated soils may fail. Wastewaters then are able to enter surface waters before adequate treatment occurs. Extremely porous soils may also provide inadequate treatment because of minimal contact with the substrate. Impacts include contamination with pathogenic organisms, nutrient and organic enrichment, and in some instances, toxicants. These pollutants can impact both surface and groundwaters. Surface waters can experience high bacteria concentrations which affect swimming beaches and shellfish growing areas (additional discussion below). Organic enrichment can lower dissolved oxygen concentrations, change instream biota and affect the aesthetic quality of a waterway.

On-site wastewater treatment systems also are a source of nutrients. Eutrophication and the resulting habitat degradation can occur with the influx of phosphorus and nitrogen. Such concerns have prompted sewering and restoration measures at several lowland lakes.

The number of failed septic systems in any given location and time is a function of several local factors, however generalized failure rates have been reported for the Puget Sound Basin ranging from 3.5 to 5 percent (PSWQA, 1986). Others have found rates as high as 10 percent in selected drainages (Determan et al., 1985)

Groundwater quality impacts from on-site systems are not uniform statewide for the reasons discussed above. Localized aquifer protection measures are now being discussed in consideration of the recent Groundwater Management Area legislation. Historical actions over potential on-site wastewater treatment degradation of sole source aquifers have occurred in the Spokane Valley, and Chambers Creek. Sewer systems or land use planning have resulted.

Surface water quality impacts specifically related to on-site wastewater systems are difficult to separate from other sources. Ecology, (1989d) estimated that no coastal waters were impaired or threatened. However; rivers, estuaries, and lakes are potentially impacted by 8.9, 10.9, and 7.6 percent, respectively. Of these, the most significant impacts are associated with the potential eutrophication of lakes and the decertification of shellfish growing areas.

Nonpoint sources such as failing septic systems are responsible for changing the classification of many shellfish growing areas. The Department of Social and Health Services (DSHS, 1989) has restricted shellfish harvest because of nonpoint sources in twenty nine of the forty limited areas. Part of the recent change in the status of specific embayments is due to new development and people. Growth must occur responsibly. Part of the observed changes in water quality is a function of increased monitoring efforts by DSHS. The more one is out looking for potential problems, the more will be found. This will continue to occur until all areas are characterized completely.

The quality of runoff can be improved by several treatment and control measures. Once in place, reversing impacts to the environment may occur in a year or less in some instances. Identification of all sources is at times very difficult and ultimately slows remedial actions. For example, reclassified shellfish growing areas have yet to be cleaned up to the point where the classification could revert back. Contaminated sediments represent a longer term threat and will take several years before impacts diminish.

RESOURCE EXTRACTION/EXPLORATION/DEVELOPMENT

Mining is currently not a large industry in Washington. In the past, mining played a major role in the economy of the state, so many of the ecological problems from mining are from inactive or abandoned sites.

Resource extraction activities, especially activities related to processing or storing tailings and wastestreams, can affect surface and ground water quality. In turn, any water quality problems from these sites can effect the health of aquatic communities, terrestrial wildlife, livestock, and people.

Sand and gravel pits in all areas of the state are the single largest resource extraction industry. Coal, gold, zinc, lead, silver, and uranium mines have been active in the past and some continue to work on a smaller scale. Minor gas and oil exploration has taken place, but without major field development. Ore smelting, aluminum, gas and oil refineries are covered in the point source section.

Sedimentation from mining activity is probably the largest and most widespread ecological threat to surface and ground waters. Sand and gravel pits and other mines are required to limit sedimentation by filtration or ponding. By-in-large, these methods have been successful where instituted. Other impacts from various mining activities are listed in Table 1. Acid mine drainage has been a very minor problem at abandoned coal mine areas because of the coal's low sulfur content (Packard, Skinner, and Fuste', 1988). Although it will probably be covered in another section of the 2010 Report, the ecological hazards posed by leaking radionuclides into ground- and surface water at an inactive uranium mine near Spokane deserves special attention. Most resource extraction sites only impact local biota within a dilution zone. However, there are cases such as Railroad Creek near Holden where 10 miles of stream have been eliminated as fish spawning and rearing habitat because of zinc contamination from abandoned mine tailings (Patmont et al, 1988). Several other abandoned mines are in remote areas so resource damage assessments have never been made.

According to a recent nonpoint assessment (Ecology, 1988c), the statewide impact from resource extraction appears to be small (Table 1). Only 3.5% of the state's assessed rivers and streams, and 2% of the estuarine areas are affected by these industries. (This is about 0.4% of the state's total river and stream mileage and 1.4% of the estuary area.) Lake Roosevelt is the only lake that has been designated as being impacted by resource extraction activities. The lake accounts for 50% of the assessed lake surface area in the state (Ecology, 1988c). Since the primary source of contamination is the smelter located upstream in British Columbia, the impairment area was placed under the Iron, Steel & Miscellaneous Metals Production point source category (Table 2).

In general, it appears that multi-agency regulation of resource extraction activities in the state have been successful in limiting the degrading impacts of sites on the aquatic environment. Data are not available to properly scale a state-wide assessment. The data on resource extraction impacts are limited and the actual impact could be double the stated value. Even so, the impact from resource extraction is currently viewed as minor both in severity and prevalence relative to other sources of nonpoint pollution.

Since many mineral resources are non-renewable, it is likely that Washington will see more extraction, exploration, and development activity in the future. Offshore exploration for gas and oil may be likely, an area where the state has had little or no regulatory experience. New mining operations and reactivation of old mining sites will occur. These will probably be under tighter environmental control than was exercised in the past. Total impacts from resource extraction activities will probably not increase if enforcement resources keep pace with industry growth.

ATMOSPHERIC DEPOSITION

Atmospheric deposition is very difficult to quantify as is the potential water quality degradation. It additionally should be considered under the ambient air pollution threat. Two items of special note are the decline of lead and arsenic emissions in recent years. The use of unleaded gasoline has lowered lead emissions, and the main source of arsenic was removed when the Asarco Smelter closed in Tacoma in 1986.

HIGHWAY MAINTENANCE AND RUNOFF

Highway runoff can be contaminated with solids, metals, and many organic compounds, both priority and non-priority. Water and sediments can be affected. Highway runoff is similar to other stormwater and is therefore included in that section under the Point Source Discharges to Water.

POINT SOURCE DISCHARGES TO WATER

Point sources discharge wastewater to surface or ground waters at discrete locations. Usually waters are confined in some way, e.g.,to a pipe, and can therefore be characterized at that location. Combined sewer overflows, stormwater systems, and municipal and industrial wastewater treatment plants are all considered point sources under the regulations. Nonpoint sources however, can and do affect the quality of the point source discharges.

DETAILED SUMMARY OF POINT SOURCE DISCHARGES TO WATER

INDUSTRIAL FACILITIES/PROCESSES
Pulp and Paper Processing

The pulp and paper industry is Washington's largest group of industrial dischargers with a total combined flow estimated at 400 million gallons per day. Sixteen mills (Table 5) are currently operating statewide. Ten discharge to estuarine waters and remaining six to streams/rivers, primarily the Columbia River (Ecology, 1989a). The lower Columbia River also receives effluent from two additional pulp mills located in Oregon and one in Idaho (Wong, 1989).

Major pollutants associated with pulp mill effluent generally fall into two broad categories: conventionals; which include microbial pathogens, suspended solids, biochemical oxygen demand, and nutrients; and priority toxic organics; primarily dioxins/furans and chlorination products. The major ecological effects expected from conventional pollutants include; sediment organic enrichment/anoxia, reductions in benthic community populations and suitable habitat, algal blooms, and shellfish closers. Priority toxic organics can accumulate in sediments and bioaccumulate in fish/shellfish. This can cause benthic community problems, fish/shellfish consumption restrictions, and water quality violations (Ecology, 1989b; EPA, 1988).

Estuaries, streams and rivers in Washington are extremely productive and sensitive ecosystems. While impacts from conventional and toxic pollutants would be most severe in the vicinity of outfalls, a high potential for adverse ecological impacts could be expected throughout the receiving environment. In addition, due to the bioaccumulation potential of several toxic components in pulp mill effluents, more than one trophic level could potentially be affected. While onsite groundwater degradation is not expected to be a major concern, some goundwater impacts could be associated with disposal of sludge at landfills.

Intensity and duration of ecological effects are a function of a pollutant's toxicity, persistence, fate and transport processes, partitioning and bioaccumulation potential. Taking these factors into account, ecological recovery times would be expected to be on the order of years to centuries for most of the above mentioned pollutants

(Harwell and Kelly, 1986).

Estimates of the minimum and maximum amount of statewide surface waters potentially impacted by pulp mill discharges are presented below. Because Ecology (1988a) does not differentiate between industrial type, the following assumptions were used to calculate the maximum amount of surface waters potentially impacted.

Estuaries- All receiving water (i.e. bay where the discharge is located) is potentially impacted by discharge.

Streams/Rivers- All downstream sections are potentially impacted by discharge, except where dams are present. In the case of discharge to impoundments, the distance downstream to the nearest dam was used because solids tend to accumulate in the impoundments.

The above totals were then divided by the total amount of estuaries (2943 square miles) or stream/river miles (40,492 miles) in the state to obtain the total percentage potentially impacted.

Based on these calculations, approximately 6 percent of estuaries and 0.6 percent of stream/river miles present in Washington are potentially impacted by pulp mill discharges. In contrast, Ecology's 1988 statewide water quality assessment estimates that 2 percent of Washington's estuaries are affected by industrial discharges (Ecology, 1988b). This value probably represents a minimum since not all (72 percent) of the state's estuaries were actually assessed in the water quality report. Therefore the most reasonable estimate probably lies in the range of 2-6 percent (Table 2).

In Puget Sound, industrial dischargers account for approximately 10 percent of the total flow discharged from all pollutant sources (Arnold et al, 1987; PSWQA, 1988). Roughly 30 percent of the industrial total or 3 percent of the Puget Sound total could potentially be attributed to pulp and paper mills. The above mentioned figures should be used as estimates only since a limited amount of information was available on the actual extent and severity of ecological damage associated with pulp mills on either a site specific or statewide basis.

Employment projections for the pulp and paper industry indicate a 15 percent decline in the workforce by the year 2010 (BPA/NWPPC, 1988). Based on this information and historical trends in treatment technologies and effluent quality, ecological impacts from the pulp and paper industry should continue to decline in the absence of industry expansion.

Primary Metals Production

Iron, Steel and Misc. Metals Production- The iron and steel production and casting industry in Washington generally encompasses a small group of dischargers. Approximately four facilities permitted to discharge wastewater fall into this category statewide, with the majority located in the Seattle area. Industrial flows are typically under 1 million gallons/day, although one plant discharges 16 million gallons/day (Ecology, 1989c; URS, 1980). Receiving waters encompass both marine and freshwater systems. In addition to iron and steel production facilities located in Washington; Cominco Limited, the world's largest integrated lead-zinc smelting and refining plant, discharges an average annual flow of 78 million gallons per day to the Columbia River at Trail, B.C. approximately twelve miles upstream of the Canadian-Washington border (Ministry of Environment, 1979). This border represents the upper limit of Lake Roosevelt, the impoundment behind Grand Coulee Dam.

Major contaminants associated with the above mentioned facilities are; metals, cyanide, and priority organics (polynuclear aromatic hydrocarbons). The major ecological concerns associated with discharge of these contaminants include; sediment contamination, benthic community depressions, tissue bioaccumulation, potential tissue consumption restrictions, and water quality violations (Ecology, 1989b; Harwell and Kelly, 1986).

Estuaries, streams and rivers in Washington are extremely productive and sensitive ecosystems. The extent of ecological impact from iron and steel and miscellaneous metals production facilities discharges would be highly dependent on the dilution and flushing characteristic present in the receiving environment near the outfall. Severe ecological impacts would primarily occur in the vicinity of the discharge, and most likely affect only a localized area of the receiving environment. An exception being the Cominco facility which has been shown to affect approximately 165 miles of the Columbia River/Lake Roosevelt (Johnson et al, 1988; Ministry of Environment, 1979). In addition, due to the potential for tissue bioaccumulation of toxic components, several trophic levels could be impacted. While onsite groundwater degradation is not expected to be a major concern, some goundwater impacts could be associated with disposal of sludge at landfills.

Ecological recovery in the absence of direct discharge of toxic metals and organics from the above mentioned facilities and indirect sources of these pollutants such as sludge disposal at landfills could be expected to occur within the time frame of decades to centuries (Harwell and Kelly, 1986).

Data were not available to determine the amount of statewide surface waters impacted by discharges from the iron and steel production industry, since the Department of Ecology only maintains records of facilities with waste discharge permits. Based on the small number of permitted facilities alone, professional judgment would indicate that the total percentage of surface waters affected statewide is low. However, as previously stated ecological impacts could potentially be severe in the vicinity of the outfall. In contrast, an Ecology (1988a) assessment attributes Cominco Limited impacts to approximately 13% of Washington's total acreage of lakes and reservoirs, or 51% of the assessed acreage (Table 2). The calculation assumptions are as follows;

Lake Roosevelt acreage affected by Cominco Limited= 79,000 acres

Total acreage of Lakes and Reservoirs in Washington= 613,582 acres

Dividing Lake Roosevelt total by total in state= 13%

Employment forecasts indicate that the primary metals production industry's workforce is expected to expand by about 15 percent by the year 2010 (BPA/NWPPC, 1988).

Aluminum Production- Seven primary aluminum production facilities, shown in Table 6, are currently operating statewide in Washington with a combined flow of 36 million gallons/day and a total production capacity of 3700 tons/day of aluminum (Ecology, 1989a). Two of these facilities discharge wastewater to marine waters while the remaining five discharge to streams and rivers, primarily the Columbia River. The lower Columbia River also receives effluent from two mills located in Oregon (Wong, 1989).

Major pollutants associated with aluminum mills include toxic organics (polynuclear aromatic hydrocarbons and PCB) and toxic inorganics (metals and fluoride). The primary ecological concerns associated with both toxic organics and inorganics in marine and freshwater environments include sediment contamination, benthic community depressions, tissue bioaccumulation, potential fish consumption restrictions and water quality violations (Ecology, 1989b; EPA, 1988).

Estuaries, streams and rivers in Washington are extremely productive and sensitive ecosystems. While impacts from toxic organics and inorganics would be most severe in the immediate vicinity of outfalls, a high potential for adverse ecological impacts could be expected throughout the receiving environment. Generally speaking, as dilution and flushing in the area of the discharge decrease, the potential for adverse environmental impacts increases. In addition, due to the potential for bioaccumulation of several toxic components present in effluents from these facilities, multiple trophic levels in the ecosystem could be affected. While onsite groundwater degradation is not expected to be a major concern, some goundwater impacts could be associated with disposal of sludge at landfills.

Intensity and duration of ecological effects are a function of a pollutant's toxicity, persistence, fate and transport processes, partitioning and bioaccumulation potential. Taking these factors into account, for toxic organics and inorganics, ecological recovery times would be expected to be on the order of decades to centuries (Harwell and Kelly, 1986).

Assumptions used to calculate the maximum amount of statewide surface waters potentially impacted by aluminum mills are as follows;

Estuaries- Estimated that approximately 5-10 square miles around the outfall are potentially impacted by the discharge.

Streams/Rivers- See Pulp and Paper Processing

Based on these calculations approximately 0.6 % percent of the total square miles of estuaries and 0.3 percent of the stream miles present statewide are potentially impacted by aluminum mill discharges. The estimated area and miles of assessed water bodies are 0.8% and 2.6%, respectively (Table 2). These figures should be used as estimates only since a limited amount of information was available on the actual extent and severity of ecological damage associated with these facilities on either a site specific or statewide basis.

Employment forecasts generated by the Bonneville Power Administration for the year 2010 indicate that the aluminum industry's workforce is expected to remain fairly stable (BPA/NWPPC, 1988).

Food Processors

The food processing industry in Washington encompasses a diverse group of facilities located statewide. Major processor types include; seafood products, meat packers, fruits and vegetables, berries, dairy products (excluding dairies) and speciality products. There are over 280 food processing facilities statewide in the above mentioned groups permitted to discharge wastewater to both marine and freshwater systems. Flow from these facilities is typically a few thousand gallons/day; however, some plants discharge up to 7 million gallons/day (Ecology, 1989c; URS,1980).

Major contaminants associated with the food processing industry include; biochemical oxygen demand, suspended solids, and nutrients. Major ecological concerns associated with discharge of these contaminants include; sediment organic enrichment, dissolved oxygen depletion, siltation (habitat loss), and algal blooms (Harwell and Kelly, 1986).

Estuaries, streams and rivers in Washington are extremely productive and sensitive ecosystems. The extent of ecological damage from food processor discharges would be highly dependent on the dilution and flushing characteristic present in the receiving environment near the outfall. Severe ecological impacts would primarily occur in the vicinity of the discharge, and most likely affect only a localized area of the receiving environment. Groundwater quality impacts are not expected. Ecological recovery from conventional pollution, in most instances, could be expected to occur within the time frame of years to decades in the absence of the discharge (Harwell and Kelly, 1986).

Data were not available to estimate the amount of statewide surface waters impacted by discharges from the food processing industry.

Employment forecasts generated by the Bonneville Power Administration for the year 2010 indicate that the food processing industry's workforce is expected to remain fairly stable (BPA/NWPPC, 1988).

Metal Finishers

This is a group of smaller industrial facilities which include; electroplaters, etching/galvanizing operations and metal fabricators. Approximately nine facilities permitted to discharge wastewater fall into these categories statewide. Flow is typically a few thousand gallons/day with receiving environments being both marine and freshwater systems (Ecology, 1989c; URS, 1980).

Major contaminants associated with the metal finishing industry are metals, cyanide, priority organics (polynuclear aromatic hydrocarbons, phenols and solvents) and pH. The major ecological concerns associated with discharge of these contaminants include; sediment contamination, benthic community depressions, tissue bioaccumulation, potential tissue consumption restrictions and water quality violations (Norton and Johnson, 1984; Harwell and Kelly, 1986).

Estuaries, streams and rivers in Washington are extremely productive and sensitive ecosystems. The extent of ecological impact from metal finishing discharges would be highly dependent on the dilution and flushing characteristic present in the receiving environment near the outfall. Severe ecological impacts would primarily occur in the vicinity of the discharge, and most likely affect only a localized area of the receiving environment. However, due to the potential for tissue bioaccumulation of several toxic components present in effluents from metal finishing operations, multiple trophic levels could potentially be impacted. While onsite groundwater degradation is not expected to be a major concern, some goundwater impacts could be associated with disposal of sludge at landfills. Ecological recovery could be expected to occur within the time frame of decades to centuries in the absence of the discharge (Harwell and Kelly, 1986).

Data were not available to determine the amount of statewide surface waters impacted by discharges from the metal finishing industry, since the Department of Ecology only maintains records of facilities with waste discharge permits. Based on the small number of permitted facilities alone, professional judgment would indicate that the total percentage of surface waters affected statewide is low. However, as previously stated ecological impacts could potentially be severe in the area of the outfall.

Employment forecasts generated by the Bonneville Power Administration indicate that the metal fabricating industry's workforce is expected to expand by about 15 percent by the year 2010 (BPA/NWPPC, 1988).

Oil Refineries

There are six oil refineries in the State with a total discharge to Puget Sound of approximately 10 million gallons per day (Ecology, 1989a). The location of each refinery is presented in Table 7.

Wastewater generated by these refineries receives secondary biological treatment before being discharged. Major pollutants of concern in treated wastewater include; chemical oxygen demand (COD), ammonia, oil and grease, polyaromatic hydrocarbons (PAHs), phenols, sulfide and metals (chromium, hexavalent chromium, copper, etc). Stormwater runoff from the plant site and storage area can also carry pollutants to receiving waters. Oil spills from loading facilities are another potential ecological threat.

Receiving environmental impacts from oil refinery discharges may include: the contamination of water, sediment, and aquatic and benthic organisms; acute and chronic impacts on aquatic and benthic organisms; and bioaccumulation of toxics.

These ecological effects may be localized in the vicinity of each outfall. Ecological effects of accidental oil spills from loading facilities would be highly variable depending on the oil type and quantity spilled. Ecological (aquatic and coastline) recovery time also varies with type and amount spilled.

The refineries are located in groups of two and discharge in the same general waterbody location. Potentially impacted areas from these discharges was estimated assuming a 10 square mile area around each group of two refineries is affected. The US Oil and Sound Refining discharges were assumed to potentially impact entire Commencement Bay (12.4 square miles).

Based of these assumptions, 1.1 percent of the total estuaries in the State are potentiaaly impacted by oil refinery effluents. This number should be used a rough estimate since information on the actual extent and severity of ecological impact caused by refineries is limited.

Employment projections (BPA/NWPPC, 1988) for oil refineries show a gradual increase in the next two decades (24 percent increase by 2010). Ecological effects will likely increase also as oil refineries expand production or new facilities are built.

Inorganic and Organic Chemical Manufacturing Plants

Table 7. Oil refineries in Washington

Refinery	Location	Discharge Location	Average Wastewater Discharge (MGD)	Oil Production (barrels per day)
ARCO	Ferndale	Strait of Georgia	3.0	150,000
BP Oil	Ferndale	Strait of Georgia	1.4	75,000
Shell Oil	Anacortes	Fidalgo Bay	3.0	95,000
Texaco	Anacortes	Fidalgo Bay	3.0	100,000
Sound Refining	Tacoma	Hylebos Waterway	0.045	8,000
US Oil	Tacoma	Blair Waterway	0.25	27,000

In the State, there are approximately 20 chemical plants that discharge to surface waters or to municipal sewer systems (Ecology, 1989c). Wastewater from chemical plants will vary widely depending on the type of product made (e.g., inorganic or organic chemicals) and the process used to make the chemical. Effluent can consist of both cooling water and process wastewater. Cooling water discharges will usually be the largest part of the total discharge.

Ecological effects caused by chemical plant effluents will vary with the wastewater characteristics. Major concerns may include biological oxygen demand (BOD), pH, chemical oxygen demand (COD), oil and grease, chemicals (either inorganic or organic), metals and thermal discharges. Chemicals added to cooling water to retard the growth of slime may also affect receiving waters. Plants discharging to publically owned treatment works (POTWs) may cause treatment plant upsets (e.g., with high/low pH discharges or slug pollutant loadings) or chemically contaminate sewage sludge.

Pollutants may also enter the environment from surface water runoff from the plant site. Chemical spills or leaks from process units or storage areas may also be an environmental threat to surface or ground waters.

These ecological impacts will vary with the wastewater characteristics and may be localized in the immediate vicinity of each outfall. Thermal discharges may have relatively mild receiving water effects while chemically contaminated wastewater may have more intense effects (e.g., acute or chronic toxicity on receiving water biota or the bioaccumulation of toxics). Case studies involving chemical plant effluent characteristics and ecological effects are listed in the appendix.

Potentially impacted area from chemical plant effluents discharging over 1 million gallons per day was calculated in the same manner as for aluminum mills and oil refineries. Based on these calculations, 0.8 percent of the marine estuaries and 0.4 percent of rivers and streams in the State are potentially impacted by chemical plant discharges. These numbers should be used as rough estimates since information on the actual extent and severity of ecological impact caused these discharges is limited.

Employment projections (BPA/NWPPC, 1988) for the inorganic and organic chemical industry show a decrease in the next two decades (a 2.7 percent drop for inorganic chemical industry and a 0.6 percent decline for the chemical industry by 2010). Ecological effects are therefore assumed to remain the same or decrease slightly in the next two decades.

Electrical Utilities (power generating plants)

There are only a few power generating plants (coal or wastewood fired) in the State that discharge wastewater (Ecology, 1989c). Additionally, there are two commercial nuclear power plants that discharge wastewater (Ecology, 1989e). One plant is near Richland while the other is in Oregon on the lower Columbia River near Kalama. Wastewater discharged from power generation plants consists mostly of cooling water. Concerns from these effluents may include metals, thermal discharges, oil and grease and organics (eg compounds added to the cooling water to retard the growth of slime).

Ecological effects may be localized in the near vicinity of each outfall. Thermal discharges may cause temperature increases in the receiving water that threaten aquatic life. Organics and metals may have acute and chronic effects on receiving water biota.

Electrical energy demand for the State is projected to increase in the next decade (BPA/NWPPC, 1988). New power generating plants will probably be built to meet this demand. Ecological impacts associated with electrical utilities are therefore assumed to be increasing in the next two decades.

MUNICIPAL FACILITIES

Municipal Wastewater Treatment Plants

There are a total of 268 NPDES (national pollution discharge elimination system) municipal wastewater discharge permits in the State (Ecology, 1988a): 45 major (discharging over 1 MGD) and 223 minor (under 1 MGD). Of the 45 majors, 28 discharge to the Puget Sound basin (PSWQA, 1988). Concerns associated with wastewater treatment plant (WTP) effluents include biological oxygen demand (BOD), nutrients (ammonia and phosphorus), microbial pathogens, metals, organics, chlorine, and chlorinated organics produced during wastewater disinfection.

A summary of water quality impacted areas due to municipal discharges is given in Table 2 (Ecology, 1988a). In most cases, some other source (e.g., nonpoint pollution, industrial discharges, CSOs) also contributed pollutants to an impacted area. Therefore, the values in the table may overestimate (by an assumed factor of 2 to 10 times) the waterbody area impacted solely due to the municipal discharges.

For rivers and streams, microbial pathogens, metals and nutrients from WTPs impact the largest areas (12.5, 7.2 and 3.9 percent respectively). For marine estuaries, microbial pathogens, organics and metals impact the largest areas (11.6, 1.8 and 1.5 percent respectively).

By examining WTP effluent characteritics, potential impacts from municipal sources can also be estimated. For instance, chlorine data has been routinely collected during Environmental Investigation Class II treatment plant inspections. A summary of chlorine toxicity expected in water bodies receiving WTP effluent, assuming a worst case dilution, is presented in Table 8. It shows that a high percentage of WTPs will cause chlorine toxicity when the receiving water dilution is below 100:1.

Receiving environmental effects from WTP effluents may include organic enrichment and associated receiving water D.O. depletion; algal blooms caused by nutrients (ammonia and phosphorus); bacterial contamination of shellfish; chlorine, organic and metal acute/chronic toxicity on aquatic and benthic organisms; and contamination and bioaccumulation of toxics (organics, metals).

Ecological effects from municipal wastewater discharges may be localized in the vicinity of each outfall or may affect larger areas. As indicated above, WTP discharging to smaller rivers or streams (e.g., in eastern Washington) may have substantial chlorine impacts. WTPs discharging to larger water bodies may still have chlorine toxicity in the immediate mixing zone of the outfall.

Acute and chronic toxic effects from chlorinated organics or other organics may also be localized in the near vicinity of the outfall. BOD, nutrients, and microbial pathogens may impact a much wider area (e.g., inlets or reservoirs downstream of WTPs).

In general, the level of wastewater treatment will improve in the next decade. All major existing primary treatment plants are in the process of upgrading or plan to upgrade to secondary treatment. Furthermore, The Washington Centennial Clean Water Fund is currently providing money for treatment plant improvements and upgrades.

Ecology is currently implementing a biomonitoring policy to help control and reduce toxic WTP effluents. Future NPDES monitoring requirements for major dischargers may include effluent particulate testing for toxics, sediment testing around the outfall and water quality monitoring at the edge of the dilution zone. Corrective action will be costly (e.g., requiring additional treatment or identifying the specific source of the problem) but will result in a lessened ecological impact.

More wastewater will be generated as the population of the State increases. Conditions in NPDES permits ensure that wastewater generated by a municipality will not exceed its plant design capacity. When 85 percent of the capacity has been reached, the permittee must submit a plan to address treatment capacity (e.g., either expand the plant or limit development so that plant capacity is not exceeded). In the future, federal, state or local money needs to be available for the expansion or upgrading of treatment plants.

Only a portion of the marine estuaries (2114 square miles of 2943 total square miles) and rivers and streams (4621 miles of 40492 total miles) in the State were assesed. Therefore, the total area effected

Table 8. Summary of chlorine toxicity expected in waters receiving WTP effluent.

Assumed Dilution Ratio	# of plants over criteria*	% of plants with available data+
10:1	35	80
20:1	33	75
50:1	26	59
100:1	18	41
200:1	10	23

* - EPA 4 day water quality criterion for chlorine

\+ - Data was collected from inspections conducted from 1980 to 1987 at 44 WTPs throughout the State statewide for a specific concern can not be accurately determined. However, since problem areas are monitored or studied more often, the percentage of assesed areas impacted in this report overestimate the percentage of areas impacted Statewide.

Municipal Sources (Pretreatment)

WTPs may receive wastewater from a wide variety of industries (e.g. metal finishers, food processors, automotive repair shops, laundries, etc). Industrial pretreatment programs are designed to regulate discharges which may pass-through pollutants to receiving waters, interfere with treatment plant operations, cause NPDES permit violations, contaminate sludge, or harm treatment plant operators.

There are currently nine cities throughout the state that have implementated or are in the process of implementing industrial pretreatment programs (Winters, 1989): Seattle, Spokane, Tacoma, Vancouver, Everett, Lynnwood, Pierce County - Chambers Creek plant, Bremerton and Richland.

Ecology policy requires that WTPs with a design flow of 5 MGD or greater develop local pollutant discharge limits. These local limits define how much of a particular pollutant an industry is allowed to discharge to the sewer system. Ecology policy also requires that WTPs with a design flow of 3 MGD or greater complete an industrial users survey (a list of all industries and commercial establishments that discharge to the WTP). These surveys are useful in determining which WTPs should develop pretreatment programs. In addition, the surveys help identify industries that might require a state wastewater discharge permit.

Combined Sewer Overflows (CSO) and Stormwater

CSOs and stormwater are now being regulated as point source discharges. CSOs receive domestic sewage and other wastewater along with stormwater. During dryer weather, all of the water in the pipe is usually treated at a municipal wastewater facility. During wet weather events, the pipe surcharges and discharges directly to surface waters. Domestic wastewater quality is very similar to urban stormwater and the following discussion is therefore inclusive. Stormwater consists of contaminated runoff from industrial, commercial, construction, residential areas, and highways. It has elevated concentrations of metals, bacteria, organic compounds, sediment, oxygen demanding compounds, nutrients, and debris. Sediments contaminated with metals and toxic organics are routinely found around storm outfalls. Fishery habitat is degraded by poor water quality and waterways sustain substantial hydrographic modification. CSOs and storm sewers can also have a large aesthetic impact.

The intensity of the impact ranges from minimal, in a few cases, to severe depending on land uses in the drainage. The trend for stormwater and CSO runoff is toward more control and treatment. CSOs are being eliminated for all but a one in ten year storm, and storm water runoff in the larger urban areas will be permitted under the National Pollutant Discharge Elimination System (NPDES) within the next five years. Smaller cities in the Puget Sound basin will also have to develop stormwater management plans (PSWQA, 1988).

Ecology (1988a) and the WBTS database (Ecology, 1989d) provide an estimate of the impact associated with CSOs and storm sewers. The combined assessed water quality impacted areas for lakes, rivers and streams, estuaries, and coastal waters is 42.5, 11.8, 46.7 and 0.0 percent, respectively.

Increased urban growth and its impervious surfaces will exacerbate the stormwater problem that exists today. Control programs will be costly to implement and at the current rate, will not likely be completed by the year 2010.

COAL AND ORE MINING
OIL AND GAS DEVELOPMENT
PLACER MINING AND OTHER ACTIVITIES

See RESOURCE EXTRACTION/EXPLORATION/DEVELOPMENT discussion in the nonpoint source section.

Reference List

Arnold, F. D. , J. D. Lowe and D. R. G. Farrow, 1987. The National Coastal Pollutant Discharge Inventory, Estimates for Puget Sound. Draft Report. Produced by Strategic Assessments Branch, NOAA Rockville, MD.

Bervall, J., 1989. Personal Communication. Washington Department of Natural Resources, Olympia WA.

BPA/NWPPC, 1988. Economic Forecasts for the Pacific Northwest. Prepared by Bonneville Power Administration and Northwest Power Planning Council.

Daly, J., 1989. Personal Communication. Washington St. Dept. of Agriculture.

Determan, T. A., B. M. Carey, W. Chamberlain, and D. Norton, 1985. Sources Affecting the Sanitary Conditions of Water and Shellfish in Minter Bay and Burley Lagoon. Washington St. Dept. of Ecology Report No. 84-10 186pp.

DSHS, 1989. Second Annual Inventory of Commercial and Recreational Shellfish Harvest Areas in Puget Sound. Shellfish Section Report. Olympia WA.

Ecology, 1988a. 1988 Statewide Water Quality Assessment 305(b) Report. Washington State Department of Ecology Publ. No. 88-9.

Ecology, 1988b. Water Quality in Washington: A Summary of the 1988 Statewide Water Quality Assessment. Washington State Department of Ecology Report No. 88-20.

Ecology, 1988c. Nonpoint Source Pollution Assessment Report. May 1988 Draft. Washington St. Dept of Ecology Report No. 88-4.

Ecology, 1989a. Industrial Section: Issues and Facilities Status Briefing Papers. Internal Briefing Papers to Ecology Management.

Ecology, 1989b. Clean Water Act Section 304(L) Technical Report. Vol. 1, List of Waterbodies Required Under Section 304(L).

Ecology, 1989c. Washington Dischargers Permit Fee Inventory System. Database.

Ecology, 1989d. Water Body Tracking System Database. Maintained by Ed Rashin Washington St. Dept. of Ecology.

Ecology, 1989e. Releases from Radioactive Wastes/Radioactive Materials: Comparative Risks for Washington State. May, 1989 draft. Washington State Department of Ecology. Environment 2010 Radiation Subcommittee.

EPA, 1987. Nonpoint Source Discharges to Surface Waters, Rivers and Lakes. Risk Assessment Report. EPA Region X.

EPA, 1988. Ecological Risk Assessments: Publically Owned Treatment Works and Industrial Point Source Discharges. Draft Report EPA Region X.

Harwell, M. A. , and J. R. Kelly, 1986. Ecosystem Research Workshop on Ecological Effects from Environmental Stresses. Ecosystems Research Center, Cornell University. Prepared for EPA Comparative Risk Project.

Johnson, A. , D. Norton and B. Yake, 1988. An Assessment of Metals Contamination in Lake Roosevelt. Washington State Department of Ecology, 77pp.

Ministry of Environment, 1979. Kootenay Air and Water Quality Study Phase II: Water Quality in the Lower Columbia River. British Columbia Ministry of Environment Report No. 0322512. 238pp.

Norton, D. and A. Johnson, 1984. Metals in City Waterway Sediment off American Plating Co., J. M. Martinac Shipbuilding Corp. , and Fick Foundry Co. , April, 1984. Completion Report on WQIS Project 5 (Part 2) for the Commencement Bay Nearshore/Tideflats Remedial Investigation.

OFM (Office of Financial Management), 1987. State of Washington Data Book. 302 pp.

Packard, F. A. , E. l. Skinner and L. A. Fuste'. 1988. Effects of Coal Mine Drainage on the Water Quality of Small Receiving Streams in Washington, 1975-1977. U. S. Geological Survey Water Resources Investigations Report 85f-4274 65 pp.

Patmont, C. R. , G. J. Pelletier, E. B. Welch, D. Banton, and C. C. Ebbesmeyer, 1989. Lake Chelan Water Quality Assessment. Prepared by Harper-Owes for Washington State Department of Ecology.

PSWQA, 1986. Issue Paper Non-Point Source Pollution. Puget Sound Water Quality Authority. Seattle, Wa.

PSWQA, 1988. State of Sound 1988 Report. Puget Sound Water Quality Authority, Seattle, Wa.

PTI, 1989. Puget Sound Dredged Disposal Analysis Baseline Survey of Phase I Disposal Sites. Prepared for Washington Department of Ecology. 126pp.

URS, 1980. Industrial Waste Survey. Prepared for Washington State Department of Ecology. URS Company, Seattle, Wa.

Winters, N., 1989. Personal Communication. Washington State Department of Ecology.

Wong, P. , 1989. Personal Communication. Oregon Department of Environmental Quality.

HUMAN HEALTH EFFECTS RELATED TO POINT AND NONPOINT SOURCE DISCHARGES TO WATER

A. Description of Analytical Approach and Data Sources

Data Sources

Human health effects were assessed by examining the current risks from consuming recreationally caught fish and shellfish from the waters of Washington State, or from full immersion bathing at swimming beaches. Worst and average case scenarios were compared using fish and shellfish data compiled from various studies performed around the state. Recommended risk assessment techniques were then applied (USEPA, 1989). Those contaminants with probable known sources are indicated. However, most contaminants creating the health risks are associated with both point or non-point sources, and cannot be readily apportioned.

Table 1 summarizes the major contaminants we evaluated that could potentially cause adverse health effects to people consuming fish or shellfish harvested in the state. The selected contaminants can be roughly divided into three categories: 1) seven carcinogenic chemicals, 2) five non-carcinogenic chemicals, and 3) two biological agents. The contaminants were chosen after reviewing data from: Washington Dept. of Ecology fish tissue monitoring program and special studies (Hopkins and Clark, 1985; Johnson, Norton, and Yake, 1986 & 1988; Patmont et al, 1989); compilations of Puget Sound fish and shellfish data (Tetra Tech, 1988; Yake, Joy, and Johnson, 1984); and shellfish data from the Washington Dept. of Social and Health Services (DSHS, 1986; Faigenblum, 1988) and U.S. Food and Drug Administration (Kaysner, et al, 1987a,b). To our best knowledge, only fillet fish tissue concentrations were used. Tetra Tech (1988) did not state if all their compiled data were fillet. Whole body shellfish tissue concentrations were used; all shellfish samples were collected from Puget Sound.

Several elements were not included in this assessment. The following contaminants were not assessed for lack of data: viruses, tributyl tin, heterocyclic hydrocarbons, phthalate esters, phenolic compounds, various herbicides and pesticides, resin acids, guiacols, and antibiotics (used in fish culture and agriculture). Many of these contaminants are just receiving investigation and research. Their environmental threat is uncertain, especially as it relates to bioaccumulation and human consumption. Also, ingestion of crayfish, seaweed, crab and other seafood products were not

Table 1. Contaminants assessed as part of the 2010 human health risk evaluation.

CONTAMINANT	PRIMARY EXPOSURE	HUMAN HEALTH EFFECTS	SEVERITY SCORE*
DDT	FISH	SUSPECTED CARCINOGEN	
DIELDRIN	FISH	SUSPECTED CARCINOGEN, LIVER ENLARGEMENT NEUROTOXIC EFFECTS	
ALPHA-BHC	FISH & SHELLFISH	SUSPECTED CARCINOGEN	
PCB	FISH & SHELLFISH	SUSPECTED CARCINOGEN, CHLOROACNE LIVER DYSFUNCTION, NEUROPATHIC DISORDERS SUSPECTED FETOTOXIC	
DIOXIN	FISH	SUSPECTED CARCINOGEN	
CARCINOGENIC PAH	SHELLFISH	SUSPECTED CARCINOGEN	
ARSENIC	FISH & SHELLFISH	SKIN CANCER, NEUROTOXIC	
ENDOSULFAN	FISH	NEUROTOXIC	6
ENDRIN	FISH	SUSPECTED TERATOGEN, NEUROTOXIC SUSPECTED FETOTOXIN	7, 6 6
CADMIUM	FISH & SHELLFISH	KIDNEY DAMAGE, POTENTIAL FETOTOXIC	3, 6
LEAD	FISH & SHELLFISH	HEMOTOXIC, NEUROTOXIC, REPRODUCTIVE DISORDERS HIGH RISK TO CHILDREN AND PREGNANT MOTHERS	4, 6 5, 6
MERCURY (METHYL)	FISH & SHELLFISH	NEUROTOXIC	6, 3
PARALYTIC SHELLFISH POISON	SHELLFISH	NEUROTOXIC	6, 3
VIBRIO PARAHAEMOLYTICUS	SHELLFISH	GASTROENTERITIS	4

* SEVERITY IS SCORED USING NATIONAL COMPARATIVE RISK PROJECT LIST FOR NON-CARCINOGENS (USEPA,1989)

assessed because data were lacking. Finally, the health risk from consuming commercial fish products was not assessed. Commercial products were assumed to generally have a lower contamination risk than recreationally obtained products because of the common open-water fishing grounds and quality regulations required of commercially caught products.

In terms of actual health statistics, only the biological agents have yet been implicated in any illness or deaths (DSHS, 1986; F. Cox, DSHS, personal conversation). None of the other contaminants have been the subject of detailed, state-wide epidemiological studies involving exposure through food.

Assumptions for Risk Assessment

Carcinogenic and Non-carcinogenic Contaminants

The following set of equations were used to calculate carcinogenic and non-carcinogenic risk (Tetra Tech, 1988):

Dose = (Concentration x Ingestion rate)/ Body weight
where, dose is mg/kg body weight/day
concentration is mg/kg
ingestion rate is kg fish/day
and, is the average lifetime body weight of 70 kg (US adult male)

Then,
Carcinogenic risk = 1 - e(-Potency factor x Dose)

or, Non-carcinogenic risk index = Dose/Reference dose

where, Potency factor and Reference dose are given in mg/kg/day (Table 2)

Several assumptions on absorption, ingestion, and potency or reference dose were made while calculating risks. No absorption rate factors were included in the calculation, although the most recent potency factor for arsenic appears to have the 0.1 absorption rate built-in (compare Tetra Tech 1986 to 1988). Ingestion rates were based on the work performed by Tetra Tech for Puget Sound (Tetra Tech, 1988):

	High	Average
Fish	95.1 g/day	12.3 g/day
Shellfish	21.5 g/day	1.1 g/day

The high rate is one that 5% of the fishing or shellfish harvesting population partakes, and the average reflect the consumption of 50 % of the fishing public (Tetra Tech, 1988).

HEALTH RISK TABLES

Table 2. Potency factors and reference doses for selected contaminants.

CONTAMINANT	REFERENCE DOSE (mg/kg/day)	POTENCY FACTOR (mg/kg/day)	REFERENCE
DDT		0.34	TETRA TECH, 1988
DIELDRIN		30.40	TETRA TECH, 1986
ALPHA-BHC		11.12	TETRA TECH, 1988
PCB		7.70	TETRA TECH, 1988
DIOXIN		156000	TETRA TECH, 1986
CARCINOGENIC PAH		11.50	TETRA TECH, 1988
ARSENIC		1.50	TETRA TECH, 1988
ENDOSULFAN	0.0001		TETRA TECH, 1988
ENDRIN	0.001		TETRA TECH, 1986
CADMIUM	0.0003		TETRA TECH, 1988
LEAD	0.001		TETRA TECH, 1988
MERCURY (METHYL)	0.0003		TETRA TECH, 1988

The average lifetime body weight of 70kg. was used to calculate dose assuming a constant (high or average) daily ingestion rate and exposure over 70 years. Children, ethnic minority populations, pregnant women, and prenates were not covered in this assessment and would not be well represented by the 70kg. standard body weight, ingestion rates, or duration assumptions.

The maximum concentration detected in the state was used with the high ingestion rate to characterize the maximum exposed individual (MEI). Average tissue concentrations with average ingestion rates were used to evaluate general exposures.

A calculation was also required to estimate the affected population exposed to the contaminants. There are an estimated 1.12 million fishermen (Table 3) in the state based on license records (Jones and Stokes, 1988). Licenses are not required for recreational shellfish harvesting. So, the number of shellfish harvesters was estimated in the following manner:

> Washington Dept. of Fisheries (WDF) estimates there were 1.2 million user trips for clams on public beaches in 1986 (Westley, 1989). Price et al (1978) reported that 36% of the people they interviewed on south-central Puget Sound beaches dug clams six times a season; another 62% dug three times a season, and 2% dug 24 times a season. If these percentages are applied to the entire state, then:
>
> $$(0.62 * x * 3)+(0.36 * x * 6)+(0.02 * x * 24)= 1.2 \text{ million user trips}$$
>
> so, x = ~300,000 clam diggers
>
> We further assumed that the same 300,000 people made the 1.1 million oyster user trips reported by WDF in 1986 (Westley, 1989).

The MEI population was calculated in the following manner:

> According to the Tetra Tech (1988) estimate, 5% of the fishing and shellfish harvesting population eat their catch at the higher ingestion rate. We further assumed that only the harvester consumes at the higher rate, not his/her family and friends. To account for geographic differences in contaminant concentrations, we assumed 10% of the high consumption harvesters take their catch from areas where high level contamination is likely. For example, the maximum total DDT concentration were taken from fish caught in two or three drainages of eastern Washington. These drainages could likely support 10% of the fishing population, but only detailed study of creel census would verify this. Similarly,

Table 3. Fishing public in Washington State (Jones & Stokes, 1988)

Total Fishermen (16 yrs & older)	1,122,300
Total Days Fishing	19,565,100
Average per Fisherman	17
State-Resident Fishermen	982,300
Freshwater	705,300
Saltwater	562,800
Types of Fish Sought (Days/Fisherman)	
Salmon	15.3
Steelhead trout	15.3
Other trout	15.5
Bass	17.5
Panfish	14.8
Catfish	17.8
Walleye	19.8
All other freshwater fish	12.0
Anything	17.3

PCBs and other contaminants have been a problem in urban areas of Puget Sound which effects approximately 10% of the marine recreational fishing and shellfish harvesting areas. Multiplying the fishing and shellfish harvesting populations by 5% and then 10% gave us a population of MEIs of 0.5 percent of the total fishing or shellfish harvesting population, i.e. 5600 fishermen and 1500 shellfish harvesters.

Biological Agents

Biological agents present in shellfish and causing illness were also included in the risk assessment. Although they are caused by naturally occurring organisms, some experts believe their recent infestation into local marine waters is a result of degraded water quality. The causative organisms inhabit the waters of Puget Sound, Strait of Juan de Fuca, and portions of the coast. They are ingested by shellfish usually in the late summer. Gonyaulax catenella and other dinoflagellates ingested by shellfish carry the toxin causing paralytic shellfish poison (PSP). People who eat PSP contaminated shellfish can experience tingling of extremities and dizziness, or with serious poisoning incidents, neurotoxic symptoms and death. Another type of organism causing illness are bacteria of the genus Vibrio, e.g V. cholerae, V. vulnificus, and V. parahaemolyticus. They can cause severe gastrointestinal distress, and when other health complications occur, death.

DSHS has a PSP monitoring network and public notification process in place. Commercial shellfish growers are closed down and public beaches are posted when PSP concentrations exceed a standard. Commercial shellfish sold for consumption by the public have not yet been involved in PSP poisoning incidents. Local health departments and the media are notified of the hazard at local beaches. Still, not everyone is educated about the danger of PSP.

Vibrio is not as extensively monitored as PSP and is present in most shellfish growing waters of the state. Cases of reported poisoning have involved poor shellfish handling and cooking practices as much as through consumption of raw shellfish. Food poisoning from Vibrio can occur from shellfish collected recreationally or bought from a commercial grower and served in a restaurant (personal conversation, F. Cox, DSHS).

Incidences of PSP or food-borne illness within the state are reported through local doctors, hospitals, and health departments to DSHS (Table 4). Severe PSP incident statistics are probably accurate; slight poisoning cases are

Table 4. Reported Incidences of Paralytic Shellfish Poison (PSP) and Vibrio Poisoning in Washington St

YEAR	# SICK	# EXPOSED	FOOD TYPE	AGENT	PLACE	FOOD HANDLING	TOTAL CASES
1978	4	5	PECTINS	PSP	HOME	UNSAFE SOURCE	14
	2	3	MUSSELS	PSP	HOME	UNSAFE SOURCE	
	3	3	MUSSELS	PSP	HOME	UNSAFE SOURCE	
	1	1	MUSSELS	PSP	HOME	UNSAFE SOURCE	
1979	3	3	CLAMS	PSP	HOME	UNSAFE SOURCE	14
1980							3
1981							0
1982							0
1983							5
1984	1	1	OYSTERS	VIBRIO	UNKNOWN	UNSAFE SOURCE	1
1985	2	8	RAW OYSTERS	VIBRIO	HOME	INADEQUATE HOLDING	10
	2	4	SCALLOPS	PSP	HOME	UNSAFE SOURCE	
	1	2	SCALLOPS	PSP	HOME	UNSAFE SOURCE	
1986	3	6	VARIETY SHELLFISH	VIBRIO	RESTAURANT	INADEQUATE COOKING	8
	1	1	RAW OYSTERS	VIBRIO	HOME	INADEQUATE COOKING	
	1	1	RAW OYSTERS	VIBRIO	HOME	INADEQUATE COOKING	
	1	3	RAW OYSTERS	VIBRIO	HOME	INADEQUATE COOKING	
	2	3	SHRIMP	VIBRIO	RESTAURANT	INADEQUATE COOKING	

* The total number of foodborne illnesses involving shellfish for that year
Includes PSP, Vibrio, Hepatitis, Staphylococcus aureus and others

Table 5. Enterococcus and Escherichia coli data (Vasconcelos & Anthony, 1985) and resultant rates of gastroenteritis expected (Cabelli, 1983; DuFour, 1983).

BEACH	DATE	ENTEROCOCCUS /100 ML	ILLNESS** /1000	E. COLI /100 ML	ILLNESS /1000
ALKI BEACH, SEATTLE	6/77	51	4	6	
	9/77	3		5	
	8/78	2		5	
	8/80	6		0	
	9/81	4		1	
	GEO. MEAN*	6	2	3	< 1
GOLDEN GARDENS, SEATTLE	6/77	12		18	
	9/77	2		3	
	8/78	0		1	
	8/80	20		47	
	9/81	2		1	
	GEO. MEAN	4	< 1	5	< 1
GREEN LAKE, SEATTLE	6/77	6		0	
	9/77	460	12	60	
	8/78	4		3	
	8/80	0		1	
	9/81	13		4	
	GEO. MEAN	11	1	4	< 1
JUANITA BEACH, KIRKLAND	6/77	31	2	120	1
	9/77	370	12	64	
	8/78	22		120	1
	8/80	100	6	220	4
	9/81	16		44	
	GEO. MEAN	53	7	98	4
LAKE SAMMAMISH BELLEVUE	6/77	6		0	
	9/77	12		14	
	8/78	8		54	
	8/80	69	5	100	1
	9/81	2		4	
	GEO. MEAN	10	1	12	< 1
RIVERSIDE STATE PARK SPOKANE	6/77	38	2	500	7
	9/77	38	2	1100	10
	9/78	4		83	
	10/80	54	4	350	6
	10/81	17		23	
	GEO. MEAN	22	4	205	7
SUNCREST BEACH SPOKANE	6/77	10		10	
	9/77	2		1	
	9/78	18		0	
	10/80	0		1	
	10/81	90	6	10	
	GEO. MEAN	8	< 1	3	< 1

* Geometric mean of five samples pooled and resultant rate of gastroenteritis expected

** Rate of gastroenteritis expected based on statistical coverage by number of samples taken probably less well reported, maybe 1 in 20 (personal conversation, F. Cox, DSHS). Food poisoning incidences of Vibrio or other illnesses from contaminated shellfish are poorly reported, probably 1 in 100 (personal conversation, F. Cox, DSHS).

Swimming

The risk of contracting gastroenteritis from swimming at bathing beaches in the state was assessed using local work performed by Vasconcelos and Anthony (1985) and epidemiological studies by USEPA (Cabelli, 1983; DuFour, 1983). The concentrations of Escherichia coli and enterococcus organisms have been correlated to incidence of gastroenteritis contracted while swimming at marine and freshwater beaches (Cabelli, 1983; DuFour, 1983). Selected E. coli and enterococcus data from Vasconcelos and Anthony (1985) are shown in Table 5 for several beaches during a long Northwest swimming season (June to October).

Swimmers potentially exposed to illness because of their activity were calculated as follows:

> Attendance at freshwater state parks in 1986 was about 4 million; attendance at Puget Sound saltwater state parks was around 9 million (OFM, 1987). To account for county and city park attendance we increased each by 2 million for totals of 6 million and 11 million. These statistics include multiple visits by individuals to parks, so we divided the totals by three as the average visit per season. Surveys cited by the Puget Sound Water Quality Authority (1988) state that 57% of the in-state vacationers swim. This statistic gives us a swimming populations of 1.1 million and 2.1 million, respectively. Cabelli (1983) found that in the four study areas (New York, Boston, Lake Pontchartrain and Alexandria-Egypt) used to evaluate indicator organisms and health effects, consistently 60% of the beach-goers participated in full-immersion swimming. Applying this statistic to the swimming populations above give us 0.7 million exposed population in freshwater areas and 1.3 million in saltwater areas.

B. Findings

Ingestion of Fish and Shellfish

Carcinogens

The USEPA considers carcinogenic risks greater than 1 x 10-3 to be subject to regulatory action, while those below 1 x

10-7 would not be (Tetra Tech, 1988). Between these two risk terms is the grey area of 'case-by-case' action or inaction, where USEPA would decide depending upon the size of the population at risk.

The analysis indicates the MEI in this state to be at most risk from PCB, but also: total DDT, alpha-BHC, dieldrin and dioxin concentrations in fish; carcinogenic polynuclear aromatic hydrocarbons (PAH) pose the highest risk in shellfish (Table 6). The MEI may also have to be concerned about arsenic in fish, and arsenic, PCB, and alpha-BHC in shellfish. According to this analysis, ingestion by the MEI population (see above) of fish highly contaminated with PCBs could result in 123 additional cases of cancer over 70 years. Similarly, high consumption of PAH rich shellfish could result in 4 additional cases of cancer over 70 years.

None of the risk values for average consumption of fish or shellfish with average contaminant concentrations were greater than the 1 x 10-3 carcinogenic risk index guideline for action. Arsenic, PCB, total DDT, alpha-BHC, dieldrin and carcinogenic PAH values for fish or shellfish were greater than the 1 x 10-7 no action risk. PCBs were again the highest risk for fish resulting in a potential 38 additional cases of cancer over 70 years in 50% the recreational fishing population (560,000-see above). PAHs in shellfish resulted in a possible 2 addition cases of cancer in half of the recreational shellfish harvesters.

Non-carcinogens

Non-carcinogenic risk index values above 1 are considered to be of concern (Tetra Tech, 1988). The analysis in Table 6 indicates the MEI in this state to be at risk from lead and mercury concentrations in fish; and cadmium, in shellfish. The MEI may also have to be concerned about cadmium in fish, since the 0.6 index value is near 1. As stated earlier, these contaminants have a potential of effecting 5,600 fish or 1500 shellfish harvesters. The severity of the health effects from these contaminants are demonstrated by their National Comparative Risk Project Score listed in Table 1.

None of the risk values for general exposure (average ingestion rate of fish or shellfish with average contaminant concentrations) were greater than the non-carcinogenic risk index guideline for action.

PSP and Food-borne Illness

ble 6. Contaminant concentrations (mg/kg) and resultant risk values selected for human health effects evaluation, Environment 2010 Project.

	FISH CONCENTRATION		SHELLFISH CONCENTRATION		FISH CONSUMPTION RISK		SHELLFISH CONSUMPTION RISK	
NTAMINANT	MAXIMUM	AVERAGE	MAXIMUM	AVERAGE	MAXIMUM	AVERAGE	MAXIMUM	AVERAGE
T	3.10	0.30	--	--	1.4E-03	1.8E-05	--	--
ELDRIN	0.12	0.01	--	--	4.9E-03	5.3E-05	--	--
PHA-BHC	0.17	0.015	0.0001	0.00005	2.6E-03	2.9E-05	3.4E-07	8.7E-09
B	2.10	0.02	0.23	0.045	2.2E-02	2.7E-05	5.4E-04	5.4E-06
OXIN	0.0000079	--	--	--	1.7E-03	--	--	--
RCINOGENIC PAH	--	--	0.75	0.062	--	--	2.6E-03	1.1E-05
SENIC	20.70	0.27	22.10	3.20	4.2E-03	7.1E-06	1.0E-03	7.5E-06
DOSULFAN	0.03	0.001	--	--	0.41	0.002	--	--
DRIN	0.005		--	--	0.01	--	--	--
DMIUM	0.21	0.005	1.30	0.20	0.95	0.003	1.33	0.01
AD	6.20	0.20	2.00	0.20	8.42	0.04	0.61	0.003
RCURY (METHYL)	0.78	0.02	0.10	0.02	3.53	0.01	0.10	0.001

Nine severe and one mild case of PSP were reported in 1978, but fewer have been reported in each following year (to 1986, the last year of summarized data). If the nine cases are taken as a maximum annual incidence rate of severe cases, and we multiply the single mild case by 20 to account for public under-reporting, the maximum risk to the 300,000 recreational shellfish harvesters is approximately 3 severe cases in 100,000 and 7 mild cases in 100,000. The average risk is an order of magnitude or more lower since many years have had no reported incidents of PSP poisoning. PSP levels usually exceed standards only a few weeks of the shellfish harvesting season and only on certain beaches.

Vibrio appeared in the DSHS food poisoning statistics in 1984 (Table 4). Reported cases of Vibrio parahaemolyticus poisoning seemed to increase in the following two years, and included two incidents (5 cases) involving restaurants in 1986. Cases of reported poisoning have involved both poor shellfish handling and cooking practices, and consumption of raw shellfish. Vibrio cholerae has been found in water, sediment, and shellfish tissue in various parts of the state (Kaysner, et al, 1987a). Vibrio cholerae 01 infection was implicated as a complicating factor in one death in 1988, but was not reported in any other cases (personal conversation, F. Cox, DSHS). Vibrio vulnificus has been identified in state benthic sediments, but has not been implicated in any illnesses (Kaysner, et al, 1987b).

Assuming the three reported cases of raw oyster consumption in 1986 actually represents 300 because of poor public reporting, and further assuming only one-fourth of the recreational shellfish harvesters eat raw oysters, the maximum risk becomes 4 in 1000 for the 75,000 raw oyster eaters.

Swimming

Assuming the data by Vasconcelos and Anthony (1985) to be representative of urban marine and freshwater beaches, we applied the rates of swimming associated illness also listed in Table 5. Generally, 1 or 2 in 1000 swimmers would be expected to become ill from marine beach swimming, and 1 to 7 in 1000 at freshwater beaches. If we assume one-third of the full-immersion swimmers are exposed to this level of risk because they swim in urban areas, we would expect 230 to 1630 cases of gastroenteritis in freshwater swimming populations, and 430 to 870 cases from swimming in marine waters.

C. Discussion of Uncertainty

There are several major areas of uncertainty involved in this assessment which could severely change the stated risk, especially with contaminant risk from fish and shellfish ingestion:

- o the analytical quality of the data
- o the balance of sites (impacted and non-impacted)
- o the balance of species and other species variables (size, season, sex, food source)
- o estimations of potency factors and reference doses
- o estimations of consumption rates
- o contaminant changes (losses or gains) during storage and meal preparation
- o contaminant absorption rates via ingestion

Of these, probably uncertainties in species type and location have the largest effect that could be refined given more time and require some explanation.

The summarized carcinogen and non-carcinogen data do not indicate some of their somewhat regional and species specific characteristics. For example, all shellfish values for the MEI are for Puget Sound and are generally not applicable to coastal areas. Maximum arsenic and PCB fish concentrations are also Puget Sound urban embayment and bottom fish specific. On the other hand, the fish in some eastern Washington drainages are more likely to have elevated burdens of DDT, mercury, cadmium, lead, alpha-BHC, and dieldrin.

Most of the contaminant data used to calculate maximum and average concentrations are from species not commonly taken for consumption, e.g. squawfish and suckers. Resident game fish (Table 3) may have an entirely different range of tissue burdens of these contaminants. Major game fish species, salmon and steelhead trout, are anadromous and only pass through contaminated areas. Most data collected have shown lower tissue burdens of contaminants in these game species (Johnson, Norton, and Yake, 1986; Puget Sound Water Quality Authority, 1988). There is also a tendency for the data to portray impacted areas more than non-impacted areas, i.e. a bias toward sites likely to have problems.

On the other hand, the determination of the maximum exposed individual and exposed population to these contaminants were meant to be broad, but may be underestimates. For example, some minority populations may have a higher risk of exposure due to greater fish consumption habits, or because the fish species harvested are more likely to be contaminated due site selection (e.g. urban inner harbors) or the species trophic habits. Also, the risk of exposure to pregnant women, prenates, neonates, people with medical disabilities, or the elderly may be greater than depicted in the assessment.

It is our opinion that the possible overestimation of the maximum and average contaminant concentration, off-sets the underestimation for exposed individuals and populations to give a reasonable estimate of risk. Calculating a high and low range would infer a higher level of confidence in the estimate than exists.

Uncertainties with the risk assessment from PSP and Vibrio are of a slightly different character. Increased monitoring and public education efforts will keep the risk from PSP low. However, as PSP infects new areas not yet monitored, cases of poisoning can occur even from commercially harvested shellfish. Such an incident resulted in five cases of PSP in 1988 (Faigenblum, 1988), and could potentially effect a larger population, e.g. people consuming shellfish in local restaurants or from local seafood stores. Our understanding of the ecology of dinoflagellates predicting PSP outbreaks is very limited, so the future area effected is unknown. The population at risk probably has a large margin of error and requires more field research.

With Vibrio, the stated maximum risk is probably higher than the actual since it becomes a food poisoning potential only when water temperatures are elevated for several days. This is also a time when oysters are likely to be spawning and not particularly good for eating, so fewer people harvest at these times. Estimating the risk for contracting Vibrio from restaurants is too difficult at this time because an estimate of the potentially affected population is not known.

The stated risks of gastroenteritis to swimmers would probably portray the extreme case, especially in marine waters. Swimming populations at marine parks and full-immersion swimming data remain unknown for Washington beaches. Also, some of the worst cases (Riverside, Alki, and Golden Gardens) are in vicinity of large wastewater treatment plant outfalls, some of which have, or will be undergoing upgrades in the future. Few other public bathing beaches are similarly exposed to large municipal outfalls.

D. Structure or Anatomy of the Risk

The tissue concentrations of several of the know or suspected carcinogenic contaminants appear to be decreasing, and will probably continue to do so. The strict controls placed on the application of DDT, alpha-BHC, dieldrin and the use of PCBs over 10 years ago appear to have been effective in reducing point and non-point sources of these contaminants. In turn, it appears as though fish tissue burdens of pesticides in eastern Washington waters, and PCBs in Puget

Sound marine life are declining (Johnson et al, 1986; Puget Sound Water Quality Authority, 1988). The elimination of the smelter in Tacoma has also reduced the potential for continued high arsenic tissue burdens in local fish and shellfish. Runoff from areas contaminated with arsenic fallout and enriched benthic sediments may continue to be sources of non-point contamination for several years. Many of the worst cases of carcinogenic PAH contamination have occurred from poor industrial practices (wood treating, loading and fuel storage). Better regulation and enforcement of these industries and sensitivity of the public has helped to keep poor past practices from re-occurring. Chronic non-point contamination (storm sewers, general industrial area run-off, auto emissions) from carcinogenic PAHs is likely to continue, especially in urbanized areas.

It is difficult to imagine widespread contamination from yet undiscovered carcinogenic compounds. However, it is very possible that the harmful effects of chemicals we use now, or are developed in the future, are not fully known. An example are dioxin compounds. Some cogeners are extremely carcinogenic to lab animals and aquatic organisms, but their toxicity to humans is unknown. The toxicity may occur at the nanogram/liter level. This makes sample analysis difficult and expensive so few environmental samples have been analyzed. The data collected so far indicated there are dioxins in some sediments, fish, water and pulp mill wastes at these minute levels. However, the ecological and human health significance of the types of dioxins identified at the concentrations detected in the environment are not adequately known. Dioxins are only one group of compounds. It is likely we are and will be exposed to other unknown carcinogens in our food and water into 2010, that require further assessment and control.

Sources of non-carcinogens also appear to be decreasing. The use of unleaded gasoline has already reduced the amount of lead emissions into the atmosphere. This will decrease non-point sources of lead reaching waterways and accumulating in biota tissue. Lead emissions from the Tacoma smelter have also been eliminated. Lead and mercury are no longer used as agricultural pesticides. The British Columbia refinery on the Columbia River and mining areas of northeast Washington and the Idaho panhandle will continue to be sources of lead for some time. Mercury contamination from pulp mills is no longer a threat. Other non-point sources of mercury, cadmium, and lead may continue, but tissue burdens will probably drop except in highly urbanized areas or mining/refining impacted areas.

The forecasts for future incidences of PSP and Vibrio shellfish poisonings are uncertain. In 1988, for the first time in recent history, shellfish beds in south Puget Sound were closed because of PSP. As PSP effects more beaches the likelihood of a poisoning incident increases. However, the dynamics of Gonyaulax blooms are not well understood, so the duration of the current infestation of Gonyaulax in Puget Sound is uncertain. There is yet no agreement among experts whether non-point contamination and Gonyaulax blooms are connected. Vibrio flourishes in warmer waters. If there is truly a global warming trend, the incidences of poisoning could increase. Increased consumer awareness of proper shellfish storage and preparation should decrease poisoning episodes.

The infection rate of swimmers may increase as population increases because more treatment plants will be necessary to support the population, and these plants may be placed closer to swimming areas than they currently are. No major changes in wastewater disinfection and discharge methods are foreseen to decrease effluent populations of infectious organisms. Although conversion of primary to secondary treatment may help. Finally, if global warming occurs, more people may be swimming and infectious disease organisms may have a slower die-off rate resulting in a higher incidence of infections.

REFERENCES

Cabelli, V., 1983. Health Effects Criteria for Marine Recreational Waters, U.S. Environmental Protection Agency Report EPA-600/1-80-031, Research Triangle Park, N.C. 98 pgs.

Cox, F.,1989. Personal conversation, Environmentalist with the Washington Dept. of Social and Health Services, Shellfish Sanitation Division, Olympia, WA

DSHS, 1986. Tabularized data: "Foodborne outbreaks associated with shellfish as vehicles of transmission in Washington, 1975 - 1986" Washington Dept. of Social and Health Services, Shellfish Sanitation Division, Olympia, WA, 2pgs.

DuFour, A., 1983. Health Effects Criteria for Fresh Recreational Waters, U.S. Environmental Protection Agency Report EPA-600/1-84-004, Research Triangle Park, N.C.

Faigenblum, J., 1988. Chemicals and Bacteriological Organisms in Recreational Shellfish. Washington Dept. of Social and Health Services and U.S. Environmental Protection Agency, 109pgs.

Hopkins, B. and D. Clark, 1985. Basic Water Monitoring Program Fish Tissue and Sediment Sampling for 1984. Washington Dept. of Ecology Report 85-7, November 1985, Olympia, Washington, 43 pgs.

Johnson, A., D. Norton, and B. Yake, 1988. An Assessment of Metals Contamination in Lake Roosevelt Washington Dept. of Ecology, Water Quality Investigations Technical Report, Olympia, WA., 77pgs

Johnson, A., D. Norton, and B. Yake, 1986. Occurrence and Significance of DDT Compounds and Other Contaminants in Fish, Water, and Sediment from the Yakima River Basin Washington Dept. of Ecology Report 86-5, Olympia, WA, 89 pgs.

Jones and Stokes Associates, Inc., 1988. Report from Harvey Van Veldhuizen to Greg Kellogg, U.S. Environmental Protection Agency, Region 10., Seattle, WA, 15 pgs.

Kaysner, C., C. Abeyta, Jr., M. Wekell, A. DePaola, Jr., R. Stott, and J. Leitch, 1987a. "Virulent strains of Vibrio cholerae from estuaries of the United States west coast" Applied and Environmental Microbiology 53(6): 1344-1348.

Kaysner, C., C. Abeyta, Jr., M. Wekell, A. DePaola, Jr., R. Stott, and J. Leitch, 1987b. "Virulent strains of Vibrio vulnificus isolated from estuaries of the United States west coast" Applied and Environmental Microbiology 53(6): 1349-1351.

OFM, 1987. State of Washington Data Book 1987. Office of Fiscal Management, Olympia, WA., 302pgs.

Patmont, C., G. Pelletier, E. Welch, D. Banton, and C. Ebbesmeyer, 1989. Lake Chelan Water Quality Assessment. Harper-Owes Consultants for the Washington Dept. of Ecology, Olympia, WA.

Price, M., K. V. Ladd, J. Evans, L. Francis, R. Hoelzer, K. Rutherford, J. Scott, and R. Shumate, 1978. The Role of South-Central Puget Sound as a Public Food Source: Impact of Heavy Metals. The Evergreen State College, NSF Grant Technical Report, Olympia, WA., 194pgs.

Puget Sound Water Quality Authority, 1988. State of the Sound 1988 Report. Washington State Puget Sound Water Quality Authority, Seattle, WA., 225pgs.

Tetra Tech, Inc., 1988. Health Risk Assessment of Chemical Contamination in Puget Sound. Tetra Tech, Inc. for the U.S. Environmental Protection Agency, Region 10, Puget Sound

Estuary Program, Seattle, WA, 102 pgs.

Tetra Tech, Inc., 1986. Guidance Manual for Health Risk Assessment of Chemically Contaminated Seafood. Tetra Tech, Inc. for the U.S. Environmental Protection Agency, Region 10, Puget Sound Estuary Program, Seattle, WA, 72 pgs.

USEPA, 1989. "Washington Environment 2010: Outline for Reports on Environmental Threats" Handout given to committee participants at 2010 meeting, Feb. 1989, Olympia, WA. 6 pgs

Vasconcelos, G. and N. Anthony, 1985. "Microbiological quality of recreational waters in the Pacific Northwest" Journal Water Pollution Control Federation 57(5):366-377

Westley, R., 1989. Report on recreational shellfish harvesting given to the Washington State Shellfish Technical Committee, March, 1989. Olympia, WA.

Yake, B., J. Joy, and A. Johnson, 1984. "Chemical contaminants in clams and crabs from Eagle Harbor, Washington State, with emphasis on polynuclear aromatic hydrocarbons" Washington Dept. of Ecology, Water Quality Investigations Section, Olympia, WA, 28 pgs.

THREATS RELATED TO DISCHARGES TO GROUND WATER

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Environmental and Health Risks

Environmental Effects

The impacts of contaminated ground water on the general environment are not well-documented or understood. In situations where ground water discharges to a stream, lake, marine waters or wetlands, the potential exists for contamination of the surface waters and impacts to its beneficial uses, including wildlife habitat, fisheries, and recreation. This often occurs during normal low flow periods in summer or drought years when streams are dependent on ground water for the majority of their flow. Many lakes and wetlands occur where the land surface dips below the upper surface of an aquifer, and thus are ground water "windows."

The effects of contaminated ground water on marine and freshwater sediments is unknown.

Health Effects

The primary health effects from contaminated ground water are through drinking water sources. Practically every discharge to the ground has the potential to contaminate a drinking water source. Drinking water is defined as all ground waters that are suitable for drinking. This includes those waters that are presently used and those waters that may be used as future sources.

It is estimated that 85% of the ground waters can be defined as an existing or potential source of drinking water.

Existing Use

Presently 95 percent of the state's public water systems use ground water. These systems serve 50 percent of the population. In addition, another 21 percent of the population rely on private wells. This equals a total of 71 percent of the states population relying on ground water for their drinking water. Over 25 counties rely on ground water for 75-100 percent of their supply for drinking water (Ecology 1986).

Future Use

The reliance on ground water is expected to increase by the year 2010. Although this increase is difficult to quantify, it is reasonable to assume that the proportion of the population relying on ground water will be higher than is currently the case. This will be due to less availability of surface waters which are currently fully appropriated, therefore increasing the demand on ground water.

Contamination of Drinking Water

Due to the difficulty, and often times impossibility, of cleaning up contaminated ground water, any contamination could be considered a significant threat to drinking water supplies. Often by the time a contaminant is detected in the ground water, the soil has become saturated with the contaminant and represents a persistent source of future contamination.

Early detection of drinking water contamination is essential to a successful cleanup, but this not always occurs. Public water systems have historically been required to do periodic monitoring for inorganic contaminants. Only recently have monitoring requirements been expanded to include selected volatile organics. Monitoring requirements for small water systems are inadequate for detection of contamination. For example, Class 4 water systems (those serving 2-10 connections) only require one initial sample and no regular sampling for inorganics. Monitoring for the more toxic organic compounds will not be required on the majority of the small water systems. The inadequate monitoring requirements of small water systems (SWS) becomes even more significant in view that SWS have more than doubled in the last 10 years.

Private wells are even more at risk of having undetected contamination. There are no monitoring requirements for private wells. Many private wells are more susceptible to contamination because of poorer construction.

Existing Contamination

Ground water supplies can be contaminated from numerous sources. It is often the cumulative effect of these sources that causes significant impacts to drinking water.

Data from the Department of Social and Health Services show that in the last four years there have been over 85 water systems that have exceeded the MCL for nitrate. Many of the systems have nitrate levels two and three times the maximum concentration level (MCL). Data for inorganic chemicals was not readily accessible.

Monitoring for volatile organic compounds (VOCs) has been done this past year. Out of 2800 Class 1 and Class 2 systems, 725 have been monitored. Eight percent of these systems showed some level of a contamination. Assuming this is an indication of all larger systems, approximately 225 systems may have some level of organic contamination.

There is no state-wide data base on private well contamination although numerous private wells have been verified as contaminated.

Contamination of Drinking Water in 2010

It is reasonable to assume that if state practices continue at status quo, we can expect significant increases in contamination of drinking water in the year 2010. This assumption is based on two facts:

1. Many sources of drinking water have shown levels of contamination which are presently at low levels and are not considered a threat to human health. Due to the nature of ground water contamination, these levels will continue to increase because of both the lack of source control and continued leaching from already contaminated soils.

2. Development of new sources will uncover contamination that previously existed but was undetected.

Analytical Approach and Methods

Threats to ground water are difficult to quantify for of two reasons. First, very little ground water quality data has been collected; second, the data that has been collected resides mostly in personal file cabinets and personal computers. Data collection and management of ground water quality data is years behind surface water data-gathering efforts.

Quantitative data were included where contamination was documented. Qualitative data and best professional judgement was used where data were not available. For this analysis, we assumed ground water contamination from hazardous waste sites, landfills, underground storage tanks and spills was being addressed in the respective reports. This analysis did not address contamination documented from the above sources and/or sites.

The primary form of data collection was through a telephone survey to various programs within Ecology, and other state and local agencies. The information gathered through this survey was used to characterize each activity's threat to ground water. The threat of each activity was quantified based on the following:

A) Magnitude of Contamination
B) Contaminant Characteristics
C) Contaminant Diversity
D) Geographic Scale of Impacts
E) Beneficial Use
F) Uncertainty Factor
G) Regulatory and Agency Capability
H) Trend Rating
I) Contaminant Toxicity

The above criteria were used to calculate a numerical value representative of both the existing and projected threat of each activity on human health. This numerical value was then converted to a relative value of high, medium and low.

The Environmental Protection Agency's vulnerability index was used to calculate the cumulative effect of various activities on ground water and human health by county.

Summary of Findings

The key findings are represented in Table 1 and Table 2. Out of a total of fifteen activities, agricultural chemicals, underground injection control and general industry presented the highest threats to ground water and human health. Sources such as oil refineries and aluminum plants that are regulated very closely under programs such as the Resources Conservation and Recovery Act (RCRA), represented the least present and future threat to the environment.

All of the activities evaluated showed an increase in their threat to the environment in the year 2010 except oil refineries, aluminum plants and pulp and paper. The relative health threat of each activity did not change in the year 2010 though the overall health threat did increase.

Table 1: Summary, Ground Water Hazard Rating

Source	Existing Hazard	2010 Hazard	Relative Health Threat*
Aluminum	4	4	Low
Oil Refineries	4	4	Low
Sand & Gravel Mining	8	13	Medium
Pulp & Paper	9	9	Medium
Salt Water Intrusion	11	17	Medium
Resource Extraction	12	18	Medium
Municipal Sludge	13	19	Medium
Animal Feeding Operations	14	14	Medium
Municipal Waste Water	15	22	Medium
Food Processors	16	23	Medium
Onsite Domestic Systems	16	20	Medium
Agricultural Chemicals	16	24	High
General Industry	22	39	High
Underground Injection	28	49	High

* Represents relative health threats of contamination for both now and the year 2010. This is not meant to imply that the overall threat will not increase between now and the year 2010. The threat does increase for all activities except oil refineries, aluminum plants, and pulp and paper processing.

Existing Threat Scale 1 - 35

2010 Threat Scale 2 - 70

Aluminum Production

Several aluminum production plants are on the National Priority List because of past ground water contamination. In the past improper storage of potliner was the main source of contamination. Presently all seven plants are permitted under RCRA and either ship the potliner off site or have an approved storage building. On-site process storage lagoons are in the process of being approved. Most ground water problems from aluminum plants are now being controlled by RCRA requirements.

Contaminant of Concern: Cyanide, fluoride,PCB and PAHs

Documented/Suspected Contamination: Cyanide levels of 100 ppb and fluoride contamination have been documented in the ground water. Ground water contamination at aluminum sites has been very extensive and considered impossible to fully clean up.

Distribution and Scope of Problem: There are 16 aluminum plants in the state. No increase or reductions are expected in this industry in 2010. Current thought is that RCRA requirements have made ground water contamination a problem of the past. Since the requirements have not withstood the test of time, however, it is possible new ground water problems will emerge by 2010.

Existing Hazard Rating: 4

2010 Activity Hazard Rating: 4

Relative Threat to Human Health: Low

Concentrated Animal Feeding Operations

Concentrated animal feeding operations include dairies, feedlots, chicken farms, and other operations where large numbers of animals are kept in a restricted area. While some operations have good manure handling practices, many do not. In addition, manure management has tended to focus on preventing surface water contamination. Until recently, the impacts of manure lagoons and manure spreading on ground water were not taken into account.

State law allows Ecology to require state waste discharge permits but at present this is done only for very large operations (over 700 animals). About two dozen permits have been issued, most of which do not address ground water impacts. While the majority of dairy herds are less than 200 milking animals, the ratio of land area per animal is more critical than herd size in determining potential impacts to ground water quality from manure disposal.

Contaminants of concern: Nitrates and coliform bacteria.

Documented/suspected contamination: Because of the focus on surface water, little work has been done to document contamination of ground water from manure storage and disposal. Well monitoring done in Fishtrap and Bertrand Creek watersheds in Whatcom County, which are largely dairy, shows nitrates frequently above 5 ppm. A well drilled by the city of Lynden for its municipal water supply had to be abandoned because of excessive nitrates.

Distribution and scope of activity: There are about 1300 commercial dairies statewide, 80 percent of which are located on the west side of the Cascades. Dairies tend to cluster in river valleys on soils that are too draughty or too wet for crop production, conditions which can lead to ground water contamination.

There are about two dozen large feedlot operations, most of them on the east side of the state. The number of smaller feedlots is not known, nor is the number of chicken farms.

Existing Hazard Rating: 14

2010 Activity Hazard Rating: 14

Relative Threat to Human Health: Medium

Food Processors

Washington has four major categories of food processors that discharge part of their processing waste stream to the ground. These are fruit, potato, other vegetables, and a collection of meat, fish, and poultry processors. The waste material in most cases is discharged either to the land by spray irrigation or the material is discharged to a lagoon. Although these operations are located across the state, the bulk of the fruit operations are found in the Central region of the state, vegetables and fish; in the Puget Sound, and potatoes are primarily processed in Eastern Washington.

Contaminants of Concern: Nitrates, BOD, PH, TDS (All), Sugar, Diphenol Amine (DPA), Sulfates (Fruit), cyanide (carrots), Chlorides (peas and seafood) The amounts and methods of discharge may vary by process.

Documented or Suspected Contamination: Ecology has documented contamination in all regions of the state and from all types of processing. The most extensive monitoring program is in place in the Eastern Region. They begun to closely monitor the application process and loadings of the effluent applied to the land. In all cases land application is tied to the agronomic rate of nutrient uptake to prevent ground water contamination. Eastern Washington found that applications were exceeding those rate by up to 10 times. They have instituted stricter controls and required monitoring. In some cases this has forced processors to consider alternative treatment facilities since the cost of acquiring additional land may be prohibitive. The level of nutrient contamination has been substantial with ground water levels of nitrates reaching 30ppm in areas that have elevated nitrates to begin with.

Distribution and Number of Sites: There are currently 32 food processors with records of permits for the discharge to ground or ground water of processing effluent. These represent only the largest operators and does not reflect the small operations or the field processors who wash and rinse the produce prior to delivery from the fields. In all regions there is an increasing trend to require tighter controls and monitoring on land applications. On the east side of the mountains there is very little discharge to surface systems. This is due in part to the lower availability of surface water. This has caused an increase in the number of applications for discharges to ground for a host of materials. Most of the area is dependent on shallow and vulnerable aquifer systems and that has been a major force behind the increased level of monitoring found there.

Existing Hazard Rating: 16

2010 Activity Hazard Rating: 23

Relative Threat to Human Health: Medium

General Industry

General industry activities include machine shops, electroplaters, gas and oil users, painters, contractors, cleaners, print shops, agricultural waste disposal, fertilizer and pesticide applicators, auto wreckers, electrical utilities, gravel pits, fish farms, landfills, and electroplaters.

Contaminants of Concern: Route of contaminant entry into ground water ranges from disposal of unwanted product or chemicals into drainfields and lagoons to spills and leaks draining onto the soils, ditches, and stormwater disposal facilities. Range of chemicals released is a function of the need of the substance and the level of care given to its containment. Examples of substances that have been found in the ground water include chrome and other heavy metals, organic solvents such as trichloroethylene, gasoline and oil, fertilizers, and pesticides and herbicides from the mixing and handling of these substances. Substances which have found their way into the ground water through the dumping and storage of substances over vulnerable aquifers, in pits, and near wells.

Documented or Suspected Contamination: It is not unusual for regional office staff to receive 50 or more ground water quality complaints in one year. The complaints involve the full range of industrial activities and contaminants. In a two year period one of the regional offices received 100 complaints.

In response to complaints, Ecology has found nitrates in the ground water from fertilizer applicators. The cause was stormwater disposal into a well. As a result of a gasoline leak and solvents in washwater we found benzene and toluene in the ground water. In another case landfill leachate added vinyl chloride to the ground water. A drainfield used by a dry cleaner added perchloroethene and trichloroethylene to the ground water. Leachate from sludge disposal by a chemical company polluted the ground water with trichloroethylene. Spills and leaks from an electroplater caused chrome to enter groundwater in excess of the federal drinking water standards. A gasoline spill resulted in benzene in ground water at 231 ppb.

Distribution and Number of Sites: Contaminated ground water can be found across the width and breadth of the state. Industrial spills, leaks, discharges have contaminated shallow aquifers as well as deep aquifers. A common denominator for finding ground water contaminating is testing the ground water for contaminants. Eighteen of 51 enforcement actions by Ecology in 1987 involved either contaminated ground water or contaminated soils which are likely indicator of contaminated ground water. These enforcements are uniformly divided across the state.

Existing Hazard Rating: 22

2010 Activity Hazard Rating: 39

Relative Threat to Human Health: High

Municipal Waste Treatment Facilities

The treated effluent in central and eastern Washington communities generally has access to the ground water in one of three ways. These are 1) land application and spray irrigation, 2) bentonite lined lagoons for evaporation and anaerobic degradation of waste, and 3) infiltration basins and drainfields. All of these activities provide a pathway for contamination of the ground water. In Western Washington the same access does not exist since most municipal wastewater systems discharge to surface water bodies and not to ground. Given the limited availability of adequate receiving waters in the eastern and central portions of the state this has not been an option.

Contaminants of Concern: Nutrients (nitrates, phosphorus, chlorides), pathogenic bacteria and viruses, high BOD, and a collection of organic contaminants petroleum products and solvents that could be disposed of via a municipal wastewater system. Contaminant concentrations in these systems can range from high for nutrients and BOD to much lower levels for metals and organics.

Documented or Suspected Contamination: Ecology has documented several instances of contamination associated with municipal wastewater systems. In the CRO there are 4 suspected sites currently under investigation they include 2 infiltration systems, 1 bentonite lagoon, and 1 irrigation system. ERO has reported that many of the problem lagoon systems are upgrading to infiltration or irrigation systems. ERO has instituted a policy of requiring site evaluations prior to permitting new sites, and older permits are being reevaluated with particular attention to the need for ground water monitoring.

Distribution and Number of Sites: Presently the Ecology has permits for 26 facilities across the state. CRO has permits only for its spray irrigation systems. ERO estimates that it has approximately half of its major systems permitted. As older systems fail or are renovated they will shift from lagoons to land treatments. It appears that monitoring will be a part of the permit requirements. Lagoon systems are located all over the state and all are viewed as potential threats to ground water. Most of these are not permitted unless the site has recently been investigated or has been renovated. The contaminant concerns are the same for these systems as described above. Many small towns have relied on these percolation/evaporation systems to handle their municipal wastes.

Existing Hazard Rating: 15

2010 Activity Hazard Rating: 22

Relative Threat to Human Health: Medium

Oil Refineries

There are three potential routes for ground water contamination from the state's six oil refineries; land treatment fields for waste, surge ponds for waste water treatment, and accidental product spills. All of the refineries are permitted through the Resource Conservation and Recovery Act (RCRA). Ground water monitoring wells are installed to detect any problems resulting form the waste treatment fields. Because of RCRA permitting, it is presently felt that the major concern for ground water contamination in product spills which cannot be monitored for or anticipated.

Contaminants of Concern: Volatile organics including benzene, toluene, xylene, and ethyl benzene. Metals including chromium, nickel, and vanadium.

Documented/Suspected Contamination: Ground water contamination from the land treatment fields has been documented in the past and has been subject to remedial actions. The potential for contamination still exists but the process is now regulated much more so than in the past. Surge ponds for storing waste water are a suspected source of contaminations because they are currently unlined. All six of the refineries have had product spills of varying size. Several have shown ground water contamination.

Distribution and Scope of Activity: There are currently six refineries. Four of these land treat their waste. Employment projections for oil refineries show an increase of 24% by the year 2010. Potential for ground water contamination will also likely increase.

Existing Hazard Rating: 4

2010 Activity Hazard Rating: 4

Relative Threat to Human Health: Low

Pulp and Paper Processing

Pulp and paper processing has always been considered primarily a surface water concern but ground water concerns are now being acknowledged. Due to the location of these plants, the ground water is usually very shallow and highly vulnerable to leaching form contamination source. Storage yards for logs and chips, wastewater treatment lagoons and the inplant treatment process are all potential contamination sources. Pulp and paper plants are currently permitted through NPDES for surface water. No permitting is done for ground water impacts although Ecology is considering requiring ground water monitoring at selected sites.

Contaminates of Concern: Priority toxic organics including dioxin, halogenated chlorides,and forams. Cyanide, copper and zinc are also a concern.

Documented/Suspected Contamination: In plant spills are both a past and present problem. Waste water treatment lagoons are a suspected source of present contamination.

Distribution and Scope of Activity: There are currently 16 pulp and paper plants. With a continued decline in the industry and better regulation of existing plants, ground water contamination potential is not expected to increase in the year 2010.

Existing Hazard Rating: 9

2010 Activity Hazard Rating: 9

Relative Threat to Human Health: Medium

Resource Extraction/Exploration and Development

Mining includes underground mines, surface hard rock mines, sand and gravel pits and coal mines. Mineral extraction activities can contaminate ground water through a variety of ways. Both the mining operation and the operating plant have processes which may impact ground water. Disturbance of the ore body, allowing contact between the ore body and the ground water and contamination from chemicals used in heap leaching all have the potential to impact ground water. Wastewater produced during the processing must be properly managed to minimize potential of ground water contamination.

Regulation at these sites vary. All sites are required to be permitted by Department of Natural Resources but it is Ecology's responsibility to regulate and require monitoring for activities which may impact the ground water. Unless their is a specific discharge to waste water treatment process on site, Ecology does not have permitting authority. This type of regulatory structure makes it difficult to ensure ground water is being protected.

Contaminates of Concern: Cyanide, Sulfuric Acid, Mercury, and any mineral in the ore body such as copper, lead, selenium, zinc and arsenic. These contaminates are primarily associated with precious and base mineral mines. In addition, products used on sight such as oil and gas may cause contamination at all types of mining operations.

Documented/Suspected Contamination: Very little ground water monitoring has been done around mining operations. The Holden Mine, abandoned on the Wenatchee National Forest, have spoil piles which have leached high concentrations of arsenic. The Granite Falls area in Snohomish county has high levels of arsenic in drinking water wells that may be associated with past mining. The Department of Natural Resources expects there are more past sites that have not been discovered.

Distribution and Scope of Activity: There are currently three precious metal and one base metal mine in operation. These sites are most likely to have metals within the ore body or cyanide through the leaching process come in contact with the ground water. There are also approximately 20 sites involved in mining of industrial minerals.

Precious metal production is expected to significantly increase in the state. (Joseph 1988) Two new mines are projected to be in production in 1990. In addition, approximately 60 different sites have had mineral exploration and development in 1988 for precious metals.

Existing Hazard Rating: 12

2010 Activity Hazard Rating: 18

Relative Threat to Human Health: Medium

Sand and Gravel Mining

The surface extraction of hard rock, sand and gravel is widespread in the state and plays an important role economically in many of the rural counties in the State. In general these types of mining activities pose limited threats to ground water quality. Their chief threat comes in the potential exposure of the aquifer by excavation pits and the increased access of contaminants to the aquifer either directly or via leaching through the porous overburden. There are also associated risks from the allied industry found near the larger sites. These include cement, asphalt, concrete, rock crushing operations, and their associated discharges.

Contaminants of Concern: Dust, TDS, turbidity, petroleum products, solvents, and other chemical associated with the related industry.

Documented or Suspected Contamination: In the Spokane Valley area there has been documented problems with exposure of the aquifer and resulting localized contamination from the light industry in the area. Once the contaminants reach the exposed ponds they have effectively entered the aquifer. Similar contamination has occurred in the Oak Harbor with a smaller mine. In most cases outside of systems like the Spokane aquifer, the contamination is localized but can impact the surrounding wells. High turbidity rinsate can foul nearby wells and spilled materials on the site will leach through the porous material and reach the ground water. Other incidents of ground water contamination associated with surface mining have been reported by both the NWRO and the SWRO of the department of Ecology. Other type of contamination have been reported. These include use of pits as rearing pond for salmonids, and the general use of the excavations as dumping sites for a variety of materials.

Distribution and Number of Sites: There are currently 327 permitted pits in the state. These are pits larger than 3 acres and are permitted by DNR without direct input from Ecology. At the present time there are only 4 sites with State waste Discharge Permits to discharge to ground. There are an additional estimated 2000 non-permitted sites falling under the 3 acre size limit. The future trend in these mining activities are heavily tied to economic markets. As the value of gravel goes up, so will the number of mining operations along with the relative risk to ground water. Presently there few sites that maintain ground water monitoring and most of that is limited to water level information. There are no established BMP's for operations in or near the water table recommended by either DNR or Ecology.

Existing Hazard Rating: 8

2010 Activity Hazard Rating: 13

Relative Threat to Human Health: Medium

Agricultural pesticides

The term "pesticides" includes insecticides, rodenticides, fungicides, and herbicides. In the last ten years the potential for these chemicals to contaminate ground water has been brought forcefully to our attention. Misuse, poor storage practices, and improper mixing or container disposal account for some of the problems, but not all. In the case of certain chemicals, application to field crops according to recommended procedures is also responsible for contamination of ground water. The potential for contamination exists wherever agriculture exists, with the highest risk where there are unconfined aquifers, permeable soils, shallow water table, irrigation, and other factors that contribute to vulnerability.

Contaminates of concern: Any chemical pesticide may contaminate ground water if handled improperly. Under conditions of normal field application, the chemicals of most concern are those with "leacher" characteristics. These chemicals or their metabolites tend not to bind readily to soil particles, tend to be soluble in water, and tend to be more or less stable in the soil, particularly below the root zone. The EPA has compiled a list of about 60 known or suspected leachers. This list includes chemicals that are known to leach and have been found in ground water, and those with similar chemical characteristics.

Documented/suspected contamination: More than 60 pesticides have been found in groundwater in the US so far. Many of the areas in which these chemicals are found have geological characteristics similar to Washington's agricultural lands.

In Washington State, a 1984 DSHS study found thirteen domestic wells in Skagit, Whatcom, and Thurston counties with levels of EDB above the health advisory (0.02 ppb). Ten wells were public water supplies serving a total of about 550 persons. In 1988-9, Ecology conducted a Pesticide Pilot Study in portions of three agricultural counties. Of the 81 wells tested, 23 showed indications of at least one pesticide. Seven detections were above recommended standards. In a USGS study in Franklin and Benton counties, 5 out of 24 wells tested showed traces of one or two pesticides each.

Distribution/scope of activity: Agriculture is the single most widespread land use in the state. Most of the agriculture in the state currently relies on the use of chemicals. Other large scale activities such as roadside management, maintenance of parks and golf courses, and forestry also use these chemicals.

Existing Hazard Rating: 16

2010 Activity Hazard Rating: 24

Relative Threat to Human Health: High

Agricultural Nutrients

There are two major sources of nutrients for crop production: commercial fertilizers and animal manures. Nitrates from both sources can contaminate ground water, particularly when the amount present in the soil is more than a crop is capable of using. The potential for contamination exists wherever agriculture exists, with the highest risk where there are unconfined aquifers, permeable soils, shallow water table, irrigation, and other factors that contribute to vulnerability.

Contaminates of concern: Primarily nitrates: other nutrients tend to bind readily to soil particles.

Documented/suspected contamination: In the Pesticide Pilot Study, nitrates were detected in 61 of the 81 wells sampled. Eighteen of these were above the drinking water standard. A current USGS ground water study in Franklin and Benton counties has taken a total of 700 samples from 420 wells. About 20 percent of the wells have nitrate levels above the drinking water standard, with the highest value at 100 ppm (parts per million). In Franklin County, 32.5 percent of the wells tested showed nitrates above the standard. In Benton County, 10.1 percent were above this level. Some limited historical data indicates that, prior to irrigation, nitrate levels in northern Benton County were below 0.1 ppm. No historical data exists for the rest of the study area. DSHS data from monitoring of public water supply systems also includes a number of nitrate levels above the drinking water standard.

Distribution/scope of activity: Agriculture is the single most widespread land use in the state. Most crop production in the state uses fertilizers. Other large scale activities such as roadside management, maintenance of parks and golf courses, and forestry also use fertilizers.

Existing Hazard Rating: 16

2010 Activity Hazard Rating: 24

Relative Threat to Human Health: High

Domestic Septic Systems

Effluent from domestic septic systems (private and community) contains a number of organic and inorganic compounds that could contaminate the ground water if found in sufficient quantity. Septic systems depend on dilution and anaerobic activity to reduce the level of contaminants in the household waste stream to acceptable levels that will not pose a risk to human health. Private systems serve one home. Small community systems function the same but are intended for multiuser or larger volume systems where there are no sewer connections. These conditions are often found on the urban/rural fringe of the developed communities around the state. On site septic systems are the dominant form of household waste treatment for most of the rural area of the state. In these areas the risk of contamination of drinking water is also higher because these areas typically have a higher dependence on private wells or small water systems. Generally the wells and septic systems on individual lots are closer together than would be found with other waste treatment systems.

Contaminants of Concern: Nitrates, Chlorides, Phosphorous, pathogenic bacteria. Other contaminants include organic compounds, metals, and solvents used in the household waste stream.

Documented or Suspected Contamination; Contamination is suspected in all areas of the state where septic systems are used in areas with porous soils and multiple systems per acre densities. Contamination has been documented in 24 counties across the state for elevated nitrates, chlorides and/or coliform bacteria. Noted studies include work in the Spokane-Valley area (Spokane), Deer Park (Spokane), Clovers Chambers Creek (Pierce), and Multistory Spring (Thurston). DSHS has estimated septic failure rates from 3-5 percent. EPA has estimated that up to 50 percent of the existing systems are not operating satisfactorily but may not yet be classified as failing.

Distribution and Number of Sites: The sites are located predominately in rural and urban/rural fringe zones. Many of the sites on the fringe will be replaced with sewer hookups. There are an estimated 575,000 septic systems in the state. Since 1979, local health offices have issued permits for onsite sewage systems. Many of the systems in place today were installed prior to 1979 and may not meet current siting standards. Local community septic systems are permitted by DSHS based on volume. Presently there is no monitoring required on any of the systems unless it is a part of an investigation or in response to a complaint.

Existing Hazard Rating: 16

2010 Activity Hazard Rating: 20

Relative Threat to Human Health: Medium

Municipal Sludge

Sludge is the solid material left over from the wastewater treatment process. Sludge is utilized/disposed through land application methods and incineration. Leaching of nutrients and metals from land application may cause contamination of ground water. Sludge is land applied for silviculture, agriculture, soil improvement (Christmas tree farms, turf farms,etc.) compost for landscaping and home use and is used as cover for land fills. Lagoons and landfilling are used to a lesser extent. As a general rule, ground water monitoring is not required at sludge application sites. Contamination is mitigated by using best management practices which includes application at agronomic rates.

Contaminants of Concern: Nitrates and chlorides are the primary concern. Bacteria can be a problem with shallow ground water. Not enough research has been done to determine the potential for ground water contamination from metals and organics.

Documented/Suspected Contamination: No data was available from ground water monitoring at existing sludge sites. Research has shown that by putting sludge on yearly at agronomic rates you can minimize the leaching of nitrates and chlorides to levels exceeding drinking water MCLs. When sludge is applied every 3-5 years as is done at silviculture sites, leaching of nitrates and chlorides in the first six months is more likely to contaminate ground water above the MCL. Research has shown that when sludge is land applied under certain conditions at rates higher than agronomic rates, nitrates can contaminate ground water at levels in excess of 50 ppm.

Distribution and Scope of Activity: A recent survey of approximately 25 percent of the sludge producers across the state, including the 40 largest municipalities, states a total of 39,676 tons of sludge solids are produced for land application annually. This amount is predicted to increase to 83,011 tons/year by 1997 and to 100,738 tons/year by 2007. This increase is based on more secondary treatment of wastewater and population growth.

Existing Hazard Rating: 13

2010 Activity Hazard Rating: 19

Relative Threat to Human Health: Medium

Salt Water Intrusion

In the coastal areas of the state, the increased use of ground water, coupled with reduction in effective infiltration, has corresponded to increases in the incidence of elevated chlorides in well water. These changes have affected the dynamics between the freshwater/saltwater interface. The net result is an increasing rate of coastal well contamination. In many cases the increase has been seen as a local effect (Lummi Island) and in other areas the impact appears to present a gradual rise over a large area. The net result is the reduction in quality of aquifer as a source of drinking water.

Contaminants of Concern: Chlorides and TDS related to marine waters.

Documented or Suspected Contamination: Sea water intrusion has been documented in most of the Islands and coastal areas of Washington. The USGS has published a number of water supply bulletins specifically referencing the contamination in San Juan, Island, Whatcom, and other Puget Sound counties. Specific studies were undertaken to compare the expansion of the intrusion, comparing results from a 1978 survey with an earlier one. Overall increased water demand in coastal areas coupled with increased development toward the terminus of the fresh water lens have had a major impact on the extent of contamination. Associated issues of loss of recharge and effective infiltration have added to the problem.

Distribution and Number of Sites: The incidence of intrusion is estimated at approximately 10 percent over the near coastal zone. The extent of the intrusion is a function of the aquifer characteristics and demand. It is assumed that the incidence of contamination will increase and have the greatest impact on private domestic systems. At the present time, treatment is generally reduced pumpage or relocation of the well. Most intervention/remediation plans are exceedingly expensive and not very effective in the heterogeneous sediments found in the in the coastal basins in Washington.

Existing Hazard Rating: 11

2010 Activity Hazard Rating: 17

Relative Threat to Human Health: Medium

Underground Injection Wells

Stormwater runoff from urban, industrial and commercial areas is directed into a stormwater collection system and them delivered to dry wells. Typically spills, leaks, or intentional dumping of materials allow contaminants to enter the ground through these wells. The contaminants could include a variety of materials associated with light industry, packaging, or small businesses. The discharge often includes varying amounts of petroleum products, solvents, metals or other toxic chemicals that flush from the grounds with the stormwater.

Contaminants of Concern: Heavy Metals (Pb, Ar, Cn), Volatile Organic Compounds, Organic Solvents, Petroleum Products.

Documented or Suspected Contamination: Contamination is suspected in all areas of the state where injection wells are used. By design the dry well bypasses the treatment potential of the soil layer. Contamination has been documented in all 39 counties of the state. Soil and ground water contamination has been observed for heavy metals from electroplaters, chlorinated solvents from chemical handling and spillage, high nitrates from fertilizer handling facilities. An airplane stripping company discharged phenols into a dry well the drainage threaten a public water supply well. A waste pile leachate from a fertilizer company carried zinc and cadmium contaminate stormwater into the ground water. Drainage and spillage from a chemical handling facility was collected by stormwater and carried chrome into the ground water exceeding the drinking water level for chrome.

Distribution and Number of Sites: Presently there are 200 permitted UIC wells statewide. The underground injection control well inventory lists 20,000 wells across the state. This gives a permit ratio of 1:100. That also assumes that the inventory covers all of the wells in the state which seems to be optimistic.

It can be assumed that, as Washington's population grows, so will the number of small businesses and industry that will discharge materials into storm systems. Our current level of tracking can be expected to improve but it is unlikely that it could catch up and keep pace with such an expansion.

Existing Hazard Rating: 28

2010 Activity Hazard Rating: 49

Relative Threat to Human Health: High

CUMULATIVE RISK TO GROUND WATER

Table 2 is a summary table that draws on preliminary assessments done by EPA and the Department of Ecology. The Table lists the counties of Washington state, their relative ground water vulnerability, along with an estimate of their reliance on ground water. A simple multiplication of the two values yields a crude measure of the county's ground water vulnerability.

The resulting value, or cumulative index of risk, highlights those counties that both have a strong dependence on the resource and appear to face the greatest risk.

Table 2: Cumulative Risk to Groundwater by County

COUNTY	EPA VUL. RATING	RELIANCE ON GW	CUMULATIVE RISK	RISK HISTOGRAM
ADAMS	3.00	4.00	12.00	xxxxxxxxxxxx
ASOTIN	2.00	4.00	8.00	xxxxxxxx
BENTON	5.00	3.00	15.00	xxxxxxxxxxxxxxx
CHELAN	4.00	1.00	4.00	xxxx
CLALLAM	4.00	4.00	16.00	xxxxxxxxxxxxxxxx
CLARK	5.00	4.00	20.00	xxxxxxxxxxxxxxxxxxxx
COLUMBIA	1.00	4.00	4.00	xxxx
COWLITZ	4.00	3.00	12.00	xxxxxxxxxxxx
DOUGLAS	3.00	4.00	12.00	xxxxxxxxxxxx
FERRY	2.00	4.00	8.00	xxxxxxxx
FRANKLIN	4.00	4.00	16.00	xxxxxxxxxxxxxxxx
GARFIELD	1.00	4.00	4.00	xxxx
GRANT	5.00	4.00	20.00	xxxxxxxxxxxxxxxxxxxx
GREY'S H.	4.00	1.00	4.00	xxxx
ISLAND	2.00	4.00	8.00	xxxxxxxx
JEFFERSON	2.00	4.00	8.00	xxxxxxxx
KING	4.00	1.00	4.00	xxxx
KITSAP	3.00	4.00	12.00	xxxxxxxxxxxx
KITTITAS	3.00	3.00	9.00	xxxxxxxxx
KLICKITAT	3.00	4.00	12.00	xxxxxxxxxxxx
LEWIS	5.00	4.00	20.00	xxxxxxxxxxxxxxxxxxxx
LINCOLN	3.00	4.00	12.00	xxxxxxxxxxxx
MASON	4.00	4.00	16.00	xxxxxxxxxxxxxxxx
OKANOGAN	4.00	4.00	16.00	xxxxxxxxxxxxxxxx
PACIFIC	2.00	2.00	4.00	xxxx
PEND OR.	2.00	3.00	6.00	xxxxxx
PIERCE	4.00	3.00	12.00	xxxxxxxxxxxx
SAN JUAN	2.00	2.00	4.00	xxxx
SKAGIT	4.00	2.00	8.00	xxxxxxxx
SKAMANIA	2.00	4.00	8.00	xxxxxxxx
SNOHOMISH	5.00	4.00	20.00	xxxxxxxxxxxxxxxxxxxx
SPOKANE	5.00	4.00	20.00	xxxxxxxxxxxxxxxxxxxx
STEVENS	4.00	4.00	16.00	xxxxxxxxxxxxxxxx
THURSTON	4.00	4.00	16.00	xxxxxxxxxxxxxxxx
WAHKIAKUM	1.00	4.00	4.00	xxxx
WALLA WA.	5.00	4.00	20.00	xxxxxxxxxxxxxxxxxxxx
WHATCOM	5.00	1.00	5.00	xxxxx
WHITMAN	3.00	4.00	12.00	xxxxxxxxxxxx
YAKIMA	5.00	4.00	20.00	xxxxxxxxxxxxxxxxxxxx

Discussion of Uncertainty

Several major areas of uncertainty involved in this assessment could significantly change the estimated risk, in particular the lack of quantitative data, the structure of the rating, and the estimates of ground water vulnerability.

Uncertainty was factored into the rating system. The higher the uncer tainty, the higher the potential risk. In other words, the unknown risk was given more points than the known.

A major criterion in the rating system is regulatory capability. Both the state's regulatory authority and the resources needed to enforce that authority were evaluated. This criterion also assumed that permitting programs such as RCRA significantly reduced the threat of a activity even if it had been known to contaminate the ground water in the past. If the assumption of regulatory capability is wrong, the ratings would change significantly.

Another level of uncertainty comes from having several staff employ their best professional judgement to evaluate risk. This type of analysis will always add a certain measure of uncertainty.

Structure or Anatomy of the Risk

The risk of ground water contamination to drinking water supplies depends on many variables. According to this analysis, the risk will increase by the year 2010 if management of the resource does not become more prevention-oriented. The exception may be for those point source activities which are currently regulated under a strict permitting program such as RCRA.

Many contamination sources are either unknown or are not being managed to prevent ground water contamination. With the past emphasis on protection of surface waters, ground waters have become the effective alternative. It is anticipated that many of the discharges from these past practices are in the process of reaching ground water and will be detected in the next decade.

Although contamination of ground waters currently exists, the most critical risk is more one of the future. Ground water contamination is often a process that builds over time and is not detected until the contamination sources are many and the problem is irreversible. In Washington the anatomy of the risk is such that with preventive management significant widespread contamination can be avoided.

REFERENCES

Anderson, Henry W. Jr. Pleistocene Stratigraphy of Island County: Part II: Ground-Water Resources of Island County. Department of Water Resources, Water Supply Bulletin No. 25, 1968

Cline, Denzel R. Ground Water Resources and Related Geology North-Central Spokane and Southeastern Stevens Counties of Washington. U.S. Geological Survey, Water Supply Bulletin No. 27, 1969.

Cogger, Craig. On-Site Septic Systems and Ground Water Pollution: Problem, Solutions, and Unknowns. Northwest Nonpoint Source Pollution Conference, March 24-25, Seattle, WA.

Craun, G.F. A Summary of Water Borne Illness Transmitted Through Contaminated Groundwater. Journal of Environmental Health. 48:122-127.

Dion, N.P, and Sumioka, S.S. Seawater Intrusion into Coastal Aquifers in Washington. Prepared in cooperation with USGS, Water Supply Bulletin 56, 1984.

Ebbert, J.C. Quality of Ground Water in the Principal Aquifers of Northeastern-North Central Washington. U.S. Geological Survey Water Resources Investigations Report 84-4102, 1984

Ebbert, J.C., and Payne, K.L. Quality of Ground Water in the Principal Aquifers of Southwestern Washington. U.S. Geological Survey Water Resources Investigations Report 84-4093, 1985

Ecology, Department of. <u>1988 Statewide Water Quality Assessment 305(b) Report</u>. Water Quality Program, Olympia. June 1988.

Ecology, Department of. <u>Ground Water Quality Unit Data Base</u>.

Ecology, Department of. <u>Project Update on Pilot Study on Agricultural Chemicals in Selected Ground Water Areas of Washington</u>. Olympia. May 7, 1989.

Ecology, Department of. <u>Nonpoint Source Pollution Assessment and Management Program, Final Draft</u>. August 1988

Ecology, Department of. <u>Southwest Regional Office Complaint Tracking System From 1986 to Date</u>.

Ecology, Department of. <u>Summary of Groundwater Violations from Enforcement Activity Tracking System</u>: Enforcement dockets #: 85-556, 87-S105, 87-E347, 88-S239, 88-E233, 89-N205, 89-S119, and 89-E102.

Ecology, Department of. <u>Summary of Groundwater Violations from Enforcement Activity Tracking System from 1984 to date</u>.

Everett, Jim. Personal communication, June 20, 1989. United States Geological Survey, Tacoma, Washington.

Goldstein, Lawrence. A Review of Arsenic in Ground Water with an Emphasis on Washington State. Master thesis, The Evergreen State College, 1988

Joseph, Nancy. Washington's Mineral Industry - 1988. Washington Geologic Newsletter, Vol.17, No.1.

King County Planning Division. Ground Water Resource Protection: A Handbook of Local Planners and Decision Makers in Washington State. Prepared in cooperation with Washington Department of Ecology. December, 1986.

Manahan, Stanley E. Environmental Chemistry. Brooks/Cole Publishing Co., Monterey, CA, 1984

Natural Resources, Department of. Directory of Washington Mining Operations. Open File Report 87-7, 1987.

Parsons, Douglas W. and James M. Witt. Pesticides in Groundwater in the Untied States of America: A Report of a 1988 Survey of State Lead Agencies. Oregon State University Extension Service. Corvallis, Oregon. June, 1988

Puget Sound Estuary Program. Pesticides of Concern in the Puget Sound Basin: A Review of Contemporary Pesticide Usage. Prepared for U.S. Environmental Protection Agency. September 1988.

Regional Sludge Committee. Regional Sludge Survey. March 1989.

Social and Health Services, Department of. Results and Implications of the Investigation of Ethylene Dibromide in Ground Water in Western Washington. DSHS Water Supply and Waste Section. February, 1985.

Taylor, Marilou. They Shoot Oysters Don't They: Henderson Inlet: A Case Study in Nonpoint Source Bacterial Pollution. Northwest Nonpoint Source Pollution Conference, March 24-25, Seattle, WA.

Turney, G. L. Quality of Ground Water in the Columbia Basin, Washington, 1983. U.S. Geological Survey Water Resources Investigations Report 85-4320, 1986

Turney, G. L. Quality of Ground Water in the Puget Sound Region, Washington. U.S. Geological Survey Water Resources Investigations Report 84-4258, 1986

United States Environmental Protection Agency. Agricultural Chemicals in Ground Water: Proposed Pesticide Strategy. Office of Pesticides and Toxic Substances, Washington, D.C. December, 1987.

United States Geological Survey. Washington Ground-Water Quality. Water-Supply Paper 2325, 1986.

Walters, Kenneth L. Reconnaissance of Sea-Water Intrusion Along Coastal Washington, 1966-68. Department of Ecology, 1971

Whatcom County Conservation District. Livestock Impacts on Water Resources in Bertrand and Fishtrap Creek Watersheds, Whatcom County, Washington. Lynden, Washington, 1988.

Personal Communication with:

- Kim Anderson, Department of Ecology
- Mark Crooks, Department of Ecology
- Paul Skyllingstad, Department of Ecology
- Roberta King, METRO
- Nancy Joseph, Department of Natural Resources
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Part 9

Risk Evaluation Reports
for
Drinking Water Contamination

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---------------------WASHINGTON ENVIRONMENT 2010------------------

HUMAN HEALTH RISKS ASSOCIATED WITH DRINKING WATER

in

WASHINGTON STATE

INTRODUCTION

The state of Washington has had a drinking water program since the early 1900's for the purpose of protecting the public health by assuring safe and reliable drinking water. This program is derived from the basic authority of the State Board of Health to adopt rules to protect public water supplies (RCW 43. 20. 50), with additional authority and regulations described in RCW 70.116, RCW 70.119 and 119A, and RCW 70.142. The establishment of such a program reflected the realization that water is a critical mode of transmission for many chemical, physical, and bacteriological agents.

The state regulations are responsive to the federal Safe Drinking Water Act (SDWA), passed in 1976 and amended in 1986. Appendix A contains a list of the contaminants and levels currently regulated by the state. The regulations include water quality standards, sampling, treatment and public notification requirements. Appendix B contains the names, health information, and status of the several contaminants listed in the 1986 amendments and for which the State Board of Health will eventually establish state regulations. The 1986 amendments expanded the number of drinking water contaminants that are regulated. Maximum Contaminant Levels (MCLs) have been, or are being, established for over 100 contaminants. The MCL, once promulgated in regulations, becomes the legally enforceable criteria for drinking water quality. It is the maximum permissible level of a contaminant in water. It reflects the feasibility of attaining protection based on economic factors, technology for remedial actions, analytical capabilities, and health protection goals.

Historically the major concern with drinking water focused on microbial agents and aesthetic concerns such as color, taste, odors and hardness. However, the expansion of the regulations to include many chemical constituents reflects the societal changes of recent decades. These changes have created opportunities for the introduction of chemical contaminants into both surface and ground water sources used for drinking water.

Ground and surface waters used for drinking water may be contaminated by a number of sources, such as:

* effluent discharges from sources such as septic tanks, sewer overflows, and other point sources;

* non-point sources, such as leaching or runoff from waste sites, agricultural practices, mining and industrial processes;

* cross-connections in water supply systems;

* leaching of construction materials used in pipes and water supply systems;

* leaking underground storage tanks;

* disinfection by-products and other additives; and

* naturally occurring contaminants, such as fluoride and naturally occurring radioactive materials (e.g., uranium and radon).

These and other sources may contribute a variety of contaminants to drinking water consumed at the tap. Pathogens, disinfection byproducts, pesticides, heavy metals, radionuclides, and toxic organics may be present. Human health may be impacted if the ingested drinking water contains levels of chemical, physical, or microbial agents known to be hazardous to health. In addition, drinking water can serve as a mode of transmission for contaminants either that cause health impacts if they are volatilized and inhaled or that cause damage by dermal contact.

In addition to MCLs, health protection goals, termed Maximum Contaminant Level Goals (MCLGs), are the levels at which "no known or anticipated adverse effect on the health of persons occur and which allows an adequate margin of safety." The MCLG for any carcinogen is zero regardless of any sources of information that might indicate a rationale for a higher level. While a stringent viewpoint would argue for the use of MCLGs as the levels recorded in drinking water regulations, the EPA believes that the use of MCLs is sufficiently protective of public health.

The Health Advisories referenced in Appendix B are developed by the Environmental Protection Agency. They provide the background on health effects, analytical status, and treatment technologies useful in assessing and addressing drinking water contamination. As such they provide important background for risk management and are early indications of the MCLGs and eventual MCLs. The lowest levels given in the health advisories are generally associated with assessments of impacts over long-term or lifetime exposures.

Washington state regulations impact public water systems serving two or more connections. Over 12,500 such systems currently exist in the state. Of these, ~12,000 serve less than 100 connections. The numbers of small water systems (SWS) are increasing in the state as are the numerous problems associated with them. For example, in the last ten years, the number of SWSs has grown from 4,728 to over 12,000. These small public water systems serve less than 17% of the population statewide. A variety of problems plague small water systems, including inadequacies of design and construction, operation, and maintenance and management. Fewer than 200 public water systems serve over 80% of the population. Ninety-five percent of the public water systems use ground water and serve fifty percent of Washington's population. Surface water sources provide drinking water for the other fifty percent of the state's population.

ANALYTICAL APPROACH AND DATA SOURCES

General Approach Taken:

The assessment of health risks in drinking water followed closely the approach taken by EPA in assessing similar risks for Region X.[1] For non-carcinogenic end points of toxicity, adequate dose/response models are not available for application to any type of quantitative risk assessment. Instead, the potential population facing contaminant exposure was compared to the reference dose and a toxicity index calculated. The reference dose is an estimate of daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects during a lifetime. The toxicity index presented an indication of potential risk, while the population exposed presented an indication of the magnitude of the potential impact in the state.

For carcinogenic endpoints, an estimate of incidence was made using the EPA Carcinogen Assessment Group (CAG) unit risk value. These were used in conjunction with the level of the contaminant of concern in the drinking water and an estimate of the population exposed to determine annual incidence. For any given contaminant, the theoretical estimate of cancer incidence was:

$$\frac{\text{(unit risk) (avg. exposure concentrations) (population exposed)}}{\text{70 years}}$$

Historical drinking water monitoring data, special study reports, agency surveys and studies from other agencies were examined for any documented evidence of elements or compounds found in public drinking waters in Washington state. Any contaminant documented at levels greater than trace amounts or present in at least two separate sites was selected for study.

Sources, Contaminants, Exposure Pathways and Effects:

All regulated public drinking water supplies were considered as potential sources of contaminants. Any contaminant regulated by state or federal mandate was considered in the preliminary analysis. While drinking water is a source of not only contaminant ingestion, it can also serve as a route of exposure from inhalation as well as dermal contact. For example, the major routes of exposure to trihalomethanes (THMs) in drinking water are through ingestion. However inhalation of THMs, such as chloroform, can also occur as the compound is released into the air from hot water usages such as showering, bathing and washing clothes and dishes.[1] Some studies with chloroform have shown that exposure from the inhalation of indoor air is likely to exceed exposure from the ingestion of tap water.

The same phenomenon is of concern when radon is present as a water contaminant. The health concern associated with radon in drinking water relates to lung cancer from inhalation of radon released from the water rather than reflecting any radiotoxicity associated with ingestion.

Even though other routes of exposure can occur with drinking water, the only route of exposure considered significant in this risk assessment was that from ingestion. This was because of the low levels of contaminants present, the number of variables to consider, and the complexity of analyses. Both cancer and non-cancer effects potentially associated with ingestion were examined.

Rationale for Contaminants Examined:

Chemical Contaminants

While there are many potential contaminants in drinking water, not all drinking water contaminants were subjected to a quantitative risk assessment. Contaminants selected for the quantitative risk assessment were only those that have been detected in Washington water supplies. In addition, they were considered important in terms of public health for the following reasons:

* The monitoring data were either confirmed or viewed with confidence with respect to accuracy, and would be considered valid;

* The contaminants were noted to impact a significant number of people or were noted to occur in more than one occasion within the state;

* Water facilities information (population, members of sources, types of sources, etc.) collected from the public systems was valid.

* Some contaminants have had historical significance with regard to public health concerns. (Appendix C contains summaries of the types of health impacts associated with certain contaminants.)

With the foregoing criteria, thirteen contaminants shown in Table 1 were considered to be of potential concern in Washington's drinking water.

A few additional points need to be made about the contaminants of concern. Arsenic and fluoride at high levels were found only in small community water supplies and were due to natural sources. Fluoride at levels from 0.8 to 1.7 mg/L appears beneficial for reducing dental caries and osteopororsis. Long-term consumption of water high in fluoride (8 - 20 mg/L) is reported to cause mottling of teeth and bone changes, such as fluorosis.(2)

Copper is primarily found as a result of the corrosion of copper plumbing. Ingestion of a single dose of 15 mg of copper has been reported to cause nausea, vomiting, diarrhea and intestinal cramps. Individuals with Wilson's and Menke's diseases are at higher risk from copper exposure than the general public. These persons have a genetic disorder resulting in abnormal copper absorption and metabolism causing neurological and other serious health problems.(3)

THM, or trihalomethanes, are volatile organic compounds (VOCs) formed as by-products of drinking water chlorination. While four different THMs can be formed, the most common THM found in public drinking water supplies is chloroform.(4) If THMs are present, chloroform is usually found in the highest concentration. The MCL listed for THM is for the total concentration of any combination of all THMs present.

Since there is no reference dose for nitrates, no risk assessment was calculated for noncancer risks. Nitrates present in drinking water in excess of 45 mg/L (10 mg/L as N) are associated with the development of methemoglobinemia or "blue babies". This tends to be a problem largely confined to infants less than three months of age and primarily to agricultural areas. There have been no cases of methemoglobinemia in the state in at least 15 years.(5)

Certain other contaminants have not been included in the analysis and warrant brief mention. Asbestos is known to occur naturally in the Puget Sound basin, and high concentrations have been, measured in the Everett and Seattle water supplies.(1) In addition, asbestos-cement pipe is commonly used in water distribution systems and is known to release asbestos fibers as it erodes. EPA has proposed to establish a MCL of 7.1×10^6 fibers/liter. However, due to the lack of monitoring data in the region, very limited health effect information via ingestion and expected low risk based on its potency and national occurrence data, it has not been included in the analysis.

A number of synthetic organic contaminants other than pesticides, such as PCB's, acrylamide, and non volatile organic solvents are scheduled for regulation. They have not been included in the analysis since national monitoring data indicate that these contaminants rarely occur in public supplies and would therefore present a small risk in comparison to other contaminants.[1]

There is approximately a thirty-fold variability in the unit risk factors available for radon. This makes a meaningful risk assessment associated with drinking water difficult. NAS (1986) notes that "the radiation associated with most water supplies is such a small proportion of the normal background to which all human beings are exposed that it is difficult, if not impossible to measure any adverse health effects with certainty." In addition, there is no current MCL for radon. In certain locations in Washington, levels of radon ranging from 100 to 631 pCi/L have been detected in drinking water supplies. Since radon is fairly soluble in water, it is possible for significant amounts of radon to build up in underground aquifers. Radon in the water would then be released when the well water was used in the house, contributing to the airborne levels. However, assuming an average water usage rate, house volume and ventilation rate, and assuming that only half of the radon in the water is released, a rule of thumb is that 10,000 pCi/L of radon in the water will contribute about 1 pCi/L of radon to the indoor air.[6] Drinking water would have to contain about 40,000 pCi/L of radon to be solely responsible for an average airborne level corresponding to EPA's guideline of 4 pCi/L. Levels measured in Washington have fallen far below these figures even in areas where there are naturally occurring radioactive materials in the soils. Thus negligible health risks from radon in drinking water are anticipated.

Another potential group of drinking water contaminants of concern in the state is petroleum products or their constituents. The currently observable impacts of spills, discharges, or leaking underground storage tanks on drinking water are few in number. However, in studies of supplies where benzene has been observed in concentrations in excess of levels of concern, the source of contamination has been identified as a gasoline storage leak or a spill. Since there are many underground storage tanks in the state that may be leaking these contaminants near drinking water sources, more monitoring for petroleum constituents is needed before the extent of this contaminant in drinking waters of the state can be determined.

One of the petroleum constituents, benzene, is currently a regulated compound for which a risk assessment was calculated. However, there are several other constituents such as toluene, xylenes, or benzene-based compounds which may be of concern. They are often found when benzene is observed, but the health implications for these contaminants at the levels at which they have been found is not clear.

Without better definition of the occurrence and health risk of the petroleum product/constituents, it is difficult to extend quantitative estimates of the risk posed to consumers of public water supplies. Some risk can be assumed given the opportunity for these types of contaminants to enter drinking water. As such, they must be viewed as significant at least in terms of their potential to impact public health.

Appendix C contains a list and description of the health effects of those chemicals selected by EPA for a Region X risk analysis of public water supplies. Some are the same as those contaminants selected for this risk assessment. However, not all of EPA's regional assumptions for selecting chemicals carried over to the contaminants selected for this assessment. Thus slightly different lists of contaminants were assessed.

Microbial Contaminants

Historical records abound with reported cases of disease transmission from microbial agents transmitted by drinking water supplies. Bacteria, protozoa and viruses can all be transmitted by the ingestion of water. Since 1978, cases of waterborne disease in the state of Washington have included Giardiasis, Shigellosis, Yersinia, and several from unknown etiological agents. Since there are literally hundreds of possible microbial agents, agent-specific monitoring does not occur. Instead an indicator organism (e.g. coliform) is used to assess the bacteriological quality of water. Turbidity is also measured, since the more turbid the water, the less effective the disinfection process. Unfortunately there appears to be no recognized relationship between turbidity or coliform levels in drinking water and the incidence of any, or all waterborne diseases. Therefore risk estimates for the state population serviced by public drinking water systems were developed from the reports of disease incidence. Data of interest were restricted only to cases where public drinking waters were shown to carry a microbial pathogen or where the source of the disease was epidemiologically shown to be drinking water.

<u>Data Sources Used; How Manipulated:</u>

* The sources of information for the risk assessment included:
* Records of all monitoring analyses for the state drinking water program;
* Disease incidence reports for the state;
* Special studies conducted by various state or federal agencies which involved data acquired from public water systems;
* Surveys of water systems which experienced a contamination problem.

Data acquired for localized situations were considered with respect to water source classification--either surface or ground water. This was then projected on a statewide basis with regard to specific populations which used either ground or surface water. In instances where the data were limited, they were either applied to the specific applicable population without extrapolation, or they were scaled-up to the total public water system population by multiplying the percentage of contaminant occurrence in the specific monitored population times the total drinking water system population. Consideration was given to the nature of the contaminant and whether it applied to either or both ground and surface waters when scaling-up was done.

Critical Assumptions Made:

The major assumptions in the analyses and manipulation of contaminant data were:

* When limited data were to be used in extrapolations to statewide projections, the percentage of occurrence in the tested population would apply throughout the state or to the appropriate subset population (i.e. , those on either ground, surface, or both water supplies).

* Population estimates were based on data collected by DSHS that was considered accurate.

* Health impacts would only be recognized when contaminant levels exceeded regulatory MCLs or levels documented in health advisories of EPA.

* Population exposure concentrations were based on existing MCL's, proposed MCL's, or actual exposure data if available.

* Chloroform constitutes the major fraction of THMs and it was assumed that projections regarding THMs could be based on mean chloroform exposure levels for chlorinated surface water supplies. The population exposed to THM was assumed to be the population using chlorinated surface systems.

* It was inappropriate and unreasonable to make projections if no validated data were available.

* The figure used in calculations of proportion of infants less than one year of age to total population in Washington was 0.0154.

* Incidence of microbial disease was based on true incidence. No attempt was made to relate true incidence to levels of coliform bacteria or turbidity.

* The true impacted population for lead and copper exposure was considered one-sixth of the total exposed population because of non-equal distribution of contaminant levels in consumer tap water during various diurnal periods.

* Five percent of all systems which have a positive result for VOC monitoring will exceed a VOC MCL.

* For microbiological contaminants, the reportings of water borne disease (from drinking water) were considered to underestimate true occurrence by four-fold.

<u>Toxicologic Assumptions Used</u>:

Certain basic assumptions and procedures were used to calculate the health risks. Among them were:

* Only oral routes of exposure, assuming 100% absorption were considered.

* Risk calculations assumed a lifetime exposure and a consumption of two liters of water/day by a 70 Kg individual.

* The reference dose (RfD) was accepted as the appropriate estimate of daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects during a lifetime.

* The cancer potency factors and reference doses available through EPA' s database were accepted as valid. If potency factors were not established or were too variable, as in the case of radon, carcinogenic risk was not calculated as it was felt results would be misleading rather than helpful. This was also the approach taken for noncancer risks, i.e., if a reference dose was not given, no risk calculation was attempted. Thus there are no estimates given for the potential noncancer risks associated with nitrate or arsenic.

* A toxicity index was considered an indicator of anticipated health effects. A toxicity level of 1.0 indicates a "safe" level at which point there is no expected health effect.

<u>Approach to Scaling Up</u>:

Estimates for the populations impacted by drinking water contaminants were determined in two ways:

1. If the existing monitoring data were considered complete on a statewide basis, they were used directly to estimate populations impacted;

2. If the data were localized or not thought to realistically reflect the potential impact for the statewide population, projections of impacted populations were scaled-up from the known information to give estimates of the statewide impact. Typically the extrapolations were ones of best professional judgment, reflecting knowledge of the types of systems, water sources, populations served and geographical locations with similar characteristics.

Sensitivity Analysis:

The objective of this analysis was to assess the risk of any documented contaminant in Washington drinking waters. This risk analysis provides a reasonably conservative risk assessment for chemical contaminants. Cancer risks which were calculated are theoretical upper bound estimates.

Higher risks would be calculated if detection limits were used as the basis of exposure to chemicals and if other exposure routes had been considered. If the upper limits of exposure to chemical contaminants had been used in the risk calculations, a smaller population exposure estimate would have been used. Thus the risk estimate for the state would be approximately the same as that derived from the present calculations. There may be a few "pockets" of "worst case" exposure to chemicals, as shown in Table 1.0. In these instances, the risk to a specific population may be higher than that calculated for the general population.

It is likely that many cases of waterborne illness remain undetected or are never reported. To accomodate this reality, a four-fold multiplier was used as suggested by EPA. This probably provides the "best" estimate of disease. It may well be that the "worst case" assumption should be at least a ten-fold projection, while the "best case" would be that the number of diseases reported represent all cases.

DESCRIPTION OF FINDINGS

With respect to chemical contaminants, estimated excess cancer risks from drinking water contaminants are generally considered negligible for the contaminants which were analyzed. Considering the noncancer risks, fluoride was the only drinking water contaminant examined which exceeded the reference dose. This was specific for a small segment of the population, reflecting a unique situation in the state. This is not a serious health threat at the levels seen because the toxic effect is teeth mottling in children, which is of cosmetic concern only.

Waterborne disease continues to be spread by drinking water. Since 1978, there have been 357 documented waterborne disease cases in Washington state. These have included Giardiases, Shigellosis, and Yersinia, as well as unknown etiological agents. More than one-half of the reported cases were for Giardiases. Using a four-fold multiplier to account for under reporting of incidence, the total estimated cases since 1978 are 1428. This suggests an average annual incidence of at least 14.3 cases of waterborne disease each year.

Very few of the contaminants of concern had an established EPA severity index associated with noncancer risks. One exception was lead, whose severity index varies from 3 to 7, depending on the extent and type of neurological damage, retardation, or learning disability associated with the exposure. Since the Washington data indicate a toxicity index of 0.2, there is little cause for concern. As noted earlier, high levels of fluoride are primarily linked to mottling of teeth. Fluoride can thus be assigned a severity index of 2. Ingestion of copper at levels high enough to cause gastrointestinal symptoms suggests a severity index of 4 for the general population. However, for that segment of the population who cannot appropriately metabolize copper, the severity index of 6 may be the appropriate number. At high doses, arsenic can cause symptoms ranging from gatrointestinal problems, changes in finger and toenails, abnormal skin pigmentation to even possibly death. Thus a severity index ranging from 4 to 7 could probably be assigned arsenic.

Microbial contaminants have a severity index ranging from 4 to 7, reflecting the full range of health effects possible from exposure to pathogens, including gastrointestinal disease and mortality. In an era where we have become enamored with quantitative risk assessments and chemical contamination concerns, this serves as a reminder that, at least with drinking water, the importance of microbial impacts must not be forgotten.

The highest cancer risk identified in this assessment was associated with chloroform levels (6 excess cancers predicted). This is actually quite a low number and is only one-third of the estimate for chloroform at the MCL which is based on health, competing risks, and technical considerations.

Waterborne disease caused by microbial agents can be considered an example of "acute" health effects associated with drinking water. These as well as acute cases of chemical intoxication can occur as a result of cross-connections and backsiphonage. A cross-connection is any direct or indirect connection between a potable and nonpotable water system. As a result of backflow, the potable water sytem can easily become contaminated. Such connections are not uncommon. Appendix E contains two descriptive accounts of outbreaks associated with cross-connections in the Northwest. Cross-connections are always a potential source of acute waterborne disease.

UNCERTAINTY

Since the risk assessment evaluated only contaminants which had been detected in Washington drinking water, there is some sense that the analysis provides a good view of the health risk associated with drinking water in the state. However, the assessment can not be considered a comprehensive one, since the lack of adequate potency factors or reference doses for some of the contaminants left the risk analysis incomplete. Additional routes of exposure and many classes of chemicals, especially pesticides in ground water, were not evaluated. In addition, no attempt was made to evaluate contaminants in private drinking water systems.

A concern expressed by the EPA assessment of the region which can be echoed by this assessment is that the arsenic, nitrates, and EDB exposure assessments were related to groundwater exposures. Compliance monitoring data suggest that these contaminants are of minimal risk in surface supplies, since they were not detected.

As discussed previously risk associated with radon exposure was not calculated for three reasons: the unit risk factors ranged over thirty-fold; population exposure estimates could not be scaled-up with any degree of confidence; and results would be misleading.

There is always uncertainty in scaling up, particularly if a contaminant is found in a small system and that result used to estimate larger exposures. since larger systems are more likely to be aware of water quality problems and correct them, scaling- up may well overestimate the risk.

EPA regional estimates for certain contaminants are found in Appendix D. Within the Region X data are instances where data specific to supplies in Washington state were generated. While these data are similar to the statewide findings of this assessment, the quantitative estimates differ. This points out the difficulty in undertaking risk assessments with limited data and attempting to put "numbers" on the results. Public health risk is probably adequately protected with either data set, but when in doubt the larger margin of safety would be preferred. With this perspective, this assessment may underestimate the risk associated with lead in the state.

The best risk estimate is that dealing with microbial contamination leading to waterborne illness. It is based on true incidence of disease, not theoretical calculations which project disease.

ANATOMY OF RISK

In many ways the risk, or rather the apparent lack of significant health risk, associated with Washington's drinking water could be anticipated. Since a drinking water program has been in existence for so many years, the public supplies have been protected and monitored for some time. Many of the potential problems which were detected were associated with smaller systems or were in specific geographical areas. Both are anticipated variables in the current drinking water program. They also point to potential future concerns as population growth in the state forces residents into new areas where ground or surface waters have seldom been tapped for drinking water. This means the sources of such new, and possibly, small systems must be carefully developed. In addition the state's anticipated population growth will make demands on existing systems. Conflicts could arise between the various user groups of our water resources, and care must be taken to assure future water quality and quantity for drinking water purposes is not compromised.

Even though this analysis does not document any major risk, this risk assessment should be regarded as tentative and incomplete. There are significant information gaps regarding levels of contaminants, exposed populations, and exposure assessment methods which should be addressed to develop a more comprehensive assessment.

The impact of microbial contamination has been emphasized, and it should be. It is important to note that the reported cases of Giardiases all occurred in systems which provided filtered and disinfected surface water. If the treatment plants had been operating properly, it can be assumed that none of these cases would have occurred. When determining risks to consumers of public water supplies, the operation and management of the facilities designed to provide safe drinking water can not be ignored. This is true not only for the control of microbial contamination but also for efforts aimed at corrosion control and subsequent reductions in the levels of lead and copper found in drinking water. It is perhaps in the area of operations that the greatest risk to health may be found.

The importance of good operations and maintenance points to a major concern for the future. It has been noted that the numbers of small water systems (SWSs) have been rapidly increasing. For the last decade, there have been an average annual increase of 610 small systems in the state.[11] These systems have between two and 1000 connections. Unfortunately it is in small water systems that the greatest problems regarding operation and maintenance are likely to be encountered. There are several reasons for this, but since SWSs are usually privately owned, they have limited access to public financing such as grants and low-interest loans. In addition, SWSs typically have an inadequate rate base, which further limits their ability to finance capital improvements and provide appropriate operation and maintenance. While a Task Force has been established by the state drinking water program to formulate solutions to the many problems confronting SWSs, resolution of the problems are complex and will take much time. In general it is desirable to eliminate existing inadequate small water systems through the formation of regional systems. The Public Water Supply Coordination Act (RCW 70.116) has been shown to be a valuable tool to improve the safety and reliability of drinking water.[12]

Another problem that will remain, and even possibly grow as SWSs grow in the future, is the problem of waterborne disease outbreaks associated with cross-connections. A national study of waterborne outbreaks found that nearly 40% of the outbreaks were due to distribution system deficiencies.(13) The primary factor in such outbreaks was a cross-connection and backsiphonage. While these generally impact small areas and a few people, it is not always the case as is demonstrated by the examples given in Appendix E. Such situations will no doubt continue to be a major potential cause of acute waterborne illness.

For the future, attention focused upon the operations/maintenance aspect of water systems may well do more to avert disease incidence than any other means which has been historically used.

In summary, the health risks associated with the state's drinking water appear to be few. Our drinking water is in "good shape" in most instances. There are, however, "pockets" of concern for some contaminants for small populations and increasing concerns for the expansion of small water systems and their related operational/maintenance problems. SWSs may rely on water treatment as the best way to solve problems, but it is often not the best nor most appropriate strategy. Certainly source control and water monitoring are equally important.

With respect to source control, our state may face major challenges in the future as its population grows. While large municipalities in Washington currently enjoy good source control of their drinking water,, increasing and conflicting demands for the use of protected watersheds could conceivably remove that protective factor from the drinking water systems.

The search for toxics in drinking water is really a task in its infancy. As additional monitoring and analyses are developed, more may be discovered regarding the long-term quality and health impact of water supplies. The better the analyses, the more likely they will document potential problems.

REFERENCES

1. Environmental Protection Agency. 1989. Draft Human Health Risk Assessment: Public Drinking Water Supplies. EPA Region 10 Comparative Risk Evaluation Summary Reports.

2. Salvato, Joseph A. 1982. Environmental Engineering and Sanitation, Third Edition. New York: John wiley and Sons.

3. Office of Environmental Health Programs. 1988. Copper in Drinking Water. Toxic Substances Fact Sheet. State of Washington: DSHS.

4. Office of Environmental Health Programs. 1988. Trihalomethanes in Drinking Water. Toxic Substances Fact Sheet. State of Washington: DSHS.

5. Office of Environmental Health Programs. 1989. Nitrates in Drinking Water. Toxic Substances Fact Sheet. State of Washington: DSHS.

6. Environmental Protection Agency. 1988. Radon Reduction Techniques for Detached Houses. (EPA/625/587/019). North Carolina: Research Triangle Park: Office of Research and Development.

7. Office of Environmental Health Programs. 1989. DSHS Drinking Water Program. Overview. State of Washington: DSHS.

8. Office of Environmental Health Programs. 1987. Task 1. Ground Water Quality Criteria. Contract No. 6500-54712, July 1, 1985 and Supplenmental Contract, 1987. State of Washington: DSHS.

9. Office of Environmental Health Programs. 1989. Draft Revision of Drinking Water Regulations, WAC 248-54. State of Washington: DSHS. 10. Office of Envirorunental Health Programs. 1988. Rules and Regulations of the State Board of Health Regarding Public Water Systems. State of Washington: DSHS.

11. Office of Environmental Health Programs. 1989. Small Water System Problems: An Assessment. State of Washington: DSHS.

12. Environmental Protection Agency. 1989. Ensuring the Vaiability of New Small Drinking Water Systems, A Study of State Programs. (EPA-570/9-89-004). Office of Water (WH-550).

13. Craun, Gunther F. "Outbreaks of Waterborne Disease in the United States," Journal AWWA. July 1981, pp 360-369.

14. Office of Environmental Health Programs. 1987. Arsenic. Toxic Substances Fact Sheet. State of Washington: DSHS.

Table 1.0

CONTAMINANTS OF CONCERN

Element or Compound of Concern	Highest Measured Level (mg/L)	Population Exposed to Highest	Proposed MCL (mg/L)
Arsenic	4.5	21	0.05
Lead	7.56	680	0.05
Copper	8.0	183	1.3
Fluoride	5.2	4,500	4.0
Nitrate (as N)	50.0	50	10.0
Surface Water THM --Chloroform	0.2794	35,000	0.10
Ground Water THM --Chloroform	0.0289	13,000	0.10
Ethylene Dibromide	0.0023	>50	0.0005
1,1,1-Trichloroethane	0.0042	12,000	0.200
Trichloroethylene	0.0124	15,500	0.005
Tetrachloroethylene --(PERC)	0.030	9,630	0.005
Benzene	0.0722	132	0.005

Table 2.0

ASSESSMENT OF CANCER RISKS

	UNIT RISK (POTENCY) (uG/L)	WATER LEVEL (uG/L)	POPL'N EXPOSED	EXCESS CANCER	ANNUAL INCIDENCE
Arsenic	5.0 x 10(-5)	50	330	0.8	1.18x 10(-2)
THM (CHLOROFORM)	1.7 x 10(-7)	31.5	1037800	5.6	7.9 x 10(-2)
EDB	2.5 x 10(-3)	0.05	2000	0.25	3.6 x 10(-3)
TCE	3.2 x 10(-7)	5	15360	0.025	3.5 x 10(-4)
Benzene	8.3 x 10(-7)	5	182	0.0008	1.1 x 10(-5)
PERC	2.9 x 10(-7)	5	384500	0.06	8.0 x 10(-4)

Theoretical estimate of total excess cancer = 6.7 (or .1 excess cancer/yr)

THM = Trihalomethanes
EDB = Ethylene Dibromide
TCE = Trichloroethylene
PERC = Tetrachloroethylene

Table 3.0

ASSESSMENT OF NONCANCER RISKS

	RfD (mg/kg/day)	EXPOSURE (mg/kg/day)	*TOXICITY INDEX	POPULATION EXPOSED
LEAD	0.0014	0.0003	0.2	232,000
COPPER	0.037	0.037	1.0	37,000
FLUORIDE	0.06	0.114	1.9	4,600
1,1,1 TRICHLOROETHANE	0.035	0.006	0.16	21,070
TCE	0.007	0.0001	0.02	15,360
PERC**	0.0143	0.0001	0.07	38,450
CHLOROFORM	0.01	0.0009	0.09	1,037,800

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*Toxicity Index = exposure/RfD
Exposure calculations = (contaminant level) x (2 liters)/7O kg
**PERC = Tetrachloroethylene

THE STATE OF THE ENVIRONMENT REPORT

VOLUME III
Part 10

Risk Evaluation Reports for Acid Deposition

ENVIRONMENT 2010

State of Washington
October, 1989

TABLE OF CONTENTS

1.0 INTRODUCTION

This assessment estimates the current ecological effects and risks associated with acid deposition in Washington State. It is intended for comparison to estimates for other environmental issues being considered in Washington 2010.

2.0 PATHWAYS TO AFFECTED ECOSYSTEMS AND POTENTIAL IMPACTS OF CONCERN

Sulfur dioxide and nitrogen oxides are the air pollutants of primary concern with respect to acid deposition effects. The major sources of these acid oxides in Washington's air have been inventoried for the National Acid Precipitation Assessment Program based on 1985 emission levels. In 1985, the major sources of sulfur dioxide emissions were coal-fired power plants (41% of the estimated total), industrial processes such as metals and petroleum refining and pulp mills (29%), transportation sources (11%), and industrial power generation (10%). Major sources of nitrogen oxides were transportation sources (60%), coal-fired power plants (14%), industrial power generation (7%), forest burning practices (6%), and industrial processes (5%). Volcanic activity is a potentially significant natural source of sulfur dioxide emissions, as was Mt. St. Helens in the early 1980's.

The primary pathway for acid precipitation to affected ecosystems is through wet and dry deposition of sulfates and nitrates. Once deposited, these strong acids may each cause nutrient leaching and acidification in sensitive watersheds, soils, and terrestrial plants. Potentially significant impacts include structural and functional changes in sensitive freshwater ecosystems, namely poorly unbuffered lakes and streams, and in coniferous forests along the western slope of the Cascade Mountains.

Sulfate and Nitrate Deposition Data

Numerous studies of precipitation chemistry have been performed in the Pacific Northwest. The majority of these studies have consisted mainly of single events (Knudson, et al., 1977), and seasonal and year-long sampling (Logan et al., 1982; Vong et al., 1985). Loranger and Brakke (1987) present chemical data from 1984 and 1985 for four National Acid Deposition program sites in Washington and Oregon. The Washington Department of Ecology has been monitoring wet acid deposition since 1983, and summary results are reported in Department of Ecology (1988) and Duncan et al. (1989). Reports prepared by Olsen, et al., 1985 and 1986 summarize air quality data contained in the 1984 and 1985 Acid Deposition Assessment Data Base. These results are also summarized in Barchet (1987).

There are currently two long-term acid precipitation monitoring networks operating in Washington: The Department of Ecology's Acid Deposition Program and the National Acid Deposition Program/National Trends Network (NADP/NTN). The NADP network currently has four stations monitoring wet deposition at low to mid elevations in Washington. During 1988, the Ecology network currently had two stations monitoring low to mid elevation wet deposition, and three stations monitoring bulk deposition (snow) in the Cascade Mountains. The mountain precipitation sites are operated during the October through May period when most of the snowpack accumulation occurs. The Ecology network has been reduced significantly since 1987, when a total of ten sites were operating, due to reduced funding. The monitoring programs depend on the cooperative efforts of various agencies, including local air pollution authorities, universities, and National Parks.

For 1988, the precipitation-weighted average pH of rainfall measured at the wet deposition sites ranged from 4.59 to 5.43, see Table 1. At the mountain precipitation sites, precipitation pH ranged from 5.20 to 5.23. Three of the sites in the Puget Sound Basin recorded weekly pH values of 4.0 or less on one or more weeks during 1988. Average annual sulfate concentrations ranged from 5.66 to 33.12 micro-equivalents per liter (μeq/l) at the wet deposition sites and 4.60 to 7.41 μeq/l at the mountain precipitation sites. Average annual nitrate concentrations ranged from 1.06 to 13.07 μeq/l at the wet deposition sites, and 3.91 to 4.17 μeq/l at the mountain precipitation sites. For 1988, annual wet deposition of sulfate ranged from 4.60 to 15.29 kilograms per hectare, and annual nitrate deposition ranged from 2.30 to 8.73 kilograms per hectare at wet deposition sampling sites in Western Washington (WDOE, 1989; NADP/NTN, 1989). Dry deposition was not measured at any of the sites in Washington.

The data on precipitation quality shows that urban and industrial air emissions of acid oxides are affecting rain and snow chemistry in Washington, generally making it more acid in some areas of the state. This is particularly true of precipitation falling on the Puget Sound basin where most of the emissions originate. The precipitation reaching the high elevations of the Cascade Mountains has significantly less excess sulfate and nitrate than found at lower elevations in the Puget Sound area, indicating a substantial "washout" and dispersion effect. This is fortunate, since alpine lakes and streams in the high mountain areas appear to be our most sensitive resources potentially affected by acid deposition.

Analysis of cloudwater and fog chemistry has shown that samples taken along the western slopes of the Cascades are considerably more acidic than measured wet deposition. Research is currently underway to determine if acidic fog can be associated with forest ecosystem effects in the northeastern United States and Europe. Some hypotheses explain European forest decline by referring to the potential interaction of ozone and highly acidic cloudwater and fog. Forest areas above the cloudlayer in the eastern U.S. have experienced more forest dieback and decline than similar lower elevation forests. Potential forest effects due to acid deposition are currently being evaluated by the Western Conifer Cooperative of NAPAP's Forest Response Program.

It will be important to continue monitoring precipitation in the future, particularly in the mountain areas. Such monitoring serves as an early warning system for detecting an increase in environmental risks associated with acid deposition. In addition, research into the possible effects of acid fog upon ecosystems along the western Cascades should continue.

Available calculations for wet deposition in 1988 indicate that we are below the thresholds associated with chronic acidification of lake systems in other parts of the world. Dry deposition is not monitored in Washington, however, adding uncertainty to the question of total deposition.

3.0 FRESHWATER ECOSYSTEMS

Washington's most sensitive aquatic resources affected by acid deposition are poorly buffered alpine lakes and streams in the Cascade Mountains. The effects of acidification on sensitive freshwater lake and stream ecosystems have been widely described; principal reviews include Malanchuk and Turner (1987), Magnuson, et al., (1983), and Haines and Johnson, (1982). Freshwater acidification results in a number of structural and functional changes in sensitive aquatic ecosystems. Effects, summarized across ecosystem parameters, are reviewed in Table 2. While the literature indicates that acid deposition and the resulting acidification of sensitive freshwater ecosystems does cause harmful biological effects on populations, there is no firm consensus regarding a critical pH value for the protection of freshwater ecosystems. According to Malanchuk and Turner (1987), lakes with pH values above 5.5 will support viable fish populations, although abnormalities in some fish and other organisms have been reported at higher pHs. At pH values below 5.0, serious population disturbance will occur in most cases. Henriksen and Brakke (1988) defined the critical pH value for the protection of biological systems as 5.3. Data from Landers, et al. (1987) indicate that the minimum fall index pH value of lakes sampled in potentially sensitive regions in Washington was 5.84. The sample mean was 7.05. Results from lake sampling undertaken by Washington's Department of Ecology are shown in Table 5. These sampling results indicate that the mean pH of sampled lakes in potentially sensitive Washington watersheds ranged from a low value of 6.28 in the South Cascades to a high value of 6.69 in the North Cascades. These data indicate that pH levels of sensitive lakes in Washington are generally above threshold values thought to cause biological effects in freshwater ecosystems. While this analysis is based largely on fall pH values, late spring and early summer pH values measured in Cascade lakes have been found to be considerably lower (<5.5). These lower pH values associated with snowmelt events tends to occur during the critical season for certain aquatic organisms (e.g. the egg-laying season for amphibians).

Freshwater Lake Monitoring Data

Numerous investigators have surveyed lake water chemistry in Washington, see for example, Wissmar, et al. (1982), Logan et al. 1982, Brakke and Loranger (1986), Brakke and Waddell (1985), Duncan and Ausserer (1984), Loranger (1986), Welch, et al. (1986), Welch et al. 1989. This analysis uses results of the Western Lake Survey (Landers, et al., 1987), supplemented by results cited in Roberts, et al. (1986), and Duncan (1988), to represent selected lake water chemistry characteristics for Washington.

TABLE 1: SUMMARY OF 1988 PRECIPITATION MONITORING RESULTS

(All values are volume-weighted annual average concentrations based on weekly samples)

STATION	STATION NUMBER	pH (S.U.)	H+ (ueq/l)	NH4+ (ueq/l)	Ca++ (ueq/l)	MG++ (ueq/l)	K+ (ueq/l)	Na+ (ueq/l)	NO3- (ueq/l)	SO4= (ueq/l)	SO4=2* (ueq/l)	Cl- (ueq/l)	CATIONS (ueq/l)	ANIONS (ueq/l)
SEATTLE	102	4.59	25.78	10.89	3.58	3.14	1.21	12.77	10.59	33.12	30.34	28.54	57.37	72.25
BELLINGHAM	105	4.78	16.54	12.04	1.66	2.49	0.57	7.59	12.00	17.38	14.94	24.76	40.89	54.14
TOLT RESERVOIR	106	4.77	17.09	7.56	1.48	4.04	0.83	10.51	8.38	16.47	14.97	19.72	41.51	44.57
STEVENS PASS**	502	5.23	5.90	0.94	1.85	2.01	0.31	3.19	3.91	4.60	N/A	7.29	14.20	15.80
SNOQUALMIE PASS**	503	5.20	6.30	2.52	2.94	1.96	0.68	8.80	4.17	7.41	N/A	12.42	23.20	24.00
PORT TOWNSEND***	131	4.47	33.66	5.58	3.31	6.61	2.70	17.28	15.43	23.57	20.57	29.04	69.14	68.04
CENTRALIA	137	4.62	24.15	7.97	3.41	7.35	1.21	26.95	6.34	29.86	25.53	41.92	71.04	78.12
TURNBULL LAB	134	5.43	3.75	20.27	5.91	3.30	1.38	5.11	15.07	5.66	4.24	19.44	39.72	40.17

*Non-Sea Salt Sulfate (calculated value).

**Based on weekly samples collected November 2, 1987 to May 30, 1988.

***Based on samples collected January 1 to May 11, 1988 only.

Table 2
Summary of Current Understanding of the Effects of Acidification on Aquatic Biota

Parameter	Effects
Decomposers	Results are somewhat inconsistent across studies. • Long-term, whole-system experiments indicate no major shift in whole-system decomposition rates with acidification. • In-situ and laboratory studies, however, have consistently decreased decomposition of coarse detritus (i.e., leaf packs) at low pH. This decrease may result, in part, from decreased processing of coarse detritus by benthic invertebrates.
Phytoplankton	Acidification results in a shift in species composition, presumably favoring species better adapted to acidic conditions. • Field surveys and field experiments suggest that acidification has no major adverse effects on phytoplankton abundance: - Lower abundance in acidic lakes in some regions likely results principally from associated low nutrients loads. - Decreased productivity for individual algae species, demonstrated in laboratory experiments, is apparently compensated for by shifts to species tolerant of acidic conditions.
Zooplankton	Acidification results in a shift in species composition. • It is unclear the degree to which observed shifts in species composition result from the direct toxic effects of acidity as opposed to indirect factors such as decreasing fish predation or increasing water clarity. • Laboratory and field experiments have, however, demonstrated that pH and Al levels associated with acidification are toxic to certain zooplankton species.

Table 3 (continued)
Summary of Current Understanding of the Effects of Acidification on Aquatic Biota

Parameter	Effects
	• Results relative to potential effects on total zooplankton abundance or biomass have been somewhat inconsistent: - Field experiments indicate no significant adverse effects. - Some field surveys indicate lower abundance in acidic lakes, perhaps as a result of associated low nutrients loading.
Benthos	The tolerance of benthic macroinvertebrates to acidity varies greatly among species and among taxa.
	• Certain taxa (e.g., molluscs and mayflies) and species are absent in acidic waters. Acidification would likely result in decline of these populations.
	• Effects on benthic productivity have not been well studied. Available evidence suggests no major effects on total biomass in most systems.
Macrophytes Benthic Algae	
	• Acidification apparently favors the growth of certain attached algae, including filamentous green and blue-green algae.
	• Various hypotheses have been proposed to explain the increase in biomass of benthic algae in some acidic waters, including: - increased water clarity - succession to acid-tolerant species - decreased grazing or decomposition
	• Extensive growths of Sphagnum are not commonly observed in acidic lakes in North America.
Fish	Acidic conditions are detrimental to fish, although sensitivity to acidity varies among species.

Table 2 (continued)
Summary of Current Understanding of the Effects of Acidification on Aquatic Biota

Parameter	Effects
	• The experimental acidification of Lake 223 demonstrated loss and decline of fish populations with decreasing pH (to pH 5.0).
	• Mechanisms of effects have not been established, although direct toxicity to early life stages and recruitment failure likely play an important role in many waters.
Amphibians	Acidic conditions are toxic to amphibians.
	• Field studies of population-level responses to acidification have not been conducted.

Adapted from Malanchuk and Turner (1987).

There are far less available data regarding stream water chemistry, and virtually no comprehensive biological data available within the State. Consequently, this analysis does not explicitly address ecological risks due to stream water acidification in Washington. In addition, the analysis doesn't include explicit consideration of biological inventory data, for example, fish population inventory data. This could result in an underestimation of the risk of ecosystem effects potentially caused by acidification.

The Department of Ecology, several universities and other agencies have been involved in studies of alpine lakes in Washington for several years. EPA's Western Lakes Survey (Landers, et al., 1987) recently completed a study of the sensitivity of lakes in Washington from a broad-scale, regional perspective. The different goals and scales of these studies have yielded different and useful perspectives on the risk associated with acid deposition. A key parameter assessed in these studies is acid neutralizing capacity, or alkalinity, which indicates a lake's buffering capacity and hence its sensitivity to acid deposition.

The approach of the Western Lakes Survey Phase 1 was to conduct a onetime sampling of a large number of lakes during the fall period after seasonal mixing of lake waters had occurred. The project was designed to assess a statistically significant sample representing lakes greater than one hectare in size, to estimate the total number of lakes falling into broad categories of sensitivity. By using the fall index values determined from the sample lakes, the project yielded valuable information on the extent of lake susceptibility to chronic acidification on a regional scale.

The approach of the Ecology-funded studies has been to take the results of early reconnaissance level sampling and focus on a small number of key lakes for intensive monitoring over the long term. Lakes chosen for long-term study represent sensitive resources in different areas of the Cascades. The primary purpose of the Ecology-funded studies is to detect lake response to acid deposition. The comparatively small scale of the studies facilitates the assessment of seasonal variability in lake chemistry and response of the lakes to changes in emissions of acid oxides. Both fast and slow flushing lakes, which vary in their seasonal response, are studied.

Significant seasonal variations in acid neutralizing capacity (ANC) and pH of the lakes have been detected, indicating the sensitivity of the lakes to snowmelt influences and a potential for short term acidification effects associated with snowmelt events (Smayda, 1986; Welch et al. 1986). ANC in fast-flushing lakes in the central Cascades are has been shown to increase two to four-fold between May and September, indicating the degree to which lake chemistry is affected by snowmelt. A multi-year study of lakes in the Alpine Lakes Wilderness Area has noted a significant reduction in sulfate concentrations in ALWA lakes associated with the 1985 shutdown of a large copper smelter in Tacoma and the cessation of emissions from the Mt. St. Helens volcano. During the same time, however, there has not been a corresponding increase in the acid neutralizing capacity of the lakes, as might have been expected. (Welch, et.al. 1989b)

The results from all of these studies may be used to place Washington's alpine lakes into various categories of sensitivity based on alkalinity classes. Lakes with alkalinities below 50 μeq/l are generally referred to as "very sensitive". Based on sampling results, a large percentage of lakes in the central portion of Washington's Cascades fall into this category. However, it is important to note that a subset of these lakes fall into a category that might be termed "extremely sensitive", having alkalinity values below 25 ueq/l, with several lakes below 10 ueq/l. Many of these lakes have pH values below 5.5, when sampled during the season most affected by snowmelt. Although categorizing lake sensitivity based on fall alkalinity is useful in developing a regional comparison, it is also important to consider late spring and early summer alkalinity when the lake is most susceptible to the effects of snowmelt. It is not presently known whether snowmelt-related pH depressions are having adverse effects on lake or stream ecosystems.

Lake Acidification in Washington

To estimate the extent of acidified, sensitive, or insensitive lakes, this analysis used the Western Lake Survey (Landers, et al., 1987) to place sampled lakes into one of three categories.

Category	Measured ANC (μeq/L)
Very Sensitive	< 50
Sensitive	51-200
Insensitive	> 200

An ANC of 200 μeq/L has been frequently used as a criterion to separate lakes that may be sensitive to acid deposition from lakes that may not be (Swedish Ministry of Agriculture, 1982; Altshuller and Linthurst, 1983). Lakes with < 50 μeq/L ANC have some buffering capacity, but have been demonstrated to experience decreases in ANC during snowmelt. Note that no lakes in Washington were measured to have ANC values < 0 μeq/L in the Western Lake Survey. Thus, survey results indicate that there are currently no known acidified lakes within the State.

Table 3 indicates that fall ANC in sampled Washington lakes ranged from 3.9 μeq/L to 1995 μeq/L. The mean ANC value for sampled lakes was 245.8 μeq/L.

Twenty lakes of the Landers, et al. (1987) Washington sample had ANC values < 50 μeq/L. Landers, et al. (1987) estimated that the 95 percent upper confidence level for the population of lakes in Western Washington and Oregon with ANC values ≤ 50 μeq/L was 415 out of a total estimated population size of 1,706 lakes. Lakes with low ANC values were located along the Cascade Crest in Oregon and Washington.

Data summarized in Table 4 confirm the sensitivity of high alpine lakes in Washington. This data suggests that the highest percentage of sensitive lakes in Washington are located in the Alpine Lakes-Stevens Pass and South Cascades Regions. However, the mean ANC value for lakes sampled in the Alpine Lakes-Stevens Pass area is significantly lower than other high alpine lakes in Washington.

Using data from Table 3, the potential long-term acidification of lakes in Washington can be investigated by applying Henriksen's Model (1980). The model states that measured ANC should approximately equal the sum of non-marine calcium and magnesium, as these two elements are most commonly associated with the production of alkaline material. When ANC for a given sample is less than the sum of calcium and magnesium, Henriksen's model states that some ANC has been consumed by reaction with strong acid.

The ANC/(Ca+Mg) column in Table 3 indicates that there has been some consumption of ANC by strong acids in sensitive Washington lakes, but that the relationship between ANC and (Ca+Mg) is generally very close to 1.1, see Figure 1 for a plot of this data. Figure 1 confirms the close relationship between ANC and (Ca+Mg), suggesting little chronic acidification in Washington State.

Table 4
Western Lakes Survey - Washington

ID	NAME	ST	LONGITUDE	LATITUDE	QUADRANGLE	CLOSED PH	ANC	SO4	NO3	Ca	Mg	(Ca+Mg)	ANC/(Ca+Mg)
4B1-050	SILVER LAKE	WA	48-59'15"	121-13'45"	7.5' MT SPICKARD	6.80	35.5	15.3	2.0	33.1	5.3	38.4	0.92
4B3-045	SILVER LAKE	WA	48-58'45"	122-04'05"	7.5' MAPLE FALLS	7.93	1137.5	362.4	2.4	1219.7	186.3	1406.0	0.81
4B3-049	SHEEP LAKE	WA	48-58'22"	120-22'40"	7.5' ASHNOLA MNT	7.18	120.4	45.7	0.1	103.7	31.3	135.0	0.89
4B3-046	(NO NAME)	WA	48-57'45"	120-52'50"	7.5' SKAGIT PEAK	7.57	192.0	52.1	0.0	217.1	7.8	224.9	0.85
4B3-048	WHITE LAKES(NORTH)	WA	48-54'33"	120-32'55"	7.5' TATOOSH BUTTES	7.73	656.9	4.8	0.2	514.5	87.2	601.7	1.09
4B1-051	TAPTO LAKES (EAST)	WA	48-53'05"	121-22'05"	15' MT CHALLANGER	6.66	14.3	19.2	0.0	18.0	3.3	21.3	0.67
4B3-047	LAKE OF THE PINES	WA	48-52'54"	120-42'40"	7.5' FROSTY CREEK	7.40	296.2	41.7	0.1	268.4	54.5	322.9	0.92
4B1-049	HAYES LAKE	WA	48-51'25"	121-43'11"	15' MT SHUKSAN	7.21	450.7	42.6	0.1	409.9	37.5	447.4	1.01
4B3-052	LEASE LAKE	WA	48-50'49"	120-33'30"	7.5' MT LAGO	7.04	193.0	62.8	0.3	227.5	17.5	245.0	0.79
4B3-050	BLACK LAKE	WA	48-49'45"	120-12'25"	7.5' MT BARNEY	7.68	430.2	10.8	0.0	279.4	93.1	372.5	1.15
4C3-005	LOST LAKE	WA	48-49'18"	117-26'17"	7.5' METALINE	7.62	587.8	38.1	0.2	366.8	239.0	605.8	0.97
4B3-044	JERRY LAKE(NORTH)	WA	48-45'40"	120-55'05"	7.5' JACK MNT	7.23	216.6	17.2	0.0	185.0	35.4	220.4	0.98
4B1-048	BERDEEN LAKE	WA	48-43'00"	121-27'45"	15' MARBLE MOUNT	7.08	63.5	18.7	0.0	52.0	15.6	67.6	0.94
4B2-050	DIABLO LAKE	WA	48-42'45"	121-06'45"	7.5' DIABLO/ROSS DAM	7.44	459.0	91.1	5.3	424.6	90.0	514.6	0.89
4B3-041	SAMISH LAKE	WA	48-40'00"	122-23'00"	7.5' BELLINGHAM SOUTH	7.76	378.6	110.1	2.4	294.9	128.3	423.2	0.89
4B2-068	WATSON LAKES (WEST)	WA	48-40'00"	121-35'22"	15' LAKE SHANNON	7.24	279.2	38.6	0.1	285.9	28.0	313.9	0.89
4C3-009	LAKE SHERRY	WA	48-36'34"	117-32'33"	7.5' LAKE GILLETTE	7.40	582.9	33.0	0.3	378.7	131.6	510.3	1.14
4B2-049	(NO NAME)	WA	48-36'05"	120-56'35"	7.5' MT LOGAN	7.33	198.1	65.5	0.0	201.2	35.9	237.1	0.84
4B2-048	WING LAKE	WA	48-31'03"	120'48'18"	7.5' MT ARRIVA	7.41	127.4	9.6	0.0	99.7	26.5	126.2	1.01
4B1-047	LAMONT LAKE	WA	48-29'50"	120-31'27"	7.5' GILBERT	7.51	560.0	60.3	0.6	532.7	29.4	562.1	1.00
4B2-070	HIDDEN LAKE	WA	48-29'45"	121-11'15"	7.5' SONNY BOY LAKES	6.84	40.7	6.9	0.1	34.1	2.7	36.8	1.11
4B1-046	DOUBTFUL LAKE	WA	48-28'27"	121-02'47"	7.5' CASCADE PASS	6.91	46.6	48.8	0.0	68.4	9.9	78.3	0.60
4B2-046	LAKE NO. 2	WA	48-28'10"	121-19'44"	7.5' SNOWKING MNT	7.13	171.1	9.2	6.5	147.0	16.3	163.3	1.05
4B2-047	(NO NAME)	WA	48-24'36"	121-04'43"	7.5' CASCADE PASS	7.36	110.0	20.4	0.0	105.1	12.0	117.1	0.94
4B3-053	CASKEY LAKE	WA	48-24'07"	121-34'25"	7.5' ROCKPORT	6.51	103.3	20.5	2.2	83.1	32.9	116.0	0.89
4B3-040	DAY LAKE	WA	48-23'58"	121-57'30"	15' OSO	6.98	259.0	43.1	10.1	206.3	125.4	331.7	0.78
4B1-070	WILLIAMS LAKE	WA	48-22'20"	120-30'55"	7.5' SUN MNT	7.50	579.7	96.7	0.1	524.4	73.9	598.3	0.97
4B2-060	BATTALION LAKE	WA	48-20'45"	120-47'13"	7.5' MT LYALL	7.36	244.6	24.1	0.0	196.3	41.2	237.5	1.03
4B2-044	PEAR LAKE	WA	48-19'40"	121-19'13"	7.5' HUCKLEBERRY MNT	7.06	150.3	32.5	0.1	132.1	22.3	154.4	0.97
4C3-015	(NO NAME)	WA	48-16'18"	117-08'55"	7.5' SKOOKUM CREEK	7.77	1995.6	17.9	0.3	1093.1	666.3	1759.4	1.13
4B1-058	CANYON LAKE	WA	48-14'48"	120-59'40"	15' HOLDEN	6.78	53.6	18.3	0.0	46.4	11.2	57.6	0.93
4B2-043	SULPHUR MNT LAKE	WA	48-14'45"	121-08'15"	15' GLACIER PEAK	6.90	88.7	8.9	0.4	64.4	13.9	78.3	1.13
4B1-045	(NO NAME)	WA	48-14'28"	120-18'55"	7.5' MARTIN PEAK	7.25	146.7	48.4	3.1	135.1	16.7	151.8	0.97
4B3-039	LITTLE LAKE	WA	48-14'12"	122-00'02"	7.5' ARLINGTON EAST	6.39	141.0	30.8	12.4	108.3	79.2	187.5	0.75
4B1-044	TWIN LAKES (EASTERN)	WA	48-12'22"	121-11'31"	15' GLACIER PEAK	6.95	113.7	33.8	0.1	97.6	27.3	124.9	0.91
4B1-043	LYMAN LAKE	WA	48-11'30"	120-54'30"	15' HOLDEN	7.03	69.0	115.0	1.1	121.9	32.7	154.6	0.45
4B2-051	SADDLE LAKE	WA	48-10'44"	121-45'20"	15' GRANITE FALLS	5.84	25.6	21.2	0.5	55.7	10.7	66.4	0.39
4B2-056	LAKE JULIA	WA	48-03'58"	121-52'28"	15' GRANITE FALLS	6.38	94.5	82.2	3.6	134.9	53.0	187.9	0.50
4B1-042	LARCH LAKES(WESTERN)	WA	48-03'48"	120-44'15"	15' LUCERNE	7.19	176.5	18.5	0.0	140.2	22.6	162.8	1.08
4B2-041	COPPER LAKE	WA	48-01'55"	121-32'15"	15' SILVERTON	6.85	52.6	33.9	3.4	58.3	9.1	67.4	0.78
4B1-053	AIRPLANE LAKE	WA	48-00'10"	121-00'20"	15' GLACIER PEAK	6.94	52.8	6.5	0.0	35.2	5.2	40.4	1.31
4B3-063	BOULDER LAKE	WA	47-58'35"	123-44'53"	7.5' MT CARRIE	7.80	491.3	112.3	0.1	493.5	68.8	562.3	0.87
4B2-067	HUGHES LAKE	WA	47-57'57"	121-53'17"	15' MONROE	6.68	154.2	53.7	0.3	95.0	82.2	177.2	0.87
4B2-039	MAD LAKE	WA	47-56'03"	120-39'10"	7.5' CHIKAMIN CREEK	7.42	190.2	0.6	0.0	126.4	19.2	145.6	1.31
4B3-061	LUNCH LAKE	WA	47-54'57"	123-46'55"	7.5' BOGACHIEL PEAK	7.57	234.0	91.1	0.0	281.8	33.8	315.6	0.74

Table 4
Western Lakes Survey - Washington

ID	NAME	ST	LONGITUDE	LATITUDE	QUADRANGLE	CLOSED	PH	ANC	SO4	NO3	Ca	Mg	(Ca+Mg)	ANC/(Ca+Mg)
4B3-036	CHAIN LAKE	WA	47-54'15"	121-58'10"	15' MONROE		6.53	318.4	40.2	1.0	206.0	122.2	328.2	0.97
4B3-037	WALLACE LAKE	WA	47-54'15"	121-40'30"	15' INDEX		6.88	270.8	61.8	5.0	264.2	51.0	315.2	0.86
4B3-035	HOH LAKE	WA	47-53'57"	123-47'05"	7.5' BOGACHIEL		7.63	489.9	82.7	0.4	478.0	54.0	532.0	0.92
4B2-037	(NO NAME)	WA	47-52'01"	121-33'25"	15' INDEX		6.73	79.6	26.3	3.3	81.9	15.1	97.0	0.82
4B1-041	HEATHER LAKE	WA	47-51'30"	121-07'35"	7.5' LABYRINTH MNT		7.52	84.9	18.2	0.9	85.8	29.0	114.8	0.74
4B3-032	(NO NAME)	WA	47-50'23"	123-11'18"	15' TYLER PEAK		7.81	455.8	130.0	0.0	420.5	108.9	529.4	0.86
4B3-034	CEDAR PONDS LAKE	WA	47-48'20"	121-48'15"	7.5' SULTAN		7.39	505.5	89.5	1.4	396.2	107.6	503.8	1.00
4B1-062	JOAN LAKE	WA	47-47'32"	121-11'34"	7.5' CAPTAIN POINT		6.94	74.4	31.1	0.0	52.1	18.9	71.0	1.05
4B2-036	LAKE SERENE	WA	47-47'00"	121-34'15"	15' INDEX		6.63	39.9	30.2	6.0	51.5	8.1	59.6	0.67
4B2-053	LAKE JULIUS	WA	47-44'12"	120-52'30"	15' CHIWAUKUM MTS		7.01	61.7	24.5	0.0	48.1	12.6	60.7	1.02
4B3-031	(NO NAME)	WA	47-42'55"	121-52'00"	7.5' LAKE JOY		6.86	607.3	89.9	4.3	399.7	169.0	568.7	1.07
4B2-035	JASON LAKES (SOUTHERN)	WA	47-42'55"	120-53'25"	15' CHIWAUKUM MTS		7.22	107.7	41.3	0.0	85.7	20.6	106.3	1.01
4B3-065	(NO NAME)	WA	47-41'38"	121-58'22"	7.5' CARNATION		7.03	195.6	46.5	16.6	171.0	57.9	228.9	0.85
4B2-034	DOELLE LAKES (EASTERN)	WA	47-41'35"	121-00'05"	7.5' STEVENS PASS		6.70	77.5	8.8	0.1	55.2	10.9	66.1	1.17
4B3-068	HULL LAKE	WA	47-39'55"	121-47'50"	7.5' LAKE JOY		6.73	488.3	36.7	4.1	351.5	108.6	460.1	1.06
4B1-032	PARADISE LAKES(NORTH)	WA	47-39'20"	121-30'20"	15' MOUNT SI		6.68	47.3	16.6	1.1	40.5	11.5	52.0	0.91
4B1-061	SQUARE LAKE	WA	47-38'45"	121-07'10"	7.5' STEVENS PASS		7.00	205.5	18.5	0.1	184.4	13.7	198.1	1.04
4B1-037	(NO NAME)	WA	47-38'12"	121-07'15"	7.5' STEVENS PASS		6.89	55.3	5.4	0.8	50.5	5.8	56.3	0.98
4B3-026	HORSESHOE SLOUGH	WA	47-37'25"	121-55'20"	7.5' FALL CITY		6.89	195.8	51.0	14.5	164.7	53.6	218.3	0.90
4B2-066	CALLIGAN LAKE	WA	47-36'20"	121-40'00"	15' MOUNT SI		7.05	133.6	30.4	4.1	115.0	21.3	136.3	0.98
4B1-066	COUGAR LAKE	WA	47-36'05"	121-31'40"	15' MOUNT SI		6.51	19.1	12.7	0.5	20.5	5.2	25.7	0.74
4B2-029	BOYLE LAKES	WA	47-35'51"	121-45'22"	7.5' SNOQUALMIE		6.78	191.3	55.2	3.5	156.0	73.2	229.2	0.83
4B1-034	NAZANNE LAKE	WA	47-35'45"	121-17'25"	7.5' BIG SNOW MNT		7.05	84.4	8.0	0.0	61.9	14.0	75.9	1.11
4B1-038	BOB LAKE	WA	47-35'24"	121-03'47"	7.5' THE CRADLE		7.10	161.8	16.5	3.5	130.4	23.4	153.8	1.05
4B3-054	LAKE ARMSTRONG	WA	47-35'00"	123-01'11"	15' THE BROTHERS		6.87	112.6	15.7	0.7	75.6	48.3	123.9	0.91
4B1-067	AL LAKE	WA	47-34'55"	121-15'38"	7.5' BIG SNOW MNT		6.82	88.9	7.7	0.4	79.0	13.2	92.2	0.96
4B1-027	BEAR LAKE	WA	47-34'30"	121-23'45"	7.5' SNOQUALMIE LAKE		6.53	26.6	14.7	0.4	28.0	8.5	36.5	0.73
4B1-036	HYAS LAKE	WA	47-34'30"	121-07'40"	7.5' MT DANIEL		6.86	162.4	10.1	1.7	127.2	17.9	145.1	1.12
4B1-052	DEER LAKE	WA	47-34'15"	121-24'00"	7.5' SNOQUALMIE LAKE		6.51	20.4	14.1	0.0	23.3	7.7	31.0	0.66
4B1-029	BONNIE LAKE	WA	47-33'57"	121-16'15"	7.5' BIG SNOW MNT		7.18	123.6	7.8	1.5	95.9	21.6	117.5	1.05
4B1-031	TROUT LAKE	WA	47-33'27"	120-54'25"	15' CHIWAUKUM MTS		7.39	579.2	43.7	0.1	164.6	401.0	565.6	1.02
4B1-030	CIRCLE LAKE	WA	47-33'05"	121-09'45"	7.5' MT DANIEL		6.89	111.5	5.6	0.2	88.3	16.7	105.0	1.06
4B1-055	LAKE IVANHOE	WA	47-32'02"	121-14'15"	7.5' MT DANIEL		6.41	19.5	5.9	0.1	19.0	3.0	22.0	0.89
4B1-024	COLCHUCK LAKE	WA	47-29'30"	120-50'00"	15' MT STUART		7.65	184.4	4.9	0.2	114.7	18.3	133.0	1.39
4B1-025	SNOW LAKES (WEST)	WA	47-28'55"	120-45'22"	15' MT STUART/LIBERTY		7.11	55.2	4.1	0.3	34.0	7.5	41.5	1.33
4B1-068	CRYSTAL LAKE	WA	47-28'28"	120-48'05"	15' MT STUART		6.61	28.5	3.0	0.0	16.6	3.7	20.3	1.40
4B2-027	WICKS LAKE	WA	47-27'20"	122-42'16"	7.5' BURLEY		5.93	17.7	53.7	0.5	37.3	45.4	82.7	0.21
4B2-028	GRANITE LAKES(NORTH)	WA	47-27'20"	121-36'52"	15' BANDERA		6.79	155.9	22.9	4.3	136.7	23.9	160.6	0.97
4B1-021	TUSCOHATCHIE LAKE	WA	47-26'00"	121-28'35"	15' SNOQUALMIE PASS		7.28	157.1	33.0	0.6	144.9	20.1	165.0	0.95
4B3-021	U LAKE	WA	47-25'41"	123-04'23"	15' POTLATCH		6.28	33.4	14.7	0.1	30.1	27.0	57.1	0.58
4B1-020	OLALLIE LAKE	WA	47-25'20"	121-30'35"	15' BANDERA		6.75	97.2	12.8	0.1	74.1	12.3	86.4	1.13
4B1-022	RACHEL LAKE	WA	47-25'18"	121-19'48"	15' SNOQUALMIE PASS		7.30	104.0	12.9	0.2	95.8	11.6	107.4	0.97
4B1-057	RAMPART LAKES(SOUTH)	WA	47-24'57"	121-20'20"	15' SNOQUALMIE PASS		7.46	166.3	11.0	0.3	149.6	13.6	163.2	1.02
4B3-019	ANNETTE LAKE	WA	47-21'35"	121-28'20"	15' SNOQUALMIE PASS		6.66	65.3	27.2	0.5	67.5	6.3	73.8	0.88
4B1-019	BAKER LAKE	WA	47-21'06"	121-18'02"	15' SNOQUALMIE PASS		6.83	141.3	14.7	0.0	108.0	31.5	139.5	1.01

Table 4
Western Lakes Survey - Washington

ID	NAME	ST	LONGITUDE	LATITUDE	QUADRANGLE	CLOSED PH	ANC	SO4	NO3	Ca	Mg	(Ca+Mg)	ANC/(Ca+Mg)
4B3-060	H & H RESERVOIR NO. 1	WA	47-19'57"	120-23'50"	7.5' MISSION PEAK	9.56	1716.8	2.0	0.2	901.7	731.3	1633.0	1.05
4B3-020	CAMP LAKE	WA	47-18'50"	120-52'47"	15' MT STUART	9.25	1807.7	1.3	0.2	703.6	851.4	1555.0	1.16
4B3-018	STIRRUP LAKE	WA	47-17'44"	121-25'23"	15' SNOQUALMIE PASS	7.10	154.7	8.4	0.2	104.4	29.3	133.7	1.16
4B2-025	(NO NAME)	WA	47-13'40"	122-58'25"	7.5' SQUAXIN ISLAND	7.12	396.8	20.3	1.4	203.6	173.2	376.8	1.05
4B3-016	SUNSET LAKE	WA	47-06'34"	122-00'50"	7.5' WILKESON	7.00	344.7	59.3	43.1	236.4	134.1	370.5	0.93
4B2-064	SUMMIT LAKE	WA	47-02'22"	121-49'50"	15' ENUMCLAW	6.09	3.9	9.2	0.1	6.9	3.9	10.8	0.36
4B1-059	SPIDER LAKE	WA	47'26'55"	121-34'15"	15' BANDERA	6.54	62.5	16.3	3.4	60.6	10.8	71.4	0.88
4B1-018	CHENIUS LAKES(SOUTH)	WA	46-58'17"	121-46'42"	7.5' MOWICH LAKE	6.91	58.3	10.7	0.1	42.3	9.6	51.9	1.12
4B1-017	GOLDEN LAKES (LARGE)	WA	46-53'20"	121-53'55"	7.5' GOLDEN LAKES	6.40	81.1	11.7	0.2	52.6	19.7	72.3	1.12
4B2-024	DEADWOOD LAKES(SOUTH)	WA	46-53'12"	121-31'15"	7.5' WHITE RIVER PARK	7.67	432.9	10.7	0.1	406.7	24.7	431.4	1.00
4B1-069	GOLDEN LAKES (SW)	WA	46-53'08"	121-54'23"	7.5' GOLDEN LAKES	5.95	12.1	12.2	0.1	15.4	8.1	23.5	0.51
4B2-023	AMERICAN LAKE	WA	46-49'05"	121-27'29"	15' BUMPING LAKE	6.84	83.0	20.5	0.1	73.7	10.9	84.6	0.98
4B3-057	LAKE ALLEN	WA	46-45'54"	121-53'30"	7.5' MT WOW	7.51	419.3	92.4	0.1	414.6	70.3	484.9	0.86
4B2-062	PEAR LAKE	WA	46-44'20"	121-18'50"	15' WHITE PASS	7.13	349.0	38.7	0.1	256.8	92.9	349.7	1.00
4B2-021	DUMBBELL LAKE	WA	46-41'30"	121-22'45"	15' WHITE PASS	6.79	34.4	32.0	0.0	30.3	22.3	52.6	0.65
4B3-015	CORA LAKE	WA	46-41'20"	121-53'19"	15' RANDLE	6.81	219.5	33.6	3.2	179.2	38.7	217.9	1.01
4B2-022	SHELLROCK LAKE	WA	46-41'05"	121-20'40"	15' WHITE PASS	6.15	21.0	37.6	0.0	26.1	23.0	49.1	0.43
4B3-014	DUCK LAKE	WA	46-39'48"	122-19'40"	15' MORTON	6.67	144.5	18.7	4.1	128.7	25.7	154.4	0.94
4B2-057	DEER LAKE	WA	46-39'03"	121-24'38"	15' WHITE PASS	7.10	150.8	22.5	0.0	102.0	46.5	148.5	1.02
4B3-013	SUPRISE LAKE	WA	46-28'10"	121-21'33"	7.5' JENNIES BUTTE	7.34	503.2	55.0	1.3	326.3	140.3	466.6	1.08
4B2-019	CHAMBERS LAKE	WA	46-28'00"	121-32'00"	7.5' HAMILTON BUTTES	7.95	725.1	65.3	0.0	518.5	180.6	699.1	1.04
4B3-055	LE CONTE LAKE	WA	46-22'55"	121-24'05"	7.5' WALUPT LAKE	6.25	12.0	32.2	0.0	22.9	11.2	34.1	0.35
4B3-012	TWO LAKES(WESTERN)	WA	46-22'06"	121-27'53"	7.5' CLACIATE BUTTE	7.30	235.6	24.9	0.0	125.3	73.5	198.8	1.19
4B2-018	COUNCIL LAKE	WA	46-16'00"	121-37'40"	7.5' E. CANYON RIDGE	7.75	371.0	13.5	0.0	184.7	139.4	324.1	1.14
4B2-065	(NO NAME)	WA	46-06'30"	121-46'04"	15' LONE BUTTE	6.47	29.5	4.4	0.0	13.9	15.7	29.6	1.00
4B3-011	MERRIL LAKE	WA	46-05'35"	122-19'15"	7.5' COUGAR	7.05	196.6	11.2	0.5	124.2	40.3	164.5	1.20
4B2-016	(NO NAME)	WA	46-01'20"	121-49'47"	7.5' LONE BUTTE	6.18	27.3	11.0	0.1	18.4	15.4	33.8	0.81

Table 4
High Altitude Lakes Sampled in Washington

Table 4a
Alkalinity Classes of Lakes Sampled*

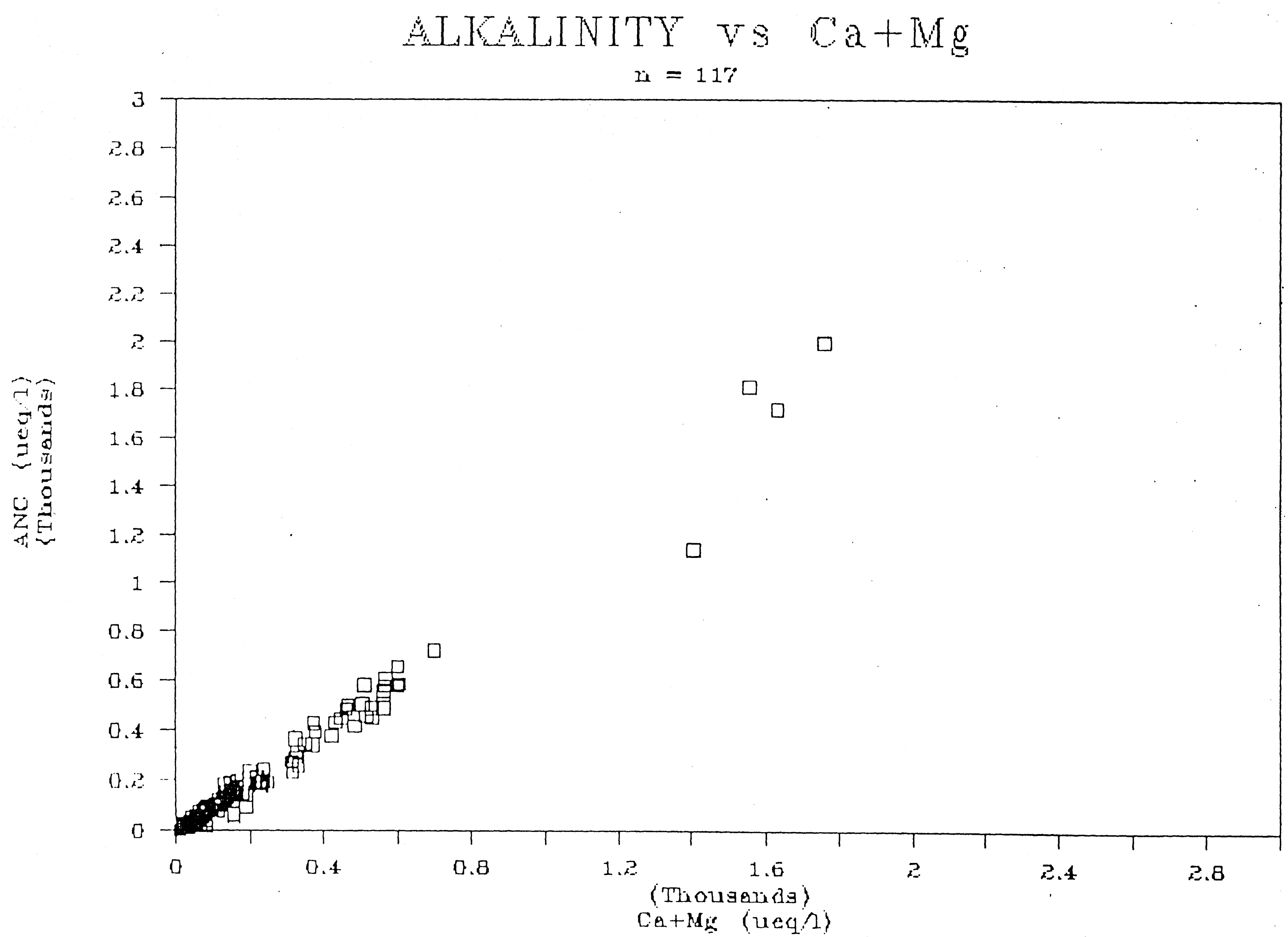
Area	Number of Lakes Sampled	Mean Alkalinity Classes (μeq/L) % of Lakes in each class 0-45	50-99	100-200	200
North Cascades	75	15	29	29	27
Alpine Lakes - Stevens Pass	20	55	40	5	0
South-Central Cascades	11	27	27	18	27
South Cascades	15	47	7	7	40
Olympics	7	0	0	14	86

* Note: Lakes sampled August & September, 1983 - 1985.

Table 4b
Mean Concentrations for Major Constituents by Area*

Area	SO_4	Cl	NO_3	ANC	H+	pH	n
North Cascades	38.0	12.17	3.00	171.96	0.20	6.69	75-79
	(35.2)	(19.77)	(9.31)	(176.36)	(03.8)		
Alpine Lakes -	17.95	9.31	0.52	49.18	0.54	6.27	20
Stevens Pass	(12.85)	(6.15)	(0.63)	(33.52)	(0.89)		
South-Central	28.28	9.21	0.18	118.48	0.23	6.64	11
Cascades	(14.96)	(3.36)	(0.83)	(102.88)	(0.28)		
South Cascades	22.61	18.13	0.22	173.3	0.53	6.28	15
	(33.19)	(915.14)	(0.27)	(197.0)	(0.56)		
Olympics	97.60	31.87	0.34	382.6	0.022	7.66	7
	(38.36)	(925.66)	(0.23)	(151.8)	(0.008)		

*Note: Lakes samples August and September, 1983-1985 Values in parenthesis are standard deviation. Adopted from Roberts, et al. (1986).Table 5



ALKALINITY vs Ca+Mg
n = 117
ANC (ueq/l)
(Thousands)
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.4
0.8
1.2
1.6
2
2.4
2.8
(Thousands)
Ca+Mg (ueq/l)

Annual wet sulfate deposition ranged between 4.6 and 15.29 kg/ha/year in 1988 in Washington (WDOE, 1989; NADP/NTN, 1989). 1984 deposition rates summarized at four sites in Washington indicate SO_4 deposition ranged between 9.50 kg/hectare/year and 23.50 kg/hectare/year (Roberts et al. 1986). Emissions of sulfur dioxide have declined substantially since 1985, due to the closure of a large copper smelter and cessation of emissions from Mt. St. Helens volcano. While current sulfate deposition rates in Washington are below those which have resulted in acidification of lakes in Eastern North America and Europe, it is not known what a "safe" deposition level is for sensitive lakes in the Cascades.

Existing acid deposition loading levels are below those thought to cause lake ecosystem effects. However, the large number of lakes with ANC values less than 50 µeq/L suggests that if acid deposition precursor emissions were to increase, that high alpine lake and stream ecosystems could be chronically acidified, resulting in structural and functional changes in sensitive ecosystems similar to those described in Table 2.

Reversibility

There have been no documented effects to aquatic ecosystems caused by acid deposition in Washington. However, if effects are discovered, reduction of precursor emissions should allow ecosystem recovery within decades.

Scale

The majority of high alpine watersheds in the State contain sensitive watersheds. Lower elevation, and the majority of watersheds and lakes in eastern Washington are less sensitive, and/or are exposed to significantly reduced levels of acid deposition.

Trend/Potential

There is no evidence of either increasing sensitivity or cumulative impact or vulnerability of high altitude watersheds in the state. Current deposition data do not allow for firm conclusions regarding trends in acid deposition at sensitive receptors in Washington.

Uncertainty

Although there is a good database available on precipitation characteristics within the Puget Sound Basin, the data for sensitive mountainous areas and Eastern Washington is sparse. Extreme site to site variability prohibits meaningful extrapolation between sites. From the limited data available for mountainous areas, it appears that concentrations of sulfate, nitrate, and the hydrogen ion are relatively low. However, almost no data is available to assess the characteristics of summer precipitation in the Cascades. Preliminary results from a fog sampling project in Mount Rainier National Park indicate that acid fog events with pH values as low as 3 may be occurring in alpine areas. Uncertainty with respect to total deposition results from a lack of data on dry deposition, which is likely to be quite significant. It is not known whether snowmelt-related episodic acidification is adversely affecting lake or stream biota.

Summer is the critical season from the standpoint of lake sensitivity. Alpine studies conducted in California have noted potentially significant short term effects associated with summer rainstorms. The potential for such episodic acidification appears to be the greatest threat currently facing sensitive Cascade lakes in Washington. While there is a noticeable snowmelt effect on the chemistry of sensitive alpine lakes, little is known about potential ecosystem effects associated with this short-term phenomena. While considerable data are available on the current status of sensitive lakes, very little is known about the status and effects on streams in sensitive alpine areas of the state. Small streams may be extremely sensitive to effects on aquatic organisms

Recommendations Regarding Information

Based on the current state of knowledge concerning acid deposition in Washington, the major emphasis should be:

1) Continued monitoring of precipitation quality and sensitive lakes using an early warning system approach to obtain meaningful information with limited resources. Develop a biological monitoring component.

2) Maintain and if possible increase monitoring of precipitation characteristics in the Cascades, and begin to assess characteristics of summer precipitation to evaluate the potential for episodic acidification.

3) Determine the potential for ecosystem effects associated with seasonal fluctuations in pH and alkalinity of alpine lakes.

4) Assess the status of small streams in sensitive areas of the state with respect to potential acid deposition impacts.

5) Continue to track current research on such areas as acid fog, deposition of toxics, and other relevant topics, and adapt environmental monitoring activities as justified by resource damage potential.

4.0 FOREST ECOSYSTEMS

There are no current reports of forest tree or ecosystem injury in Washington due to acid deposition. While understanding of forest ecosystem and tree response to acid deposition remains incomplete, numerous cases of tree decline in the eastern United States and Canada, as well as in Europe, have been associated with acid deposition by hypothesis. These hypotheses are summarized in Kulp (1987) and McLaughlin (1985), and include:

- Acid Leaching of Foliar Nutrients;
- Nitrogen Foliar Fertilization/Reduced Frost Hardiness;
- Acid leaching of Soil Nutrients;@ Aluminum Toxicity to Roots;
- Reduced Microbiological Activity; and
- Multiple Stresses.

Note that this list does not include the effects of known phytotoxicants and regional air pollutants ozone and hydrogen peroxide. Forest ecosystem effects due to ozone are considered separately in Ambient Air Pollutants.

Laboratory research reported in Kulp (1987) suggests that controlled experiments involving exposures over a span of acidity values above and below present ambient levels show no growth reduction or foliar symptoms over a wide range of tree species (both deciduous and coniferous) unless the pH is below 3.0. As shown in NADP/NTN (1988) and above, the lowest annual mean precipitation weighted mean pH in Washington is well above this threshold. While measurable growth effects or foliar injury have not been reported at acidity levels measured at NADP sites in Washington, it is possible that subtle ecosystem effects have or may occur at present acid deposition and fog levels in Washington.

Forest ecosystems above the cloudbase may be more sensitive to acid deposition and other environmental stresses than other, lower elevation, forests in Washington. The principal area of concern in Washington would be the west side of the Cascade Mountains because of proximity to acid deposition precursors, higher measured sulfate and nitrate deposition levels, and increased elevation and cloud cover.

Uncertainty

There is no evidence that acid deposition is affecting forest ecosystems in Washington. However, it is possible, based on data from the eastern United States, Canada and Europe, that acid deposition may be affecting forest ecosystems in areas that receive high levels of hydrogen ion deposition. It is not known if hydrogen ion deposition levels are high enough to cause any forest ecosystem effects in Washington.

REFERENCES - ACID DEPOSITION

Barchet, W.R. 1987. "Acid Deposition and Its Gaseous Precursors," In: L. Kulp (ed.) Interim Assessment the Causes and Effects of Acid Deposition, Volume III. National Acid Precipitation Assessment Program, Washington, DC.

Brakke, D.F. and T.J. Loranger. 1986. Acid neutralizing Capacity of Lakes in the North Cascades Area of Washington State. Water, Air and Soil Poll. 30:1045-1053.

Brakke, D.F. and D.A. Waddell. 1985. Water Chemistry in the North Cascades of Washington, pp. 79-101. In: J.H. Baldwin (ed.), Acid precipitation in the Pacific Northwest. University of Oregon, Eugene, OR.

Department of Ecology. Washington State Air Monitoring Data for 1986. DOE 88-22. Olympia, WA.

Duncan, L.C. P. McGinty, D. Byrnes, J. Costello, and T. Lee. 1989. Measurement and Assessment of the Composition of Bulk Winter Precipitation at Snoqualmie and Stevens Pass Sites, Winter 1987-88 (Precipitation Chemistry Monitoring Report V). Report to Department of Ecology. Central Washington University, Chemistry Department. Ellensburg, Washington.

Duncan, L.C. 1988. Personal Communication. Chemistry Department, Central Washington University, Ellensburg, WA.

Duncan, L.C. and W. Ausserer. 1984. Acid precipitation in the Washington Cascades, Phase II. Final Report Contract A-119-WASH, Washington Water Research Center. Pullman, WA.

Haines, T.A. and R.E. Johnson (eds.). 1982. Acid Rain/Fisheries. American Fisheries Society, Bethesda, MD.

Henriksen, A. 1980. "Acidification of Freshwaters - A Large Scale Titration." Proc. Int. Conf. Ecol. Impact of Acid precip., Oslo, Norway, pp. 68-74.

Henriksen, A. and D. Brakke. 1988. Environmental Science and Technology 22:8.

Knudson, E.J., D.L. Deuwer, G.D. Christian and T.V. Larson. 1977. Application of Factor Analysis to the Study of Rain Chemistry in the Puget Sound Region. Chemometrics Theory and Application, ACS Symp. Series 52. B.R. Kowalski (ed.), Washington, DC.

Landers, D.H., et al. 1987. Western Lake Survey Phase 1, Characteristics of Lakes in the Western United States. EPA 600/2-86/054a.

Landers, D.H., J.M. Eilers, D.F. Brakke, W.S. Overton, P.E. Kellar, M.E. Silverstein, R.D. Schonbrod, R.E. Crowe, R.A. Linthurst, J.M. Omernik, S.A. Teague, and E.P. Meier. 1987. Characteristics of Lakes in the

Western United States, Volume I; Population Descriptions and Physico-Chemical Relationships. EPA-600/3-86/054a. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C., Environmental Research Laboratory, Corvallis, Oregon and Environmental Monitoring Systems Laboratory, Las Vegas, Nevada.

Logan R.M., J.C. Derby, and L.C. Duncan. 1982. Environmental Science and Technology 16:771.

Loranger, T.J. 1986. Temporal Variability of Water and Snowpack Chemistry in the North Cascade Mountains. M.S. Thesis, Western Washington University, Bellingham, WA.

Loranger, T.J. and D.F. Brakke. 1987. A Preliminary Investigation of Precipitation Chemistry in Washington and oregon. Institute for Watershed Studies, Western Washington University, Bellingham, WA.

Magnuson, J.J., et al. 1983. "Effects on Aquatic Biology," In: R.A. Linthurst (ed.), The Acid Deposition Phenomenon and its Effects, Volume II. U.S. EPA 600/8-83-016B.

Malanchuk, J.L. and R.S. Turner. 1987. "Effects on Aquatic Ecosystems," In: L. Kulp (ed.) Interim Assessment, The Causes and Effects of Acid Deposition, Volume IV. National Acid Precipitation Assessment Program, Washington, DC.

Marshall, L. 1988. Personal Communication. U.S. Environmental Protection Agency, Region 10, Seattle, WA.

McLaughlin, S.B. 1985. JAPCA 35(5):512.

NADP/NTN. 1988 NADP/NTN Annual Data Summary, 1986. Colorado State University, Ft. Collins, CO, October.

National Atmospheric Deposition Program (IR-7)/National Trends Network. 1989. October 15, 1989 Data Retrieval. NADP/NTN Coordination Office, Natural Resource Ecology Laboratory, Colorado State University. Fort Collins, Colorado.

Olsen, A.R. and A.L. Slavich. 1985. Acid precipitation in North America: 1983 Annual Data Summary from Acid Deposition System Data Base. EPA 600/4-85-061. U.S. EPA, Research Triangle Park, NC.

Olsen, A.R. and A.L. Slavich. 1986. Acid precipitation in North American: 1984 Annual Data Summary from Acid Deposition System Data Base. EPA 600/4-86-033. U.S. EPA, Research Triangle Park, NC.

Omernik, J.M. and A.L. Gallant. Ecoregions of the Pacific Northwest. EPA 600/3-86/003, Environmental Research Laboratory, Corvallis, OR.

Roberts, D., C.M. Spens, M. Ruckelshaus, and T.L. Myers. 1986. Acid Rain Program Technical Report. Washington State Department of Ecology. Olympia, WA.

Smayda, T.J. 1986. Acid Precipitation and Cascade Mountain Lakes: Effect of Lake Flushing Rate on Temporal Variation in Chemical Content. M.S.E. Thesis. University of Washington. Seattle, Washington.

Swedish Ministry of Agriculture. 1982. Acidification Today and Tomorrow. Ministry of Agriculture, Environment Committee, Stockholm, Sweden.

Vong, R.J., T.V. Larson, D.S. Covert, and A.P. Waggoner. 1985. Measurement and Modeling of Western Washington Precipitation Chemistry. Dept. of Civil Engineering, Univ. of Washington, Seattle, WA.

Washington Department of Ecology. 1989. Acid Precipitation Data Base, August 21, 1989 Data Retrieval. Washington Department of Ecology, Water Quality Program. Olympia, Washington.

Welch, E.B., D.E. Spyridakis and K.B. Easthouse. 1989a. Acidification Potential in High Mountain Lakes in Washington: 6. Final Report to Department of Ecology. University of Washington, Department of Civil Engineering. Seattle, Washington.

Welch, E.B., D.E. Spyridakis, K.B. Easthouse, T.J. Smayda and L.C. Duncan. 1989b. Response to a Smelter Closure in Cascade Mountain Lakes. Water, Air, and Soil Pollution (in press).

Welch, E.B., D.E. Spyridakis, and T. Smayda. 1986. Temporal Variability in Acid Sensitive High Elevation Lakes. Water, Air, and Soil Pollution. 30: 35-44.

Wissmar, R.G., J.E. Richey, A.H. Devol, and D.M. Eggers. 1982. "Lake Ecosystems of the Lake Washington Drainage Basin." In: R.L. Edmonds, (ed.), Analysis of Coniferous Forest Ecosystems in the Western United States. Hutchison Ross Publishing Company, Stroudsburg, PA.

THE STATE OF THE ENVIRONMENT REPORT

VOLUME III
Part 11

Risk Evaluation Reports
for
Hydrologic Disruptions

ENVIRONMENT 2010

State of Washington
October, 1989

DISRUPTIONS TO THE HYDROLOGIC CYCLE CAUSED BY HUMAN ACTIVITIES

[Ecological Effects of Hydrologic Changes Brought About by Hydraulic Modifications, Water Use, and Land Use]

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Washington Environment 2010
Ecological Risk Assessment of
Disruptions to the Hydrologic Cycle
Caused by Human Activity

Definition of the Subject Area

For purposes of this risk analysis, disruptions to the hydrologic cycle are considered to result from "source" activities. These source activities induce hydrologic changes which then stress ecologic systems (e.g."stressors") creating ecological effects.

Source activities include a variety of modifications to water courses, the withdrawal and use of water from both surface and ground water sources and other, less direct but equally significant disruptions of the hydrologic cycle brought about by changes in land use.

Specific subjects to be analyzed include the ecological effects of the following;

1. dam construction and operation
2. surface water withdrawal
3. ground water withdrawal
4. construction and flood control in streams, lakes riparian areas and flood plains
5. dryland agricultural practices
6. livestock grazing
7. urban development

Organization of the Report

This report is organized by subject area, as shown above. This organizational scheme results in repetitious reporting of ecological effects because many of the subject areas have the same impact on the hydrologic cycle. The advantage of reporting redundancy in the context of this report, however, is that the reader can develop an understanding of the cumulative impacts that will result if a water body is subjected to more than one of the source activity analyzed.

The Hydrologic Cycle

The hydrologic cycle forms the broadest possible context for this risk analysis. The Resource Conservation Glossary, Third Edition,(1982), as published by the Soil Conservation Society of America, defines the hydrologic cycle as," the circuit of water movement from the atmosphere through various stages or processes, as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration."

Analysis of the sources activities and physical effects that follows will touch upon each of the elements of the hydrologic cycle, as defined by the Resource Conservation Glossary. In this manner the reader will develop a wholistic understanding of the environmental effects of disruptions to the hydrologic cycle caused human activities.

Analytical Approach

Human activities change the quantity and quality of water in various parts of the hydrologic cycle. In turn, this creates ecological stresses which lead to ecological changes affecting man and other species. Unfortunately, other than rough estimates, very little quantitative information is available on the cumulative ecological effects of the hydrologic disruption.

As a result, the following analysis rely upon a literature search and, the best professional judgement of the contributing authors when no literature was available.

Additionally, this analysis assumes the following model for effects of sources/stressors;

Stressor/Source>>>Primary Ecologic (Hydrologic) Effect>>>
>>>>>>Secondary Ecological Effect.

Finally, this report raises many questions about the ecological effects of human induced changes in the hydrologic cycle which have heretofore received little or no attention in Washington.

DAM CONSTRUCTION AND OPERATION

Description

This analysis is limited to the impact of dam construction and operation on the hydrologic cycle and the ecological effects of the same.

Dams are generally of two types -- "reservoir" dams which backup water in order to create sufficient head drop at the generators and "run-of-the-river " dams which backup very little water.

A total of 80 hydropower projects are on-line in Washington. About 78 megawatts of small hydropower has come on-line in the last eight years.

Of the 165,000 acres of lakes in western Washington, 75,000 acres are reservoirs (45%).

Summary of Key Findings

Hydrologic effects

Flow volume in streams is regulated by controlled release from reservoirs and is diminished by seasonal diversions to canals.

Downstream of reservoirs the water temperature is changed. Compared to natural conditions, the uppermost waters in reservoirs become warmer during summer, while water at greater depths in the reservoir stay colder. The water temperature downstream than depends on whether upper or lower level reservoir water is released.

Dissolved oxygen becomes depleted in the deeper, slow moving reservoir waters.

Nitrogen gas from the atmosphere is entrained and results in nitrogen supersaturation in the extremely turbulent water at the base of dam spillways.

Bed-load and suspended-load sediment moving down the stream is blocked by many dams in Washington. Bed-load is comprised of coarser materials that are too large to be suspended by turbulent action of the water and which, instead, roll along the streambed; this portion obviously will not pass over a spillway near the top of a dam. Finer sediment which is, ordinarily, suspended along free-flowing stream reaches will tend to settle out of the slower moving water in reservoirs. Sediment accumulates behind these dams, slowly filling the reservoir and decreasing the water storage capacity. Fortunately, most of the Columbia and Snake river dams, among Washington's largest, were designed to allow sediment passage by providing for water release at the base of the dams. In many other dams, however, the sediment accumulation is an increasing problem.

Sediment trapping by dams will change the character of sediments downstream of the dam. Gravel supply from upstream areas may be cutoff. Downstream of the dam the streambed and banks will be eroded in response to the excess energy made available by the lack of sediment.

Projects on streams with high bedloads or suspended sediment loads may accumulate large amounts of material in the pool formed by a diversion structure. Sufficient material may be collected that the diversion of water is impaired. Occasional cleaning by dredging or sluicing may be necessary. These activities can affect water quality and must be scheduled to minimize effects on fish and downstream water quality.

Reservoirs are characterized by reduced water velocity, which may result in changes in water temperature, dissolved oxygen levels, turbidity, water chemistry, and aquatic habitat. In deep reservoirs, thermal and chemical stratification is likely to occur with potentially significant effects on the biota in and downstream of the reservoir. Downstream effects can be beneficial or adverse, depending on the site and facility design. In general, creation of a reservoir transforms an ecosystem dependent on moving water into one dependent on still water. This results in substantial changes in the distribution, abundance, and diversity of organisms and in the carrying capacity of the habitat.

Creation of a reservoir may also flood valuable natural or cultural resources. These include roads, utilities, buildings, sites of historic, cultural, archeological, or scientific interest; productive farm or forest land; terrestrial, riparian, and stream-dependent habitat; free flowing/whitewater streams, waterfalls and associated recreation areas. Creation of a reservoir may attract new shoreline development thus introducing a wide range of secondary environmental effects associated with such activities. New recreation opportunities can be created which displace existing recreational activities associated with free-flowing streams and natural environment, however, reservoir fluctuations may limit these favorable factors. The scenic value of the site is usually altered and sometimes impaired.

The operation of a reservoir hydroelectric project generally results in large changes in reservoir level. Fluctuations may be daily, seasonal, or both. Alteration in the natural flow regime can be detrimental to downstream aquatic life forms and recreation. The drawdown zone is typically unattractive, biologically unproductive, and subject to erosion. Water quality may be affected by the decay of flooded organic matter and the release of soil chemicals into the water. Reduced water velocity causes the streams' natural sediment load (together with associated nutrients and other chemicals) to be trapped in the reservoir. The channel downstream may be degraded over time by the reduction in bed load transport.

Ecological effects

Potential environmental effects are associated with all components of hydropower development, including the diversion dam, reservoir (if one exists), penstock, powerhouse, access roads, and transmission corridors. Impacts are likely to arise from the construction of these facilities as well as from their operation and maintenance. These effects occur both at the project site and downstream. For a given site, the magnitude of effects depends greatly on the size and type of the project as well as its particular features.

Generally, projects involving an existing dam (or, for small projects, no dam at all) will have fewer adverse effects than projects requiring construction of a new dam and impoundment. Similarly, run-of-river and diversion type projects (assuming maintenance of adequate instream flows for diversion projects) will generally be more environmentally acceptable than projects involving a storage reservoir.

Any structure built within a stream channel has the potential to impede movement of aquatic organisms (especially migrating fish) and sediment. A diversion structure can cause direct mortality of fish at the intake if velocities are such that the fish become trapped at the intake screen. If no screen exists, the fish may go through the water turbines, usually with high mortality rates. A poorly designed intake structure may cause vortexing and entraining of air in the penstock. The resulting high levels of dissolved gas (principally nitrogen) can cause a fatal condition in fish similar to "the bends."

Pipeline, canal, or penstock leakage can destabilize slopes and lead to pipeline failure, land slides, or other mass wastage of slopes. Resulting erosion can drastically affect stream productivity. Public safety may also be affected in downslope or downstream areas. Contingency planning is important as well as the incorporation of leak detection and automatic shut-off mechanisms.

Construction of a dam or diversion structure presents considerable potential for adverse environmental effect. Erosion and bed load (sediment) increases can occur when clearing the stream bank, blasting underlying bedrock, or during construction within the steam channel. Standards for water quality must be met during all phases of construction. Harm to fish and wildlife can be minimized by working within the stream channels during low flow periods. Clearing and revegetation for the project facilities, pipelines, transmission line right-of ways, and access roads can affect wildlife in the area.

Dam construction has created many highly troublesome fisheries problems, especially the reduction of anadromous fish and resident fish spawning and rearing areas. Anadromous fish passage, habitat alteration, and water quality changes are other major fisheries problems associated with dam construction (PNWRBC, 1970).

Operation of hydropower dams in meeting peak power demand may cause fluctuations in stream levels, thus reducing fish rearing area and stranding eggs.

Riparian and upland terrestrial habitat is inundated by impounded waters and is permanently lost.

Aquatic habitat is expanded by reservoirs, especially favorable for some types of resident fish, but the physical and chemical conditions are significantly changed compared to the original stream conditions. Spawning areas for anadromous fish are lost because the flow velocity is slowed and water depth increased in the reservoir.

Anadromous fish migration is impeded or effectively blocked. Spawning and rearing habitat may be permanently lost in the entire area upstream of the dam.

Streambed substrate may be altered downstream of the dam if sediment is captured behind the dam. For instance, spawning gravel must be constantly replenished to replace that moved downstream by bedload transport. If the gravel is trapped behind the dam the substrate downstream for some distance (?) will not have the gravel necessary for spawning and early growth of anadromous fish.

Project operation can also adversely effect the streams natural resources. Insufficient instream flows through a bypass reach with affect fish and wildlife habitat, water quality, recreation, scenic and aesthetic values, navigation, and other environmental values. Decreases in instream flows can reduce fish habitat and aquatic productivity. In some cases, barriers that were insignificant under natural flows can become impassible to migrating fish. When carried out too rapidly, project start-up can partially dewater the bypass reach, stranding fish. This can also create a surge of water below the powerhouse, causing erosion, sediment transfer, and fish and wildlife habitat damage. Conversely, a sudden shutdown will cause a surge of water in the bypass reach and dewatering below the powerhouse. Ramping rate (rate of change in flow) limitations are necessary to avoid these effects.

Returning anadromous fish can be attracted by fast-moving water discharging from the powerhouse tailrace, delaying their upstream migration. Migration behavior may be impaired when changed water flow patterns fail to provide proper orientation cues. Such delays can reduce subsequent spawning success due to depletion of stored energy reserves and increased opportunity for predation. Proper location and design of the tailrace can reduce or eliminate this problem.

Detailed Summary of Estimated Risk

The following table summarizes the primary (hydrologic) and secondary ecological effects of dam construction and operation.

Table 1

Summary of The Ecological Effects of Dam Construction and Operation

SOURCE	STRESSOR	ECOLOGICAL EFFECTS
Dam Construction and Operation	stream flow volume fluctuations	blocking aquatic organisms (e.g.fish)
	stream temperature alterations	sediment transport interruptions
	dissolved oxygen depletion	fish mortality
	bed-load/sediment transport interruption	

vortexing and entraining of air at the penstock	fish mortality
sediment trapping behind dam and gravel deprivation downstream of dam	loss of spawning and rearing habitat for anadromous fish
increased bank erosion	
reservoir creation	reduced water velocity low dissolved oxygen turbidity,thermal and chemical stratification flooding of natural and cultural resources expansion of aquatic habitat, loss of upland and riparian habitat creation of recreation opportunities,loss of anadromous fish spawning opportunities
penstock,pipeline and canal leakage	slope destabilization and land slides decreasing stream productivity

Severity of Ecological Impacts

Because of permanent blockage of passage by the large, mainstem hydropower dams, such as Grand Coulee, Chief Joseph, and the Hells Canyon Complex, assessable anadromous fish habitat in the Columbia River Basin has decreased from 13,000 miles of stream (before 1850) to 8,900 miles of stream, presently, a 31 % loss of habitat. The average annual salmon runs on the Columbia are presently about 2.5 million fish each year. Prior to European settlement there may have been 10 to 16 million fish each year. This is a 75 to 85 % loss of fish. Both the habitat and fish losses are dramatic effects. The loss of fish is not proportional to the loss of habitat because many other factors have degraded fish reproduction.

The Washington Fisheries Dept. did a cursory and incomplete analysis of habitat loss to dams in Western Washington, exclusive the Columbia River Basin. This analysis found over 233 lineal miles of lost revering habitat but only for mainstem channels. Thus the many miles of tributary streams lost (perhaps several thousand) were not counted.

Environmental Impact Statements, such as the one prepared by Seattle City Light for the Skagit Hydroelectric Project, show severe effects on upper watershed habitats and wildlife. Statewide estimates of total habitat areas and wildlife populations are not available from which to make comparisons with losses due to dams.

Reversibility of Ecological Impacts

Recent well-planned but costly efforts will restore some of the fisheries losses in the Yakima River Basin. Other parts of the Columbia River Basin affected by dams are not slated for restoration to the same degree. Permanently lost habitat due to migration blockage can never be replaced.

Scale of Ecological Impacts

Dams are found statewide and often times are built at several locations on the same river, creating cumulative effects such as the nitrogen narcosis problem described above.

Altogether there are 58 dams exclusively for hydropower in the Columbia River basin. In addition, there are 78 multipurpose dams. Not all of these dams are in Washington.

Sensitivity of Ecosystems Affected

Rivers and streams are highly sensitive to the massive environmental alteration represented by dams and reservoir creation.

The biological processes in a free flowing river may be substantially altered and the the number and diversity of species changed when dams are constructed.

Productivity and Uniqueness of Ecosystems Affected

Rivers and streams are complex, highly productive ecosystems.

Uncertainty of This Analysis

The environmental effects of dam building and operation of dams for hydropower and irrigation are certain and well documented.

SURFACE WATER WITHDRAWAL

Description

This analysis is limited to the diversion of water from streams. Stream diversion can have impacts in several dimensions including, but not limited to, hydrological, biological and social.

This analysis however is limited to the effect of stream water withdrawal on stream hydrology, stream water quality and the ecological effects associated with changes in the same.

Effects on the hydrologic cycle

Reduced streamflow results from the taking of water. Because of the minimal summer rainfall usually occurring in many areas of the state, naturally occurring summer and fall low flows are found in many rivers and streams. Impacts become significant sooner on smaller streams as a relatively greater amount of streamflow is lost more quickly from the channel. During summer and fall low flow periods, ground water recharge constitutes the base flow remaining in streams.

As flow decreases water temperature and velocity are altered, leading to changes in water chemistry and physical properties, dissolved oxygen availability, biological oxygen demand, and attendant effects on the aquatic biota. Reduced dilution of permitted waste and non-point pollutant discharges could be an effect of flow diversion.

Recharge of areas depending on stream flow may be affected, such as wetlands. This may also affect ground water recharge in some instances.

In some areas of irrigation diversion, seepage from canals and reservoirs and recharge of areas downward of irrigated areas have led to formation of wetland and riparian habitat.

Ecological effects

The biological effects of reduced flows occur both at the aquatic and terrestrial levels. When instream flow is limiting on the low flow side, fish and fish habitat are impacted through reductions in flow, cover, stream velocities and aquatic production of food species, increased temperatures, crowding, competition for food, and predation. Where populations have already been impacted, further diversion may cause severe impact. Relative abundance or scarcity of desirable species and of overall species diversity could be impacted.

Wildlife which depend on given levels of instream flow during certain life-stages may be affected in several ways: diminution of flow may either eliminate habitat and food or increase competition for these elements; increased predation might also result.

Wetlands and other riparian habitats could be adversely impacted by diversion of stream flow. Decreased recharge to wetlands could lead to alteration in hydrology and both animal and plant species. In streams, dewatering the stream could lead to changes in shoreline vegetation. Estuarine habitat could also be affected through changes in flows, salinity and chemistry.

In some cases, reduction of high flows can improve fisheries habitat if high levels of flow have been limiting to production.

As noted above in the hydrologic effects regarding wetland and riparian habitat formation through seepage and rising water tables, irrigation can have beneficial effects on habitat diversity.

The social elements of instream resources, generally the recreational and aesthetic, can also be impacted by diversion. Depending on the type of recreation, different uses prefer high flows (white water kayaking), while others prefer lower flows (innertubing, swimming).

Detailed Summary of estimated Risk

The following table presents a summary of ecological risks associated with withdrawal of water from streams.

Table 2

Summary of The Ecological Effects of Surface Water Withdrawal

SOURCE	STRESSOR	ECOLOGICAL EFFECTS
Surface Water withdrawal	decreased flow	reduction in fish habitat
	velocity alterations	reduction in fish food species
	Water chemistry changes	fish crowding increased predation, competition for food
	changes in availability of dissolved oxygen	reduction of instream species diversity
	changes in biochemical oxygen demand	elimination of wildlife habitat, increased competition for food in wildlife population, increased predation
	reduced ability to dilute permitted waste and non-point pollution	

reduced wetland and groundwater recharge capacity	reduction in discharges to wetlands and alteration of water chemistry in estuarine wetlands
formation of wetlands and riparian zones	

Severity of Impacts

The largest volumes are taken for municipal, irrigation, and hydroelectric uses. Hydroelectric power generation in many cases diverts water for a relatively short distance and then returns water to the stream channel. Irrigation return flows may also recharge streams or aquifers. Small domestic water supply diversions which use surface water for inside uses or outside watering of lawns and gardens are widespread on streams and springs across the state. Many streams have had relatively smaller percentages of flow diverted, but still suffer impacts of diversion. The cumulative effects of many small diversions can become significant.

Since summer and fall low flows are limiting to fish production in many areas, reduction in flows can have an immediate impact on fish populations and productivity. Production in small and medium-sized streams can be severely impacted relatively quickly because of channel size and flow distribution and the high productivity of such streams.

Structures such as dams which block access to upstream spawning areas and which dewater streams have impacted runs. Salmon and other valuable native fisheries have been seriously affected in many rivers and streams across the state. Construction of the Grand Coulee Dam cut off passage to about one third of the accessible salmon and steelhead habitat in the entire Columbia River basin. Other dams on the Columbia and Snake Rivers and their tributaries were at least partially responsible for the drastic reduction in the size of fish runs returning to the largest salmon-producing stream in the world. Irrigation storage and diversion projects on a number of Columbia River tributaries such as the Walla Walla, Okanogan and Yakima rivers have severely reduced returning fish runs. Power developments on Columbia River tributaries such as the Wenatchee, White Salmon, Cowlitz and Lewis Rivers have also seriously affected natural fish runs by blocking passage to upstream areas and inundating habitat. In the Puget Sound drainages, power and water supply dams on many rivers affect natural fish production. Irrigation in basins such as the Dungeness and Nooksack basins reduces stream flows formerly used by fish. Estimates of average annuyal salmon and steelhead runs before development in the Columbia River drainage range from 10 to 16 million fish. Average annual run size was estimated in 1986 at 2.5 million fish (Northwest Power Planning Council).

Reversibility of Ecological Impacts

The ecological effects of diversion could be reversed to some extent by augmenting low flows. This would allow the recapture of fish habitat. Some irreversible losses have occurred through loss of genetic stocks and species which were endemic. However, restoration of flows could lead to reestablishment or increases in aquatic and terrestrial ecosystems.

The state's present system of setting instream flow levels by regulation does not affect existing water rights. This type of regulation does not provide a mechanism for restoration if resources in a stream have already been severely impacted. Water rights issued subsequent to the adoption of a regulation are interruptible when flows drop to a specified level, which can lead to protection of resources.

Some enhancement of summer flows might occur where storage and redistribution of high flows to augment summer and fall low flows is a possibility, and where the benefits of impoundment outweigh potential disadvantages.

Hatchery manipulation of runs has been a widespread fix for impacts to native fisheries in the past and continues to be. Hatchery programs have had mixed success. Maintenance of natural stocks of fish is still a priority for fisheries managers, requiring the protection of fish habitat and flows.

Mitigation of impacts can occur to some extent through habitat improvement and riparian management. Providing artificial spawning habitat is a form of fisheries mitigation. Maintaining large organic debris in the channel during logging operations and assuring a future supply of large trees to the stream channel, and managing riparian habitat for consideration of instream resources and water quality are important.

Other factors impact low summer flows besides appropriations, such as timber harvesting: changes to hydrologic patterns combined with diversions can aggravate impacts to instream resources. Managing land use, such as the extent of watershed deforestation, can ameliorate low summer flows.

More efficient use of water and water conservation efforts to make diverted water go further will reverse or mitigate future impacts. Conjunctive use of surface and ground water supplies to minimize impacts at critical times of the year has promise as a means of lessening impacts. Artificial recharge of aquifers by using high winter flows is also a means of storing water which may have a side effect of mitigating impacts of surface water diversion at critical times of the year.

There are several other areas in which improvements to low summer flows could be made through better management practices: in housing and industrial development and construction (the amount of watershed which is developed or covered with asphalt, for example); in cattle grazing around riparian areas to maintain riparian ecosystem integrity and improve stream flow and stream habitat; and in forest practices, looking at impacts of watershed deforestation and attendant low flow exacerbation.

The state is also looking at implementing a water conservation program which could potentially lead to augmentation of summer low flows, or an extending of the existing diverted water supply through transfers among offstream water users. The latter would not augment summer flows, but could delay future impacts through increased diversion.

Scale of Ecological Impacts

The effects of diversion of surface water are widespread across the state. Some unimpacted streams exist, especially in headwaters areas and other areas primarily in federal ownership, such as National Parks and Wilderness Areas.

Sensitivity of Ecosystems Affected

Streams and rivers are sensitive, complex ecosystems which can be severely impacted by withdrawals.

Productivity and Uniqueness of Ecosystems Affected

Streams can be very productive ecosystems for aquatic organisms, along with the riparian zones. Where streams are not productive because of lack of nutrients, water quality is generally high. Rivers are not replaceable resources. Once water is diverted, it is difficult to return it to the stream.

Uncertainty of This Analysis

The effect of withdrawals on rivers and streams are certain and well documented.

The extent of impact of surface water diversion on instream resources is uncertain. Fisheries are valued by society, changes in production and attempts to mitigate past losses have been discussed above. Ties between production, habitat, and flow have not been clearly defined, but a correlation between flow availability and production has been documented. Habitat (and water availability as an element) is usually the measure, and is done on a case-by-case basis. Fisheries habitat is the most quantified element of instream resources: wildlife habitat, fish production, recreation, aesthetics and other values are even more difficult to quantify. Another consideration is the increased value of these resources in the future as population and demand increase.

CONSTRUCTION AND FLOOD CONTROL IN STREAMS, LAKES, RIPARIAN AREAS, AND FLOODPLAINS

Description

This analysis is limited to the ecological effects of stream channel alterations (e.g. dikes and levees), dredging and filling, bridging and cavorting.

Numerous other construction/human activities take place in and around streams and lakes. Examples are docks, launch ramps, logging, bulkheads, outfall structures, and conduit crossing. The impacts of these activities are considered to be analogous to channel alterations, dredging and filling, bridging and cavorting As a result, no specific analysis of this latter group of activities is provided.

Hydrologic effects

Stream channel alterations, in general, result in straightened channels with less length and **higher** gradient. This destroys existing pool and riffle ratios. Flood control projects, in particular, restrict channels to maintain a self-cleaning status, but eliminate the potential for the streams to reestablish a satisfactory pool-riffle ratio (PNWRBC, 1970).

Constraining a stream within dikes or levees often leads to aggradation **(raising of the grade)** of the stream bed during floods. The result is less water storage capacity in the channel which, in turn, leads to overbank flooding during smaller volume floods than before levee construction.

The hydrologic effects of dredging **and filling are nearly identical. Both** reduce **the** shallow water area and increase **the proportion of** deep water area. Removal **or addition** of streambed materials causes continuous and excessive bedload movement**, shifting of substrate,** and turbidity **for long periods following the activity.**

Streams channels are constantly shifting. Airphotos for the Yakima River show an average yearly channel migration of 10 meters (from 1939 to 1973). **Gravel mining on the floodplain has increased the migration rates.** Dramatic channel shifts **have** occur**red** during overbank flooding as the flow**ing water** cut through **channel** banks into gravel pit areas. The Yakima River channel has shifted in this fashion as much as 300 meters, virtually overnight (Dunne and Leopold, 1978).

Bridges built with too little free space above the water can catch and accumulate flood debris such as logs, stumps, and tree limbs which impede the flow, backup flood waters, and cause more overbank flow.

Improper bridge construction or culvert installation may cause excessive erosion and heavy siltation downstream **which continues for some time after construction completion.**

Poorly designed (how?) bridges can also increase stream velocity, resulting in channel scouring. As gravel is scoured from the streambed, spawning habitat is eliminated. If velocity becomes excessive, fish migration can be reduced or eliminated.

Culverts tend to increase flow velocities by straightening the stream course and increasing the gradient. This can result in higher turbidity, bank erosion, or channel scouring. Undersized culverts can cause upstream flooding during high flows.

Bridges may also increase flow velocities by restricting the channel at higher flows.

Ecological effects

All streambed mining, **dredging, and filling** reduces and degrades spawning and rearing habitat. Fish egg and insect larvae mortalities are generally high where shifting gravel conditions occur. The loss of suitable gravel from bars forces crowding of spawning in remaining areas. Large numbers of fry and fingerlings are invariably trapped and die in the pits and pockets left by gravel excavations of riverbanks when rivers recede during low-flow periods (NWRBC, 1970).

Human developments adjacent to lakes and streams destroys habitat and lowers water quality.

Flood control measures further reduce and degrade the fish and wildlife habitat.

Straightening of channels destroys existing pool and riffle ratios essential to feeding, spawning and rearing.

Riprap for bank protection usually eliminate streamside vegetation. This reduces insect populations which serve as food for fish. Loss of shade provided by plants can result in water temperature increases which are injurous to resident fish. Loss of vegetation also affects wildlife which use the riparian zone for migration, feeding, and rearing. These projects also eliminate aquatic vegetation used by animals such as beaver, muskrat, shorebirds, and waterfowl, and which provide habitat for a variety of reptiles and amphibians.

Bank protection measures often decrease or eliminate shallow water areas. Fish dependent on shallow water for escape are then subject to higher predation. (Ballard Locks example). Also, habitat is lost for small fish which feed in shallows.

Costruction of bank protection devices often increases turbidity, siltation, and sedimentation. Excessive sedimentation can destroy spawning habitat. Severe siltation and turbidity can abrade fish gills, causing stress and respiration problems and can clog digestive tracts. This results in higher fish mortality and higher susceptibility to disease. Projects may also eliminate spawning habitat by their mere presence (explain?).

Channel diversions almost always adversely effect spawning or rearing habitat. Aquatic habitat is completely eliminated downstream in the abandoned channel section. The abandoned channel length may vary from a few feet to several miles. The new channel usually cannot duplicate or replace lost habitat (for many years?). A change in the composition of species or a reduction in numbers usually occurs. Stream reaches downstream of the new channel often suffers siltation, bank erosion, or channel scouring as the river re-adjusts to the new reach.

The reduction of shallow water area by dredging and instream gravel mining can have the following ecological effects:

* changes occur in species composition and abundance of fish, benthic organisms, and vegetation. In turn, this affects wildlife, such as shorebirds, waterfowl, and mammals which use shallow areas for feeding.
* contaminated sediments disturbed or re-suspended by dredging may be harmful to aquatic life.
* increased turbidity, siltation, and sedimentation downstream of dredging operations can destroy spawning habitat and fish food sources.
* spawning habitat can be directly eliminated.

Heavy sedimentation downstream ruins gravel substrate for egg-hatching and initial fish development.

Culverts may increase flow velocity so much that the reach becomes impassable by fish. Improper culvert placement may create a waterfall at the outlet, which is too high for fish to jump over. Culverts which are too long can also block fish passage (how?). When placed in spawning habitat, culverts eliminate a portion of the habitat.

Bridge approaches and abutments often extend into or to the water's edge. Many animals such as racoon, river otter, bobcat, and deer use the shore areas as "transportation" corridors. This use is blocked by bridges and may be eliminated by a number of closely spaced bridges.

Detailed Summary of Ecological Effects

Table 3

Summary of The Ecological Effects of Construction and Flood Control in Lakes, Riparian Areas, and Floodplains

SOURCE	STRESSOR	ECOLOGICAL EFFECTS
Stream Channel Alterations (e.g. dikes, levees)	decreased length and higher stream gradient	degradation of spawning and rearing habitat
	decreased pool/riffle ratio	fish egg and insect larvae mortality
	rising stream bed during floods, causing overbank flooding	fish crowding
		fish fry and fingerling mortality
Dredging and filling	induced continuous excessive bed-load movement,	elimination of

		stream side vegetation causing thermal change
	reduction of shallow water area increased proportion of deep water	lossof wildlife habitat
	induced shifting of substrate	increased predation
	increased turbidity	abrading of fish gills, sedimentation of spawning gravels
Bridging/Culverts	debris trapping causing flooding	
	excessive erosion and heavy siltation	alteration in number and diversity of species in the water and benthos
		resuspension of contaminated sediments
	increased stream velocity causing scouring of gravel	loss of fish spawning area
		interference with fish passage.

Severity of effect

Effects on aquatic habitat may last for several years after bridge construction.

Effects of poor culvert installation continue until installation is corrected but then may last for several years. Slotted weirs within culverts will stabilize stream velocities.

Reversibility of Ecological Impacts

Spawning beds and fry and fingerling habitat can be restored with appropriate mitigating measures. Streamside vegetation can be reestablished to some degree. Loss of water from the original water course is not likely to be reversible and does cause a loss of anadromous fish while the run adapts to the new, channelized streambed (4-5 years).

Scale of Ecological Impacts

From 1943 to 1980 Washington State participated in 2,023 flood control projects with a total cost of $40,400,000, of which approximately $9,000,000 was state funds.

Presently, the state is spending approximately $4,000,000 per biennium on this kind of work statewide, usually in the form of 50% project cost share.

Sensitivity of Ecosystems Affected

aquatic ecosystems are generally considered to be quite sensitive.

Productivity and Uniqueness of Ecosystems Affected

Aquatic ecosystems are considered to be productive and unique.

Uncertainty of This Analysis

The effects of construction in and adjacent to streams, lakes, riparian areas and in floodplains are certain and well documented.

FOREST PRACTICES

Description

This analysis confines itself to ecological effects of logging, forest chemical use and road building (to support logging). Logging is defined here as the practice of clear cutting.

Other forest practices such as site preparation, slash burning, and reforestation are specifically outside the scope of this analysis.

Hydrologic effects

The majority of Washington's streams and rivers originate from forested watersheds. The quantity and quality of most fifth order and smaller streams are strongly influenced by forests and thus forest practices. These small and medium size streams are the important rearing areas for resident and anadromous fish as well as the major source of surface water within the State.

This section is limited to the detrimental effects of forest practices on the hydrologic cycle. These effects generally occur offsite, that is downstream of the forest practice.

Although logging is generally perceived as the practice most damaging to the environment, other activities, especially forest road construction, site preparation and slash burning, reforestation, and forest chemicals, also have adverse as well as beneficial effects. However, the remainder of this section discusses logging and the forest roads that serve logging. Logging (clearcut, selection, and thinning) disturbs about 340,000 acres per year. Two-thirds of these acres are in western Washington. Road construction and other forest practices disturb additional acres.

Logging reduces a site's interception and evapotranspiration. Soils remain wetter longer into the summer and re-wet sooner in the fall. Water that was used by the trees is now available for streamflow or groundwater recharge. Logging, especially clearcutting, can have major effects on streamflow, potentially altering annual flow volumes and the timing and magnitude of low flows and peak flows. Changes in runoff amounts can increase erosion and subsequent movement of suspended sediment and bedload in streams.

Death or removal of riparian vegetation, by either herbicides or logging can elevate water temperature by exposing the water surface to solar radiation. Also, the change in riparian structure from larger to smaller trees can reduce large organic debris necessary to maintain a stable channel. The quantity of pools and riffles will be reduced and the quantity of rapids and shallows will increase.

Logging can also reduce slope stability resulting in an increased frequency of debris avalanches. Sediment from debris avalanche occurrences can deposit large volumes of sediment in channels, drastically modifying the sediment supply for decades.

Forest roads necessary for logging and other forest practices disturb about 8 percent of the forest lands they serve. A fully developed road system increases the surface drainage network, potentially increasing peak stormflows. Unpaved roads present considerable erosion potential, the amount depending on how well roads are maintained and how much they are used. Where terrain is steep and soils unstable, debris avalanches related to forest roads are an important type of erosion. Road related debris avalanches have been identified as the most serious process contributing to reduced water quality on forest lands.

The major effect of both logging and forest roads is the impairment of water quality via increased sediment transport. Suspended sediment is generally considered the most significant pollutant in forest streams.

Mans activities in the forest have the potential for affecting many segments of the hydrologic cycle. Forest practices can alter:

- o the distribution of water and snow on the ground,
- o the amount intercepted or evaporated by foilage,
- o the amount stored in the oil or transpired by vegetation, and
- o the physical structure of soil governing the rate and pathways of water movement to stream channels.

During early days of logging (1880-1920) logs were transported by floating. Stream channels were severely altered which changed the substrate, banks, morphology and riparian areas (NWPPC, 1986).

After 1940 logging increased significantly, moving farther inland. Road construction and other practices were done on steeper land leading to increased erosion and stream sedimentation (PNWRBC, 1970).

Poorly conducted or laid-out, extensive clear cutting creates excessive intermittent runoff, and increases streamside erosion and stream siltation (PNWRBC, 1970).

The modifications to the hydrologic regime, both water quantity and quality, alter the aqautic habitat of fish. Increased water temperature can cause lower growth rates in salmonid fish. Increased erosion causes changes in turbidity, bottom gravel composition and channel structure. Debris torrents may block fish migration, reduce spawning gravel quantity and quality, reduce rearing habitat, reduce the fish food supply, and impair water quality.

Ecological effects

The major effect on fish came from blockage of habitat at road crossings. The second major effect was loss of habitat complexity caused by removal of woody debris from channels. Other effects were sedimentation on spawning gravels, degradation of water quality (increased water temperature and decrease dissolved oxygen), and accidental creation of debris barriers in streams. Recent intensive forest management practices involving aerial applications of fertilizers, pesticides, and herbicides have increased the potential for widespread acute and chronic harm to aquatic ecosystems.

Inadequate cleanup of logging debris along streams contributes to anadromous fish migration barriers (PNWRBC, 1970).

Clear-cutting adjacent to streams eliminates shade and cover resulting in rising water temperature, losses of terrestrial and aquatic food organisms, and increased predation (PNWRBC, 1970).

Yarding logs in streams disrupt habitat and leads to increase bedload movement.

Improper logging road construction and maintenance increases slope failure and erosion, leading to silting and muddying of nearby streams.

Careless defoliating unnecessarily reduces rainfall interception.

Higher flood peak flows are especially damaging to anadromous fish in winter and spring when gravel is moved and eggs are washed away and young fish are killed by excessive silting and stranding (PNWRBC, 1970)

Detailed Summary of Ecological Risk

The following table summarizes the effects of logging and log road building on the hydrology and ecology of the forest.

Table 4

Summary of The Ecological Effects of Forest Practices

SOURCE	STRESSOR	ECOLOGICAL EFFECTS
Logging*	reduction of site's interception and evapotranspiration functions	blocking fish passage
		loss of habitat complexity in streams
	alteration of soil moisture patterns	water quality degradation, sedimentation of streams, creation of debris barriers in streams.
	alteration of flow regime in impacted streams thus changing stream's erosion, sediment and bed-load characteristics	
	aerial application of herbicides & fertilizers	death or removal of riparian vegetation; altering water temperature and destabilizing streambanks, loss of terrestrial

	reduction in slope stability result- in debris avalanches and sediment deposition in affected streams.	and aquatic food organisims
	alteration of the distribution of water and snow on and in the ground	
	alteration of the amount of water intercepted/evaporated by foilage	
	changes in water movement to stream channels	
Forest Roads	increased impervious or semi-pervious surface causing increased surface water runoff	
	increased erosion degrading water quality	

*

Logging practices have improved over time. Rivers are no longer used for log transport and extensive use of buffer strips along streams has eliminated much of the damage to aquatic ecosystems. However, logging on fragile soils and logging roads continues to cause sedimentation, accelerated occurrence of debris avalanches, and associated fisheries problems.

To address these continuing effects, representatives of State agencies, private industry, tribes, and environmental groups met to discuss the adverse effects of forest practices. The result was the Timber/Fish/Wildlife agreement (TFW) consisting of a series of recommendations to improve the conduct and regulation of forest practices in Washington. The agreement represents an historic shift in natural resource management by introducing several new elements to the regulation of forest practices. Major improvements were the introduction of monitoring, evaluation, and research to document the interactions and effects of forest practices and the use of inter-disciplinary teams of natural resource specialists to review forest practices with a high potential for adverse effects.

The intended result is a continual improvement in forest practices and a reduction in adverse environmental effects. Whether the TFW process results in an improvement in forest practices remains to be seen.

Severity of effects

Streams of lower Columbia River basin (all tribs downstream of Snake River confluence) probably affected more severely than upstream as log harvest was and remains many times greater.

IRRIGATION DISTRIBUTION WORKS AND ON-FARM IRRIGATION PRACTICES

Description

This analysis of the ecoloical effects of Irrigation distribution works and on-farm practices is limited to canals and sprinkler, trickle and furrow irrigation on farms.

Hydrologic effects

Canal leakage becomes ground water recharge and may create perched water tables in formerly unsaturated soils or rising water tables in unconfined aquifers. In some areas this artificial recharge has **created** a long-standing supply of ground water.

In places the resulting water table rises to ground surface, creating wetlands in low-lying areas and supplementing seasonal streamflow in natural drainage ways. A substantial portion of the wetlands in eastern Washington have been created in this fashion. Sometimes this flooding affects developed areas not associated with the farms. In the Columbia Basin Project area, the Bureau of Reclamation has been sued for damages from this flooding.

Return flow from irrigated fields results when water in excess of plant requirements is applied. Some excess water must be applied in order to prevent "salt" buildup in the soils. Ordinarily the excess water infiltrates the soil and percolates to the water table. At times the soil infiltration capacity is exceeded and and the excess water runs off the field surface; this is more likely to occur on land under furrow irrigation, rather than sprinkler or trickle irrigation. Whether the excess irrigation water becomes ground water recharge or surface runoff, most of the water (some is evaporated) eventually returns to a stream and may contain undesirable levels of fertilizer nutrients, pesticides, herbicides, and sediment.

Ecological effects

The availability of irrigation water has resulted in reduction of dryland habitat that was not previously cultivated.

Return flow has created new fish and wildlife habitat through the formation of new wetlands and streams, in some areas. (Where?)

Irrigation development is the primary cause or major contributor in reducing fish runs in lower Columbia River tributaries. This is due to unscreened diversions and relatively lower flows during the dry season.

Detailed Summary of Ecological Effects

The following table summarizes the ecological risks associated with irrigation distribution works and on-farm practices.

Table 5

Summary of The Ecological Effects of Irrigation Distribution Works and On-Farm Irrigation Practices

SOURCE	STRESSOR	ECOLOGICAL EFFECTS
Canal Leakage	ground water recharge	reduction of dryland habitat
	creation of perched water tables	creation of fish and wildlife habitat via streams and wetlands creation
	rising water tables	
	increased ground water supply	
	wetlands creation flooding of land	reduction of fish runs in the lower Columbia system and low summer flows due to diversion to canals
	increased seasonal streamflow	
Return Flow (i.e. application of water excess to plant requirements	water table recharge	unintended transport of ag. chemicals
	surface water runoff	

Severity of Ecological Impacts

Loss of lands uncultivated prior to irrigation means the entire loss of the natural wildlife ecosystem and its productivity. The acreage loss of such land in Washington has not been estimated.

Reversibility of Ecological Impacts

The instream and out of stream effects are totally reversible only if irrigation is discontinued.

The use of proper on-farm water management techniques as recommended by the SCS, however, can eliminate all return flow from the surface of an irrigated field. Return flow from excess infiltration (not used by plants) could be substantially reduced but not entirely eliminated because of the need for leaching of salts. Some soils with extremely high percolation rates should not be irrigated.

Through practices such as irrigation scheduling and proper application methods, farmers can reduce the occurrence of return flow quality problems.

Scale of Ecological Impacts

The problem occurs throughout the State but is concentrated in eastern Washington. The amount of land affected is more than that reflected in irrigated acreage amounts. The streams are effected for their entire length downstream of the practice.

Irrigated agriculture is the largest user of water in Washington. Most of this use occurs in eastern Washington. Irrigation on the west side occurs principally in northwestern Whatcom County, northeastern Clallam County, and small parts of the other counties.

The largest expansion of irrigated lands in Washington occurred after Grand Coulee Dam was built and the first half of the Columbia Basin Irrigation Project was developed. Since 1979, irrigation development, statewide, has grown slowly from approximately 1.84 million acres to just under 1.97 million acres in 1988. There are continuing efforts, as yet unsuccessful, to develop the second half of the Columbia Basin Irrigation Project and irrigate another 500,000 acres with "reserved" water rights from the Columbia River.

Most of this acreage is served by surface water deliveries in canals. Over two-thirds of this acreage is under sprinkler irrigation. An estimated 200 irrigation-water intake structures are located on streams of the Columbia River Basin in Washington (NWPPC, 1986).

Hundreds of miles of irrigation canals exist in Washington. Most of these are more than forty years old and unlined; **lacking lining** the canals lose significant amounts of water through the bed and banks. The newer canals are, for the most part, located in the Columbia Basin Project. Lately there has been a shift to pressurized systems, **in place of lateral canals (off the main),** to avoid sole reliance on gravity flow **in canals.**

Some return flow (aka tailwater) from the canal back to the stream is inevitable because some water must spill at the lower end in order to maintain operating water levels within the channel. **That is,** operating water levels must be high enough that gravity diversion to adjacent fields is posssible.

On-farm **water** distribution in Washington is largely through sprinkler systems (pressure) and furrow or trickle (gravity) methods. **The** efficiency **of these systems, the amount of water accually used by crops relative to the total amount applied, varies greatly.** Sprinkler efficiency ranges from 65 to 80 %, furrow efficiency from 45 to 80 %, and trickle efficiency from 80 to 90 %.

Sensitivity of Ecosystems Affected

The arid and semi-arid stepp regions of Washington are generally considered to present a fragile ecosystem, in their natural state.

The streams and rivers used as sources for irrigation water are sensitive aquatic ecosystems.

Productivity and Uniqueness of Ecosystems Affected

The fisheries productivity losses due to reduced streamflow, in basins such as the Yakima, are extremely high. Almost all of that basin is prime habitat for most species of fish. However, there is now too little water for the fish at critical times of the year. The fishery resource declined almost in direct proportion to the irrigated agriculture development.

The oral history provided by the Native Americans in that area describes a thriving anadromous fishery; pre-development era fish runs are estimated to have been as high as half a million fish. Recently, that figure has reached a low of 2,500 fish.

DRYLAND AGRICULTURAL PRACTICES

Description

Dryland Agricultural practices, as used in this section, includes all operations involved in farming but does not include animal husbandry and grazing. Grazing is described in a separate section.

Hydrologic effects

Initial cultivation or changing from grazing to cultivation causes dramatic soil and vegetative changes. Soil infiltration rate may be reduced by plowing and other cultivation. Summer fallow in bare-ground condition eliminates plant transpiration and reduces direct evaporation but does not enhance percolation to aquifers except during wetter than average years.

The most severe hydrologic effects of dryland agriculture are the increase in runoff and increase in soil erosion from fields, riparian areas and stream channels near the fields. Downstream effects are higher flows, turbidity, siltation of natural substrate, increased sediment transport, increased channel erosion, and more rapid channel migration.

Ecological effects

Increased sedimentation and sediment transport interfers with all forms of aquatic life

Detailed Summary of Ecological Effects

Table 6

Summary of The Ecological Effects of Dryland Agriculture

SOURCE	STRESSOR	ECOLOGICAL EFFECTS
Dryland Agriculture (i.e. cultivation, summer fallow as bare ground)	alters soil infiltration rate	negative impacts on aquatic biota
		topsoil loss
	eliminates plant transpiration	
	exacerbates erosion	
	increases runoff	

increases flows,
siltation, turbidity
sediment migration
channel erosion and
channel migration
in impacted streams

Severity of Ecological Impacts

The ecologic effects are extremely severe in heavily cultivated areas. Grain fields are cultivated from road edge to road edge and often too close to streams. Snowmelt runoff channels are usually plowed under and are often fallow during the snowmelt season.

Reversibility of Ecological Impacts

Many of the ecological effects are reversible even if cultivation continues. The Soil Conservation Service and Agricultural Extension Service have excellent recommendations for and will support the least damaging farming practices but cannot get nearly enough support from government or the farmers. The farmers need economic incentives to chanage. Some government price support and land set-aside programs are counterproductive to implementation of best farming practices.

Scale of Ecological Impacts

This is a state-wide problem but is obviously most severe where the largest percentages of the land are cultivated. Erosion and instream sediment effects are greatest in the Palouse area of southeastern Washington. This area has some of the highest erosion rates in the country, largely due to the type of soil and terrain.

Sensitivity of Ecosystems Affected

Aquatic ecosystems are complex and sensitive.

Topsoil is an irreplaceable resource in many of the most impacted counties of this state.

Productivity and Uniqueness of Ecosystems Affected

The productiviy of Washington State's dryland agricultural areas is directly linked to the ability to manage soil loss induced by on farm practices. The following table illustrates the magnitude of the threat of erosion to non-irrigated cropland.

Table 7

Estimated Annual Sheet, Rill and Wind Erosion
In Tons Per Acre on Non Irrigated Cropland
(Source: Soil Conservation Service)

Sheet & Rill		Wind		Total	
1982	1987	1982	1987	1982	1987

6.18	6.73	1.99	2.26	8.17	8.99

An erosion rate of 5 tons per acre per year is considered the maximum acceptable level for maintenance of soil productivity.

Uncertainty of This Analysis

The impacts of dryland agriculture practices are certain and well documented, particularly by the U.S. Soil Conservation Service in their Conservation Reserve Program.

LIVESTOCK GRAZING

Description

This analysis is limited to the effects of livestock (e.g. cattle, sheep, horses) grazing in water sheds and the implications of that practice for the hydrologic cycle and water shed ecology related to that cycle.

Livestock move and forage throughout a watershed but are most attracted to riparian areas adjacent to streams and lakes and use this part of the range more heavily. Riparian areas comprise only 1 to 2 % of the watershed area but up to 80 % of forage is obtained there (Platts, 1985).

Hydrologic effects

Watersheds subject to intensive grazing suffer from increases in peak runoff and erosion as well as decreased infiltration because of soil disturbance and compaction. These changes lead to decreased ground water recharge and decreased baseflow (ground water discharge to streams during the dry season).

The worst effects of grazing occur in riparian areas where vegetation is overgrazed and trampled, moist soils (compared to uplands) are severely compacted, and stream channels are widened by trampling of stream banks, all leading to greatly increased erosion.

The lack of streamside shading by vegetation leads to increased water temperature. The increased sediment load from all parts of the watershed -

* carries pollutants into the water,
* increases water turbidity,
* deposits silt on stream gravels, and
* the sediment accumulates in reservoirs.

Ecological effects

Sedimentation of aquatic habitat and destruction of riparian vegetation damage are the major ecological effects. This has occurred throughout most of the available range lands.

Studies have found that fish production in ungrazed streams were 2.4 to 5 times greater than in grazed streams (Platts, 1981).

Detailed Summary of Ecological Effects

Table 8

Summary of The Ecological Effects of Livestock Grazing

SOURCE	STRESSOR	ECOLOGICAL EFFECTS

Livestock Grazing	incrreases in peak runoff	
	decreased infiltration	
	decreased baseflow	
	decreased groundwater recharge	
	loss of riparian vegetation	stream temperature fluctuations
	soils compaction	
	stream channel widening	
	increased sediment load	increases in stream turbidity
	reservior siltation	sedimentation of aquatic habitat,reduced fish production

Severity of Ecological Effects

The need for protecting riparian habitat from livestock continues to be a serious issue. With the exception of forest practices, grazing causes the most widespread disruption of the hydrologic processes in Washington.

The worst effects occur in late summer and early fall when lack of water causes animals to congregate near streams.

Reversibility of Ecological Effects

Platts (1985) states that riparian habitats are productive and resilient and can soon recover. Proper range management could increase fish populations tne-fold of the next several decades. Another study (USDA, ?) predicted that by reducing stream temperatures and intra-gravel siltation by 60% would result in a three-fold increase in salmon and steelhead production.

Scale of Ecological Effects

Approximately one-third of Washington's land area is used for livestock grazing. This amounts to 11.9 million acres (Anon., 1984). Included in grazing lands are rangeland, native pasture, meadows, and forests with herbaceous understory. The number of animals far exceeds wildlife numbers and so the effects are much more pronounced.

Sensitivity of Ecosystems Affected

Productivity and Uniqueness of Ecosystems Affected

Uncertainty of This Analysis

URBAN CONSTRUCTION

Description

This analysis is limited to the effects of storm drainage detention ponds and home building along streams on the hydrologic cycle and the ecological effects of the same.

Hydrologic effects

Higher than normal peak flows causes erosion along stream channels. Shifting channel.

Stormwater detention attempts to correct for the increased runoff and higher peaks flows caused by development. Poor design may actually increase bedload movement and channel erosion. This has only recently been recognized (Moglen and McCuen, 1988).

Ecological effects

Home building along streams leads to removal of streambank vegetation which acts to stabilize soils, serve as habitat cover for fish and filters runoff of fertilizers and oil. So soils may erode and aquatic habitat and water quality are degraded.

Mass movements of clay and silt cause compaction of spawning gravel and suffocation of embedded eggs. Field and stream bank erosion cause similar problems (PNWRBC, 1970).

Detailed Summary of Ecological Effects

Table 9

Summary of The Ecological Effects of Detention Ponds and Homebuilding Along Streams

SOURCE	STRESSOR	ECOLOGICAL EFFECTS
Storm Water detenetion ponds and homebuilding along streams	increased peak stream flows	loss of riparian vegetation
	increased bedload movement and stream channel erosion	loss of wildlife habitat
		loss of cover for fish
		loss of filtration for fertilizers

and oil

siltation of spawning gravel

suffocation of fish eggs

Severity of Impacts

Reversibility of Ecological Effects

Scale of Ecological Effects

Storm drainage detention ponds are built to retain and slowly release storm runoff. These structures are used statewide.

Sensitivity of Ecosystems Affected

Productivity and Uniqueness of Ecosystems Affected

URBAN DEVELOPMENT

Description

This analysis is limited to the impacts of urban, suburban and industrial development on the hydrologic cycle and the ecological effect of those impacts. The focal point of this analysis is creation of impervious surfaces resulting from building and road construction.

Urban development involves the human activities and land uses that occur after rural land is converted to urban, suburban, and industrial communities. Increased population densities lead to higher densities of buildings and roads which make much of the areas impervious or impermeable to water infiltration.

Population growth during this century has involved a continuous increase in the ratio of urban to rural dwellers. In 1967 the United Nations predicted that by the year 2000, half of the world's population will be urban. This is likely to be true in Washington, also.

The natural environment in an urban area eventually becomes fundamentally changed. In its place a man-made environment evolves with accompanying changes in the quantitative and qualitative aspects of the hydrologic cycle.

Hydrologic Effects

The hydrologic cycle is affected by man's activities more dramatically in urban areas than in any other part of the land. In other words the hydrologic effects per unit area are greatest in these areas. Leopold (1968) states: "There are four interrelated but separable effects of landuse changes on the hydrology of an area: changes in peak flow characteristics, changes in total runoff, changes in quality of water, and chanages in hydrologic amenities. The hydrologic amenities are what might be called the appearance or the impression which the river, its channel and its valleys, leaves with the observer. Of all land use changes affecting the hydrology of an area, urbanization is by far the most forceful."

Hydrologic changes due to urban development may also occur in drainage patterns, erosion and sediment movement, water demands, and shifts in the water balance between evaporation, infiltration, recharge, and runoff.

Hydrologic problems develop in urban areas because of the steadily increasing demand for water, physical changes to the land that alter the natural water balance, and the non-point pollution of water by wastes in runoff. Extraordinary means must then be taken for the critical problems of waste disposal, storm water and erosion control, and water supply. (McPherson, 1974)

The specific hydrologic problems in urban areas are:

* concentration of population and industry is accompanied by rising water needs which soon exceed the natural supply in the area;

* waste water volumes grow, placing chemical burdens on rivers, lakes, and marine waters.

* the increase in impervious surfaces reduces the infiltration of rain water, reduces ground water recharge, and greatly increases the volume and peak rates of stormflow runoff (Canning, 1988).

* increased volumes and peak flow rates of urban stormwater runoff leads to enlargement of the stream channel by scouring during the high flows (ibid). The channel scouring destabilizes stream banks and eventually undermines and removes protective vegetation which may not easily be re-established.

* extensive use of ground water and reduction of recharge will deplete ground-water storage, reducing the base flows of streams and aggrevate water quality problems through less dilution.

* increasing amounts and kinds of wastes, plus a decrease in the space or number of suitable places for disposal, complicates water quality protection.

Ecological Effects

The ecological effects of hydrologic changes due to urban development are felt largely in the riparian and aquatic ecosystems. The increased storm water runoff carries higher sediment loads off the land and erodes the stream's channel. Thus, riparian and aquatic habitat is degraded or destroyed by erosion and siltation.

Lower baseflows as a result of less ground water recharge has the same effect as direct surface-water withdrawal. Aquatic habitat area is decreases at lower flow, spawning may be disrupted, and migrating fish may not be able to pass up or down the stream.

<u>Detailed Summary of Ecological Effects</u>

Table 10

Summary of The Ecological Effects of Urban Development

SOURCE	STRESSOR	ECOLOGICAL EFFECTS
Urban Development (e.g. impervious surface and population growth)	changes in peak flows	degradation of riprian habitat
	changes in total runoff	increased waste

changes in water quality	loads in surface and ground water
degradation of hydrologic amenities	reduced baseflows in strams due to impaired infiltration
alteration of drainage patterns	increased sediments
	fish spawning disruptions
erosion and sediment movement	
increased water demand	
alteration in the balance between evaporation,runoff infiltration and recharge	

Scale of Impact

The urban percentage of the total land area of Washington is quite small, probably less than 5 % . Large urban populations are highly dependent on outlying areas for water, however, because the water available in the urban area is never sufficient and often is made unusable by urban pollution. The urban water quality effects extend for large distances downstream in rivers or far out into marine waters.

GROUND-WATER WITHDRAWAL

<u>Description</u>

This analysis is limited to the changes in the hydrologic system that result from the withdrawal of water from the ground and the ecological effects of that withdrawal.

The ground water in Washington's aquifers is, at any given moment, far greater in volume than the surface water in rivers and lakes. It is found in soil and rock materials beneath all parts of the State. However, ground water is not evenly distributed because of varying geologic, topographic, and climatic conditions.

The amount of ground water in aquifer storage is only partly available for human use because of economic cost and environmental effects. In the simple sense of extracting and distributing all the water from all subterranean depths, we could never afford the materials and power required to do so.

On the environmental side, the continual natural discharge of ground water to streams supplies all of the dry season flow in undammed rivers of Washington. Ground-water discharge to marine waters prevents the intrusion of saltwater into coastal aquifers.

<u>Hydrologic effects</u>

When a well is pumped the immmediate effect is for water levels to decline in a conical shaped region centered at the well. In unconfined (water table) aquifers the conical region is dewatered, while in a confined aquifer the effect is, at first, principally a pressure decrease. In either situation ground-water storage is reduced. As pumping continues water-levels decline and the pressure effects spread until water is captured from one of two possible sources, either rejected recharge or discharge to streams (Bredehoeft, 1983).

Ground-water storage is always depleted to some extent, proportional to the rate of extraction, and water levels decline.

Pumping from a particular aquifer may affect adjoining aquifers. Recharge to underlying or overlying aquifers may be reduced, depending on the direction of ground water flow. Flow is downward in recharge areas and upward in discharge areas.

Salt-water intrusion occurs in coastal aquifers, both on islands and the mainland. This often occurs, even at very small rates of withdrawal, when the wells are located close to the natural salt water / fresh water transition zone (the interface).

Unintended migration of contaminants may occur if pumping occurs close to contaminated sites. This hydrologic procees is the same as for saltwater intrusion.

Ground water / surface water interaction: Dry season flow (aka low flow) in an unregulated (no dams or diversions) stream is entirely dependent on ground water discharge. This discharge is reduced a finite, though not always measurable, amount by ground water pumping in almost all hydrogeologic settings.

Ecological Effects

The ecological effects occur where spring flow or streamflow is reduce and is no different than the effects of surface-water withdrawal.

Detailed Summary of Ecological Effects

Table 11

Summary of The Ecological Effects of Ground - Water Withdrawal

SOURCE	STRESSOR	ECOLOGICAL EFFECTS
Ground-Water Withdrawal	draw down cone formation decrease in pressure in a confined aquifer dewatering in un-confined aquifer storage reduction reduced recharge to underlying or overlying aquifers Salt water intrusion unintended migration of contaminates	Eco effects occur when ground water discharge to streams is reduced and are no different than surface water withdrawals

Severity of Impacts

Ground water use for agriculture has caused severe decline in water levels in some parts of the State. Water levels have declined as much as 300 feet in the area around Odessa and Lind and as much as 150 feet in the area around Pullman. Significant water level declines are also occuring in small areas of the Yakima and Walla Walla river basins. Annual pumping in these all these areas of decline exceeds recharge such that water levels do not recover during the period between irrigation seasons.

Reversibility of Ecological Effects

Scale of Ecological Effects

Not important in most parts of the State.

Sensitivity of Ecosystems Affected

No information.

Productivity and Uniqueness of Ecosystems Affected

No information.

Trends in Activity

Ground water production has not increased significantly in the last ten years, however, the distribution of usage is shifting from one area to another.

Trends in Ecological Effects - Prospects for Control, Successes in Management, and Opportunities for Enhancements

Uncertainty of This Analysis

REFERENCES

Anon. (1989) Potential for improving water use efficiency in Washington. Washington State Water Research Center, Pullman, Washington.

Anon. (1984) Washington State Grazing Land Assessment. Washington Rangeland Committee, Washington Conservation Commission. Published by Washington State University, Cooperative Extension Service.

Canning, Douglas J. (1988) Urban Runoff Water Quality: Effects and Management Options. Shorelands Technical Advisory Paper No. 4, 2nd edition, Shorelands and Coastal Zone Management Program, Washington Department of Ecology, Olympia, 71 p.

Dunne, Thomas and Leopold, Luna (1978) Water in Environmental Planning. W.H. Freeman and Co., San Francisco, CA.

Geppert, R. R., Lorenz, C. W., and Larson, A. G. (1984) Cumulative effects of forest practices on the environment: a state of the knowledge. Ecosystems, Inc., prepared for the Washington Forest Practices Board, 208 pp.

Martin, L.J. (1982) Ground Water In Washington. Report No. 40, Washington Water Research Center, Washington State University, Pullman, Washington, 43 pp.

McPherson, M. B., chairman (1974) Hydrological Effects of Urbanization. Co-ordinating Council of the International Hydrological Decade, Report of the Sub-group on the Effects of Urbanization on the Hydrological Environment, The Unesco Press, Paris, 280 p.

Moglen, Glenn E. and McCuen, Richard H. (1988) Effects of Detention Basins On In-stream Sediment Movement. Journal of Hydrology, V. 104, p.129-139.

Northwest Power Planning Council (1986) Council Staff Compilation of Information On Salmon and Steelhead Losses in the Columbia River Basin. Portland, Ore., 252 p.

Pacific Northwest River Basins Commission (1970) Comprehensive Study of Water and Land Related Resources, Puget Sound and Adjacent Waters, Appendix XI, Fish and Wildlife. Fish and Wildlife Technical Committee, Puget Sound Task Force.

Platts, W.S. (1981) Influence of forest and rangeland management on anadromous fish habitat in western North America -- No. 7. Effects of livestock grazing. In General Technical Report, PNW-124. U.S. Dept. of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, 25 pp.

Platts, W. S. (1985) Riparian-stream Management. In National Range Conference Proceedings, Opportunities for the Future. Oklahoma City, Oklahoma, Nov. 6-8, 1985. U.S. Department of Agriculture, p. 70-74.

Washington Dept. Ecology (1987) Instream Resources and Water Allocation Program Review, Draft Environmental Impact Statement. Water Resources Program. Olympia, WA.

Williams, R. W., Laramie, R.M., and Ames, J.J. (1975) A Catalog of Washington Streams and Salmon Utilization, Vol. 1. Puget Sound Region. Washington Dept. of Fisheries, Olympia, Wa.

Williams, R. W., Laramie, R.M., and Ames, J.J. (1975) A Catalog of Washington Streams and Salmon Utilization, Vol. 2. Coastal Region. Washington Dept. of Fisheries, Olympia, Wa.

Wolcott, Ernest E. (1965) Lakes of Washington, Volume I, Western Washington. 2nd edition. Division of Water Resources, Water Supply Bulletin No. 14, Olympia, Wa., 619 pp.

Wolcott, Ernest E. (1973) Lakes of Washington, Volume II, Eastern Washington. 3rd edition. Department of Ecology, Water Supply Bulletin No. 14, Olympia, Wa., 650 pp.

THE STATE OF THE ENVIRONMENT REPORT

VOLUME III
Part 12

Risk Evaluation Reports for Regulated Hazardous Waste Sites

ENVIRONMENT 2010

State of Washington
October, 1989

I. BACKGROUND

This analysis considers the environmental threat posed to human health and to ecosystems by active hazardous waste sites. The federal Resource Conservation and Recovery Act (RCRA) and state hazardous waste laws regulate these sites. As an EPA-authorized state, Washington, through the Department of Ecology, is responsible for monitoring these sites for compliance with state and federal regulations.

Active hazardous waste sites are defined as treatment, storage, and disposal facilities (TSDFs). Treatment refers to any process designed to render waste less hazardous or to reduce its volume. Incineration, filtration, steam stripping, and solidification are examples of treatments. Disposal technologies include landfills, waste piles, deep-well injection systems, surface impoundments, and land treatment (spreading waste on land, for example). Storage is defined as containment of hazardous waste on a temporary basis in a manner that does not constitute disposal.

Humans may be exposed to health risks from active hazardous waste sites in the following ways:

- Ingestion of contaminated surface water or ground water
- Exposure to airborne vapors or particulates
- Ingestion of contaminated crop or animal products (including seafood)
- Dermal absorption through direct contact with contaminated soil or water
- Ingestion of contaminated soil.

Ecosystems may be damaged by:

- Runoff, spills, or dumping to surface water
- Leaching to ground water that discharges to surface water
- Contaminated soil, air deposition
- Harm to animals through ingestion of or direct contact with contaminated soil or water, or through inhalation.

This analysis excludes consideration of nonhazardous municipal and industrial waste sites, inactive hazardous waste sites, and radioactive substances--all of which are analyzed elsewhere. The Hanford section of this report does, however, consider radioactive mixed waste. The analyses of other problem areas--notably ambient air, point source discharges to water, nonpoint discharges to waters, and contamination of drinking supplies--may address themselves to risks that this analysis also considers.

At this time, active hazardous waste sites are extensively regulated. RCRA Subtitle C (1977), the Hazardous and Solid Waste Amendments of 1984 (HSWA), and the State Hazardous Waste Management Act (1989) impose strict waste management requirements on TSDFs including permits for operation and closure, reporting requirements, and minimum performance standards.

II. SUMMARY OF FINDINGS

- A quantitative measure of risks posed by active hazardous waste sites in the state of Washington is not possible with the currently available data.

- The public perceives the risks associated with TSDFs to be high, but the federal and state regulations set up a reasonably effective system for mitigating those risks.

- Hazardous waste generators, because they are not as well regulated as TSDFs, may pose greater risks than TSDFs.

- The EPA found that ecological threats at RCRA facilities are not commonly investigated, and that no standard methods exist to aid in the assessment of ecological risks. In Washington, however, an environmental review, which may include an Environmental Impact Statement, is part of the permitting process.

- In general, older facilities may pose higher risks than newer facilities, which are built under more stringent environmental regulations.

III. ANALYTIC APPROACH/DATA SOURCES

The limits of time, budget, and data narrowed the scope of this study from an intended quantitative risk assessment to a primarily qualitative analysis. RCRA sites by their very nature defy easy generalizations. The risks associated with TSDFs will vary by the facilities' waste management practices, the quantity of the wastes handled, and the specific characteristics of the waste stream. Other considerations include a facility's design, operating condition, and site characteristics, along with the potential exposure pathways to human and ecological receptors--all of which vary from site to site. The human population in any particular facility's area is another variable of potentially wide range--TSDFs are located in isolated sites in rural counties and in densely populated urban centers. Some sites are in industrial areas and others are adjacent to residential neighborhoods.

Several attempts to come up with a representative sample of TSDFs failed. The number of different variables is one reason for the difficulty of this effort, and the wide range of possibilities within variables is another. But the biggest problems are that the risks associated with a particular site are determined by the particular combination of factors at that site. Toxicity and quantity of wastes are both important factors, but they cannot be evaluated outside the context of an analysis of exposure pathways to human or ecological receptors. As a result, the only reliable way to evaluate the risks of a group of TSDFs is to analyze each one individually and to compare the overall results.

This analysis therefore rejects both the attempt at a representative sample of sites as well as the attempt to define the worst case site. A representative sample probably does not exist, and the worst case site could only be determined by a complete site-by-site risk assessment.

In addition to these problems, a quantitative risk assessment of the state's TSDFs faces some data deficiencies. A sound risk assessment requires site-specific information that currently is not readily available. On-site ground water and emissions stack monitoring data are good, but off-site down-gradient and down-wind data are nonexistent or only sporadically available.

Nor is there any systematic gathering of information on exposure pathways and proximate human and ecosystem receptors.

The infeasibility of using a representative sample of TSDFs or of developing a worst case site eliminates those approaches to this analysis and leads to the analytical approach of reviewing the entire universe of sites. Rather than determining the risks to a maximum exposed individual (MEI) or other quantitative measures of risk, this analysis presents information about the group of active hazardous waste sites in the state--number of facilities, waste handling technologies, waste stream characteristics, location--and attempts to characterize in a qualitative way and risks associated with TSDFs. The human health and ecological risks are considered separately in the Findings section.

This report reviews other hazardous waste studies--including some risk assessments of hazardous waste sites--and where possible compares risks associated with TSDFs to risks in other areas. Most of the data in this report come from Department of Ecology records--Part A and Part B permit applications in particular--and from interviews with hazardous waste professionals in the Department. The Findings section reviews other studies, and the Bibliography includes a complete list of references.

The absence of quantitative data and analyses may make the task of comparing risks across environmental threats more difficult. This report attempts to provide those charged with that task with at least a sound understanding of the risk issues concerning active hazardous waste sites.

IV. FINDINGS

A. Human Health Findings

The data limitations preclude a quantitative risk assessment of the human health risks associated with Washington's TSDFs. The other studies that have attempted quantitative risk assessments, including the national study, all have inherent weaknesses. The applicability of the findings from any of those studies to the Washington RCRA sites remains an open question. None of the hazardous waste professionals associated with this study was comfortable with the idea of using a representative sample of sites from the Washington universe, primarily because of the uniqueness of each facility, and the idea of applying analyses from other areas to the Washington situation entails an even greater leap.

That these studies are not conclusive does not mean, however, that they are not useful in combination with professional judgment. The general agreement among the studies that human health risks posed by TSDFs rank in the moderate to low range relative to other environmental threats is shared by Washington hazardous waste professionals. The state and federal regulations governing TSDFs constitute the most important factor mitigating risk according to hazardous waste professionals. Washington further benefits from the limited land disposal in the state. And even the Hanford units, which pose a potentially higher risk to human health, are currently contained.

B. Ecological Findings

As with the human health risks, the data for a quantitative risk assessment of the ecological risks associated with RCRA facilities were not available. The Colorado study found no information on the ecological impacts of RCRA facilities, and the other studies ranked the ecological risks of TSDFs low. The EPA Summary of Ecological Risks found that, nationally, ecological threats posed by RCRA facilities were not commonly investigated. Under SEPA, however, Washington TSDFs all undergo an environmental review.

A key hazardous waste manager in the state rates the potential ecological risks higher than the human health risks based on the conviction that we do not know enough about the cumulative impacts on ecosystems, and that ecosystems may prove to be more vulnerable than humans to these cumulative effects.

C. The Universe of Sites

This study considers only those facilities that intend to continue operating as a TSDF. It excludes facilities that are still reporting to the Department of Ecology, but are no longer handling new wastes. There are 46 sites that meet the criteria for inclusion here--the Hanford Reservation, which has 59 units, and 45 other TSDFs spread throughout the state. Data were available for all 59 of the Hanford units, and for 42 of the 45 others.

The distinction between Hanford and all the other TSDFs is an important one. The scale and unique history of Hanford, along with its radioactive mixed waste, distinguish the 59 Hanford units from those in the rest of the state. In addition, the Department of

Ecology has negotiated with the federal Department of Energy a plan to clean up the Hanford Reservation. The development of the Hanford clean-up plan anticipates a careful assessment of human health and environmental risks associated with both current and past practices at Hanford. The limited analysis here includes the 59 Hanford units and presents the Hanford data alongside the data on the other 45 sites. A separate section discusses the Hanford Reservation in somewhat more detail.

The nature of the operation conducted at the state's TSDFs varies from site to site. The Hanford units handle primarily radioactive mixed waste resulting from the production of nuclear materials for national defense programs. The other 45 facilities include:

Chemical manufacturers/processors	11
Military installation	7
Smelters	6
Cleaning products manufacturers	5
Refineries	4
Aerospace	3
Hazardous waste handlers	2
Fertilizer manufacturer	1
Carbon recycler	1
University	1

D. Determinants of Risk

The human health and ecological risks posed by active hazardous sites depend upon the following four elements:

1. Waste Management Practices

There is little information available regarding the comparative human health or ecological risks posed by various waste technologies, and any TSDF, regardless of waste technology, can be designed and operated in such a way that it poses no significant risk. Nevertheless, the waste technology employed and the quantity of waste managed often correlate to some degree to estimates of risk. The regulatory requirements themselves imply a hierarchy of risk in the three basic practices: disposal is a higher risk practice than treatment, which in turn is a higher risk practice than storage. Landfills, for example, generally pose greater health risks than incinerators because he nonsudden environmental contamination associated with landfills presents a greater risk than the sudden contamination associated with incinerators. This is because the sudden contamination involves immediate and known releases that are subject to quicker corrective action. Managers have direct control of an incinerator, and can quickly shut it down in the event of a dangerous release. The risks of a landfill, on the other hand, are latent, and managers do not exercise direct control.

2. Waste Characteristics

RCRA defines hazardous waste as "a solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may..." pose a "substantial present or potential hazard to human health or the environment when improperly...managed..." The criteria for the identification and listing of hazardous wastes include toxicity, persistence, degradability, potential for accumulation, flammability, corrosiveness, and reactivity. The potential for a chemical waste to migrate offsite is another important risk issue, and so the waste's physical state, or volatility, and its solubility in the surrounding media become relevant factors.

3. Exposure Pathways

Risk assessments of active hazardous waste sites focus primarily on ground water contamination from land disposal sites, and on air emissions from incinerators. Other exposure pathways, such as inhalation of volatile organic chemicals from landfills, and ingestion of fugitive dust from landfills or particulate matter from incinerators, can also be significant. Other potential exposure pathways include fugitive emissions from surface impoundments or waste piles, wind dispersal of particulates, and volatile emissions from organic treatment or stabilization processes.

4. Receptors

The resident and transient populations near a facility comprise the likely nonoccupational receptors for a human health risk assessment. Sensitive sub-populations--children, the elderly, or persons with chronic diseases or susceptibility to particular adverse effects, for example--may exist within the general population. Ecological risk assessments consider receptors such as wildlife, flora, and aquatic species, and particularly any endangered species that may be affected.

E. Handling Technology

Washington's TSDFs report their activities to the Department of Ecology according to the following categories:

Storage:

Container (barrel, drum, etc.); Tank; Waste Pile; Surface Impoundment

Treatment:

Tank; Surface Impoundment; Incinerator; Other (chemical, thermal)

Disposal:

Injection Well; Landfill; Land Application; Ocean Disposal; Surface Impoundment

This report reorganizes the Ecology system in order to group together all handling methods that entail contact with land. This scheme includes in the Land Disposal category all the land-based handling methods, adding Waste Piles and Surface Impoundments from the Department of Ecology Storage and Treatment categories. Table 1 shows the number of facilities by the handling methods they use in this revised scheme. Of the 45 non-Hanford sites, 13 practice some type of land disposal; and at Hanford, the figures are 18 of the 59 units.

TABLE 1: NUMBER OF WASHINGTON STATE TSDFS BY HANDLING METHOD

Handling Method	All Sites but Hanford	Hanford Units
Treatment	14	36
Storage	29	25
Land Disposal	13	18
Total No. of Sites	45	59

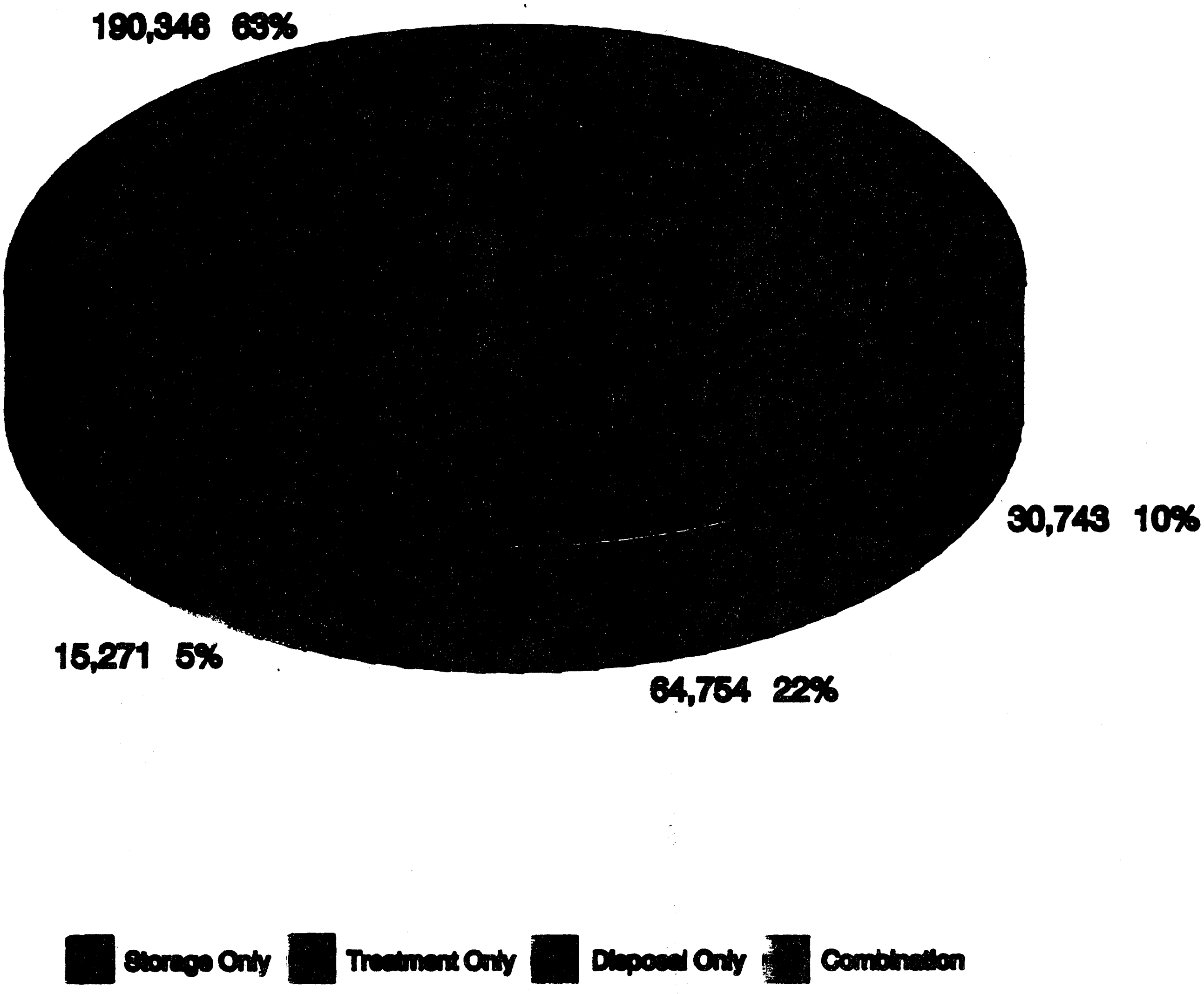
Note: Several TSDFs use more than one handling method so the number of facilities by handling method will not sum to the Actual number of sites.

Source: Part A permit applications

Figure 1 offers an illustration of the composite waste quantities managed by TSDFs under the various handling methods. As noted at the bottom of Figure 1, these data come from the Department of Ecology 1986 Hazardous Waste Annual Report. At the time of that report--the most recent one available--Hanford's RCRA units that handle radioactive mixed waste were not reporting to the Department of Ecology. As a result, the data from that report--used here and elsewhere in this study--are not precisely comparable to other Ecology data. The data in Tables 1 and 2, by contrast, come from the Part A permit applications filed by the TSDFs.

Table 2 provides information on the quantity of waste managed under each of the handling methods. These data are included in each TSDF's Part A permit application. A comparison of the Hanford units to the other 42 sites for which data are available gives a sense of the scale of Hanford: in most handling method categories, the quantity managed by Hanford far exceeds the totals for the other sites.

Figure 1 TSD Facility Handling Methods Used In 1986



301,115 Tons

Source: Department of Ecology 1986 Hazardous Waste Annual Report Summary

TABLE 2: SUMMARY OF HAZARDOUS WASTE QUANTITIES BY HANDLING METHODS

	ALL SITES BUT HANFORD			HANFORD		
HANDLING METHOD	No. of Sites	Quantity	Unit	No. of Units	Quantity	Unit
Storage						
Container (S01)	29	2,345,794	G	17	12,501,500	G
					22,000	L
					432	C
Tank (S02	24	5,420,775	G	8	137,348,900	G
Subtotal Storage		7,766,569	G		149,850,400	G
					22,000	L
					432	C
Treatment						
Tank (T01)	12	300,038	U	13	43,143,549	U
		1	D		70	V
		75,000	G			
Incineration (T03)	None			2	210	E
Other (T04)	8	36	D	24	12,000	G
		200	E		29,658,630	U
		212,200	U		221	V
		1,668	B			
Land Disposal						
Storage:						
Waste Pile (S03)	5	98,155	Y	1	5	C
		40	V			
Surface Impoundment (S04)	2	396,627	NA	None		
		8,000	Y			
Treatment:						
Surface Impoundment (T02)	1	3,400	U	2	501,000	U
Disposal:						
Injection Well (D80)	None			None		
Landfill (D81)	2	355	A	9	755	A
					8,640,000	G
					238,000	U
Land Application (D82)	4	61	B	None		
Surface Impoundment (D84)	2	70	A	8	32,413,750	G
		80,600,900	G			

Note: A TSDF may use more than one handling method.

Key to Units:
A--Acre-feet
B-Acres
C--Cubic Meters
D--Tons per Hour
E--Gallons per Hour
G--Gallons
L--Liters
U--Gallons per Day
V--Liters per Day
Y--Cubic Yards

F. Waste Stream

Hazardous waste types can be characterized by physical and chemical states, and by toxicity. The Ecology reporting requirements break down the waste streams of generators and TSDFs into considerable detail.

Table 3 displays the Washington hazardous waste stream by chemical type. This table comes from the Interim Report of the Pacific Northwest Hazardous Waste Advisory Council, and places the Washington waste stream in the Region 10 context.

TABLE 3. PNW HAZARDOUS WASTE BY CHEMICAL FORM FOR 1986/7 (TONS)

	Alaska		Idaho		Oregon*		Washington		Region 10	
Inorganic	790 0.6%	59.5%	1,096 0.8%	37.1%	13,197 9.9%	54.8%	118,637 88.7%	51.2%	133,720 100.0%	51.4%
Organic	207 0.3%	15.6%	1,120 1.8%	37.9%	4,183 6.6%	17.4%	57,541 91.3%	24.8%	63,051 100.0%	24.2%
Organic/ Inorganic	330 0.5%	24.9%	740 1.2%	25.0%	6,706 10.6%	27.8%	55,458 87.7%	23.9%	63,234 100.0%	24.3%
Total	1,327 0.5%	100.0%	2,956 1.1%	100.0%	24,086 9.3%	100.0%	231,636 89.1%	100.0%	260,005 100.0%	100.0%

*Oregon waste was distributed based on the combined percentage distribution of WA/AK/ID wastes.

Source: Interim Report of the Pacific Northwest Hazardous Waste Advisory Council

Table 4 uses the waste codes, and provides more detail on the total waste stream. These figures--also from the Interim Report--differ slightly from those in the Department of Ecology Annual Report: the Interim Report shows the total Washington waste stream as 231,636 tons; the comparable figure from the Ecology Annual Report is 23,539 tons. Table 4 shows that Washington's TSDFs managed considerably more moderately toxic waste than extremely toxic waste. The difference between extremely toxic and moderately toxic is the same distinction as between extremely hazardous waste (EHW) and dangerous waste (DW). A waste may be designated as EHW on the basis of toxicity or persistence. Likewise, a high level of concentration of a chemical in a waste stream may designate the waste as EHW, while a lower concentration may lead to a DW designation. Generators and TSDFs in Washington generate and manage both EHW and DW waste streams.

TABLE 4: THE PACIFIC NORTHWEST'S TWENTY LARGEST WASTE STREAMS 1986/7 (TONS)

		Alaska	Idaho	Oregon	Washington	Region 10	% of Total	Cum. Total
WT02	Washington Moderately Toxic (by UCD codc)	N/A	N/A	N/A		86,719	33.4%	33.4%
	456 Other Waste Treatment Sludge				29,508		11.3%	
	151 Inorganic Solids				27,704		10.7%	
	531 Contaminated Rags				7,775		3.0%	
	514 Contaminated Soil/Sand				5,589		2.1%	
	454 Paint Sludge				5,181		2.0%	
	141 Aqueous Solutions w/Heavy Metals				3,170		1.2%	
	289 Oily Wastes w/Water				1,936		0.7%	
	253 Detergents & Soaps				1,935		0.7%	
	286 Oil/Water Separator Sludge				1,176		0.5%	
	*** Others				2,745		1.1%	
WT02D006**	Washington Moderately Toxic/Mixed	N/A	N/A	N/A		24,266	9.3%	42.7%
	514 Contaminated Soil, Sand				24,246		9.3%	
	*** Others				20		0.0%	
D002	Corrosives	118	411	3,985	18,627	23,141	8.9%	42.7%
WP03**	Historical Tarry Waste	N/A	N/A	N/A		16,857	6.5%	58.1%
	514 Contaminated Soil, Sand				16,449		6.3%	
	*** Others				417		0.2%	
WT01	Washington Extremely Toxic	N/A	N/A	N/A		14,381	5.5%	63.6%
	151 Inorganic Solids				11,633		4.5%	
	224 Other Organic Liquids				1,654		0.6%	
	*** Others				1,094		0.4%	
D001	Ignitables	187	696	1,700	7,742	10,325	4.0%	67.6%
F006	Electroplating Sludges		289	2,023	6,618	8,930	3.4%	71.0%
K061	Emission Control Dust			3,312	3,520	6,832	2.6%	73.6%
D008	Metal Sludges	39	245	2,262	2,916	5,462	2.1%	75.7%
K051	API Separator Sludges	22			4,518	4,540	1.7%	77.5%
WT02/D007	Washington Moderately Toxic/Mixed	N/A	N/A	N/A		4,218	1.6%	79.1%
	454 Paint Sludge**				3,004		1.2%	
	*** Others				1,214		0.2%	
D007D002	Chromium Solutions	N/A	N/A	N/A	3,593	3,593	1.4%	80.5%
W001**	Washington PCBs	N/A	N/A	N/A		2,771	1.1%	81.6%
	401 PCB Oils 50-500 PPM				2,702		1.0%	
	*** Others				69		0.0%	
D006D007	Heavy Metal Contaminated Dirt, etc.	N/A	N/A	N/A	2,432	2,432	0.9%	82.5%
U209**	Tetrachloroethace Contam. Water/Soil				1,835	1,835	0.7%	83.2%
WT02D007D008	Washington Moderately Toxic/Mixed	N/A	N/A	N/A		1,810	0.7%	83.9%
	141 Aqueous Solutions w/Heavy Metals				1,172		0.5%	
	*** Others				638		0.2%	
WP02W001**	Washington Moderately Persistant	N/A	N/A	N/A		1,722	0.7%	84.6%
	514 Contaminated Soil, Sand				1,722		0.7%	
D008D002	Acid Cleaners, Spent Etchant	N/A	N/A	N/A	1,532	1,532	0.6%	85.1%
D006D007D008D002	Spent Sulfuric Acids, Battery Acids, etc.	N/A	N/A	N/A	1,453	1,453	0.6%	85.7%
U928U088**	Contaminated Soil	N/A	N/A	N/A	1,191	1,191	0.5%	86.2%
Twenty Largest Waste Streams		366	1,641	13,282	208,720	224,012	86.2%	
All Other Waste Streams		961	1,315	10,804	22,916	35,993	13.8%	
Total, All Waste Streams		1,327	2,956	24,086	231,636	260,005	100.0%	

**Generally nonrecurrent waste streams

Interim Report to the Council, 3/11/89

G. Import/Export

According to the 1986 Annual Report, Washington is a net exporter of hazardous waste. Of the hazardous waste generated in the state in 1986, over half (52%) was shipped out of state. Table 5 shows a state-by-state import/export analysis of Washington's transactions. Most of the exported waste goes to Oregon, and of the 96,223 tons sent there in 1986, 95,260 tons went to one facility--Chem-Security Systems, in Arlington.

TABLE 5: STATEWIDE HAZARDOUS WASTE EXPORT/IMPORT ANALYSIS

By State in 1986	Tons Exported to	Tons Imported From
Oregon	96,223	5,327
Idaho	5,050	653
California	3,772	1,502
Alaska	0	304
Others	17,366	3,463
Total	122,411	11,249

Source: Department of Ecology 1986 Hazardous Waste Annual Report

Washington's reliance on Oregon for the disposal of hazardous waste may pose a problem in the future. With no commercial disposal site of its own, Washington could find itself vulnerable to political or public opinion shifts in its neighbor state. While there is no apparent reason to anticipate a change in the status quo, neither is there any reason to think such a change could never occur. Interstate commerce regulations guarantee free trade between states, but local opposition to the import of waste could result in the imposition of taxes or fees on the waste.

Table 6 shows the recent history of the movement of waste between Washington and Oregon. Washington exports waste primarily because it has no commercial disposal facility or incinerator. The imported waste from Oregon is primarily low-level radioactive mixed waste.

TABLE 6: WASHINGTON AND OREGON EXPORT/IMPORT ANALYSIS

Year	Tons Exported to	Tons Imported From
1982	22,441	1,738
1983	26,263	1,204
1984	84,218	10,671
1985	62,449	5,041
1986	96,223	5,327

Source: Department of Ecology 1986 Hazardous Waste Annual Report

H. Location

Exhibit 2 shows the distribution of TSDFs on the map of Washington. Sites range from the relative isolation of rural counties to the densely populated urban centers. King and Pierce Counties both have eight sites, and Spokane County has five. Yakima and Whatcom each have three sites, and no other county has more than two. The King, Pierce, Spokane, and Snohomish County sites--a total of 23--are concentrated in or near urban areas.

The specific location of an active hazardous site can be an important determinant of risk--both to human health and to the environment. A thorough risk assessment would include site-specific information about exposure pathways and populations and ecosystems in the area.

I. Hanford

The federal government has produced nuclear materials for defense programs at Hanford since 1943. The hazardous waste resulting from the production processes include radioactive and chemical materials. The majority of Hanford's waste is a combination called radioactive mixed waste (RMW). Hanford's 59 RCRA units currently operate under interim status authority obtained through the submittal of a Part A permit application, updated to include RMW facilities in May 1988. Of these 59 units, 24 will continue to operate, and the other 35--for the most part smaller units--will go through closure. The closure process may in some cases take as long as 30 years, and so for the purposes of this report, all 59 units are included. Exhibit 3 is a map of the 560-square-mile Hanford Reservation.

The U.S. Department of Energy operates Hanford, and the EPA and the Washington Department of Ecology regulate activities there under RCRA, the Washington State Hazardous Waste Management Act, and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or "Superfund"). These three parties negotiated for over a year on a plan for the cleanup, permitting, and closure activities at Hanford. The Superfund Amendments and Reauthorization Act (SARA) amended CERCLA to extend CERCLA coverage to federal facilities, and to stipulate that Superfund monies are not available for cleanup of federal facilities.

The EPA has developed a National Priorities List (NPL) of hazardous waste sites identified for Superfund cleanup. EPA uses its Hazard Ranking System to score sites based on an evaluation of potential human health and environmental risks. EPA has proposed four Hanford areas--designated 100, 200, 300, and 1100 Areas--for inclusion in its National Priorities List. (See Exhibit 4.)

EPA, Ecology, and the Department of Energy have prepared a draft Community Relations Plan for the Hanford Site. The plan includes a

Exhibit 2

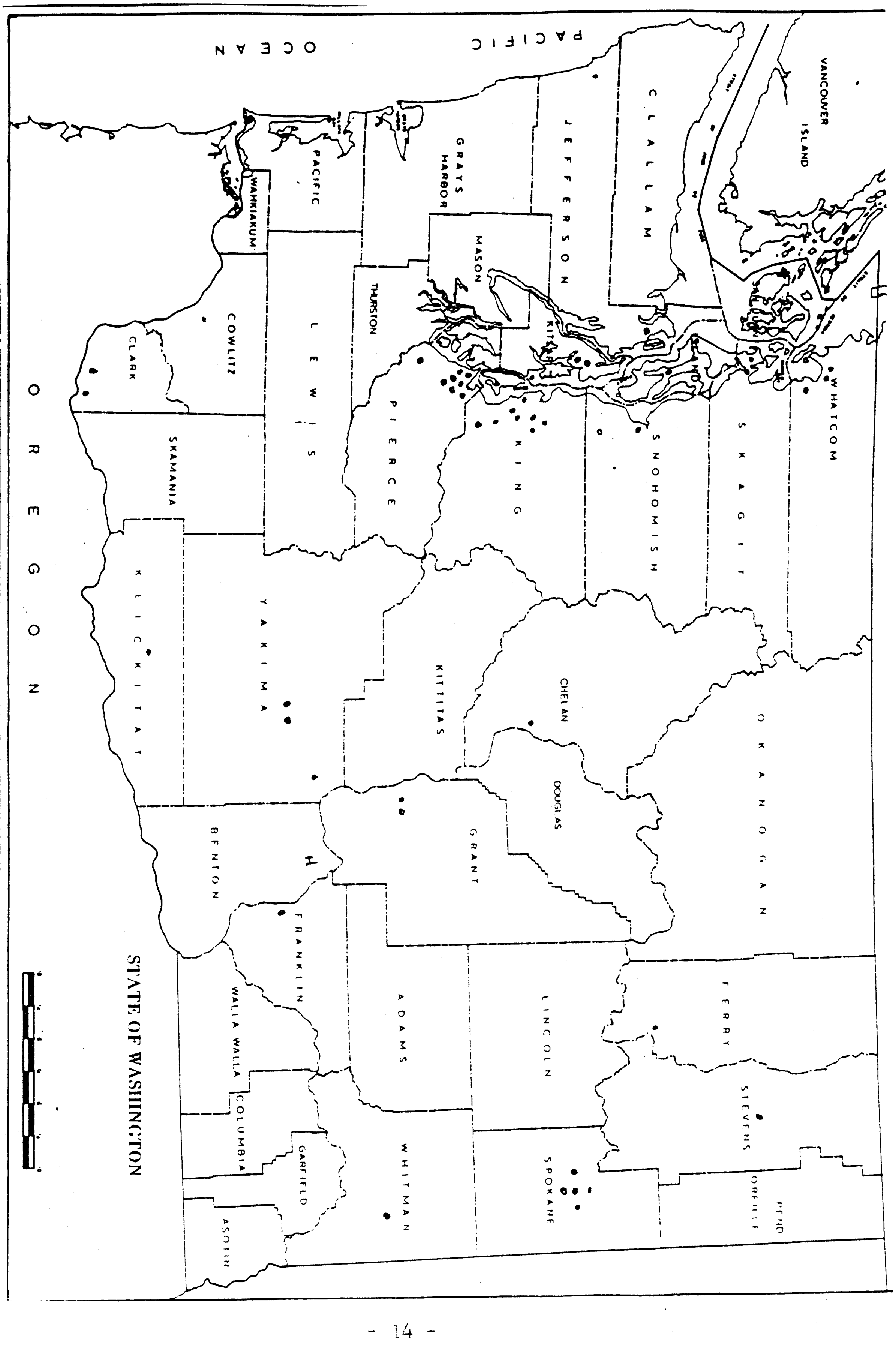
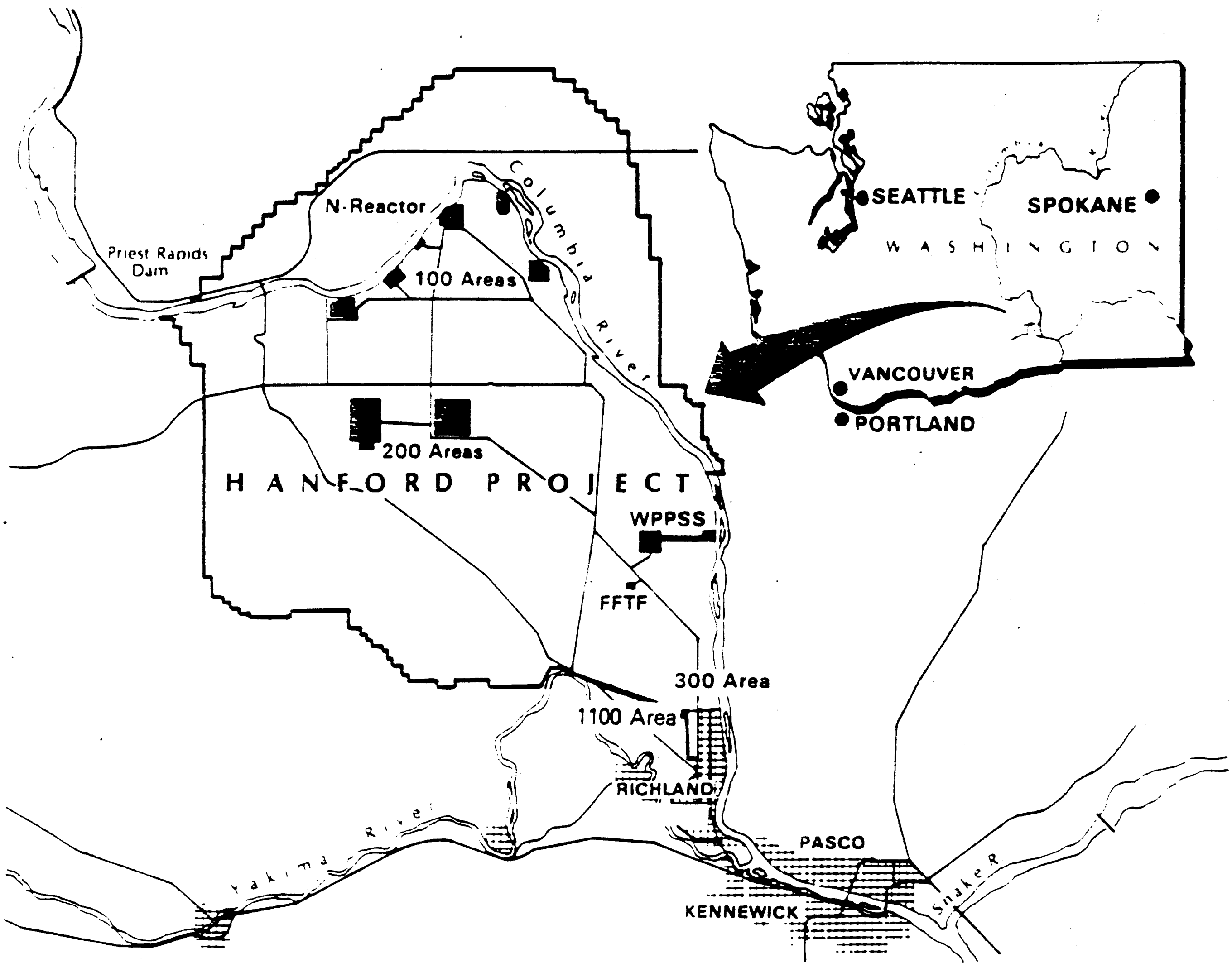
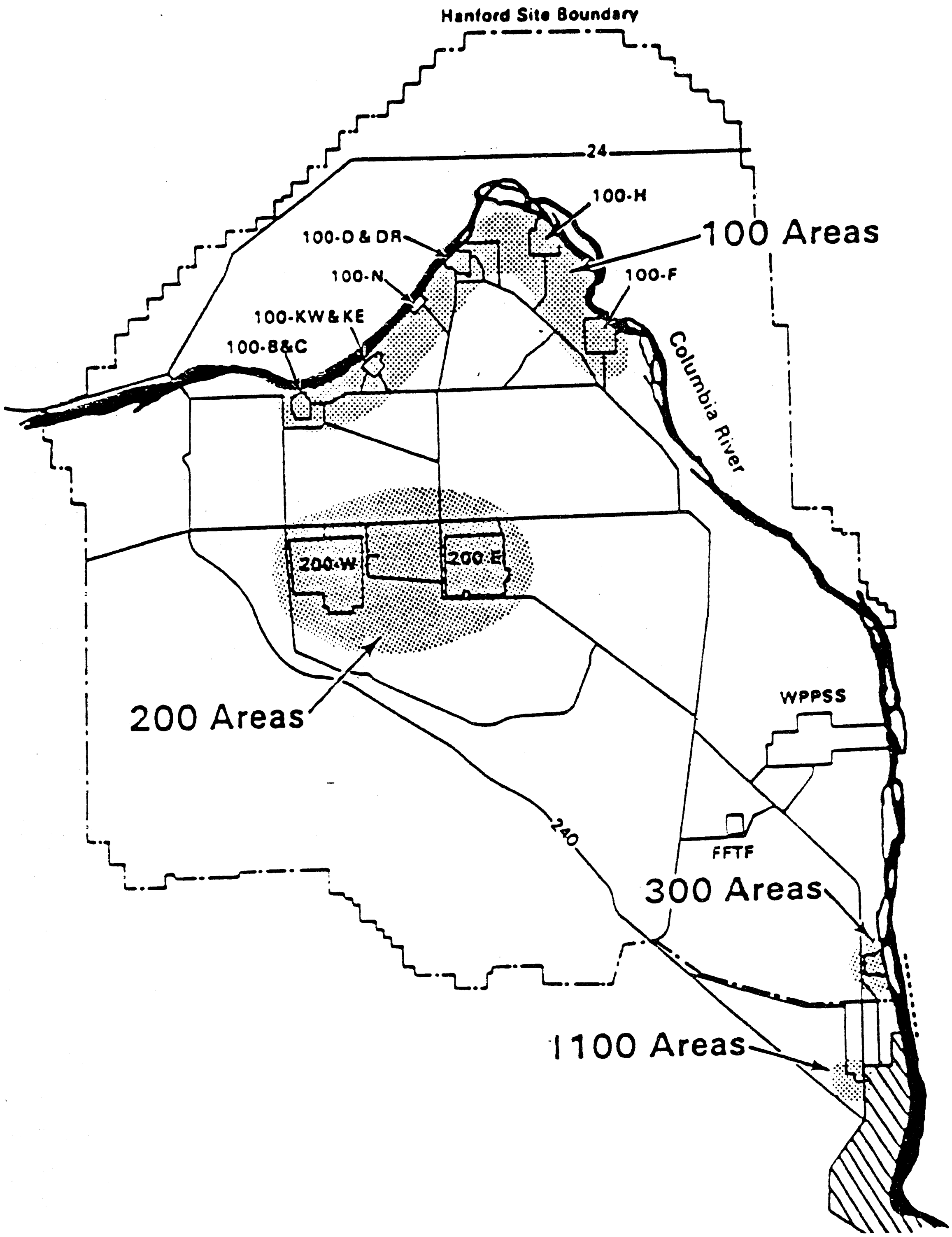

STATE OF WASHINGTON
PACIFIC OCEAN
OREGON
VANCOUVER ISLAND
CLALLAM
JEFFERSON
GRAYS HARBOR
MASON
KITSAP
ISLAND
WHATCOM
SKAGIT
SNOHOMISH
KING
PIERCE
THURSTON
LEWIS
PACIFIC
WAHKIAKUM
COWLITZ
CLARK
SKAMANIA
KLICKITAT
YAKIMA
KITTITAS
CHELAN
DOUGLAS
OKANOGAN
GRANT
BENTON
FRANKLIN
WALLA WALLA
ADAMS
LINCOLN
FERRY
STEVENS
PEND OREILLE
SPOKANE
WHITMAN
COLUMBIA
GARFIELD
ASOTIN

Exhibit 3



Priest Rapids Dam
N-Reactor
Columbia River
100 Areas
200 Areas
HANFORD PROJECT
WPPSS
FFTF
300 Area
1100 Area
RICHLAND
PASCO
KENNEWICK
Yakima River
Snake R
SEATTLE
SPOKANE
WASHINGTON
VANCOUVER
PORTLAND

Exhibit 4



Hanford Site Boundary
24
100-H
100 Areas
100-D & DR
100-N
100-F
100-KW & KE
100-B&C
Columbia River
200-W
200-E
200 Areas
WPPSS
240
FFTF
300 Areas
1100 Areas

brief description of the four proposed NPL areas at Hanford. For each area, EPA identifies the primary contaminants and the potential exposure pathways that could present human health and environmental risks. This information is part of the HRS scoring package. A Remedial Investigation--being performed on the assumption that the four areas will be included in the final NPL--will determine whether other contaminants that have been identified, or that may be identified later, warrant concern or require cleanup actions. The following descriptions of the four proposed NPL areas at Hanford are excerpted from the draft Community Relations Plan.

<u>100 Area Contamination</u>

The contamination in the 100 Area resulted primarily from the disposal of reactor coolant water. The primary contaminants are strontium-90, a radioactive isotope, and chromium, a metal. These could pose human or environmental threats through exposure to ground and surface water contaminated by these two substances. The 100 Area has approximately 11 square miles of waste disposal locations and contaminated ground water.

Contamination in the 100 Area originated from cribs, trenches, and contaminated reactor cooling water that leaked through retention basins to the ground water. The contaminants eventually flowed into the Columbia River. Retention basins were used from the 1940s through the early 1970s. During this period, unplanned releases of contaminated water also took place.

The possible pathways for human exposure to strontium and chromium are through the use of water from the Columbia River for recreation, irrigation, manufacturing, or drinking. The Columbia River is a possible route of exposure since both surface and ground water from the 100 Area flow toward the river; however, no wells within three miles of the 100 Area presently draw drinking water from the contaminated aquifer. Current releases are controlled under a National Pollutant Discharge Elimination System (NPDES) permit and DOE requirements that are comparable to NRC rules for releases from commercial reactors to surface waters. Monitoring results show that concentrations of radionuclides identified in the river are below drinking water standards set by EPA and the State of Washington.

<u>200 Area Contamination</u>

Ground water samples taken between 1984 and 1987 in the 200 Area revealed that concentrations of tritium, radioactive isotopes of iodine, uranium, cyanide, and carbon tetrachloride had risen during that four-year period. Releases of tritium (the radioactive isotope of hydrogen) and radioactive isotopes of iodine resulted from chemical processing operations at REDOX and PUREX. The wastes containing these contaminants have been disposed in ponds, cribs, trenches, and reverse wells. At the same time, uranium (a radioactive element and a product of UO_3 Plant operations), cyanide (an organic compound used to precipitate cesium during uranium recovery), and carbon tetrachloride (a chlorinated organic solvent used in the plutonium extraction process in the Plutonium Finishing Plant) wastes were disposed into soil columns.

Although uranium, cyanide, and carbon tetrachloride generally bind to the soil in the 200 Area, some of those three substances plus chromium and tritium can be found in large ground water "plumes," or areas of contamination within the aquifer. The tritium plume, for example, extends east to the Columbia River. In total, the 200 Area contains 230 known disposal locations that generated 215 square miles of contaminated plumes. Potential pathways for human exposure to the contaminated ground water are public and private wells and the Columbia River. Existing data suggest there is no current danger to the public from those sources.

300 Area Contamination

The main contaminant in the 300 Area is uranium, which resulted from fuel fabrication operations. As Hanford's 100 Area production reactors (except N Reactor) were shut down in the 1960s, fuel-manufacturing support activities from the 300 Area also declined. During the late 1960s and early 1970s, uranium-contaminated wastes were disposed in the north and south ponds (pools in which the movement of liquid wastes is restricted due to soil retention) and several trenches. At one time there were fourteen disposal locations in the 300 Area, which currently has approximately five square miles of radioactive contamination. Potential exposure pathways include wells in the North Richland area, the Columbia River, and an irrigation well used by Battelle Farm Operations. Existing data indicate there is no current danger to the public from those sources.

1100 Area Contamination

Contaminants in the 1100 Area are liquid battery acid containing lead and sulfuric acid, and ethlene glycol (antifreeze), both of which could potentially contaminate the ground water beneath the 1100 Area. The lead and sulfuric acid (an inorganic acid) resulted from the disposal of batteries between 1954 and the 1970s. The batteries were brought from the 100 Area and placed in an unlined disposal pit west of the 1171 building. The ethylene glycol resulted from leaks of antifreeze stored in a 5,000-gallon underground tank beneath the 1171 building. The tank leaked between 1976 and 1978 and was removed from the ground in 1986.

Potential exposure pathways of concern for the contaminants in the 110 Area are related to ground water. These pathways include municipal water system recharge wells belonging to the City of Richland, located adjacent to the 1100 Area. The Battelle farm irrigation well is also located nearby. Quarterly samples of nine wells adjacent to the 1100 Area have yet to detect the above-mentioned contaminants. The area has been stabilized with an asphalt cover to prevent contaminants from being washed away with rain or being blown by winds.

The Single Shell Tanks, in Area 200, are a special concern. In "The Proposed Hanford Compliance and Cleanup Program: A Citizen's Guide," the Department of Ecology describes the issue:

> These underground tanks, some dating back to 1944, store more than 36 million gallons of highly radioactive and chemically toxic wastes. Much of the liquid that can be pumped out has been removed from the tanks and stored in newer, double-shell tanks, although an estimated 6.8 million pumpable gallons of liquid remain.
>
> Sixty-six of the single-shell tanks are known to have leaked at least 500,000 gallons since 1956. There is no proof of ground water contamination caused by these leaks, but there is extensive soil contamination beneath the tanks.
>
> The Agreement calls for an extensive management program regarding the single-shell tanks. The tanks must be pumped to the extent possible. The remaining wastes must be characterized and a plan for removing, treating, and disposing of the waste must be developed.

J. Other Studies

Several studies have explored the human health and ecological risks associated with active hazardous waste sites. The most relevant of these are reviewed and summarized below.

Summary of Ecological Risks, Assessment Methods, and Risk Management Decisions in Superfund and RCRA, EPA Draft, March 1989

This report analyzes the nature and extent of ecological threats at RCRA facilities. It also examines RCRA ecological risk assessment methods, management issues, and management needs. EPA regional and state professionals, responding in interviews, generally stated that, "ecological threats at RCRA facilities are not commonly investigated or that no standard methods exist to aid in the assessment of ecological threats." These professionals stated that ecological threats at RCRA facilities receive inadequate consideration, and they identified several potential uses for ecological information in RCRA decision making - setting permit requirements, determining appropriate cleanup levels, and the siting of facilities, for example.

The report finds that little is known about the characteristics or extent of ecological damage from RCRA facilities, and that the precise nature of ecological threats at RCRA facilities is not well understood, but that the waste management practices conducted under all RCRA program areas nevertheless appear to pose a substantial potential threat to the environment. "Most ecological damage," the report states, "was characterized in aquatic ecosystems and included fish kills and reduced community diversity and structure. It is not clear, however, whether most ecological damage does actually occur in aquatic habitats, or it is simply easier, and therefore more common, to characterize impacts in this medium. Reported chronic terrestrial habitat damage includes impaired health and fertility of plant and animal species." The report also finds that the contaminants associated with ecological damage include virtually all waste types managed at RCRA sites.

The report includes the following conclusions:

> Although this analysis of facility characteristics suggests some patterns concerning practices, settings, and wastes that pose the most severe ecological threats, it is questionable whether quantitative projections based on these results can be made for the RCRA facility population as a whole. Such extrapolations are tenuous, mainly due to the limited nature of the available data characterizing the RCRA facilities and the lack of representatives (in a statistical sense) of the sites examined. Sufficient data to accurately characterize the nature and extent of ecological impacts at RCRA facilities are generally not available. Nonetheless, perhaps the most significant conclusion to be drawn from this analysis is that the wide range of hazardous and nonhazardous substances managed at RCRA facilities, the numerous release and ecological exposure pathways, and the diverse nature of the observed ecological impacts indicate that releases from these facilities have the potential to affect all environmental media and major ecosystem types. Hence, releases in wetlands, floodplains, surface waters, or in ecologically vital or sensitive habitats should be considered a potential source of ecological damage.

Unfinished Business, EPA, February 1987

The Cancer Risk Work Group ranked active hazardous waste sites 13th out of 31 environmental threats. Pesticide risks from consumer and professional exterminator use ranked 12th, and industrial non-hazardous waste sites ranked 14th. The Cancer Group noted that individual risks can be high, that no nationwide estimates are available, and that there are probably fewer than 100 cancer cases annually. The Group warns that the rankings may reflect inadequate data, and that variations in coverage of a threat complicates the rankings. Specifically, not all carcinogens in a threat area were covered, and neither were all exposure routes.

The Non-Cancer Risk Work Group rated active hazardous waste sites as LOW risks. The Group ranked RCRA sites as an entire problem without reference to specific substances, and based the low ranking on the very low number of humans potentially exposed, and on the low exposure concentrations relative to levels of concern. The Group expressed a medium level of confidence in its ranking of active hazardous waste sites, and estimated that it had considered 10-30 percent of the problem. The Group also noted the need for higher-quality data on exposure to substances capable of causing non-cancer health effects.

The Ecological Risk Work Group ranked active hazardous waste sites in its rank group 6, the lowest risk group of threats. The other two threats in rank group 6 are radiation other than radon, and underground storage tanks. The Work Group finds that these threats are characterized by few large releases, that the impacts are local and usually low, and that the RCRA sites benefit from a high degree of control. The Group attaches a moderate degree of uncertainty to their ranking of this group.

EPA Regional Risk Assessments

Both Regions 1 (Boston) and 10 (Seattle) have attempted risk assessments of active hazardous waste sites in projects similar to Washington's Environment 2010. The Boston study uses a Regional Hazardous Waste Planning Model to assess risks associated with various hazardous waste handling methods. The model relies on generator-specific data on quantities of waste handled, management practices, location, average release algorithms, and data on exposure parameters. The study ranks the cancer health risks and the ecological risks posed by RCRA sites as low.

The Region 10 human health risk assessment focuses on one Oregon RCRA facility designated by a consensus of professional judgment to be the worst case among the universe of sites. The study bases its risk assessment on current concentrations of Tricholoethane (TCE) in off-site wells, a model of potential concentrations of TCE and 1,1,1-Tricholoethane, and assumptions about people drinking water from private and public wells. The analysis scales up by multiplying the number of projected cancer cases by 165 - the number of RCRA facilities in the region - to get a conservative upper bound cancer risk estimate.

The Region 10 ecological risk assessment uses 180 as the number of RCRA facilities in the region, the focuses on 10 selected by RCRA project managers as likely candidates for ecological damage. This study finds that of the documented impacts to ecosystems, the problems are localized and fairly well understood.

Health Effects of Releases from Active Hazardous Waste Facilities in Colorado, prepared for Colorado Environment 2000 by Industrial Economics, Inc., draft April 24, 1989

This study examines health risks associated with ground water exposure for five selected RCRA facilities. Based on site-specific data, modeling of fate and transport of contaminants, and assumptions about population risks, this study finds a wide range of potential cancer risks at the selected facilities. At one site the upper bound on estimated individual cancer risk is high. The study assigns several uncertainties to its estimates of cancer risks. The CE2000 report found no information on the ecological impacts of RCRA facilities.

K. Discussion

Hazardous waste professionals generally agree that the state and federal regulations provide an effective system for controlling risks associated with TSDFs. Active land disposal facilities are inspected once a year, and all others are inspected every other year unless a facility can demonstrate a low environmental impact, in which case it would be inspected less often. The inspections are thorough, and while there have been handling violations, the current noncompliance issue of concern is the failure to provide ground water monitoring at a sufficient level. This shortcoming does not mean that there are releases, but rather that some releases may go undetected. At both Hanford and the other RCRA sites, the ground water is the primary exposure pathway of concern.

The age of a facility is a factor in its potential effectiveness - in general older facilities pose a potentially higher risk than newer ones for the good reason that newer ones are built under better designs and stricter requirements. The permitting process, however, ensures that all facilities meet the same requirements regardless of age. A facility - whether older or not - can operate under an interim status, but to achieve final status all facilities must meet the current requirements. At present, nine facilities in the state are operating under final status.

The hazardous waste regulations consider land disposal a higher risk handling method than storage or treatment, and the professionals tend to agree. There are 18 units at Hanford and 13 other TSDFs throughout the state practicing some type of land disposal. Refineries practicing land treatment of oil sludges and smelters using surface impoundments or waste piles for disposal of spent potliner account for the vast majority of the waste handled in a land disposal method at the 13 sites.

Organic chemicals are a higher concern than other wastes because they are more mobile and pose a greater threat to the ground water. Almost a quarter (24.8%) of the Washington waste stream is organic chemicals, and another 23.9 percent is a combination of organic and inorganic.

With no commercial disposal facility in the state, Washington exports just over half of the waste it generates. This practice presumably increases the transportation risks - not evaluated here - and lowers the state's risks for treatment, storage, and disposal of hazardous waste. Two proposals for the siting of incinerators are currently under evaluation in the state. These or any other additional facility would presumably increase the risks to human health and the environment to the extent that more receptors are potentially exposed to dangerous substances.

The EPA finding in the Summary of Ecological Risks that ecological threats at RCRA sites are not commonly investigated does not hold in Washington State. The State Environmental Policy Act (SEPA) requires an environmental review of TSDFs. The further EPA finding that no standards exist to aid in the assessment of ecological threats is contradicted by the cleanup standards set by the regulations. This same report says that most ecological damage was characterized in aquatic ecosystems and included fish kills, but no know damage from Washington TSDFs has gone beyond contamination of soil and ground water.

V. UNCERTAINTY

Comments by hazardous waste professionals within the Department of Ecology suggest that generators pose risks similar to TSDFs. There are approximately 3,500 generators in the state, many of them small businesses - auto body shops, dry cleaners, printers, and others. The regulations that govern generators are not as comprehensive as those for TSDFs, and Ecology has only 13 inspectors assigned to the 3,500 generators. There are no reliable figures on generators' noncompliance with handling procedures, but professional estimates range anywhere from 25-75 percent of the universe.

Whereas the RCRA facilities are in the hazardous waste handling business, many small generators see themselves as printers or cleaners, and not as hazardous waste handlers. They may believe that they cannot afford the costs of compliance, and they may be confused and intimidated by the regulations. These difficulties, some hazardous waste professionals think, may lead to illegal dumping or other noncompliance of significant risk to human health and the environment. One hazardous waste manager points out that the potential risks of TSDFs may be higher than the risks of generators, but that in actuality the generators pose greater risks because they are not nearly so well regulated.

VI. TRENDS

The state is moving towards a waste management hierarchy that would include the following elements in priority order: source reduction; recycling; chemical, physical, or biological treatment; incineration; stabilization; and land disposal. This approach is consistent with HSWA regulations that mandate the elimination of over 400 chemicals from the list of those that can currently be included in land disposal. A focus on on-site handling and proper management at the source are part of the future emphasis, along with a regional approach to waste management.

The risks associated with RCRA facilities are likely to decrease over time because of proper attention and awareness of the risks. Unless the current emphasis on hazardous waste sites decreases, the risks should continue to go down.

BIBLIOGRAPHY AND PERSONNEL SOURCES

A. T. Kearney, Inc. "RCRA Facility Priority Ranking Study Report." Prepared for U.S. Environmental Protection Agency Region 10, Seattle; November 1988.

Dryden, P.S. and Haddad, S.G. "Risks Associated with the Transportation of Hazardous Waste." Second National Hazardous Waste Management Conference, Sydney, Australia; November 1987.

Industrial Economics, Inc. "Health Effects of Releases from Active Hazardous Waste Facilities in Colorado." Prepared for Colorado Environment 2000, Denver; April 24, 1989 (draft).

Pacific Northwest Hazardous Waste Advisory Council. "Interim Report on the Current and Preferred Management Options for the Hazardous Waste Generated in the Pacific Northwest." March 11, 1989.

U.S. Environmental Protection Agency. "Summary of Ecological Risks, Assessment Methods, and Risk Management Decisions in Superfund and RCRA." Washington, D.C.; March 1989 (draft).

U.S. Environmental Protection Agency. "Unfinished Business: A Comparative Assessment of Environmental Problems." Washington, D.C.; February 1987.

U.S. Environmental Protection Agency, Region 1. "The Risk Reduction Project: A Comparative Assessment of Environmental Problems in New England." Boston; December 1988.

U.S. Environmental Protection Agency, Region 10. "Ecological Risk Assessment: Active Hazardous Waste Sites." (draft).

U.S. Environmental Protection Agency, Region 10. "Human Health Risk Assessment: Active Hazardous Waste Sites." (draft).

U.S. Environmental Protection Agency, Washington Department of Ecology, and U.S. Department of Energy - Richland Operations. "Community Relations Plan for the Hanford Site, Benton County, Washington." (draft).

U.S. Environmental Protection Agency, Washington Department of Ecology, and U.S. Department of Energy - Richland Operations. "The Proposed Hanford Compliance and Cleanup Program: A Citizens Guide." (draft).

Washington State Department of Ecology Solid and Hazardous Waste Program. "1986 Hazardous Waste Annual Report Summary." Olympia; September 1988.

The following Department of Ecology staff members contributed to the development of this report:

Kim Anderson, Robert Carruthers, Marc Crooks, Tom Eaton, Pati Hill, Dan Kjosness, Carol Knudson, Dan Kruger, Toby Michelina, Ted Mix, Lisa Newman, Tim Nord, Dave Polivka, Susan Ridgely, Roger Stanley, Cullen Stephenson, Ellen Thompson and Wayne Wooster.

In addition, Ann DeVries of Ross and Associates, and Celia Evans, Babette Faris, and Kathryn Kelly of Environmental Toxicology International, also contributed to this report.

THE STATE OF THE ENVIRONMENT REPORT

VOLUME III
Part 13

Risk Evaluation Reports
for
Uncontrolled
Hazardous Waste Sites

ENVIRONMENT 2010

State of Washington
October, 1989

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INACTIVE HAZARDOUS WASTE SITES
A SUMMARY OF COMPARATIVE RISKS
MIKE BLUM 6/8/89

BACKGROUND

THE THREAT: This report analyzes the threat to human health and the environment from inactive hazardous waste sites.

DEFINITION/CHARACTERIZATION: The definition/characterization of the risk is as follows: First, I need to define what an inactive hazardous waste site really is and then to identify how abandoned hazardous waste sites differ or are similar to threats analyzed in other parts of the Washington Environment 2010 report.

Classically, the definition of inactive hazardous waste sites are those site where chemical contamination exists that "cause or have the potential to cause" impacts to public health and/or the environment and have no identifiable person or party who was or currently is "responsible". Responsible means the financial and/or technical capability and willingness to investigate and cleanup the chemical contamination. Those sites, for example, might include former industrial sites whose owner has since gone bankrupt or the "midnight dump" site where chemicals are illegally disposed of, sometimes in the dark of the night. Luckily, these types of site are not very numerous in Washington. Most sites have known owners and/or operators, though their willingness to investigate or cleanup their sites may be a different matter.

The definition of inactive hazardous waste sites which will be used in this report, are again those sites where chemical contamination is causing or has the potential to cause threats to human health and the environment. No distinction will be made as to whether a "responsible" party or not is identified. A better term, which will be used along with inactive in this report, is "uncontrolled" hazardous waste sites. For example, an active industrial facility which generates hazardous waste and handles it properly, may also have an old waste lagoon which was used before hazardous waste regulations were in existence and is now causing or has the potential to cause problems. That portion of the property has waste which are "uncontrolled", while the remainder of the facility is still active and proper waste handling is occurring.

THE LAWS: Both the Federal and State Governments have enabling legislation to allow them to investigate or cleanup hazardous waste sites (using government moneys) or to require the identified responsible party to cleanup the site. The Federal law is the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund. The Federal Superfund program has established a list of sites, known as the National Priorities List (NPL). The NPL contains the nation's worst sites contaminated by hazardous waste. The U.S. Environmental Protection Agency (EPA) has the responsibility for implementing and enforcing Superfund.

The Washington State law which addresses the investigation and cleanup of hazardous waste sites is known as the Model Toxics Control Act (MTCA). The MTCA or Citizen's Initiative took effect on March 1, 1989. It replaced the Hazardous Waste Cleanup Law (Chapter 70.105B RCW) which was passed by the State Legislature in 1987. The Department of Ecology (Ecology) has the responsibility for implementing and enforcing the MTCA. Many facets of Washington's law reflects what is contained in CERCLA.

THE DATA BASE: Currently, Washington State does not have a prioritized list for all the sites in the State, similar to the Superfund NPL. Under the MTCA, Ecology is to develop a ranked list of all the known and potential hazardous waste sites in the State. That prioritized list will not be developed for many months. Ecology has recently developed a computer data base of all known or potential sites contaminated by hazardous waste. (Hazardous substances that are spilled automatically become hazardous wastes.) That data base, known as the Site Management Information System (SMIS) is kept by the Hazardous Waste Investigations and Cleanup Program within Ecology. The primary purpose of establishing the data base has been for work load and milestone (work progress) tracking. The secondary purpose is to have a computer listing of all known or potential sites in the State from which to generate various reports. As noted above, Ecology is to develop a ranked list of sites. A ranking model is being developed to create a prioritized site list. The model will eventually be used to rate and rank all contaminated sites in Washington. The ranking of sites will be on a comparative risk basis. The results of the ranking of sites will help Ecology to prioritize its' work on sites, as there are more sites requiring work than current resources will accommodate. Of course, other factors such as politics, public concern, media attention, etc. may influence when work on sites begins, in addition to a purely "scientific" approach or model.

The SMIS data base, a listing of about 700 site, includes the following categories of sites:

- Superfund or NPL sites
- State sites with confirmed hazardous waste present
- State site with potential hazardous waste present
- State sites which are undergoing long term monitoring;
- State sites considered free of contamination
- State sites contaminated but posing no known threats
- State sites for which cleanup is complete under the MTCA or CERCLA

(See Attachments 1,2, and 3. Attachment #1 is the SMIS list of about 700 sites; #2 is the site category list, and #3 is the SMIS "fact sheet" summary .)

The SMIS site list contains an extremely wide variety of sites. They range in scope and complexity from the Mom and Pop gas station/deli to the Hanford Nuclear Reservation. Businesses large and small are on the list, municipally and privately owned landfills, Department of Defense sites, mining sites, port facilities, Resource Conservation and Recovery Act treatment storage and disposal facilities (RCRA-TSD's), RCRA generators, private homes and apartment buildings, spill sites, illegal drug labs, marine or freshwater sites, etc. are also on the list. Of all the varieties of types of sites on the list, they also include both active and inactive sites or facilities. Basically, any site that is known or suspected to be contaminated with hazardous waste has been placed on the SMIS list.

As can be noted on the site category list (attachment #2), because hazardous substances are found at a site, that does not mean that cleanup or further investigation is required. Also, a large number of sites are on the list, in the "C2" category, which are "potentially" contaminated sites. Initial investigations and reports have lead Ecology to believe that contamination may exist, but at this time, there is not confirmed laboratory or field determinations of the presence of hazardous substances. Once sampling has occurred, the site may move to the "contamination confirmed" category ("C1") or it may fall into either the "considered free of contamination" category ("M") or "contaminated but not a threat" category ("P").

In the list of SMIS sites, are numerous sites which might be "double counted" in threats analyzed in other areas of the Washington Environment 2010 report. The other threats include:

- Active hazardous waste sites (Resource Conservation and Recovery Act (RCRA) regulated facilities),
- Materials Storage (storage tanks)
- Non-hazardous waste sites (landfills).
- Accidental releases (spills)
- Point Source pollution (discharge pipes)
- Non-point source pollution (runoff and/or seeps)

As noted earlier, some RCRA facilities may have active waste site areas that are controlled and other areas of the facility which are uncontrolled. Figure #1 (attached) shows a breakdown of the major categories of sites in the SMIS database. It also visually presents the potential for double counting with other threats.

ECOLOGY SURVEY: For the purposes of this report, in lieu of a state hazard ranking system, many of the sites on the SMIS list have been rated by Ecology site managers and field inspectors. The ratings were to look at the site for their risk to human health and their risk to the environment. The rating of the sites was done on a best professional judgement basis, mostly using the knowledge they have in their heads. Their experience with these sites ranges from minimal knowledge to many years of first hand experience. Those sites where the Ecology inspector had little or no knowledge, or was unwilling to make a best professional guess, have been grouped in the "unknown" category. Only compilations of the ratings are included in this report, without specific reference to individual sites and its' hazard rating which was done by Ecology staff. The individual ratings are not available for public review. The cover letter and the risk rating criteria which was sent to the appropriate Ecology employees for their rating of public health and environmental risk, as well as their estimate of affected population, is included as Attachment #4. A sample of the hazard rating sheet is included as Attachment #5.

OTHER RELEVANT BACKGROUND INFORMATION: Sites that were evaluated by the Ecology inspectors were rated based on the current conditions of the site. Several of the large Superfund sites have or are in the process of being cleaned up. The imminent threats have been mitigated in many cases. As time goes by, the risks associated with other sites will be decreasing too. Prioritization or work on sites by Ecology has been determined by the relative risks present at the beginning of work on the sites. Sites will maintain their relative ranking on Ecologys' workload priorities, in spite of work accomplished at the sites, otherwise project priorities would be shifting all the time. There is always some shuffling of workload priorities, as new sites are discovered or existing sites are investigated further. The shifting may increase or decrease the relative priority of a site, or add it to the list if it is a newly discovered site. When new high priority sites are discovered and added to the list, lower priority projects sometime fall off the list of current things to work on. Sites will always remain on the SMIS list, though they might fall off the "program plan list" (the list of sites Ecology is currently working on). For example, a high public health risk site is or should be worked on until the site is cleanup up, rather than only working on the site until its' risk is reduced to a medium risk, then going on to other high risk sites. Ecology is working to cleanup sites (eliminate or significantly reduce the risk), not just mitigate them.

This analysis of uncontrolled hazardous waste sites follows similar studies conducted nationally and in selected EPA regions. A study of EPA Region 10, including Washington State, was initiated during 1988. Many of the inactive hazardous waste sites in Washington for which detailed risk information is available were also included in the EPA Region 10 study. The total universe of inactive hazardous waste sites considered in this study is largely overlapping with the CERCLIS list (an EPA listing of known or potential uncontrolled hazardous waste sites) of sites in Washington State that EPA Region 10 has compiled. The projections of total risks in the EPA Region 10 comparative risk study included the population of sites on the CERCLIS list. The current investigation builds on the results and methods of the previous comparative risk studies.

The total number of uncontrolled hazardous waste sites in Washington State that will be listed is not known; for this threat evaluation, a total population of 800 sites is assumed.

Both human health and ecological risks are included in this evaluation. Information sufficient to characterize these risks on a site-specific basis is not available until detailed site investigations have been performed. Most of the sites for which such detailed information is available are in fact NPL sites. About 25 risk assessments have been written for sites which are under investigation and/or cleanup. The risk assessments reviewed for this report are as follows:

Whatcom County Ethylene Dibromide (EDB) Sites
Frontier Hard Chrome - Vancouver, Clark County
Western Processing - Kent, King County
Commencement Bay - Nearshore/Tideflats, Pierce County
Wyckoff/Eagle Harbor - Bainbridge Island, Kitsap County
Tacoma Tar Pits - Tacoma, Pierce County
American Crossarm - Chehalis, Lewis County
Well 12-A - Tacoma, Pierce County
Cascade Pole - Olympia, Thurston County
Ponder Corner - (Wells H1 & H2) - Lakewood, Pierce County
Asarco Smelter (offsite) - Ruston/Vashon, Pierce County
Asarco Smelter (onsite) - Tacoma, Pierce County
Gas Works Park - Seattle, King County
Strandly PCB Site - Kitsap County
Northwest Transformer - Whatcom County
Midway Landfill - Kent, King County
Colbert Landfill - Colbert, Spokane County
Northside Landfill - Spokane, Spokane County
Tacoma Landfill - Tacoma, Pierce County

Most of the available risk assessments characterized only human health impacts. This is due to the fact that the emphasis of the Federal Superfund program has historically been on human health and not the environment.

The general approach used in this evaluation is to compile and review information on risks from available detailed studies, assess the probable distribution across the total population of sites of risk levels (the issue of "representativeness" of the detailed studies), and then to make projections of the possible range of risks posed by the total population ("scaleup") of sites.

Fewer than 5 percent of the sites listed on the state inventory have detailed risk assessment studies available for review. Although these studies have generally conformed to the EPA's recommended approach (cf. Superfund Public Health Evaluation Manual), significant differences in assumptions and risk evaluation methods result in a distinct lack of standardization in the available risk assessments. No attempt to further standardize the risk assessment approaches of the various site risk assessments was undertaken as part of this evaluation. The comparisons and summations of risks across sites therefore include all of the (significant) differences in exposure and risk assumptions and calculations. Wherever identification is possible, however, risks based on extreme assumptions have not been included in this evaluation.

Many types of facilities and past practices are represented on the SMIS inventory of uncontrolled or inactive hazardous waste sites. A partial but by no means exhaustive list includes the following: municipal landfills, recycling and disposal sites, electroplating and other manufacturing facilities, primary and secondary smelters, wood treating facilities, estuarine areas (urban embayments), pesticide manufacture and other chemical facilities, pesticide storage and use, petroleum facilities, coal gasification, and mining operations.

The hazardous substances present at inactive hazardous waste sites include all of the major contaminant groups. Common contaminants found at these sites include the following: numerous metals, polychlorinated biphenyls (PCB's), polynuclear aromatic hydrocarbons (PAH's) and other semivolatile compounds (e.g., phthalates and phenolics), volatile organic compounds (especially solvents and petroleum constituents), pesticides, and dioxins/furans. Attachment #1 identifies the major contaminant groups confirmed or suspected at the inactive hazardous waste sites as well as the environmental media that is or may have been impacted.

Existing or potential exposures to these contaminants can occur by a number of different pathways. Ingestion, inhalation, and dermal contact pathways have been considered for a variety of onsite and offsite exposure scenarios, such as: using surface or ground water sources for drinking water and cooking; eating locally grown vegetables or meat/milk; eating fish and shellfish from affected environments; incidental soil ingestion, particularly for children; direct contact and dermal absorption from playing or working in soils; bathing, swimming, or other potential contact exposures; inhalation from showering and cooking, where contaminants may volatilize into the breathing zone; and inhalation of vented gases or resuspended particulates from the site.

Major transport pathways for contaminants from these sites to surrounding areas include leaching of contaminants from soils, ground water transport, surface water runoff, and wind transport of gases and resuspended particulates. Certain contaminants also volatilize at appreciable rates from soil, surface water, and ground water sources at sites and may either be transported and dispersed or accumulated in enclosed spaces offsite. Some offsite media, such as sediments and to a lesser degree soils, may over time accumulate concentrations of contaminants originating from uncontrolled hazardous waste sites.

Potentially affected populations generally considered in evaluating the risks posed by uncontrolled hazardous waste sites include existing receptors (e.g., closest residences) and hypothetical receptors to account for possible future land uses. Worker and residential exposed populations can be evaluated independently. Children and other populations that may be at special risk are often considered in independent evaluations of risk as well. Carcinogenic risks and acute or chronic noncarcinogenic risks may result from contaminant exposures, with a large number of different specific health outcomes and affected organs possible, depending on the contaminant(s) and type of exposure. Cancer risks are generally not distinguished as cancer occurrence (morbidity) or cancer mortality, although in some cases (e.g., generally nonlethal skin cancers) there may be an order of magnitude or greater difference in morbidity versus mortality risks.

Potential ecosystem impacts from uncontrolled hazardous waste sites include effects on the occurrence, abundance, and health of terrestrial, aquatic, and marine species as well as the quality of environmental media supporting ecosystems.

The risks evaluated in this study are primarily baseline risks for sites before remediation actions are performed. A few of the available risk assessment studies define risks after some initial remedial actions have been taken; no baseline risks are estimated for these sites. This is appropriate for evaluating how future actions or resource allocations could affect risks for these specific sites. However, post-remediation risks are not necessarily an appropriate basis for projecting risks for other unstudied and unremediated (and maybe even undiscovered) sites for which remediation and resource allocation decisions still have to be made.

Finally, some risks are not included at all in this evaluation. The risks from actually performing remediation at sites (e.g., risks associated with the treatment and/or transportation of contaminated materials or site cleanup worker exposures) are not included. Risks associated with radioactive wastes, such as those at the Hanford sites included on the state inventory of sites, are also not evaluated here.

HUMAN HEALTH RISKS

INTRODUCTION: The assessment of human health risks relied on two complementary sources of information: available risk assessment studies and the results of a survey of Ecology site managers and inspectors, as part of this investigation.

Detailed risk assessment studies have been completed for a small percentage of the sites listed on the state inventory. A total of 19 available studies representing 18 different sites (separate studies were prepared for onsite and offsite areas at the Asarco Smelter site in Tacoma) were reviewed (see list on page 5???). Only 2 additional sites, both municipal landfills, are believed to have completed risk assessments available. Risk assessments for several other sites are expected to be completed within the next several months. This evaluation therefore included nearly all available studies of human health risks associated with inactive hazardous waste sites. The sites for which detailed risk assessments were available represented a number of different types of facilities, although not all of the types included in the state inventory list were included or reflected in proportion to their occurrence.

The second source of information was a survey that polled Ecology site managers and inspectors located in the headquarter and regional offices for their best professional judgments on the magnitude (high, medium, low, unknown) of potential health risks and the size (six categories or unknown) of potentially exposed populations on a site-specific basis. This information was not used to directly evaluate human health risks. Rather, the results were used to make judgments about the relative distribution of risks across the total population of sites and the representativeness of the risks from the small number of studied sites (mostly NPL sites) for the large number of remaining sites. A simple linear scaleup of risks based on the total number of sites was rejected in favor of a scaleup based on distributional assumptions, as discussed below. However, for the limited use made of the survey information in this risk evaluation, neither the lack of complete results nor the various methodological questions that could be raised about the survey approach (e.g., inter-rater reliability) are considered likely to affect judgments based on the survey.

ANALYTICAL APPROACH: The general approach used for evaluating human health risks was the compilation of estimated risks for sites with completed risk assessment studies, the evaluation of those results to derive risks on a per site per year basis, and the scaleup of total risks to the total expected population of inactive hazardous waste sites, with consideration of the likely distribution of risk levels across sites.
Direct epidemiological evidence for human health impacts for inactive hazardous waste sites is almost totally lacking. Very few epidemiological studies have been performed for these sites. The most studied site is probably the Asarco Smelter, where elevated urinary arsenic concentrations were found (mostly during the period of plant operation) in children without accompanying observable health impacts. Only slightly suggestive evidence of an increase in lung cancer rates in surrounding populations has been found in one out of several lung cancer mortality studies of surrounding populations for that site. (That finding, if substantiated, would properly be associated with the environmental threat of toxic air pollutants from a stationary source). The available information on human health risks is therefore exclusively from estimates of potential health risks rather than documented health impacts. Since most estimates of health risks are intentionally conservative, the results are best interpreted as (reasonable?) upper bounds for risks rather than true predictions (best estimates).

Summary information from each site-specific risk assessment was compiled and entered into a large spreadsheet table (see Table 1 - attached). This table includes information on the type of site, the reference(s) reviewed, major contaminants evaluated for human health risk, health outcomes evaluated, maximally exposed individual (MEI) risks for cancer and noncancer outcomes, the exposure pathways and scenarios evaluated, the size of potentially exposed populations, and the potential incidence of adverse health effects. Many of the risk assessments reviewed present a large number of results reflecting different exposure scenarios and modeling assumptions. This multiplicity of results poses some significant problems for easily summarizing available risk studies. A full understanding of site-specific results may
require reference back to the original document.

Table 2 (attached) provides the number of sites from the state inventory list (697 total sites) in each county and the number of sites reviewed for this evaluation, also by county. This provides a basis for assessing the spatial distribution of sites and the representativeness of sites with available risk assessment studies. Over 50 percent (355 of 697, 51 percent) of the sites in the state are in one of three high-population counties: King, Pierce, and Spokane. Of the site risk assessments reviewed, 11 of 18 (61 percent) are from these counties. The distribution of listed sites west/east of the Cascades is 542/155, or 78%/22%. The 18 site risk assessments reviewed are distributed 16/2, or 89%/11%.

Table 2A (attached) extends the site distribution information to include the results of the Ecology survey of judged human health risks. Counts by rating category are provided for each county. Counties with relatively high percentages of sites rated high or medium for health risks are Chelan, Kitsap, and Yakima. Yakima and Chelan County sites appear to include a higher-than-typical ratio of sites with possible pesticide contamination.

Table 3 (attached) provides a summary of the ratings for population potentially exposed for sites in each of the human health risk categories in the Ecology survey. The overall percentages for human health risk categories high/medium/low/unknown or unrated are 7%/17%/28%/48%, respectively. The ratings of human health risk are visually presented in Attachment #6. The population category counts within each human health risk category were normalized by dividing by the total for that health risk rating, with and without the unknown population category. The results show reasonable consistency across health risk categories; that is, the judged populations potentially affected do not appear to be distributed differently for different human health risk ratings.

MEI RISKS: The calculated cancer and noncancer risks for various exposure pathways and scenarios at the 18 sites reviewed are listed in Table 1. The cancer risks cover a range of more than eight orders of magnitude, from 9.7E-1 (hypothetical drinking water exposure at the Wyckoff site) to 3E-9 (seafood ingestion at the Cascade Pole Company site). For some pathways and scenarios not listed, incremental cancer risks are essentially zero (contaminant concentrations at approximately background concentrations). Even though differences in risk assessment approach and specific risk modeling assumptions may contribute substantially to this variation in specific cases, the true range of MEI risks is still believed to be large, if not quite as large as indicated in the available studies. For noncancer health outcomes, the results are similar. Hazard indices, calculated as the ratio of estimated dose (exposure) to acceptable (reference) dose, range from much less than 1.0 to a maximum of 143 (Frontier Hard Chrome) for the risk assessment studies reviewed. Although "average" or "typical" site MEI values may be discussed, this variability implies that risks for a given site may be much higher or lower than the average.

The MEI cancer risk values from Table 1 were listed in rank order to assess the overall distribution of results across sites. Multiple values representing different scenarios or assumptions for risk estimates at one site were included where they existed. The majority of sites had MEI risks between 1E-4 and 1E-2, which may be considered the "modal range" for MEI risks. All MEI risks greater than 1E-2 represented hypothetical exposure scenarios to possible future populations; the risks in the modal range represented both hypothetical and existing populations. Thus, it appears that extremely high MEI risk values may be associated with "what if" scenarios of possible exposure to uncontrolled hazardous substance releases at inactive hazardous waste sites (what if someone uses contaminated ground water for drinking water? what if children live and play in areas of highly contaminated soil?), while conservatively estimated MEI risks to existing populations are often several orders of magnitude lower (but still above 1E-4). A few sites where interim or emergency remedial actions were taken may actually have had MEI risks at or above the 1E-2 level for existing populations (primarily ground water use). Common contaminants for MEI cancer risks include arsenic, PCBs, PAH compounds, dioxins, pesticides, and volatile organic compounds (solvents).

Overall, the available risk assessment studies support the concept of a distribution of MEI cancer risks across sites over 6 to 8 orders of magnitude, with a peak in the 1E-4 to 1E-2 range. Factors to consider in evaluating any MEI risk are hypothetical versus existing exposure scenarios, the degree of conservatism in risk modeling assumptions (e.g., contact rates and contaminant concentrations), and whether risks are for baseline or post-remediation site conditions.

How representative are the 18 reviewed sites for the total inactive hazardous waste site inventory, assumed to be 800 sites? There are several reasons to conclude that they are generally at the high end of the distribution of risks across sites. First, most of the reviewed sites are Superfund sites that were listed on the NPL in large part because of concerns for potential human health risks. Second, a review of additional site files provides qualitative support that risks for additional sites should on average be somewhat lower than for NPL sites (lower contaminant concentrations or extent, less population exposure potential). Third, the Ecology survey of site managers and inspectors provides evidence that there are judged to be significant differences in human health risks across sites. The conclusions reached for this evaluation are: 1) any site from the inventory could have MEI cancer risks equal to or greater than the upper range of risks reported in the 18 sites reviewed, and 2) a subset of the total of 800 sites, estimated to be approximately 100 sites, may have a distribution of MEI risks comparable to that found in the 18 reviewed sites, while the remaining 700 sites have an overlapping distribution with the "modal range" of MEI risks shifted lower by something like 2 or 3 orders of magnitude. (The mixing of hypothetical and existing receptor populations across sites in risk evaluations creates some difficulties for this concept of a risk distribution, particularly where the probability of hypothetical scenarios actually occurring is not considered). It may in fact be useful to think of three groups of sites rather than two, with the third group consisting of a set of minimal risk sites with modal risks shifted lower by an additional several orders of magnitude.

Similar conclusions are reached for MEI noncancer risks. The available studies are deemed representative of a subset of the total population of sites. While any site could have high MEI noncancer risks (expressed as a high Hazard Index (HI)), the majority of sites are expected to have a distribution of MEI risks with modal values shifted lower compared to the 18 sites reviewed. The contaminants associated most frequently with high HI values at the sites reviewed are metals (lead, chromium) and noncarcinogenic volatile organic compounds (1,1,1-trichloroethane, 1,1-dichloroethene). The sites with available risk assessment information may be biased toward selection of sites with carcinogenic contaminants. Remaining sites could therefore have a higher proportion of sites with significant noncarcinogenic health risks than is represented by the sites reviewed here.

INCIDENCE: The available risk assessment studies provide almost no information on projected incidence of adverse health effects; in many cases, they do not even provide estimates of the size of potentially affected populations. The exceptions are the Northwest Transformer and Commencement Bay Nearshore/Tideflats seafood ingestion risk assessments, both of which include estimated incidence. Human health risks have for the most part been characterized by MEI risks rather than incidence in existing studies of inactive hazardous waste sites.

To estimate incidence appropriately, the joint distribution of individual risks and exposed populations is needed. The data are not available in existing studies to map the varying individual risk levels as a function of location (e.g., distance) and correlate them with population size. The focus has instead been on MEI risk levels, or at least on selected point-of-exposure risks, such as at a defined existing residence. The only known location for which a joint distribution has been attempted is the Asarco Smelter, for which EPA (Schaum) in the early 1980's assessed the joint distribution of ambient air arsenic concentrations and population to estimate lung cancer incidence.

A conservative approach for estimating an upper bound on incidence for inactive hazardous waste sites was adopted for this evaluation, based on the lack of detailed information adequate to support a more appropriate estimate. This evaluation is for the limited purpose of deriving a comparative ranking among environmental threats in the Washington Environment 2010 study; the results, particularly the site-specific results, should not be used for any other purposes and are not considered to be best estimates nor predictions of actual incidence.

For each site, MEI cancer risks and estimates of exposed populations were compiled. At sites where exposed population data were lacking, including many sites where hypothetical future land use scenarios were evaluated, population sizes were assumed based on judgment. This approach for assigning missing values is consistent with the general order-of-magnitude precision in the upper bound incidence estimates derived for this evaluation. The MEI cancer risks were multiplied by the exposed population at each site to provide an upper bound estimate of incidence. The incidence values derived in this way for different sites were then summed and a measure of incidence on a per site per year basis was calculated. Finally, this measure was used together with some assumptions about the distribution of risk and populations affected across the total number of sites (assumed to be 800) to produce an estimate of total incidence.

Several additional features of the approach taken should be noted. Where multiple MEI risks for different scenarios are provided for a site, the most conservative among them is generally used. This most conservative result for incidence is defined as the one that produces the highest incidence value, considering both the MEI risk and population size. Incidence values for both worker (occupational) and residential exposures, and for both existing populations and hypothetical future populations (due to growth alone or change in land use), are included at some of the sites. The summation of incidence may be done for all scenarios, for residential scenarios only, for existing populations only, or for various combinations of these exposure scenarios. A range of incidence values will result. Finally, all cancer risks are assumed to be additive in this estimate, and in at least one case (Asarco Smelter, skin cancer outcomes) the cancer outcome is expected to have a low mortality rate. Therefore, this estimate of cancer incidence does not distinguish morbidity and mortality.

The data on MEI cancer risks and (assumed) exposed populations for each site reviewed, are provided in Table 1. The upper bound incidence results at individual sites range from very nearly 0 to a maximum of about 15 (Asarco Smelter) over a 70-year period. Considering the options for scenarios to be included, the cancer incidence for all 17 sites combined (no estimate for Gasworks Park) is about 30 to 48 over 70 years, or 0.025 to 0.04 per site per year. This range of incidence values is used as a basis for deriving an estimate for all 800 sites.

A linear scaleup to 800 sites using the higher value of 0.04 per site per year results in an estimate of 32 per year or 2,240 over 70 years. This is, however, believed to be a gross overestimate because the 17 sites reviewed are not representative of the total population; they are biased toward the higher-risk and higher-incidence sites. The bases for this conclusion are reviewed above in the discussion of MEI risks.

The survey results in Table 3 (attached) can be used to illustrate the distributional aspects of incidence among the total population of sites. High incidence results from the combination of MEI risk levels and population size. Consider sites with a rating of high for human health risk; incidence may be "high" for those sites where population exceeds 100. For sites rated medium on human health risk, similarly high incidence estimates may result only where population exceeds 1,000. This reasoning suggests a partitioning of the total population of 800 sites for deriving an estimate of incidence.

The estimate for total incidence is derived based on the following partitioning of sites, arrived at using best professional judgment only:

100 sites @ 0.025 to 0.04 per site per year

200 sites @ 0.006 to 0.01 per site per year

500 sites @ 0.0006 to 0.001 per site per year

The incidence levels per site per year are assumed to decrease by factors of 4 and 10 between the first and second and second and third categories of sites, respectively. The numbers of sites in each category are assumed to increase as the incidence levels decrease. The resulting estimates for total incidence for 800 sites are 4.0 to 6.5 per year, or 280 to 455 over 70 years.

The sensitivity of these results to one or a few highly significant sites was examined. An MEI risk of 5E-3 and a population of 20,000 would produce an estimated incidence of 100, or 1.43 per site per year (example: municipal water supply with significant level of contamination). A population of 1,000 at an MEI risk as high as 1E-2 would result in an estimated incidence of 10, or 0.14 per site per year. These examples suggest that at worst, a small number of sites with significant risk levels, would add only several cases per year to total incidence, resulting in a value still less than 10 per year.

If the number of sites with any quantifiable risk is 400 rather than 800, and the same relative distributional assumptions hold (sites allocated 50/100/250), total incidence would be one- half of the previous estimates. A range of 400 to 800 site may include most reasonable estimates of total site count.

Finally, the assumed incidence measures (per site per year) are believed to be very conservative. For the 17 sites reviewed, a substantial portion of the values reflect hypothetical exposure scenarios and populations with an uncertain (in some cases extremely unlikely) probability of occurrence. The factors of decrease in incidence measures for the second and third categories used in the derivation of total incidence are also judged more likely to be too low than too high. All of the MEI risk estimates and population estimates used to project incidence at the 17 sites reviewed also are conservative.

CONCLUSIONS: The conclusion reached in this evaluation of incidence is that all inactive hazardous waste sites in Washington are likely to have a cumulative upper bound incidence of between 1 and 10 cancers per year, with values at the low end of this range more likely. Values less than 1 per year are also possible.

An estimate of the total population potentially exposed to noncarcinogenic contaminants at levels producing a Hazard Index greater than 1.0 is difficult to derive based on available data. For the 17 sites reviewed, that total population is an estimated 2,150, including hypothetical future exposure scenarios. A linear scaleup to 800 sites would imply a potentially exposed population of more than 100,000. This is believed to be a gross overestimate. The cancer incidence results suggest that a value of 5% to 20% of the linear scaleup value may be more reasonable, or approximately 5,000 to 20,000 people (including hypothetical future populations) exposed at Hazard Index scores greater than 1.0. The level of confidence in these values is low based on limitations in the available data. One significant site (e.g., a municipal water supply using contaminated groundwater) could easily double these estimates.

DISCUSSION: All of the estimates for human health risks from inactive hazardous waste sites are based on exposure/risk calculations rather than direct observations. No confirming evidence for adverse health effects is available. There are many sources of uncertainty in the estimates, including the following:

- o the total number of sites that will be identified and found to have some quantifiable risks (i.e., not listed and then deleted)
- o the representativeness of available risk assessments for the remaining population of sites and the true distribution of risks across sites
- o the potential that total risks could be dominated by a very small number of sites
- o the degree of overlap with other environmental threats being evaluated and the allocation of risks between these overlapping problem areas
- o the probability of occurrence of hypothetical exposure scenarios used to judge potential human health risks
- o the degree of conservatism in available risk estimates, and the significant differences in risk estimation approaches among available studies
- o the timing of risks, for example, based on modeling of ground water plume development and expected time of exposure for downgradient populations

Individual exposure and risk calculations are subject to a large number of uncertainties related to each of the parameters and assumptions needed to complete the calculation. Contact rates, contaminant concentrations at receptor locations, potency factors, the populations considered exposed (existing or hypothetical), and numerous other elements of the calculation are uncertain. Agency policy has driven these calculations to be conservative, with a low probability of underestimating risks. The available risk estimates may therefore reflect this conservatism and may represent conservative (upper bound) values. When translated to projections for a much larger number of sites, this conservatism has a multiplicative effect on the estimates of total risk or incidence.

In general the estimated individual (MEI) risks for inactive hazardous waste sites can be relatively high. The populations exposed are, however, typically not very large, constraining the estimates of incidence. (Exceptions where relatively large populations are exposed include Well 12A and the areas surrounding the Asarco Smelter).

The sites reviewed under-represent eastern Washington, based on the proportion of sites in the current inventory from eastern counties. There are also no chemical or pesticide manufacturing or handling facilities included within the site risk assessments reviewed. The available studies may not be adequately representative of certain facility types, contaminants, or geographic locations that could affect site risks or the incidence of adverse health effects.

No one contaminant or class of contaminants appears to dominate the risks in this environmental threat. Sites with MEI risks from 1E-4 to 1E-2 represent a variety of contaminants.

SUMMARY: Detailed risk assessments for 18 sites were used as a basis for estimating MEI risks and incidence of adverse human health impacts for inactive hazardous waste sites. The representativeness of these sites for an assumed total population of 800 sites and the distribution of human health risks across that total number of sites were considered in the evaluation.

Inactive hazardous waste sites reflect a broad range of MEI risks, with the upper end of that range representing very significant risks (1E-2 or higher). The sites reviewed had a "modal range" of MEI risks of approximately 1E-4 to 1E-2. Those sites are believed to represent a subpopulation biased toward higher risks compared to the overall population of inactive hazardous waste sites.

An upper bound for the total incidence of cancer for 800 sites was estimated using an assumed allocation of sites to three levels of risk and population exposure. Total incidence (upper bound) is estimated to be from 1 to 10 cancer cases per year, with values at the lower end of the range more likely and values below 1 case per year possible. The total population exposed to noncarcinogenic contaminants at a Hazard Index greater than 1.0 is very difficult to estimate with available data, but may be from 5,000 to 20,000 for 800 sites.

ECOLOGICAL RISKS

INTRODUCTION: With a few notable exceptions, the risk and endangerment assessments reviewed for this evaluation either did not discuss ecological risks at all or provided only the most cursory discussion of environmental and ecological effects. The risks considered in available risk assessments have been human risks, except for sites where marine/estuarine impacts were a prominent reason for originally placing the site on the Superfund NPL (e.g., Commencement Bay Nearshore/Tideflats and Wyckoff/Eagle Harbor).

As a result of this limited amount of available information, ecological risks are discussed at a qualitative level only in this evaluation. Best professional judgment was used to attempt to characterize the types of ecosystem impacts from inactive or uncontrolled hazardous waste sites and their potential significance.

A survey of Ecology site managers and field inspectors was conducted for their best professional judgement regarding environmental risks posed by inactive or uncontrolled hazardous waste sites. A summary of the results, showing the distribution of risk ranges by county, is attached as Table 2B. Also, a bar chart visually presenting the distribution of risk categories, is included as Attachment #7. The distribution of environmental risk categories of high/medium/low/unknown or unrated for all 697 sites in the SMIS database was 71/122/170/325 or 10%/18%/25%/47% respectively.

ANALYTICAL APPROACH: A general characterization of ecological risks was developed from the perspectives of both sources (site types) and receptors (affected ecosystems). The types of environmental impacts and flora and fauna damage associated with particular types of sites were first considered in an overview of potential ecosystem risks from the perspective of sources. Then ecosystem impacts and measures of risk for defined ecosystems were compiled based on the limited available database for inactive hazardous waste sites and best judgment. A substantially improved database or evaluation approach appears to be required to begin to quantify ecological risks for these sites.

OVERVIEW OF SITE TYPES: A number of site types can be identified which have characteristic kinds of ecosystem impacts associated with them. Several site types are briefly discussed below; this list is not meant to be complete with respect to the types of inactive hazardous waste sites on the current state inventory list.

1. Urban Embayments and Nearshore Manufacturing and Industrial Facilities. The rich biological resources of many marine/estuarine systems may be impacted by the release of contaminants of many kinds from nearshore sites. Stormwater runoff, ground water discharge, direct waste disposal practices, and atmospheric transport and deposition of contaminants may be involved in impacts to water quality, sediment quality, and biota. Sites that are designated within this site type often include a large number of potential sources, both site specific and regional (e.g., collected stormwater

runoff). Examples include Commencement Bay Nearshore/Tideflats and Harbor Island. Other sites may have only one or a few potential sources and may focus on selected contaminants. Examples include Cascade Pole (Olympia) and Wyckoff/Eagle Harbor.

2. Landfills and Recycling Operations. Many kinds of potentially hazardous materials are commonly present at landfills, including municipal landfills, and recycling sites. Some recycling sites have in fact been operated more as disposal sites. The most common problems at these sites are leachate generation and the contamination of ground water resources and soil contamination. Nearby aquatic resources can be affected by ground water recharge, surface runoff, or other pathways of contaminant transport; nearby soils may be impacted by runoff or resuspension and deposition of contaminated particulates, creating potential impacts for terrestrial biota. Transformer recovery and salvage yards are a subcategory of this type of site for which PCBs and dioxins are contaminants of major concern. Sites such as Toftdahl Drums, Western Processing, Northwest Transformer, Strandley/Manning, and the numerous active and inactive landfills from the state inventory are included in this site type.

3. Wood Treating. The nature of the chemicals involved in wood treating operations (biocides) and the common operating practices of the industry historically create the potential for ecological impacts. Loss of product through spills and normal operations, retort cleanout sludges, and soil and ground water contamination have all been noted as potential problems at these sites. A number of these sites are located nearshore with potential impacts to marine/estuarine resources. Sites in this category include Wyckoff/Bainbridge Island, Cascade Pole (Olympia), American Crossarm, and Oeser. Similar chemical contaminants in similar settings occur at sites involved with historical coal or oil gasification, such as Gasworks Park and Quendall Terminal.

4. Mining and Smelting. Mining operations commonly have major potential for ecological impacts due to their degree of surface disturbance and possible releases of contaminants from treatment chemicals (e.g., cyanide) or from mineralized resources (heavy metals). The number and scale of mining sites within Washington, however, is limited. Primary and secondary smelters have been identified with air emissions of contaminants (e.g., arsenic, copper, lead, aluminum, fluoride, acid gases) that are transported and deposited over broad areas. Vegetative stress and accumulation of contaminants in soils can result, as well as accumulation of contaminants in aquatic and marine sediments with effects on biota. The Asarco Smelter and a secondary lead smelter on Harbor Island are examples of this type of site. Electroplating facilities may also be considered as sources of metals, but with surface water and ground water impacts of primary concern rather than air emissions. Electroplating rinsewaters and sludges are potentially of ecological concern if improperly handled.

5. Chemical/Pesticide Manufacturing and Storage. The nature of pesticide chemicals (biocides) makes their release a potential source of ecological risks. Other chemical manufacturing may also invlove contaminants of potential biological toxicity. Ground water and surface runoff contamination from spills or residues of chemical

manufacture or storage are potential pathways of primary concern. Sites such as Reichhold, Pennwalt, and numerous pesticide handling facilities in agricultural areas of the state are included in this category.

ECOSYSTEM IMPACTS: Three ecoregions in the state (Omernik and Gallant, July 1986, EPA/600/3-86/033) include most of the currently listed inactive hazardous waste sites. The three ecoregions in Washington are the Coast Range, the Puget Lowland, and the Columbia Basin. Most of the listed sites (see Table 2) are in the areas west of the Cascade Mountains and are therefore in the first two ecoregions, primarily the Puget Lowland. Sites in Clark County are included in the Willamette Valley ecoregion.

The ecosystem in which most impacts have been identified to date is the marine/estuarine ecosystem, and especially urban embayments. Two of the sites reviewed - Commencement Bay Nearshore/Tideflats and Wyckoff/Eagle Harbor - have been studied in detail and have documented impacts. Freshwater ecosystems have not been studied in comparable detail. The Western Processing site has identified impacts to Mill Creek, a tributary to the Duwamish River, and some impacts in Hylebos Creek (from the B & L Woodwaste site and others) have also been noted. Terrestrial ecosystems have not been studied in any detail in the sites reviewed for this evaluation. A brief general discussion of potential risks for these ecosystems follows.

1. Marine and Estuarine Ecosystems. Ecological risks in these ecosystems can be defined based on the investigations of urban embayment sites (EPA, Puget Sound Estuaries Program) as well as Remedial Investigations of NPL sites such as Commencement Bay and Eagle Harbor. Risks include:

- changes in species composition and depressed species abundances
- sediment toxicity, as shown directly in bioassay tests and chemical concentrations exceeding apparent effects thresholds
- bioaccumulation of contaminants in fish and shellfish tissues
- fish disease (e.g., liver tumors) and mortality as shown in reciprocal transplant experiments and bioassay tests
- reproductive effects
- localized exceedance of some ambient water quality criteria

2. Freshwater Ecosystems. The ecological risks in freshwater ecosystems are similar to those in marine/estuarine ecosystems, but less well documented to date. Risks include:

- exceedance of ambient water quality criteria, showing a potential for toxicity effects and avoidance behavior
- changes in species composition and depressed species abundance

- potential impacts on spawning and reproduction
- bioaccumulation of contaminants in fish tissues
- accumulation of contaminant concentrations in freshwater sediments, with potential toxicity and food-chain effects
- fish disease and excess mortality

3. Terrestrial Ecosystems. Terrestrial ecosystem risks may be more limited for this environmental threat than risks to other ecosystems. They are virtually undocumented in the available site studies. The Colbert site study suggests a possibility of risks from livestock watering using contaminated ground water, and possible risks to birds have been mentioned in one or two site studies. Mining and smelting sites probably affect the largest areas within terrestrial ecosystems. Mining sites are not prominent on the state inventory. Limited information on terrestrial impacts is available for major smelting sites in the state. Ecosystem risks may include:

- denudation and chronic loss of vegetative cover. (This does not appear to be documented in the Washington State).
- vegetation stress and reduced vigor and growth
- bioaccumulation of contaminants (natural vegetation, crops, terrestrial fauna)
- disease or mortality in sensitive species of terrestrial fauna (e.g., bees)

DISCUSSION: Ecological risks for inactive hazardous waste sites may overlap with other environmental threats and be double-counted. Allocation of ecological risks should be reviewed by site categories.

The percentage of sites that is expected to produce ecological damages cannot be estimated from the available data for sites reviewed in this evaluation. However, previous estimates from the national comparative risk study and the EPA Region 10 CERCLIS file coding suggest that no more than 10 or 15 percent, and probably half that number, of the total site inventory will produce any ecosystem damages.

On a site-specific basis, impacts may be severe. Only a few sites can be expected to result in spatially extensive impacts; for most sites, impacts will be relatively confined in area. Multiple-source urban embayment sites probably provide the extreme case for extent of impacts. The primary resources affected in the state appear to be marine/estuarine resources, reflecting the concentration of sites in the Puget Sound region and the significance accorded to those resources. Without remedial actions, ecosystem effects may be long-lasting, especially for contaminants that are not very biodegradable (e.g., heavy metals, some PAH compounds).

Even tentative conclusions such as these are deemed preliminary and uncertain based on the limited available information on ecosystem risks.

SUMMARY: The available data on ecosystem risks are very limited. Generalized risks for marine/estuarine, freshwater aquatic, and terrestrial ecosystems are identified. Marine/estuarine resources appear to be the most affected based on current information. Ecosystem impacts from inactive hazardous waste sites are judged to be of low to moderate severity state-wide, but potentially severe on a site-specific basis. They are generally localized in extent and may be long-lasting due to the accumulation and persistence of contaminants and slow natural recovery processes.

REFERENCES

The reports of several previous comparative risk studies were reviewed for this evaluation. These studies included the national EPA study ("Unfinished Business: A Comparative Assessment of Environmental Problems", February 1987), the EPA Region 10 study (Abandoned Hazardous Waste Sites memoranda), and a Denver-area study ("A Discussion of Potential Human Health Risks and Natural Resource Damages From Metro-Denver 'Superfund' Sites", May 1987).

Risk Assessment Reports for individual sites were also reviewed (see Table 1 for identification). I would like to gratefully acknowledge the assistance of Greg Glass (Greg Glass, Inc.) who was able to compare and contrast the available risk assessments, to "crunch numbers", and to help in developing the assumptions used throughout this report using his best professional judgement.

TABLE 1 (PAGE 1 OF 19)
EVALUATION OF DETAILED RISK ASSESSMENT

SITE NAME: Tacoma Smelter (on-site) Pierce County

REFERENCE: Remedial Investigation Volume #4 by ETI (4/89)
Baseline Risk Assessment

SITE TYPE: Copper Smelter, Industrial

CONTAMINANTS: Metals (As, Sb, Cd, Cu, Cr, Pb, Hg, Ni), HPAH's, PCB's

HEALTH OUTCOMES: Cancer (As, Cr, Cd, Ni, HPAH's. PCB's)
Noncancer

MEI RISKS: Onsite Residential(OR): 1E-1 to 3E-3
Offsite Industrial(OI): 3E-2 to 5E-4
Offsite Residential(OFFR): 4E-4 to 4E-5
Offsite Residential (Hazard Index): 4 to 60 for Pb

PATHWAYS/SCENARIOS: OR for ingestion (soil, vegys) inhalation, & dermal
OI for ingestion (soil), inhalation, and dermal
OFFR for partial inhalation and ingestion (soil deposition)
All onsite receptors are hypothetical

POPULATION EXPOSED: OR is 100 estimated
OI is 500 estimated
OFFR (see Ruston/Vashon site)

INCIDENCE: OR is 0.3 to 10
OI is 0.25 to 15

ECOLOGICAL EFFECTS: Onsite metals concentrations exceed plant tolerances. Groundwater and surface waters and air deposition contribute to marine impacts.

TABLE 1 (PAGE 2 OF 19)
EVALUATION OF DETAILED RISK ASSESSMENT

SITE NAME: Tacoma Smelter, Ruston/Vashon (Pierce County)

REFERENCE: Endangerment Assessment by Black & Veatch (9/88)

SITE TYPE: Copper Smelter, Offsite Residential

CONTAMINANTS: Arsenic

HEALTH OUTCOMES: Cancer (skin & lungs)

MEI RISKS: lung 4.7E-4 to 3.5E-4
skin 3.7E-3 to 1.1E-3

PATHWAYS/SCENARIOS: Risks by distance (4 increments)
0 - 1/2 mile shown here
High use and residential areas
Ingestion (soils, house dusts) &
Inhalation (indoor & outdoor)
Existing populations

POPULATION EXPOSED: Assume 0 - 1/2 mile is 3,000
1/2 - 1 mile is 3,000

INCIDENCE: 0 - 1 mile: lung is 1.4
skin is 5.0

ECOLOGICAL EFFECTS: Not Applicable

TABLE 1 (PAGE 3 OF 19)
EVALUATION OF DETAILED RISK ASSESSMENT

SITE NAME: Tacoma Tar Pits (Pierce County)

REFERENCE: Risk Assessment by Envirosphere (7/87)

SITE TYPE: Coal gasification (historical), industrial

CONTAMINANTS: PAH's (BaP), Lead, PCB's

HEALTH OUTCOMES: Cancer (PAH's, PCB's)
Noncancer (lead)

MEI RISKS: (not given in report; back calculated)
BaP: 1.0E-3 to 5E-4
PCB's: 2E-4
Lead: Hazard Index about 10 to 20
(Based on maximum concentrations & soil concentration objectives)

PATHWAYS/SCENARIOS: Worker exposures by inhalation, ingestion, & dermal.
Dermal controls risks given assumptions.
Nonstandard assumptions used in calculating exposures & risks.

POPULATION EXPOSED: Assume 100 (hypothetical future)

INCIDENCE: 0.1

ECOLOGICAL EFFECTS: Onsite bird population evaluated and not considered affected.
Surface runoff and groundwater discharges to the Puyallup River and Commencement Bay Nearshore Tideflats.
Maximum concentrations exceed ambient water quality criteria, but adequate dilution available.

EVALUATION OF DETAILED RISK ASSESSMENT

SITE NAME:Commencement Bay Nearshore Tideflats (Pierce County)

REFERENCE:Versar (4/85)
ATSDR Health Assessment (7/88)
Feasibility Sediment Cleanup Goals (PTI - 2/89)

SITE TYPE:Port, Tideflats Area, Industrial, Multiple Sources

CONTAMINANTS:(Numerous) Metals, PCB'c, LPAH's, HPAH's, other organics

HEALTH OUTCOMES:Cancer and Noncancer

MEI RISKS:No ADI exceedances at <0.5 lb/day consumption
Total cancer risk at 1 lb/day 6.5E-3 (esp. PCB's & As)
Fish liver ingestion risks up to 1E-2 (PCB's)

PATHWAYS/SCENARIOS:Only fish/shellfish ingestion pathway (see ATSDR comments)
Various ingestion rates evaluated
Concentration data for raw, not cooked fish

POPULATION EXPOSED:(Tacoma/Pierce County Health District survey)
Total population = 15,220 at various consumption rates

INCIDENCE:PCB cancers: 1 to 2 per 70 years
All other constituents: cumulative < 1/70 years

ECOLOGICAL EFFECTS:Apparent Effects Threshold (AET) derived based on measured biological impacts. Bioassay testing toxicity, benthic community effects, bioaccumulation in tissues.

TABLE 1 (PAGE 5 OF 19)
EVALUATION OF DETAILED RISK ASSESSMENT

SITE NAME: Ethylene Dibromide (EDB) Sites (Whatcom County)

REFERENCE: Phase I Investigation by Black & Veatch (6/86)
(Branchflower)
DSHS letter by Nash (8/88)

SITE TYPE: Agricultural pesticide application

CONTAMINANTS: EDB

HEALTH OUTCOMES: Cancer and Reproductive Toxicity

MEI RISKS: Exceeds proposed MCL and advisory levels
Cancer risks at 2 sites using EPA-Weibull Model
A: 9.8E-5 to 1.5E-3
B: 4.0E-4 to 6.5E-3
(other models x200+ lower)

PATHWAYS/SCENARIOS: Drinking water ingestion
(No dermal permeability constant, so dermal pathway not evaluated)
(Showering estimated to result in inhalation exposure at 40% of drinking water exposure)

POPULATION EXPOSED: 8 wells tested positive
(No population information given. Estimated 20 people at each well = 160)

INCIDENCE: (order of magnitude)
< 1 per lifetime
(6.5E-3 x 160 = 1)

ECOLOGICAL EFFECTS: Not discussed

TABLE 1 (PAGE 6 OF 19)
EVALUATION OF DETAILED RISK ASSESSMENT

SITE NAME: Western Processing (King County)

REFERENCE: Feasibility Study/Subsurface Cleanup by CH2M-HILL (3/85)

SITE TYPE: Waste treatment/recycling
Industrial

CONTAMINANTS: 90 priority pollutants and 29 carcinogens
Indicators: metals, PCB's and VOC's

HEALTH OUTCOMES: Cancer and noncancer

MEI RISKS: Onsite surface soils (OS) 5E-7(workers), 2E-5(residential)
Onsite subsurface soils(OSS) 2E-4(workers), 1E-2(residential)
Hazard Index (lead) 5.7 to 141 (OS, OSS)
Offsite (OFF) soils 3E-5 (workers), 1.5E-3 (residential)
Hazard Index (lead) 3.8
Drinking water 8E-3 (workers(W)), 3E-2 (residential(R))

PATHWAYS/SCENARIOS: OS/W,R: Onsite soil ingestion, surface workers, residential
OSS/W,R: onsite soil ingestion, subsurface workers, residential
OFF: Offsite soil ingestion, surface
Drinking water: Hypothetical onsite drinking water
(Note: missing risks for PAH's, other compounds)

POPULATION EXPOSED: Assume 100 (R) and 200 (W)

INCIDENCE: (Including drinking water and OSS) Workers: 1.6
Residential: 4.0

ECOLOGICAL EFFECTS: Mill Creek affected, species abundance and composition. Ambient Water Quality Criteria exceeded. High sediment concentration of contaminants.

TABLE 1 (PAGE 7 OF 19)
EVALUATION OF DETAILED RISK ASSESSMENT

SITE NAME: Northwest Transformer (Whatcom County)

REFERENCE: EPA Risk Assessment in Feasibility Study by HDR (8/88)

SITE TYPE: Recycling electrical equipment

CONTAMINANTS: PCB'c, Dioxin/Furans

HEALTH OUTCOMES: Cancer

MEI RISKS: Dioxins: <1E-6
PCB's: Soils residential 2E-3
Grazing residential 2E-2
Offsite Drinking Water: 1 to 3E-5

PATHWAYS/SCENARIOS: Hypothetical future residential: soil ingestion, vegetable ingestion, drinking water, inhalation, dermal
Cattle grazing and beef/milk ingestion
Offsite drinking water ingestion

POPULATION EXPOSED: (as stated) Onsite residential population:16
Beef/milk ingestion population:4
Offsite population:8

INCIDENCE: Onsite residential: 0.001/year
Grazing: 0.007/year
Offsite drinking water: <0.00002/year

ECOLOGICAL EFFECTS: none discussed

TABLE 1 (PAGE 8 OF 19)
EVALUATION OF DETAILED RISK ASSESSMENT

SITE NAME: Frontier Hard Chrome (Clark County)

REFERENCE: Endangerment Assessment by Dames & Moore / Bovay

SITE TYPE: Electroplating

CONTAMINANTS: Cr, Ni, Pb, PCE, TCE, TCA, CCL4

HEALTH OUTCOMES: Cancer and noncancer

MEI RISKS: TCE 1.44E-4
PCE 1.47E-2
Hazard Index: Cr 143, TCA 6, (>drinking water standards)
Soil ingestion > Acceptable Daily Intake (ADI) for Cr and Pb (possible)

PATHWAYS/SCENARIOS: Monte Carlo Simulation Methods
Groundwater and soil ingestion
Fugitive dust inhalation
(hypothetical groundwater use)

POPULATION EXPOSED: Not discussed
Assumed: Drinking water population = 50
Onsite soils population = 100

INCIDENCE: Drinking water 0.75

ECOLOGICAL EFFECTS: Adequate dilution in Columbia River. Information that discharge to treatment plant previously toxic to biological organisms.

TABLE 1 (PAGE 9 OF 19)
EVALUATION OF DETAILED RISK ASSESSMENT

SITE NAME: Wyckoff / Eagle Harbor (Kitsap County)

REFERENCE: Assessment of ERA's by Tetra Tech (12/87)
Preliminary Natural Resource Survey by NOAA (10/88)

SITE TYPE: Wood Treating, Industrial

CONTAMINANTS: (Creosote, PCP)
HH Indicators: ethylbenzene, phenol, TetraCP, PCP, BaP, & HPAH, dioxin/furans
(Note: NOAA also metals, but not high in soils and groundwater)

HEALTH OUTCOMES: Cancer and noncancer

MEI RISKS: (Note: at maximum concentrations)
4E-1 to 9.7E-1 (with all HPAH included)
Cumulative Hazard Index to 0.4 to 2.9 (without TetraCP, ND)
Shellfish ingestion only: 1E-5 to 8E-4

PATHWAYS/SCENARIOS: Ingestion: soils, groundwater, shellfish
Scenarios: Children (5 years), workers (40), lifetime residential (70)
(Calculations at maximum concentrations, at solubility limits for groundwater, without groundwater, and at no access)
Assumes 100% absorption

POPULATION EXPOSED: Not discussed.
Assume: population 500 for shellfish
100 for onsite

INCIDENCE: Using worst case risks: soils = 0.2
shellfish = 0.4
(groundwater = about 100%)

ECOLOGICAL EFFECTS: Exceedances of AWQC. Reductions of up to 1,000,000+ (flouranthene) required.
Sediment AET's exceeded.
Data support depressed benthic abundances, tissue bioaccumulation, toxicity, liver disease.
Resources: benthic prey species for salmon, spawning area.

TABLE 1 (PAGE 10 OF 19)
EVALUATION OF DETAILED RISK ASSESSMENT

SITE NAME:Cascade Pole (Thurston County)

REFERENCE:Risk Assessment by ERT (5/87)

SITE TYPE:Wood treating, industrial

CONTAMINANTS:HPAH's, Pentachlorophenol, Dioxin/furans, phenol, benzene

HEALTH OUTCOMES:Cancer: HPAH's, benzene, dioxin
Noncancer: PCP, phenol, & total PAH's

MEI RISKS:Seafood ingestion: 3E-9
Child: 2E-4 to 6E-4
Adult: 4E-4
Hazard Index: <1
Acute dermal effects possible

PATHWAYS/SCENARIOS:Seafood ingestion from contamination of water quality and sediments.
Child exposures from ingestion, inhalation, dermal
Adult exposures from ingestion, inhalation, dermal
Acute dermal effects concentrations

POPULATION EXPOSED:Assume: 100 (workers - hypothetical future)

INCIDENCE:0.04

ECOLOGICAL EFFECTS:Estimated concentration of groundwater discharge are less than AWQC. (Ecology questions model of groundwater discharge)

TABLE 1 (PAGE 11 OF 19)
EVALUATION OF DETAILED RISK ASSESSMENT

SITE NAME: American Crossarm (Lewis County)

REFERENCE: EPA Region 10 Risk Assessment (Post flooding)

SITE TYPE: Wood treating
Residential community affected by flood residues

CONTAMINANTS: Dioxin, PCP

HEALTH OUTCOMES: Cancer

MEI RISKS: Onsite soils: 2 to 5E-5
Homes: maximum 3.2E-3 before cleaning
maximum 6E-4 after cleaning
average 8E-4 before cleaning
average 8E-5 after cleaning

PATHWAYS/SCENARIOS: Risks evaluated after flooding of site. Cleanup actions taken at offsite homes.
Pathways: soil ingestion, dermal, inhalation
Onsite workers, residents (hypothetical)
Existing offsite residences

POPULATION EXPOSED: Offsite: 15 homes and 2 businesses
Assume: population = 50 offsite
population = 100 onsite

INCIDENCE: 0.035

ECOLOGICAL EFFECTS: Not discussed.
Contaminants spread around areas near the site by flooding.

TABLE 1 (PAGE 12 OF 19)
EVALUATION OF DETAILED RISK ASSESSMENT

SITE NAME: Well 12A Tacoma (Pierce County)

REFERENCE: Feasibility Study. Final Draft Report by EPA (7/84)

SITE TYPE: Municipal supply well, (oil sludge disposal)

CONTAMINANTS: PCE, TCE, Trans 1,2-DCE, 1,1,2,2-Tetrachloroethane

HEALTH OUTCOMES: Cancer and noncancer

MEI RISKS: Drinking water: 5E-6 to 2E-5 at existing conditions
3E-4 potential
Hazard index < 1
Soils: 2.1E-7 to 6.3E-5
Worker inhalation: x4 OSHA 8 hour
(Baseline = no treatment)

PATHWAYS/SCENARIOS: Drinking water: well used 90 days per year, lifetime and x6 reservoir dilution
Soils: range of assumption for ingestion, dermal contact. High soil contact rate (1-10 grams/day)
Inhalation: by soil disturbance, volatilize contaminants

POPULATION EXPOSED: Assume: Population = 500 for onsite soils
Population = 60,000 for drinking water

INCIDENCE: 1.23

ECOLOGICAL EFFECTS: Not discussed

TABLE 1 (PAGE 13 OF 19)
EVALUATION OF DETAILED RISK ASSESSMENT

SITE NAME:Ponders Corner (Pierce County)

REFERENCE:Feasibility Study by CH2M-Hill (7/85)

SITE TYPE:Dry Cleaners, solvent disposal

CONTAMINANTS:PCE, TCE, Trans 1,2-DCE

HEALTH OUTCOMES:Cancer

MEI RISKS:With air stripping: Drinking water 7E-8, bathing dermal 1E-7, inhalation small
Hypothetical private well: 9E-6 drinking water, 9E-6 contact
Soils (40 years): 6E-9

PATHWAYS/SCENARIOS:Lakewood water supply, drinking water, and bathing (dermal, contact, inhalation)
Private well ingestion and inhalation
Contaminated soils contact, volatilization

POPULATION EXPOSED:Assume: water district population = 20,000
soil population exposed = 100

INCIDENCE: 0.0034

ECOLOGICAL EFFECTS:Gravelly Lake, Clover Creek evaluated. No significant impacts; much less than AWQC.

TABLE 1 (PAGE 14 OF 19)
EVALUATION OF DETAILED RISK ASSESSMENT

SITE NAME: Colbert Landfill

REFERENCE: Feasibility Study by Golder Assoc. and Envirosphere Co (5/87)
ATSDR Health Assessment (4/88)

SITE TYPE: Municipal landfill (solvent disposal)

CONTAMINANTS: 1,1,1-TCA, 1,1-DCE, 1,1-DCA, TCE, PCE, Methylene Chloride

HEALTH OUTCOMES: Cancer and noncancer

MEI RISKS: (Risks at maximum concentration in groundwater)
Calculated from Risk Assessment MAC's
- 6.3E-3 for DCE
- 1.0E-3 for MC
- 7.2E-5 for TCE
- 3.3E-5 for PCE
- TOTAL with DCE is 7.4E-3
- TOTAL w/o DCE is 1.1E-3

Hazard Index
- 28 for TCA
- 27 for DCE

Indoor Air < OSHA Standards
Possible Dermal Risk from showers

PATHWAYS/SCENARIOS: Groundwater uses: Drinking water ingestion, dermal, and inhalation.
Impacts to human health via crops and livestock discounted.
Impacts at Little Spokane River considered.
MAC's: Maximum allowable concentration derived using 20% from drinking water and 20% from dermal exposure.
Latin Hypercube sampling technique used.

POPULATION EXPOSED: Population within 3 miles = 1,500. Assume 50% potentially affected without controls, or population of 750.

INCIDENCE: 5.55 with DCE as carcinogen
0.825 without DCE

ECOLOGICAL EFFECTS: Concentrations in Little Spokane River much less than Aquatic Water Quality Criteria even at 7 day, 10 year low flows.
Possible chronic toxicity to aquatic species; possible impacts from livestock watering.

TABLE 1 (PAGE 15 OF 19)
EVALUATION OF DETAILED RISK ASSESSMENT

SITE NAME:North Landfill (Spokane County)

REFERENCE: Feasibility Study by CH2M-Hill (8/88)
ATSDR Health Assessment (4/88)

SITE TYPE:Municipal Landfill, Dry cleaning sludges and POTW skimmings

CONTAMINANTS:PCE, TCE, 1,1,1-TCA, 1,1-DCA, (other VOC's detected at low concentrations and frequency) -

HEALTH OUTCOMES:Cancer and noncancer

MEI RISKS:ATSDR at maximum concentrations in groundwater data:
PCE 5.8E-5, TCE 7.9E-6 (drinking water)
CH2M-Hill at calculated possible concentrations at locations: total oral plus inhalation risk of 2 to 3E-6.
TCA hazard index < 1.0

PATHWAYS/SCENARIOS:Groundwater: drinking water ingestion, inhalation from groundwater use, dermal contact.
Assumes: inhalation at x1-6 drinking water ingestion
dermal at x1-10 drinking water ingestion

POPULATION EXPOSED:With expected growth population = 65. Also 35 private wells put on alternate water supply
Assume: population = 150

INCIDENCE: 0.0099

ECOLOGICAL EFFECTS:No significant impacts to Spokane River, aquatic, or terrestrial species expected.

TABLE 1 (PAGE 16 OF 19)
EVALUATION OF DETAILED RISK ASSESSMENT

SITE NAME:Midway Landfill (King County)

REFERENCE:Feasibility Study Endangerment Assessment by Parametrix/ICF (4/88)
Feasibility Study Pathways Report (10/88)

SITE TYPE:Municipal Landfill

CONTAMINANTS:Air pathways only: 18 VOC's (halogenated aliphatics, monocyclic aromatics, ketones, carbon disulfide)

HEALTH OUTCOMES:Cancer and noncancer

MEI RISKS:2E-6 to 4E-8 for adults
9E-7 to 2E-8 for children
Hazard Index for all is much less than 1.0
Concentrations less than U.S. ambient concentrations
(Risks adjusted for Non-detects in data)

PATHWAYS/SCENARIOS:Exposure from gas flares, offsite gas vents, and subsurface gas migration
Adults: MEI, reasonable maximum and most plausible scenarios
Children: Reasonable maximum and most plausible

POPULATION EXPOSED: Census tract totals: 14,423
Impact area: 8,230
(Increase of about 30% by year 2000)
(Retail businesses not included)

INCIDENCE: <0.01 (Does not include groundwater pathway)

ECOLOGICAL EFFECTS:Not discussed

TABLE 1 (PAGE 17 OF 19)
EVALUATION OF DETAILED RISK ASSESSMENT

SITE NAME: Tacoma Landfill (Pierce County)

REFERENCE: Remedial Investigation by Black & Veatch (12/87)

SITE TYPE: Municipal landfill

CONTAMINANTS: Vinyl chloride, benzene, chloroethane, toluene, methylene chloride, 1,1-DCA, 1,2-DCA

HEALTH OUTCOMES: cancer and noncancer

MEI RISKS: (at maximum concentrations offsite estimated from existing onsite data)
- 4.76E-3 Total cancer risk
- 4.7E-3 vinyl chloride
- Inter-monitoring risk 6.7E-7
- Hazard Index < 1.0
- Inhalation exposures from landfill gas less than Threshold Limit Values (TLV)

PATHWAYS/SCENARIOS: Groundwater: drinking water ingestion
Inhalation only gas flares, seepage, and migration of landfill gas

POPULATION EXPOSED: Assume: 100 (in unincorporated areas offsite)

INCIDENCE: 0.47

ECOLOGICAL EFFECTS: Leach Creek evaluated. Concentrations < AWQC.
Minimal aquatic or terrestrial biological effects.

TABLE 1 (PAGE 18 OF 19)
EVALUATION OF DETAILED RISK ASSESSMENT

<u>SITE NAME</u>:Strandley Scrap Metal (Kitsap County)

<u>REFERENCE</u>:Focused Feasibility Study by Tetra Tech (7/85) cited in Maxim 1989

<u>SITE TYPE</u>:Recycling electrical equipment

<u>CONTAMINANTS</u>:PCB's

<u>HEALTH OUTCOMES</u>:Cancer

<u>MEI RISKS</u>:Worst Case: 5.4E-1
Mid Case: 5.4E-3
Low case: 1.8E-6

<u>PATHWAYS/SCENARIOS</u>:Soil ingestion
Note: Maxim quotes very high soil contact rates by Tetra Tech (about x100 usual values).
(As of 5/5/89 original study has not been reviewed)

<u>POPULATION EXPOSED</u>:Not discussed

<u>INCIDENCE</u>:Not discussed

<u>ECOLOGICAL EFFECTS</u>:Not discussed

TABLE 1 (PAGE 19 OF 19)
EVALUATION OF DETAILED RISK ASSESSMENT

SITE NAME: Gas Work Park (King County)

REFERENCE: Eaton of University of Washington (Committee report sent by Parks Department 5/9/89)

SITE TYPE: Historical gasification plant, industrial site (converted to city park)

CONTAMINANTS: HPAH's

HEALTH OUTCOMES: Cancer

MEI RISKS: (See notes)

PATHWAYS/SCENARIOS: Detailed exposure models evaluated and compared to other HPAH (BaP) exposures. Quantitative risks not calculated, but comparative risks shown to be small. Some hot spots identified.

POPULATION EXPOSED: Recreational uses: Parks Department has data.

INCIDENCE: very low

ECOLOGICAL EFFECTS: Groundwater discharges to Lake Union and possible impacts on water quality and biota being studied.

TABLE #2

DISTRIBUTION OF SITES BY COUNTY
TOTAL COUNT: 697 (AS OF 6/5/89)

	COUNTY	TOTAL NO. OF SITES	RISK ASSESSMENTS REVIEWED
	ADAMS	4	
	ASOTIN	1	
	BENTON	16	
	CHELAN	12	
	CLALLAM	2	
	CLARK	41	1
	COWLITZ	18	
	DOUGLAS	3	
	FERRY	2	
	FRANKLIN	5	
	GRANT	10	
	GRAYS HARBOR	8	
	ISLAND	10	
	JEFFERSON	5	
	KING	212	3
	KITSAP	20	2
	KITTITAS	11	
	KLICKITAT	1	
	LEWIS	11	1
	MASON	5	
	OKANOGAN	13	
	PACIFIC	3	
	PIERCE	99	7
	SKAGIT	15	
	SKAMANIA	1	
	SNOHOMISH	32	
	SPOKANE	44	2
	STEVENS	5	
	THURSTON	19	1
	WALLA WALLA	3	
	WHATCOM	36	2
	WHITMAN	2	
	YAKIMA	28	
TOTALS	32	697	19

TABLE #2A

DISTRIBUTION OF SITES BY COUNTY
HUMAN HEALTH RISK RATINGS BY COUNTY
TOTAL COUNT: 697 (AS OF 6/5/89)

COUNTY	NO. OF SITES	RISK ASSESSMENTS REVIEWED	RATED HUMAN HEALTH RISKS HIGH	MED	LOW	UNK/UNRATED
ADAMS	4			1	3	
ASOTIN	1				1	
BENTON	16		3	1	3	9
CHELAN	12		3	3	2	4
CLALLAM	2			2		
CLARK	41	1	1	14	3	23
COWLITZ	18			1	3	14
DOUGLAS	3		1	1	1	
FERRY	2				2	
FRANKLIN	5				2	3
GRANT	10		1		9	
GRAYS HARBOR	8			2	1	5
ISLAND	10			2	1	7
JEFFERSON	5				3	2
KING	212	3	5	33	58	116
KITSAP	20	2	2	6	2	10
KITTITAS	11				3	8
KLICKITAT	1					1
LEWIS	11	1		2	6	3
MASON	5				2	3
OKANOGAN	13		3	1	7	2
PACIFIC	3			1		2
PIERCE	99	7	6	29	15	49
SKAGIT	15				1	14
SKAMANIA	1					1
SNOHOMISH	32			3		29
SPOKANE	44	2	5	1	30	8
STEVENS	5		1		4	
THURSTON	19	1	3	2	7	7
WALLA WALLA	3				3	
WHATCOM	36	2		4		32
WHITMAN	2					2
YAKIMA	28		9	3	13	3
TOTALS	697	19	43	112	186	357

TABLE #2B

DISTRIBUTION OF SITES BY COUNTY
ENVIRONMENTAL RISK RATINGS BY COUNTY
TOTAL COUNT: 697 (AS OF 6/5/89)

COUNTY	NO. OF SITES	RISK ASSESSMENTS REVIEWED	RATED ENVIRONMENTAL RISKS			
			HIGH	MED	LOW	UNK/UNRATED
ADAMS	4		1		3	
ASOTIN	1				1	
BENTON	16		3	2	2	9
CHELAN	12		4	2	4	2
CLALLAM	2			1	1	
CLARK	41	1	1	16	3	11
COWLITZ	18			3	4	11
DOUGLAS	3				3	
FERRY	2				2	
FRANKLIN	5				2	3
GRANT	10		1		9	
GRAYS HARBOR	8			3	1	4
ISLAND	10			2	1	7
JEFFERSON	5				3	2
KING	212	3	23	37	37	115
KITSAP	20	2	6	4		10
KITTITAS	11				3	8
KLICKITAT	1		1			
LEWIS	11	1	1	1	6	3
MASON	5				2	3
OKANOGAN	13		3	3	5	2
PACIFIC	3			1		2
PIERCE	99	7	5	31	17	46
SKAGIT	15				2	13
SKAMANIA	1					1
SNOHOMISH	32		1	4		27
SPOKANE	44	2	6	1	31	6
STEVENS	5		1		4	
THURSTON	19	1	3	2	7	7
WALLA WALLA	3				3	
WHATCOM	36	2	1	3	4	28
WHITMAN	2					2
YAKIMA	28		10	5	10	3
TOTALS	697	19	71	122	170	325

TABLE #3

INVENTORY OF SITES
HUMAN HEALTH RISK, POPULATION AT RISK, AND ENVIRONMENTAL RISKS
ECOLOGY SURVEY RESULTS

HUMAN HEALTH RISKS VERSUS POPULATIONS

		POPULATION CATEGORY (1)						
	TOTAL	A	B	C	D	E	F	UNKNOWN
HUMAN HEALTH RISK								
HIGH	47	0	1	3	10	8	6	19
MEDIUM	116	0	1	12	41	45	8	9
LOW	196	8	9	36	46	36	29	32
UNKNOWN/UNRATED	338	1	0	4	3	1	3	326
TOTALS	697	9	11	55	100	90	46	386

NORMALIZED VALUES (DISTRIBUTION BY RISK CATEGORY)

HIGH	0.067	0.000	0.021	0.064	0.213	0.170	0.128	0.404
MEDIUM	0.166	0.000	0.009	0.103	0.353	0.388	0.069	0.078
LOW	0.281	0.041	0.046	0.184	0.235	0.184	0.148	0.163
UNKNOWN/UNRATED	0.485	0.003	0.000	0.012	0.009	0.003	0.009	0.964
TOTAL	1.000	0.013	0.016	0.079	0.143	0.129	0.066	0.554

NORMALIZED VALUES WITHOUT UNKNOWN POPULATIONS

HIGH	0.000	0.036	0.107	0.357	0.286	0.214
MEDIUM	0.000	0.009	0.112	0.383	0.420	0.075
LOW	0.049	0.055	0.219	0.280	0.220	0.177
UNKNOWN	0.083	0.000	0.333	0.250	0.083	0.250

ENVIRONMENTAL RISK RATINGS

HIGH	71
MEDIUM	121
LOW	170
UNKNOWN/UNRATED	335
TOTAL	697

(1) POPULATION CATEGORIES
A = 0
B = 1-10
C = 10-100
D = 100-1,000
E = 1,000-10,000
F = 10,000+

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Attachment #1

SITES BY COUNTY
WASHINGTON DEPARTMENT OF ECOLOGY
HAZARDOUS WASTE INVESTIGATIONS AND CLEANUP PROGRAM

COUNTY	SITE CAT.	SITE NAME	LOCATION ADDRESS	CITY	ZIP	AFFECTED ENVIRONMENTS G-WATER	S-WATER	AIR	SOIL	SEDIMENT	CONTAMINANTS #1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	WASTE MGNT PRACTICE 1	WASTE MGNT PRACTICE 2	WASTE MGNT PRACTICE 3
Adams	C1	Burlington Northern (Othello)	WHEELER ST.	OTHELLO	99344	P	F	F	T	F	S	S				C										SPILL	TANK	N/A
	C1	CMC Real Estate (Othello)	CUNNINGHAM STREET	OTHELLO	99344	P	F	F	T	F						C										IMPOUNDMENT	SPILL	N/A
	C1	Soil and Crop	101 W. 1st & Broadway	Othello	99344	T	P	U	T	P	C	S	C		C											TANK	SPILL	IMPROPER HANDLING
	C1	W W T Batum Facility	Batum Rd, 3.25 S Batum	Batum	99169	P	F	F	P	F					C	C										SPILL	N/A	N/A
Asotin	C2	Asotin County Landfill	Peola Road 75	Clarkston	99403														C	C				C	C	LANDFILL	N/A	N/A
Benton	M	Basin Recycling & Reload	27th & Ely	Kennewick	99336																					N/A	N/A	N/A
	C1	Benitz Farm Dump	Case Rd. & Hanks Rd.	Prosser	99350	P	P	F	P	P					S									C		LANDFILL	PESTICIDE DISPSL	N/A
	M	Chevron Chemical Company	Bowles RD E	Kennewick	99336	T	T	F	T	F												C				TANK	SPILL	N/A
	C2	Eastgate Park	E 10th Av & Oak St	Kennewick	99336	P	P	F	T	F					C											LANDFILL	N/A	N/A
	C2	General Chemical	E Perkins Rd	Kennewick	99336	P	F	F	T	T		C			C											PESTICIDE DISPSL	IMPROPER HANDLING	N/A
	M	Gier Construction	3264 Haney	Finley(Kennewick)	99336																					N/A	N/A	N/A
	A	HANFORD - 100-AREA (DOE)	100 area	Richland	99352	T	P	F	T	U		C						C				C	C			LANDFILL	IMPROPER HANDLING	N/A
	A	HANFORD - 1100-AREA (DOE)	1100 area	Richland	99352	T	P	F	T	U								C				C	C			LANDFILL	IMPROPER HANDLING	N/A
	A	HANFORD - 200-AREA (DOE)	200 area	Richland	99352	T	P	F	T	U		C						C				C	C			LANDFILL	IMPROPER HANDLING	N/A
	A	HANFORD - 300-AREA (DOE)	300 area	Richland	99352	T	P	F	T	U		C						C				C	C			LANDFILL	IMPROPER HANDLING	N/A
	C2	Hicks Road Dump	Johnson and Hicks	Grandview		P	F	F	P	F					S											PESTICIDE	LANDFILL	N/A

REPORT:MEDIALEG.DFR 11/88
T=TRUE F=FALSE P=POTENTIAL U=UNKNOWN S=SUSPECTED C=CONFIRMED
LISTINGS BY LOCATION

1. Halogenated Organic Compounds
2. Metals-Priority Pollutants
3. Metals-Other
4. Polychlorinated Bi-Phenuls (PCB)
5. Pesticides
6. Petroleum Products
7. Phenolic Compounds
8. Non-Chlorinated Solvents
9. Dioxin
10. Polynuclear Aromatic Hydrocarbons
11. Reactive Wastes
12. Corrosive Wastes
13. Radioactive Wastes
14. Conventional Contaminants Organic
15. Conventional Contaminants Inorganic

Attachment #1

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SITES BY COUNTY
WASHINGTON DEPARTMENT OF ECOLOGY
HAZARDOUS WASTE INVESTIGATIONS AND CLEANUP PROGRAM

COUNTY	SITE CAT.	SITE NAME	LOCATION ADDRESS	CITY	ZIP	AFFECTED ENVIRONMENTS G-WATER	S-WATER	AIR	SOIL	SEDIMENT	CONTAMINANTS #1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	WASTE MGNT PRACTICE 1	WASTE MGNT PRACTICE 2	WASTE MGNT PRACTICE 3
Benton	M	Phillips Pacific Chem Co	Rd. Bowles Road	Finley(Kennewick)	99336	T	F	F	F	F												C		C		DISPSL SPILL	N/A	N/A
	M	Pyrenco	Hwy 12 & Wilgus Hwy	Prosser	99350																					N/A	N/A	N/A
	M	Richland City Landfill	Grosscup Rd	Richland	99352																					LANDFILL	N/A	N/A
	M	Tri-City Herald	107 N Cascade	Kennewick	99336	P																				N/A	N/A	N/A
	C2	US Ecology, Inc.	Rte 4 (200 area DOE Reserve)	Richland	99352																					N/A	N/A	N/A
Chelan	M	ALCOA-Wenatchee Works	Malaga Highway 8	Wenatchee	98801	F	F	F	P	F															C	LANDFILL	N/A	N/A
	C1	Cascade Helicopter	E. SULLIVAN ST. & AIRPORT RD	CASHMERE	98815	P	F	F	T	F					C											PESTICIDE DISPSL	SPILL	N/A
	C2	Cashmere Landfill	.1 Mi E of Division S	Cashmere	98815	P	P	F	P	P					S											LANDFILL	N/A	N/A
	C2	Chelan Co. Landfill	S Wenatchee - S. of Crawford	Wenatchee	98801	P																				LANDFILL	N/A	N/A
	C2	Dryden Landfill	12 Mi W of Wenatchee	Wenatchee	98801	P	P	F	P	P					S									S		LANDFILL	N/A	N/A
	M	Hi-Valley Disposal	711-A N Wenatchee	Wenatchee	98801																					N/A	N/A	N/A
	C1	Holden Mine Tailing/Wenatch	T31N R17E WM Sec 7	Holden	98816	P	P	F	T	P		C														IMPROPER HANDLING	N/A	N/A
	M	Lincoln Park Landfill	Mission & Crawford	Wenatchee	98801	P	F	F	P	F				S										S		LANDFILL	N/A	N/A
	M	Malaga Landfill	10 Mi E of Wenatchee	Wenatchee	98801	P	P																			LANDFILL	N/A	N/A
	M	Peshastin Creek	T23,24N/R17,18E/Sec 21	Dryden	98821		T		T			S														N/A	N/A	N/A
	M	S Wenatchee Av Landfill	S Wenatchee Av,S of Crawford	Wenatchee	98801	P			P																	LANDFILL	N/A	N/A
	M	Worthen St Landfill	Worthen St-N of Orondo St	Wenatchee	98801	P	P																			LANDFILL	N/A	N/A

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6. Petroleum Products
7. Phenolic Compounds
8. Non-Chlorinated Solvents
9. Dioxin
10. Polynuclear Aromatic Hydrocarbons
11. Reactive Wastes
12. Corrosive Wastes
13. Radioactive Wastes
14. Conventional Contaminants Organic
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SITES BY COUNTY
WASHINGTON DEPARTMENT OF ECOLOGY
HAZARDOUS WASTE INVESTIGATIONS AND CLEANUP PROGRAM

COUNTY	SITE CAT.	SITE NAME	LOCATION ADDRESS	CITY	ZIP	AFFECTED ENVIRONMENTS G-WATER	S-WATER	AIR	SOIL	SEDIMENT	CONTAMINANTS #1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	WASTE MGNT PRACTICE 1	WASTE MGNT PRACTICE 2	WASTE MGNT PRACTICE 3
Clallam	C1	Daishowa America Company Ltd.	Ediz Hook - Marine Drive	Port Angeles	98362 -004	T	P	F	T	T	C			C		C										IMPROPER HANDLING	N/A	N/A
	C1	Lincoln Square Apartments	Lincoln St. & 8th Avenue	Port Angeles	98362	P	P	P	T	P						C										TANK	N/A	N/A
Clark	C1	Aerowest	9115 NE 117TH AVE	VANCOUVER	98682	T	P	U	P	U	C					S	S	S								SPILL	IMPROPER HANDLING	N/A
	C1	ALCOA-Vancouver	5701 NW Lower River Rd.	Vancouver	98666	T	P	U	T	U														C	C	IMPROPER HANDLING	N/A	N/A
	C1	Allied Chemical Corporation	W 26th St Extension	Vancouver	98666	T	P	F	T	F			C													IMPROPER HANDLING	N/A	N/A
	C1	Arco Service Station #6211	N.E. HWY 99 and N.E. MINNEHAHA	Vancouver		P	F	F	T	F						C				S						SPILL	TANK	N/A
	C1	Arco Station	NE 78th & St.Johns Road	Hazel Dell	98665	P	F	F	T	F						C				C						SPILL	TANK	N/A
	C2	Automotive Services, Inc.	2001 W. Fourth Plain, Bldg 3	Vancouver	98660	U	U	U	P	U	S					S		S								N/A	N/A	N/A
	C2	Borden Chemical-Ink Div	6115 NE 63rd St	Vancouver	98661	P	P	U	P	U		S										S				N/A	N/A	N/A
	C2	Carborundum Co.	PORT OF VANCOUVER	Vancouver	98660	U	U	U	U	U										S						UNKNOWN	N/A	N/A
	C2	Carter Berry, Inc.	118 NW 139th St.	Vancouver	98665	U	U	U	P	U		S														N/A	N/A	N/A
	C2	Cascade Tempering	Bldg 39 & Bldg 5	Vancouver		P	U	U	P	U		S												S	S	SPILL	IMPROPER HANDLING	N/A
	C2	Circle C Landfill	31313 PARADISE PARK ROAD	RIDGEFIELD	98642	P	P	U	P	U		S					S									LANDFILL	N/A	N/A
	C1	Columbia Marine Lines	6305 NW Lower River Road	Vancouver	98666	T	U	F	P	U						C										IMPROPER HANDLING	N/A	N/A
	C2	Columbia Pest Control Dump	8405 Calef Road (NE?)	Vancouver	98665	P	U	U	P	U		S			S											N/A	N/A	N/A

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7. Phenolic Compounds
8. Non-Chlorinated Solvents
9. Dioxin
10. Polynuclear Aromatic Hydrocarbons
11. Reactive Wastes
12. Corrosive Wastes
13. Radioactive Wastes
14. Conventional Contaminants Organic
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SITES BY COUNTY
WASHINGTON DEPARTMENT OF ECOLOGY
HAZARDOUS WASTE INVESTIGATIONS AND CLEANUP PROGRAM

COUNTY	SITE CAT.	SITE NAME	LOCATION ADDRESS	CITY	ZIP	AFFECTED ENVIRONMENTS G-WATER	S-WATER	AIR	SOIL	SEDIMENT	CONTAMINANTS #1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	WASTE MGNT PRACTICE 1	WASTE MGNT PRACTICE 2	WASTE MGNT PRACTICE 3
Clark	N	Crosby & Overton	15212 NE 72 Ave	Vancouver	98665	F	P	F	P	F						S										DRUM	N/A	N/A
	C2	English Pit	912 NE 192nd Ave.	Vancouver	98662	P	P	U	P	P		S														LANDFILL	N/A	N/A
	C1	Exxon Gas Station	604 179th and Ridgefield	Vancouver		T	F	F	T	F					C					C						TANK	SPILL	N/A
	C2	FMC Corporation-Vancouver	1710 S Access Rd	Vancouver	98661	U	U	U	P	U	S			S												N/A	N/A	N/A
	C2	Fort Vancouver Plywood	W 13th St., Foot of	Vancouver	98660	U	U	U	P	U		S					S									N/A	N/A	N/A
	A	Frontier Hard Chrome Inc	113 'Y' Street	Vancouver	98661	T	F	P	T	F		C														IMPROPER HANDLING	N/A	N/A
	C2	GATX Terminals Corporation	Foot of 16th Street	Vancouver	98660	U	U	U	P	U						S				S						N/A	N/A	N/A
	C2	George Sellinger Site	25212 NE 77th Ave	Vancouver	98660	P	P	U	P	U	S	S						S								N/A	N/A	N/A
	C2	International Paper Co.	Healy Rd, End of Cy of 503	Amboy	98607	U	U	U	P	U					S					S						N/A	N/A	N/A
	C1	L & C Deli	NE 20th Ave. and NE 139th St.	Hazel Dell	98665	T	F	F	T	F						C										TANK	SPILL	N/A
	C2	Larch Mountain (DNR)	15314 NE DOLE VALLEY	YACOLT	98675	U	P	U	U	U						S								S		N/A	N/A	N/A
	C1	Leichner Brothers Landfill	9411 NE 94 Ave	Vancouver	98666	T	U	T	S	U	S	C	C					S								LANDFILL	N/A	N/A
	C1	McCall Oil	1309 West McLoughlin Avenue	Vancouver		P	F	F	T	F						C				C						SPILL	TANK	IMPROPER HANDLING
	C1	McClary Columbia Corp	625 S 32nd St	Washougal	98671	T	P	P	T	U	C							S								IMPROPER HANDLING	N/A	N/A
	C1	Pacific Northwest Plating	7608 NE 47th Ave.	Vancouver	98661	T	P	U	P	U		C	S													TANK	SPILL	IMPROPER HANDLING
	C2	Pacific Wood Treating Corp.	111 W Division	Ridgefield	98642	P	P	U	P	U							S									TANK	N/A	N/A
	C2	Pendleton Mills	A St. & 17th St.	Washougal	98671	U	U	U	P	U		S														N/A	N/A	N/A
	C2	Pioneer Plating - NE 47th Ave.	7608 NE 47th Ave.	Vancouver	98661	U	U	U	P	U		S														N/A	N/A	N/A
	C1	Port of Vancouver	3103 NW LOWER RIVER RD	VANCOUVER	98660	P	T	U	U	T		C				S								S		SPILL	IMPROPER HANDLING	N/A
	C2	Robertson's Paint Shop	1414 E. Mill Plain	Vancouver	98664	U	U	U	P	U		S												S	S	N/A	N/A	N/A
	C2	Seaport Chemical	13008 142nd Ave E	Puyallup	98574	P	F	F	P	P								S						S		N/A	N/A	N/A

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9. Dioxin
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12. Corrosive Wastes
13. Radioactive Wastes
14. Conventional Contaminants Organic
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SITES BY COUNTY
WASHINGTON DEPARTMENT OF ECOLOGY
HAZARDOUS WASTE INVESTIGATIONS AND CLEANUP PROGRAM

COUNTY	SITE CAT.	SITE NAME	LOCATION ADDRESS	CITY	ZIP	AFFECTED ENVIRONMENTS G-WATER	S-WATER	AIR	SOIL	SEDIMENT	CONTAMINANTS #1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	WASTE MGNT PRACTICE 1	WASTE MGNT PRACTICE 2	WASTE MGNT PRACTICE 3
Clark	C2	SEH America Orchards	4111 NE 112TH AVENUE	VANCOUVER	98662	P	P	P	P	U	S	S					S	S								UNKNOWN	N/A	N/A
	C1	Tidewater Barge Lines, Inc.	SE 6 Beach Drive	Vancouver	98661	P	U	U	U	T		S						C								IMPOUNDMENT	IMPROPER HANDLING	N/A
	L	Toftdahl Drum Site	22033 NE 189 St	Brush Prairie	98606	P	F	F	T	F		C		C	C		C	C								DRUM	N/A	N/A
	C2	USDOE-BPA Ross Substation	5411 NE Hwy 99	Vancouver	98666	U	U	U	P	P				S												DRUM	TANK	IMPROPER HANDLING
	C2	Vancouver Gas Manufacturing	9th & Lincoln Streets	Vancouver	98660	U	U	U	P	U						S										N/A	N/A	N/A
	C2	Vancouver Ice & Fuel	1112 W. 7th St.	Vancouver	98666	P	U	U	P	F						S				S						N/A	N/A	N/A
	C2	Vanrich Casting	1200 West 13th St.	Vancouver	98666	U	U	U	P	U		S														N/A	N/A	N/A
Cowlitz	C2	Binn and Sons Dumpsite	T5N, R1E, Sec 31	Woodland	98674	P	P	U	P	U		S														LANDFILL	N/A	N/A
	C2	Coal Creek Dspl-Cowlitz Co	6150 Ocean Beach Hwy	Kelso	98632	P	U	U	P	U		S					S									N/A	N/A	N/A
	C2	Cowlitz County SLF	85 Tennant Way	Kelso	98632	P	U	U	P	F	S	S														LANDFILL	N/A	N/A
	N	Fuel Processors (Arrcom)	701 Bozarth St	Woodland	98674	P	U	U	P	U						C										TANK	N/A	N/A
	C2	Gearhardt Gardens	Freedom Way	Longview	98632	U	U	U	P	U		S														LANDFILL	N/A	N/A
	C1	Int'l Paper (IP) Site C	ADJACENT TO 10 INTNL. WAY	LONGVIEW	98632	P	U	U	T	U								C								N/A	N/A	N/A
	C1	IP Site B-Longview	10 INTERNATIONAL WAY	Longview	98632	T	P	F	T	F	C	S				C	C		S	C						IMPOUNDMENT	N/A	N/A
	C2	IP Site C-Longview	10 International Way	Longview	98632	P	P	U	U	U								S								LANDFILL	N/A	N/A
	C1	Kalama Chemical Inc	1296 NW 3rd St	Longview	98625	T	T	P	T	P		C					C	S								DRUM	IMPOUNDMENT	SPILL
	C2	Kalama Dump S	T6N, R1W, Sec 33, WM	Kalama	98625	P	P	U	P	U		S						S								LANDFILL	N/A	N/A
	L	Longview Fibre	Fibre Way	Longview	98632	T	T	P	T	T		C														N/A	N/A	N/A
	C2	Ostrander Rock Dspl Site	6150 Ocean Beach Hwy	Kelso	98632	P	P	F	P	U		S						S							S	LANDFILL	N/A	N/A
	C2	PCB DRUM KALAMA	Green Mountain Road & Land Rd.	Kalama	98625	U	U	F	P	F				S												N/A	N/A	N/A
	C2	Radakovich Landfill	4646 Mt. Solo Rd	Longview	98632	P	P	F	P	U		S												S		LANDFILL	N/A	N/A
	C1	Reynolds Metals - Longview	4029 INDUSTRIAL WAY	RICHMOND	98632	T	T	U	T	U														C	C	LANDFILL	N/A	N/A

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LISTINGS BY LOCATION

1. Halogenated Organic Compounds
2. Metals-Priority Pollutants
3. Metals-Other
4. Polychlorinated Bi-Phenuls (PCB)
5. Pesticides
6. Petroleum Products
7. Phenolic Compounds
8. Non-Chlorinated Solvents
9. Dioxin
10. Polynuclear Aromatic Hydrocarbons
11. Reactive Wastes
12. Corrosive Wastes
13. Radioactive Wastes
14. Conventional Contaminants Organic
15. Conventional Contaminants Inorganic

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SITES BY COUNTY
WASHINGTON DEPARTMENT OF ECOLOGY
HAZARDOUS WASTE INVESTIGATIONS AND CLEANUP PROGRAM

COUNTY	SITE CAT.	SITE NAME	LOCATION ADDRESS	CITY	ZIP	AFFECTED ENVIRONMENTS G-WATER	S-WATER	AIR	SOIL	SEDIMENT	CONTAMINANTS #1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	WASTE MGNT PRACTICE 1	WASTE MGNT PRACTICE 2	WASTE MGNT PRACTICE 3
Cowlitz	N	Reynolds Metal-Cable Plant	4393 Industrial Way	Longview	98632	U	U	U	P	U			S												S	UNKNOWN	N/A	N/A
	C1	West Coast/Mobil Oil Co.	64 Port Way	Longview	98632	T	U	U	P	U						C										TANK	SPILL	N/A
	L	Weyerhaeuser(Wyco) Co Longview	3535 Industrial Way	Longview	98632	T	F	F	T	U		C	C													IMPROPER HANDLING	N/A	N/A
Douglas	C2	E. Wenatchee/Dependable Displ.	191 Webb Rd	E. Wenatchee	98801	P	F	F	P	F					S											LANDFILL	PESTICIDE DISPSL	N/A
	C1	INLAND AIR SERVICE	Badger Mtn. Rd - Fancher Field	E. Wenatchee		P	P	F	P	F					C											PESTICIDE DISPSL	SPILL	N/A
	L	Pangborn Field	Grant Road	E. WENATCHEE	98801	F	P	F	T	U					C											PESTICIDE DISPSL	SPILL	N/A
Ferry	C2	Hecla Knob Hill Mine	Knob Hill county Road	Republic	99166	F	T	F	F	U		C				S										IMPOUNDMENT	N/A	N/A
	N	Mt Tolman Project	Colville Indian Res	Keller	99140																					N/A	N/A	N/A
Franklin	M	Allegheny Industrial Elec.	Hwy 12	Pasco	99301																					N/A	N/A	N/A
	N	Lewis Street Tank Site	N. side of Lewis Street	Pasco	99301	P	F	F	U																C	TANK	N/A	N/A
	B	Pasco Landfill	Kahlotus & Hwy 12	Pasco	99301	T	F	F	P	F	C	S													S	LANDFILL	IMPOUNDMENT	PESTICIDE DISPSL
	C1	Port of Pasco	AINSWORTH AND W. 9TH	PASCO	99301	T	T	F	T	F	S	C				C										TANK	SPILL	N/A
	N	Puregro Company	N Glade & Selph Land	Pasco	99302				T													C				SPILL	N/A	N/A
Grant	C2	Grant Co-Ephrata Landfill 1	Hwy 28	Ephrata	98823	P																				LANDFILL	N/A	N/A

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9. Dioxin
10. Polynuclear Aromatic Hydrocarbons
11. Reactive Wastes
12. Corrosive Wastes
13. Radioactive Wastes
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Grant	C2	Grant Dangerous Waste Site	A Road 9SE	Royal City	99357	P	P								S											LANDFILL	N/A	N/A
	N	Greenacres Northwest Inc	Warden Rd & 1 SE	Warden	98857																					N/A	N/A	N/A
	M	International Titanium	1320 Rd. 3 NE	Moses Lake	98837	P	U	F	P	F													C			SPILL	N/A	N/A
	M	Northwest Transformer Serv.	Sec3,T21N,R27E	Ephrata	98823	P	U	U	P	U				C												DRUM	N/A	N/A
	C1	Old Larson Air Force Base	Grant County Airport	Moses Lake	98837	T	U	U	U	U								C								UNKNOWN	N/A	N/A
	N	Puregro Company	Star Rt 99N Beverly Rd	Quincy	98848	F	F	F	F						C											N/A	N/A	N/A
	C2	WA Army Natnl.Guard Shop #2	426 First Street S. E.	Ephrata	98823	P			P							S		S								SPILL	N/A	N/A
	N	Western Farm Services	Highway 2	Coulee City	99115				T						C											IMPROPER HANDLING	N/A	N/A
	N	Western Farmers Inc	2nd Av & A St SE	Quincy	98848	F	F	F	F						C											N/A	N/A	N/A
Grays Harbor	C1	Aberdeen Landfill/Sanitation	4201 OLYMPIC HIGHWAY	ABERDEEN	98520	T	T	T	P	P	C	S					S							C		LANDFILL	N/A	N/A
	C1	Amanda Park - Private Well	Hwy 101 & S Shore Rd	Amanda Park	98526	T	P	U	P	U			C					S						C		SPILL	IMPROPER HANDLING	N/A
	C1	Hoquiam Municipal Landfill	Olympic Hwy 101 1/2 N cy	Hoquiam	98550	T	T	F	P	P		C						S						S		LANDFILL	N/A	N/A
	C1	Most Western Laundry	Corner of B&16th Sts	Hoquiam	98550	P	U	U	T	U	C					C		S		S						DRUM	IMPROPER HANDLING	SPILL
	C2	Roderick Timber Co.	301 HAGARA ST.	ABERDEEN	98520	P	P	F	P	P		S		S		S	S			S						IMPROPER HANDLING	LANDFILL	SPILL
	C2	South Union Landfill	S Union Rd	Elma	98541	U	U	U	P	U		S														LANDFILL	N/A	N/A
	C2	WA Army Natnl.Guard Shop #1	298 Clemons Road	Montesano	98563	P	U	U	P	U						S		S								SPILL	N/A	N/A
	C1	Weyerhaeuser Paper Co.	Highwa 101	Cosmopolis	98537	U	P	F	P	U												C			C	IMPROPER HANDLING	LANDFILL	N/A

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Island	N	Coupeville Landfill	Hwy 20	Oak Harbor	98277	P						S														LANDFILL	N/A	N/A
	C2	Cultus Bay Landfill	Cultus Bay Rd.	Whidbey Island	98277	P	P		P																	LANDFILL	N/A	N/A
	C2	Freeland Landfill	Hwy 525	Freeland	98277	P			P																	LANDFILL	N/A	N/A
	C2	Hastie Lake Landfill	Hastie Lake Rd-3 mi sw/cy	Oak Harbor	98277	P			P			S						S								LANDFILL	N/A	N/A
	N	Island Disposal Inc.	525 Hwy 20	Coupeville	98239																					N/A	N/A	N/A
	N	Melco Manufacturing	2845 N Goldie Rd	Oak Harbor	98277	F	F	F	T	F		C														IMPROPER HANDLING	N/A	N/A
	C2	Oak Harbor Landfill	Goldie Rd	Oak Harbor	98277	P	P																			LANDFILL	N/A	N/A
	A	US Navy-NAS Whidbey Is-Ault	Ault Field, NAS Whidbey I	OAK HARBOR	98278																					IMPROPER HANDLING	N/A	N/A
	A	US Navy-NAS Whidbey Is-Seaplan	NAV-WHIDBEY ISLAND	OAK HARBOR	98278-5500	T	T	F	T	T	C	C		S	S	C		S						S	S	IMPROPER HANDLING	N/A	N/A
	C2	USNAVY - NAS Whidbey Island	Hwy 20 & Ault Field Rd.	Oak Harbor	98278																					N/A	N/A	N/A
Jefferson	C1	Jefferson County Transit	1615 SUMS WAY	PORT TOWNSEND	98368	U	T	U	T	F		C				C										TANK	IMPROPER HANDLING	N/A
	N	Milwaukee RR Right-of-Way	RR Milepost 11	Discovery Bay	98368	P	T	F	T	U	C	S														SPILL	N/A	N/A
	C1	Olympic Testing Lab	2 1/4 Mile North on Road 18	Quilcene	98376	P	T	U	P	F		C										C				IMPROPER HANDLING	N/A	N/A
	C1	Pt. Townsend Gas Mfg. Site	1035 Monroe St.	Port Townsend	98368	F	P	F	T	U										C						IMPOUNDMENT	SPILL	N/A
	C1	US Naval Undersea Warfare Stat	Indian Island	Hadlock	98366	T	P	F	T	T	C	C	C			C		C			C	C		C	C	LANDFILL	IMPROPER HANDLING	N/A
King	C2	6th Avenue South Landfill	2901 6th Ave S.	Seattle	98134				P																	LANDFILL	N/A	N/A
	N	A J Zinda Company	37405 Pacific Hwy S	Federal Way	98003																					N/A	N/A	N/A

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King	C2	ABC Metal Finishing Inc.	528 Pontius N	Seattle	98109							S										S				N/A	N/A	N/A
	L	Ace Galvanizing Inc	429 S 96th	Seattle	98108	U	T	U	U	U		C														IMPROPER HANDLING	SPILL	N/A
	C2	Acme Plating Works	601 N 35th	Seattle	98103	P			P			S										S				N/A	N/A	N/A
	C1	Advance Co.'s, Inc.	9585 8th Ave S	Seattle	98101	U	T	U	T	U		C														IMPROPER HANDLING	SPILL	N/A
	C2	Airco Welding Prod	7700 14th Av S	Seattle	98108	P	P	P	P	P		S				S						S	S			IMPOUNDMENT	IMPROPER HANDLING	N/A
	C1	Alaska Pacific Fisheries	2360 W. COMMODORE WAY	SEATTLE	98199	F	T	P	F	T	S	C	C	S	S	C	S	S		S	S	S		C	C	DRUM	TANK	SPILL
	C2	American Can Company	400 Baker Blvd	Seattle	98188	P												S								N/A	N/A	N/A
	C2	American Tar Co	1700 N Northlake Way	Seattle	98103	P			P							S				S					S	N/A	N/A	N/A
	C2	Andrew Brown Manufacturing		Kent	98031																					N/A	N/A	N/A
	C2	And-All Electrochrome Inc	6332 6th S	Seattle	98108	P			P			S										S			S	SPILL	DRUM	N/A
	C1	ARCO - Tank Farm	1652 SW Lander St.	Seattle	98134	P	P	F	T	P						C										SPILL	TANK	N/A
	N	Argent Chem Laboratories	14929 NE 40 St	Redmond	98007																					N/A	N/A	N/A
	C2	Asahipen America, Inc.	1128 SW Spokane St	Seattle	98134	P			P									S								TANK	N/A	N/A
	C2	Ash Grove Cement West, Inc.	3801 E Marginal WayS	Seattle	98134	P				P			S			S									S	N/A	N/A	N/A
	N	Ashland Chemical Co	831 Fifth Av S	Kent	98031																					N/A	N/A	N/A
	C1	Asko Processing Inc	434 N 35th	Seattle	98103	U	U	U	T	U	C	C						C				C				IMPROPER HANDLING	N/A	N/A
	N	Atlas Demolition	1015 3rd	Seattle	98104	P	T		T	P								S								IMPOUNDMENT	N/A	N/A
	N	Austin Mack	2739 Sixth Ave S	Seattle	98134	F	F	F	T	F								C								SPILL	N/A	N/A
	C2	Bahnmiller Autobody Shop	3734 A St SW	Auburn	98002	P			P			S						S								N/A	N/A	N/A
	C2	Ballestrasse Logging	28015 SE 432nd St	Enumclaw	98022	P			P								S									N/A	N/A	N/A
	C2	Bayside Disposal Co.	7201 W Marginal Way S	Seattle	98106				P							S		S								N/A	N/A	N/A
	C2	Belle Field Landfill	11201 SE 8th	Bellevue	98005																					LANDFILL	N/A	N/A
	C2	Bellevue Plating Co Inc	1513 128th PL NE	Bellevue	98005							S														STORM DRAIN	N/A	N/A

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King	C2	Black Nugget Mine-NE/Creek	Black Nugget Road	Issaquah	98027																					N/A	N/A	N/A
	C2	Black Nugget Mine-Rock Tunn	Black Nugget Road	Issaquah	98027																					N/A	N/A	N/A
	C2	Black Nugget Mine-SW/Creek	Black Nugget Road	Issaquah	98027																					N/A	N/A	N/A
	C1	BNR- Roundhouse Site	Tracks Parallel to MS	Skykomish	98288	T	T	F	T	T						C										SPILL	IMPROPER HANDLING	N/A
	C2	Boeing Co- Auburn	700 15th Street SW	Auburn	98002																					N/A	N/A	N/A
	N	Boeing Co- Kent Benaroya	20651 84 St	Kent	98034																					DRUM	N/A	N/A
	C2	Boeing Co- Kent Space Center	20403 68th Ave S	Kent	98032		T					S						S			S	S		S		N/A	N/A	N/A
	C1	Boeing Co- North Field	Ellis Ave. & E. Marginal Way	Seattle	98108	T	P	U	T	T	C	S	S	C		C		C	S			C			C	TANK	SPILL	N/A
	C1	Boeing Co- North Fld.JP4 Tanks	Ellis Ave. & E. Marginal Way	Seattle	98108	T	F	U	T	F						C										TANK	SPILL	N/A
	N	Boeing Co- Plant 2	7755 E Marginal Wy S	Seattle	98124		T		T																	N/A	N/A	N/A
	C1	Boeing Co- Renton	Eighth and Logan	Renton	98055	T	T	U	T	U	C	C	C			C	S	C		S		S			C	TANK	SPILL	N/A
	C1	Boeing Co.- Isaacson/Thompson	8541 E Marginal Way S	Seattle	98107	S			T				C													N/A	N/A	N/A
	L	Boeing Developmental Center	9725 E Marginal Wy S	Seattle	98124	T	U	U	T	U	C															TANK	N/A	N/A
	N	Borden Chemical Company	421 1st Ave N	Kent	98031		T																			N/A	N/A	N/A
	C2	Bow Lake Landfill	S 188th St & Military Rd S	Tukwila	98188	P	P	P	P		S		S							S						LANDFILL	N/A	N/A
	C1	Bronson Way Texaco	1408 Bronson Way	Renton	98055	T	F	F	T	F	C					C										TANK	SPILL	N/A
	L	Burien/SW Suburban Sewer Dist.	10th Ave. SW & SW 154th	Seattle	98166	T	F	U	T	U						S										SPILL	N/A	N/A
	C2	Cabot Ind.	8202 S. 200th St	Kent	98031																					N/A	N/A	N/A
	C1	Cedar Falls Landfill	16901 Cedar Falls Rd SE	North Bend	98045	T	T	P	F	F		C												C	C	LANDFILL	N/A	N/A
	C1	Cedar Hills Landfill	16645 228 Ave SE	Issaquah	98038	T	T	T	T	U	C	C	C	C	S	C	S	S		S			C	C	C	LANDFILL	IMPOUNDMENT	N/A
	L	Central Painting	4749 W. Marginal Way SW	Seattle.	98106	T	F	F	T	F		C	C					C								IMPROPER HANDLING	N/A	N/A

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HAZARDOUS WASTE INVESTIGATIONS AND CLEANUP PROGRAM

COUNTY	SITE CAT.	SITE NAME	LOCATION ADDRESS	CITY	ZIP	AFFECTED ENVIRONMENTS G-WATER	S-WATER	AIR	SOIL	SEDIMENT	CONTAMINANTS #1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	WASTE MGNT PRACTICE 1	WASTE MGNT PRACTICE 2	WASTE MGNT PRACTICE 3
King	C1	Champion Intnatl- Ballard Mill	4025 13th Ave. West	Seattle	98107	T		P	T	T	C					S				C						TANK	IMPROPER HANDLING	N/A
	N	Chem Securities Systems	10602 NE 38th Pl	Kirkland	98033																					N/A	N/A	N/A
	C2	Chemcentral Solvents Co	7601 S 190th	Kent	98031	P	T											S						S		IMPOUNDMENT	N/A	N/A
	C2	Chemical Processors Inc	Pier 91	Seattle	98119		T		T			S	S			S				S		S				SPILL	N/A	N/A
	N	Chemical Processors Inc	7500 Detroit Ave SW	Seattle	98108																					DRUM	N/A	N/A
	C2	Chemical Processors Inc	734 S Lucile St	Seattle	98108	T			T			S	S		S	S		S			S	S				N/A	N/A	N/A
	C2	Chromium Inc	1005 S King	Seattle	98104							S										S				SPILL	TANK	N/A
	C2	Coal Creek Development Corp.	166th Way SE	Bellevue	98027	P																		S		LANDFILL	N/A	N/A
	N	Corliss Landfill- South Sect.	N 165 St. & 1st Ave NE	Seattle	98133	P	P	F	T	F	S	C	C	S	S	C	S	S		S				C	S	LANDFILL	N/A	N/A
	N	Crosby & Overton Inc	3406 13th SW	Seattle	98134																					N/A	N/A	N/A
	N	Crossroads Mall Dry Cleaners	NE 8th & 156th Ave.	Bellevue	98005																					N/A	N/A	N/A
	N	Crowley Environmental Serv	3400 E Marginal Wy S	Seattle	98134																					N/A	N/A	N/A
	C1	Custom Circuit Technology	11807 NE 116th	Kirkland	98033	U	T	U	P	P		C	C													SPILL	IMPOUNDMENT	N/A
	C2	D & S Petroleum		Federal Way	98002																					N/A	N/A	N/A
	N	Dimensional Engineering	9407 E Marginal Wy	Seattle	98108	P																				N/A	N/A	N/A
	C1	DOT Landfill	PACIFIC HWY. & W. MARGINAL WAY	SEATTLE	98168	P	T	F	T	U		C				C										IMPROPER HANDLING	LANDFILL	N/A
	C2	Duvall Landfill	22905 Old Wood/Duval	Duvall	98019				P																	LANDFILL	N/A	N/A
	C2	Duwamish River-Boeing Plt 2	7700 E Marginal Way	Seattle	98124		P			P		S										S				SPILL	N/A	N/A
	C1	Duwamish Shipyard, Inc.	5658 W Marginal Way SW	Seattle	98106	P	T	P	T	T		C	C			C		C								DRUM	IMPROPER HANDLING	N/A
	C2	Eastgate Abandoned Landfill	2805 160th Ave SE	Bellevue	98008	P	P		P																	LANDFILL	N/A	N/A
	C2	Enumclaw Landfill	29000 SE 440 St	Enumclaw	98022	T	T		T		S	S	S		S	S		S		S				S	S	LANDFILL	N/A	N/A
	C2	Factoria Pit (Sunset Park)	132 Ave SE & SE 38th	Bellevue	98105	P	P		P																	LANDFILL	N/A	N/A
	C2	Federal Way Landfill	S 352 & I-5 Puyallup	Auburn	98002	P	P		P		S		S		S					S						LANDFILL	N/A	N/A
	N	Fiberlay Inc	1158 Fairview Ave N	Seattle	98109																					N/A	N/A	N/A
	C1	First Ave Bridge Landfill	7700 block of 2nd	Seattle	98108	U	U	T	T	P															C	LANDFILL	IMPROPER	N/A

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LISTINGS BY LOCATION

1. Halogenated Organic Compounds
2. Metals-Priority Pollutants
3. Metals-Other
4. Polychlorinated Bi-Phenuls (PCB)
5. Pesticides
6. Petroleum Products
7. Phenolic Compounds
8. Non-Chlorinated Solvents
9. Dioxin
10. Polynuclear Aromatic Hydrocarbons
11. Reactive Wastes
12. Corrosive Wastes
13. Radioactive Wastes
14. Conventional Contaminants Organic
15. Conventional Contaminants Inorganic

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COUNTY	SITE CAT.	SITE NAME	LOCATION ADDRESS	CITY	ZIP	AFFECTED ENVIRONMENTS G-WATER	S-WATER	AIR	SOIL	SEDIMENT	CONTAMINANTS #1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	WASTE MGNT PRACTICE 1	WASTE MGNT PRACTICE 2	WASTE MGNT PRACTICE 3
			Ave SW																								HANDLING	
King	C2	Four Tek Industries	Cedar Grove Rd	Issaquah	98027	P	P																			N/A	N/A	N/A
	C1	Gas Works Park(Wa Ntl Gas)	N 34th & Burke Ave N	Seattle	98103	T	P	P	T	T		C								C						SPILL	IMPROPER HANDLING	N/A
	C2	General Disposal Corp	1415 NW Ballard Way	Seattle	98107	P	P	P	P							S		S								SPILL	N/A	N/A
	C2	Genesee Landfill	Genesee St & 43rd Ave. So.	Seattle	98118	P	P		P		S	S			S					S						LANDFILL	N/A	N/A
	C1	Golden Penn Oil Company	2937 13th Ave. S.W.	Harbor Island	98134	P			P		S	S		C		C		C								IMPROPER HANDLING	TANK	N/A
	C2	Guardsman Products, Inc.	13535 Monster Rd S	Seattle	98178	P	P		P																	SPILL	DRUM	N/A
	N	H & H Oleson Landfill	NE 152nd Pl NE & SE 155th	Woodinville	98072																					LANDFILL	N/A	N/A
	C2	Haller Lake Landfill	N 125 St E of Aurora	Seattle	98133	P	P	P																		LANDFILL	N/A	N/A
	C1	Harbor Ave Landfill	Harbor Ave SW & SW Florida St	Seattle	98124	T	T		T	P		C	C	C		C								C		LANDFILL	N/A	N/A
	A	Harbor Island		Seattle	98134	T	T	T	T	P	C	S	S	C		C	S	S	S	S				S	S	IMPOUNDMENT	SPILL	IMPROPER HANDLING
	L	Hobart Landfill	23421 Issaquah-Hobart Rd	Issaquah	98027	T	P	P	T	F	C	C	C		S	C		C						C	C	LANDFILL	N/A	N/A
	C2	Honeywell Inc	5305 Shilshole Av NW	Seattle	98107		P					S				S		S								N/A	N/A	N/A
	C1	Houghton Landfill	NW of NE 60th & 120 Av NE	Kirkland	98033	P	P	P	T		S	S			S	C				S						LANDFILL	N/A	N/A
	C1	H.P. Construction/Arrow Transp	19249 15th Ave. NW	Richmond Beach	98177	P	U	U	T	U						C										TANK	SPILL	N/A
	N	Ideal Basic Industries	Edge of Town	Grotto	98288																					N/A	N/A	N/A
	N	Ideal Basic Ind-Cement Plt	5400 W Marginal Way	Seattle	98106																					N/A	N/A	N/A
	C1	Industrial Office Complex	2955 11th Ave SW	Seattle	98134	U	U	U	T	U					C			C							C	IMPROPER HANDLING	N/A	N/A
	C2	Industrial Plating Corp	2411 6th S	Seattle	98134							S						S				S		S		N/A	N/A	N/A
	C2	Inland Transportation Co	6737 Corson S	Seattle	98108		P			P	S	S	S			S		S				S		S		STORM DRAIN	SPILL	N/A

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7. Phenolic Compounds
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9. Dioxin
10. Polynuclear Aromatic Hydrocarbons
11. Reactive Wastes
12. Corrosive Wastes
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King	C2	Interbay Old Landfill	W Wheeler St & 15th Ave W	Seattle	98119	P	P		P		S	S			S					S						LANDFILL	N/A	N/A
	C1	J H Baxter & Company Inc	5015 Lk WA Blvd N	Renton	98055	P	P	F	T	P		S				S	C			C						TANK	IMPOUNDMENT	N/A
	N	J J Jackson Septic Tank S	15671 SE139 Pl	Renton	98055																					N/A	N/A	N/A
	C2	Jarvie Paint Mfg Co	760 Aloha St	Seattle	98109	P			T		S	S	S					S								N/A	N/A	N/A
	C2	Judkins Park	23rd & Norman St	Seattle	98122				P																	N/A	N/A	N/A
	C2	Kenmore Landfill	68 Ave N.W/Bothell So. of Wyne	Kenmore	98155																					LANDFILL	N/A	N/A
	B	Kent Highlands Landfill	240th & Military Rd	KENT	98031	T	P	T	P	P	S	C	S	S	S	S	S	S		S	S			S	C	LANDFILL	N/A	N/A
	C1	Kenworth Truck Company	8801 E Marginal Way S	Seattle	98108	T	P	F	T	P	C	S				C	C	C								SPILL	TANK	N/A
	C2	King 4 Coal Co Mine, A	SE Newcastle-Coal Ck	Newcastle	98006																					N/A	N/A	N/A
	N	King Co Airport Maintenance	6518 Ellis Av S	Seattle	98108	F	P	F	T	F		C				C										DRUM	TANK	N/A
	C1	Lake Union Drydock	1315 Fairview Ave. East	Seattle	98102	F	T	F	T	T	C	C		S		C	S	C				C		S	S	DRUM	SPILL	N/A
	C1	Lake Washington School Dist.	8749 122nd Ave NE	Kirkland	98033	T	P	F	T	F	S	S	S	S		C										TANK	IMPROPER HANDLING	SPILL
	C2	Landsburg Mine-Rogers Seam	Kent-Kangley Rd	Black Diamond	98010																					N/A	N/A	N/A
	N	Lee & Eastes Tank Lines	2418 Airport Wy S	Seattle	98134																					N/A	N/A	N/A
	C2	LIDCO	7113 S 196th	Kent	98031	P	U	U	P	U	S	S		S	S	S		S		S				S	S	SPILL	N/A	N/A
	C2	Lockheed Shipbldg. Co. Yard 1	2929 16th Ave SW	Seattle	98134					P		S			S	S	S	S		S				S	S	IMPROPER HANDLING	N/A	N/A
	N	Lovstead Industries	3300 Airport Wa S.	Seattle	98108		F					S	S													N/A	N/A	N/A
	C2	L-Bar Products Inc.	26000 Blk Diamond/Ravensd Rd.	Seattle	98051	P	P		P			S										S				LANDFILL	N/A	N/A
	C2	Magnolia Fertilizer	1144 Ballard Way	Seattle	98133		P								S											N/A	N/A	N/A
	C1	Malarkey Asphalt Co.	8700 Dallas Ave. S.	Seattle	98108	P	P	F	T	T		C	C	C		C										TANK	N/A	N/A
	N	Mannesmann Tally Corp	8301 S 180 St	Kent	98031																					N/A	N/A	N/A
	C1	Maralco	7730 S. 202nd	Kent	98032	U	T	P	T	T		C	C											C		IMPROPER	TANK	N/A

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																										HANDLING		
King	N	Marine Disposal Corporation	Pier 35	Seattle	98134																					LANDFILL	N/A	N/A
	C1	Marine Vacuum Service, Inc.	1516 S. Graham St.	Seattle	98108	P			T			S	S			C		C								TANK	N/A	N/A
	N	Maritime Building	911 Western	Seattle	98136																					N/A	N/A	N/A
	C2	Mastercraft Metal Finishing	1175 Harrison St	Seattle	98109							S										S				N/A	N/A	N/A
	C2	Meridian Landfill	170th N & Meridian	Seattle	98133				P		S	S			S					S						LANDFILL	N/A	N/A
	C2	Metal Laundry Incorporated	614 12th	Seattle	98122	P			P			S														N/A	N/A	N/A
	N	Metro Alki Treatment Plant	3380 Beach DR SW	Seattle	98116																					N/A	N/A	N/A
	C1	Metro Lake Union Facility	1602 N. Northlake Way	Seattle	98103	P	P	F	T	P		C	S			C				S						TANK	IMPROPER HANDLING	N/A
	N	Metro South Base	11911 E. MARGINAL WAY SOUTH	SEATTLE	98168	P	T	F	F	T		C				C										IMPROPER HANDLING	N/A	N/A
	C2	METRO- Central Operating Base	1333 Airport Way S	Seattle	98134	P			P			S				S									S	TANK	N/A	N/A
	C1	Metro-North Facility	N. Northlake Place	Seattle	98103	P	P	F	T	P		C	S			C				S						N/A	N/A	N/A
	B	Midway Landfill	24808 Pacific Hwy S	Seattle	98031	T	F	P	F	F	C	C	C				C			C	S			C	C	LANDFILL	N/A	N/A
	C1	Mobil Bulk Facility- Renton	2423 LIND AVE SW	RENTON	98055	T	F	F	T	F						C										SPILL	N/A	N/A
	C1	Mobil Oil- Canal Bulk Plant	1101 NW 45th St.	Seattle	98107	T			P							C										TANK	SPILL	N/A
	C1	Mobile Truck Service	2214 4th Ave. S.	Seattle	98134	P	P	U	T	F		C				C										SPILL	IMPROPER HANDLING	STORM DRAI
	C1	Monterey Apartments Site	622 1st Av W/ Queen Ave N/ Roy	Seattle	98109	T	F	P	T	F						C										TANK	N/A	N/A
	C1	MST Chemicals, Inc.	6020 W Marginal SW	Seattle	98108	P			P	P		S	S									S				IMPOUNDMENT	N/A	N/A
	C2	Newcastle Mine Timber Shoot	SE Newcastle-CoalCR	Newcastle	98006																					N/A	N/A	N/A
	C2	Newcastle Mine-Air Vent	SE Newcastle-Coal Rd	Newcastle	98006																					N/A	N/A	N/A
	C1	Non-Ferrous Metals, Inc.	2905 13th Ave. SW	Seattle	98134	P	P	U	T	U		C		C												IMPROPER HANDLING	N/A	N/A
	N	North Coast Chemical Co	6300 17th AV S	Seattle	98108		T																			N/A	N/A	N/A
	C1	Northwest Cooperage Co., Inc.	7152 1st Av S	Seattle	98108	T	P	T	T	P	C	C	C	C	C	S	C	C	U	C	U	U	U			IMPROPER HANDLING	N/A	N/A

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King	N	Northwest Transformer Ser.	33729 9th Ave S	Federal Way	98003																					N/A	N/A	N/A
	N	Olympic Home Care Products	1141 NW 50th	Seattle	98107				T							S										SPILL	TANK	N/A
	M	Olympic Pipe Line Co.	2444 13th Ave. SW	Seattle	98134	T										S										SPILL	N/A	N/A
	C2	Olympic Steamship Co., Inc.	8220 S 212th St	Kent	98031	P			P							S										TANK	N/A	N/A
	C1	PACCAR	1400 N 4th St	Renton	98055	T	P	F	T	P	C	C	C	C		C	C	C		C					C	LANDFILL	DRUM	TANK
	C2	Pacific Chem & Cleaning Co	2200 4th S	Seattle	98134																					N/A	N/A	N/A
	C2	Pacific Chemical	500 7th Ave S	Kirkland	98033	P	P				S	S			S		S			S		S				N/A	N/A	N/A
	C2	Pacific Coast Coal	T21NR6E	Black Diamond	98010	P	P					S	S												S	LANDFILL	N/A	N/A
	N	Pacific Iron & Metals	2230 4th Ave. S.	Seattle	98125	F	T	F	T	F		C	C	C												IMPROPER HANDLING	N/A	N/A
	C2	Pacific Landfill	S of 3 Av SE/White River	Pacific	98047	P	P	P	P																	LANDFILL	N/A	N/A
	C2	Pacific Marine Environ. Lab	7600 Sand Point Way NE	Seattle	98115	P			P																	N/A	N/A	N/A
	C2	Pacific Molasses Co.	3200 11th Ave. SW	Seattle	98134	P	P		P	P		S	S									S		S		N/A	N/A	N/A
	C2	Palmer Coking Coal Co.	31407 HWY 169	Black Diamond	98010	P	P	U	U	U		S						S								N/A	N/A	N/A
	N	Palmer Coking & Coal-Newcastle	Newcastle Road	Seattle	98027																					N/A	N/A	N/A
	N	Pioneer Enamel Manufacture	5531 ARPT Way S	Seattle	98108																					N/A	N/A	N/A
	N	Poles Incorporated	826 102 NE	Bellevue	98009																					N/A	N/A	N/A
	C1	Precision Engineering	12131 So Director	Seattle	98108	T	T	T	T	T	C	C						C								SPILL	IMPROPER HANDLING	N/A
	N	Preservative Paint Company	5410 ARPT Way S	Seattle	98108	T			T																	N/A	N/A	N/A
	C2	Puget Sound Tug & Barge	1102 SW Massachusett	Seattle	98121																					N/A	N/A	N/A
	N	Quadrant Corporation	34461 9th Ave S	Federal Way	98003				T																	DRUM	N/A	N/A
	A	Queen City Farms	N 1/2 Sec 28-Maple Vly Qd	Seattle	98038	T	P	F	T	F														C	C	LANDFILL	N/A	N/A
	A	Queen City Farms	22420 S. E. 168th Way	Issaquah	98027	T	P	F	T	P	C	C	S	C	C	C	C	C	S	C				C	C	IMPOUNDMENT	N/A	N/A
	C1	Quendall Terminals	4503 Lk WA Blvd N	Seattle	98055	P	T	F	T	T						S	C			C					S	TANK	IMPROPER	SPILL

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King	C2	Ravenna Landfill	S of NE 45th & E of Montlake	Seattle	98105	P	P	P	P	T	s	c	c	s	c	c	s	s	s	c	s	s	s	c	c	LANDFILL	HANDLING N/A	N/A
	C2	Ravenna Landfill	So. of NE 45th & E of Montlake	Seattle	98195	T	P		P			c														LANDFILL	N/A	N/A
	C2	Redondo Oil Pit, King Co.	16th Ave S & SW Dash Point Rd.	Redondo	98054	P	U	U	P	U						s				s						N/A	N/A	N/A
	C2	Reichold Chemical	5900 W Marginal Way	Seattle	98106	P	F	F	P	P	s						s									IMPROPER HANDLING	TANK	DRUM
	C2	Renton Highlands Landfill	NE 3rd st. 500' W of NE 4th	Renton	98053																					LANDFILL	N/A	N/A
	C2	Renton Highlands Landfill	NE 3rd St., W of NE 4th St	Renton	98053				P																	LANDFILL	N/A	N/A
	C2	Renton Junction Landfill	1800 Monster Rd	Renton	98055	P	P		P																	LANDFILL	N/A	N/A
	N	Renton Transfer Sta	S of NE 4th St	Renton	98057																					LANDFILL	N/A	N/A
	C2	Repair Technology, Inc.	400 S. 96th	Seattle	98108	P	P					s		s												IMPROPER HANDLING	N/A	N/A
	C2	Rhone-Poulenc Inc.	9229 E Marginal Wy S	Seattle	98108	P			P				s													N/A	N/A	N/A
	N	Rudd Paint and Varnish Co.	1608-30 15th Ave W	Seattle	98119																					N/A	N/A	N/A
	C1	Seafab Metal Corp.	2700 16th Ave SW	Seattle	98134	T	U	U	T	U		c										c				IMPOUNDMENT	N/A	N/A
	C2	Seattle City Light Storage	3613 Fourth Ave S	Seattle	98108			P						s												N/A	N/A	N/A
	C1	Seattle Cooperage	7152 1ST S.	Seattle	98108	P	T	P	T	T	c	c	c	c	c	c		c				c		c	c	IMPROPER HANDLING	N/A	N/A
	C1	Seattle Iron & Metals	2955 11th Ave. SW	Seattle	98134	T	T	T	T	T		c	c	c												IMPROPER HANDLING	N/A	N/A
	N	Seattle N Transfer Station	34th N & Carr Pl	Seattle	98103																					LANDFILL	N/A	N/A
	N	Seattle Post Intelligencer	521 Wall ST	Seattle	98121																					N/A	N/A	N/A
	N	Seattle Rendering Works	5795 S 130th PL	Seattle	98168																					N/A	N/A	N/A
	N	Seattle So Transfer Station	8100 2nd AV S	Seattle	98118		T																			LANDFILL	N/A	N/A

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9. Dioxin
10. Polynuclear Aromatic Hydrocarbons
11. Reactive Wastes
12. Corrosive Wastes
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SITES BY COUNTY
WASHINGTON DEPARTMENT OF ECOLOGY
HAZARDOUS WASTE INVESTIGATIONS AND CLEANUP PROGRAM

COUNTY	SITE CAT.	SITE NAME	LOCATION ADDRESS	CITY	ZIP	AFFECTED ENVIRONMENTS G-WATER	S-WATER	AIR	SOIL	SEDIMENT	CONTAMINANTS #1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	WASTE MGNT PRACTICE 1	WASTE MGNT PRACTICE 2	WASTE MGNT PRACTICE 3
King	C2	Seattle Steel, Inc.	2414 SW Andover	Seattle	98106	T			T			S	S			S										IMPOUNDMENT	IMPROPER HANDLING	N/A
	C2	Seattle, Port of- Leckenby Co.	9819 46th Ave SW	Seattle	98134				P			S	S	S												N/A	N/A	N/A
	C1	Seattle, Port of, Term 5	26th Av SW & W Marginal Wy SW	Seattle	98126	T				T	C	C			C	C	C									UNKNOWN	N/A	N/A
	C1	Seattle, Port of- Terminal 30	Port of Seattle	Seattle	98134	T	P		T	T						C				C						TANK	IMPROPER HANDLING	N/A
	C1	Shell- Old Tank Farm	Part of Terminal 18	Seattle	98134	T	T	F	T	T						C										SPILL	IMPROPER HANDLING	N/A
	C1	Shell- Tank Farm	2720 13th Ave SW- Terminal 18	Seattle	98134	T			T	P						C										TANK	IMPROPER HANDLING	N/A
	C2	Sinclair & Valentine, L.P.	655 S Andover St	Seattle	98108	P			P			P	P					P								TANK	IMPROPER HANDLING	N/A
	N	Sno-King Garbage Company	8901 Willows Rd	Redmond	98052																					N/A	N/A	N/A
	C2	Southpark Landfill	S Park W of 5th SW	Seattle	98168	T	P		P		S	S			S	S				S						LANDFILL	N/A	N/A
	C1	Sternoff Metals	7201 Marginal Way E.	Seattle	98108	U	T	U	T	U		C		C												SPILL	IMPROPER HANDLING	N/A
	C1	Sternoff Metals Corporation	1600 SW 43rd St	Renton	98055	T	P	P	T	U	C	S	C			C			S	S					C	IMPROPER HANDLING	SPILL	N/A
	C2	Strip Mine No 3	166th Way SE	Issaquah	98027																					N/A	N/A	N/A
	C1	Sundstrand Data Control Inc	15001 NE 36th St	Redmond	98073 -9701	P	F	F	T	F	C	C						C				C				DRUM	TANK	N/A
	N	Sunset Park/Tub Lake Dump	S 136 & 18 Av S	Seattle	98104	T	T	T	T							S										SPILL	N/A	N/A
	C1	S. 96th Street Ditch	96th St & Duwamish River	Seattle	98108	P	P	P	T	P	S	C	C	S	S	C	S	S	S	C	S	S	S	S	S	SPILL	IMPROPER HANDLING	N/A
	C1	Texaco USA- Harbor Island	2225 13th Ave SW	Seattle	98134	T	P	P	T	P		S			S	C				S				S	S	SPILL	IMPROPER HANDLING	N/A
	C1	Todd Shipyards	1801 16th SW	Seattle	98134	U	T	F	U	T								C				C				DRUM	TANK	N/A
	N	Toomey Property Site	28836 164 SE	Kent	98031																					PESTICIDE	N/A	N/A

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King	C2	Tyee Lumber & Mfg	3737 A St SE	Auburn	98002	P	P		P								S									APPLIC IMPROPER HANDLING	TANK	N/A
	C1	Union Station Site	Jackson St., 4th Ave.	Seattle		P	P	U	T	U						C										IMPROPER HANDLING	N/A	N/A
	C2	United Construction Supply	18298 Andover Park W	Tukwila	98288		P									S					S					DRUM	STORM DRAIN	N/A
	N	United Services	3450 16th Av W	Seattle	98119																					N/A	N/A	N/A
	C2	Universal Manufacturing Corp.	14410 NE 190th St.	Woodinville	98072 -0277	P	P		P		S	S						S				S			S	DRUM	TANK	N/A
	C1	Unocal-Seattle Marketing Term.	Broad St & Western Av & Bay St	Seattle	98121	P	U	F	T	P						C										TANK	SPILL	N/A
	N	US Naval Station Puget Sound	7500 Sand Point Way NE	Seattle	98115	P	P		P					S	S	S										UNKNOWN	SPILL	N/A
	C1	Value Plating & Metal Pol	3207 11th Ave SW	Seattle	98134	P	P	F	P	T		C	C									S				IMPROPER HANDLING	SPILL	DRUM
	L	Vashon Landfill	18850 130th Av SW	Sunset Beach	98070	P	T	U	U	F		S	C			S	S							S	S	LANDFILL	N/A	N/A
	N	Vashon-Nike Missile Silo	7 miles So. of Vashon Ferry	Vashon Island			T							S	C											IMPOUNDMENT	SPILL	N/A
	C2	Wa Natural Gas - Seattle Plant	N 34th & Burke Ave. N.	Seattle	98111																					N/A	N/A	N/A
	C2	Washington Natural Gas	319 S 3rd St	Renton	98055	U	U	U	P	U														S		SPILL	DRUM	N/A
	C2	Wesmar Company Inc	1451 NW 46th	Seattle	98107																					N/A	N/A	N/A
	A	Western Processing Co Inc	7215 S 196th St	Seattle	98031	C	C	S	C	C	C	C	C	C	C	S	C	C	S	C	S	S		S	C	LAND APPLICATION	N/A	N/A
	C2	Western Tank Properties, Inc.	1500 Airport Way S	Seattle	98134																					N/A	N/A	N/A
	C2	Weyerhaeuser Seattle Lab	3233 11th St SW	Seattle	98134	P			P	P	S	S			S		S	S	S	S						N/A	N/A	N/A
	N	Widing Transportation Inc	24300 Pacific Hwy S	Kent	98031											S										N/A	N/A	N/A
	C2	Williams Lake	Mt.Baker-Snoqualmie Nat Forest	North Bend	98045	U	P	U	U	U		S														N/A	N/A	N/A

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King	C1	Wyckoff Co-West Seattle	2801 SW Florida St	Seattle	98126	T	T	P	T	T	C	C	C			S	S			C				S	S	IMPROPER HANDLING	SPILL	DRUM
	C1	Zandt Brass Foundry	3400 Harbor Ave. SW	SEATTLE	98126	T	P	P	T	P		C									C					SPILL	IMPROPER HANDLING	N/A
Kitsap	C1	Bainbridge Isl LF	End of Vincent Rd	Bainbridge	98110	P	T	F	P	U	C	C				C	C			C				C	C	LANDFILL	IMPROPER HANDLING	N/A
	A	Bangor Ordnance Disposal	Clear Cr Rd, Bldg 1100	Bangor	98315	T	T	U	T	T	C	C	S	S	S	C		S			S			S	S	IMPROPER HANDLING	N/A	N/A
	C2	Constitution Ave. Landfill	Constitution Ave & Porter	Bremerton	98310	P	P	U	P	U		S														LANDFILL	N/A	N/A
	A	Eagle Harbor (Wyckoff)	Creosote PL NE	Bainbridge Is	98110	T	T	F	T	T	C	C	C	C		C	C	C	S	C				C		SPILL	TANK	IMPROPER HANDLING
	C1	Hansville Landfill	31645 Hansville Rd, NE	Little Boston	98366	T	P	P	F	F		C					C	C								LANDFILL	N/A	N/A
	A	Naval Undersea Warfare Eng Stn	Highway 308, East End	Keyport	98345 -0580	P	P	P	T	P	C	C	S	S	S	C	S	S		S	C	C		C	C	DRUM	LANDFILL	TANK
	L	Olympic View Sanitary Ldfl	10015 SW Barney White Rd	Port Orchard	98366	T	P	U	U	F		C	C											C	C	LANDFILL	N/A	N/A
	N	Peninsula High School	14015 62nd Ave NW	GIG HARBOR	98335																					N/A	N/A	N/A
	C2	Pioneer Quarry Site-Proposed	T24N,R1E,Sec 20	Bremerton	98310	P	P	U	P	U		S														LANDFILL	N/A	N/A
	C1	Strandley/Manning Site	Willow Rd off of Hwy 302	Purdy		P	T	U	T	T				C												LAND APPLICATION	N/A	N/A
	C2	US EPA- Manchester Laboratory	7411 Beach Dr. E	Manchester	98353	P			P			S	S													N/A	N/A	N/A
	C2	US Naval Hospital - Bremerton	Boone Road	Bremerton	98312 -1898	P		P	P				S													N/A	N/A	N/A
	C2	US Naval Supply Ctr- Drmo Yard	N of Wycoff St between X & Y	Bremerton	98314				P					S												N/A	N/A	N/A

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Kitsap	C1	US Navy Supply Center	Orchard Pt/Little Cl	Manchester	98353	T	T		T				S	C		C										IMPROPER HANDLING	LANDFILL	TANK
	C2	US Navy-Bangor Submarine Base	Clear Creek Road, Bldg. 110	Bangor	98315																					N/A	N/A	N/A
	C2	US Navy-Jackson Park Ldfl	Unnamed Road E of Root Rd	Bremerton	98312																					N/A	N/A	N/A
	C2	US Navy-Puget Sound Shipyd	1st street	Bremerton	98314																					N/A	N/A	N/A
	C2	U.S. Navy - Camp Wesely Harris	W/Chico-Wildcat Lake	Unincorporat	98310																					N/A	N/A	N/A
	C2	VIP Landfill	Kitsap Wy/Oyster Bay	Bremerton	98314	P	U	U	U	U		S														LANDFILL	N/A	N/A
	C2	Wyckoff Co:- Bainbridge Island	5350 Creosote Pl. NE	Bainbridge Island	98110	P	P	U	P	P							S									N/A	N/A	N/A
Kittitas	M	East Kittitas Co Landfill	A-Line Road & Munday Rd	Kittitas	98934	P	P																			LANDFILL	N/A	N/A
	M	Ellensburg Disposal Co	607 N Railroad Ave	Ellensburg	98926																					N/A	N/A	N/A
	M	Ellensburg Transfer Station	Industrial Way	Ellensburg	98926																					N/A	N/A	N/A
	M	Horlick Landfill	E. of Horlick Road	Ellensburg	98926																					LANDFILL	N/A	N/A
	M	Kachess Dump #3	Kachess Dam Rd W	Easton	98925	P																				LANDFILL	N/A	N/A
	M	Keechelus Dump	Lk Kachess-Cooper Pass Rd	Easton	98525	P																				LANDFILL	N/A	N/A
	C1	Mid-State Aviation	1101 BOWERS ROAD	ELLENSBURG	98926	P	F	F	T	P					C											PESTICIDE DISPSL	SPILL	N/A
	M	Porky Park Farms	Hwy 1.. 5 MI W Thorp	Thorp	98946	T	T																			N/A	N/A	N/A
	M	Ryegrass Balefill	Sec16,T17N,R21EWM 10	Kittitas	98934	P	P																			LANDFILL	N/A	N/A
	M	Teanaway Dump	Teanaway Rd.	Cle Elum	98922																					LANDFILL	N/A	N/A
	M	West Ellensburg Landfill	Thorp Highway	Thorp	98946																					LANDFILL	N/A	N/A

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SUBJECT TO REVISION

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Klickitat	N	Columbia Aluminum Corporation	Hwy 14, 1 mi N of Day Dam	Goldendale	98620	T	P	F	T	P														C	C	IMPOUNDMENT	N/A	N/A
Lewis	A	American Crossarm & Conduit	100 Chehalis Av Sw	Chehalis	98532	T	T	P	T	T					C	C	C		C	C						IMPOUNDMENT	SPILL	LANDFILL
	B	Centralia Municipal Landfill	1313 S Tower	Centralia	98531	T	T	F	P	P		C		S				S								LANDFILL	IMPROPER HANDLING	N/A
	C1	Cummings Oil Co. Inc.	Intersection of 2nd & Market	Chehalis		P	P	U	P	U						C										TANK	N/A	N/A
	C1	Grange Supply - Chehalis	State Street	Chehalis	98532	P	F	F	T	F						C				S						TANK	SPILL	N/A
	C1	NW Hardwoods Inc. Fill Sites	3000 Galvin Road	Centralia	98531	T	P	U	P	P							S							C		LANDFILL	N/A	N/A
	C1	Packwood Lumber Company	12832 U.S HIGHWAY 12	Packwood	98361	T	T	U	T	T						C	C			S						SPILL	IMPROPER HANDLING	N/A
	C1	Ross Electric of WA-Coal Cr	346 Coal Creek Rd	Chehalis	98532	P	P	F	T	U				C		S										IMPROPER HANDLING	SPILL	N/A
	C1	Ross Electric-Logan Hill	1015 Logan Hill Rd	Chehalis	98532	U	U	T	T	U				C												IMPROPER HANDLING	N/A	N/A
	C1	Utility Transformer Service	5234 St Hwy 6	Pe Ell	98572	P	P	F	T	P				C		C		S								SPILL	IMPROPER HANDLING	DRUM
	C2	WA Army Natnl.Guard Shop #4	309 Byrd Street	Centralia	98531	P	U	U	P	U						S		S								SPILL	N/A	N/A
	N	Weyerhaeuser Company	151 Haskins Rd	Chehalis	98532	F	F	F	T	F					C			C								LANDFILL	IMPROPER HANDLING	DRUM
Mason	C2	Goose Lake	NW of Shelton Hwy101	Shelton	98584	P	P	U	U	P						S	S			S				S	S	SPILL	N/A	N/A
	C1	Mason County Landfill	Highway 10, N. of Shelton	SHELTON	98584	T	U	U	T	U	S	C	C	S	S	S	S	S	S	S				C	C	LANDFILL	LAND APPLICATION	UNKNOWN
	C2	Shelton Landfill	West end of 'C' Street	Shelton	98594	P	P	U	P	U	S	S	S	S	S	S	S	S	S	S	S	S		S	S	LANDFILL	N/A	N/A

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Mason	C2	Simpson Timber Company	Sawmill/Plywood Waterfrnt	Shelton	98584	P	U	P	P	P									S							N/A	N/A	N/A
	C1	Unocal Station (Shelton)	1ST Street	Shelton	98584	U	T	U	T	F						C										IMPROPER HANDLING	SPILL	N/A
Okanogan	C2	Alder Mill	T33N/R22E, Sec 17,18	Twisp	98856	P	P	F	P	T		C	C													IMPOUNDMENT	N/A	N/A
	C1	Arden's Country Store	B&O Street	Malott	98829	P	P	T	T	P						C								C		TANK	SPILL	N/A
	C2	Canamera Milling & Smelting	Colville Indian Res	Okanogan	98840	P	P	F	T	T		S	S													IMPOUNDMENT	N/A	N/A
	M	Custom Apple Packers Inc	1 Mi W of So city limits	Brewster	98812	P	F	F	P	F					S											IMPOUNDMENT	N/A	N/A
	M	D A Thorndike & Sons Inc	S Appleway	Oroville	98844	P	P	F	P	P					S											IMPOUNDMENT	N/A	N/A
	M	Ellisforde Tibbs Landfill	Highway 97	Ellisford	98855	F	P	F	T	F					S											LANDFILL	N/A	N/A
	M	Enloe Dam	4 Mi N of Oroville	Oroville	98844	P	P	F	T	P				C												SPILL	N/A	N/A
	C1	Oroville Dump	Nighthawk Hwy;4 mi W Oroville	Oroville	98844	P	P	F	T	P	C				C											LANDFILL	PESTICIDE DISPSL	N/A
	A	Silver Mountain Mine	Sec 34 T38N R26E WM	Loomis	98827	P	F	P	P	F		C														IMPROPER HANDLING	N/A	N/A
	M	Starcrisp, Inc.	244 Van Duyn St S	Okanogan	98840	P	P	F	P	P					S											IMPROPER HANDLING	N/A	N/A
	C1	Tonasket Post & Rail	185 Clarkston Mill Road	Tonasket	98855	P	P	F	T	F							C									LAND APPLICATION	N/A	N/A
	N	Turner Pesticide Dump	2.5 mi. South of Mallott	Omak	98741	P	P	F	T	F					C											PESTICIDE DISPSL	IMPROPER HANDLING	N/A
	C2	USDOI-BLM Kaaba Texas Mine	T40N,R25E,Sec 23	Nighthawk	98855	P	P	F	P	F		S														IMPROPER HANDLING	LANDFILL	N/A
Pacific	C2	Old Baleville	St Rt 105 5 mi W of	Baleville	98577	F	F	F	P	U		S												S		LANDFILL	N/A	N/A

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2. Metals-Priority Pollutants
3. Metals-Other
4. Polychlorinated Bi-Phenuls (PCB)
5. Pesticides
6. Petroleum Products
7. Phenolic Compounds
8. Non-Chlorinated Solvents
9. Dioxin
10. Polynuclear Aromatic Hydrocarbons
11. Reactive Wastes
12. Corrosive Wastes
13. Radioactive Wastes
14. Conventional Contaminants Organic
15. Conventional Contaminants Inorganic

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SUBJECT TO REVISION

SITES BY COUNTY
WASHINGTON DEPARTMENT OF ECOLOGY
HAZARDOUS WASTE INVESTIGATIONS AND CLEANUP PROGRAM

COUNTY	SITE CAT.	SITE NAME	LOCATION ADDRESS	CITY	ZIP	AFFECTED ENVIRONMENTS G-WATER	S-WATER	AIR	SOIL	SEDIMENT	CONTAMINANTS #1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	WASTE MGNT PRACTICE 1	WASTE MGNT PRACTICE 2	WASTE MGNT PRACTICE 3
Pacific	N	Rainbow Valley Landfill	I-101 Route 2 Box 300	Raymond	98577	P	U	U	P	U														S	S	LANDFILL	N/A	N/A
	C1	Weyerhaeuser Truck Shop		Raymond	98577	T	T	U	T	F						C										SPILL	TANK	IMPROPER HANDLING
Pierce	C2	Airo Services Inc	4110 E 11th St	Tacoma	98421	P	P	U	P	U						S				S						TANK	N/A	N/A
	C2	Aladdin Plating Co Inc	1657 Center St	Tacoma	98409	U	U	U	P	U		S	S													N/A	N/A	N/A
	C1	Allied Chemical-Tac. Works	1410 Thorne Rd	Tacoma	98401	P	T	U	T	P		C	C									C				IMPOUNDMENT	N/A	N/A
	C2	Alpine Plating	1551 Center St	Tacoma	98409	P	U	U	P	U		S	S													N/A	N/A	N/A
	A	American Lake Gardens	6411 146th St. SW	Tacoma	98439	T	U	F	P	U	C	C				S	S	S						C		LANDFILL	N/A	N/A
	C1	American Plating	2110 East D St	Tacoma	98421	P	P	U	T	P		C														IMPROPER HANDLING	N/A	N/A
	C1	American Surplus Sales Co	2916 S Tacoma Way	Tacoma	98402	P	U	F	T	F		C			C							C		S		N/A	N/A	N/A
	C1	ASARCO Inc.	Ruston Wy & N 51st	Tacoma	98407	S	T	U	T	T		C													S	IMPROPER HANDLING	SPILL	LANDFILL
	C2	Brazier Forest Industry	1501 Taylor way	Tacoma	98421	P	U	U	P	U		S			S											DRUM	N/A	N/A
	N	Brekke Enterprises	1320 Tidehaven Rd	Tacoma	98424	P	U	U	P	U												S				DRUM	SPILL	N/A
	N	Buffalo Don Murphy-Eatonville	Scott Turner Rd	Eatonville	98328	P	P	F	T	F	C															DRUM	SPILL	N/A
	C1	Buffalo Don Murphy-Waller R	6401 Waller Rd E	Tacoma	98443	T	T	F	T	F	C								C							SPILL	IMPROPER HANDLING	N/A
	C1	B&L Woodwaste Fill	Between 77 Ave E &PPL Road	Tacoma	98354	T	T	F	T	P		C												S	S	LANDFILL	N/A	N/A
	C1	Cascade Pole Co (McFarland)	1640 E Marc Ave	Tacoma	98404	P	P	U	P	P		S			S	S	C		S	S						IMPROPER HANDLING	N/A	N/A
	N	Cascade Steel Drums Inc	620 E 112th	Tacoma	98445	P	U	U	P	U	S					S		S								DRUM	N/A	N/A
	C1	Cascade Timber #1	3626 Marine View Dr.	Tacoma	98421	P	T	F	P	P		C												S		IMPROPER HANDLING	N/A	N/A
	C1	Cascade Timber #2	S. Taylor Way	Tacoma	98421	P	T	F	P	P		C				S				S				C		TANK	N/A	N/A

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9. Dioxin
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12. Corrosive Wastes
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HAZARDOUS WASTE INVESTIGATIONS AND CLEANUP PROGRAM

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Pierce	C2	Cascade Timber #3	Thorne Road	Tacoma	98421	U	P	U	P	U		S				S				S						UNKNOWN	N/A	N/A
	C1	Chemical Processors Inc	1701 Alexander Av	Tacoma	98421	T	F	U	T	U	C							C								DRUM	TANK	SPILL
	C1	Chemical Process.Inc./Parcel A	1701 Alexander Ave	Tacoma	98421	T	F	I	T	F	C		C			C		C		C						DRUM	TANK	SPILL
	C2	Comm Bay-Deep Waters	Middle of Bay	Tacoma	98402	U	P	F	F	P	S															N/A	N/A	N/A
	A	Comm Bay-Nearshore	Comm Bay-Waterway/Shoreline	Tacoma	98402	T	T	U	T	U	C	C	C	C	C	C	C	C	S	C				C	C	STORM DRAIN	IMPROPER HANDLING	TANK
	C1	Comm Bay-Ruston/Vashon	Ruston, Vashon I/N Tacoma	Tacoma	98402	T	T	T	T	T		C	C												C	IMPROPER HANDLING	SPILL	N/A
	A	Comm Bay-S Tacoma Channel	So Tac Channel of Co	Tacoma	98402	T	P	F	T	P	C	C	C	C	C	C	C	S	C	C			S			DRUM	LANDFILL	N/A
	C1	Coski Industrial Dump	5403 Pendle Lange Rd	Tacoma	98422	U	P	U	T	U		S		C		S				C						LANDFILL	N/A	N/A
	N	Crosby & Overton	2320 Milwaukee Way E	Tacoma	98421	F	F	F	F	F						C						C				TANK	N/A	N/A
	C1	Don Oline Landfill	1801 Alexander	Tacoma	98421	P	P	U	P	U	C	C														LANDFILL	N/A	N/A
	C1	DuPont/Weyco	Barksdale Ave.	Tacoma	98327	U	T	U	T	U		C		C		C				C	C	C		C	C	DRUM	IMPROPER HANDLING	LANDFILL
	C1	D. Street Petroleum	Approx 3rd-7th & D St	Tacoma	98401	T	P	U	T	S		S				C				S						SPILL	N/A	N/A
	C1	Fife Mobil Station	5405 PACIFIC HIGHWAY E	FIFE	98424	P	T	U	T	F						C										TANK	SPILL	N/A
	N	Fife Pesticide Drums	6217 20th St. EAst	Fife	98424	F	F	F	T	F					C											SPILL	N/A	N/A
	C2	General Electric	3309 E West Rd	Tacoma	98421	U	U	U	P	U				S												N/A	N/A	N/A
	C1	General Metals	1902 Marine View Drive	Tacoma	98422	P	T	U	T	P		C		C												IMPROPER HANDLING	N/A	N/A
	C2	General Plastics	3401 S 35th St	Tacoma	98409	P	U	U	P	U															S	N/A	N/A	N/A
	L	Georgia Pacific Resins	1754 Thorne Rd	Tacoma	98421	T	T	U	T	U							C									DRUM	LANDFILL	N/A
	C1	Kaiser Aluminum & Chem Corp	3400 Taylor Wy	Tacoma	98421	P	U	U	T	T										C				C	C	IMPOUNDMENT	IMPROPER HANDLING	N/A
	A	Lakewood/Ponders Corner	1-5 & New York Ave	Tacoma	98438	T	F	U	T	F	C							C								IMPROPER HANDLING	N/A	N/A

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Pierce	C1	Lilyblad Petroleum Inc	2244 Prt of Tacoma R	Tacoma	98401	T	T	U	T	U	C					S										DRUM	TANK	SPILL
	C2	Lincoln Avenue Landfill	1837 Lincoln Ave	Tacoma	98401	U	U	U	P	U		S														LANDFILL	N/A	N/A
	C2	Lincoln Ave. Ditch	Port of Tac Rd/Lincoln Av	Tacoma	98421	U	P	U	P	P						S								S	S	N/A	N/A	N/A
	C1	Louisiana Pacific	3701 Taylor Way	Tacoma	98401	S	T	F	T	U		C												S		IMPROPER HANDLING	N/A	N/A
	C1	Manke Lumber Co-Sumner Plt	13702 8th Ave NE	Sumner	98390	U	T	U	U	T					C											IMPOUNDMENT	IMPROPER HANDLING	N/A
	C2	McChord AFB (12 sites)	62nd ABG/DEEV	McChord AFB	98438 -5436	T	U	U	P	U				S		S		S	C							N/A	N/A	N/A
	C2	McChord Custom Cleaners	12923 Bridgeport Way	Tacoma	98438	P	U	U	P	U		S						S								N/A	N/A	N/A
	A	McChord(FormerWashRackSite 54)	62 ABG/DEEV	McChord AFB	98438 -5436	T	P	P	T	U	C	C	C		C	C	C	S		C				C	S	IMPROPER HANDLING	N/A	N/A
	C1	McNeil Island	1403 COMMERCIAL	Steilacoom	98388	T	P	U	T	U	C	S		C												IMPROPER HANDLING	N/A	N/A
	C2	Murray Pacific #1	3502 Lincoln Ave E	Tacoma	98421	S	S	U	S	S		S												S		N/A	N/A	N/A
	C1	Murray Pacific #2	Blair Waterway?	Tacoma		S	S	U	S	S		C												S		LAND APPLICATION	N/A	N/A
	C1	Music Machine, The	Corner of 38th and 'M'	Tacoma		T	U	U	T	F						C										TANK	SPILL	N/A
	C2	National Oil Dumpsite	NE Cor 25&Wilkeson	Tacoma	98409	P	U	U	P	U						S										LANDFILL	N/A	N/A
	C2	North Tacoma Landfill	Near Surprise Lake	Tacoma	98401	P	U	U	P	U		S						S						S		LANDFILL	N/A	N/A
	C2	Northern Auto Elec Rebuild	12012 Pacific Hwy	Tacoma	98499	U	U	U	P	F						S									S	N/A	N/A	N/A
	C2	NW Monitor Molded Products	9350 47th SW	Tacoma	98499	P	U	U	P	U		S												S		N/A	N/A	N/A
	C2	Occidental Chem (Alex Ave.)	605 Alexander Ave	Tacoma	98421	P	P	U	P	U	S											S				N/A	N/A	N/A
	C2	Occidental Chem (Marine View)	Marine View Drive	Tacoma	98422	P	P	P	P	U	S											S				LANDFILL	N/A	N/A
	C1	Occidental Chem./Dauphin Site	2911 Pacific Hwy E	Tacoma	98424	P	P	U	P	F	C											S				LANDFILL	N/A	N/A
	N	Parkland Gas Spill	13106 Pacific Ave	PARKLAND	98444	T	P	T	F	F						C										TANK	SPILL	N/A
	C2	Pederson Oil Co.	1622 Marine View Dr	Tacoma	98412	U	U	U	P	U						S				S						UNKNOWN	N/A	N/A

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HAZARDOUS WASTE INVESTIGATIONS AND CLEANUP PROGRAM

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Pierce	C1	Pennwalt Corporation	2901 Taylor Way	Tacoma	98421	T	P	U	T	U	S	C			S							S		S	S	LANDFILL	SPILL	IMPROPER HANDLING
	C1	Pennwalt-3009 Taylor Way Site	3009 Taylor Way	Tacoma	98421	P	T	F	P	P		C												S		IMPROPER HANDLING	N/A	N/A
	C1	Petarcik (Occidental Chemical)	911 Pacific Hwy E	Tacoma	98424	T	T	U	T	F	C											S				LANDFILL	N/A	N/A
	C1	Petroleum Reclaiming Serv.	3003 Taylor Way		98421	U	T	U	P	U						C				S						TANK	N/A	N/A
	C2	Ponders Auto Parts Inc	12828 Pacific Hwy SW	Tacoma	98499	U	P	U	P	U	S	S				S										N/A	N/A	N/A
	C1	Portac	4215 East-West Road	Tacoma	98421	P	T	U	T	P		C	C		C	C			S	C						SPILL	IMPROPER HANDLING	DRUM
	C2	PRI Northwest	606 Alexander Ave N	Long Beach	98427	P	U	U	P	P						S				S						UNKNOWN	N/A	N/A
	C2	Puget Sound Oil Co.	21716 Orville Rd. E.& Fisk Rd	Orting	98360	U	U	U	P	U						S										N/A	N/A	N/A
	C1	Puget Sound Power & Light	RT. 1, BOX 69 (CAMP 6 RD)	Bellevue	98360	T	T	U	T	T	C	C														SPILL	IMPROPER HANDLING	N/A
	C2	Purdy Landfill	14151 54th AV NW	Gig Harbor	98373	U	U	F	P	F		S														LANDFILL	N/A	N/A
	C2	Puyallup City Landfill(Old)	Off Main Ave	Puyallup	98371	U	U	F	P	U		S														LANDFILL	N/A	N/A
	C2	Puyallup Landfill	Pierce Co.	Federal Way	98003	P	U	F	P	U		S														LANDFILL	N/A	N/A
	C1	Reichhold Chem Inc	2340 Taylor Wy	Tacoma	98421	T	P	F	T	U	C	C		C			C	C	S							IMPOUNDMENT	LANDFILL	IMPROPER HANDLING
	C1	Rosch Property	30220 72nd Ave S.	TACOMA	98580	P	U	F	U	F	C			C	C	C	C					C			C	DRUM	N/A	N/A
	C2	Simpson	733 E 11th St.	Tacoma	98421	P	P	P	P	F		S							S							N/A	N/A	N/A
	L	Simpson - Tacoma Kraft Co.	801 PORTLAND AVE	TACOMA	98421	U	F	F	F	T							C			C				C		IMPROPER HANDLING	N/A	N/A
	C1	Stauffer Chemical Company	2545 Lincoln Ave	Tacoma	98421	T	T	U	T	T		C	C			C		C				C				IMPOUNDMENT	N/A	N/A
	C2	Tacoma Boatbuilding Co.	1840 Marine View Dr.	Tacoma	98421	P	P	U	P	P	S													S	S	N/A	N/A	N/A
	C1	Tacoma Landfill	3510 S Mullen	Tacoma	98409	T	T	T	T	T	C	C	C		C	C		S		C		S				LANDFILL	N/A	N/A
	C1	Tacoma Spur/24th and A	24 S & E 'A'	Tacoma	98402	T	P	F	T	F	S					S	S	S		C						TANK	N/A	N/A
	C1	Tacoma Swamp	S 56th & Madison	Tacoma	98421	T	U	F	T	F	C	C	C	C	C	C			S	C			S			IMPROPER HANDLING	N/A	N/A

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Pierce	C1	Tacoma Tar Pits	Portland Av & River	Tacoma		P	U	U	T	F	S									C						N/A	N/A	N/A
	C1	TAM Engineering Corp.	3033 S Lawrence	Tacoma	98411	P	P	F	P	U	C	C				C						S				DRUM	SPILL	N/A
	B	Thun Field Landfill	17975 Meridian S	Puyallup	98371	T	U	U	T	F	C	C												C	S	LANDFILL	N/A	N/A
	L	U of W Pack Forest	T16N,R4E,Sec 29	Lagrande	98328	T	P	F	P	F													C			LANDFILL	N/A	N/A
	C2	U S Gypsum Company	2301 Taylor Way	Tacoma	98421	P	P	F	P	P		S										S				N/A	N/A	N/A
	C2	Union Pacific RR-Tunnel	Jefferson/25th& Ctr	Tacoma	98421	U	U	U	P	F						S										N/A	N/A	N/A
	A	US Army-Fort Lewis-Ldfl No5		Fort Lewis	98433	T	P	P	P	P			C											C	C	LANDFILL	N/A	N/A
	L	US Gypsum-HWY 99	State Route 99	Tacoma	98354	P	P	F	P	U		C												C	S	LANDFILL	N/A	N/A
	L	US Gypsum-Puyallup	925 River Rd	Puyallup	98371	P	P	F	P	U		C													S	LANDFILL	N/A	N/A
	N	US Oil & Refining Co.	3001 Marshall Ave	Tacoma	98421	P	P	F	P	P		S				S										SPILL	IMPROPER HANDLING	N/A
	C2	USAF - McChord AFB - Bldg 792	62ABG/DEEV	MCChord AFB	98438 -5436				T							C										N/A	N/A	N/A
	C1	USAF-MCCHORD AFB, AREA A	62ABG/DEEV	MCChord AFB	98438 -5436	T	U	U	T	F	C	C			C	C	C									LANDFILL	TANK	SPILL
	C1	USAF-MCCHORD AFB, AREA C-Site:	62ABG/DEEV	MCChord AFB	98438 -5436	T	F	U	P	F	C	C			C	C	C			C						IMPROPER HANDLING	TANK	SPILL
	C2	USAF-MCCHORD AFB, AREA D	62ABG/DEEV	MCChord AFB	98438 -5436	T					C															N/A	N/A	N/A
	C1	USAF-MCCHORD AFB, AREA E	62ABG/DEEV	MCChord AFB	98438 -5436	T	F	F	T	P						C								C		IMPROPER HANDLING	LANDFILL	SPILL
	C2	USAF-MCCHORD AFB,BLDG 1173	62ABG/DEEV	MCChord AFB	98438 -5436				T							C										N/A	N/A	N/A
	C1	USARMY-Ft Lewis Logistics Cntr	T19N/R2E-21,22,26,27	Fort Lewis	98433 -5000	T	P	U	T	U	C															SPILL	IMPROPER HANDLING	N/A
	C2	Washington Natural Gas	2200 E River St	Tacoma	98421	U	U	U	P	U						S										N/A	N/A	N/A
	C1	Wasser Winters	1602 Marine View Dr	Tacoma	98421	P	T	U	P	P		C				S				S						UNKNOWN	N/A	N/A
	C1	Well 12-A	S 36th & Pine	Tacoma	98421	T	F	U	T	F	C	C	C	C	C	C	C	S	C	C						DRUM	SPILL	N/A

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HAZARDOUS WASTE INVESTIGATIONS AND CLEANUP PROGRAM

COUNTY	SITE CAT.	SITE NAME	LOCATION ADDRESS	CITY	ZIP	AFFECTED ENVIRONMENTS G-WATER	S-WATER	AIR	SOIL	SEDIMENT	CONTAMINANTS #1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	WASTE MGNT PRACTICE 1	WASTE MGNT PRACTICE 2	WASTE MGNT PRACTICE 3
Skagit	C2	Bear Creek Powerhouse	Lk Shannon-T36N,R8E	Concrete	98237	P	P	U	P	U				S		S										SPILL	N/A	N/A
	C1	EDB 2 Skagit County	Birdsview Berry Farm	MT. VERNON	98237	T	F	F	U	F					C											PESTICIDE APPLIC	N/A	N/A
	N	General Chemical Corporation	655 N Texas Rd	Morristown	98221	P	P					S														IMPOUNDMENT	N/A	N/A
	N	Impact Industries Sulphur Pile	1325 B Hwy.	Mt. Vernon	98273		T															S				LAND APPLICATION	N/A	N/A
	C2	LTV Energy Products	500 Metcalf St	Sedro Wooley	98284				T																	N/A	N/A	N/A
	N	March Point Landfill	1/4 Mi E of BN's Whitmarsh	Anacortes	98221	P	P	F	P	F							S									LANDFILL	N/A	N/A
	C1	Mt Vernon Gasoline Spill	College Wy & Freewy Dr- SE Crn	Mt. Vernon	98273	T	F	T	U	F						C										SPILL	N/A	N/A
	C1	Northwest Petrochemical Corp.	708 N Texas Rd, March Point	Anacortes	98221	P	P	F	T	F							C									IMPROPER HANDLING	N/A	N/A
	C2	P M Northwest Dump	Hwy 20 Swinomish I R	Anacortes	98221	P	P	U	U	U		S				S								S		LANDFILL	N/A	N/A
	C2	Sakuma Bros Birdsview Berry	3593,3596,3575,3658	Concrete	98237																					N/A	N/A	N/A
	C1	Sedro Wooley Gas Spill/Leak	Corner Borseth & Ferr St.	Sedro Woolley	98284	T	F	T	T	F						C										TANK	SPILL	N/A
	C1	Septic Tank Lagoon	Kelleher Rd & Old Hwy 99 N	Burlington	98233	P	U	F	P	T														C	C	IMPOUNDMENT	N/A	N/A
	N	Shell Oil Co	March Point Rd	Anacortes	98221																					N/A	N/A	N/A
	C2	Texaco Puget Sound Off-Site	March's Point	Anacortes	98221																					N/A	N/A	N/A
	N	Texaco Refining & Marketing	March Pt	Anacortes	98221																					N/A	N/A	N/A
Skamania	C2	USA COE Hamilton Island Lndfl	Bonneville Lock & Dam	North Bonneville	98639	P	P	F	P	P		S	S	S		S	S			S				S		LANDFILL	IMPROPER HANDLING	N/A
Snohomish	N	Arlington Ford	Hwy 9 & Highlands Dr	Arlington	98223				T							C										SPILL	N/A	N/A

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LISTINGS BY LOCATION

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5. Pesticides
6. Petroleum Products
7. Phenolic Compounds
8. Non-Chlorinated Solvents
9. Dioxin
10. Polynuclear Aromatic Hydrocarbons
11. Reactive Wastes
12. Corrosive Wastes
13. Radioactive Wastes
14. Conventional Contaminants Organic
15. Conventional Contaminants Inorganic

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Snohomish	C2	Arlington/Marysville Ldfl	Arlington Airport	Arlington	98223	P	P	U	P	U											S			S		LANDFILL	N/A	N/A
	C2	Biringer Berry Farm	6219 88th St. NE	Marysville	98270	T			T						S											PESTICIDE APPLIC	N/A	N/A
	C2	Boeing Cmrcl. Airpln.- Everett	3003 W. Casino Rd	Everett	98203	P	P	U	P	P		S				S		S			S	S		S	S	N/A	N/A	N/A
	C2	Boeing Co- Tulalip Test Site	Tulalip Ind. Reser.	Marysville	98270	P	U	U	P	U				S		S										DRUM	N/A	N/A
	C2	Bryant Landfill	6306 Grandview Rd	Arlington	98223	T	P	F	F	F		S												S	S	LANDFILL	N/A	N/A
	N	Cathcart Landfill	14528 Hwy 9	Snohomish	98290		P																	C	C	LANDFILL	N/A	N/A
	N	Chevron USA Inc-Asphalt	20555 Richmond Beach	Richmond Bch	98177																					N/A	N/A	N/A
	N	Circuits Engineering	1802 180th SE	Bothell	98011	P	T	F	P	F		C														SPILL	IMPROPER HANDLING	N/A
	C1	DFSP Mukilteo Tank Farm	1 Front St.	Mukilteo	98275	T	P	T	T	U						C		S								TANK	N/A	N/A
	C2	Everett City Landfill	2902 36th St SE	Everett	98201	P	T	U	U	F		S	S			S								S	S	LANDFILL	N/A	N/A
	C1	Everett Tire Fire	3002 Wetmore	Everett	98201	U	T	P	T	F		C								C						IMPROPER HANDLING	N/A	N/A
	C1	Go East Corp. Landfill Site		Everett	98201	P	T	P	U	F		S									S			C	C	LANDFILL	N/A	N/A
	C1	J H Baxter & Company	188th & 66th Av NE	Arlington	98223	P	T	F	T	T	C															IMPROPER HANDLING	SPILL	N/A
	C2	Lake Goodwin Landfill	18520 Frank Waters R	Stanwood	98292	U	U	U	T	U				S										S	S	LANDFILL	N/A	N/A
	N	Lake Roesiger Landfill	19619 Dubuque Rd	Snohomish	98290	P																				LANDFILL	N/A	N/A
	C1	Lake Stevens Landfill	131 Ave NE	Everett	98258	T	T	F	U	F		C	C											C	C	LANDFILL	N/A	N/A
	N	Lynnwood Plating	2107 196th SW	Lynnwood	98036	P	P					S														N/A	N/A	N/A
	C2	Maltby Warehouse & Field	S End of Yew Rd	Maltby	98290	P	P	U	P	U						S										DRUM	N/A	N/A
	C1	Monroe Landfill	T28N,R6E,Sec26	Monroe	98272	P	P	F	U	F														C	C	LANDFILL	N/A	N/A
	N	Northwest Garbage	1821 180 SE	Bothell	98011																					N/A	N/A	N/A
	N	Northwest Transformer Services	6510 216 St SW UnitC	Mountlake Terrace	98043																					N/A	N/A	N/A
	N	Oso Landfill	31705 Lk Cavenaugh	Arlington	98223																					LANDFILL	N/A	N/A
	C1	Pallister Paint	1037 Center road	Everett	98204	P	F	F	T	F	C	C		C		C		C		C				C		IMPROPER HANDLING	N/A	N/A

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9. Dioxin
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WASHINGTON DEPARTMENT OF ECOLOGY

HAZARDOUS WASTE INVESTIGATIONS AND CLEANUP PROGRAM

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Snohomish	N	Scott Paper Co-Everett	2600 Federal Way	Everett	98201	U	U	F	P	P															C	TANK	N/A	N/A
	C2	Simpson Paper Co.- Pulp Plant	NE of S 3rd Av at 48th St SE	Everett	98201	P	P	U	P	P		S														N/A	N/A	N/A
	C1	Sisco Landfill	7500 Wade Rd	Arlington	98223	P	T	U	P	F		S	S				S							S	C	LANDFILL	N/A	N/A
	C2	Snohomish Landfill	68th SE & 118th Dr SE	Snohomish	98290	P	P																			LANDFILL	N/A	N/A
	N	Tulalip Landfill	US Hwy 99 at Ebey Slough	Marysville	98270																					N/A	N/A	N/A
	C2	Union Oil of California	11720 Unico Rd	Edmonds	98020	T										S										N/A	N/A	N/A
	C2	USAF-Defense Fuel Supply Depot	Front St & Loveland	Mukilteo	98275	T			T			S				S										SPILL	TANK	N/A
	C2	Verax Chemical Company	20102 91st Av SE	Snohomish	98290																					N/A	N/A	N/A
	N	Weyerhaeuser Kraft-Everett	101 Marine View Dr	Everett	98201																					LANDFILL	N/A	N/A
Spokane	C1	Alaska Steel and Supply	E. 3410 DeSmet	Spokane	99202-4584	U	U		T				S	C												IMPROPER HANDLING	N/A	N/A
	C2	Aluminum Recycling Corp.	E 3412 Wellesley	Spokane	99207	P		P			O	O	O	O	O	O	O	O	O	O					S	N/A	N/A	N/A
	N	Aluminum Recycling-Trentwood	2317 N Sullivan Rd	Veradale	99216				T																S	N/A	N/A	N/A
	N	American Building Center	523 Dishman-Mica Hwy	Spokane	99214																					N/A	N/A	N/A
	N	American Recycling	E 6203 Mission	Spokane	99211																					N/A	N/A	N/A
	C1	American Tar Company	North 111 Erie St	Spokane	99202	T	P	F	T	U										C						SPILL	N/A	N/A
	C1	Argonne Road	N. 6018 Argonne Road	Spokane	99207	T	U	U	T	U	C		S												C	LAND APPLICATION	IMPROPER HANDLING	N/A
	N	Atomic Chemical Corporation	E 41 Gray St	Spokane	99210	P	P																			DRUM	N/A	N/A
	N	B J Carney & Company	1102 N Howe	Spokane	99206				T								C									N/A	N/A	N/A
	N	Burlington Northern-Hillyd.	Sec 34 T26N R43E Wm	Spokane	99207				T					C												SPILL	N/A	N/A
	B	Colbert Landfill	Elk-Chatteroy Road	Spokane	99005	T	P	P	P	U	C		S											C	C	LANDFILL	IMPROPER HANDLING	LAND APPLICATIO
	N	Columbia Light Transformer	20 Mi N of Spokane	Spokane	99201																					LANDFILL	N/A	N/A

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Spokane	N	Columbia Paint Co Inc	N 112 Haven	Spokane	99202																					N/A	N/A	N/A
	B	General Electric-Old Site	E 4323 Mission Ave	Spokane	99211	T	F	F	T	F	C	S		C												IMPROPER HANDLING	N/A	N/A
	N	Gober Marshall Septage Site	Cheney-Spokane Rd	Marshall	99020	P	P	F	T	U														C		LAND APPLICATION	N/A	N/A
	N	Gobers Septic Disposal	Hallet Rd	Spokane	99204	P	P																			LAND APPLICATION	N/A	N/A
	N	Great Western Chem Co of WA	N 1420 Thierman Rd	Spokane	99206				T													C				TANK	N/A	N/A
	A	Greenacres Landfill	Liberty Lake	Spokane	99019	T	F	P	T	F	C	S	S		S	S	C			C				C	C	LANDFILL	N/A	N/A
	N	Hagen Dry Cleaners	N 20 Pines Rd	Spokane	99205																					N/A	N/A	N/A
	N	Heglar-Kronquist	Hegler Rd & Kronquist Rd	Spokane	99021	T			T																	LANDFILL	N/A	N/A
	N	Ideal Basic Industries	Pine Rd & E Empire	Spokane	99211							C														LANDFILL	N/A	N/A
	C1	Inland Empire Plating	W. 1205 COLLEGE AVENUE	Spokane	99201	F	F	F	T	F		C														IMPROPER HANDLING	N/A	N/A
	M	Inland Foundry Inc	N 11200 Market	Mead	99021	U	U	T	T	U																LANDFILL	N/A	N/A
	C2	Inland Metals,Inc.	E. 528 Trent	Spokane	99202	U	P		T					C	-	S										IMPROPER HANDLING	UNKNOWN	UNKNOWN
	A	Inland Pit	N 3808 Sullivan Rd. & Kiernan	Spokane	99220																					N/A	N/A	N/A
	L	Kaiser Aluminum & Chem Corp	E 15000 Euclid	Spokane	99215	T	U	U	T	U															C	LANDFILL	N/A	N/A
	B	Kaiser Aluminum & Chem. Corp.	Hawthorne Rd 1.2 mi Div. Rd.	Spokane	99207	T	P	U	T	U														C	C	IMPOUNDMENT	N/A	N/A
	C2	Marshall Landfl	Marshall City Limits	Marshall	99020	P	P																			LANDFILL	N/A	N/A
	B	Mica Landfill	Hwy 27	Spokane	99211	P	P	P	P	F	S	S			S			S						S	S	LANDFILL	N/A	N/A
	B	NORTH MARKET STREET	N.MARKET ST./FREYA ST.AREA	SPOKANE	99207	T			T		C	C				C				C						IMPOUNDMENT	TANK	SPILL
	A	Northside Landfill	W. 5502 Nine Mile Road	Spokane	99211	T	P	U	T	U	C	C												C	C	LANDFILL	N/A	N/A

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Spokane	L	Southside Landfill	65TH & Regal	Spokane	99223	P	F	F	P	F	S															LANDFILL	N/A	N/A
	N	Spokane Gas Manufacturing Site	Erie & Bradley Sts	Spokane	99201	P	P	P	P							C										SPILL	N/A	N/A
	C1	Spokane Intnl.Arpt.Business Pk	S 3000 Geiger Blvd, PO Box 192	Spokane	99219	P	U	U	P	U	S					C										IMPROPER HANDLING	N/A	N/A
	A	Spokane Junk Yard	N. 3322 Cook St.	Spokane	99207	F	F	F	T	F				C												IMPROPER HANDLING	N/A	N/A
	N	Spokane Transformer Company	2500 E Springfield	Spokane	99202				T					C												N/A	N/A	N/A
	N	Troy Laundry	E 2322 Sprague	Spokane	99202	T																				SPILL	N/A	N/A
	N	Union Carbide-Linde Div	4020 N Market	Spokane	99207																					N/A	N/A	N/A
	N	United Paint Manufacturing	E 19011 Cataldo	Greenacres	99016																					N/A	N/A	N/A
	A	USAF-Fairchild Air Base	US Hwy 2 W of Spokane		99011	T	P	P	T	T	C	C		C	S	C	S	C						C	C	SPILL	TANK	LANDFILL
	N	USDOE-BPA Bell Substations	E 2400 N Hawthorne R	Spokane	99201	F	F	F	T	F				C												SPILL	N/A	N/A
	M	WA Dept of Transportation	N 2714 Mayfair	Spokane	99207	P			P		S							S								LANDFILL	DRUM	N/A
	M	Western Farm Services	Hwy 27	Latah	99018	F	F	U	F	U					C											TANK	PESTICIDE APPLIC	N/A
	N	Western Fruit Express	E Market St N of Fra	Spokane	99207																					N/A	N/A	N/A
Stevens	N	Callahan Mines-Pond	20 mi. NW of Colville	Colville	99114																					LANDFILL	N/A	N/A
	C1	Dawn Mining Company Mill Ponds	Hwy 231, City Center	Ford	99013	T	T	F	F	F													C			IMPOUNDMENT	N/A	N/A
	C1	L-Bar Products	Hwy 395 . Mi S. of Chewelah	Chewelah	99109	T	P	T	T	F		S													C	IMPROPER HANDLING	N/A	N/A
	C2	Midnight Mine	T28N,R37E,Section12	Wellpinit	99040		T					S														LANDFILL	N/A	N/A
	N	Northwest Alloys Inc.	62 MI N Spokane H395	Addy	99101																					N/A	N/A	N/A
Thurston	C1	C B Bumper Company Inc	4325 113th Ave SW	Olympia	98502	T	P	F	T	F			C												C	IMPROPER	N/A	N/A

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																										HANDLING		
Thurston	C1	Cascade Pole Inc - McFarland	1100 Washington St	OLYMPIA	98501	T	T	U	T	T					C	C	C		C	C				C		IMPROPER HANDLING	N/A	N/A
	C1	Ceder Creek Corrections (DNR)	BORDEAUX ROAD	LITTLEROCK	98556	U	U	U	T	U	C					C										SPILL	IMPROPER HANDLING	N/A
	C1	EDB 1 Thurston County	INTERSECTION OF YELM HIGHWAY	OLYMPIA		T	F	F	T	F					C											PESTICIDE APPLIC	N/A	N/A
	C1	J & B Exterminators	5647 Libbey Road	Olympia	98501	F	T	T	T	F					C	C					C			C	C	IMPROPER HANDLING	PESTICIDE APPLIC	N/A
	C1	J.R. Setina Manufacturing	2926 YELM HIGHWAY SE	OLYMPIA	98501	F	T	U	T	F	C	C	C			C		C			C	C		C	C	IMPROPER HANDLING	SPILL	N/A
	C1	Lacey Compound(DNR)	8410 MARTIN WAY EAST	LACEY	98504	P	U	U	T	U	C					C										SPILL	IMPROPER HANDLING	N/A
	N	Ostrom Mushroom Farms	8323 Steilacoom Rd SE	Lacey	98503	P	F	F	F	P					S											IMPOUNDMENT	N/A	N/A
	C2	O'Brien Property	1805 Abernathy Rd NE	Olympia	98506	P	U	U	P	U		S				S						S			S	SPILL	N/A	N/A
	C1	Pacific Powder Company	13120 Tilley Rd S	Olympia	98502	P	T	U	T	F			C			C								C	C	IMPROPER HANDLING	LANDFILL	N/A
	N	Pacific Sand and Gravel	1831 Carpenter Rd	Lacey	98506	P	P	F	P	F				S		S										N/A	N/A	N/A
	C2	Puget Sound Power & Light S	2703 Pacific Ave	Olympia	98501	P	P	U	P	U				S												SPILL	N/A	N/A
	C1	Restover Truck Stop	93rd Ave SW & I-5	Olympia	98502	T	F	F	T	F						C								C		SPILL	TANK	N/A
	N	Spooners Strawberry Farm	3323 Yelm Hwy	Olympia	98503	T	U	U	P	P					C											N/A	N/A	N/A
	C1	Treasure Chest	1919 NW DIVISION	OLYMPIA	98502	U	T	U	T	F											C	C		C		UNKNOWN	N/A	N/A
	C1	Unocal Station (Olympia)	900 CAPITOL WAY	OLYMPIA	98502	U	T	U	T	F						C										TANK	N/A	N/A
	C1	USDA PAC NW Forest Range Exp	3625 93rd Ave. S.	Tumwater	98501	P	P	F	T	F					C		C		S							N/A	N/A	N/A
	C1	Weyerhaeuser Co-Box Plant	7727 Union Mill Rd SE	Olympia	98507	P	P	F	T	F		C	C			C								S	S	LAND APPLICATION	N/A	N/A
	C2	Wolph's Second Hand Store	6711 Old Highway 101	Olympia	98502	P	P	U	P	U		S				S										N/A	N/A	N/A

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4. Polychlorinated Bi-Phenuls (PCB)
5. Pesticides
6. Petroleum Products
7. Phenolic Compounds
8. Non-Chlorinated Solvents
9. Dioxin
10. Polynuclear Aromatic Hydrocarbons
11. Reactive Wastes
12. Corrosive Wastes
13. Radioactive Wastes
14. Conventional Contaminants Organic
15. Conventional Contaminants Inorganic

SITES BY COUNTY
WASHINGTON DEPARTMENT OF ECOLOGY
HAZARDOUS WASTE INVESTIGATIONS AND CLEANUP PROGRAM

COUNTY	SITE CAT.	SITE NAME	LOCATION ADDRESS	CITY	ZIP	AFFECTED ENVIRONMENTS G-WATER	S-WATER	AIR	SOIL	SEDIMENT	CONTAMINANTS #1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	WASTE MGNT PRACTICE 1	WASTE MGNT PRACTICE 2	WASTE MGNT PRACTICE 3
Walla Walla	N	Boise Cascade - Wallula	Highways 12 & 395	WALLULA	99363	U	U	F	U	U												C				LANDFILL	N/A	N/A
	C1	Walla Walla Farmers Coop	W. ROSE & MULLAN	WALLA WALLA	98362	T	F	F	T	F					C										C	IMPROPER HANDLING	PESTICIDE DISPSL	N/A
	N	Walla Walla Gas Manufacturing	Rose & 6th Ave	Walla Walla	99363				T							C										TANK	N/A	N/A
Whatcom	N	Acme Landfill	Mosquito Lake Rd	Acme	98220				F					S	S											LANDFILL	N/A	N/A
	C1	Acme/LUSTs	Acme	Acme	98220	T			T							C										TANK	N/A	N/A
	N	ARCO Petroleum-Cherry Point	4519 Grandview Rd	Ferndale	98248																					N/A	N/A	N/A
	C2	Bellingham-Old City Dump	Roeder Av	Bellingham	98225	P	P	U	P	P		S					S									LANDFILL	N/A	N/A
	N	Boulevard Park	N End Bayview Drive	Bellingham	98226				T					C												TANK	N/A	N/A
	N	Campbell Residence	831 E Axton Rd	Bellingham	98226				F					S												N/A	N/A	N/A
	C2	Cedarville Landfill	Cedarville Road	Bellingham	98226	P	P	P	P	P															S	LANDFILL	N/A	N/A
	N	Columbia Cement	Marine Dr	Bellingham	98225																					N/A	N/A	N/A
	N	Crosby & Overton Inc	2032 Humboldt	Bellingham	98225																					N/A	N/A	N/A
	C1	EDB 3 Whatcom County	INTERSECTION OF NORTHWOOD RD	LYNDEN	98264	T	F	F	U	F					C											PESTICIDE APPLIC	N/A	N/A
	C2	Everson Goshen Dspl	T39N, R3E, Sec 24	Bellingham	98247	P	P	U	P	U				S	S											N/A	N/A	N/A
	N	Frank Brooks Manufacturing	Iowa & Orleans St	Bellingham	98225		T		T					C												IMPROPER HANDLING	N/A	N/A
	C1	Georgia Pacific Corporation	300 W Laurel	Bellingham	98225	P	U	F	T	U		C	S													IMPROPER HANDLING	N/A	N/A
	N	Georgia Pac-Bio Trtmt Lgn	Foot of C St	Bellingham	98225		T					S														N/A	N/A	N/A
	N	Intalco Aluminum	Mountain View Rd	Ferndale	98248	P	P	F	P	U														C	C	LANDFILL	N/A	N/A
	C2	J. Downing Private Well	1124 Birch Bay Lynden	Lynden	98264	T									S											PESTICIDE APPLIC	N/A	N/A
	C2	Kenmar Company Inc	6065 Kickerville Rd	Ferndale	98248	P	U	U	P	P						S		S				S		S		N/A	N/A	N/A
	C2	Lummi Indian Reser. Dump	Chief Martin Rd	Bellingham	98226	P	P	U	P	U		S			S											LANDFILL	N/A	N/A
	C2	Lummi Shore Dump	Hwy 520, WNW of City	Bellingham	98227	P																				LANDFILL	N/A	N/A

REPORT:MEDIALEG.DFR 11/88

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LISTINGS BY LOCATION

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5. Pesticides
6. Petroleum Products
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SITES BY COUNTY
WASHINGTON DEPARTMENT OF ECOLOGY
HAZARDOUS WASTE INVESTIGATIONS AND CLEANUP PROGRAM

COUNTY	SITE CAT.	SITE NAME	LOCATION ADDRESS	CITY	ZIP	AFFECTED ENVIRONMENTS G-WATER	S-WATER	AIR	SOIL	SEDIMENT	CONTAMINANTS #1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	WASTE MGNT PRACTICE 1	WASTE MGNT PRACTICE 2	WASTE MGNT PRACTICE 3
Whatcom	N	Lynden Airport	8631 Depot Rd	Lynden	98227	T	F	F	T	F					C											IMPROPER HANDLING	N/A	N/A
	C2	Meadowdale Water Assoc Well	Kamm & Northwood Rd	Lynden	98264	T									S											PESTICIDE APPLIC	N/A	N/A
	N	Mobil Oil Corporation	3901 Unick Rd	Ferndale	98248																					N/A	N/A	N/A
	C2	Murray Chris-Craft Cruisers-W.	9th & Harris	Bellingham	98225																					N/A	N/A	N/A
	C2	Newhalem Dump	1 mile West of Newhalem	Newhalen	98283	P	P	U	P	P		S		S												LANDFILL	N/A	N/A
	N	Nooksack Valley Disposal	250 BirchBay Lynden	Lynden	98264																					N/A	N/A	N/A
	C1	Northwest Pipeline Corp.-Sumas	Sumas Dist 4738 Jones Road	Sumas	98295	P	F	F	T	F				C												IMPROPER HANDLING	N/A	N/A
	C2	Northwest Transformer	107 S Harkness	Everson	98247				T					S												N/A	N/A	N/A
	A	Northwest Transformer-Slvg	6882 Mission St	Everson	98247																					IMPROPER HANDLING	N/A	N/A
	A	Northwest Trnsfrmr-Downtown	107 S Harkness St	Everson	98247																					IMPROPER HANDLING	N/A	N/A
	C2	Northwest Trnsfrmr-Goodwin	Off Goodwin Rd. by So. Pass	Everson	98247	T			T					C		C										N/A	N/A	N/A
	C1	Oeser Cedar	730 Marine Dr	Bellingham	98225	P	P	F	T	F				C												IMPROPER HANDLING	N/A	N/A
	C2	Olivine Ash Landfill	928 Thomas Rd.	Bellingham	98226																					LANDFILL	N/A	N/A
	N	Pt. Roberts Landfill	2030 Benson Rd	Point Roberts	98281	P	P	F	P	F			S											S	S	LANDFILL	N/A	N/A
	C1	R.G. Haley Intl Corp	Foot of Cornwall Av	Bellingham	98225	U	F	F	T	F				C		S	C									IMPROPER HANDLING	N/A	N/A
	C2	Sumas River Dump Site	Tributory to Frazer	Sumas	98295																					N/A	N/A	N/A
	C1	Thermal Reduction Landfill	1524 Slater Rd	Bellingham	98226	T	T	T	T	P		C												C		LANDFILL	N/A	N/A
Whitman	C1	Palouse Producers	NW 325 STATE	PALOUSE	99161	P	T	F	T	F						C										TANK	SPILL	IMPROPER

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WASHINGTON DEPARTMENT OF ECOLOGY
HAZARDOUS WASTE INVESTIGATIONS AND CLEANUP PROGRAM

COUNTY	SITE CAT.	SITE NAME	LOCATION ADDRESS	CITY	ZIP	G-WATER	S-WATER	AIR	SOIL	SEDIMENT	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	WASTE MGNT PRACTICE 1	WASTE MGNT PRACTICE 2	WASTE MGNT PRACTICE 3
Whitman	C1	WA State Univ Landfill	Airport Rd .25 Mi From Hwy.270	Pullman	99164	P	F	F	P	P	C	C	C	C	C	C	C	C		C	C	C	C			LANDFILL	N/A	HANDLING N/A
Yakima	M	Boise Cascade-Yakima Site	805 N 7th St	Yakima	98901	P	P																			N/A	N/A	N/A
	C2	Cameron - Yakima, Inc.	1414 S. 1st Street	Yakima	98907	P	P	P	P	P	S							S								IMPROPER HANDLING	N/A	N/A
	C2	Central Engineering & Machine	1104 E. Mead Avenue	Yakima	98903	P	F	F	P	F	S		S					S						S	S	N/A	N/A	N/A
	C1	Cliff's Battery Service	Scoon & Woodin Rd	Sunnyside	98944	P	P	F	T	T		C	C													SPILL	N/A	N/A
	C2	CMX Corporation	206 W. Mead Ave.	Yakima	98902	P			P																S	N/A	N/A	N/A
	C1	Crop King	1 East King	Yakima	98901	T	F	F	T	T	C				C											DRUM	SPILL	PESTICIDE DISPSL
	C2	Evergreen Products	Highway 97	Parker	98939	P	P	F	P	P					S	S										SPILL	PESTICIDE DISPSL	IMPROPER HANDLING
	A	FMC-Farm Machinery Corp	4 W. Washington Ave	Yakima	98903	T	F	F	T	F	C				C											PESTICIDE DISPSL	IMPOUNDMENT	N/A
	C1	Frank Wear Cleaners	106 S. 3rd Avenue	Yakima	98902	P	F	F	T	P	C															SPILL	N/A	N/A
	M	Grandview City Landfill	Rte I	Mabton	98935																					LANDFILL	N/A	N/A
	C1	Irwin Research & Development	1702 S. 24TH AVE	YAKIMA	98903	P	P	F	P	F	C	S						S								SPILL	DRUM	N/A
	M	John Deere-Yakima Works	S 3rd Pacific	Yakima	98901																					LANDFILL	N/A	N/A
	M	Mueller Hop Products Inc	1716 Gordon Rd	Yakima	98901																					N/A	N/A	N/A
	C2	Paxton Sales Corporation	108 W. Mead Ave.	Yakima	98902	P	P				S	S													S	DRUM	SPILL	N/A
	M	Rainier Plastics Company	1101 Ledwich Av	Yakima	99202																					N/A	N/A	N/A
	C1	Richardson Airways, Inc.	Yakima Municipal Airport	Yakima	98901	P	P	F	P	F					C											PESTICIDE DISPSL	SPILL	N/A
	C2	Shields Bag & Printing Co.	1009 Rock Ave	Yakima	98902	P		U			S							S								IMPROPER HANDLING	N/A	N/A
	C1	Sunnyside Municipal Well	Well #1, Grant	Sunnyside	98944	T	U	F	T	U	C												C			UNKNOWN	N/A	N/A

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SITES BY COUNTY
WASHINGTON DEPARTMENT OF ECOLOGY
HAZARDOUS WASTE INVESTIGATIONS AND CLEANUP PROGRAM

COUNTY	SITE CAT.	SITE NAME	LOCATION ADDRESS	CITY	ZIP	AFFECTED ENVIRONMENTS G-WATER	S-WATER	AIR	SOIL	SEDIMENT	CONTAMINANTS #1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	WASTE MGNT PRACTICE 1	WASTE MGNT PRACTICE 2	WASTE MGNT PRACTICE 3
Yakima	M	Terrace Hts Landfill	Street Roza Hill Dr & N 76	Yakima	98901	P	F	F	P	F																LANDFILL	N/A	N/A
	A	USDA-Pesticide Laboratory	3706 W. Nob Hill Rd.	Yakima	98902	P	P	F	C	F					C											PESTICIDE APPLIC	N/A	N/A
	M	Valicopter Site	720 N 16th St	Yakima	98902	P	P	F							C											PESTICIDE DISPSL	SPILL	N/A
	C1	Woods Industries #1		YAKIMA	98901	P	F	F	P	F					C									C		IMPROPER HANDLING	DRUM	N/A
	C2	Woods Industries #2	NE 8TH AVE.& West J St.	YAKIMA	98902	P	F	F	P	F					S											SPILL	PESTICIDE DISPSL	N/A
	A	Yakima Ag. Research Lab	3706 W. Nob Hill Blvd.	Yakima	98902	P	F	F	T	F					C									C		PESTICIDE DISPSL	N/A	N/A
	C2	Yakima Old City Landfill	S 18th St/Yakima R. Mile 112	Yakima	98901	P	P	F	P			S			S											LANDFILL	N/A	N/A
	A	Yakima Plating	1804 S 3rd Av	Yakima	98902	T	F	F	T	F		C	C													IMPROPER HANDLING	SPILL	N/A
	C2	Yakima Valley Spray Co.	1122 S. 1st Street	Yakima	98901	P	P	F	P	P					S											SPILL	PESTICIDE DISPSL	IMPROPER HANDLING
	C1	Zwight Logging	222 Keys Rd	Yakima	98901	T	P	P	P	F						C								S		SPILL	IMPROPER HANDLING	N/A

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Attachment #2

April 5, 1989 **SITE CATEGORIES IN SMIS**

DRAFT

A = National Priorities List (NPL) Sites; Federal Lead. These sites are on the Environmental Protection Agency's (EPA) National Priorities List (NPL). They are a high priority for investigation and cleanup by EPA.

B = National Priorities List Sites; State Lead. Same as above except the Department of Ecology is chiefly responsible for investigation and cleanup activities at these sites.

C1 = State Sites; Confirmed Hazardous Substance Sites. Sites where the presence of hazardous substances has been confirmed by laboratory or field determinations. These sites may require further investigation, cleanup, and monitoring. The state is responsible for assuring cleanup of these sites if necessary. Some of these sites are being operated under local, state or federal permits. Some of these sites, once more information is available may be recategorized as "P".

C2 = State Sites; Potential Hazardous Substance Sites. These sites have been reported to Ecology. Agency staff have done an initial investigation and have determined that further investigation is necessary. These sites are either in the process of being sampled or are awaiting sampling. If hazardous substances are not found, the site will be coded "Z" and if hazardous substances are found in low levels, the site will be coded "M". Neither "Z" nor "M" sites will appear on the list of known or potential sites. If, however, investigation reveals a significant presence of hazardous substances the site will be coded "C1". The state is responsible for assuring investigation of these sites.

L = State Sites; Those Undergoing Long-Term Monitoring. Sites that have undergone cleanup (remedial action) and are being monitored to assure attainment of cleanup levels. The state is responsible for these sites.

P = State Sites; Those Sites Contaminated but posing no known threat to human health or the environment under current standards and factors available to the Department.

N = State Sites; Those For Which Cleanup Has Been Conducted under statutes other than the new Hazardous Waste Cleanup Act of 1987, 70.105B RCW (replaced March 1, 1989 with the Model Toxics Control Act).

M = State Sites; Those Sites Considered Free of Contamination from hazardous substances. With respect to the complaint under investigation, these sites did not appear to be contaminated with hazardous substances.

D = Sites For Which Cleanup is Complete Under Either 70.105B, the Model Toxics Control Act or under Federal superfund law.

Attachment #3

HAZARDOUS WASTE INVESTIGATIONS & CLEANUP PROGRAM
Site Management Information System (SMIS)
"Fact Sheet" Summary
March 15, 1989

1. National Priority List (NPL) Sites:

Type	Definition	Number
EPA Lead	[Site Category] = A	32
Ecology Lead	[Site Category] = B	9
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	Total:	41

2. Sites Requiring Investigation, Clean-up and/or Monitoring:

Type	Definition	Number
NPL	[Site Category] = A or B	41
State-Known	[Site Category] = C1	214
State-Potential	[Site Category] = C2	252
Long-Term Mon	[Site Category] = L	16
-------------	--------------------	---
	Total:	523

3. Breakdown by Ownership Type:

Type	Category	Number
Public	County	36
	Municipal	37
	Federal	41
	State	13
	Tribal	4
	Publicly-Owned (Bnkrpt)	2
	Sub-Total:	133
Private	Private	303
	Financial-Inst Owned (Bnkrpt)	1
	Sub-Total:	304
Other	Mixed	16
	Unknown	70
	Sub-Total:	86
	Total:	523

4. Landfills (by Ownership Type):

Type	Category	Number
Public	County	29
	Federal	15
	Municipal	26
	State	7
	Tribal	3
	Sub-Total:	80
Private	Private	47
	Financial-Inst Owned (Bnkrpt)	1
	Sub-Total:	48
Other	Mixed	7
	Unknown	12
	Sub-Total:	19
	Total:	147

5. Sites by Waste Management Practice Category:

Category	Number
Drug Lab	0
Drum	37
Impoundment	30
Improper Handling	146
Landfill	147
Land Application	8
Pesticide Applic	11
Pesticide Dispsl	18
Spill	117
Storm Drain	4
Tank	73
Unknown	130
Total:	721

Note: Total is greater-than 523 because up to three waste management practice categories may be entered per site.

6. Sites by Selected Waste Categories:

Waste Category	Status	Number
Petroleum Products	Suspected	77
	Confirmed	107
	Total:	184
Pesticides	Suspected	20
	Confirmed	20
	Total:	40

Attachment #4

1/4

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
HAZARDOUS WASTE INVESTIGATIONS AND CLEANUP SECTION

March 17, 1989

TO: Mike Gallagher
Jerry Jewett – w/o ATTACHMENTS
Pete Kmet
Clar Pratt
Emily Ray – w/o ATTACHMENTS
Mike Rundlett
Claude Sappington
Mike Wilson

THROUGH: Carol Fleskes CF

FROM: Mike Blum Mike Blum

SUBJECT: Washington Environment 2010 Comparative Risk Assessment for "Uncontrolled Hazardous Waste Site" - I NEED YOUR ASSISTANCE

I am a member of the Washington Environment 2010 Technical Advisory Committee which is looking at comparative risks for various threats to the State's resources. I have attached a list of the resources and the threats being characterized by the Technical Committee for your information. The threat for which I am responsible is "uncontrolled hazardous waste sites". I am looking at impacts to public health, the environment, and economic damages from uncontrolled sites, strictly in a generic/broad brush approach. When doing your rating, base it on existing conditions, not the past nor in the year 2010.

I need you and your staffs' assistance in the following ways:

1. For the sites in your section, please rate them according to risk to the environment and also for risk to public health. The rating criteria you should use is BEST PROFESSIONAL JUDGEMENT. You may use the "Chance Model" to help you rate each site (attached). All that I am looking for is ratings of low, medium, or high. Circle the most appropriate rating in each category.

2. Also, for the sites in your section, please give the number of potentially affected people. On the sheets, you will find population ranges, i.e.; 0; 1-10; 10-100; 100-1000; 1000-10000; and 10000 plus. Again, use BEST PROFESSIONAL JUDGEMENT. Circle the most appropriate population affected.

3. If you do not have enough information to rate the risks or know the population, you may say unknown. Please keep the unknown category to a minimum.

4. Has there been any public health or environmental risk assessment done for the site. Please circle the applicable answer.

I would like your responses by April 3, 1989. To give you an idea of the time to do these rating, I would expect you to spend no more than a couple minutes per site. If you have any questions, please give me a call at Scan 585-3043 or (206) 438-3043. Thanks for your help in this matter. I will be out of the office from March 24 through March 31, 1989.

MB:mb

"CHANCE"
STATE HAZARD RANKING SYSTEM

WHAT IS THE POTENTIAL THREAT TO <u>HUMAN HEALTH</u> AT THE SITE UNDER INVESTIGATION?

<u>Potential Threat to Human Health</u>

High - documented contamination of drinking water supply with a known or suspected animal or human carcinogen or toxicant as a result of the site.

High - documented contamination of surface waters which provide primary contact activities (swimming, fishing) or are a drinking water source with a known or suspected animal or human carcinogen or toxicant as a result of the site.

Medium - documented extensive on-site soil contamination or the existence of subsurface sludge pits with a known or suspected animal or human carcinogen or toxicant.

Low - suspected soil contamination with a known or suspected animal or human carcinogen or toxicant;

- OR -

Low - spatially limited, documented soil contamination with a less toxic, relatively immobile compound (for example, an eighth acre site contaminated with inorganic lead where drinking water wells are more than a mile away and soils are silty).

Low - very little risk of human health damage.

Low - the site does not warrant our attention due to the lack of significant contamination or the fact that it's managed.

WHAT IS THE POTENTIAL FOR ENVIRONMENTAL DEGRADATION DUE TO THE SITE UNDER INVESTIGATION?

Potential for Environmental Degradation

Estimate the potential for environmental degradation at the site based upon the following relative ranking guides:

High - significant (drinking water wells in vicinity, major recharge zones) groundwater or surface water resources are known to be contaminated with a suspected or known animal or human carcinogen or toxicant as a result of the site.

High - less significant waters are contaminated (i.e., seasonally saturated groundwater zones; Class B or C surface water).

Medium - due to your knowledge of the site, its probable (but currently unconfirmed) that significant groundwater or surface water resources are contaminated as above.

Medium - less significant waters are suspected of being contaminated

Low - at this time, on-site contamination appears to be limited to soils and contaminant movement is minimal.

Low - the contaminant is confined in some marginal manner.

Low - the site poses minimal environmental degradation.

Attachment #5

ENVIRONMENT 2010
REPORT

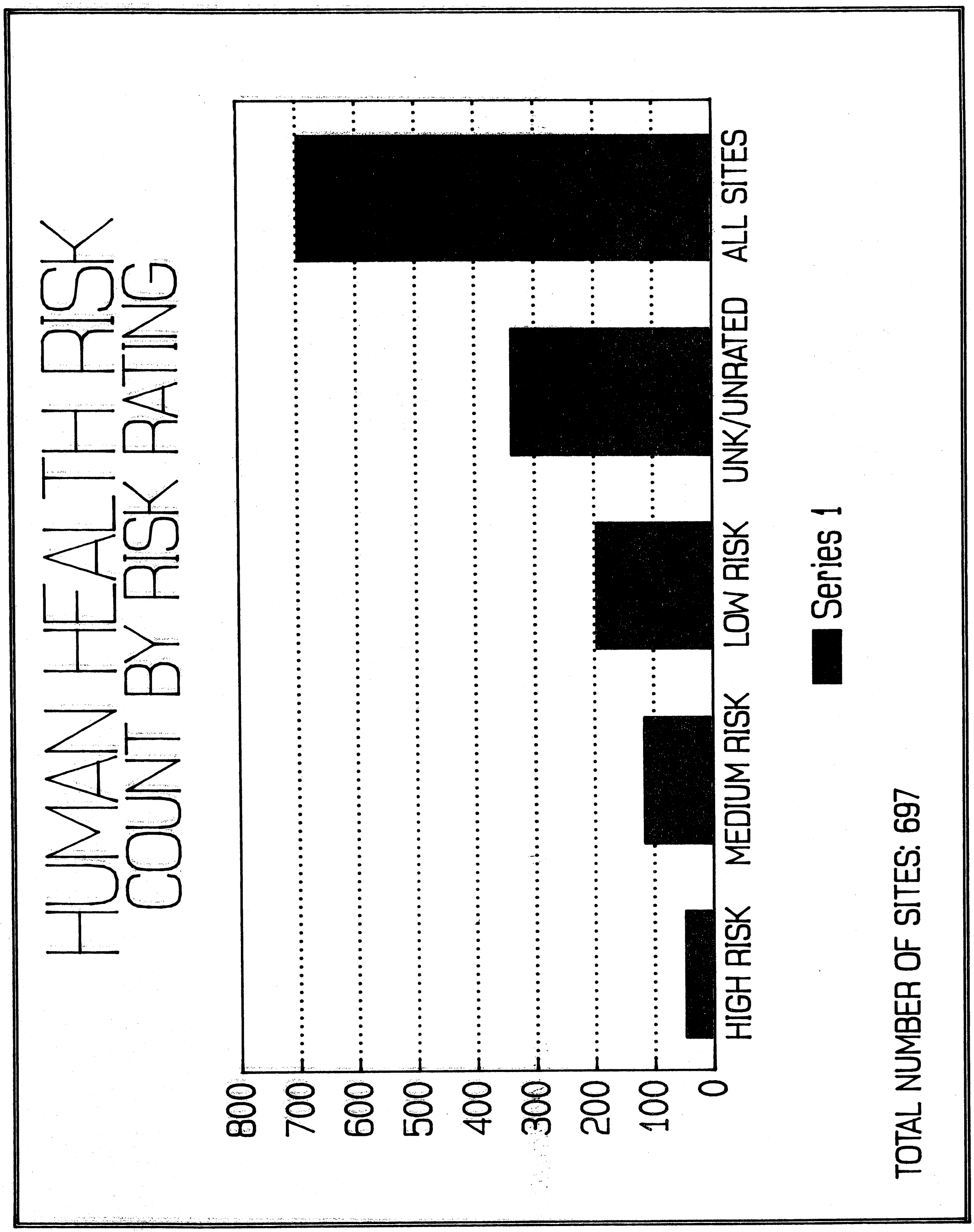
COUNTY DESC	SITE CAT.	SITE NAME	LOCATION ADDRESS	CITY	PUBLIC HLTH. RISK	ENVIR. RISK	POP. EXPOSED	PUBLIC HLTH. RISK ASSES.	ENVIR. RISK ASSESS	COMMENTS
King	C2	Washington Natural Gas	319 S 3rd St	Renton	H M L U	H M L U	A B C D E F U	Y N	Y N	
King	C2	Wesmar Company Inc	1451 NW 46th	Seattle	H M L U	H M L U	A B C D E F U	Y N	Y N	
King	A	Western Processing Co Inc	7215 S 196th St	Seattle	H M L U	H M L U	A B C D E F U	Y N	Y N	
King	C2	Weyerhaeuser Seattle Lab	3233 11th St SW	Seattle	H M L U	H M L U	A B C D E F U	Y N	Y N	
King	N	Widing Transportation Inc	24300 Pacific Hwy S	Kent	H M L U	H M L U	A B C D E F U	Y N	Y N	
King	C2	Williams Lake	Mt.Baker-Snoqualmie Natnl.Frst	North Bend	H M L U	H M L U	A B C D E F U	Y N	Y N	
King	C1	Wyckoff Co-West Seattle	2801 SW Florida St	Seattle	H M L U	H M L U	A B C D E F U	Y N	Y N	
King	C1	Zandt Brass Foundry	3400 Harbor Ave. SW	SEATTLE	H M L U	H M L U	A B C D E F U	Y N	Y N	
Kitsap	C1	Bainbridge Isl LF	End of Vincent Rd	Bainbridge	H M L U	H M L U	A B C D E F U	Y N	Y N	
Kitsap	A	Bangor Ordnance Disposal	Clear Cr Rd, Bldg 1100	Bangor	H M L U	H M L U	A B C D E F U	Y N	Y N	
Kitsap	C2	Constitution Landfill	Constit AV & Porter	Bremerton	H M L U	H M L U	A B C D E F U	Y N	Y N	
Kitsap	A	Eagle Harbor (Wyckoff)	Creosote PL NE	Bainbridge Is	H M L U	H M L U	A B C D E F U	Y N	Y N	
Kitsap	C1	Hansville Landfill	31645 Hansville Rd, NE	Little Boston	H M L U	H M L U	A B C D E F U	Y N	Y N	
Kitsap	A	Naval Undersea Warfare Eng Stn	Highway 308, East End	Keyport	H M L U	H M L U	A B C D E F U	Y N	Y N	
Kitsap	L	Olympic View Sanitary Ldfl	10015 SW Barney White Rd	Port Orchard	H M L U	H M L U	A B C D E F U	Y N	Y N	
Kitsap	N	Peninsula High School	14015 62nd Ave NW	GIG HARBOR	H M L U	H M L U	A B C D E F U	Y N	Y N	
Kitsap	C2	Pioneer Quarry Site-Propose	T24N,R1E,Sec 20	Bremerton	H M L U	H M L U	A B C D E F U	Y N	Y N	

H=HIGH U=UNKNOWN C=10-100 F=10,000+
M=MEDIUM A=0 POP. D=100-1000 Y=YES
L=LOW B=1-10 E=1,000-10,000 N=NO

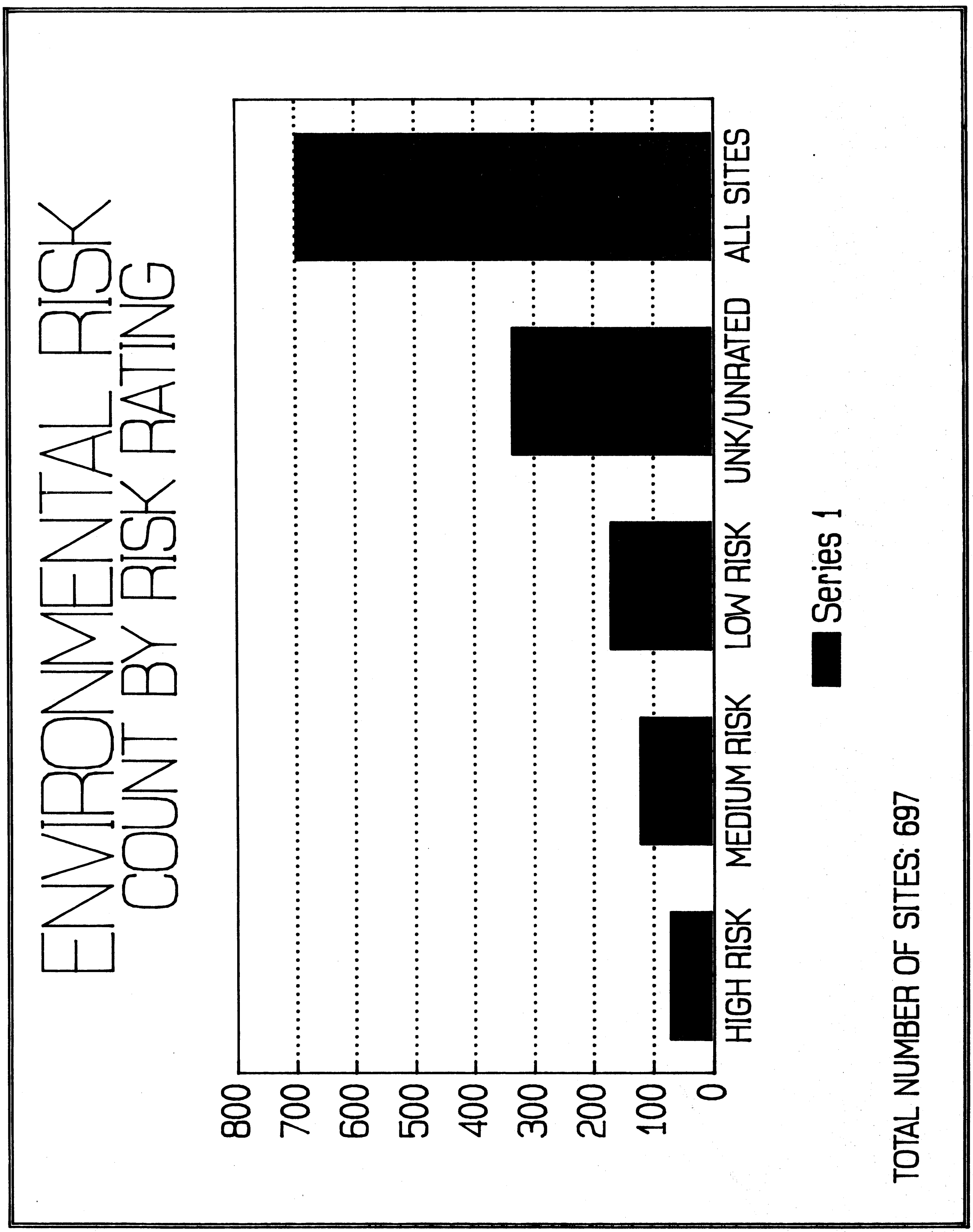
Attachment #5

Attachment #6

Attachment #6



Attachment #7



Attachment #7

Attachment #7

FIGURE #1

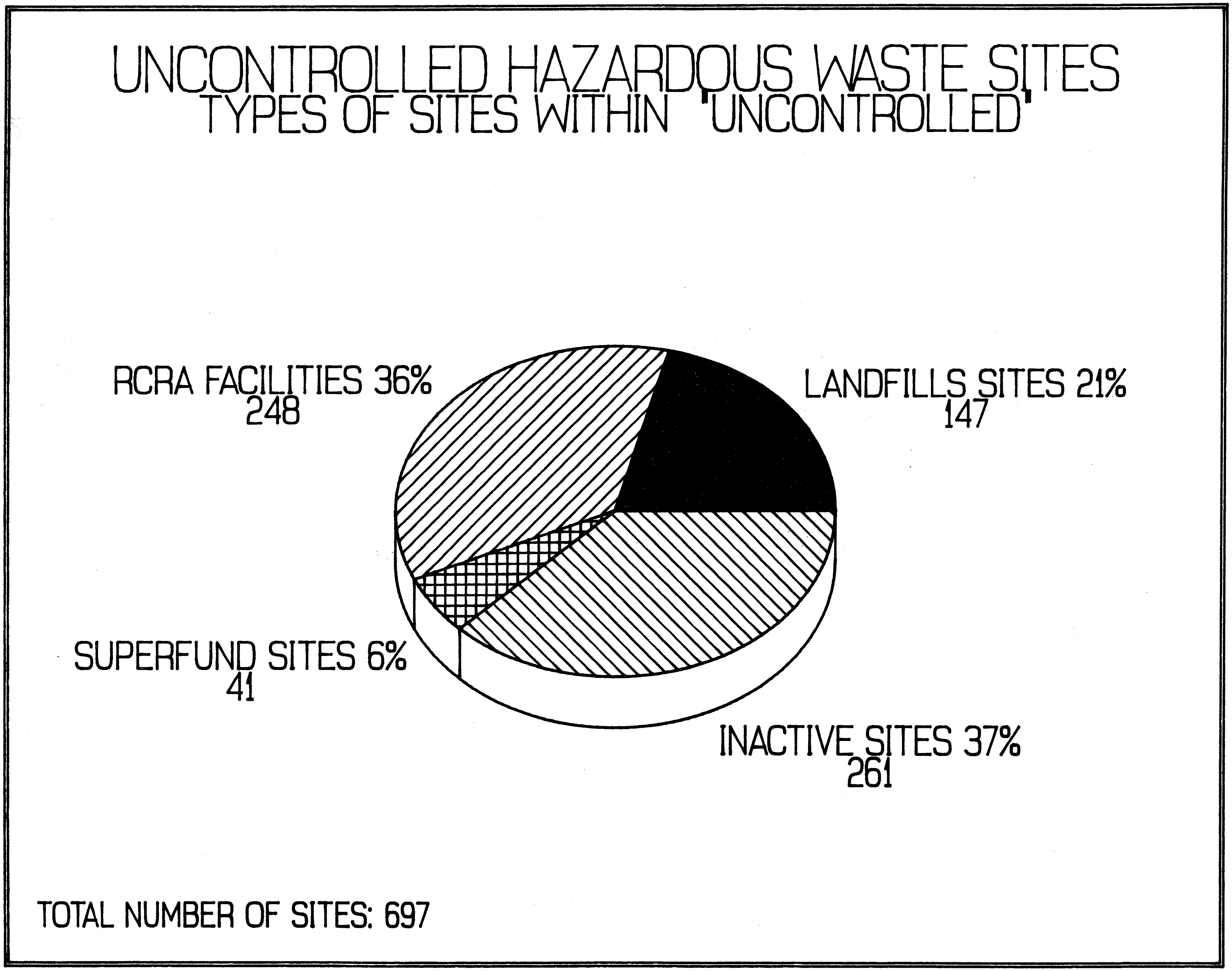


Figure #1

THE STATE OF THE ENVIRONMENT REPORT

VOLUME III
Part 14

Risk Evaluation Reports
for
Nonhazardous Waste Sites

Environment 2010

State of Washington
October, 1989

I.

A. Environmental Threat: Non-hazardous Sites

B. Definition:

Includes two major types of waste sites - municipal and industrial - containing primarily non-hazardous waste.

The municipal waste site universe consists of currently operating landfills, as well as closed landfills. It also includes municipal refuse incinerators and their associated ash landfills, as well as sewage treatment primary and secondary sludges. These are either landfilled in municipal landfills or spread on the land to enhance soil properties. The threat from non-hazardous waste sites is primarily ground water contamination and surface water pollution. Air pollution from incinerators is also a threat that is receiving increased attention. Soil contamination is also a potential from the application of municipal treatment sludges to the land.

The industrial waste site universe consists of landfills, surface impoundments and landspreading sites. Wastes reflect the diversity of the State's economic base, and include pulp and paper, aluminum mill, transportation manufacturing and the chemical industry sludges. Industrial wastes tend to be more homogenous than municipal waste and contain little or no household hazardous waste, as does municipal waste. Other toxicants may however be present at low concentrations in significant volumes.

Exposure pathways for industrial waste would match municipal sites except that the air pollution pathway may be lower, due to the more homogenous and perhaps inorganic nature of the wastes.

Risks from this category could be double-counted with other sources of ground and surface water contamination, contamination of drinking water and ambient air pollution.

Major Pollutants

1. Ground and Surface Water

   a. Conventional Pollutants

      - Biochemical Oxygen Demand
      - Chemical Oxygen Demand

- Nutrients, Nitrogen, Phosphorous, etc.
- Suspended Solids/Color
- Oils and Grease

b. Toxics

- Metals

  - Lead
  - Cadmium
  - Iron
  - Manganese
  - Chromium
  - Zinc
  - Copper
  - Nickel

- Organics

  - Solvents
  - Pesticides
  - Plasticizers

C. Disease vectors (Pathogens - viruses, bacteria, etc.)

2. Air Quality (Mostly from incinerators)

a) Conventional Pollutants

- Particulates
- Carbon Monoxide
- Nitrogen Oxides
- Sulfuric and Hydrochloric Acids
- Methane and Carbon Dioxide

b) Toxics

- Hydrogen Sulfide
- Vinyl Chloride
- Dioxins
- Organic Solvents (Benzene and Chlorinated Solvents)

<u>Major Sources</u>

Facilities and Activities

- Landfills
- Incinerators
- Recycling/Reuse
- Land Application/Treatment
- Surface Impoundments
- Emplacement As Fill Material
- Ocean Disposal
- Piles (Tires, etc.)

Major Damage Pathways

A. Human Health

- Ingestion of contaminated surface and ground water.
- Inhalation of dust and/or gases
- Ingestion of crops grown on contaminated soil.
- Ingestion of aquatic organisms that have contacted contaminated water.
- Direct dermal contact with contaminated soils.
- Ingestion of contaminated soils.
- Fire or explosion from migrating gases (e.g., methane).
- Vector borne illness from rats, sea gulls, mosquitoes, flies, etc.

B. Ecological

- Contaminated runoff to surface water impacting aquatic flora and fauna.
- Contaminated leachate, surfacing or otherwise discharging to surface water and causing impacts as above.
- Impacts on burrowing or grazing animals or plant growth from soil contamination or impacts on plants from methane migration.

C. Economic

- Loss, or degradation of drinking and irrigating water supplies due to contamination of ground or surface water.
- Loss of potential water supplies.
- Loss of property values to nearby residents from gas migration, odors, noise, birds and other aesthetic damages.
- Loss of recreational use of area (swimming, fishing) and loss of commercial fishing from contaminated waterways.

II. Human Health Risk

A. Description of Analytical Approach and Data Sources

1. General Approach Taken

The general approach was to look at municipal landfills that had undergone risk assessments in the remedial action program for the State of Washington. There is also an attempt to estimate risk assessment from methane migration. Scale up to the entire site was estimated by using a recently completed landfill inventory.

Another effort was made to look at conservative values for risk assessments from out-of-state landfills. Table AA summarizes the types of data that are currently available. Note that some studies give a single number. Another gives a range and still another gives a frequency distribution of risk estimates for the ground water ingestion pathway.

Table AA. Literature Sources on Cancer Risks to Individuals Ingesting Ground Water Down-Gradient from Municipal Landfills

Study	Landfill Status	Risk, Excess Cover Deaths Lifetime for a Maximum Exposed Individual (MEI)
Douglas, Mass. Landfill (1)	Proposed with Environmental Controls	3.6×10^{-6}
Jeffco, Colorado Landfill (2)	Existing -- Few Controls	Upper bound 8.9×10^{-4} Best estimate 2.8×10^{-6} Lower bound 2.7×10^{-8}
EPA Subtitle D Study (3)	Existing -- 6034 Landfills In U.S.A.	% a/ 0.1 1×10^{-4} 5.5 1×10^{-4} to 1×10^{-5} 11.8 1×10^{-5} to 1×10^{-6} 82.6 1×10^{-6}

a/ Percent of landfills by number having indicated risk.

Note that the risk of 1×10^{-4} appears to be an maximum risk number except for the Colorado data whose upper bound estimates are closer to 1×10^{-3}. Note, this table does not include inhalation risk from showering with contaminated ground water.

These risks are calculated from models that use a formula of the following type:

Risk = Quantity of leachate * Chemical Concentration * Deletion of Aquifer * Dose Conversion Factor * Toxicity Factor

Where Risk = Excess cancer death risk per year from ingestion of contaminated ground water.

Quantity of Leachate = Based up calculations of a water balance entering and leaving a landfill.

Chemical Concentration = Concentration of toxic pollutants either measured in a landfill leachate or data from other landfills. Organic solvents are usually used.

Dilution of Aquifer = Dilution that occurs when leachate quantity is diluted into an upper aquifer, based on measured or assumed ground water velocity, and dispersion models.

Dose Conversion Factors = Quantity of water ingested by a person drinking ground water which is usually assumed to be 2 liters per day.

Toxicity Factor = Cancer potency factor for each chemical in leachate; a measure of how strongly carcinogenic a chemical is $(mg/kg/day)^{-1}$.

2. Sources, Pollutants Exposure Pathways Effects Examined (See Table A).

3. Rationale for elements examined; important elements not examined.

   Other sources of risk from non-hazardous waste facilities, such as incinerators, sludge application sites, surface impoundments and others were not examined because the risks from some, like incinerators, would be addressed in other threats and also risk assessments from some sites did not exist. Ground water and air quality pathways are the most likely exposure for residents around landfills, compared with runoff water and direct contact derived by or soil ingestion pathways. Most closed municipal landfills are limited access for humans or are converted to parks, golf courses, or other benign uses that limit human pathways.

4. Data sources used; how manipulated.

   Existing risk assessments in the State of Washington for closed or closing landfills that have been investigated under the "Superfund" effort have been used for chronic assessments from ground water and air quality contamination. Data from a Federal Register was used to estimate risk assessment from methane explosions. See Section II.B.2. for further details.

5. Critical Assumptions Made

a) All landfills are as badly contaminated as the four landfills for which risk assessments were performed. Many landfill undoubted did not receive as much commercial or industrial waste as the four urban landfills did, and so the risk scale up is conservative.

b) The hydrogeologic and climatic setting could be quite different than the four landfills-three of which are located in Western Washington where the rainfall is high. This could affect the volume of leachate produced, the rate of ground water dispersion and other factors. The assumption is that all landfills would have similar dispersion patterns.

c) The existence of public water supplies to replace contaminated ground water could eliminate the ground water risk, altogether.

6. Toxicological Assumptions Used

a) Chronic Toxicity - Cancer

Table CC. summarizes the four State of Washington municipal landfills that have undergone risk assessment under the remedial action program. The Table CC. covers risk from the ingestion of drinking water and inhalation of volatiles from showering in contaminated ground water. The major risk pathway was exposure to contaminated drinking water by ingestion and inhalation of volatile solvents during showering. Risk levels range from 4×10^{-4} to $4 \times 10^{-3+}$ excess cancer lifetime cases for a maximally exposed individual. This assumes an individual spends his/her entire life at the point of exposure and that no remediation occurs at the site.

To assess the risk from direct emissions of volatiles and other contaminants into the air from the landfill surface and from flares, a risk factor of 1×10^{-6} excess cancer cases was taken from one of the studies (4). It represents a condition in which some gas controls are present at the landfill.

b) Chronic Toxicity - Non-Cancer

Table CCC. summarizes the four State of Washington municipal landfill having non-cancerous chronic toxicity. A toxic hazard index of 20 was chosen as a reasonable worst case ratio. These ratios were attributable to the metals of manganese and zinc in one case, and three organic solvents in another case. (See detailed summary, Section B.2)

c) Acute physical hazard from methane migration (see Table C for calculations and assumptions).

7. Approaches to Scaling Up

The approach to scaling up was to try to estimate the number of exposed individuals at four landfills for which risk assessments were obtained. Some judgement had to be used to estimate the population at risk. Maps of residential areas were examined or knowledgeable staff in the Department of Ecology or the consulting community using similar techniques and assumptions the following population numbers were counted for population exposed up to ¼ of a mile down gradient from the active area boundary:

Midway Landfill	88 Persons
City of Tacoma Landfill	100 Persons
Leichner Landfill	less than 550 Persons
Colbert Landfill	85 Persons

For major urban sites, 100 persons at risk seemed to be a appropriate and conservative number, since the risk factors were for the most exposed individual.

To calculate a state-wide population, exposed, the following methods were used:

a) A new developed landfill inventory was used along with annual volumes of waste received. This inventory is included in Appendix I. Municipal landfills were classed as small, medium, and large according to a scale as follows:

Small: Less than or equal to 24,000 yd^3/year (less than 50 tons/day)

Medium: Greater than 24,000 yd^3/year (50 - 250 tons/day) to 121,700 yd^3/year

Large: Greater than 121,700 yd^3/year (Greater than 250 tons/day)

(Note: All tonnage figures are calculated at compacted densities of 1,500 lbs/yd^3 as reported on the inventory)

b) Next the landfills were classed as either rural or urban, by their setting, and

c) A matrix was used to assign a population exposure figure to each landfill using the 100 person figure for large urban sites, and "scaling down" by factors of 10. The matrix is as follows:

		Landfill Setting	
		Rural	Urban
Size of Landfill	Small	.1	1
	Medium	1	10
	Large	10	100

Figures given are projected population exposed for each landfill size and setting combination.

d) The matrix was then applied to each municipal landfill in the inventory and the population exposed was totaled. The number calculated was 690 persons. (See Appendix I for individual landfill ratings)

8. Sensitivity analysis of alternative assumptions, if done. Not performed.

B. Description of Key Findings

1. Summary

a) 0.01 cancer cases per year from State of Washington municipal landfills was calculated due to:

- Ground water contamination and drinking water ingestion/showering - inhalation cancer routes, and

b) 0.004 sudden deaths per year from methane migration statewide.

c) In addition 690 persons living around State of Washington landfills would be exposed to non-cancerous chemicals above acceptable levels, causing chronic illness and disease.

2. Detailed Summary of Estimated Risks

a) Tables B and C are attached.

b) Ground water contamination pathway - cancer and non-cancer chronic exposures were calculated from four risk estimates done for the following landfills:

- Midway Landfill in Kent, Washington (4)
- Colbert Landfill in Spokane, Washington (5)
- Leichner Landfill in Clark County, Washington (6)
- City of Tacoma landfill in Tacoma, Washington (7)

<u>Cancer Estimates</u>

Risk estimates were given for volatile chlorinated organic solvents such as vinyl chloride, methylene chloride, the dichloro ethanes and dichloroethenes, as well as the trichloroethane and trichloroethenes. Not all four risk assessments covered the same suite of pollutants. Most calculated risk estimates at or near 1,000 feet down gradient from the active landfill area. Risk estimates varied from $4x10^{-4}$ to $4x10^{-3+}$. A value of $1x10^{-3}$ was chosen as representative and a scale-up (for the State of Washington) performed.

<u>Non-Cancer Estimates</u>

The hazard index figures were extracted from the same risk assessments mentioned above. Three of the four sites showed conditions in which the hazard index could exceed 1.0 which indicates that ambient concentrations exceed threshold safety levels. The metals such as lead, copper, manganese, zinc seemed to be primarily responsible for the non-cancer chronic exposure, although chlorinated solvents were the primary cause at the Colbert Landfill. Index values of as high as 55 as noted. The 690 person figure exposed was used as discussed in Section II.A.7. above.

2. Inhalation Route for Landfill Gases

Excess cancer deaths from the threat of direct exposure to landfill gas emissions was calculated from one risk estimate done for the Midway Landfill in Kent, Washington (4). A most exposed individual cancer risk of $1x10^{-6}$ was shown for exposure to landfill gases penetrating nearby basements (through soil migration). 18 different organic compounds formed the base of the risk estimate.

A scale up was performed assuming that the exposed population was 10 times that of exposure to landfill gases. The experience of Midway where approximately 250 homes with four persons per home (1,000 persons) is a base to figure from. See footnote c/, Table A.

Table B shows a Washington State incidence of $1x10^{-4}$ excess cancer cases per year due to the inhalation pathway.

Inhalation non-cancer chronic estimates in the same Midway study showed ratios of modeled concentrations to ambient standards (the Hazard Index) that were much less than 1.0. This indicates that no population would be exposed to chronic non-cancer effects from inhalation of landfill gases.

3. Sudden Death from Landfill Gas Migration

Incidence of sudden death from explosion of methane gas in nearby dwellings was estimated from nationwide statistics. This figure yields a risk for landfills of $4x10^{-5}$ deaths/landfill year sudden deaths, scaled up would yield, statewide, $4x10^{-3}$ deaths/year.

II. C. Trends-Human Health

During the last five years, the public health threat from poorly designed, poorly located, poorly operated and poorly closed landfills has become well publicized. The Midway Landfill and three other National Priority List landfills, and many others nominated, has pointed to health threats from gas migration in the soil and leachate migration in ground water. These threats are being addressed by a variety of regulatory and legal avenues including:

1. Dangerous waste rules that now prohibit a wide variety of toxic materials from being placed in municipal landfills.

2. Design, location, operations, maintenance closure and post-closure standards contained in revised solid waste standards.

3. A cleanup program that is systematically examining the public health threat from active, closing, and closed landfills, and taking the necessary steps to prevent impact to the public.

4. Lastly, important steps are being taken to some reduce and recycle wastes to minimize the impact from disposing of wastes in landfills. Seattle, for example, is shooting for a 60 percent recycling target. These and similar efforts statewide should help to slow the per capita rise in waste generation and help to off-set the areas projected population growth by the year 2010.

Several other negative trends should also be noted.

1. Toxic emissions from landfill gases may present a large threat to nearby populations. Ambient air standards for vinyl chloride gas and other toxicants are being lowered. The trend towards closing and capping landfills may enhance soil migration and population risk.

2. Other forms of waste management may present different risks that need careful analysis. The threat to surface waters from land application sewage sludge and toxic metal emissions from the use and disposal of solid waste incinerator ash are two examples of these threats from carrying out higher waste management practices.

3. The buildup of contaminants in recycled commodities like newsprint or mixed paper also needs to be carefully followed to ensure that unsuspected human exposure does not occur from recycling of commodities.

III. Ecological Risks

A. Description of the Analytical Approach and Data Sources

1. <u>General Approach</u> - Unlike human health effects there is little quantitative information available on ecological risk assessment even where landfill sites are listed as state or federal superfund sites. One site, described later did look at exposure pathways that would occur from ground water seeps and discharges to a nearby river. That study looked at risks from the halogenated solvents. Because landfill leachate, and to some lesser degree, landfill runoff contain more frequently

much higher levels of eventual contaminants like organic acids, high biological oxygen demand (BOD) as well as inorganics, the methodology looks at qualitative risks to the environment from these contaminants using the suggested outline for the 2010 project. No scale-up of ecological risk in total for the state has been possible methodologies for ecological risk assessments from landfills have been very difficult to construct or locate.

2. Sources, Pollutants, Exposure Pathways, Effects

Table D-1 summarizes ecological impacts from non-hazardous landfills. One impact is primarily aquatic impacts from contamination by leachate and runoff. The other impact arises from gas migration in the soil and emission to the atmosphere; carbon dioxide and methane are the major constituents of landfill gases. Impacts on the environment are most prominently local when soil migration of landfill gases occurs. Dead vegetation is a common symptom of such ecological stress. Global impacts of methane and carbon dioxide emissions may also be possible from the greenhouse effect, leading to dramatic climatic change. The relative contribution of municipal landfills to the overall methane and carbon dioxide global emission budget was not available.

Table D-2 summarizes the pollutants, exposure pathways and effects for the Colbert Landfill study -- the most definitive examination of possible ecological risks for superfund landfills in the State of Washington. It shows that most pathway exposure scenarios result in little or no acute or chronic toxicity to vertebrate animals, exposed in the Little Spokane River, at springs or from pumping contaminated ground water.

What the study did not address was the ecological impact from more conventional pollutants, like conventional organics and inorganics that may reach the Little Spokane River and contribute to the deterioration of that body of water. Many municipal landfills are also closer to river streams and wetlands because landfills historically have been sited on lands not suitable for habitation or any other human activity. Section B1 describes that effort.

3. Rationale for Elements Examined; Important Elements Not Examined

Ecological impacts from municipal landfills has been little studied; most of the information is not available. Most importantly, the overall impact is difficult to determine; for example, potential contamination of rivers and streams must be viewed from a basis of what contamination that may already be present.

III. B. Trends. Ecological. No information.

B. Description of Findings

1. Given the close proximity of many municipal landfills to streams, river, wetlands and estuaries, it is very likely that principal landfill impose environmental stresses for aquatic life, and other organisms existing in those ecosystems.

   To gain a handle on what general impacts these facilities may have, Table D/E is first presented to list some of the stressors that landfill leachate and contaminated runoff may pose for ecological systems. The list of stress agents was taken from an EPA workship entitled "Ecosystems Research Center -- Workshop on Ecological Effects from Environmental Stress" December 1986, Cornell University.

   Tables E-1 to E-4 were then constructed from Table 4 of the workshop document referenced above. It is an effort to qualify ecological impact <u>if</u>, for example, <u>high strength leachate from a landfill found its way into a surface body of water</u> like a stream, river or wetland. No time was available to determine whether hydraulic dilution of a landfill leachate discharge would significant lessen these impacts. Similar statements can also be made about Table E-4 that lists greenhouse gases ecological effects.

2. Surface water quality effects from acids, biochemical oxygen demand and toxic organic and inorganic pollutants in leachate are likely to occur on a local ecosystem level. Reversibility is moderate taking decades or in some respects, centuries.

3. Vegetative stresses around landfills may be present from migrating gases. Greenhouse effects from carbon dioxide and methane may be present but the relative contribution compared to other sources is unevaluated.

TABLE A. NONHAZARDOUS WASTE SITES - LANDFILLS
HEALTH EFFECTS
MATRIX OF KEY PROBLEM ELEMENTS

STRESSOR OR SOURCE	SOURCE(S) OR STRESSORS	TRANSPORT PATHWAY(S) EXPOSURE ROUTE(S)	POTENTIAL HEALTH EFFECTS	POPULATION EXPOSED	COMMENT
#1: Landfill Leachate	Organic Solvents	Discharge to ground water, migration off site and ingestion [a/]	1. Cancer	690 [b/]	
			2. Chronic Non-Cancer Toxicity	690 [b/]	
#2: Landfill Gases	Organic Solvents and Plasticizers	Emission to air from landfill or from flares and inhalation	1. Cancer	6900 [c/]	
			2. Chronic Non-Cancer Toxicity	6900 [c/]	
	Methane	" " "	Acute Physical hazard from methane explosion and fire.	6900 [c/]	

Footnotes

a/ Exposure to solvents may also occur through inhalation of vapors upon showering with contaminated ground water.
b/ See Appendix I for Inventory of Municipal Landfills and Exposed Population. Also Section II.G. of text.
c/ Assumes exposed population to air borne or soil borne landfill gases is 10 times that of ground water due to Midway experience (250 homes x 4 persons/home = 1,000 per site)

TABLE B
NON-HAZARDOUS WASTE SITE THREAT
RISK ASSESSMENT RESULTS: CHRONIC EXPOSURES

	CANCER			NON-CANCER CHRONIC			COMMENTS
Stressor, Source (or other category)	Estimated Incidence	Estimated MEI Risk	Uncertainty	Effect	Pop. Exposed Above Threshold	Hazard Index Exposure/ Threshold	Source
Organic Solvents (Drinking/Showering)	$690 \times 1 \times 10^{-3}$ 70 Years = 0.01	1×10^{-3}	5×10^{-3} to 1×10^{-4}	Solvent and Heavy Metal Toxicity	690	20	Table CC.
Organic Solvents and Other Chemicals Inhalation	6900 70 years x 1×10^{-6} = 1×10^{-4}	1×10^{-6}	1×10^{-5} to 1×10^{-8}	Chronic Toxicity	0 a/	6×10^{-3}	
TOTAL Cancer Deaths	0.01 Excess Cancers Per Year				690 Population Exposed Above Threshold		
Methane Migration Deaths	4×10^{-3}						Table C

a/ Toxicity index is less than less than 1, therefore population exposed is zero.

TABLE C. CALCULATION OF RISK FROM METHANE MIGRATION AND SUDDEN DEATH FROM FIRE/EXPLOSION

Source of Data: Federal Register August 30, 1988 p. 33319

Risk of death from methane explosion $= \dfrac{\text{5 Deaths}}{\text{6,000 Landfills x 20 Years}} = 4 \times 10^{-5} \dfrac{\text{Deaths}}{\text{Landfill Year}}$

(20 Years is the appropriate time that large sites have been around)

$$\text{Incidence} = 4 \times 10^{-5} \dfrac{\text{Deaths}}{\text{Landfill Year}} \times 105 \text{ Landfills} = 4 \times 10^{-3} \dfrac{\text{Deaths}}{\text{Year}}$$

TABLE CCC. SUMMARY OF STATE OF WASHINGTON
MUNICIPAL LANDFILL RISK ASSESSMENT FOR NONCARCINOGENIC
CHRONIC TOXICITY (MOST EXPOSED INDIVIDUAL)

Landfill Name and Location	Contaminants	CDI: RfD Ratio a/ (The Hazard Index)	Comments
Midway Landfill Kent, Washington	4 chlorinated hydrocarbons 4 organic solvents 4 metals 1 monomer/plasticizer	6,000 feet downgradient 1) 5×10^{-4} (Adults) b/ 2) 2×10^{-3} (Children) b/ 1,000 feet downgradient c/ 1) 2 2) 8 b/	6,000 Feet (down gradient) 1,000 Feet c/ (down gradient)
Colbert Landfill Colbert, Washington	1,1,1-trichloroethane 1,1-dichloroethylene 1,1-dichloroethane	55	At point of maximum concentration
Leichner Brothers Landfill Vancouver, Washington	1,1-dichloroethane 1,1,1-trichloroethane Cr, Mn, Zn	Adult 23 Child 9.8	
City of Tacoma Landfill	1,1-dichloroethane toluene	Less Than Less Than 1 Less Than Less Than 1	Subchronic Chronic

a/ Ingestion and inhalation of volatiles from showering. Hazard index is the sum of hazard indexes for each of the contaminants listed in column II.
b/ Plausible maximum case.
c/ East of landfill - southern gravel aquifer

TABLE CC. SUMMARY OF STATE OF WASHINGTON
MUNICIPAL LANDFILL RISK ASSESSMENTS FOR CARCINOGENIC RISK

Landfill Name and Location	Status	Nearest Down Gradient Wells a/	Contaminants	Maximum Exposed Individual Risk c/ I d/	S d/	Total
Midway Landfill Kent, WA	Closed Municipal Landfill	6,000 Feet e/	vinyl chloride, arsenic, 1,2-dichloroethane 1,1-dichloroethene bis(2-ethyl hexyl)phthalate	$3x10^{-7}$	$8x10^{-8}$	$4x10^{-7}$
		1,000 Feet f/	Same as above	$7x10^{-4}$	$3x10^{-4}$	$1x10^{-3}$
City of Tacoma Landfill	Active Municipal Landfill	1,200 Feet	vinyl chloride, benzene, 1,2-dichloroethane methylene chloride	$4.1x10^{-4}$	N.D.	$4x10^{-4}$
Leichner Brothers Landfill Vancouver, WA	Active Municipal Landfill	1,200 Feet g/	vinyl chloride, 1,1-dichloroethene, tetra chloroethylene trichloroethene	$2x10^{-4}$	$1x10^{-5}$	$2.1x10^{-4}$
		400 Feet h/	Same as above	$1x10^{-4}$	$4x10^{-4}$	$5x10^{-4}$
Colbert Landfill Colbert, WA	Closed Municipal Landfill	400 Feet ?	1,1-dichloroethylene trichloroethylene tetrachloro-ethylene methylene chloride 1,1,1-trichloroethane i/ 1,1-dichloroethane i/	N.C. k/	$4x10^{-3}$ j/	$4x10^{-3+}$

Footnotes:

a/ Wells currently used for drinking water
b/ Contaminants used in risk assessment
c/ In excess cancer risk for a 70 year lifetime; assumes no remediation of risk.
d/ I = Risk for ingestion of ground water; S = risk from showering and inhalation of volatiles.
e/ Existing wells 6,000 feet east of landfill.
f/ Potential wells 1,000 feet east of landfill.
g/ Current residential scenario.
h/ Future potential wells.
i/ Non-carcinogens.
j/ Calculated by lead author from reported maximum concentrations.
k/ Not calculated by lead author.

TABLE D-1. NON-HAZARDOUS WASTE SITES - LANDFILLS
ECOLOGICAL IMPACTS

MATRIX OF KEY PROBLEM ELEMENTS

STRESSOR OR SOURCE	SOURCE(S) OR STRESSOR(S)	TRANSPORT/ EXPOSURE PATHWAYS	ECOSYSTEM AFFECTED	ENDPOINTS OR EFFECTS	COMMENTS
#1: Landfill Leachate/ Runoff(*)	Acids B.O.D. Toxic Organics Toxic Inorganics Turbidity (*)	Direct discharge (from runoff); migration in ground water and discharge to surface water (from landfill leachate)	Streams, rivers and wetlands	Chronic or acute animal or fish toxicity, etc.	
#2: Landfill Gases	Methane and Carbon Dioxide Gases	Direct emission to atmosphere, or migration in soils and subsequent emission to atmosphere	Coniferous and deciduous forests; all ecosystems	Dead or dying vegetation Global warming	

TABLE D-2 ECOLOGICAL IMPACTS
COLBERT LANDFILL ECOLOGICAL RISK ASSESSMENT

MATRIX OF KEY PROBLEM ELEMENTS

STRESSOR OR SOURCE	SOURCE(S) OR STRESSOR(S)	TRANSPORT/ EXPOSURE PATHWAYS	ECOSYSTEM AFFECTED	ENDPOINTS OR EFFECTS	COMMENTS	ORDERS OF MAGNITUDE FACTORS OF SAFETY
#1: Leachate from N.P.L. Landfill	5 chlorinated Solvents	a) Aquifer to river (aquatic organisms)	River	Concentrations meet ambient water quality criteria	Lower Aquifer	5
	2 Chlorinated	b) Ingestion by Mammals	River Seeps/ground water	No animal toxicity (acute)		3-5
	Solvents	Ground water spring or surface water concentrations	River/seeps springs	No animal toxicity (Chronic)		Greater than 1

TABLE D/E

MATRIX RELATING ECOLOGICAL STRESSES WITH EPA LIST OF ENVIRONMENT PROBLEMS

Adapted from Cornell Study

Stress Agents

Air Sources

Greenhouse gases

Water Sources

Acids
BOD
Toxic Organics
Toxic Inorganics
Turbidity

Terretrial Sources
Solid Matter a/
Toxic Organics and Inorganics a/

Other Environmental Problems

Ground Water Contamination

a/ Dropped from the EPA/ERC Workshop Matrix (Cornell Study) because inclusion lead to no useful information.

TABLE E-1

Summary Sheet for Risk Assessment Results

Threat: Nonhazardous Waste Sites Landfills

Stressor: Acids from Leachate/Runoff

Ecosystem: Freshwater Ecosystems [a/]

1. Intensity of Inpact on Structure and Functional Integrity

   a. Species Level: Certain likelihood of high intensity impact on species important to humans (such as salmonid fish).

      Source: Cornell Report

   b. Ecosystem/Habitat Level: High impact, but localized, potential effects on biotic community structure; potential effects on ecological processes.

      Source: Cornell Report

2. Reversibility: Decades (10-100 years) Cornell Report

   Somewhat dependent upon natural alkalinity of surface streams. Eastern Washington streams tend to have higher alkalinity than wetter high-precipitation Western Washington streams.

3. Scale of Effect: Ecosystem Cornell Report

4. Sensitivity/Vulnerability of Ecosystem/Species to Cumulative or Synergistic Impacts. Unknown.

5. Trend: Fewer but larger sites is leading to large impacts at fewer sites. Controls being instituted at State and Federal level may lessen impact of leachate and runoff on streams.

6. Productivity/Uniqueness: Unknown

7. Uncertainty: High

8. Comments: None

Footnote:

a/ Includes lakes, streams, and wetlands (freshwater, only).

TABLE E-2

Summary Sheet for Risk Assessment Results

Threat: Non Hazardous Waste Sites (Landfills)

Stressor: B.O.D. from Leachate/Runoff

Ecosystem: Freshwater and Wetland Ecosystems

1. Intensity of Impact on Structure and Functional Integrity

   a. Species Level: Medium ecological impact and high ecological impact for wetlands and fresh waters respectively. Likelihood is high. Lake and streams less able to handle additional carbon and nutrient loading than wetlands. Potential effects on species important to humans (such as salmonid fish) for freshwater ecosystems. Cornell Report

   b. Ecosystem/Habitat Level: High impact, but localized for freshwater ecosystems. Medium impact, localized for wetlands.

      Source: Cornell Report

2. Reversibility: Years (0-10) to decades (10-100 years) for lakes years (0-10 years) for streams and years (0-10 years) for wetland ecosystems.

   Source: Cornell Report

3. Scale of Effect: Ecosystem. Cornell Report

4. Sensitivity/Vulnerability of ecosystem/species and cumulatus or synergistic impacts. Unknown.

5. Trend: See item 5, table E-1

6. Productivity/Uniqueness: Unknown

7. Uncertainty: High

8. Comments: None

TABLE E-3

Summary Sheet for Risk Assessment Results

Threat: Non Hazardous Waste Sites (Landfills)

Stressor: Toxic organics and inorganics from leachate/runoff

Ecosystem: Freshwater and Wetland Ecosystems

1. Intensity of Impact on Structure and Functional Integrity

   a. Species Level: High ecological impact for freshwater ecosystems, although buffered aquatic ecosystems are somewhat less sensitive than unbuffered ecosystems to toxic inorganic impacts. Likelihood of impacts is certain once contaminants have reached surface water ecosystems. Medium ecological impact for toxic organics in wetland ecosystems.

   b. Ecosystem/Habitat Level: High impact but localized. Potential effects on biotic community structure, and potential effects on ecological processes, except for the case of toxic inorganics in wetland ecosystems. Cornell Report

2. Reversibility: Decades (10-100 years) to centuries (100-1,000 years) Cornell Report.

3. Scale of Effect: Ecosystem Cornell Report

4. Sensitivity/Vulnerability of Ecosystem/Species to cumulative or synergistic impacts. Unknown.

5. Trend: See Item 5, Table E-1
6. Productivity/Uniqueness: Unknown

7. Uncertainty: High

8. Comments:

TABLE E-4

Summary Sheet for Risk Assessment Results

Threat: Non Hazardous Waste Sites (Landfills)

Stressor: Greenhouse Gases

Ecosystems: Freshwater, terrestrial, marine, estuarine and wetland ecosystems

1. Intensity of Impact on Structure and Functional Integrity

   a. Species Level: Certain likelihood of high intensity impact on individual species in all ecosystems (dependent on relative contribution of methane and carbon dioxide from landfills and other anthropoghic and natural sources.) Species affected would be important to humans from an economic and ecological standpoint.

   b. Ecosystem/habitat level - High impact and global in impact. Effects in biotic community structure and ecological processes.

2. Reversibility: Centuries to indefinite (greater than 1,000 years).

3. Scale of Effect: Global

4. Sensitivity/Vulnerability of Ecosystem/Species to cumulative or synergistic impacts. High.

5. Trend: Per capital generation of solid waste is increasing at a time of growing population, leading to increased emission of greenhouse gases.

6. Productivity/Uniqueness: Unknown

7. Uncertainty: High

8. Comments: None

References

1. "Health Risk Assessment of the Proposed Landfill for Municipal Solid Waste in Douglas, Massachusetts" Vol. I. Text and references, prepared by Alan Eschenroeder, David Burmaster, Scott Wolff, and Alison Taylor. Alanova, Inc. consultants. September 26, 1988.

2. Potential Human Health Risks and Economic Damages from Management of Non-Superfund Wastes and Materials in Metro-Denver. Industrial Economics, Incorporated and Woodward-Clyde Consultants. May 1988.

3. Federal Register August 30, 1988, p. 33320

4. "Midway Landfill Draft Feasibility Study Endangerment Assessment." Parametrix, Consultant, 1988d.

5. "Feasibility Study: Colbert Landfill, Spokane, Wash." Golden Associates and Envirosphere Co., May, 1987. Vol. I and II.

6. "Leichner Landfill: Remedial Investigation Report" Sweet-Edwards/EMCON, Inc., February 14, 1988.

7. "Revised Tacoma Landfill Endangerment Assessment Report," Black and Veatch December, 1987.

Compliance

F = Fair
P = Poor
G = Good

S = ≤ 24,000 yd³/year
m = 24,100 to 121,700 yd³/year
l = > 121,700 yd³/year

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Active Non-HAZARDOUS SOLID WASTE FACILITIES

¶ WDOE ¶ REGION	¶ COUNTY ¶ NAME	¶ FACILITY ¶ NAME	¶ FACILITY ¶ OWNER	¶ SWCODE	OVERALL RATING	¶ Size category	Setting	Exposed Population
Central	Okanogan	Okanogan Landfill	Okanogan County	2-LF01	F	S	R	0.1
Eastern	Adams	Bruce Landfill	Adams County	01-LF01		m	R	1
Eastern	Adams	Washtucna T.S.	Adams County	01-TS01				
Eastern	Adams	Lind T.S.	Adams County	01-TS02				
Eastern	Adams	Ritzville T.S.	Adams County	01-TS03				
Eastern	Adams	Othello T.S.	Adams County	01-TS04				
Eastern	Adams	Williams T.S.	Adams County	01-TS05				
Eastern	Adams	Benge T.S.	Adams County	01-TS06				
Eastern	Adams	Schrag T.S.	Adams County	01-TS07				
Eastern	Asotin	Asotin County Landfill	Asotin County	02-LF01		l	R	10
Central	Benton	Richland Landfill	City of Richland	03-LF01	A	S	R	0.1
Central	Benton	A2-W	Phil Whitney	03-LF02		m	R	1
Central	Benton	Hanford Landfill	U.S.D.O.E.	03-OW01		a/		
Central	Benton	Eastmont T.S.	Kennewick Disposal	03-TS02				
Central	Chelan	Alcoa Landfill	Alcoa Company	04-ID01				
Central	Chelan	Holden Village Landfill	Holden Village	04-LF01		S	R	0.1
Central	Chelan	Manson Landfill	Chelan County	04-LF02	P	m	R	1.0
Central	Chelan	Cashmere Landfill	City of Cashmere	04-LF03	F	S	U	1.0
Central	Chelan	Dryden Landfill	Chelan County	04-LF05	F	m	R	10
Central	Chelan	Keyes Sludge Site	Keyes Fiber Company	04-SU01				
Central	Chelan	Asamera Minerals Landfill	Asamera Corp.	04-SW07				
Central	Chelan	Wenatchee T.S.	City of Wenatchee	04-TS01	A			
Central	Chelan	Dryden T.S.	Chelan County	04-TS02				
Southwest	Clallam	Port Angeles Landfill	City of Port Angeles	05-LF01		m	R	10
Southwest	Clallam	Lake Creek Landfill	Clallam County	05-LF02		m	R	10
Southwest	Clallam	Neah Bay Landfill	Makah Indian Nation	05-LF03		b/		
Southwest	Clallam	Soilganic Services	Soilganic Services	05-SU01				
Southwest	Clallam	Blue Mountain T.S.	Clallam County	05-TS01				
Southwest	Clallam	Clallam Bay T.S.	Clallam County	05-TS02				
Southwest	Clallam	ITT Rayonier 13th & M	ITT Rayonier	05-WW01				

Exposed Population Matrix

	R	
s	.1	
m	1	1
l	10	1

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a/ Hanford landfills not included - Special waste
b/ Indian Reservation landfills not included. No data

Setting
R = Rural
U = Urban

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WDOE REGION	COUNTY NAME	FACILITY NAME	FACILITY OWNER	SWCODE	OVERALL RATING	Size category	Setting	Exposed Population
Southwest	Clallam	ITT Rayonier (Shotwell)	ITT Rayonier	05-WW02				
Southwest	Clallam	M & R 13th & M		05-WW03				
Southwest	Clallam	Lawson Landfill	Dan Lawson	05-WW04				
Southwest	Clark	Leichner Landfill	Leichner Brothers	06-LF01		l	U	100.
Southwest	Clark	Circle C Landfill	Carl Carlson	06-LF02		l	R	10
Southwest	Clark	Hallstrom Landfill	Raymond Hallstrom	06-LF03		m	R	1.
Southwest	Clark	Lady Island Landfill	James River Corp.	06-WW01		c/		
Eastern	Columbia	Columbia County T.S.	Columbia County	07-TS01				
Southwest	Cowlitz	Sari Pit Site (expansion)		08-ID01				
Southwest	Cowlitz	Cowlitz County Landfill	Cowlitz County	08-LF01		l	R	10.
Southwest	Cowlitz	Weyerhaeuser Landfill	Weyerhaeuser Company	08-SU01				
Southwest	Cowlitz	Larson Farm		08-SU02				
Southwest	Cowlitz	Kalama Chemical Inc.	Kalama Chemical Inc.	08-SU03				
Southwest	Cowlitz	Bill Cox Tire & Wheel	Bill Cox	08-TP01				
Southwest	Cowlitz	Toutle T.S.	Cowlitz County	08-TS01				
Southwest	Cowlitz	K & M T.S.	Cowlitz County	08-TS02				
Southwest	Cowlitz	Radakovich Disposal Site	Radakovich Construction	08-WW01				
Southwest	Cowlitz	Ostrander Rock Landfill	Ostrander Rock Company	08-WW02				
Southwest	Cowlitz	Cavenham Landfill	Cavenham Forest Prod.	08-WW03				
Southwest	Cowlitz	I-P Site	International Paper	08-WW04				
Southwest	Cowlitz	Weyerhaeuser Landfill	Weyerhaeuser Company	08-WW05				
Southwest	Cowlitz	Swanson Fuel	Swanson Fuel	08-WW06				
Southwest	Cowlitz	Minor Rd. Site	Cavenham Forest Prod.	08-WW07				
Southwest	Cowlitz	Toutle #1		08-WW08				
Southwest	Cowlitz	James Anderson Landfill	James Anderson	08-WW09				
Southwest	Cowlitz	Grays River Shake Mill		08-WW10				
Central	Douglas	Eastmont Landfill	Waste Management Inc.	09-LF01	G	l	R	10.
Central	Douglas	Pine Canyon Landfill	Douglas County	09-LF02	F	S	R	0.1
Central	Douglas	Bridgeport Bar Landfill	Douglas County	09-LF03	A	S	R	0.1
Central	Douglas	Bridgeport Bar T.S.	Douglas County	09-TS01	G			

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c/ Industrial landfills not included in risk analysis.

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¶ WDOE ¶ REGION	¶ COUNTY ¶ NAME	¶ FACILITY ¶ NAME	¶ FACILITY ¶ OWNER	¶ SWCODE	OVERALL RATING ¶	Size category	Setting	Exposed Population
Eastern	Ferry	Torboy Landfill	Ferry County	10-LF01		s	R	0.1
Eastern	Ferry	Inchelium Landfill	Colville Conf. Tribes	10-LF02		b/		
Eastern	Franklin	Pasco Landfill?	Larry Dietrich	11-LF01	A	f/		
Eastern	Garfield	Garfield County Landfill	Garfield County	12-LF01		s	R	0.1
Eastern	Grant	Ephrata Landfill	Grant County	13-LF01	F	l	R	10.
Eastern	Grant	Grand Coulee Landfill	Grand Coulee Cities	13-LF02	F	s	R	0.1
Eastern	Grant	I-90 Landfill	Grant County	13-LF03		s	R	0.1
Southwest	Grays Harbor	Aberdeen Landfill	Harold LeMay	14-LF01		l	u	100.
Southwest	Grays Harbor	Hoquiam Landfill	City of Hoquiam	14-LF02		m	R	1.
Southwest	Grays Harbor	Hogans Corner T.S.	Grays Harbor County	14-TS01				
Southwest	Grays Harbor	Ocosta T.S.	Grays Harbor County	14-TS02				
Southwest	Grays Harbor	Elma-McCleary T.S.	Grays Harbor County	14-TS03				
Southwest	Grays Harbor	Pacific Beach T.S.	Grays Harbor County	14-TS04				
Southwest	Grays Harbor	Oakville T.S.	Grays Harbor County	14-TS05				
Southwest	Grays Harbor	Humptulips T.S.	Grays Harbor County	14-TS07				
Southwest	Grays Harbor	Cedarville T.S.	Grays Harbor County	14-TS08				
Southwest	Grays Harbor	Copalis T.S.	Grays Harbor County	14-TS09				
Southwest	Grays Harbor	J & R Corp. Landfill	J & R Corporation	14-WW01				
Southwest	Grays Harbor	F & R Quarry Site #1	Friend & Rikalo	14-WW02				
Southwest	Grays Harbor	Nevakah Road Site	Friend & Rikalo	14-WW03				
Southwest	Grays Harbor	Chairman Point Site	Friend & Rikalo	14-WW04				
Southwest	Grays Harbor	F & F	Friend & Friend	14-WW05	A			
Northwest	Island	Whidbey Island Landfill	Island County	15-ID01		d/	R	
Northwest	Island	Camano Island Landfill	Island County	15-ID02		d/	R	
Northwest	Island	Island County Landfill	Island County	15-LF01	A	m	R	1.0
Northwest	Island	Whidbey I. NAS Landfill	U.S.N.	15-LF02		s	R	0.1
Northwest	Island	Oak Harbor T.S.	Island County	15-TS01				
Northwest	Island	Coupeville T.S.	Island County	15-TS02				
Northwest	Island	Camano T.S.	Island County	15-TS03				
Northwest	Island	Bayview T.S.	Island County	15-TS04				

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d/ Inert/demolition site. NOT INCLUDED IN RISK ANALYSIS

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¶ WDOE ¶ REGION	¶ COUNTY ¶ NAME	¶ FACILITY ¶ NAME	¶ FACILITY ¶ OWNER	¶ ¶ SWCODE	OVERALL RATING	¶ ¶ Size Category	Setting	Exposed Populatic
Southwest	Jefferson	Jefferson County Landfill	Jefferson County	16-LF01		m	R	1.0
Southwest	Jefferson	Port Townsend Paper	Port Townsend Paper	16-LF02				
Northwest	King	Newcastle Landfill	Coal Creek Develoment Co.	17-ID01				
Northwest	King	Cedar Hills Landfill	King County	17-LF01		l	R	10.
Northwest	King	Enumclaw Landfill	King County	17-LF02		m	u	10.
Northwest	King	Duvall Landfill	King County	17-LF03		s	R	0.1
Northwest	King	Hobart Landfill	King County	17-LF04		s	R	0.1
Northwest	King	Vashon Landfill	King County	17-LF05		s	R	0.1
Northwest	King	Carnation Landfill	City of Carnation	17-LF06		s	R	0.1
Northwest	King	Cedar Falls Landfill	King County	17-LF07		s	R	0.1
Northwest	King	L-Bar Products	L-Bar	17-SW01				
Northwest	King	Mt. Olivet Cemetary	American Mem. Services	17-SW01				
Northwest	King	First Northeast T.S.	King County	17-TS01				
Northwest	King	Renton T.S.	King County	17-TS02				
Northwest	King	Algona T.S.	King County	17-TS03				
Northwest	King	Houghton T.S.	King County	17-TS04				
Northwest	King	Bow Lake T.S.	King County	17-TS05				
Northwest	King	Factoria T.S.	King County	17-TS06				
Northwest	King	Evergreen T.S.	King County	17-TS07				
Northwest	King	Eastmont Dev. T.S.	Eastmont Dev. Corp.	17-TS08				
Northwest	King	South Park T.S.	King County	17-TS09				
Northwest	King	Fremont T.S.	King County	17-TS10				
Northwest	King	Skykomish Drop Box		17-TS11				
Northwest	Kitsap	Blue Cascade Landfill	Chuck Childress	18-ID01		d		
Northwest	Kitsap	Morrison Gravel Landfill	Don morrison	18-ID02		d		
Northwest	Kitsap	Olympic View Landfill	Kitsap County	18-LF01	A	l	?	10.
Northwest	Kitsap	Hansville Landfill	Kitsap County	18-LF02		l	R	10.
Central	Kittitas	Ryegrass Landfill	Kittitas County	19-LF01		l	R	10.
Central	Kittitas	Ellensburg Bailing Stn.	City of Ellensburg	19-TS01				
Central	Kittitas	Cle Elum T.S.	Kittitas County	19-TS02				

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¶ WDOE ¶ REGION	¶ COUNTY ¶ NAME	¶ FACILITY ¶ NAME	¶ FACILITY ¶ OWNER	¶ SWCODE	OVERALL RATING	¶ Size Category	Setting	Exposed Population
Central	Klickitat	Horsethief Pt. Landfill	Klickitat County	20-LF01		m	R	1.0
Central	Klickitat	Recycled Aluminum Co.	Robert Barnes	20-SW01				
Southwest	Lewis	Centralia Landfill	City of Centralia	21-LF01		f/		
Southwest	Lewis	WIDCO Landfill	WIDCO	21-LF02		S	R	0.1
Southwest	Lewis	Northwest Hardwoods	Northwest Hardwoods Inc.	21-WW01				
Eastern	Lincoln	Harrington Landfill	Lincoln County	22-LF01		m	R	1.0
Eastern	Lincoln	Odessa Landfill	City of Odessa	22-LF02		S	R	0.1
Eastern	Lincoln	N.W. Lincoln Co. Landfill	Lincoln County	22-LF03		S	R	0.1
Eastern	Lincoln	Davenport Landfill	City of Davenport	22-LF04		S	R	0.1
Eastern	Lincoln	Sprague Landfill	City of Sprague	22-LF05		S	R	0.1
Eastern	Lincoln	Almira Landfill	City of Almira	22-LF06		S	R	0.1
Southwest	Mason	Mason County Landfill	Mason County	23-LF01		l	R	10.0
Southwest	Mason	Shelton Landfill	City of Shelton	23-LF02		m	R	1.0
Southwest	Mason	Belfair T.S.	Mason County	23-TS01				
Southwest	Mason	Hoodsport T.S.	Mason County	23-TS02				
Southwest	Mason	Dayton Landfill	Simpson Timber Company	23-WW01				
Central	Okanogan	Brett-Pit Landfill	U.S.D.I.	24-ID01				
Central	Okanogan	Ellisford Landfill	Okanogan County	24-LF02	P	S	R	0.1
Central	Okanogan	Twisp Landfill	Okanogan County	24-LF03	P	S	R	0.1
Central	Okanogan	Loomis Landfill	Sheep Mt. Cattle Co.	24-LF04	P	S	R	0.1
Central	Okanogan	Pateros Landfill	City of Pateros	24-LF05	P	S	R	0.1
Central	Okanogan	Nespelem Landfill	Colville Conf. Tribes	24-LF06		b/		
Central	Okanogan	Eastmont Development T.S.	Eastmont Development	24-TS01				
Central	Okanogan	Methow Valley T.S.	Okanogan County	24-TS02	G			
Central	Okanogan	Cavenham Landfill	Cavenham Forest Products	24-WW01	G			
Southwest	Pacific	Rainbow Valley Landfill	Larry Bale	25-LF01	F	m	R	1.0
Southwest	Pacific	Pacific Disposal T.S.	Art Alexander	25-TS01				
Eastern	Pend Oreille	N. Pend Oreille Landfill	Pend Oreille County	26-LF01		S	R	0.1
Eastern	Pend Oreille	S. Pend Oreille Landfill	Pend Oreille County	26-LF02		m	R	1.0
Eastern	Pend Oreille	Tiger South Lnadfill	WSDOT	26-SW01				

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¶ WDOE ¶ REGION	¶ COUNTY ¶ NAME	¶ FACILITY ¶ NAME	¶ FACILITY ¶ OWNER	¶ SWCODE	OVERALL RATING	¶ Size Category	Setting	Exposed Population
Southwest	Pierce	Northwest Composting	Same	27-CP01				
Southwest	Pierce	Tacoma Landfill	City of Tacoma	27-LF01	A	l	u	100.
Southwest	Pierce	Hidden Valley Landfill	Land Recovery Inc.	27-LF02	F	f/		
Southwest	Pierce	Purdy Landfill	Pierce County	27-LF03		m	u	10.
Southwest	Pierce	Fort Lewis Landfill	U.S. Army	27-LF05		m	u	10.
Southwest	Pierce	McNeil Island Landfill	WA. Dept. of Corrections	27-LF06		S	R	0.1
Southwest	Pierce	Puget Sound By-Products	Same	27-SI01				
Southwest	Pierce	Key Center T.S.	Pierce County	27-TS01				
Southwest	Pierce	Lakewood T.S.	Pierce County	27-TS02				
Southwest	Pierce	South Prairie T.S.	Pierce County	27-TS03				
Southwest	Pierce	Grice Landfill	E. Grice	27-WW01		e/		
Northwest	San Juan	San Juan Landfill	San Juan County	28-LF01		S	R	0.1
Northwest	San Juan	Orcas Island Landfill	San Juan County	28-LF02		S	R	0.1
Northwest	Skagit	Inman Landfill	Skagit County	29-LF01	A	l	R	10.0
Northwest	Skagit	Gibraltar Landfill	Skagit County	29-LF02		S	R	0.1
Northwest	Skagit	South Landfill	Skagit County	29-LF03		S	R	0.1
Northwest	Snohomish	Cathcart Landfill	Snohomish County	31-LF01	G	l	R	10.
Northwest	Snohomish	Monroe Landfill	City of Monroe	31-LF02		S	U	1.0
Northwest	Snohomish	Darrington Landfill	Town of Darrington	31-LF03		S	R	0.1
Northwest	Snohomish	Bryant Landfill	Snohomish County	31-LF04		S	R	0.1
Northwest	Snohomish	Ebey Island	Solganic Service Corp.	31-SU01				
Northwest	Snohomish	North Snohomish T.S.	Snohomish County	31-TS01				
Northwest	Snohomish	J.H. Baxter Landfill	J.H. Baxter Company	31-WW01				
Northwest	Snohomish	Northwest Hardwoods	Same	31-WW02				
Northwest	Snohomish	Sisco	Ron Baker	31-WW03				
Northwest	Snohomish	Summit Timber	Summit Timber Company	31-WW04				
Northwest	Snohomish	J.H. Baxter Landfill - N.	J.H. Baxter Company	31-WW05				
Northwest	Snohomish	Smith Island	Weyerhauser Co.	31-WW06				
Eastern	Spokane	Park Drive Landfill	Spokane County	32-ID02		d/	R	
Eastern	Spokane	Wilson Landfill	Ralph Wilson	32-ID03		d/	R	

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e/ Landfill of woodwaste

f/ State or Federal N.P.L. site covered under inactive hazardous waste site threat

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¶ WDOE ¶ REGION	¶ COUNTY ¶ NAME	¶ FACILITY ¶ NAME	¶ FACILITY ¶ OWNER	¶ SWCODE	OVERALL RATING	¶ Size Category d/	Setting	Exposed Population
Eastern	Spokane	44th & Sands Landfill	Joe Bascetta	32-ID04				
Eastern	Spokane	Old Materne Pit Site	Charles Materne	32-ID05				
Eastern	Spokane	8th & Carnahan Pit	Acme Concrete	32-ID06				
Eastern	Spokane	Broadway Pit	Acme Concrete	32-ID07				
Eastern	Spokane	KACC-Mead Landfill	Kaiser Aluminum	32-ID08				
Eastern	Spokane	Central Pre-Mix Site	Central Pre-Mix Company	32-ID09				
Eastern	Spokane	Bascetta Demo Site		32-ID11				
Eastern	Spokane	Yardley Landfill	Central Pre-Mix Company	32-ID13				
Eastern	Spokane	Whitman College Site	Whitman College	32-ID14				
Eastern	Spokane	Swan Disposal Site	Robert Swan	32-ID15				
Eastern	Spokane	WS-C-12 Landfill	WDOT	32-ID16				
Eastern	Spokane	Mica Landfill	Spokane County	32-LF01		f/		
Eastern	Spokane	Myers Landfill	Thomas Myers	32-LF02		S	R	0.1
Eastern	Spokane	Marshall Landfill	Glenn Gillson	32-LF04		l	R	10.
Eastern	Spokane	North Landfill	Spokane County	32-LF05		f/		
Eastern	Spokane	South Landfill	City of Spokane	32-LF07		l	u	100.
Eastern	Spokane	Four Lake Tire Pile	AA Distributing	32-TP01				
Eastern	Spokane	A.A. Auto Wrecking	Same	32-TP02				
Eastern	Spokane	Lindsay Tire Pile	John Lindsay	32-TP03				
Eastern	Spokane	Lindsay Tire Pile	John Lindsay	32-TP06				
Eastern	Spokane	Maak Tire Recyclers	Carl Maak	32-TP07				
Eastern	Spokane	Fairfield T.S.	Spokane County	32-TS01				
Eastern	Spokane	Deep Creek T.S.	Spokane County	32-TS02				
Eastern	Spokane	Sunshine Recyclers T.S.	Sunshine Disposal	32-TS03				
Eastern	Spokane	Appleway T.S.		32-TS04				
Eastern	Spokane	Quartz Quarry Landfill	Dan Loshbaugh	32-WW01		e/		
Eastern	Stevens	Stevens County Landfill	Stevens County	33-LF01	F	S	R	0.1
Eastern	Stevens	Northwest Alloy Landfill	Northwest Alloys Inc.	33-SW01				
Eastern	Stevens	Loon Lake T.S.	Stevens County	33-TS01				
Eastern	Stevens	Northport T.S.	Stevens County	33-TS02				

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DEPT OF ECOLOGY - SHWP
SOLID WASTE INVENTORY
DESCRIPTION BY REGION

March 13, 19

WDOE REGION	COUNTY NAME	FACILITY NAME	FACILITY OWNER	SWCODE	OVERALL RATING	Size Category	Setting	Exposed Population
Eastern	Stevens	Hunters T.S.	Stevens County	33-TS03				
Eastern	Stevens	Ford III T.S.	Stevens County	33-TS04				
Eastern	Stevens	WWP-Tripp Landfill	Fred Tripp	33-WW01				
Southwest	Thurston	Hawks Prairie Landfill	Thurston County	34-LF01		m	R	1.0
Southwest	Thurston	Four Hoop Sludge Site	Four Hoops Bio Treatment	34-SU01				
Southwest	Thurston	Rochester T.S.	Thurston County	34-TS01				
Southwest	Thurston	Rainier T.S.	Thurston County	34-TS02				
Southwest	Wahkiakum	Rosburg Landfill	Bob Torppa	35-LF01		S	R	0.1
Southwest	Wahkiakum	Cathlamet Dump		35-LF02		S	R	0.1
Southwest	Wahkiakum	K & M Drop Box		35-TS02				
Eastern	Walla Walla	Sudbury Road Landfill	Walla Walla County	36-LF01	A	m	R	1.0
Eastern	Walla Walla	Soil Life Systems	Soil Life Systems	36-LF02		S	R	0.1
Eastern	Walla Walla	Burbank T.S.		36-TS01				
Eastern	Walla Walla	Boise Cascade Landfill	Boise Cascade	36-WW01				
Northwest	Whatcom	Lynden Drop Box	Whatcom County	37-DB01				
Northwest	Whatcom	Birch Bay Drop Box	Whatcom County	37-DB02				
Northwest	Whatcom	Bellingham Drop Box	Whatcom County	37-DB03				
Northwest	Whatcom	Glacier Drop Box	Whatcom County	37-DB04				
Northwest	Whatcom	T.R.C. Landfill	Thermal Reduction Corp.	37-LF01		m	R	1.0
Northwest	Whatcom	Cedarville Landfill	Whatcom County	37-LF02		m	R	1.0
Northwest	Whatcom	Olivine R.R. Landfill	Olivine Corp.	37-LF03		S	R	0.1
Northwest	Whatcom	Y Road Landfill	Whatcom County	37-LF04		S	R	0.1
Northwest	Whatcom	Pt. Roberts Landfill	Whatcom County	37-LF05		S	U	1.0
Northwest	Whatcom	Twin Falls Impoundment		37-SI01				
Northwest	Whatcom	Charles Hoekema Site	Same	37-SU02				
Northwest	Whatcom	Bert Schefer Site	Sam	37-SU02				
Northwest	Whatcom	Curtis House Site	Same	37-SU03				
Northwest	Whatcom	Gerrit Feenstra Site	Same	37-SU04				
Northwest	Whatcom	Pioneer Pacific Farms	Same	37-SU05				
Northwest	Whatcom	Frank Vogel Jr. Site	Same	37-SU06				

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DEPT OF ECOLOGY - SHWP
SOLID WASTE INVENTORY
DESCRIPTION BY REGION

¶ WDOE ¶ REGION	¶ COUNTY ¶ NAME	¶ FACILITY ¶ NAME	¶ FACILITY ¶ OWNER	¶ SWCODE	OVERALL RATING	¶ Size Category	Setting	Exposed Population
Northwest	Whatcom	Jeff Brozen Site	Same	37-SU07				
Northwest	Whatcom	Sumas Transport	Same	37-SU08				
Northwest	Whatcom	Richard Pem Site	Same	37-SU09				
Northwest	Whatcom	Bert Pelleboer Site	Same	37-SU10				
Northwest	Whatcom	Harry Tiemersma Site	Same	37-SU11				
Northwest	Whatcom	Clarence Osgood	Same	37-SU12				
Northwest	Whatcom	Airport Woodwaste Site	Georgia Pacific Co.	37-WW01				
Northwest	Whatcom	Hilltop Farm	Georgia Pacific Co.	37-WW02				
Eastern	Whitman	Whitman County Landfill	Whitman County	38-LF01		m	R	1.0
Central	Yakima	Ahtanum Drop Box	Yakima County	39-DB01	A			
Central	Yakima	Selah Drop Box	Yakima County	39-DB02	A			
Central	Yakima	Cowiche Drop Box	Yakima County	39-DB03	A			
Central	Yakima	Naches Drop Box	Yakima County	39-DB04	A			
Central	Yakima	Tampico Drop Box	Yakima County	39-DB05	A			
Central	Yakima	Nile Drop Box	Yakima County	39-DB06	A			
Central	Yakima	Tieton River Drop Box	U.S.F.S.	39-DB07	A			
Central	Yakima	Terrace Hts. Landfill	Yakima County	39-LF01	G	l	U	100.
Central	Yakima	Snipes Mt. Landfill	Yakima County	39-LF02	F	m	R	1.
Central	Yakima	Cheyne Road Landfill	Yakima County	39-LF03	F	m	R	1.
Central	Yakima	Grandview Landfill	City of Grandview	39-LF04	F	s	U	1.
Central	Yakima	Yakima Nation Landfill	Yakima Indian Nation	39-LF05				
Central	Yakima	Yak. Firing Ctr. Landfill	U.S. Army	39-LF06	F	b/s	R	0.1
Central	Yakima	Boise Cascade Landfill	Boise Cascade Corp.	39-WW01				

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INTRODUCTION

This is an assessment of the human health and ecological risks associated with materials storage in the State of Washington. Materials storage -- one of 23 environmental threats being analyzed in Washington Environment 2010 -- includes releases of petroleum products and other chemicals from stationary tanks that are above, on, or under the ground.

Leaks from storage tanks or their associated piping can have a variety of adverse impacts on human health and the environment. Stored products, which include motor fuels, heating oils, solvents, and lubricants, can release toxic chemicals such as benzene, xylene, toluene, TCE, TCA, and PCE into groundwater and surface water bodies, contaminating drinking water supplies and adversely affecting aquatic ecosystems. In addition, vapors from gasoline leaks can migrate into sewer systems and private homes, contaminating the air and introducing the risk of fire and explosion.

In recent years, the contamination of drinking water supplies, the evacuation of homes and other buildings, explosions in sewer lines, and other incidents linked to leaking underground storage tanks have drawn considerable public and legislative attention. This attention led to the recent promulgation of comprehensive federal and state regulations of underground storage tanks that now control both new and existing underground tanks that store petroleum and other chemicals.

This analysis does not address all modes of materials storage; rather, it focuses on a particular subset of the threat -- underground storage tanks that store petroleum-based products such as gasoline. The reason for this focus is twofold: 1) most of the available data on materials storage focuses on petroleum-based underground storage tanks (USTs); and 2) the vast majority of USTs in Washington State (over 95 percent) store petroleum-based products. (1) Though brief sections on above-ground storage tanks and tanks that store nonpetroleum-based chemicals are included near the end of this report, there is not sufficient data available on either of those types of storage facilities to adequately assess the human health or ecological risks they pose.

This analysis focuses on the following human health and ecological risks associated with petroleum-based underground storage tanks:

- Human Health Risks:
  - The cancer risks associated with drinking UST-contaminated water;
  - The cancer and noncancer risks associated with inhaling UST-contaminated air (i.e., gasoline vapors); and
  - The risks of injury or death due to fire or explosion

Ecological Risks:

- Toxicity to aquatic ecosystems from contamination of surface water bodies

This analysis focuses exclusively on the human health and ecological risks associated with leaking tanks; it does not address the economic and quality-of-life impacts associated with the contamination of groundwater supplies, which could be significant.

It is important to note that this analysis does not include storage at active or inactive hazardous waste sites, nor does it include sudden and accidental releases from storage tanks (e.g., a sudden rupture or spill like the Ashland Oil release into the Monongahela River in Pennsylvania in 1988). The risks associated with these threats are analyzed separately and presented in other reports. Nonetheless, some double-counting of UST-related risks is likely to occur in these reports, as well as in the reports on point source discharges to water, nonpoint source discharges to water, and drinking water contamination.

It is also important that this analysis be interpreted as intended. It is intended to provide rough estimates of the relative risks associated with materials storage in Washington State, for the purposes of comparison with other environmental threats; these results should not be construed as accurate estimates of the absolute levels of risk associated with materials storage.

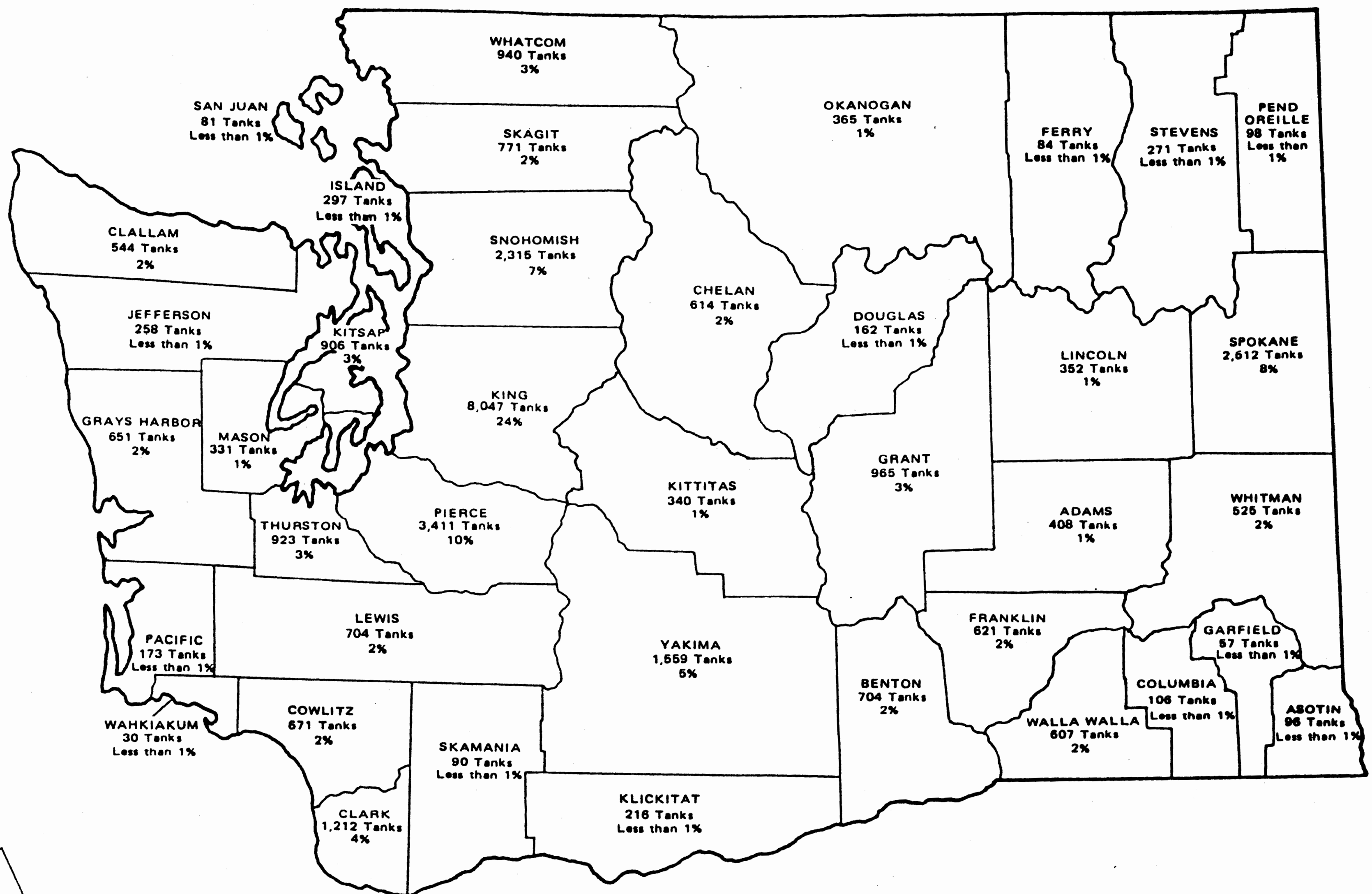
BACKGROUND

There are roughly 45,000 underground storage tanks in the State of Washington (1). General information about these tanks is collected and maintained by the state's Department of Ecology, in keeping with federally mandated notification requirements. Some of those data that are particularly relevant to the potential risks posed by the state's USTs are highlighted below:

- USTs tend to be concentrated in heavily populated areas. National data collected and analyzed in support of the federal UST regulations showed a high correlation between population density and the concentration of USTs (6). State data show a similar relationship. As Figure 1 illustrates, close to 50 percent of the state's tanks are located in four urban counties: Snohomish, King, Pierce, and Spokane. The close proximity of human populations to tank populations has implications for both human health and ecological risk. Specifically, the probability of human exposure to UST releases is greater than the probability of exposure to other localized threats that tend to be further away from human populations (e.g., inactive hazardous waste sites, nonhazardous waste sites). On the other hand, human exposure to contaminated groundwater in urban areas might be lessened by the fact that fewer private wells are found in such areas. While public water supplies often draw from underground supplies as well, they do not usually draw from the more vulnerable unconfined aquifers, and the quality of the water is better-regulated than is the case for private supplies (6). There are important exceptions to this rule in Washington State, however. For example, public water supplies in Spokane, Clallam, and Pierce counties draw from shallow, unconfined aquifers, according to the state's Department of Health and Human Services.

FIGURE I.

UNDERGROUND STORAGE TANKS IN WASHINGTON STATE BY COUNTY



As for ecological risks, the probability of significant ecological exposure to UST releases is diminished since tanks tend to be located away from sensitive ecosystems, in areas where human activities have already displaced natural ecosystems. Exceptions occur when USTs are located over high water tables, or near surface water bodies. (7)

- The vast majority of USTs in the state (about 85 percent) are made of bare steel. About 55 percent of the state's USTs are greater than 15 years old, and 70 percent are "unprotected," meaning they have no means of internal (e.g., lining) or external (e.g., fiberglass coating) protection. (1) Studies suggest that older steel tanks without corrosion protection are the most likely to leak. (6) A 1984 study by the Congressional Research Service for example, stated that "experts estimate a typical steel tank's life expectancy to be about 15-20 years (8). And in 1986, an EPA survey of 12,444 UST releases indicated an average tank age of 17 when the leaks occurred (9).

- About a third of the underground tanks in the state (28 percent) use only daily inventory records to detect leaks, while another third have no leak detection method at all. (1) Leaks that do occur, then, may go undetected longer than they would if more sophisticated leak detection systems were in place, increasing their chances of reaching human or ecological receptors.

- Many of these statistics are changing due to new federal and state regulations. The federal regulations, proposed in 1987 and finalized last year, controls the installation of new tanks requiring protection against corrosion and/or leak detection. The regulations also require the phased removal or upgrade of existing unprotected tanks (i.e., those in the ground when the regulations took effect). State UST officials agree that, if implemented as intended, these regulations, in conjunction with their state counterpart, should reduce the number of older and unprotected tanks, substantially improve leak detection capabilities, and therefore reduce the human health and ecological risks posed by leaking tanks (10).

OTHER ASSESSMENTS OF UST-RELATED RISKS

The human health and ecological risks associated with underground storage tanks have been studied before. In 1987, the U.S. Environmental Protection Agency published a study titled Unfinished Business: A Comparative Assessment of Environmental Problems, which included an analysis of underground storage tanks. Their analysis of human health risks focused on ingestion of water contaminated with benzene; it did not address other chemicals, nor did it consider airborne risks, or the possibility of injury or death due to fire or explosion. Using an elaborate model that turned information on tank characteristics and hydrogeologic settings into estimates of the fate and transport of contaminated groundwater, the EPA estimated less than one excess cancer case per year nationwide due to leaking USTs. Based on that analysis and its collective professional judgement, teams of senior EPA staff rated the cancer and noncancer risks associated with leaking USTs as "low" (7).

A separate team of senior EPA staff personnel also rated leaking USTs low in terms of ecological risks, citing two reasons: 1) because "most USTs are located in or near severely disturbed or previously destroyed natural areas"; and 2) because, "although leaks from both petroleum and chemical USTs can result in significant local ecological effects if an ecosystem is exposed, most releases...do not move very far from the point of discharge and do not result in significant ecosytem exposure" (7).

Also in 1987, a consulting firm, under contract to the U.S. EPA, conducted a risk assessment of the human health and ecological risks posed by leaking USTs in support of the development of the federal UST regulations. This analysis also focused on groundwater as the primary pathway of concern, and benzene as the major pollutant of concern. With a sophisticated model using national data on such factors as UST leak rates, groundwater velocities, and well locations, the analysis developed a range of exposure scenarios. It estimated that seven to 20 percent of the USTs in the country pose risks greater than 10-E6 to the maximum exposed individual (MEI, i.e., the person likely to be most exposed to the release), and that UST-related risks to the MEI ranged from zero to 10-E4. In other words, that assessment suggests that, for seven to 20 percent of USTs nationwide, the likelihood of the maximum exposed individual contracting cancer is one in a million; for all USTs, the likelihood of the MEI contracting cancer ranges from zero to one in 10,000.

Their analysis of potential ecological risks concluded that a "large number" of streams could potentially be contaminated by leaking USTs. That assessment, however, assumed that all contaminated groundwater plumes discharged into nearby streams, and did not assume any dilution, degradation, or other fate and transport processes that would affect the concentration of the plumes.

In 1988, as part of an EPA-sponsored Integrated Environmental Management Project (IEMP) in Denver, CO, a consulting firm assessed the human health risks posed by a large UST release in Northglenn, CO. About 34,000 gallons of gasoline leaked from an underground storage tank at a Chevron station there, producing gasoline vapors in sewer lines and in a number of homes that led to a series of explosions and evacuations. The analysis of that release concluded that the potential carcinogenic risk associated with drinking water contaminated with gasoline is low, since "a person is likely to taste the gasoline prior to consuming water having benzene concentrations which would create a carcinogenic risk greater than 10-E6." (3) That study did suggest, however, some potential for human health effects from breathing air contaminated with gasoline vapors (i.e., benzene). Using ambient air data on gasoline vapors collected in nearby homes shortly after the Northglenn release, the study estimated individual carcinogenic risks of 5.5 x 10-E5 to 1.8 x 10-E4. (3)

Last year, the EPA's Region 10 office analyzed the human health risks posed by USTs within its jurisdiction (Washington, Idaho, Oregon, and Alaska) as part of its Comparative Risk Project. That analysis, using a rough groundwater modelling approach, estimated less than one excess cancer case per year and no significant noncancer risks in the Region due ingestion of water contaminated by leaking USTs. The Region 10 analysis, like many of its predecessors, focussed on gasoline in drinking water, and did not consider the air pathway.

HUMAN HEALTH RISKS

As noted earlier, this analysis focuses on three types of UST-related human health risks: ingestion of contaminated groundwater, inhalation of contaminated air, and the risk of injury or death due to fire or explosion. Each of these risks will be addressed separately below.

INGESTION OF CONTAMINATED GROUNDWATER

Background: The potential for human exposure to groundwater contaminated with benzene due to a leak from a petroleum-based UST in Washington State is significant. As noted earlier, there are some 45,000 underground storage tanks in the state, most of which are located in populated areas, and many of which (anywhere from one to 35 percent, with 11 percent as the best estimate) are thought to be leaking. (1) In addition, the state is heavily reliant on groundwater for its drinking water supply. About 50 percent of the state's residents drink from groundwater supplies. (11)

On the other hand, there are factors mitigating against significant exposure to gasoline-contaminated water. For example, while about 50 percent of the state's residents rely on groundwater for drinking water, most of those residents receive their drinking water via public supply systems. Larger public supplies are typically more carefully regulated and monitored than smaller supplies, and private supplies, so that long exposures to hazardous levels of contamination from larger public supplies are less likely. Contamination in smaller public supplies, and in private supplies may go undetected for longer periods. In addition, gasoline has relatively low taste and odor thresholds, so that people can detect the contamination and stop their exposure to it relatively quickly. (3)

Gasoline has, in fact, appeared in drinking water supplies in the state on a few occasions, according to the Department of Health and Human Services (DSHS), which implements the state's drinking water program. An analysis of drinking water in Washington State, conducted by DSHS as part of Washington Environment 2010, states that "currently observable impacts of spills, discharges, or leaking underground storage tanks on drinking water are few in number...(but) in studies of supplies where beenzene has been observed in concentrations in excess of levels of concern, the source of contamination has been identified as a gasoline storage leak or a spill." (11)

A survey of state UST officials provided a number of examples of recent UST leaks that have resulted in well contamination. For example, a drinking water supply in Acme, Washington recently was contaminated with petroleum released from one or more of a dozen underground storage tanks in the area. Alternative water was provided while a new well was drilled. (10)

Analytic Approach: Cancer risks to the maximum exposed individual (MEI) and to the population as a whole were estimated by taking a conservative exposure concentration for benzene from a previous assessment, and estimating the population exposed to that concentration. This analysis provides a "worst-case" estimate of groundwater-based UST cancer risks by making very conservative assumptions about both the number of people in the state who are likely to be exposed to contaminated groundwater, and about the levels of benzene to which they might be exposed. The key assumptions that underlie this analysis are as follows:

- Benzene is the primary carcinogen of concern, since it is generally considered to be the constituent in gasoline that is the most toxic and is present in the highest concentrations. (3,5,6)

- The upper bound of the human taste threshold for gasoline is the highest concentration of gasoline to which an individual would be exposed for a long enough time to incur significant risk. In other words, this analysis assumes that the point at which the least sensitive individual can taste gasoline in water marks the highest concentration of gasoline in water to which a person would be exposed over an extended period. The level of benzene that corresponds to that level of gasoline in water (see Table 1) is used as the exposure concentration for the MEI in this analysis. The analysis assumes that concentrations above the taste threshold would be readily detected and therefore avoided.

- Everyone in the state who depends on groundwater for drinking water is ingesting water that is contaminated with gasoline at the upper bound of the human taste threshold. There are no data available on the number of people who are actually being exposed to gasoline-tainted water; nor is there any reasonable way to estimate this number short of sophisticated modeling that was not within the time and resource constraints of this evaluation. This assumption, albeit an unrealistic one, helps to put the drinking water risks into perspective. Sensitivity analysis of this assumption is presented below.

Findings: The risk to the maximum exposed individual (MEI) of ingesting water contaminated by petroleum-based USTs is 1.46 x 10-E5. That is the individual excess lifetime cancer risk associated with drinking water that is contaminated with benzene at the level at which the least sensitive individual would taste gasoline. It assumes ingestion of two liters of water a day over a 70-year lifetime, and EPA's cancer potency factor for ingestion of benzene (.026 l/kg/day). In other words, an individual drinking two liters of water contaminated with gasoline at the upper bound of the human taste threshold everyday for 70 years has about a 1.5 in 10,000 chance of contracting cancer. See Table 1 for details.

TABLE 1.

ESTIMATED CARCINOGENIC RISK LEVELS FOR DRINKING WATER CONTAMINATED WITH GASOLINE

Range of Gasoline Taste Thresholds In Water (ppb)[1]	Benzene Concentrations In Water (ppb)[2]	Risk[3]
500	9.70	1.46×10^{-5}
100	1.94	2.93×10^{-6}
5	0.097	1.45×10^{-7}

1 API Report 4419, Review of Published Odor and Taste Threshold Values of Soluble Gasoline Components

2 Assumes 1.94% benzene in liquid gasoline

3 Risk = Benzene Concentration * Daily Water Intake * Potency Factor
= Benzene Concentration * 0.029 l/kg/day * 0.052

Applying that individual excess lifetime cancer risk to the entire potentially exposed population in Washington State yields a population risk of about 34 excess cancer cases over a 70-year period, or .49 excess cancers per year. As stated above, this assumes that all of the state's residents who drink groundwater (about 2,282,500 people) are exposed to a level of benzene corresponding to the upper bound of the human taste threshold for gasoline over a 70-year lifetime. If that assumption is altered, the results are altered accordingly. For example, if we assume that only three-quarters of those drinking groundwater in the state are exposed, the estimate of annual cancer cases drops to .37. If we assume that one-half or one-quarter are exposed, the estimate is .24 or .20 cancer cases per year, respectively.

Conclusions: The cancer risks associated with drinking water contaminated with gasoline are probably low, since people can taste the gasoline, and therefore avoid exposure to it, before it reaches a level that poses significant risks.

Uncertainty: There is considerable uncertainty in this analysis, since it is not based on actual monitored or modelled concentration data, and realistic data on the population exposed. For example, the MEI analysis assumes an exposure concentration of benzene at the upper bound of the human taste threshold for gasoline; most people probably would detect the gasoline at lower concentrations.

In addition, the population risk estimate assumes that all of the state's residents who drink groundwater are exposed to the MEI level of benzene; given the localized nature of most UST leaks, the actual number of people exposed is likely to be much lower than that, perhaps by orders of magnitude. In addition, those people whose drinking water comes from public supplies are unlikely to be exposed for long periods of time even if contamination does occur, since those systems are monitored regularly under the state's drinking water program.

On the other hand, the analysis does not consider other constituents in gasoline, some of which are also carcinogenic (e.g., toluene, EDB), which biases the results downward.

INHALATION OF CONTAMINATED AIR

Background: As is the case for contaminated groundwater, the proximity of USTs to human populations increases the potential for human exposure to air contaminated by a release. In fact, such exposures have occured elsewhere in the country (e.g., in Northglenn, CO), and they have occurred here. Several years ago, for example, gasoline vapors caused by at least one UST release led to evacuations at the Monterey Apartment complex in Seattle. One of the units has been permanently vacated due to high levels of gasoline in the air. Alarm systems have been installed in other units to indicate when gasoline vapors in those units are approaching the explosion threshold. (10)

National data, however, indicate that exposures to gasoline vapors from UST releases are relatively uncommon. The aforementioned release incident survey suggested that only two percent of all USTs have leaks that result in gasoline vapors in homes. (9) In addition, gasoline has an easily identifiable odor; the human odor threshold for gasoline mitigates against lengthy human exposure to high levels of gasoline in the air.

Analytic Approach: The cancer and noncancer risks to the MEI from inhaling gasoline-tainted air were estimated by assuming exposure to the upper bound of the human odor threshold for gasoline, and the corresponding levels of benzene, toluene, and zylene. A range of cancer and noncancer risks to the population was estimated by applying a range of possible ambient concentrations, as determined in a previous risk assessment, to a range of estimates of exposed populations. The key assumptions that underlie this part of the analysis are as follows:

- The highest concentration of gasoline in air to which a person would be exposed is that level that corresponds to the upper bound of the human odor threshold. The assumption is that people would smell concentrations higher than this, and take action to avoid exposure.

- Two percent of all USTs have leaks that result in vapor releases; on average, these vapor releases reach one household. This assumption is based on national data from the UST release incident survey, which is the best information available on populations exposed to air releases. (9) Sensitivity analysis of this assumption is presented below.

- On average, each household consists of four people. This is a national estimate based on census statistics.

Findings (cancer): The excess lifetime cancer risk to the maximum exposed individual is 2.4 x 10-E3. This is the individual risk associated with breathing air that has been contaminated with gasoline at the upper bound of the human odor threshold (32.52 micrograms per cubic meter). This assumes the individual breathes 20 cubic meter of air a day over a 70-year lifetime, and it assumes EPA's cancer potency factor for inhalation of benzene (.026 cubic meters/kg/day). In other words, an individual breathing 20 cubic meters of air contaminated with gasoline at the upper bound of the odor threshold everyday for 70 years would have a 2.4 in 1000 chance of contracting cancer.

The population risk associated with inhalation of gasoline vapors caused by UST releases ranges from .0001 ("best case" to .35 ("worst case") excess cancers per year. See Table 1 for the the assumptions, rationale, and calculations.

Findings (noncancer): The Northglenn study assessed the noncancer risks posed by two constituents deemed likely to have the highest hazard indices (i.e., relationships between exposure concentrations and health effects thresholds) -- toluene and o-xylene. For each of the gasoline concentrations assumed in estimating cancer risks to the MEI and to the population, the corresponding concentrations of both toluene and o-xylene are well below the health effects thresholds (i.e., the reference doses) for those contaminants. See Table 3 for the details.

Findings (acute): There is no state data on actual acute effects of exposure to gasoline vapors caused by UST releases. However, Table 4 lists the acute effects reported by people exposed to gasoline vapors due to the Northglenn UST release. If Washingtonians are exposed to similar ambient levels of gasoline -- as assumed in the "best estimate" scenario in the cancer risk analysis -- then we can expect similar acute effects to occur. We cannot, however, determine how many of the people exposed would experience acute effects, or how severe those effects would be.

Conclusions: Cancer risks to the maximum exposed individual due to inhalation of gasoline vapors are potentially significant, since the levels of gasoline in the air that correspond to the upper bound of the human odor threshold are relatively high. The cancer and noncancer risks to the population, however, are low, since relatively few UST releases appear to result in gasoline vapors that reach human receptors.

Uncertainty: This analysis is fraught with uncertainty since it is not based on data on actual UST releases in Washington State. The estimated MEI risk is probably overstated. The ambient concentration on which the estimate of the risk to the MEI is based is higher than the maximum concentration measured in nearby homes in the wake of the Northglenn, CO release, which was a relatively large one. (National data suggest that less than five percent of all UST releases exceed 10,000 gallons (7); the Northglenn release exceeded 34,000 gallons (3).) In addition, most people are likely to smell gasoline in the air at lower concentrations and, presumably, avert further exposure.

It is difficult to assess the accuracy of the population risk estimates, since they are based on hypothetical exposure concentrations related to the range of odor thresholds. It is difficult to generalize from the Northglenn data. Even though that release was very large relative to the vast majority of leaks in Washington and elsewhere across the country, we are lacking data on the comparability of the hydrogeological dynamics that would be necessary to reasonably extrapolate from the Northglenn analysis. In addition, the estimates here are highly dependent on the assumptions made about exposed populations, which are based on national rather than state data.

Nonetheless, even worst case assumptions about ambient concentrations of gasoline and populations exposed -- assumptions that are likely to result in an overstatement of risk -- yield low population risk estimates.

FIRE AND EXPLOSION

There is no state data available on the probability of injury or death due to fires and/or explosions caused by UST releases. Data from the national release incident survey show that 155 of the 12,444 releases surveyed (about one percent) resulted in a fire or an explosion. Of those 155, about one percent (two of the releases) resulted in a death. In other words, only two of 12,444 releases (or about 1 of 6200) resulted in a death due to fire and explosion. Applying this data to a range of assumptions about the number of Washington State USTs that are currently leaking yields a range of .2 (best case, assuming a leak rate of two percent) to 3.2 (worst case, assuming a leak rate of 35 percent) estimated deaths over time due to leaks from existing tanks. Again, this estimate is based largely on national data, and must therefore be viewed with caution. In addition, the estimates of leak rates are static. There is no reliable information on the number of USTs in the state that might be leaking over time. Presumably, leak rates will decrease as controls on new and existing tanks improve under the new federal and state regulations.

ABOVEGROUND STORAGE TANKS

Releases from aboveground storage tanks are a potential source of human health and ecological risk, but there is very little information with which to assess that potential. There are thousands of aboveground tanks in the state, located mostly at oil refineries and product terminals, bulk plants and waste oil processors, and so-called "end-user" facilities, e.g., saw mills, farms, manufacturing plants, etc. (2) Refineries, product terminals, and bulk plants have a number of very large and relatively old tanks. In addition, aboveground tanks are not as closely regulated as their underground counterparts.

Spills from aboveground storage tanks (ASTs) can be caused by:

- Poor operating practices and equipment failure when petroleum products are transferred from one place to another; and
- Tanks collapsing due to corrosion, foundation disturbance, inadequate venting, or stress failure

Anecdotal information illustrates that AST releases do occur in Washington State. For example, a large aboveground storage tanks containing leaded and unleaded gasoline ruptured in 1971, discharging tens of thousands of gallons of product into Commencement Bay. In 1987, another large AST ruptured in the same general area, discharging sodium chloride into the Bay. (10)

TABLE 2.

Population Risk (Excess cancers/yr.)	Assumptions	Rationale
Best Case: (2.4 x 10-E6)(3132) = .008 cases/70 yrs. = .0001 cases/yr.	o Individual risk of 2.4 x 10-E6	o Associated with gasoline odor threshold for most sensitive individual. (3)
	o 3132 people exposed	o 39,150 petroleum-based USTs (1); 2% result in vapor releases that reach one household of four (9)
Best estimate: (2.7 x 10-E5)(3240) = .09 cases/70 yrs. = .001 cases/yr.	o Individual risk of 2.7 x 10-E5	o Associated with gasoline odor threshold for individual with avg. sensitivity (3); also associated with avg. measured ambient concentration of gasoline in homes near Northglenn, CO UST leak (3)
	o 3240 people exposed	o 40,500 petroleum-based USTs (1); 2% result in vapor releases that reach one household of four (9)

TABLE 2 (cont.)

Worst Case:		
(2.4 x 10-E3)(10,152) = 24.36 cases/70 yrs. = .35 cases/yr	o Individual risk of 2.4 x 10-E3	o Associated with gasoline odor threshold for least sensitive individual (3)
	o 10,152 people exposed	o 42,300 petroleum based USTs; 2% result in vapor releases (9); each vapor release reaches 3 households of 4 (sensitivity analysis)

Unfortunately, there is insufficient data available to comprehensively assess the risks associated with releases like these. The detection and rectification of AST leaks may be relatively quick -- and the associated risks relatively lower -- since they are more visible than leaks in USTs. Nonetheless, it is important to recognize that AST leaks may pose risks to human health and the environment that are not assessed here.

NONPETROLEUM CHEMICAL TANKS

Similarly, it is important to remember that tanks containing nonpetroleum products are also omitted from this analysis because of insufficient information. Though these types of tanks constitute a very small percentage of the state's UST universe (less than five percent), they can contain more toxic substances (e.g., solvents) that pose greater potential risks to exposed humans and ecosystems than gasoline and petroleum products.

ECOLOGICAL RISKS

There is very little information on the actual ecological impacts associated with UST releases in the state. There is limited, anecdotal information on tank ruptures on the shores of Commencement Bay discharging petroleum and nonpetroleum products into the Bay. It is difficult to discern the specific ecological impacts of those releases, however, given the many discharges into Commencement Bay over time, from

TABLE 3.

ESTIMATED CARCINOGENIC RISK LEVELS AND NON-CARCINOGENIC RATIOS FOR BREATHING AIR CONTAMINATED WITH GASOLINE

Range of Gasoline Odor Thresholds in Air ppbv[1]	(mg/m³)[3,2]	Benzene		Toluene		o-Xylene	
		Concentration[3]	Carcinogenic Risk[4]	Concentration[5]	Toxicity Ratio[6]	Concentration[7]	Toxicity Ratio[6]
10,000	(32.52)	0.3187	2.4×10^{-3}	1.086	2.1×10^{-1}	0.1886	2.7×10^{-1}
1,000	(3.252)	0.0319	2.4×10^{-4}	0.109	2.1×10^{-2}	0.0189	2.7×10^{-2}
100	(0.325)	0.0032	2.4×10^{-5}	0.011	2.1×10^{-3}	0.0019	2.7×10^{-3}
10	(0.032)	0.0003	2.4×10^{-6}	0.001	2.1×10^{-4}	0.0002	2.7×10^{-4}

1 API Report 4419, Review of Published Odor and Taste Threshold Values of Soluble Gasoline Components.

2 mg/m^3 = (ppbv* molecular weight)/29,000, assumes molecular weight of gasoline = 94.3, Denver elevation and 20°C.

3 Assumes 0.98% Benzene in gasoline vapor as mg/m^3 (based on information from API).

4 Risk = Benzene concentration * 0.29 m^3/kg/day * Potency Factor, (Benzene Potency Factor = 0.026).

5 Assumes 3.34% Toluene in gasoline vapor as mg/m^3 (based on information from API).

6 Ratio = (concentration * 0.29 m^3/kg/day)/AIC, (Toluene AIC = 1.50, o-Xylene AIC = 0.2)

7 Assumes 0.58% o-Xylene in gasoline vapor as mg/m^3 (based on information from API).

TABLE 4.

ACUTE HEALTH EFFECTS FROM
NORTHGLENN UST RELEASE

Symptom	East Area	West Area	Percentage Experiencing Symptom
Headache	47	28	35%
Fatigue	25	7	13
Irritability	19	2	8
Drowsiness	19	1	8
Cough	13	1	6
Nausea	17	4	9
Dizziness	9	3	6
Respiratory Problem	2	3	6
Eye Irritation	0	1	1
Diarrhea	4	0	1
Sore Throat	2	0	1
Vomiting	0	1	1

Total number of cases = 67

Source: Tri-county Health Department Survey, 1980.

a number of industrial sources. In addition, those incidents involved sudden ruptures, which places them in the sudden and accidental release threat category.

The best information on UST-related ecological risks appears to be that developed in EPA's Unfinished Business report. That assessment concluded that UST releases and their impacts tend to be localized, and that, while those localized impacts can be severe, the cumulative impacts are relatively low.

In Unfinished Business, an ecological risk work group consisting of roughly 15 senior EPA staff people, concluded that the overall ecosystem effects of leaking USTs are low because releases tend not to move very far from the point of discharge (i.e., they are highly localized), and because tanks are typically located in disturbed settings and therefore leaked product does not reach natural ecosystems. Exceptions occur when USTs are located above high groundwater tables (as is the case in some areas of Washington State), and near surface waters. Most documented ecological impacts are local effects on adjacent terrestrial ecosystems and aquatic systems. (7)

Nationally, less than three percent of the releases addressed in EPA's 1984 national incident survey involved damage to aquatic life, wildlife, and/or plants. (9) Comments by state UST officials suggest that releases are often controlled before they reach ecological receptors. (10) Drawing upon this admittedly scanty information, the seven ecological risk criteria are addressed briefly below:

Intensity of impact: Localized impacts of UST releases can be intense. Though there are no documented cases of severe impacts in Washington State, such impacts (e.g., fish kills in nearby streams) have occurred elsewhere in the country. The intensity of the threat is potentially high, but appears low in this state, especially from an overall, statewide perspective.

Reversibility of impact: Releases of petroleum products into surface water bodies are reversible in a relatively short timeframe via clean-up technologies and natural processes. Chemical releases, however, may be irreversible, especially if they contribute to sediment contamination.

Scale of impact: The scale of the impacts tend to be low. Though there are thousands of USTs in the state, the impacts of releases tend to be localized. In addition, USTs tend to be located in areas where the natural ecosystems have already been severely altered.

Sensitivity of the ecosystem/species affected: There is no evidence of adverse impacts due to leaking USTs on endangered species or sensitive ecosystems. However, the surface water bodies most likely to be affected by leaking USTs (e.g., Commencement Bay) are also subject to a variety of other point and nonpoint source discharges.

Trend of impacts: State UST officials agree that, due to the expected effect of the new federal and state regulations controlling both new and existing USTs, any ecological impacts that might be occurring are likely to decrease substantially over the next two decades.

Productivity/Uniqueness of the ecosystem(s) affected: UST releases could potentially affect ecosystems of particular uniqueness or value (e.g., rivers or streams that support anadromous fish runs), but there is no evidence of such impact to date.

Uncertainty of the analysis: This analysis suffers from all of the uncertainties that arise from a severe paucity of data. It is difficult to assess the reliability of these findings given the scarcity of information on ecological impacts. These conclusions are based on the small amount of information that has been developed, on logic, and on the professional judgement of environmental professionals who have considered this issue during previous assessments.

OVERALL UNCERTAINTY

There are substantial uncertainties in this analysis, which bias the findings in different directions. Most of these uncertainties are discussed in detail above. In general, the human health risk estimates that are presented are based on very conservative assumptions, made in the absense of sufficient, local, site-specific data, that tend to overstate the risks. For example, using the upper bound of the taste and odor thresholds for gasoline to estimate the MEI risks associated with ingestion of contaminated water and inhalation of contaminated air, biases the results upward. Because of conservative assumptions like that one, the human health risk estimates presented in this report represent the upper bound, i.e., the actual risks are not higher, and are very likely to be lower than those stated here. This is probably true despite the fact that the analysis focused on only one carcinogenic constituent of gasoline -- benzene.

The omission of potentially significant segments of the materials storage threat needs to be considered, however. Specifically, the omission of aboveground storage tanks and chemical tanks biases the findings downward. It is difficult to determine the extent of this bias without further research and analysis.

ANATOMY OF THE RISK

Some general conclusions about the "anatomy" of UST-related risks are worth highlighting:

- o Those living in urban areas where USTs are concentrated, are probably at greater risk from UST releases, since they are closer to the origins of those releases;

- o The potential human health risks associated with inhalation of gasoline vapors appear to be more significant than those associated with ingestion of contaminated groundwater, largely due to the difference in the taste and odor thresholds

- Petroleum-based USTs have received the lion's share of the public and regulatory attention to date, perhaps because they greatly outnumber other types of storage tanks. It is not clear, however, that these tanks represent the most worrisome segment of materials storage, especially in light of their apparent low risk.

- All UST-related risks estimated should diminish over time, according to state UST officials, due to the recently promulgated federal regulations. Those regulations require corrosion protection and leak detection for new petroleum tanks, secondary containment for new chemical tanks, leak detection of existing tanks, and phased replacement of aging tanks. One study has predicted that these regulations will reduce UST-related risks by as much as 90 percent. (7)

REFERENCES

(1) A Report on Underground Storage Tanks, Thom Lufkin, Washington State Department of Ecology, February 1987.

(2) Aboveground Storage Tanks in Washington State, Patricia Holm and Kaia Petersen, Washington State Department of Ecology, January 1989.

(3) Data and Exposure Models Used to Estimate Health Risks at Chevron Underground Storage Tank in Northglenn, CO, Woodward-Clyde Consultants, under contract to U.S. EPA, May 1988.

(4) Potential Human Health Risks and Economic Damages from Management of Non-Superfund Wastes and Materials in Metro-Denver, Industrial Economics, Inc., under contract to U.S. EPA, May 1988.

(5) Human Health Risks from Releases from Hazardous Storage in EPA Region 10, U.S. EPA, June 1988.

(6) Regulatory Impact Analysis for Proposed Technical Standards for Underground Storage Tanks, Sobotka and Company, Inc., under contract to U.S. EPA, March 1987.

(7) Unfinished Business: A Comparative Assessment of Environmental Problems, U.S. EPA, February 1987.

(8) Leaking Underground Storage Tanks: A Potential Environmental Problem, Congressional Research Service, 1984.

(9) Summary of State Reports on Releases from Underground Storage Tanks: Analysis of the National Data Base of Underground Storage Tans Release Incidents, U.S. EPA, 1986.

(10) Interviews with Department of Ecology UST staff: Dom Reale and Dick Walker (Southwest Regional Office); Joe Hickey and Gail Colburn (Northwest Regional Office); Clar Pratt and Claude Sappington (Eastern Regional Office); Bill Myers and Mike Blum (Headquarters Office, conducted by Tweedie Doe, March 1989.

(11) Human Health Risks Associated With Drinking Water in Washington State, Washington State Office of Environmental Health Programs, Drinking Water Program, March 1989.

THE STATE OF THE ENVIRONMENT REPORT

VOLUME III
Part 16

Risk Evaluation Reports for Sudden and Accidental Releases

ENVIRONMENT 2010

State of Washington
October, 1989

Human Health and Ecological Risks Associated With

SUDDEN AND ACCIDENTAL RELEASES

Introduction

This is a report on the human health and ecological risks associated with sudden and accidental releases (e.g., spills) in the State of Washington. Toxic chemicals are accidentally released into the environment in a number of ways, during transport, production, storage, and use. For example, an industrial unit might explode and emit toxics into the air, or a railroad tank car may turn over and spill toxics into surface waters, onto the ground and eventually into ground water, or in other areas near human or ecological receptors.

Pentachlorophenol, PCBs, ammonia, and sodium hydroxide are examples of hazardous materials that have been accidentally released in the past. Oil spills -- including spills of crude oil, gasoline, solvents, diesel fuel, fuel oil, and other distillates -- are also included as part of this threat.

Accidental spills and releases of hazardous materials into the environment can have catastrophic results in terms of both injury or death to humans and serious damage to the environment. The large oil spills off of the Olympic Coast here in Washington State and in Alaska's Prince William Sound are recent examples of such catastrophic possibilities.

The primary human health effects of concern are acute effects, ranging from headaches and other minor irritations to serious injury or death. Chronic exposures to accidental releases are possible, but there are no conclusive data on such exposures; it is difficult to link a chronic exposure to a sudden, one-time release. Such exposures can occur, however. The flooding of the Chehalis River a few years ago, for example, resulted in the accidental release of a large quantity of creosote and dioxin-containing pentachlorophenol wastes that swept through nearby streets and homes, contaminating toys, furniture, carpets, etc. No follow-up epidemiological health studies were conducted, however.

It is important to note that, as a general groundrule, Washington Environment 2010 risk analyses do not address risks associated with occupational exposures. According to this groundrule, then, exposures to people responding to accidental releases -- which can be significant -- should not be counted in evaluating the human health risks involved.

The ecological effects of accidental releases occur primarily in surface water bodies, e.g., bird kills or fish kills in rivers and coastal waters where spills have taken place, effects on habitat, effects on the food chain.

In addition to considering the separate effects of one-time events, the cumulative effect of relatively small releases are also of concern, particularly if the pollutant is non-biodegradable or bio-accumulative.

This analysis does not include an evaluation of the potential risks associated with off-shore oil drilling, since such drilling does not currently take place. The U.S. Department of Interior is, however, proposing a five-year leasing plan that would include drilling off the coast of Washington. That proposal is currently undergoing review and an assessment of potential environmental impacts in Washington State. If such drilling does take place in the future, we can reasonably expect some accidental releases to occur. The likely frequency and size of such releases, however -- and therefore the likely risks to water quality and coastal ecosystems (e.g., plankton, benthos, fish, marine mammals, coastal and marine birds, and threatened and endangered species -- has not been definitively characterized in this report.

Analytic Approach and Data Sources/Limitations

The analytic approach taken in evaluating both the human health and ecological risks associated with sudden and accidental releases of toxics and petroleum products consisted of several steps. First, a number of potential data sources were reviewed. (See references.) Many of these potential sources were found to be of little or no value for a number of reasons. Consequently, the following sources were selected as providing the best available information: 1) Responses to a questionnaire on major spills and responses between 1983 and 1988; 2) The 1988 records of the Department of Ecology's spill and complaint tracking system; 3) Washington State data from EPA Region 10's Acute Hazards Database for 1983 to 1988; 4) 1988 Washington State Department of Ecology Fish Kill Summary; and 5) Interviews with state officials/experts in accidental spills/releases.

The major limitation of this report is data-related. Good summary data are sparse. For example, the Department of Ecology spill complaints and investigations reports seldom report human health impacts resulting from a spill. They also do not differentiate consistently between a sudden release and a more chronic situation. In addition, none of the sources indicated the extent or cause of the injuries. For instance, it is possible that some of the injuries resulting from transportation accidents were caused by physical impacts, rather than chemical exposures.

In short, the data are far from complete. To develop statewide estimates on human and ecological risks, we relied primarily on data collected at Ecology's Southwest Regional office. The reliability and comprehensiveness of that data is questionable, however, since it is taken from complaints received by regional personnel. Most of the information was thus collected by telephone and often represents the opinion of a non-professional in terms of the quantity, pollutant, and impacts involved in a spill or release. For example, of the 500 spill reports received in the Southwest Region in 1988, about 60 percent listed the quantity released as unknown, or left the quantity column blank altogether.

Because of these data limitations, the following assumptions were necessary in order to extrapolate from available information to characterize the statewide threat:

- o Based on the professional judgment of field personnel, the reported incidents in the Southwest Region represent 40 to 75 percent of the total number of incidents actually occurring in that region, with 60 percent as a "best estimate." In other words, experts in the State believe the rate of underreporting ranges from 25 to 60 percent, with 40 percent as a "best estimate."

- o Incidents occur throughout the state in rough proportion to population. In other words, the data from the Southwest Regional Office can be extrapolated to the rest of the state based on population. State experts believe this assumption is reasonable since the main transportation routes and the higher concentrations of fixed facilities are located in the most populated areas of the state, so that accidental releases are more likely to occur there.

HUMAN HEALTH RISKS

Assessment

The first area of risk investigated was the risk to human health. Our analytic approach consisted of two primary components. First, we analyzed data from the referenced sources to arrive at generalized risk factors for human health. Second, we interviewed state officials with expertise on accidental releases, soliciting their anecdotal information and informed judgment.

The data from the Southwest Regional Office of the Department of Ecology reported human health impacts associated with nine releases in 1988. Based on the aforementioned assumptions, we scaled up for the entire state and estimated that there are between 50 and 60 releases per year in the state that result in human health impacts. Note that this refers only to acute effects; it does not include any long-term (i.e., chronic) health impacts, which cannot be estimated using available data.

Based on the previously stated assumptions and a total of 500 incidents actually reported to the Southwest Region in 1988, the following represents the best estimates for accidental release incidents and resultant health effects for 1988:

TABLE 1

Southwest Incidents:

Estimated	Potentially Signif.	Injuries
800	200	15

Statewide Incidents:

Estimated	Potentially Signif.	Injuries
3000	750	50

State officials note anecdotally that minor injuries, e.g., burns, eye irritation, headaches, are quite common, especially among those responding to accidental releases. These minor effects, however, usually go unreported. More serious injuries, however, and deaths, are rare. In 1983 four railroad cars containing ammonia derailed near Ridgefield, WA, and two people died from their exposures to the release while another was permanently disabled. This is the only death conclusively related to an accidental spill that state officials can readily recall. In 1988 a man suffering from emphazema died shortly after an accidental chemical release in Eastern Washington, and state officials believe it is possible that his death resulted from the release.

Major sources of concern:

National data suggest suggest that transportation may be a larger source of accidental releases than fixed facilities. Other data, however, suggest that the risks are roughly equal, or that those associated with fixed facilities are greater. Washington data are inadequate to form any conclusions. State officials, however, note that they are especially concerned about transportation-related accidental releases, e.g., tanker truck accidents or rail accidents. The main reason for this is the greater degree of uncertainty that surrounds transportation-related releases relative to accidental spills at fixed facilities. Transportation-related accidents can happen anywhere, and often the identities of the materials spilled are unknown initially. Fixed facilities, by contrast, are much more thoroughly tracked, and containment and cleanup equipment and personnel are more likely to be readily available. In short, releases from fixed facilities are easier to respond to, according to state officials.

State officials also note that spills during the transfer of materials in the transportation process (e.g., off-loading from barges, railroad cars, tankers) are common.

As far as fixed facilities are concerned, state officials cite pulp mills and oil refineries as the primary sources of concern.

Major pollutants of concern:

There is an insufficient number of recorded incidents involving injuries from accidental releases to draw any definitive conclusions regarding which particular pollutants might pose greater risks to human health. In many cases it is possible that the type of pollutant is less of a factor in injuries than other factors, such as the nature and location of the release. State officials note that petroleum-based products tend to be released accidentally most frequently. Nonpetroleum toxic chemicals, however, can pose a more serious risk to human health, when released or spilled, since they are often more toxic and not readily identifiable. Accidental releases of chlorine, sulfure dioxide, and other chemicals at pulp mills -- and the resulting exposures to workers and local populations -- are of particular concern.

Major exposure pathways of concern:

The data are insufficient to draw any conclusions. The air pathway and the direct exposure pathway are often significant, however, according to state experts.

Major Effects:

The seriousness or nature of injuries cannot be determined by an examination of the quantitative data. State officials, however, note that the vast majority of injuries are minor, such as burns, headaches, or eye irritation. It is also important to note that at least some of the injuries included in the data probably involve people responding to the accidental release or spill, which would be technically classified as an occupational exposure.

Rationale For Elements Examined/Assumptions

The elements of the risks examined are limited by availability of data on, and previous experiences with, accidental releases and spills within the State of Washington that resulted in measurable impacts on human health. The available data was provided to selected personnel within the Department of Ecology with actual field and management experience in hazardous material releases. The collective professional judgement of these individuals resulted in an assumption that for 1988 the available reports represented approximately sixty (60) percent of the total numbers of sudden and accidental toxic releases of materials which resulted in such measurable impacts. Therefore scaling up for the number of releases was based on this percentage.

The fact that this analysis is based solely on 1988 data introduces another component of uncertainty. Ideally, this analysis would estimate annual incidence by extrapolating from data from a number of years. Such data were not available, however. The assumption that 1988 data is representative of annual averages needs to be recognized and considered with caution.

Description of Findings

Based on available data, it would appear that there were approximately 50 spills or releases in the state in 1988 which resulted in injury to human health. State experts believe some of these injuries resulted from physical insults rather than chemical exposures, that some occurred during response actions, and that most were relatively minor.

Serious injuries or deaths, and chronic exposures, resulting from accidental releases are possible but uncommon.

There is a need to provide a consistent, more reliable accounting of human health effects from accidental releases. This would provide the basis for an accurate risk assessment upon which to base future decisions.

There are currently no known data which could be used to determine chronic human health impacts from accidental releases.

ENVIRONMENTAL RISKS

Assessment

In assessing environmental risks, a differentiation was made between risks associated with major events and those of a more chronic or smaller nature.

Two primary data sources were used in assessing the environmental risks from accidental releases and spills: 1) Southwest Regional Office incident reports; and 2) the results of a questionnaire on major incidents administered to Regional spill personnel.

Recent major events such as the Nestucca spill in Washington and the Exxon Valdez spill in Alaska dramatically demonstrate that not only can the impacts from spills be quite high, but also that such events are in all likelihood unavoidable under present control programs and procedures. In addition, remediation, cleanup and response usually cannot return the environment to its original condition. The only prediction that can be made accurately is that, given no major changes, the State of Washington will periodically experience major accidental releases of petroleum and chemical toxics. Impacts from these releases can be quite large and will be dependent upon a variety of factors including:

> Location of the spill: Various geographic locations are particularly sensitive, including highly productive areas such as estuaries, areas of ecological significance such as seal haul outs, fish spawning grounds, and mudflats, and very vulnerable sites such as sheltered rocky shores and wetlands where the oil is difficult or impossible to remove. Larger spills often affect some of the state's most sensitive and important habitats.

Weather conditions - Not only can weather conditions contribute to releases, but also can play a major role in the timing and effectiveness of cleanup activities. In some cases it could virtually eliminate cleanup activities during the critical early stages.

Volume of material spilled

Type of material spilled

Response capability - The effectiveness (e.g. speed) of response.

Time of Year - Ecological damage is greatest if the release coincides with high biological activity. Biological activity is greatest in the spring and summer, particularly in terms of nesting birds, migrating fish , and planktonic activity.

Known Releases of Ecological Significance:

From the study of available spill and release data described above, 28 large scale releases were found for the State of Washington from 1984 to 1988. (See Appendix 1.) Of these, 16 were noted to have had quantitatively measureable ecological effects. Tables 2 and 3 summarize these releases. As can be seen, these releases are almost equally divided between petroleum and non-petroleum related.

TABLE 2

Major Petroleum Releases With Environmental Impacts

Year	No. of Incidents	No. With Env. Impacts Noted	Types of Impacts Noted
1984	--	--	----
1985	3	3	sediment,groundwater
1986	1	1	sediment, groundwater
1987	3	1	----
1988	5	5	sedmt,gdwtr,fish, birds,marine life

TABLE 3

Major Non-Petroleum Releases
With Environmental Impacts

	No. of Incidents	No. With Env. Impacts Noted	Types of Impacts
1984	2	2	
1985	2	1	sedmt
1986	4	1	fish
1987	4	0	
1988	4	2	sedmt

While reliable figures on the impacts from non-reported or less significant releases and spills are unavailable, the following summary table is derived from the reports of the Southwest Region and extrapolated for the State of Washington.

TABLE 4

Statewide Estimates of Incidents Likely to Cause
Environmental Damage

# of Incidents	Potentially Significant	Envir. Impacts
3000	750	80 to 90

Major Sources of Concern:

While not conclusive, the evaluation of data suggests that petroleum related releases which are likely to affect the environment are more likely to be transportation related, whereas hazardous materials with the same effect are about equally divided between transportation related and onsite releases.

Major Pollutants of Concern:

Data indicates that the number of incidents which do or might cause environmental damage are roughly equally divided between hazardous materials and petroleum, although the severity of damage appears to be greater from petroleum products. This is probably accounted for by the differences in volume transported and possibly by a greater degree of attention paid to damage assessment for oil related spills.

Exposure Pathways of Concern:

Damage to the environment from surface water releases appears to be the primary contributor.

Major Effects:

Primary effects would appear to be death and contamination of fish, shellfish, marine mammals and other aquatic organisms, and birds. However, measurement techniques, bias toward resources with economic value, and the difficulties inherent in measuring impacts, particularly long-term, make it impossible to reach any other than a subjective determination.

Rationale for Elements Examined

The approach taken in addressing environmental risks is similar to the one used in assessing health risks. The primary difference was a change in the criterion for selecting those which were analyzed. Instead of a universe consisting of those events which had an impact on human health and safety, the universe studied was those events which were identified as having an adverse impact on the natural environment. Since there is in some cases less objective measurements (deaths, injuries, etc.) which can be used in determining environmental impacts as compared to immediate human health impacts there is a higher degree of professional judgment required in the selection of the events comprising the universe.

Description of Findings

This risk assessment demonstrated that Washington is likely to experience one large-scale oil spill to marine or estuarine water once every 1 to 3 years. State officials note that one major oil spill has occurred in the state in each of the last five years.

It is estimated there will be an average of from 3 to 6 releases per year with substantial potential for major environmental damage.

It is estimated the state also will average between 15 to 30 releases per year with significant, obvious environmental impacts from toxic chemicals and oil products. These releases will have a moderate to significant impact on the natural environment, including fish kills, contamination of groundwater, sediment contamination or impacts to a sensitive ecosystem.

Smaller one-time accidental releases of petroleum products, toxic materials and other discharges which would be expected to have some adverse ecological effects are estimated to be about 750 per year for the state. The impact from such releases is impossible to predict from the available data.

<u>Overall Conclusions</u>

Intensity of Impacts: As the data and analysis presented above indicate, the intensity of accidental releases can be very high. Large spills in sensitive areas can have significant impacts on individual organisms as well as entire ecosystems.

Scale of Impacts: The scale of the impacts associated with accidental releases is difficult to characterize. Individual spills can be large, with broad, regional impacts. Generally, however, accidental releases tend to be small, one-time, localized events. The overall, statewide scale of their impacts, then, is moderate.

Reversibility of Impacts: The reversibility of impacts is difficult to generalize about, since it is largely dependent on the location of the spill, the quantity spilled, etc. State officials believe that the effects of most surface water spills can be reversed relatively quickly, while spills to ground water are considerably more difficult to address and reverse.

Productivity/Uniqueness of Ecosystem Affected: Accidental releases can affect highly productive ecosystems, i.e., commercial fisheries and national wildlife refuges.

Sensitivity of Ecosystem Affected: Accidental releases can also affect sensitive ecosystems, i.e., coastal marine and estuarine ecosystems rich in marine birds and mammals.

Trends: It is difficult to determine definitively the likely future trend in accidental releases. On the one hand, state officials believe releases are increasing, since the transportation of petroleum products and hazardous materials is on the rise. On the other hand, response capabilities may be improving, especially in the wake of recent oil spills. Complaints are on the rise, but officials note that this may be due to heightened sensitivity and better reporting procedures.

Uncertainty: There is a great deal of uncertainty surrounding the information and analysis of the ecological impacts of accidental releases. This is a probablistic threat. And, while the probability of large releases that result in significant impacts is relatively low, the magnitude/intensity of those releases can be very high.

REFERENCES

"Oil-related Water Pollution Incidents Reported in Washington State During 1976," Washington Department of Ecology, January, 1979.

"Human Health Risks Plan of Attack for Accidental Releases of Toxics," Industrial Economics, Inc., under contract to the U.S. EPA, February, 1988.

"Ecological Damages Plan of Attack for Accidental Releases of Toxics," Industrial Economics, Inc., under contract to the U.S. EPA, February, 1988.

SARA Title III Incidents and Other Reportable Northwest Spills from 1987 and 1988.

U.S. Department of Transportation Hazardous Materials Information System

Responses to questionnaire on major spills and responses from 1983 to 1988, completed by Department of Ecology regional spill response personnel and Washington Environment 2010 staff.

Department of Ecology, Southwest Regional Office records on spill and events complaints and investigations, 1988.

U.S. EPA Region 10 Acute Hazards Database for Washington State, 1983 to 1988.

Department of Ecology Fish Kill Summary, 1988.

Interviews with Department of Ecology spill response managers and personnel (Jon Neel, Lew Kittle, Greg Sorlie).

WASHINGTON STATE
SUDDEN ACUTE ACCIDENTAL RELEASES
1984 - 1988

LOCATION	SOURCE	MATERIAL	APPROX. AMOUNT	ECOSYSTEM	KNOWN IMPACTS
1984					
Columbia R	Tanker	Oil	200,000 gal.	Wetland Surface Water	Killed 6500+ birds Oiled vegetation
Dayton	Truck	Aqua-Ammonia	1,700 gal.	Creek	21,400 fish killed
1985					
Pt. Angeles	Tanker	ANS Oil	239,000 gal.	Coastal marine/ Estuarine	Killed 4000 birds 12,468 lbs. clams Widespread beach contamination-High smelt egg kill
King Co.	Pipe	Jet Fuel	63,000 gal.	Puget Sound	-----
1986					
Kent, WA	Pipe	Chlorine	Unknown	Creek	10,560 fish killed
Near Sea-Tac	Fueling Fac.	Jet Fuel	8,000 gal.	Creek	7,000 Coho killed
Near Packwood	Lumber Co. Discharge	Sodium Penta Chlorophenate and oil	Unknown	Creek	3,623 Cutthroat & Coho killed
Near Pt. Angeles	Truck	Diesel Oil	Unknown	Creek	162 fish killed
Near Walla Walla	Pipe	Green Cement	Unknown	Creek	Heavy fish kill in spill area
Maplewood/Renton	Pipe	Diesel Oil Jet Fuel	80,000 gal.	Urban	GW contamination Evacuation
Renton	Unknown	Unknown	Unknown	River	Major fish kill
Renton	Pipe	Diesel Oil	90,000 gal.	Wetlands	Aquatic life
1987					
Spokane	Tank	Gasoline	70,000 gal.	Land	Aquifer
Edmonds	Construction	Green Cement	Unknown	Creek	2,559 Cutthroat & Coho killed/habitat destruction

LOCATION	SOURCE	MATERIAL	AMOUNT	ECOSYSTEM	KNOWN IMPACTS	APPROX.
			1988			
Spokane	Truck	Diesel Fuel and Gasoline	2,950 gal.	Land	Fire hazard and Traffic	
Republic	Truck	Diesel Oil	1,472 gal.	Creek	Unknown	
Grays Harbor Co.	Barge	Bunker C	237,000 gal.	Coastal Water	Birds, other	10,000 birds* 3 sea otters*
Anacortes	Barge	Cycle Gas	100,000 gal.	Puget Sound	Unknown Food Chain	
Anacortes	Ship	Crude Oil	4,000 gal.	Puget Sound	Unknown Threat to Padilla Bay	
Ballard	Truck	Sodium Cyanide	55 gal.	Urban	Evacuation	
Kent	Tank Farm	Acetone	900 gal.	Industrial	Hospitalization	

* These data are preliminary, and could be much higher in the final analysis.

THE STATE OF THE ENVIRONMENT REPORT

VOLUME III
Part 17

Risk Evaluation Reports
for
Litter

ENVIRONMENT 2010

State of Washington
October, 1989

LITTER

Major Sources

Pedestrians
Motorists
Uncovered trucks with unsecured loads
Improperly handled commercial refuse
Improperly handled residential refuse
Commercial loading and unloading
Construction and demolition activity
Recreational boaters
Commercial maritime trade
Commercial fishing activity
Military activity

Types

Paper products in the form of:
packaging, newspaper, magazines, napkins, cups, plates, lottery tickets, disposable diapers.

Plastic products:
HDPE, PVC, PET, HP, PP, PS in the form of bottles, cans, rings, cups, broken consumer products, car parts, pipes & tubing, nets, rope, fishing tackle, oil bottles, shrink wrap, formed packaging, plates

Glass:
Bottles, jars, auto glass, broken consumer products

Metals:
Ferrous, aluminum, copper, other non-ferrous in the form of:
White goods, auto parts, beverage cans, broken consumer products, food cans, tools, pipes, tubing, building materials, nails, screws, foil condiment packages

Building materials:
Gypsum wall board wastes, wood, paint, bricks and blocks, wire, nails, screws, roofing material, fiberglass insulation

Organic waste not mentioned elsewhere:
Food and grocery items, yard waste, tree trimming and prunings, lost firewood, tobacco products.

Non-hygenic wastes:
Hypodermic needles, condoms, nasal tissue, human and pet excrement

Medical wastes:
Disposable diapers, hypodermic needles, bandages, body parts, blood

Other:
Clothing, tires, animals

Roadside litter generation in Washington has been evaluated and quantified every two years since 1983. A new methodology was developed in 1981 for this quantification. There is comparative data back to 1975.

Litter quantification is done by a sampling method. Selected sampling sites are used to evaluate fresh litter generation. It is quantified by type and estimates of tonnage are made based on traffic volumes and weather conditions.

Acts of deliberate littering and accidental littering are also evaluated. The studies have shown that 49.1% of the observed acts of littering are accidental and 50.8% are deliberate. 45.9% of observed litter acts are form loose material from truck and unsecured loads and are considered accidental. Pedestrians account for 29.5% of the littering acts, while motorists account for 16.4%.

The amount of litter generated in the state declined by 73% between 1975 to 1983, from 76,300 tons to 8,500 tons. In 1987 roadside litter generation increased to 11,800 tons. Geographically the greatest increase, 74 percent, took place at sampling sites in the Seattle area.

Since 1982, the amount of take out food related litter has increased 68 percent. Fireworks litter increased 1600 percent. Accidental litter from sources such as unsecured loads on trucks accounted for a total of 49 percent of the acts of littering in 1987.(1)

HUMAN HEALTH RISKS

There is little data compiled on known human health risks caused by exposure to litter. Since littering incidents are random and generally covert, specifically with hazardous and medical waste, it is impossible to estimate frequency of exposure the entire population of the state is potentially exposed to some risk caused by litter.

Assumed risks include:

- *Exposure to pathogens through improperly disposed medical wastes, and to bacteria carrying material (decaying food, or dead animals).
- *Physical injury through contact (broken glass, jagged metal, blasting caps.
- *Exposure to hazardous wastes lost from vehicles or illegally dumped. For cancerous and noncancerous health effects, refer to hazardous waste section.
- *Bodily injury through vehicle accidents caused by debris in the roadway .

A study done by the University of Cincinnati Medical Center evaluated the incidence of viral infections among waste collection workers. The study concluded "that waste collection workers do not experience increased viral infections because of their occupation."(2) Risk of illness due to exposure to pathogens carried in litter is not measurable then, assuming the exposure of the general population to pathogens in litter is less than the exposure to pathogens in waste collection workers.

ECOLOGICAL RISKS

Illegally disposed and littered material are dispersed throughout the environment. It is randomly released from vehicles as well as covertly dumped in remote areas. Once dumped, the material can scatter into the waters of the state and over the land by winds, water and animals. In addition, material disposed of at permitted disposal sites can be carried by wind and birds to adjacent land.

Aesthetically, litter provides an unpleasant visual image in any area. In urban commercial areas wastes are scattered from dumpsters that are not maintained, pedestrians, cars, commercial delivery vehicles. Material accumulation along roadways and walks provide unsightly and potentially dangerous situations.

Marine debris is coming to the forefront as a major littering issue. Most of the statistical information on marine debris is only available on a global scale and at this point in time cannot be easily localized.

In 1975, the worldwide annual disposal of waste into the marine environment was estimated at over fourteen billion pounds.

Littered materials have been documented as impacting wildlife through entanglement and ingestion. For example:

*The leather back sea turtle population is in decline. The reason is believed to be the ingestion of plastic bags, mistaken for jelly fish, the turtles favored food.

*Marine mammals and birds are strangled by plastic six pack rings after becoming entangled.

*Marine birds eat plastic bits and feed to their young. Fish eat plastic bits from photo degraded plastics. The plastic is ingested and results in death by starvation or infection.

*"Ghost nets," fishing nets lost or cut loose to drift by commercial fisherman may drift for months or years. Marine mammals, fish and birds become entangled and die.(3)

The Center for Marine Conservation, in San Fransico, has compiled these additional facts regarding marine debris:

*The world fleet of vessels (excluding commercial fishing vessels) dump at least 4.8 million pounds of metal, 300,000 pounds of glass, and 450,000 pounds of plastic containers into the sea each day;

*World navies dump an estimated 163,170,000 pounds of trash into the ocean each year;

*Commercial fishing fleets dump 749 million pounds of trash and 2.2 million pounds of fishing gear into world oceans;

*Of the 280 species of seabirds worldwide, 50 species are known to ingest plastics;

*Seabirds have become entangled in many kinds of marine debris including fishing nets, monofilament fishing line, kite string, and plastic bags.(4)

An action plan was developed by the Marine Plastic Debris Task Force lead by the Department of Natural Resources, to address the problem from Washington State's perspective.

ECONOMIC DAMAGE

Damage to property (vehicles, boats): There are no statistics available at this time to quantify economic damage to personal property due to debris in roadways and waters of the state. However, in 1987, there were seventeen boating collisions with "floating objects" reported. (5)

In 1988, the Washington Department of Transportation spent approximately $1.5 million on litter pickup. The Department of Ecology, through the Ecology Youth Corps, spent an additional $.5 million picking up litter along state highways.

Additional information compiled by the Center for Marine Conservation included:

*A survey conducted in Newport, Oregon showed that 58% of the fishermen contacted had indicated they had experienced vessel problems due to plastic debris and incurred an average cost of $2,725 per vessel;
*An average of 130 tons of trash a month is collected and hauled off the 3 mile long Santa Monica beach, Santa Monica, California at a cost of $1,275, 354 in 1988.(6)

(1) "Washington Litter: 1987," Syrek, Institute for Applied Research, Sacramento, California, 12-28-87.

(2) "Incidence of Viral Infections Among Waste Collection Workers," Clark, VanMeer, Bjornson, Linnemann, Schiff, and Gartside, Institute of Environmental Health, University of Cincinnati Medical Center, 01-19-79.

(3) "A Citizens Guide to Plastics in the Ocean: More Than A Problem," O'Hara, Iudicello, and Bierce, Center for Environmental Education, Washington, D.C., 1988.

(4) Telefax communication with the Center for Marine Conservation, "Facts and Figures on Marine Debris," May 10, 1989.

(5) "1987 Washington State Recreational Boating Fatalities," Boating Safety Program, Washington State Parks and Recreation Commission, Olympia, Washington, 1987.

(6) Op.sit.

THE STATE OF THE ENVIRONMENT REPORT

VOLUME III
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Risk Evaluation Reports
for
Wetlands Loss/Degradation

ENVIRONMENT 2010

State of Washington
October, 1989

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WETLANDS LOSS AND DEGRADATION: COMPARATIVE RISKS FOR WASHINGTON STATE

EXECUTIVE SUMMARY

1 October 1989

Introduction

In the past sufficient quantitative data to adequately document Washington State's wetland resource base or trends in that base did not exist.

In response, and as a requirement of Governor Booth Gardner's Executive Order 88-03, The Department of Ecology contracted with the US Fish and Wildlife Service (FWS) to complete digitalization of National Wetlands Inventory data for Washington, and to produce a narrative report on wetlands trends including quantitative information on wetland types and locations.

The FWS report concludes that there are approximately 938,000 acres of wetlands in Washington and that they are being lost a rate of approximately 2,034 acres per year.

While other quantitative estimates of the wetlands resource are used in this risk assesment to illustrate historical uncertainties, the FWS report is considered the difinitive work in the field.

In addition to the FWS work and other quantitative resource descriptions, this report is based largely on a draft risk assessment of non-chemical alteration of wetlands done in 1987 by Region 10, US Environmental Protection Agency (EPA) for Alaska, Idaho, Oregon, and Washington; the information for Washington was extracted and edited.

Threat Definition

The Environment 2010 Technical Advisory Committee developed the following threat definition for the loss or degradation of wetlands: Loss or degradation of wetlands is non-chemical conversion or alteration which results in a net reduction to total wetland and/or impairment of the physical functions and ecological values of the affected wetland. Examples include draining and filling of wetlands.

Only direct loss of wetlands due to urbanization was analyzed; no quantitative information was available on wetlands loss due to other human activities was available. No quantitative information on wetlands degradation was available.

General Analytic Approach

The EPA analysts focused on alteration of wetland habitats, particularly from filling activities, in their ecological risk assessment. While this focus does not represent all activities or ecological effects associated with non-chemical degradation of aquatic ecosystems, EPA believes it represents the greatest potential concern for Region 10.

Findings

National and state estimates strongly indicate that wetlands are continuing to be lost at a rapid rate, although slightly less than the rate estimated for a 25-year period in the 1950s, 1960s, and 1970s. This slight decline is due in part to better state and federal wetland protection laws, although there are large gaps in the matrix of existing laws. Although agricultural development has traditionally been responsible for most wetland losses, both nationally and statewide, it has been replaced, in Washington, by industrial, commercial, and residential development, particularly in the Puget Sound trough. When discussing agricultural impacts to wetlands, it needs to be noted that thousands of acres of wetlands have been created due to irrigation runoff in eastern Washington, in particular, the Columbia Basin. It is estimated that approximately 50 percent of Washington's wetlands have been lost, and that for wetlands at major Puget Sound river deltas the loss rate is 28 to 100 percent.

Wetlands loss is extremely severe or fatal to both resident wild-life and migratory animals, such as waterfowl and shorebirds, which rely on wetlands for part of their annual life cycle.

Wetland fills are rarely reversible, especially after secondary development has occurred on the site. Diking is often reversible by merely removing the dike, except in instances where development has occurred behind the dike -- in which case it is highly unlikely the dike would be removed. Although there is presently little impetus for landowners to breach existing dikes, positive tax incentives and an active federal program to encourage removing or breaching dikes could result in many wetlands being "re-created" or enhanced. Draining can be reversed if the source of water is again provided to the drained wetland and if other factors disturbing the wetland (i.e. plowing) are removed or stopped.

Wetlands degradation and destruction is no longer primarily an agricultural problem, although agricultural activities continue to have a significant effect on wetland changes, both positive and negative. Wetlands loss is now largely a result of industrial, commercial, and residential development. Although the problem of wetlands loss is statewide in scope, the areas of greatest loss are those areas, such as Snohomish, King, and Pierce counties, which are experiencing the most rapid growth.

Trends

The EPA analysts did not develop a trends analysis. Washington Department of Ecology wetlands staff have conducted a reconnaissance level-of-detail study of trends and concluded that there was insufficient quantitative information at that time to produce a comprehensive trends analysis. The 1989 FWS study did conclude, however, that wetlands were being lost at a rate of 2,034 acres per year (total of all wetland types).

Uncertainty

Before the FWS study, estimates of wetland acreage and wetland loss rates in Washington were not very reliable. Loss rates available from EPA are even more tenuous since they generally only consider wetland losses from activities permitted under Section 404 of the Clean Water Act and do not consider indirect losses from activities on lands adjacent to wetlands or from lowered water tables and diverted stream flows.

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1. BACKGROUND

In the past, there was insufficient quantitative data to adequatley document the state's wetland resource base, or trends in that base. Existing estimates of total wetlands and wetlands loss rates, some of wich are cited here, differed substantially.

In response, and as a requirement of Governor Booth Gardner's Executive Order 88-03, the Department of Ecology contracted with the US Fish and Wildlife Service (FWS) in 1988 to complete digitalization of National Wetlands Inventory (NWI) data for Washington, and to produce a narrative report on wetlands types and locations. The FWS report is now considered the definitive Washington wetlands inventory. The quantitative estimates of 938,000 acres of wetlands remaining in the state and loss rate of 2,034 acre per year are taken from the FWS report and relied upon extensively in this risk assessment.

This report is also based partly on a draft risk assessment of non-chemical alteration of wetlands done in 1987 by Region 10, US Environmental Protection Agency (EPA) for Alaska, Idaho, Oregon, and Washington; the information for Washington was extracted and edited. Since this risk assessment done by EPA only addressed activities permitted under Section 404 of the Clean Water Act -- essentially, non-agricultural filling of wetlands -- it only documents part of the problem of non-chemical alteration of wetlands. Four other sources of information regarding national and statewide wetland losses were also used in developing this preliminary risk assessment; these other information sources are listed in Section 2.1.4.

1.1 Characterization of Threat

For purposes of the EPA risk assessment, non-chemical alteration of aquatic habitats included direct and indirect physical stresses on these habitats. Physical impacts on aquatic habitats result from a variety of human activities, including dredging and filling, channelization, drainage, impoundments, mining, shoreline stabilization, and silvicultural and agricultural activities. Emerging and rapidly expanding projects associated with physical impacts include use of wetlands for stormwater filtration and the hydrologic alteration of streams and groundwater as our population and agricultural needs increase. These physical impacts affect marine, estuarine, and freshwater systems by causing direct loss or alteration of habitat, adding suspended matter to the water column, modifying hydrology, and changing ambient water parameters.

The Environment 2010 Technical Advisory Committee developed the following threat definition for the loss or degradation of wetlands:

Definition:
Loss or degradation of wetlands is non-chemical conversion or alteration which results in a net reduction to total wetland and/or

impairment of the physical functions and ecological values of the affected wetland. Examples include draining and filling of wetlands.

Major stressors:
Loss of water
Inundation
Siltation

Major sources:
Draining
Filling
Diking (e.g. railroad berms, road building, etc.)
Urbanization
Agricultural operations

Major damage pathways:
Human Health
- None

Ecological
- Loss of feeding, nesting, and breeding habitat for waterfowl
- Loss of habitat for furbearers (e.g. beaver, mink, etc.)
- Loss of habitat for anadromous and game fish during early phases of their life cycle
- Loss or deterioration of aquifer recharge functions
- Loss or deterioration of capacity for biofiltration of contaminants

Economic Damages
- Loss of aesthetic values
- Cost of alternative forms of flood control

Additionally, Environment 2010 reviewers have noted the following issues:

Agricultural operations are a threat to wetlands loss and/or degradation; grazing is cited as a specific example of an uncontrolled activity. Jurisdictions which have adopted wetland ordinances typically exempt grazing due to the financial and other problems associated with protective fencing.

Loss of vegetated wetland edges and vegetated and aquatic connectors (corridors) is also a major problem. For many wildlife species a wetland without a vegetated edge is an incomplete habitat. One hundred and twenty one western Washington species depend on wetlands and wetland edges for some or all of their life cycle requirements (Zeigler, 1988; Brown, 1985; Guenther & Kucera, 1978).

Peat mining is destructive of a special kind of wetland, mostly in western Washington.

Vegetation removal in shallow water wetlands for purposes of "lake management" is destructive of fish and wildlife habitat. Lake management is conducted for aesthetic purposes and enhancement of recreational activities such as swimming, boating, and water skiing.

1.2 Types of Risks Analyzed

Only direct loss of wetlands due to urbanization was analyzed; no quantitative information was available on wetlands loss due to other human activities was available. No quantitative information on wetlands degradation was available.

This should not imply that wetlands managers are not concerned about degradation of wetlands -- quite the contrary, the level of concern regarding degradation equals the concern regarding direct loss. The analytical problem lies in the lack of a generally agreed upon measure of degradation. Degradation is presumed to be occurring due, but not limited to, the following nonchemical factors: vegetation removal; introduction of exotic plant species; and hydrologic disruption, e.g. diversion of surface water, lowering of water tables caused by ground water withdrawals, and alteration of the timing and quantity of seasonal surface water flows. Additionally, but beyond the scope of this analysis, wetlands managers also concerned about chemical degradation due to nonpoint pollution (principally urban and agricultural runoff) and point source pollution (principally industrial discharges and accidental spills).

2. ECOLOGICAL RISKS

2.1 Analytic Approach

2.1.1 General Approach
This report relies on summaries of analyses previously conducted for other purposes. No original analyses were prepared.

The EPA analysts focused on alteration of wetland habitats, particularly from filling activities, in their ecological risk assessment. While this focus does not represent all activities or ecological effects associated with non-chemical degradation of aquatic ecosystems, EPA believes it represents the greatest potential concern for Region 10. This concern was also expressed in EPA's **Comparative assessment of environmental problems** (EPA, 1987b, Appendix III) which stated "Physical habitat alteration is the stress that has the greatest adverse impact on ecosystems".

Other wetlands loss studies relied on the interpretation of secondary evidence, e.g. a review of a sampling of SEPA environmental impact statements.

For the purpose of this risk assessment, wetlands include: habitats where the influence of surface or ground water has resulted in development of plant or animal communities adapted to such an aquatic or intermittently wet condition. Examples include tidal flats, shallow or subtidal areas, swamps, marshes, wet meadows, bogs, and similar areas. General functions and values of wetlands are discussed in the characterization report and summarized in Table 2.1.

Table 2.1. Functions Served and Values Provided by Wetlands

Groundwater recharge and discharge.
Flood storage and desynchronization.
Shoreline anchoring and dissipation of erosive forces.
Sediment trapping.
Nutrient retention and removal.
Food chain support.
Habitat for fisheries.
Habitat for wildlife.
Active recreation.
Passive recreation, aesthetics, and heritage value.

* * * * * * * *

2.1.2 Effects Examined
Ecological risks associated with non-chemical alteration of aquatic habitats were evaluated as alteration or destruction of wetlands and the functions and values they serve. The losses (de-

struction) of wetlands were calculated in two ways to give a range of losses: a lower bound based on a Region 10 study (EPA, 1987a) and an upper bound based on a national wetlands trend study (Shaw and Fredine, 1956). This upper bound was judged by the EPA analysts to be the best information available, but also as a low estimate of the upper bound since it was estimated in the early 1950s before major population and development growth began in the Pacific Northwest. The wetland losses were itemized by major wetland type (palustrine, lacustrine, riverine, estuarine, and marine) in the Region 10 study.

2.1.3 Rationale

The EPA analysts did not describe their rationale.

2.1.4 Data Sources Used

1. **Wetlands of the United States**_(Shaw and Fredine, 1956).

2. **Environment indicators of effectiveness**_(EPA, Region 10, 1987)

3. **Wetlands of the United States: Current Status and Recent Trends** (Tiner, et al., 1984).

4. **Inventory of Wetland Resources and Evaluation of Wetland Management in Western Washington** (Boule et al., 1983).

5. **State Environmental Policy Act Wetlands Evaluation Project (Draft)** (Hull & MacIvor, 1987).

6. **Historical changes of shoreline and wetland at eleven major deltas in the Puget Sound Region, Washington.** (Bortleson, Chrzastowske & Helgerson, 1980).

7. **US Fish and Wildlife Digitizing National Wetlands Inventory Data for Washingto Department of Ecology**, 1989

2.1.5 Critical Assumptions

The following assumptions were used by EPA in their review of Section 404 and 10 permits in Region 10:

1. A drained, diked or filled wetland is completely destroyed and has a complete loss of value.

2. All wetlands have a uniform, high value. (In a more thorough review, one wouldn't merely evaluate gains and losses of "average" wetlands but would consider the functions and values of specific wetlands).

3. In using Shaw and Fredine (1956), the estimated upper bound of wetlands lost per year in Region 10 is a conservative or low estimate of the upper bound.

4. Many wetland-destroying activities are never reported or ob-

served for many reasons, including: 1.) wetland activities covered by nationwide permits requiring no public notification; 2.) the remoteness of many areas with wetland damaging activities reduces the chances that these wetland alterations will be observed; and 3.) limited resource agency staff are available to search for violations of wetlands policies and regulations.

2.1.6 Approach to Scaling Up
The EPA analysts did not use a scaling up technique.

2.2 Description of Findings

2.2.1 Summary
Although a comprehensive study of wetlands loss has not yet been completed for Washington, national and state estimates strongly indicate that wetlands are continuing to be lost at a rapid rate. Reliable trend analyses are difficult if not impossible to develop because wetlands studies conducted at different times were based on different definitions of wetlands. Although agricultural development has traditionally been responsible for most wetland losses, both nationally and statewide, it appears to have been replaced, in Washington, by industrial, commercial, and residential development, particularly in the Puget Sound trough. When discussing agricultural impacts to wetlands, it should be noted that thousands of acres of wetlands have been created due to irrigation runoff in eastern Washington, in particular, the Columbia Basin. Following is a summary of trend information from each of the data sources cited in 2.1.4 above:

1. Wetlands of the United States (Shaw & Fredine, 1956). This study estimated an average national wetlands loss rate of 0.40 percent per year, or 815 acres per year for Washington. Section 404 of the Clean Water Act only regulates the discharge of dredged material or upland derived fill into waters of the United States, including wetlands. These permits have little control over drainage, silviculture, logging, or agricultural activities, except where there is an associated discharge of dredged or fill material. The estimated loss rates for Washington include losses resulting from non-404 projects (i.e., agricultural conversions of wetlands to pasture or cropland). The EPA analysts regarded Table 2.2 to represent an upper bound for direct physical wetland loss for all states but Alaska. However, they noted that this loss rate does not include the degradation of wetlands from secondary impacts (chemical leaching from in-place sediments from a fill for example) or cumulative impacts from numerous small stresses or incremental losses to wetlands.

2. US Environmental Protection Agency, Region 10. EPA evaluated records of 2,300 Corps of Engineers Public Notices in Washington for activities requiring permits under Section 404 of the Clean Water Act and/or Section 10 of the Rivers and Harbors Act, and determined a loss rate of 186 acres per year for Washington (Table

2.3). This represents a portion of wetland losses in Region 10

Table 2.2. Estimated1 Annual Loss of Wetlands in Washington, Oregon, and Idaho.

State	Acres of Wetlands Remaining	Approximate Yearly Loss (acres)
Idaho	95,140	380
Oregon	412,120	1,650
Washington	938,000	2,034

1. Based on an estimate of the number of acres of wetlands in each state (Shaw and Fredine, 1956) and a 0.4 % per year loss rate (Shaw and Fredine, 1956) for Idaho, Oregon and Washington. The loss rate for Alaska is based on only a review of 404 permitted projects (Faris et al, 1987), Washington based on USFWS 1989.

* * * * * * * *

Table 2.3. Loss of Wetlands in Washington, Oregon, and Idaho Based on Review of Section 404 Permit Activities.

State	Palustrine	Estuarine	Marine	Lacustrine	Riverine	TOTAL
Idaho	21.20	0	0	0.38	3.33	24.91
Oregon	112.22	6.35	0.11	0.11	56.51	175.30
Wash'n	32.22	144.38	0.19	0.73	7.10	185.62

Palustrine: non-tidal wetlands dominated by trees, shrubs, and persistent emergent vegetation (i.e., wet meadows, freshwater marshes).

Estuarine: deepwater tidal habitats and adjacent tidal wetlands, including emergent saltwater marshes.

Marine: open ocean and the high energy coastline.

Lacustrine: wetlands and deepwater habitats contained within a depression (i.e., lakes).

Riverine: all wetland and deepwater habitats within a channel.

* * * * * * * *

since activities which damage or destroy wetlands but do not require a permit are not included. Examples of non-404 permitted activities which may cause physical degradation of wetlands include logging activities, drainage, water impoundment, activities markedly changing runoff or recharge, major water withdrawals, and activities which result in changes to watersheds or the hydraulic regime.

3. Wetlands of the United States: Current Status and Recent Trends (Tiner, et al., 1984). Tiner et al. estimated original wetlands acreage in the contiguous United States at 215 million acres. This acreage estimate had decreased by about 50% to 108.1 million acres by the mid-1950s. Of 99 million acres remaining in the mid-1970s, 94 million acres were estimated to be fresh water or palustrine wetlands and 5.2 million acres estuarine wetlands. Of the estimated 11 million acres of wetlands lost during a 25-year period between the mid-1950's and mid-1970's, 96% were estimated to be palustrine or freshwater wetlands; agricultural development was estimated to be responsible for 87% of these losses. Estuarine wetlands only account for about 5% of remaining wetlands but are generally better protected by state laws. It is estimated that 90% of the estuarine wetlands loss in California and four other coastal states is due to residential home construction.

4. Inventory of Wetland Resources and Evaluation of Wetland Management in Western Washington (Boule et al., 1983). Boule, et al. included acreage loss estimates that are very consistent with Tiner, et al. The 458,000 acre annual loss figure cited by Tiner has been reduced since the mid-1970s largely due to a decline in the rate of agricultural draining activities as well as better state and federal wetland protection laws. Boule et al. includes three case studies in Washington showing the following losses of freshwater wetland acreages in the following USGS quadrants:

Tenino and Yelm (south Thurston County): 55%
Tacoma South (Pierce County): 82%
Lake Washington (King County): 70%

5. State Environmental Policy Act Wetlands Evaluation Project (Draft) (Hull & MacIvor, 1987). The unpublished SEPA study done by Department of Ecology estimates that roughly half of Washington's original 800,000 acres of wetlands have been lost due to development, a figure that mirrors national wetland loss estimates. This study also indicated that freshwater marshes and forested wetlands experienced the greatest losses from development and that most of the wetlands lost were small, between 0.5 and 5 acres in size. This report also identified draining as a greater cause of wetlands loss than filling in those sites visited for the study. A conservative estimate of wetlands loss -- wetlands outside the jurisdiction of the Shoreline Management Act and considered under SEPA -- is 530 acres per year.

6. Historical changes of shoreline and wetland at eleven major deltas in the Puget Sound Region, Washington. (Bortleson,

Chrzastowske & Helgerson, 1980). Bortleson, et al. evaluated wetland loss at the major river deltas of the Puget Sound and found a loss of 28 to 100 percent of wetlands (Table 2.4).

Table 2.4. Estimated historical changes in natural habitat of principle estuaries of Washington State.

Estuary	Estimated (km2) subaerial wetland		
	Historical	Present	% change
Nooksack	4.5	4.6	+0.2
Lummi	5.8	0.3	-89.7
Samish	11.0	0.4	-96.4
Skagit	29.0	12.0	-58.6
Stillaguamish	10.0	3.6	-64.0
Snohomish	39.0	10.0	-74.4
Duwamish	2.6	0.1	-99.2
Puyallup	10.0	0	-100.0
Nisqually	5.7	4.1	-28.1
Skokomish	2.1	1.4	-33.3
Dungeness	0.5	0.5	0

Source: Bortelson et al., 1980.

* * * * * * * *

Conclusions

The Department of Ecology contracted with the US Fish and Wildlife Service (FWS) in 1988 to complete digitalization of National Wetlands Inventory (NWI) data for Washington, and to produce a narrative report on wetlands types and locations. The FWS report is now considered the definitive Washington wetlands inventory. The quantitative estimates of 938,000 acres of wetlands remaining in the state and loss rate of 2,034 acre per year are taken from the FWS report and relied upon extensively in this risk assessment.

An interpolation of national loss rates to Washington state (Table 2.2) indicates an annual loss rate of 815 acres. Two studies of wetlands loss in Washington of different classes of wetlands, (1) those regulated by the Clean Water Act, and (2) those unregulated, give incomplete estimates of wetlands loss:

Clean Water Act - 186 acres/year (Table 2.3)
Unregulated ----- 530 acres/year (Hull & McIvor, 1987)
Total ----------- 716 acres/year

These figures do not include losses due to agriculture, hobby farming, forestry, small scale development, highway construction, or other activities, all of which would add to this loss rate and likely bring the 716 acres/year figure to equal or even exceed the nationally interpolated value of 815 acres/year.

The difinitive 1989 FWS work, however, concluded that loss is occurring at a rate of 2,034 acres per year.

2.2.2 Severity
Wetlands loss is extremely severe or fatal to both resident wildlife and migratory animals, such as waterfowl and shorebirds, which rely on wetlands for part of their annual life cycle. As individual wetlands are reduced in size, diversity, and complexity, their functions and values are also reduced or lost; for example, specific wetlands may become too small to provide habitat for certain species or contribute in a measurable way to flood control).

2.2.3 Reversibility
Wetland fills are rarely reversible, especially after secondary development has occurred on the site. Diking is often reversible by merely removing the dike, except in instances where development has occurred behind the dike -- in which case it is highly unlikely the dike would be removed. Although there is presently little impetus for landowners to breach existing dikes, positive tax incentives and an active federal program to encourage removing or breaching dikes could result in many wetlands being "re-created" or enhanced. Draining can be reversed if the source of water is again provided to the drained wetland and if other factors disturbing the wetland (i.e. plowing) are removed or stopped.

Diking and draining of some wetlands is reversible under an acquisition and restoration program being considered by various resource agencies and private nonprofit organizations. This technique could also be used for project mitigation or establishment of mitigation banks.

2.2.4 Scale
Wetlands degradation and destruction is no longer primarily an agricultural problem, although agricultural activities continue to have a significant effect on wetland changes, both positive and negative. Wetlands loss is now largely a result of industrial, commercial, and residential development. Although the problem of wetlands loss is statewide in scope, the areas of greatest loss are those areas, such as Snohomish, King, and Pierce counties, which are experiencing the most rapid growth.

EPA looked at three areas of western Washington experiencing wetland losses due to commercial development pressures: the Silverdale area of Kitsap County, the suburbs east of Seattle, and Pierce County:

In the Silverdale area, an unincorporated portion of central Kitsap County, 66 wetlands totalling 650 acres are potentially affected. The threat is from developmental pressure and lack of specific wetland planning and protection other than that afforded by the Kitsap County Subarea Plan and the State Environmental Policy Act.

Wetlands losses are also occurring in the Soos Creek Planning Area of King County. The Soos Creek Planning Area shares boundaries with Renton, Auburn, Kent and Tukwila and contains 87 wetlands totalling 1,563 acres. These wetlands are threatened by strong development pressure and the potential for annexation into these cities -- which are judged to have a lesser degree of wetland protection than the county.

Pierce County wetlands are threatened primarily by residential development and are located in Spanaway (433 acres), South Hill (155 acres), Bonney Lake (252 acres), Gig Harbor (152 acres), and south Pierce County (142 acres).

It is important to remember that these are simply examples of urban wetlands losses. Similar wetlands losses are reported by report reviewers in other areas of western Washington, including the Issaquah, Federal Way, Bothell, Snoqualmie, and Redmond areas of King County.

2.2.5 Sensitivity

Wetlands are also potentially affected by degradation due to conversion of adjacent uplands habitat and to chemical pollution by urban and agricultural runoff (NRC, 1982). No analyses are known to have been conducted to quantify this impact in Washington state.

2.2.6 Trend

The EPA analysts did not develop a trends analysis. Washington Department of Ecology wetlands staff have conducted a reconnaissance level-of-detail study of trends and concluded that there is insufficient quantitative information at this time to produce a comprehensive trends analysis. However, two Washington trends reports are due to be completed by the US Fish and Wildlife in 1989; a narrative report on wetland trends due to Department of Ecology by June 30, 1989, and a more complete report entitled Wetlands of Washington to be completed by the end of the year.

2.2.7 Productivity/Uniqueness

Despite the assumptions used by EPA in their risk assessment, it is a fact that the values and functions of all wetlands are not equal. While some level of protection should be given to all wetlands, certain wetlands, because of their uniqueness or high productivity, have been targeted for preservation through acquisition by public agencies at the local, state, and federal levels. The Puget Sound Water Quality Management Plan, for instance, makes the identification and preservation of high quality wetlands in the

Puget Sound region a high priority.

EPA recognized certain wetlands in King County as unique and threatened areas, including: Bear Creek in Redmond with 83 wooded or shrub wetlands (1,055 acres) associated with the Bear Creek floodplain; East Lake Sammamish with 86 riverine and lacustrine wetlands (1,325 acres); and Snoqualmie Planning Area with 167 riverine wetlands (3,553 acres). Other King County wetlands threatened by development are located in the following planning areas: Northshore area (262 acres), Federal Way area (1,432 acres), the Newcastle area (373 acres), the Green River Valley (6 acres), and the City of Kent (127 acres).

2.3 Discussion of Uncertainty

Until current National Wetland Inventory data is available later in 1989, the estimates of wetland acreage and wetland loss rates in Washington are not very reliable. Loss rates available from EPA are even more tenuous since they generally only consider wetland losses from activities permitted under Section 404 of the Clean Water Act and do not consider indirect losses from activities on lands adjacent to wetlands or from lowered water tables and diverted stream flows.

This review makes no distinction between the quality or value of individual wetlands. Because most attention is focused on large, visible wetlands, the cumulative impacts of small wetland destruction are severely underestimated. Indirect adverse impacts to wetlands are also largely undocumented and underestimated. Threshold impacts to wetland-dependent fish and wildlife species are poorly understood and often exceeded. Until better data is available regarding current wetland acreages, wetlands loss, and the causes of wetlands loss, the overall risk of wetlands loss in Washington is underestimated.

2.4 Nature of the Risk

2.4.1 Geographic Area

Refer to Section 2.2.4.

2.4.3 Stressors and Sources

Stressors and sources considered by EPA analysts to affect wetlands are summarized in Table 2.5. Some report reviewers question the reversibility of many of the sources cited by EPA as reversible.

Table 2.5. Stresses and Sources Affecting Wetlands.

Stressor	Source	Endpoint1	Reversible2
Filling	Agriculture	HA/HDO	No
	Silviculture	"	No
	Misc Dredging & Disposal	"	No
	Urban Development	"	No
	Rural Development	"	No
	Highway/Causeway Construction	"	No
	Mining	"	No
	Stream Impoundment/ Dam Construction	"	No
	Shoreline Construction Stabilization	"	Yes
Diking	Agriculture	HA/HD	Yes
	Silviculture	"	Yes
	Misc. Dredging and Disposal	"	No
	Highway/Causeway Construction	"	No
	Shoreline Construction/ Stabilization	"	Yes
	Urban Development	"	No
	Rural Development	"	No
	Stream Impoundment/ Dam Construction	"	No
Draining	Agriculture	HA/HD	Yes
	Silviculture	"	Yes
	Urban Development	"	No
	Rural Development	"	No
	Highway/Causeway Construction	"	No
	Stream Improvement/ Dam Construction	"	No

1. HA/HD = Habitat Alteration/Habitat Destruction.
2. The practicality of reversing wetland destruction must realistically be addressed on a site specific level.

* * * * * * * *

3. REFERENCES CITED AND CONSULTED

Batie, Sandra S. & William E. Cox. 1976. Economic implications of environmental legislation for wetlands. Department of Agricultural Economics, Virginia Polytechnic Institute and State University, Blacksburg.

Bortleson, G.C., M.J. Chrzastowske & A.K. Helgerson. 1980. Historical changes of shoreline and wetland at eleven major deltas in the Puget Sound Region, Washington. USGS Series of maps.

Boule, Marc E., Nancy Olmstead & Tina Miller. 1983. Inventory of wetlands resources and evaluation of wetlands management in western Washington. Shorelands & Coastal Zone Management Program, Washington Department of Ecology, Olympia.

Brown, E. Reade (ed.). 1985. Management of wildlife and fish habitats in forests of western Oregon and Washington. Pacific Northwest Region, US Forest Service, Portland, Oregon.

Ecology, Washington Department of. 1988. 1988 Washington wetlands study report. Washington Department of Ecology, Olympia.

EPA. 1987a. Environment indicators of effectiveness. Wetlands Protection Section, EPA Region 10, Seattle, Washington.

EPA. 1987b. Unfinished business: A comparative assessment of environmental problems. Appendix III. Ecological Risk Workgroups, Office of Policy, Planning and Evaluation, Wash. D.C.

Faris, T.L., J.B. Hamilton & R.P. Stone. 1987. Report on the Alaska Region Section 10/404 permit coordination 1981-1985. NOAA Tech Memorandum NMFS F/AKR-6 46p.

Frayer, W.E., T.J. Monahan, D.C. Bowdon & F.A. Graybill. 1983. Status and trends of wetlands and deep water habitats in the coterminous United States, 1950's to 1970's. Department of Forest and Wood Sciences, Colorado State University, Fort Collins.

Guenther, Keith & Thomas E. Kucera. 1978. Wildlife of the Pacific Northwest: Occurrence and distribution by habitat, BLM District, and National Forest. Pacific Northwest Region, US Forest Service, Portland, Oregon.

Hull, Sabra & Jamie MacIvor. 1987. State Environmental Policy Act wetlands evaluation project. unpublished mss. Wetlands Section, Shorelands and Coastal Zone Management Program, Washington Department of Ecology, Olympia.

Kunz, K., M. Rylko & E. Somers. 1988. An assessment of wetland mitigation practices pursuant of Section 404 permitting activities in Washington state. National Wetlands Newsletter. In press.

National Research Council, Committee on Impacts of Emerging Agricultural Trends on Fish and Wildlife Habitat. 1982. Impacts of emerging agricultural trends on fish and wildlife habitat. National Academy Press, Washington.

NRC - see National Research Council.

Resource Planning Section. 1986a The use of wetlands for stormwater storage and nonpoint pollution control: A review of the literature. King County Department of Planning and Community Development, Seattle, Washington.

Resource Planning Section. 1986b. Viability of freshwater wetlands for urban surface water management and nonpoint pollution control: An annotated bibliography. King County Department of Planning and Community Development, Seattle, Washington.

Shabman, Leonard A. & Sandra S. Batie. 1979. Estimating the economic value of coastal wetlands: Conceptual issues and research needs. Department of Agricultural Economics, Virginia Polytechnic Institute and State University, Blacksburg.

Shabman, Leonard A. & Sandra S. Batie. 1977. Estimating the economic value of coastal wetlands: A cautionary note. Department of Agricultural Economics, Virginia Polytechnic Institute and State University, Blacksburg.

Shabman, Leonard A., Sandra S. Batie & Carl C. Mabbs-Zeno. 1979. The economics of wetlands preservation in Virginia. Department of Agricultural Economics, Virginia Polytechnic Institute and State University, Blacksburg.

Shaw, S.P. & C.G. Fredine. 1956. Wetlands of the United States. US Fish and Wildlife Service Circular 39.

Tiner, Ralph W., Jr. 1984. Wetlands of the United States: Current status and recent trends. US Fish and Wildlife Service, Washington

US Fish and Wildlife Service, National Wetlands Inventory, digitizing project for Washington Department of Ecology 1989

Williams, Gene N. & Douglas J. Canning. 1981. City of Renton wetlands study. Renton Planning Department, Renton, Washington.

Zeigler, Robert. 1988. Wetland buffers: Essential for fish and wildlife. unpublishhed mss. Washington Department of Wildlife, Olympia.

THE STATE OF THE ENVIRONMENT REPORT

VOLUME III
Part 19

Risk Evaluation Reports
for
Nonchemical Impacts
on Forest Lands

ENVIRONMENT 2010

State of Washington
October, 1989

Ecological Risk to Forest Land

A. Analytic Approach and Data Sources

The cause of stress on forest land, or any other land for that matter, comes through its use. The approach to analyzing risk for this report has been to examine the literature about changes occurring as a result of some of the more common uses of forest land and to evaluate the ecological effects .

B. Key Findings

The key findings of this risk analysis are summarized in Table 1. A more detailed discussion of the major threats to the Forest Land Resource and key findings can be found in sections B.1. through B.5. below.

B.1. Conversion of Commercial Forest Lands to Non-Forest Uses.

Conversions of forest lands to non-forest uses will result in:

1. A reduction in the diversity of flora and fauna
2. An increase in the potential for flooding
3. A reduction in groundwater recharge (See Water Resource)
4. An increased of ground and surface water
5. An increased use of the remaining forest land for timber production, recreation, wildlife and water.
6. A reduction of 0.5 to 1 billion board feet in sustained harvest level[1].
7. A reduction in CO_2 fixing potential as forest land is converted to asphalt and buildings (See Global Warming).

Sensitivity

In the period between 1930 and 1980 the population of Washington state expanded by about 2.5 million people. These new citizens needed land for cities, roads, parks, and recreation. During this period about 4 million acres of commercial forest[2] land were lost to these and other uses (Figure 1).

By the year 2010 the state's population is projected to increase by about 1.7 million people. As in decades past, these new citizens will use forest lands for homes, roads, parks, and buffers.

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[1]Assuming that the average annual growth rate for forest land in the Puget Sound Province is between 500 and 1000 board feet per acre per year.

[2] Commercial forest land is forest land capable of producing more than twenty cubic feet per acre per year of usable wood volume.

TABLE 1.
SUMMARY OF ENVIRONMENTAL STRESSES ON FOREST LANDS

Source	Stressor	Effect
Conversion of Forest Land to Non-Forest Uses	population growth and resulting urbanization	a reduction in diversity of flora and fauna
		an increase in the potential for flooding
		a reduction in groundwater recharge
		an increase in the potential for pollution of ground and surface water
		an increased use of the remaining forest land for timber production, recreation, wildlife and water
		a reduction of 0.5 to 1 billion board feet in sustained harvest level
		a reduction in CO_2 fixing potential as forest land is converted to asphalt and buildings
Conversion of Old Growth to Second Growth Forests	harvesting old growth	reductions in the amount of old growth forest
		a reduction in species diversity
		a loss of ecosystem structure and function
		habitat fragmentation

TABLE 1. (CONT.)
SUMMARY OF ENVIRONMENTAL STRESSES ON FOREST LANDS

Source	Stressor	Effect
Non-Timber Uses of Forest Land	increased non-timber uses of forest land	increased surface erosion and mass wasting increased soil compaction
Forest Road Construction, Maintenance and Use	new forest roads and the continued use of existing forest roads	a reduction in land available for tree production increased surface erosion and mass wasting
Timber Harvest	removal of trees and soil disturbance	increased surface erosion and mass wasting increased soil compaction changes in soil chemical properties a reduction in species diversity a reduction in structural diversity
Prescribed Slash Burning	removal of ground cover vegetation and soil organic matter when burning slash	increased erosion potential alterations in plant succession patterns decreased potential productivity

TABLE 1. (CONT.)
SUMMARY OF ENVIRONMENTAL STRESSES ON FOREST LANDS

Source	Stressor	Effect
Reforestation	artificial forest regeneration practices	a reduction in genetic diversity a reduction in species diversity increased soil erosion from site preparation

Even assuming better efficiency in the use of lands, it appears likely that the amount of commercial forest land will decline from slightly over 17 million acres today to a little over 16 million acres in 2010[3].

Reversibility

Some of the ecological effects can be controlled through proper planning. However, once forest land is converted to roads, housing developments and industrial sites, the ecological effects are, for the most part, irreversible or at least long-lasting.

Scale of impacts

About 65% of the projected population growth will occur within the Puget Sound Area and North Cascades Physiographic provinces in forested land adjacent to major metropolitan areas in Snohomish, King, Pierce, and Thurston Counties.

Sensitivity of ecosystems

The magnitude of these effects will depend largely on the accuracy of population projections and the types of ecosystems selected for conversion. Reductions in the diversity of both flora and fauna will occur in all ecosystems. A reduction in CO_2 fixation will occur across all sites. The greatest effect on CO_2 will occur on the most productive sites.

Ground water pollution is most common on soils which have coarse texture and are very permeable. These soils allow pollutants deposited at or near the soil surface to move rapidly to the ground water. These effects are aggravated when groundwater occurs near the surface of the soil. This type of ground water contamination has occurred in portions of Thurston County.

Increased flooding and surface run-off are most likely where major developments are located near streams. Surface water contamination is most likely in areas where soil permeability is low or where a hard pan or compacted glacial till is present in the soil. The soil features can direct pollutants contained in surface and subsurface flow into streams and lakes. The potential for flooding is increased when storm runoff from roads, parking lots, and roofs are allowed to drain into streams or rivers.

Reductions in sustainable harvest levels will be the greatest where housing and industrial developments are located on the most productive land. The more common soils in the Puget Sound Area such as Alderwood, Everett, and Indianola are moderately productive with a fifty year site index of about 110. However, productivity within this zone ranges from less than site index 90 to greater than site index 130 (USDA, 1983).

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[3]Bill Hohenstein (Personal Communication) U.S.D.A. Forest Service, North Carolina. Research Triangle Park, NC.

B.2. Conversion of Old Growth to Second Growth Forests

This section addresses major effects of the conversion of old growth on the forest land resource. A portion of the impacts of old growth conversion are included in the section effects of harvesting, road building, and reforestation. These are discussed in section B.4 of the forest lands risk analysis. The risks to forest lands associated with old growth conversion discussed here are those associated with a sizable but declining portion of the forest land base.

The first sawmill in Washington was built in 1826 near Fort Vancouver. This marked the beginning of the forest products industry in Washington and started the decline in the amount of old growth forests. In those early years timber was generally classified in one of three categories: 1. cut-over, forest land which had been harvested but had not regenerated; 2. Second growth, harvested forest land which had regenerated; and 3. Old growth, forest lands which had not been harvested. This definition of old growth was selected because: it allows for tracking the amount of unharvested forest over time and provides gross estimates of how much will remain over time.

This definition includes late successional climax forests over 250 years of age which contain several trees per acre over forty inches in diameter and many snags and down logs and are multi-layered. These types of forests provide some of the most diverse habitat for wildlife species.

The impacts of the conversion of old growth forests include:

1. A reduction in the amounts of old growth forests
2. A reduction in species diversity
3. Loss of ecosystem structure and function
4. Fragmentation of habitat

Severity

Melton (1936), estimated that about 50% of the old growth forests were still present in 1930 and that this amounted to about 11 million acres. Today slightly over 4 million acres of these forests remain (Figure 1) (USDA, 1988). Most old growth forests are managed by the Federal Government as parks, wilderness areas and commercial forests. In the year 2010, if old growth harvest rates for the region[4] are applied to Washington state, about 3 million acres of these old growth stands will still remain. Most will be located on the Olympic Peninsula and in the Cascade Mountains.

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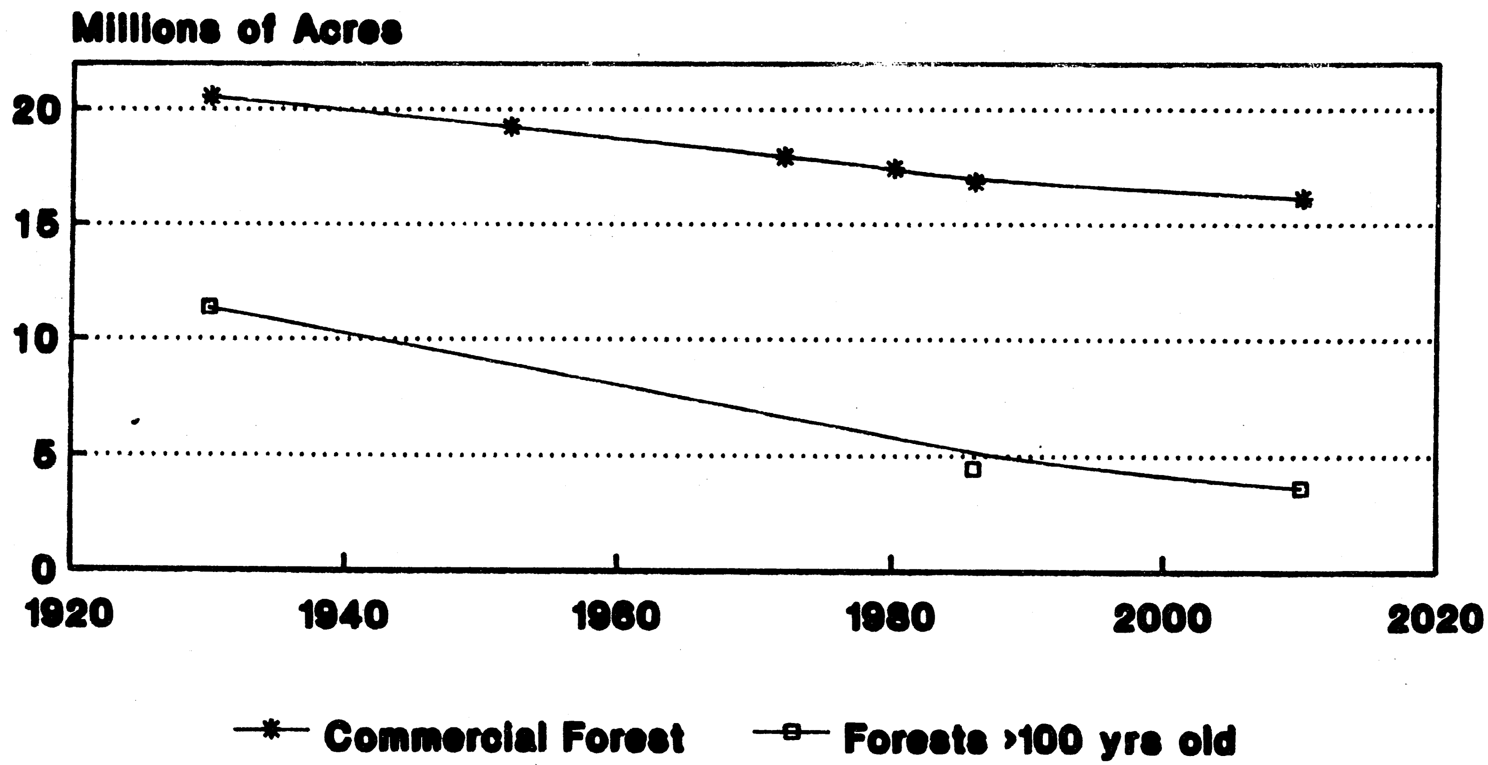
[4] Assumes a harvest rate of 40,000 acres per year. The U. S. Forest Service estimates that the rate of harvest of old growth is 36,000 to 40,000 acres per year for the entire Pacific Northwest Region (Washington plus Oregon). USDA Forest Service, 1988. Final supplement to the environmental impact statement for an amendment to the Pacific Northwest regional guide, Volume 1. Forest Service Pacific Northwest Region, Portland Oregon.

Figure 1.-Amount of Commercial Forest Land & Stands Over 100 Years Old in Washington State (1930-2010)



Source USFS SEIS 1988, WDNR 1977,
Lumber Industry in Washington
National Youth Administration 1936

More recently, the definition of old growth has changed. In current usage, it includes only late successional climax forests over 250 years of age, containing several trees per acre over forty inches in diameter. Under this definition, old growth stands are multi-layered and contain many snags and down logs. These types of forests provide a diverse habitat for many wildlife species.

About one-half of the 4 million acres of today's old forests meet this definition (USDA, 1988). It is expected that the amount of these old growth stands will decline to about 1.5 million acres or less in the year 2010.

However, a Wilderness Society study on Forest Service lands found slightly over one-half million acres of old growth or about 1/2 the amount of old growth reported in previous Forest Service inventories (Figure 1a). The study did not extend to the Washington's national parks. However, if other estimates of the amounts of old growth forest in national parks are correct, then based on these estimates about 1 million acres of old growth exist in Washington today with fifty percent preserved in parks and wilderness areas.

These late successional old growth forests are the most diverse with respect to species, structure and function of any forests in Washington (Geppert et al, 1984; Spies, 1989). Conversion of these forests to second growth stands will cause a much greater loss in diversity than the harvest of either second growth or late seral stage stands.
In addition, a portion of the late successional stage forests occur in stands too small or fragmented to support species dependent on structural and species diversity. Lehmkuhl and Ruggiero (1989,) suggests that fragmentation of old growth may be approaching a critical level for the viability of wildlife associated with these late successional forests.

Reversibility of impacts

Old growth, when defined by age and size alone, can be replaced quite easily. However the change in diversity which accompanies harvest of late successional old growth can be replaced only over a long period of time.

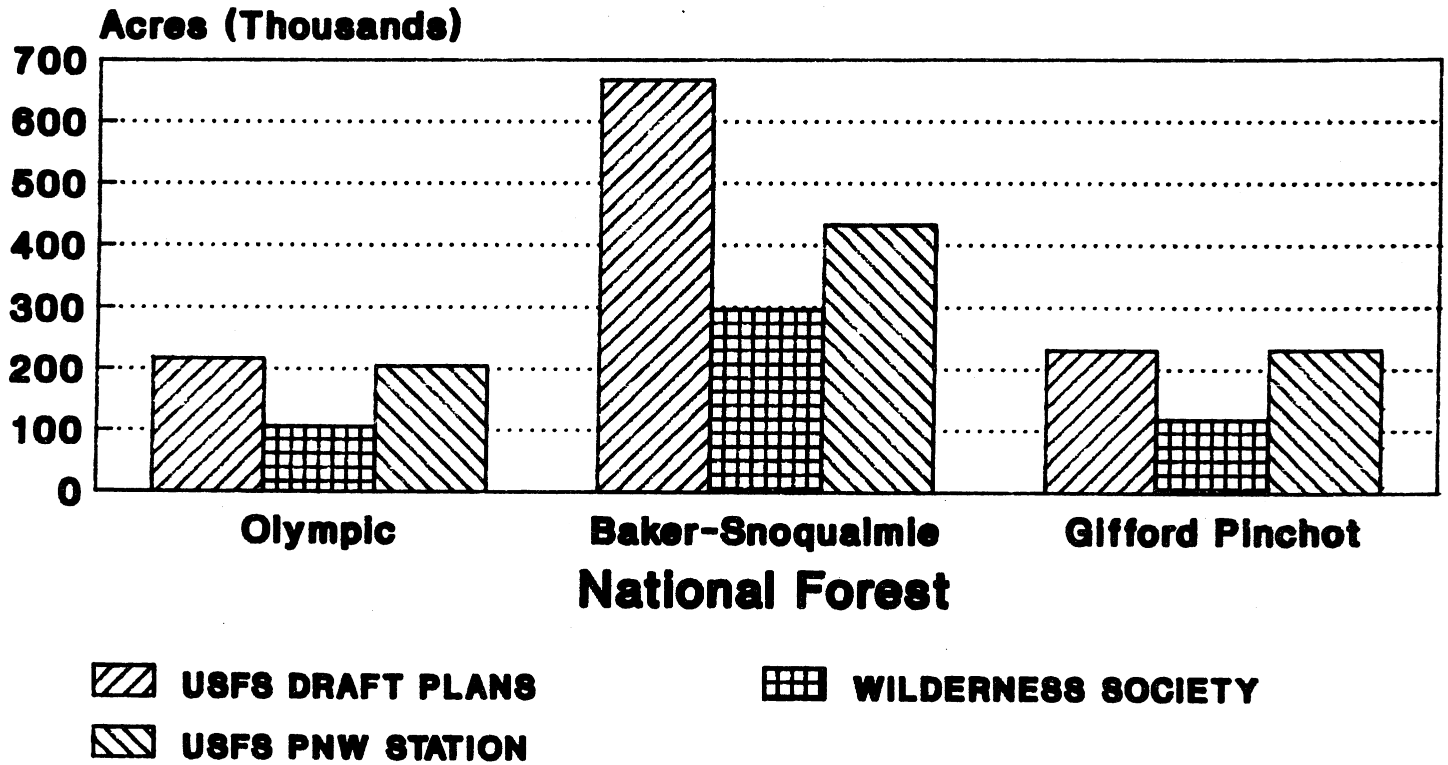
Scale

Precise estimate of the rate of harvest of old growth stands in Washington are not currently available. However, it is estimated that the rate of harvest in old growth stands for Washington and Oregon combined is between 36,000 and 40,000 thousand acres per year (USDA 1988).

Sensitivity of ecosystems

With respect to the impacts on forest lands, harvest of old growth stands on soils which are very steep, shallow and cold cause the greatest impact. While these stands may be less diverse, the soils are generally more fragile than warm, moist, fertile sites at low elevation. However,

Figure 1a.-Estimates of the Amount of Late Successional Old Growth on National Forests in Washington



Source: Wilderness Society
P. H. Morrison (1988)

concerning ecosystems risks, stands with a high degree of diversity may sustain the greatest long term impact.

B.3. Non-Timber uses of Forest Lands

Non-Timber uses of forested land have increased dramatically over the past few decades. In general, information on the magnitude of most of these uses does not exist or is available on a sporadic basis. The most consistent data base reporting non-timber use of forest land is the number of visitors at our state and national parks. Although these data reflect only a narrow range of the non-timber use of forest lands, it is felt that they reflect the general trends in recreational use of forests.

The impacts of recreation use evaluated in this section include:

1. Increased sedimentation
2. Soil compaction
3. Over crowding

Severity

Increased recreational use will result in overuse of portions of our parks, camp grounds and forested areas and will be accompanied by increased compaction, soil erosion, sedimentation of streams and a loss of pristine conditions in some of our parks. Overuse has already resulted in limits being placed on the number of visitors allowed in the North Cascades National Park (See Recreational Lands). In Mount Rainier National Park (USDI, 1976), it was observed that "As more people visit these already congested areas, more encroachment into the meadows and forest lands would occur. Already meadow vegetation is being damaged by trampling." The cause of this trampling damage is the soil compaction or soil densification which occurs as people walk repeatedly over the same area. The soil eventually becomes so dense that plant roots are unable to extract sufficient nutrients, moisture and oxygen from the soil and they die. The process of compaction also occurs as horses, or machines such as off-road vehicles repeatedly pass over a piece of ground. These compacted areas where hiking, horseback riding and ORV trails cross streams can cause increased sedimentation.

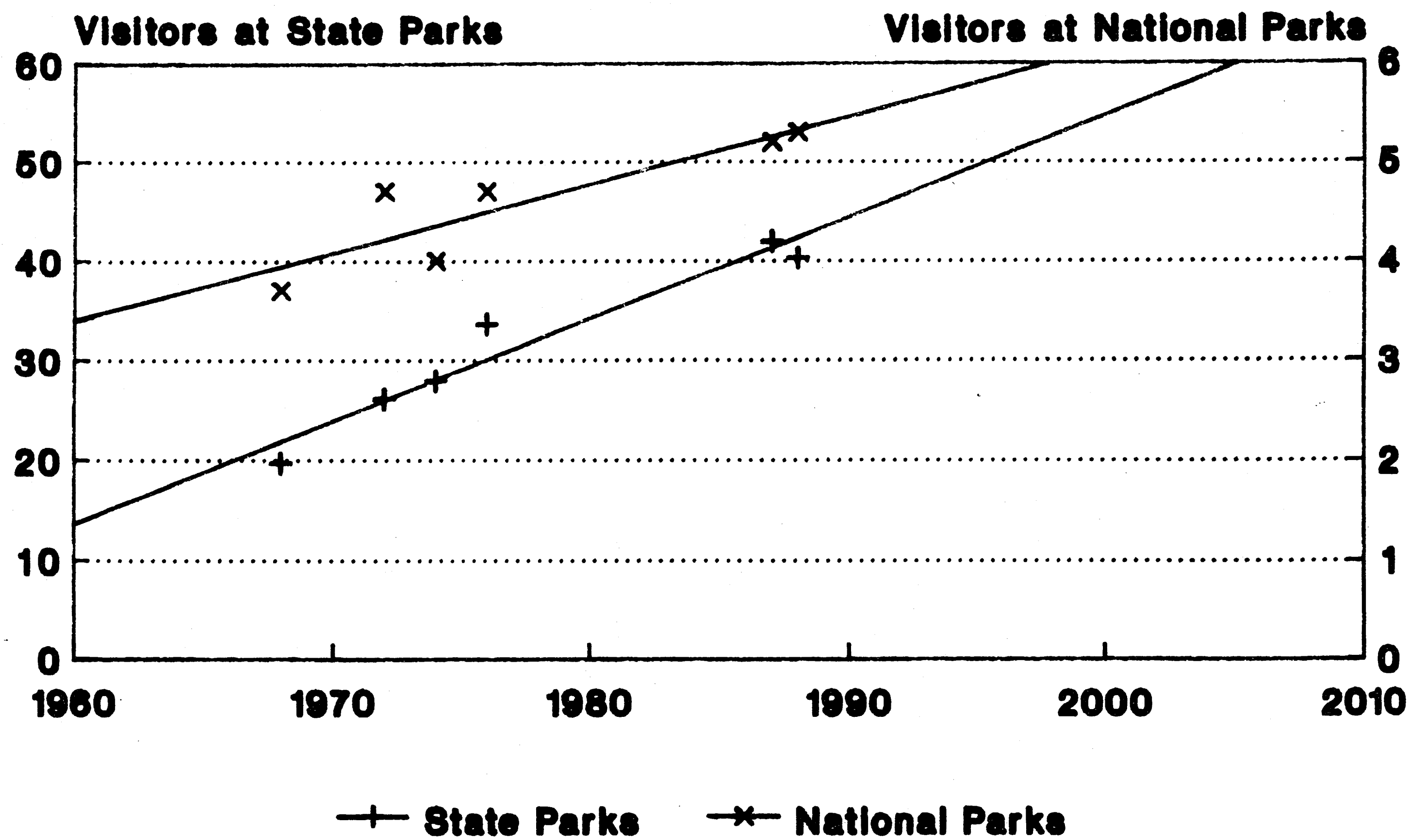
Reversibility

With care, impacted areas can be rehabilitated over a long period of time.

Scale

During the last 20 years, the number of visitors to our national parks has increased by 30 percent (data from Mount Rainier and Olympic National Parks) and state park use has doubled (data from Washington State Parks and Recreation Commission (Figure 2). In addition, the number of off-road vehicles (ORV) registered in Washington doubled in the 5 years between 1978 and 1983 (WSPRC, 1984). This shows the rapid increase in this form of recreation, much of which occurs on forested public land.
It is anticipated that recreational uses of forest land will continue to increase through 2010.

Figure 2.-Visitors at Washington's State and National Parks



Source: State Parks Commesion and
National Park Service

Sensitivity

All soils are sensitive to compaction from overuse. However, soils which are fine textured and moist during periods of use are generally most subject to compaction and erosion. All other aspects being equal, the time required for disturbed soils to recover from these effects increases as annual temperature decreases.

B.4. Silvicultural Uses of Forest Lands

Silviculture is the art and science of managing forest lands to meet the objectives of the land owner or land manager. The objectives of forest management can range from preservation of pristine conditions to maximizing profits. In Washington, silvicultural objectives include both preservation and commercial timber production. Commercial timber production has been regulated by a state forest practices act since 1946. While the first forest practices laws were enacted to insure reforestation of cut-over lands, later changes in the laws helped to insure that one of the objectives of commercial timber production is the protection of public resources.

Currently 5.4 million acres of forest land in the state are reserved for wilderness, national, state and city parks and other uses (Nickelson, 1988). In these areas silvicultural objectives vary from the maintenance of pristine conditions to providing camping opportunities with many of the comforts of home.

The rest of the forest land, about 17 million acres, is devoted to multiple-use forest management of varying degrees. These acres make up the commercial harvest base. Silvicultural activities on these lands are directed primarily toward timber production. However, these lands are also a key component in the recreational land base and many land managers have recreational sites within their commercial forests.

Management on commercial forest lands in the past and present have done much to shape the ecosystems which occur today. These activities will continue to shape the ecosystems in the future. In particular, harvesting, road building, and reforestation have done much to change the character of forest lands in Washington. The impacts of these silvicultural activities are addressed in this section.

B.4.a Road Construction, Maintenance, and Use

The impacts of road related forest activities include:

1. A reduction of land available for tree production
2. Increased erosion

Severity

Although precise estimates of the actual amount of forest land in roads are not available, Geppert et al, (1984) estimated that 1.5 million acres of forest land may eventually be occupied by roads. While roads are essential for car and truck access to forest land, these roaded lands are not available for tree growth.

Surface erosion and mass wasting also occur as a result of the construction, use, and maintenance of forest roads. Reid (1981) found that fine sediment production (2 mm and less) was increased by 4.5 and 7.2 times as a result of logging roads on two basins on the Olympic Peninsula. Road-related mass wasting activity contributed 28% of the total fine sediment yield in one basin and 38% in the other. The average total fine sediment yield for these two Olympic Peninsula basins was 0.51 tons/acre/year. About 1/3 or .17 tons per acre per year of sediment were produced by road related mass wasting. About .34 tons per acre per year of sediment was produced by other factors; including non-mass wasting road related erosion, other forest management activities and natural erosion.

Ryan[5] (personal communication) has studied sediment yields from four drainages in the Capitol Forest not subject to extensive mass wasting. Each of these drainages has experienced a wide range of forest practice activities, including road construction and timber harvest. The average fine sediment yield from these four drainages for the period 1982-1986 was 0.14 tons/acre/year.

Reversibility

In general, the process of taking land out of commercial forest production is an irreversible process. However, erosion from roads will return to background or near background levels after the roads are no longer used. Proper road abandonment procedures need to be used before background levels of sediment production can be achieved.

Scale

The extent of the road systems on forest land in Washington has not been inventoried. However, Geppert et al. (1984) suggested the total may be as high as 8% of the acres which have been harvested.

Sensitivity

A comparison of the fine sediment yield data from the Olympic Peninsula and the Capitol Forest indicates that total production may be 3 to 4 times higher in basins on the Olympic Peninsula. This difference reflects a significantly higher mass wasting potential, both road-related and natural, in the steeper mountainous portions of the Olympic Peninsula Province in comparison to the Capitol Forest and much of the rest of the Willapa Hills Province.

The average of 0.51 tons/acre/year of fine sediment production for basins on the Olympic Peninsula and 0.14 tons/acre/year for basins in the Capitol Forest is well below the 2 to 5

[5] James Ryan is a Forest Hydrologist with the Forest Land Management Division, Department of Natural Resources, Olympia, Washington.

tons/acre/year which has been accepted as tolerable from agricultural land by the U. S. Department of Agriculture. Patric et al. (1984) believe that a sediment yield not greater than 0.25 tons/acre/year from minimally disturbed forest land provides a prediction level suitable for planning purposes in many forested regions of the United State. They feel this figure may be low for forested regions of the Pacific Coast where the potential for mass wasting activity is greater.

B.4.b. <u>Timber Harvest</u>

Currently between 75 and 80 percent of the forest land in Washington is available for harvest and represents the commercial forest base. About 80 percent or 13 million acres have been harvested one or more times.

This section will examine the impacts of harvest on forest land which include;

1. Increased soil erosion
2. Increased soil compaction
3. Reduction in species diversity
4. Reduction in structural diversity
5. Changes in soil chemical properties.

<u>Severity</u>

In general, sedimentation on large blocks of managed forests is relatively low and averages about 0.25 ton/acre/year in the Pacific Northwest (Patric, 1984). However, it appears that these estimates are for drainages which contain harvested and non-harvest areas. Shumway (1984) estimated potential on site erosion at between 0.5 and 1.5 tons/acre the first year following clearcut harvesting at one site near Olympia.

Harvesting stands older than about 60 years causes a reduction in the species diversity of forest land. Geppert et al (1984) presented data which illustrated that as stands progress in successional development they tend to become more diverse. Late successional stands generally exhibit the greatest functional and structural diversity. Harvesting reduces this diversity. The reduction is least in young seral stage and greatest in older late successional stands.

Increases in bulk density of soils are most directly related to the harvest technique and to the soil's condition when harvest occurs. The factors affecting increases in bulk density include: 1. standing ground pressure and vibration; 2. frequency of passage across the compacted area; 3. the soil moisture content; 4. degree of aggregation; and 5. organic matter content.

Geppert et al. (1984) reviewed the literature on compaction and concluded;
"Timber harvest results in some level of compaction. Whether this leads to decreased site productivity depends on how much land is disturbed as compared to the density of stems required to fully occupy the site. We believe that only tractor logging is of present concern, and probably only if repeated entries are planned."

Harvesting can profoundly change the nutrient status of forest soils. The most significant changes occur during and after the harvest of old growth forests. Subsequent changes with repeated harvests are generally less pronounced and depend on the interval between harvests and the volume of material removed at each harvest.

Harvesting of old growth from the commercial forest lands causes greatest change on the chemical properties of forest soils. In general, second growth forests will have a thinner forest floor, reduced soil organic matter, proportionally more nutrients will reside in the mineral soil, and nutrient cycling will be faster (Long, 1982: Turner, 1975).

Reversibility

These changes in soil chemical properties have occurred to varying degrees on a majority of the commercial forest lands in Washington.
Geppert et. al. (1983) reviewed the literature on the effects of harvesting on chemical properties of forest soils and concluded:

> " Stem only harvesting at rotations in excess of about 60 years will probably not cause persistent changes to the nutrient cycle that will reduce tree growth. However, repeated whole-tree harvest and shortened rotations will likely deplete soil nutrients on most Washington soils. On poorer sites, lower utilization standards or longer rotations will be necessary to maintain productivity."

It seems likely that, with regard to nutrients, the commercial forest lands of Washington will remain among the most productive forests in the world through the year 2010 and beyond.

The changes in species diversity and chemical properties as a result of harvesting old growth, on the other hand, do not appear to be reversible except over a long time span.

Scale

The number of acres harvested each year has varied considerably over the past three decades (Geppert et al., 1984). In 1986 for example, about 219,000 acres were clearcut or receive a final harvest and about 116,000 acres received a partial cut.

About 6 billion board feet of timber are harvested annually in Washington, but harvest levels have ranged from about 4 to 7 billion feet since 1950 (Larson[6], personal communication). Harvest levels have exceeded 7 billion board feet only three times in the 38 years between 1950 and 1988 (Figure 3).

Although estimates of the maximum sustainable harvest in Washington vary, two recent

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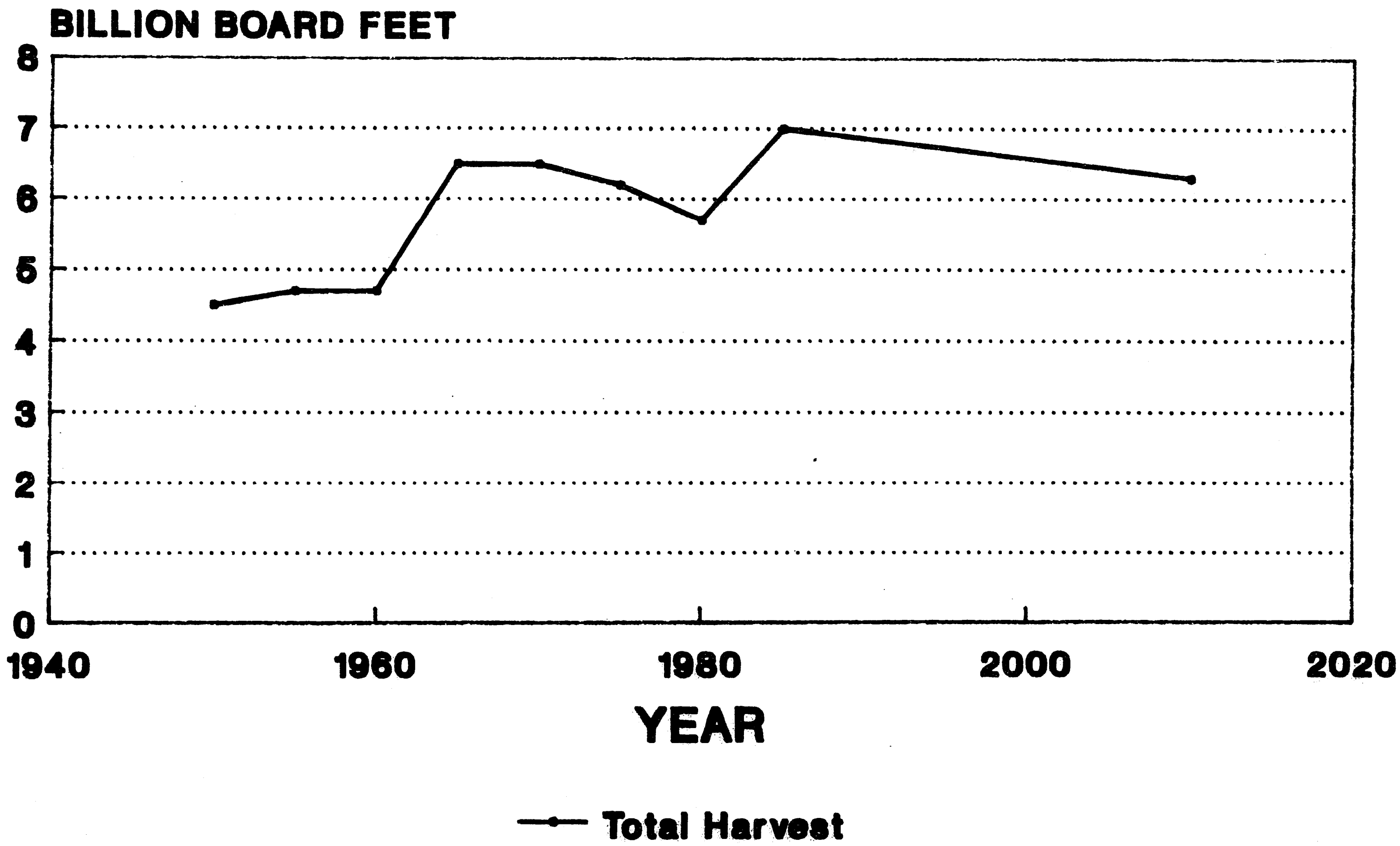
[6] Natural Resource Scientist with the Department of Natural Resources.

Figure 3.-ANNUAL HARVEST LEVEL IN WASHINGTON STATE



SOURCE: Washington State D.N.R

estimates are 7.1 and 7.5 billion feet per year[7,8]. Historically, harvest levels have been below these two estimates except on a few occasions.

Sensitivity

In general, the old growth forests are most sensitive to harvest and sensitivity is less in mature seral stage stands. It should be pointed out that all stands are to some degree sensitive to impacts of harvesting. This sensitivity can be increased considerably if poor harvesting practices are employed.

B.4.c. Slash Burning

Prescribed burning of logging slash has long been a common silvicultural activity in Washington. Fire hazard reduction and site preparation for reforestation have been the primary reasons for prescribed slash burning in modern silvicultural practice.

The impacts of prescribed slash burning include the following:

1. Slash burning can increase the potential for erosional processes.

2. Slash burning may impact plant community development.

3. Slash burning may impact potential productivity of a site.

Severity

Intense burning, whether from wildfire or prescribed slash burn, increases the potential for surface erosion. Burning increases the potential for surface erosion by removing the organic forest floor and exposing mineral soil. Formation of water-repellent soil surfaces during burning may also reduce infiltration rates and increase the potential for surface flow and surface erosion. Steep slopes and thin forest floors increase the potential for surface erosion to occur following prescribed slash burns.

Fire can accelerate plant succession, cause retrogression, or act as the renewal agent necessary to perpetuate vegetative cycles. Prescribed slash burning may remove all existing vegetation and convert a site to a successional stage which favors the establishment and growth of early

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[7]Personal communication C. J Chambers and B. D. Scott Department of Natural Resources Biometrician and Economist respectively, Olympia WA.

[8]Official estimates of the potential sustainable harvest for all forest lands in the Washington are not available. These values are based on estimates of the current amount of commercial forest land in Washington and its productivity. Changes which may occur in the future were not considered in this analysis.

successional species. Plant succession is basically dependent upon the effect of fire on the soil condition, and the condition of the residual vegetation and/or the seed source (Boyer and Dell, 1980).

The magnitude of the impacts of prescribed slash burning on potential productivity are dependent upon factors such as soil properties, topography, fire intensity, and fire frequency. Those ecosystems with the lowest potential productivity levels are those on which the impacts of slash burning are likely to be the greatest.

Reversibility

Martin, et al. (1974) indicate that moderate slash burning disturbances may occur many times without moving the plant community forward or backward in succession, but that severe disturbances will move the system toward earlier successional stages.

Alterations in soil properties due to prescribed slash burning have an impact both plant community development and potential productivity on a site. Reversibility of the impacts to plant community development and potential productivity is influenced by the original soil properties and the degree to which these soil properties are altered by prescribed slash burning. Geppert, et al. (1984) state that nutrient losses and shifts in chemical properties caused by prescribed slash burning will recover rapidly on most sites.

Scale

Prescribed slash burning occurred on 34,036 acres in Western Washington during 1987 (Carnine, 1988). This represented 40 percent fewer acres than was burned in 1884, the last peak year.
Carnine indicates that this decline in slash burning was influenced by several factors: 1. Three consecutive years with extended periods of high fire danger restricted the number of burn days; 2. Most logging on private and state ownership is conducted in second growth timber which can be more fully utilized; 3. Programs have been developed to encourage use of slash residue as firewood; 4. Decisions on the need to burn slash are more commonly being made on a site specific basis; and 5. Less public tolerance for visibility impairment due to slash burning.

Prescribed slash burning in Eastern Washington totaled 47,282 acres in 1987 (Carnine, 1988). This represented a 12 percent increase in acres, and a 13 percent decrease in tons of slash burned compared to 1986. Tons of slash burned during 1987 were 54 percent less than the last peak year of 1984. Generally, smoke management problems in Eastern Washington are minor since highly populated areas are few and most burn locations are remote. Carnine indicates that prescribed burning in Eastern Washington is expected to slowly decrease, a direct reflection of harvesting levels and weather conditions.

Sensitivity

Factors which can significantly increase the sensitivity of a site to the impacts of prescribed slash burning include: 1. Steep topography; 2. Thin organic litter layers; 3. Erodible surface soils; and 4. Low potential productivity.

B.4.d Reforestation

Reforestation can be by either natural or artificial methods. Prior to the mid-1950's, nearly all forest land in Washington was reforested naturally from seed. After the mid-1950's, planting became an important regeneration method and soon became the dominant method in western Washington. Reforestation, in particular planting, has:

1. Reduced genetic diversity
2. Reduced species diversity.

Severity

Planting practices on commercial forest land are varied. Among the silvicultural objectives are:

1. Rapid reforestation and revegetation of the site to reduce the environmental effects of timber harvesting; and
2. Rapid value growth into a harvestable timber stand.

Meeting these objectives commonly mean that seral species are planted in preference to climax species. This reforestation process contributes to a reduction in the genetic and species diversity. However, the relationship between acres planted and decrease in species and genetic diversity is not a direct one because natural regeneration occurs in many plantations throughout Washington. However, if current reforestation practices continue and genetically improved varieties of commercially important species are planted at a greater rate, genetic and floristic diversity of forest lands will decline slightly.

Reversibility

However, these trends are not irreversible. Planting can be combined with natural regeneration or several species adapted to a specific site can be planted to help reduce these effects.

Scale

Most of the 200,000 acres clearcut harvested each year are probably regenerated by planting seedlings. Currently, most of the seedlings which are planted come from seed collected in old growth and second growth stands in Washington. This contributes to the genetic diversity of the new stands. Because of the general interest in genetically improved seedlings, their use will probably increase. With this increase will come a small reduction in the genetic diversity of Washington's forests.

Sensitivity

All ecosystems which are planted can be affected. The least sensitive ecosystems are those where environmental characteristics favor natural regeneration.

B.5 Productivity/Uniqueness

Each of the ecosystems present in the State of Washington is unique in some respect. Each exhibits some unique combination of climate, soil, topography, plant and animal life. Overall, the forest lands in the state are among the most productive in the world. This high level of productivity makes Washington forest lands special. Late successional forests in Washington have declined since the 1930's. This decline, coupled with the sensitivity of these forests to man's activity, add to the uniqueness of these ecosystems.

Uncertainty

Most of the data used in this analysis lacks the quality necessary for precise analysis. Acreage figures for the amount of old growth and forest land in Washington are very imprecise. Numbers produced by one source may vary from estimates from other sources. Studies on the environmental effects of the use of forest land are seldom replicated to include the diversity of environmental conditions found in Washington. In some instances, the results apply only to extreme conditions.

The high level of variability in the data allows for only estimates of the potential impacts. Interpretation of the data was done to present data ranges and averages for existing conditions.

Structure and Anatomy of the Risk

Forest land is important to the state because it comprises about half of the total land base. The people of the state depend on this land for jobs both in the forest products, and recreation and tourism industries. In addition, forest areas are used as a playground, a source of water, wildlife, lumber, building and industrial sites, wilderness experience and habitat for old growth dependent species. In the past, when the population was smaller and the forest land base larger, forest lands could quite easily be all things to all people. However, the rapid rate of population and the decline in the forest land base produce conflicts amoung the people who use forest lands.

Some people want more old growth and wilderness to provide more habitat for old growth dependent species and more area for pristine recreational experiences. Others want more camp grounds, hiking, biking and horseback riding trails. Others want more forest products jobs or more recreation and tourism jobs.

Currently there are enough resources on our forest land base to meet the projected needs now and in 2010[9]. But, to meet these needs and maintain the quality of environment, we will need to use what we have wisely and efficiently.

Currently, Washington's forest lands are owned and managed by over 20,000 individuals, several forest products companies, Indian tribes, federal, state, county and city government entities. These landowners may have different and sometimes conflicting objectives. If we are to resolve these conflicts and reduce the stresses on our forest ecosystems, all forest land owners and managers will need to work together with users to reach mutually agreeable solutions.

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[9]The current debates relating to forest land sounds like a debate over shortage of forest resources. Today, there are 4 million acres of old growth stands in Washington including about 1 million acres of late successional. Much of this acreage is preserved in parks and wilderness areas. Including non commercial forest areas, it is reported that 5.4 million acres of forest lands are reserved for special use. The political and technical debate has been over whether this is enough.

A more productive focus would concentrate on allocating and managing this state forest land resources to fill the stated needs. Through cooperation of all forest land owners in the state, it is possible to enhance the values of existing preserved lands with little adverse effects on commercial forest production. For example, seral stage old growth which is preserved could be exchanged for climax old growth which is currently on the commercial forest base. Land exchange, land purchase and land use agreements are some of tools which can be used to make the disired allocation.

Bibliography

Boyer, D. E. and J. D. Dell. 1980. Fire Effects on Pacific Northwest Forest Soils. USDA, Forest Service, Pacific Northwest Region, Portland, OR. 59p.

Carnine, G. 1988. Washington Smoke Management Program, 1987 Annual Report. Washington State Department of Natural Resources, Division of Fire Control, Olympia, Washington. 50p.

Geppert, R. R., C.W. Lorenz and A. G. Larson. 1984. Cumulative Effects of Forest Practices on the Environment: A State of the Knowledge. Washington State Department of Natural Resources, Division of Private Forestry and Recreation, Olympia, Washington.

Lehmkuhl and Ruggiero. 1989. Abstr. In:The Old Growth Forest: Wildlife Communities and Habitat Relationships. U.S Forest Service, Pacific Northwest Experiment Station. Portland, OR.

Long, J. N. 1982. Productivity of Western Washington Coniferous Forests. In: R. L. Edmonds (ed.). Analysis of Coniferous Forest Ecosystems in the Western United States. US/IBP Synthesis Series 14. Hutchenson Ross, Stroudsberg, PA. pp 89-125.

Martin, R. E., H. E. Anderson, W. D. Boyer, J. H. Dietrich, S. N. Hirsch, V. J. Johnson, and W. H. McNab. 1979. Effects of Fire on Fuels. General Technical Report WO-13. USDA, Forest Service, Washington D.C. 64 p.

Melton W. R. 1936. The Timber Industry in Washington. National Youth Administration, National Youth Study No. 1. Washington Building, Tacoma, WA.

Morrison P. H. 1988. Old Growth in the Pacific Northwest: A Status Report The Wilderness Society, 1400 Eye St. N.W. Washington, D.C.

Nickelson J. 1988. Timber Facts for Washington. Pacific Lumber and Shipping, Portland, OR.

Patric J. H., J. O. Evans and J. D. Helvey 1984. Summary of Sediment Yields from Forested Lands in the United States. Jour. For. 82:2 101-104.

Reid L. M. 1981. Sediment Production From Gravel-Surfaced Forest Roads, Clearwater Basin, Washington. University of Washington, College of Fisheries, Fisheries Research Institute. Seattle, WA.

Shumway, J., K. Schlichte and J. Ryan 1988. Surface Soil Disturbance and Changes in Soil Properties After Felling and Yarding of Fuelwood Using a Small Cable Yarder. Department of Energy, Biomass Energy Program. Portland, OR

Spies. 1989. Abstr. In:The Old Growth Forest: Wildlife Communities and Habitat Relationships. U.S Forest Service, Pacific Northwest Experiment Station. Portland, OR.

Turner, J. 1975. Nutrient Cycling in a Douglas-fir Ecosystem with Respect to Age and Nutrient Status. Ph.D. Dissertation, Univ. of Wash. Seattle, WA.

USDA, 1983. Soil Survey of Snohomish County Area Washington USDA, Soil Conservation Service, Spokane WA.

USDA, 1988. Final Supplemental to the Environmental Impact Statement for an Amendment to the Pacific Northwest Region Guide. Vol 1. USDA, Forest Service, Pacific Northwest Region, Portland, OR.

USDI, 1976. Final Environmental Impact Statement Mount Rainier National Park/ Washington. U. S. Department of the Interior, National Park Service, Mount Rainier National Park, Ashford, WA.

WSPC, 1983. Washington's Statewide Comprehensive Outdoor Recreation Plan. Washington State Parks and Recreation Commission. Olympia, WA.

THE STATE OF THE ENVIRONMENT REPORT

VOLUME III
Part 20

Risk Evaluation Reports for Nonchemical Impacts on Recreational Lands

ENVIRONMENT 2010

State of Washington
October, 1989

ECOLOGICAL RISK ASSESSMENT: NON-CHEMICAL THREATS TO RECREATION LAND

I. INTRODUCTION

This analysis examines the ecological risks to recreation lands posed by non-chemical threats. Such activities as road-building, mineral recovery, and development cause physical changes in the environment, and may cause a loss or degradation of habitat. This report may overlap with other Environment 2010 risk assessments covering litter, air pollution, wetlands, and forest lands.

Public recreation land in Washington, for the purposes of this report, falls into four broad categories--Urban/Rural, Roaded, Semi-Primitive, and Primitive. These categories generally follow the Recreation Opportunity Spectrum described by the US Forest Service. This report does not consider private recreation lands.

The Urban/Rural areas are managed by local agencies including cities, counties, school districts, park and recreation districts, utility districts, and Indian Tribes. These areas typically include ballfields, picnic grounds, boat launches, and other city park amenities.

The Roaded areas include both natural and modified acres. The natural acres have moderate human evidences that usually harmonize with the natural environment. Facility design accomodates passenger cars. The modified acres have more human evidences--modifications such as dams, and resource extractions such as clear cuts--but these areas generally do not provide for cars. State agencies managing Roaded areas include the Departments of Fisheries, Wildlife, Natural Resources, and Washington State Parks. Federal agencies managing Roaded areas include the US Forest Service and the National Park Service.

The Semi-Primitive areas includes both motorized and non-motorized acres. Interaction between users is low, but there is often evidence of other users. On-site restrictions and controls are minimal--fire rings, hardened campsites, signs. These are typically backcountry areas, and some are open to off-road motorcycles. Management prescriptions do not preclude multiple uses that are incompatible with recreation uses, and at some point these acres may be redesignated for timber harvest, grazing, or mineral extraction. The US Forest Service manages most of the land in this category.

Primitive areas are essentially unmodified, and free of human-induced restrictions and controls. Interaction between users is usually low, and evidence of others is (or should be) minimal. Motorized use is not permitted. All of the primitive recreation in the state takes place on federal land designated as Wilderness by Congress, and managed by the US Forest Service, the Bureau of Land Management, and the National Park Service. The over four million acres of primitive land overstates the amount of recreation land available to most users. The season of use for Wilderness areas is July-October. In addition, in most of the Wilderness areas only 4-5 percent of the land is at a grade less than 35 degrees--too steep for most people to use.

Table 1 summarizes the inventory of recreation land in the state in the four main categories. This inventory includes only those lands dedicated to recreation use, with the exception of the Semi-Primitive land, which is currently managed for recreation use, but which is actually multiple-use land. The US Forest Service, which manages most of the Semi-Primitive land, has, by management prescription, the option of designating this land for resource extraction.

TABLE 1
INVENTORY OF RECREATION LANDS

Land Category	Acreage	Percentage	Management
Urban/Rural	82,093	1.06%	Local
Roaded	984,815	12.70%	State
	1,268,330	16.35%	Federal
Semi-Primitive*			
Motorized	250,563	3.23%	Federal
Nonmotorized	918,275	11.84%	Federal
Primitive**	4,252,344	54.82%	Federal
Total	7,756,420	100.00%	

* Semi-Primitive land managed by US Forest Service is multiple-use land; this acreage may overstate the actual amount of land dedicated to recreation use in the future.

** The Primitive acreage overstates the available land for recreation--much is inaccessible for part of the year because of weather conditions, and some of it is so steep that few people can use it for recreation.

Source: IAC files

II. ANALYTIC APPROACH

This analysis presents an inventory of recreation land in the state, reviews the various sources of potential threats to that land, provides case study illustrations of recreation land loss and degradation, and attempts to capture the total ecological risk by scaling up from known cases.

Several sources represent potential ecological threats to recreation land--resource extraction (timber harvest, mineral recovery), concentrated use, misuse, urbanization, development, and road-building. Table 2 summarizes these sources and their potential ecological effects, both direct and indirect, on recreation land within the four land categories. Direct effects are those that result from the source activity--the degradation of recreation land by resource extraction activities, for example. Indirect effects are the consequences of recreation shifts resulting from a source or from a direct effect. Urbanization and development, for example, may lead to more concentrated use of recreation land, which in turn results in degradation.

This shifting of recreation demand is an elusive idea. Different recreation users will adjust their recreation activities in different ways. The loss of Semi-Primitive land to recreation use resulting from timber harvesting, for example, may lead some users to shift their activities to Roaded lands. The increase of users in Roaded land may lead to additional shifts in recreation activities by other users.

There is no particular rule or governing hierarchy of recreation demand decision-making. Surveys conducted by the Interagency Committee for Outdoor Recreation (IAC) suggest that many users prefer less developed recreation areas. This stated preference, however, does not necessarily translate into behavior. A user may prefer a less developed area, but may not go to one for any of a number of reasons--not enough time, lack of information, or the comfort of familiar places.

This analysis is interested in recreation demand shifts only as a consequence of one or more of the sources of ecological threats (resource extraction, concentrated use, et. al.), and only to the extent that these shifts result in additional ecological threats. Changes in the availability of the different kinds of recreation land are important to the managers of these lands, to recreation planners, and to users. This report, however, focuses on ecological threats, and concerns itself with the loss of habitat as opposed to the loss of recreation land to recreation use.

The term "loss" implies a permanance that is not accurate in all cases. The historical loss of habitat on recreation land resulting from development may be permanant for all practical purposes, but the loss of habitat to resource recovery activities may be only temporary if the environment is allowed to recover. That is, when the resource extraction activity is completed, the land may eventually revert to a condition similar to its original condition and may become available once again for recreation uses. In the case of timber harvesting, for example, the harvested area can eventually become a second growth forest. In this illustration the effect of the loss of habitat is to some extent reversible--the second growth--but the recovery period takes 40 years.

TABLE 2
POTENTIAL ECOLOGICAL EFFECTS ON RECREATION LANDS BY VARIOUS SOURCES

Source	Land Category	Direct Effect	Indirect Effect
Resource Extraction*	Urban/Rural	None	None
	Roaded	Loss/Deg.**	Degradation
	Semi-Primitive	Loss/Deg.	Degradation
	Primitive	None	Degradation
Concentrated Use	Urban/Rural	Degradation	Degradation
	Roaded	Degradation	Degradation
	Semi-Primitive	Degradation	Degradation
	Primitive	Degradation	Degradation
Misuse	Urban/Rural	Degradation	None
	Roaded	Degradation	None
	Semi-Primitive	Degradation	None
	Primitive	Degradation	None
Urbanization/ Development	Urban/Rural	Loss	Degradation
	Roaded	Loss	Degradation
	Semi-Primitive	Loss	Degradation
	Primitive	None	Degradation
Road-building	Urban/Rural	Loss	Degradation
	Roaded	Loss	Degradation
	Semi-Primitive	Loss	Degradation
	Primitive	None	Degradation

* Resource extraction includes activities such as timber harvesting and mineral recovery.

** In this context, "Loss" refers to loss of habitat. Degradation includes such adverse effects as sanitation problems, destruction of vegetation, and disruption of wildlife.

*** There are no direct effects because the activity is prohibited.

Table 2 is an overview of the potential ecological effects of the various sources of threats. There is nothing inevitable about the outcome of every activity--urbanization does not necessarily lead to the degradation of habitat on Semi-Primitive land, for example. This overview simply provides the structure of the analysis. The case studies that follow illustrate the actual effects.

The Indirect Effect column in Table 2 tries to capture the consequences of shifts in recreation demand. The Resource Extraction source, for example, shows an indirect effect on Primitive land, namely, degradation. This indirect effect comes from the shift from other recreation lands that are lost or degraded by the resource extraction activities. In other words, this degradation would be the result of the direct effect of concentrated use and the indirect effect of resource extraction.

The sources identified in Table 2 are the most common threats to the ecosystems of recreation lands; they are not necessarily the only threats. The analysis here is limited to these threats, and the case studies do not consider all of the sources. The analysis is further limited to the activities actually conducted on the various recreation lands. Timber harvesting on adjacent lands, for example, falls outside the boundaries of this study even though such activity could have an ecological impact on the recreation land.

The case studies examine the effects of concentrated use on Urban/Rural, Roaded, and Primitive lands. The underlying assumption of this approach is that the case illustrations adequately represent the universe of recreation land within each of the specific land categories. Professional judgment supports the validity of this assumption. The approach to scaling up is to follow the underlying assumption, and to apply the findings of one case to the universe of recreation land represented by that case. Both the available information and the judgment of recreation professionals favor this treatment--the data are good, and concentrated use is posing the greatest threat to ecosystems on recreation lands.

In addition to the concentrated use case illustrations, this report also includes a discussion of the effects of urbanization and development, road-building, resource extraction, and misuse. The data sources for this report include IAC studies, interviews with key recreation professionals, and a literature review.

III. FINDINGS

The findings of this report are summarized in the following highlights:

Concentrated use currently poses the most serious ecological threat to recreation lands, especially to Primitive lands.

The most serious effect of concentrated use is degradation of habitat--sanitation problems, destruction of vegetation, disruption of wildlife.

The most significant consequences of urbanization and development are indirect--the increase in use of already overused areas.

Additional use pressure on any recreation land represents additional pressure on all recreation lands. Users shift their recreation activities in response to changing conditions, and concentrated use in one area can result in some users moving to another area.

Road-building and resource extraction are the most significant future threats to Semi-Primitive lands. The management plans of the US Forest Service include projections for timber harvesting, which along with the attendant road-building, results in significant changes in habitat and disruptions of wildlife.

The ecological damage that has occurred on Washington state recreation lands is reversible. Some habitat degraded by overuse recovers in 1-3 years; more sensitive ecosystems have longer recovery periods. The effects of resource extraction last much longer.

Semi-Primitive recreation land is at or approaching capacity use. The development of more trails in Semi-Primitive land would relieve this pressure, and provide potential relief from concentrated use in Primitive lands.

Resource extraction, on the lands considered in this study, is not a threat at present.

A. Concentrated Use

The term "concentrated use" may be defined as overuse--the result of more people trying to use a facility than the facility is designed to accomodate. The same concept applies to the land itself, that is, there is a capacity of the trails, fields, and other outdoor areas, and when use exceeds capacity the result is overuse. This analysis considers the concentrated use issue within each of the four land categories. Tables 3 and 4, taken from the State of Washington Office of Financial Management 1987 Data Book, provide some background figures on use in state and federal parks in Washington.

TABLE 3

ATTENDANCE AT WASHINGTON STATE PARKS

(Annual Attendance)

Park	Area in Acres	1981	1982	1983	1984	1985	1986
Belfair	59.76	430,078	281,373	163,499	296,765	351,434	354,371
Birch Bay	193.21	959,889	1,016,543	1,247,557	1,169,946	1,121,752	954,591
Deception Pass	2,477.29	1,971,291	2,075,270	2,514,933	2,388,930	2,960,258	3,182,477
Dosewallips	424.50	441,539	446,880	373,621	345,772	463,318	463,717
Flaming Geyser	519.94	565,216	504,591	498,189	472,094	670,235	500,692
Fort Canby	1,881.93	728,018	554,564	614,199	513,385	504,516	572,570
Fort Worden	340.56	1,035,285	962,124	381,286	596,745	554,924	433,656
Illahee	74.54	547,493	586,900	664,618	684,080	580,751	655,202
Lake Osoyoos	40.96	538,721	248,590	508,473	510,738	311,512	449,265
Lake Sammamish	431.65	1,294,179	1,309,381	1,398,095	1,149,686	1,568,041	1,528,920
Mukilteo	14.00	1,475,748	1,404,117	1,388,319	1,257,292	1,150,689	1,201,719
Ocean Beaches							
Long Beach	-	1,661,101	2,059,722	2,347,925	1,640,171	2,305,789	3,049,228
North Beach[1]	-	2,912,393	2,605,597	2,541,279	1,873,988	3,210,760	5,065,870
South Beach[2]	-	2,263,750	2,093,539	2,661,454	2,913,722	3,521,336	3,364,070
Peace Arch	20.95	805,655	653,292	719,577	671,504	652,816	1,133,605
Riverside	6,443.10	1,321,044	1,271,619	1,113,850	1,199,433	1,183,057	1,363,741
Saltwater	87.84	760,894	571,117	969,808	691,299	684,273	606,046
Sequim Bay	91.54	861,432	881,642	912,942	934,449	811,216	842,010
Twanoh	182.02	409,400	442,192	451,144	486,646	396,576	720,721
Twin Harbors	172.09	562,161	490,242	455,188	429,976	344,764	544,997
Westhaven	79.06	572,982	930,392	1,304,482	1,022,416	808,582	651,962
All Others[3]	219,985.56	17,441,277	18,306,452	20,359,301	21,747,205	23,196,544	21,371,129

[1]Ocean beach use from Cape Flattery to Damon Point.
[2]Ocean beach use from Westport to Ilwaco.
[3]Total acreage and attendance for the 178 areas not listed.

Table: VT02
Source: State Parks and Recreation Commission

TABLE 4 ATTENDANCE AT FEDERAL PARKS LOCATED IN WASHINGTON STATE

(Figures in Thousands)

Calendar Year	1978	1979	1980	1981	1982	1983[2]	1984	1985	1986
Coulee Dam National Recreational Area	716.5	789.0	835.6	875.6	821.6	667.8	624.4	519.4	800.2
Ft. Vancouver National Historical Site	224.1	203.6	198.7	273.6	243.4	247.2	277.8	270.0	287.6
Klondike Gold Rush -Seattle Unit- National Historical Park	-	37.6	48.4	56.2	53.1	52.5	62.8	145.5	157.2
Mt. Rainier National Park	2,094.1	1,981.4	2,001.0	1,964.9	1,536.0	1,582.2	1,669.2	1,638.8	1,830.8
North Cascades National Park Service Complex[1]	931.4	765.1	819.2	865.8	880.4	722.4	640.8	631.5	685.6
Olympic National Park	2,996.6	2,589.4	2,482.3	2,754.5	2,952.9	2,875.3	3,260.6	2,983.2	3,474.7
San Juan Island National Historical Park	76.7	92.4	103.4	101.6	113.4	122.6	99.4	104.3	137.0
Whitman Mission National Historical Site	106.5	119.5	98.9	97.9	98.7	109.0	106.1	105.0	110.8
Total	7,145.8	6,578.0	6,587.6	6,990.2	6,699.5	6,379.0	6,741.1	6,397.7	7,483.9

[1] Includes Ross Lake and Lake Chelan National Recreational Area.
[2] Estimated.

Note: Totals may not add due to rounding.

Table: VT03
Source: U.S. Department of Interior, National Park Service Seattle Regional Office

1. Concentrated Use on Urban/Rural Recreation Land: Greenlake

Greenlake is one of the most popular and intensively used parks in the city of Seattle. Centrally located and in the heart of a residential area, Greenlake provides recreation activities for sports teams, walkers, bikers, skaters, skate-boarders, picnickers, and others. A three-mile path around the lake is so popular that a public debate has arisen over the conflicting uses--some users want to ban bikes and skate-boards from the path.

Greenlake is representative of well-established city parks in that the recreation areas are developed for intensive use, and that the park is highly managed. There are no particularly sensitive ecosystems of concern, and any adverse ecological effects result more from misuse than from overuse--temporary degradation from litter, possible contamination of the lake, and damage to trees. Some local parks may include recreation lands that are part of more sensitive ecosystems--feeding grounds for threatened species, for example--but for the most part, Urban/Rural recreation lands are already highly developed, and the serious ecological effects occurred some time ago.

Table 5 displays in summary form the results of the ecological risk assessment of concentrated use on Urban/Rural recreation lands.

TABLE 5
SUMMARY OF RISK ASSESSMENT RESULTS
CONCENTRATED USE ON URBAN/RURAL RECREATION LANDS

Intensity of Impact: The ecological effects are modest, primarily because the lands are developed for intensive use.

Reversibility: Management options, such as closing areas to allow for regeneration, along with the low level of ecological damage, insure that the effects are reversible over time.

Scale: All local parks are subject to potential overuse, and most are experiencing overuse at least some of the time.

Sensitivity: The Urban/Rural recreation lands are not particularly sensitive, except those that may be part of larger ecosystems and may serve as habitat for threatened species.

Trend: The pressures of population growth and development are increasing the incidence of overuse.

Uniqueness: There are no known effects on ecosystems of unique values.

Uncertainty: This assessment is based on sound data and extensive experience of recreation managers.

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2. Concentrated Use on Roaded Recreation Land: Paradise

Paradise is a popular area within the Mt. Rainier National Park. Approximately 1.5 million visitors use the West entrance to the park each year, and of these, 75-80 percent drive up to Paradise. Located at an elevation of 5400 feet, the Paradise area includes an Inn with overnight accomodations and food service, and a Visitors' Center that has an auditorium, gift shop, exhibit rooms, and an observation deck. Day hikers to Camp Muir and climbing parties to the summit depart from Paradise, but most of the recreation activities are short trail hikes in the immediate vicinity. The longest trail loop in the area is five miles. The season runs from

June through mid-October.

The alpine meadows in the Paradise area started showing signs of degradation as early as the 1920s, and by the mid-1960s the Park Service initiated efforts to stop further damage. Most of the damage resulted from the trampling of vegetation where visitors left marked trails to take shortcuts or to investigate something of interest--flowers or snowfields, for example. The first corrective measure was the paving of some short trails in an attempt to define where visitors should walk.

The paving did not arrest the degradation, and over the years the Park Service has intensified its efforts to include the reinforcing of more trails, the posting of warning signs, and the roping off of sensitive or damaged areas. The park Service also began active efforts to rehabilitate the meadows. These efforts include bringing in topsoil, operating a greenhouse for the propagation of indigenous plant species, and the replanting of damaged meadows. In recent years the Park Service has been spending up to $60-80,000 per summer on these activities.

The struggle continues. For all the Park Service's attempts to prevent further degradation, visitors still leave the marked trails, and despite years of work, the alpine meadows have still not recovered. This is a particularly sensitive ecosystem of fragile plant life vulnerable to human intrusions as well as to natural phenomena--wildlife and storms can also damage this environment.

The main source of the ecological degradation is human activity, but whether to characterize this source as concentrated use or misuse is a close call. Visitation is clearly heavy, but the environmental damage does not necessarily follow from the intensiveness of use. If all the visitors stayed on the marked trails, the meadows would have the opportunity to recover. Likewise, a reduction in the number of visitors would not necesarily lead to a reduction of the damage. Users could continue to leave the trails and destroy the vegetation. These arguments notwithstanding, this report characterizes the source of ecological damage to the alpine meadows at Paradise as concentrated use.

How well the Paradise case represents the general conditions on Roaded recreation lands is a complicated issue. The basic dynamic is the same everywhere--the pressures of overuse (or misuse) are likely to evidence themselves in some form of environmental damage. But the alpine meadows are extremely fragile, and that ecosystem does not recover from damage nearly so easily as other ecosystems might. Other Roaded recreation lands in the state include such diverse areas as rainforests, deserts, and ocean beaches. These different ecosystems may be fragile in their own ways, and the management measures taken to aid in recovery from ecological damage may vary from place to place. The point for the purposes of this report is that whatever the differences in the ecosystems' sensitivity and ability to recover from damage, they are all vulnerable to the effects of overuse. According to the professional judgment of recreation planners, concentrated use threatens virtually all Roaded recreation land in Washington. Table 6 summarizes the analysis.

TABLE 6
SUMMARY OF RISK ASSESSMENT RESULTS
CONCENTRATED USE ON ROADED RECREATION LANDS

Intensity of Impact: The degradation of the alpine meadows is extreme--vegetation has been devastated.

Reversibility: Despite the best efforts of the Park Service, the meadows have not recovered, but the reason for the failure to recover is that visitors are still trampling the meadows.

Scale: The damage at Paradise is confined to the areas in the immediate vicinity of the Inn and Visitors' Center. Other Roaded recreation lands may experience a different pattern of degradation from concentrated use. Virtually all of the Roaded recreation lands in the state are at risk from concentrated use.

Sensitivity: The alpine meadows are fragile, the plant life extremely vulnerable. Other Roaded recreation lands have similiarly sensitive--albeit different--ecosystems.

Trend: The pressures of population growth and development are increasing the incidence of overuse.

Uniqueness: There are several ecosystems of unique values--alpine, desert, and ocean, for example--within Roaded recreation lands.

Uncertainty: The experience at Paradise does not apply across the board to all Roaded recreation lands--the specific situation will vary from area to area--but all the Roaded recreation land in Washington state is vulnerable to the ecological effects of concentrated use.

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3. Concentrated Use on Semi-Primitive Land

According to the professional judgement of recreation managers, the Semi-Primitive recreation lands on the west side of the Cascades are at or near capacity use, and the Semi-Primitive lands on the east side are approaching capacity use. These lands could, nevertheless, provide some relief from the concentrated use in other land categories, especially Primitive lands. The management prescriptions that govern land uses, and the access provided by trails are the key factors.

Primitive lands, which currently experience concentrated use, are managed for preservation. In any conflict with recreation, preservation takes precedence. The development of hardened campsites and fire rings, for example, are not permitted on Primitive lands. These developments, which themselves cause ecological impacts, can also help mitigate the ecological degradation that results from overuse by constraining use to certain areas.

Semi-Primitive lands, on the other hand, are managed for multiple use including both recreation and resource extraction. Hardened campsites and fire rings are permitted, and managers may pursue this option as a strategy for containing use and mitigating ecological damage. The current use could be alleviated to a large extent by the development of more trails. Additional trails would provide more access to more Semi-Primitive land, thus relieving the growing pressure of current Semi-Primitive land use, and also providing potential relief from overuse of Primitive lands.

4. Concentrated Use on Primitive Recreation Land: The Enchantments

The Enchantments are alpine lakes, a Cascade Mountains Wilderness area roughly one mile wide and three miles long located within the Wenatchee National Forest. The Enchantments Core area is a high plateau with elevations ranging from 6785-8040 feet. Access is by foot only by one of two trails--one approximately 11 miles long with an elevation gain of 5820 feet, and the other approximately six miles long with a 4390-foot elevation gain. Until 1987 the area was drawing up to 14,000 visitors per season (June-September), and was showing the signs of overuse--sanitation problems including the danger of contaminated water, destruction of vegetation, and displacement of wildlife.

In 1987 the Forest Service began implementing a permit system designed to limit visitation to 6600 persons per season. After two years under the permit system, the Enchantments have shown marked improvement. Deteriorating areas have begun to stabilize, animal populations are rebounding, users have created no new campsites or social trails, and some social trails are beginning to disappear.

In an evaluation of the program, the Forest Service quotes the comments of one happy camper: 'The permit system works! We've been visiting the Enchantments for 15 years. Through the late 70's and early 80's we saw a rapid decline in the alpine environment. In just two years of the permit system the area is already recovering.'

The Enchantments recently implemented a permit system to limit use, but it is by no means the only Wilderness area in the state to suffer the symptoms of overuse. On the contrary, most of the Wilderness areas face the same problem, and some are expected to adopt the same solution. The experience of the Enchantments area typifies the situation in Primitive recreation lands, and professional recreation planners consider the area representative of the overuse condition in Primitive lands generally.

Table 7 summarizes the ecological risk assessment results of concentrated use on Primitive recreation lands.

TABLE 7
SUMMARY OF RISK ASSESSMENT RESULTS
CONCENTRATED USE ON PRIMITIVE RECREATION LANDS

Intensity of Impact: The degradation is serious and includes compaction of soil around trees, sanitation problems, water contamination, destruction of vegetation, and disruption of wildlife.

Reversibility: The degradation that has occurred so far is reversible. After two years of limited use, the land is stabilizing, vegetation is recovering, and animal populations are returning.

Scale: The effects of overuse are apparent at virtually all the Primitive recreation areas. All of these areas are at or near capacity. The accessible parts of Wilderness areas, however, are only 4-5 percent of the total Primitive acreage, and the overuse is confined to this smaller area.

Sensitivity: There are no known species or ecosystems of particular concern affected by overuse. The potential for effects on sensitive species or habitats, however, is present in Primitive areas.

Trend: The pressures of population growth and development are increasing the incidence of overuse.

Uniqueness: There are no known effects on ecosystems of unique values.

Uncertainty: This assessment is based on sound data and extensive experience of recreation managers.

B. Urbanization/Development

As a practical matter, public recreation lands are no longer used for new development, and as a result, urbanization and development no longer lead to a direct loss of habitat. The most important current effects of urbanization and development are indirect--the tendency to intensify use.

Urbanization and development follow (and lead) population growth and in-migration. The real problem is that more people are trying to use the same amount of recreation land. The obvious consequence is more overuse, and as the previous section makes clear, the result of overuse is degradation.

C. Road-Building

The building of roads on recreation lands is inextricably linked to the extraction of natural resources. Roads provide the access necessary for timber harvesting, and both the roads and the harvesting change the character of the environment. The building of roads and the harvesting of timber both result in habitat loss and the disruption of wildlife, but these two activities have an important long-term difference. When the harvesting is complete, the environment has the opportunity to recover in the form of a second growth forest. The smaller roads that lead to harvest areas are often abandoned until the next harvest 40-60 years later. But the main roads remain, and land that was Semi-Primitive converts to Roaded.

The loss of trails serves as an indicator of the change in environmental character that results from road-building. The Olympic National Forest, for example, has lost since the early 1940s approximately 600 miles of trails (from 900 to about 300), and the Gifford-Pinchot National Forest has lost 800 miles of trails (from 1700 to 900) over the same period. The trail miles indicate the access to Semi-Primitive recreation lands, and the loss of trail miles shows how road-building changes the character of the land from Semi-Primitive to Roaded. The ecological effects of this change are a long-lasting loss of habitat to roads, and a continuing disruption of wildlife caused by the motorized traffic and increased access.

At present, road-building is not posing a threat to Semi-Primitive recreation lands because these lands are currently dedicated to recreation. The US Forest Service, however, can allow resource extraction on these lands in the future, and the Forest Service management plans include projections for timber harvesting. Road-building therefore poses a significant potential threat to Semi-Primitive recreation lands in the future. The extent of the ecological damage will depend on where and how the actual road-building occurs.

D. Other Sources

Resource extraction, misuse, air pollution, and water pollution are other sources of ecological threats to recreation lands.

Resource extraction results in significant effects--loss of habitat, disruption of wildlife--that have long recovery times. This threat is restricted, however, to multiple-use lands, and of the recreation land considered in this report, only the Semi-Primitive lands are multiple-use. In addition, these lands are currently dedicated to recreation use. The resource extraction threat to the recreation land considered here is, therefore, a future rather than a present threat: only when the Forest Service allows harvesting, grazing, or mining on those areas currently dedicated to recreation use will there be any ecological effects from resource extraction on recreation lands.

Misuse can occur any time a recreation user fails to follow the rules of a recreation area. Misuse can include anything from littering to straying off marked trails to reckless fire-building. The potential ecological effects of misuse run as wide a range as the misuse itself--anything from temporary degradation to a forest fire. There are no reliable data on misuse of recreation lands, and recreation professionals tend to view misuse as a minor threat compared to the others treated here.

Air-borne and water borne pollutants may pose ecological threats to recreation lands, but little is known about any specific ecological effects, and an analysis of these threats falls outside the scope of this report.

IV. UNCERTAINTY

This analysis is limited in three important ways--the sources not covered, the lands not covered, and the representativeness of the cases. Each of these limits contributes something to the uncertainty of the analysis.

The sources not covered include misuse, air pollution, and water pollution occurring on recreation lands. The consequences of misuse can be catastrophic--a forest fire, for example--but in general misuse poses less of a threat than other sources. Air and water pollution are more insidious, and much more difficult to evaluate. These sources may pose a current or future threat to recreation lands, but at present there are no research findings on which to base an assessment.

This report is further limited to the activities actually conducted on recreation lands. Any of the sources--resource extraction, concentrated use, et. al.--occurring on adjacent land poses a potential ecological threat to the neighboring recreation land. In the case of timber harvesting, for example, a clear cut on the border of a Wilderness area could disrupt wildlife within the Wilderness area, and could alter certain species' movements throughout their normal range. An evaluation of those effects would rely in part on the theories of island biogeography, and would be very complex. Such an analysis falls outside the scope of this report. The importance of this omission is difficult to guage--without the analysis we cannot know much about the effects except that they may be significant.

The lands not covered in this report include both private lands that support recreation, and those multiple-use public lands that are currently dedicated to resource extraction. Private recreation lands may be lost to urbanization and development, and are vulnerable to all the other sources as well. Loss and degradation of habitat on private land are potential direct effects, and public lands may suffer indirect effects. Displaced recreation users, for example, may turn to public lands, a result that could in turn increase already existing overuse. Both the direct and indirect effects may be significant, but the extent of the significance cannot be known in the absence of an analysis.

The reliability of the case illustrations as representative of the general condition of recreation lands is a matter of professional judgment. The recreation professionals who contributed to this report, based on their knowledge of Washington state recreation lands, consider the cases to be fairly representative within the limits stated in each case analysis. As with many public policy issues, there is ample room for professional disagreement.

Washington Environment 2010

Recreation Resource Characterization and Threats Bibliography

The Report of the President's Commission on Americans Outdoors: The Legacy, The Challenge, Island Press, 1987

A Literature Review: The President's Commission on Americans Outdoors, Szwak, Laura B., U.S. Government Printing Office, 1986

State of Washington Data Book 1987, Washington State Office of Financial Management

1988 Population Trends for Washington State, Washington State Office of Financial Management

The Washington State Economy: An Assessment of Its Strengths and Weaknesses, Washington State Economic Development Board, 1987 Report to the Legislature

"Recreation, Park, and Open Space Standards and Guidelines," Lancaster, Roger A., Editor, National Recreation and Park Association

Two Decades of Progress: Outdoor Recreation 1962-1982, A 20 Year Report to the People of Washington, Felton, Gerald, Interagency Committee for Outdoor Recreation, 1982

"Final Report and Proceedings of the Governor's Conferences, Recreation and the Economy, 1982," Interagency Committee for Outdoor Recreation, 1982

Recreation Resources: A Heritage for the Future, Interagency Committee for Outdoor Recreation, 1986

Governor's Recreation Resource Advisory Committee, Final Report, Governor's Recreation Resource Advisory Committee, 1984

Washington Statewide Outdoor Recreation Plan, Interagency Committee for Outdoor Recreation, 1979

Washington Statewide Outdoor Recreation Plan, Interagency Committee for Outdoor Recreation, 1986

North Cascades National Park Final Management Plan, US Department of the Interior, National Park Service, 1988

Draft Environmental Impact Statements for Proposed Land and Resource Management Plans from the following National Forests: Colville, Gifford Pinchot, Mt. Baker-Snoqualmie, Okanogan, Olympic, Wenatchee.

THE

STATE

OF THE

ENVIRONMENT

REPORT

VOLUME III
Part 21

Risk Evaluation Reports
for
Nonchemical Impacts
on Range Lands

ENVIRONMENT 2010

State of Washington
October, 1989

Washington Environment 2010
Loss and Degradation of Rangeland
Risk Analysis

Background

This paper provides an analysis of the ecological risks associated with the loss and/or degradation of Washington State rangeland.

Loss or degradation is defined as nonchemical change which eliminates or degrades rangeland. Nonchemical changes also diminish ecological values, constrain recreational opportunities, and preclude future use options.

This analysis is limited to the ecological risks associated with rangeland loss and degradation. It must be noted, however, that the primary use of Washington rangeland is stock grazing (e.g. cattle, sheep, horses and goats). Additionally, rangeland provides wildlife habitat and that often translates into hunting opportunities for in and out of state sportsman. As a result, ecological degradation of rangeland has direct economic consequences for the state's agriculture and tourist industries.

Two categories of rangeland will be analyzed. Those are " rangeland, " as defined by the Washington State Grazing Land Assessment, Washington State University Cooperative Extension, July 1984 and " grazable forest land " (or grazable woodland) as defined in conversation with Martha Chaney a recognized expert in the field and consultant to the above referenced research effort.

According to the Grazing Land Assessment, " Rangeland is primarily covered with native vegetation and generally occurs on sites too isolated, too rough, or with soil too shallow, sandy, alkaline, or rocky for agricultural development." Grazable woodland is, " open forest with understory vegetation suitable for use as forage."

The Grazing Land Assessment states that there are 7,000,000 acres of rangeland and 5,500,000 acre of grazable woodland in Washington. This amounts to approximately 23% of the state's land base.

Much of this grazable land is privately owned. " Most Washington native grazing lands are in the Columbia Basin and in open forests on the peripheral Cascade, Okanogan, and Blue mountains ," all in eastern Washington (source: Grazing Land Assessment).

The following state and federal agencies have a major role in management of rangeland and grazable woodland; Bureau of Land Management, U.S. Forest Service, Soil Conservation Service, Washington Department of Wildlife and the Washington Department of Natural Resources.

Analytical Approach

GENERAL APPROACH

This analysis is based solely upon literature review. No original research was conducted.

The standard method for analyzing the condition of rangeland is defined in terms of successional stages of vegetative cover. This method assumes a healthy rangeland will exhibit a climax cover of plant communities dominated by native grasses, forbs and shrubs valuable as forage for wild and domestic animals. In total, there are four successional stages; climax, late seral, middle seral, and early seral as defined below.

> Climax state- exhibits little change in potential plant community for the site. Between 75-100% of the kinds and amounts of vegetation produced would be found in climax.
>
> Late seral- these communities produce between 51% and 75% of the kinds and amounts of vegetation found in climax.
>
> Middle seral- these communities produce between 26% and 50% of the kinds and amounts of vegetation found in climax.
>
> Early seral- these communities produce between 0% and 25% of the kinds and amounts of vegetation found in

climax.

While different agencies use different descriptors for range condition, they all rely on this scheme of plant community successional stage as their basis for assessment. The three schemes of descriptors are those used by the SCS, the U.S. Forest Service(U.S. F.S.) and the Bureau of land Management (BLM).

These three schemes can be correlated as follows;

1. Climax plant community equates to "excellent" range condition in the SCS system. " Climax" is used by both the Forest Service and the Bureau of Land Management.

2. Late Seral plant community equates to "High Seral" in the Forest service system and" Good " range condition in the SCS system.

3. Middle Seral plant community is used by the BLM and the U.S. F.S. and equates to " Fair" range condition in the SCS system.

4. Early Seral plant community is " Low Seral" in the U.S. F.S. and equates to "Poor" range condition in the SCS scheme.

SOURCES, PATHWAYS, EFFECTS ETC.

The following table (Table 1) summarizes the sources, stressors and the effects of nonchemical degradation of rangeland and grazable woodland.

It is important to note that the traditional pathways for environmetal degradation (e.g. air and water) are less significant on the range than human activity. For example, motorized recreation often kills native vegetation, destabilizing plant cover allowing the opportunity for noxious weeds to establish themselves and for erosion to start. Similarly, the seeds of noxious weeds can be transported to Washington State's rangeland in the grills and bumpers of vehicles of recreational users or animal transporters from out of the region. As a result, human use in general and recreational use in particular is seen as the single most significant " transporter " of rangeland degradation agents. For purposes of Table 1, this fact will be reflected in the " Sources/Stressors " Column.

Table 1

SOURCES/STRESSORS	EFFECTS
Recreation activity (e.g. use of R.V.'s and ORV's)	Noxious weed introduction, native plant kills, soil compaction resulting in reduction in usable grazing land.
Overgrazing	Loss of plant cover, alteration in mix of plant species (reducing forage values) and change Seral state of plant community.
Erosion	Loss of topsoil
Conversion to Cropland	Loss of forage/cover for Wildlife.

RATIONALE FOR ELEMENTS EXAMINED

These are considered to be the major sources of rangeland and grazeable woodland degradation in the best professional judgement of the Washington State Department of Agriculture.

DATA SOURCES

The following sources of data were used in this analysis:

1. <u>Washington State Grazing Land Assessment</u>, Washington State University Cooperative Extension, July 1984
2. <u>Washington's Soil and Water: Condition and Trends</u>, United States Department of Agriculture, Soil Conservation Service, undated
3. <u>Protecting Our Resources An Investment</u>, Washington State Conservation Commission,1982

CRITICAL ASSUMPTIONS

None

SCALING UP

No scaling up was required. Data is presented on a statewide basis.

SENSITIVITY ANALYSIS

None

DESCRIPTION OF FINDINGS

The following table summarizes the ecological condition of rangeland in Washington State.

Table 2

Ecological Condition of Washington State Rangeland, All Owners

(sources: SCS 1982, Washington State Grazingland Assessment and Butrille,John F., Deputy Regional Forester; letter to Chief, Forest Service; August 6,1986)

Owner	Acres	Ecological Condition
Bureau of Land Management	7,493	Climax
	35,376	Late Seral
	40,725	Middle Seral
	59,556	Early Seral
	1,249	Seeding /1
	106,324	Unclassified /2
U.S. Forest Service	87,980	Climax
	158,840	High (e.g.Late) Seral
	418,280	Middle Seral
	430,280	Low (e.g.Early) Seral
State & Private	620,070	Climax

	1,183,770	Late Seral
	1,803,840	Middle Seral
	1,916,580	Early Seral
	112,740	other
Total	6,983,103 /3	

Footnotes: 1. " Seeding" is not defined by the Bureau.
2. Unclassified is a Bureau designation for areas without vegetation or unsuitable for grazing such as rock outcrops, sand Dunes, or extremely steep slopes.
3. The total is less than the 7,000,000 acre figure used earlier because the Bureau of Land Management choose not to survey the condition of 83,334 acres of rangeland in their ownership. If the unsurveyed rangeland is added, the total rangeland inventory Statewide rangeland inventory becomes 7,066,437 acres.

This analysis concludes that 10% of Washington State rangeland is in "Excellent" condition, 20% is in "Good" condition, 32% is in "Fair" condition, 35% is in "Poor" condition and 3% is either unsurveyed, seeded or unclassified.

Over-grazing has been attributed as the cause of a "less than good" (either poor or fair) rating of approximately 3,547,000 acres of grazable land in Washington State (per tel/con with Jim McClinton, SCS, Spokane).

Approximately 560,000 acres of grazingland are rated poor or fair due to inundation by noxious weeds.

The Soil Conservation Service estimates that 27% of all rangeland and 40% of all grazed forestland require additional protection from erosion. Rangeland is estimated to be eroding at a rate of 1.1 average tons per acre per year. Grazable forestland is estimated to be eroding at a rate of .8 average tons per acre per year.

These erosion rates are unacceptable for rangeland but are much lower than the 5 tons per year considered acceptable for agricultural land. The difference lies in the fact that rangeland soil cover is unusually thin (one of the key distinguishing features of rangeland statewide). As a result, rangeland is highly susceptible to erosion induced degradation.

SCALE

The facts that 23% of the State is rangeland and 67% of that land is in less than " Good " condition, leads this author to conclude that the scale of impacts to rangeland and grazed forestland are broad.

REVERSIBILITY

The impacts discussed above are reversible. Improved grazing practices, watering facilities and noxious weed control programs are examples of methods used to restore the condition of rangeland and grazed forestland.

It must be recognized, however, that rangeland restoration is an unusually long term proposition, requiring literally decades in most cases. The low precipitation rates, thin soils and competition between introduced plant species and native rangeland plants for limited water and nutrients are all factors in determining the length of time required to regenerate a degraded parcel of rangeland.

SENSITIVITY OF ECOSYSTEM

The climax plant community on rangeland and grazed forestland is sensitive and highly productive. Additionally, the association of plant species on the semi-arid rangelands may be unique to those lands, making the ecosystem vulnerable.

Once rangeland has been locally depleted, it may take years with proper management for it to return to it's climax state. In some cases a climax state may be irretrievable.

UNCERTAINTY

The nonchemical degradation of rangelands is certain and well documented.

THE
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Part 22

Risk Evaluation Reports
for
Nonchemical Impacts
on Agricultural Lands

ENVIRONMENT 2010

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Washington Environment 2010
Nonchemical Impacts on Agricultural Land
Risk Analysis

Background

This paper provides an analysis of the ecological risks associated with the nonchemical degradation of agricultural lands in Washington State.

Nonchemical degradation is defined as physical modifications of croplands, dairy farm lands and poultry farm lands that result in a reduction of total acreage available for production.

For purposes of this analysis the nonchemical impacts will be limited to conversion of agricultural land and wind and waterborne erosion.

It is important to note that there are about 38,000 farms in Washington. In 1986 these farms produced 3.06 billion dollars of production value in the top forty commodities alone. The top six commodities (e.g. apples, milk, cattle and calves, wheat, potatoes and hay) accounted for nearly two-thirds of that farm production value.

The state's agriculture industry is involved in large scale production of bulk commodities as well as smaller scale production of specialized, often high valued commodities.

In both cases, however, the agricultural land base upon which production depends is threatened by conversion to other uses and soil erosion.

Analytical Approach

This analysis relies entirely upon a literature review of existing documents and telephone conversations with employees of the Soil Conservation Service (see bibliography).

The literature and therefore, this analysis rely upon an examination of the sources and effects of erosion and conversion. Pollutants and pathways are not generally issues except to the degree that eroded topsoil becomes wind or waterborne. Those cases, erosion contributes to nonpoint water pollution and a variety of air quality problems which lend themselves to more traditional risk examination. These issues are addressed in the air quality and water sections of the Washington Environment 2010 report.

Additionally, this analysis required no scaling up. The data sources are generally statewide.

Finally, no sensitivity analysis was performed on the existing data.

Description of Findings

For purposes of clarity, findings will be divided into two sections; one on erosion and one on conversion.

EROSION

SEVERITY

Based upon the 1977 National Resource Inventory, the Soil Conservation Service (SCS) sheet and rill erosion resulting from the application of water to irrigated cropland is estimated to be about 11.5 million tons of soil annually (source; SCS Multi Year Plan). Erosion from Spring runoff on about 1.6 million acres of irrigated cropland subject to this phenomenon is estimated to be another 1.3 million tons.

Wind erosion on about 100,000 acres of these irrigated croplands was estimated to produce another 2 million tons of soil loss. Thus, the 1977 NRI estimated total erosion of topsoil on Washington's irrigated land at approximately 14.8 million tons annually.

The preliminary results of the 1987 NRI have been tabulated. Table 1, taken from those preliminary results, presents the estimated average annual sheet and rill erosion by class of agricultural land and compares the estimates for for 1982 and 1987 (Source: James F. McClinton, Soil Conservation Service).

Table 1
Estimated Annual Sheet and Rill Erosion
in Tons Per Acre

Non Irrigated Cropland		Irrigated Cropland		Total Cropland		Pasturland	
1982	1987	1982	1987	1982	1987	1982	1987
6.18	6.73	1.46	1.25	5.20	5.58	.19	.29

Table 2 presents the estimated annual average wind erosion in tons per acre, again comparing 1982 and 1987.

Table 2
Estimated Annual Wind Erosion
Tons Per Acre (McClinton)

Nonirrigated Cropland		Irrigated Cropland		Total Cropland		Pasturland	
1982	1987	1982	1987	1982	1987	1982	1987
1.99	2.26	8.24	7.71	3.29	3.40	.15	.26

In addition to sheet,wind and rill erosion many acres of both irrigated and nonirrigated cropland are affected ephemeral gullies. The following data summarizes the affect of ephemeral gullies on the state's irrigated and nonirrigated croplands;

Total Acres Affected..................1,035,500
Total Acres Not Affected..............6,717,700
Soil Loss in Tons/Acre
on affected cropland..................10.42

The SCS Multi- Year Plan states that," Soil erosion on dry and irrigated cropland is the most serious land resource problem in Washington State and reduction of soil erosion is the first priority of the soil conservation service."

The SCS Multi-Year Plan summarizes the severity of erosion in Washington State as follows;

County	Total_ Cropland (acres)	Average Annual Erosion (tons)	Tons per Acre
Clallam	11,200	49,754	4.44
Island	7,967	22,539	2.82
Jefferson	2,350	5,370	2.28
King	15,569	22,767	1.46
Kitsap	1,537	1,954	1.27
Pierce	15,628	29,828	1.9
San Juan	4,429	9,158	2.06
Skagit	67,516	102,016	1.51
Snohomish	30,448	61,248	2.01
Whatcom	68,444	119,328	1.74
Clark	35,730	83,960	2.35
Cowlitz	7,713	19,426	2.51
Grays Hrb.	14,134	30,968	2.19

Lewis	38,789	84,578	2.18
Mason	2,044	4,688	2.29
Pacific	6,716	14,332	2.13
Skamania	1,387	5,584	4.03
Thurston	12,547	11,094	.89
Wakiakum	4,034	8,868	2.19
Adams	844,662	5,667,972	6.71
Chelan	41,117	108,585	2.641
Douglas	572,775	3,452,150	6.02
Grant	636,987	5,269,922	8.27
Lincoln	890,996	7,171,968	8.05
Okanogan	154,113	695,565	4.51
Benton	421,818	2,413,454	5.72
Franklin	367,225	2,251,200	6.13
Kittitas	120,794	583,182	4.82
Klickitat	218,980	1,224,900	5.59
Walla Walla	573,620	5,881,000	10.25
Yakima	417,000	2,948,300	7.07
Asotin	83,179	746,111	8.97
Columbia	191,559	2,458,267	12.83
Ferry	23,884	119,420	5.0
Garfield	201,718	2,411,036	11.95
Pend Oreille	28,459	132,895	4.67
Spokane	426,783	4,120,830	9.66
Stevens	140,367	675,635	4.8
Whitman	1,091,558	15,189,812	13.9
Totals	7,795,776	64,230,630	8.24 (average ton/acre)

The SCS measures erosion rates using two models called," Universal Soil Loss Equation ," for water erosion and the ," Wind Erosion Equation " for wind erosion. These models are field verified at several in situ erosion measuring stations.

It should be noted that the SCS considers an erosion rate of 5 tons per acre per year acceptable. The reason is that natural replenishment of nutrients,(e.g. the soil building process), sustains soil fertility at that level of erosion.

REVERSIBILITY

With proper management practices, soil erosion can be controlled, if not reversed.

The cornerstone of efforts to control erosion in the state is the Federal SCS's Conservation Reserve Program

(CRP). Under this program, the federal government takes responsibility for aggressively managing the erosion problem in Washington. Farmers are paid under terms of 10 year contracts to take highly erodible land out of production and plant it with either trees, grass or wildlife cover.

The following table illustrates the number of acres in the CRP, by County, in Eastern Washington. The subset of Eastern Washington Counties was chosen because that is where the highest rates of erosion are occurring.

County	Acres
Adams	177,037
Asotin	25,260
Benton	33,162
Chelan	483
Columbia	17151
Douglas	153,904
Ferry	1,949
Franklin	72,705
Garfield	12,668
Grant	65,855
Kittitas	1,666
Klickitat	45,053
Lincoln	95,323
Okanogan	17,969
Pend Oreille	198
Spokane	33,111
Stevens	4,854
Walla Walla	97,268
Whitman	20,235
Yakima	32,316

(source; SCS, 1989)

Exhibit 1 provides a table of the eastern Washington counties currently participating in the CRP, the number of farms, acres and contracts. Generally there does not appear to be a direct correlation between the counties with the highest erosion rates and highest CRP participation rates. Erosion of cropland then, may be considered a risk that is not yet highly controlled.

In Columbia County, for example, cropland acreage totals 191,559 and the erosion rate is 12.83 tons per acre per year. Throughout the County, however, only 68 farms and 15,381 acres are participating in the CRP.

The reason that government efforts to improve CRP participation in the high risk Counties have achieved limited success is simply that farmers in high risk counties, like Columbia, can make more money by continuing to farm threatened land than by signing CRP contracts.

The CRP provides a usefull regulatory response to the problem of erosion and is particularly applicable to those Counties with a high per centage of cropland suseptible to erosion. While the correlation between the greatest risk Counties and CRP participation rates is not high, the program personnel hope to improve the risk/participation relationship in the near future. The SCS, for example, will increase CRP payments in two of Washington's counties in 1990. The assumption being tested by this piolt project is that higher payments will result in higher participation rates (source: Stu Trefry, Washington State Department of Agriculture).

Exhibit 2 is a map of acerage in CRP in eastern Washington that graphically illustrates the current level of participation in the CRP.

<u>SCALE OF IMPACTS</u>

The scale of erosion itself is illustrated by the above tables. Impacts associated with erosion are directly proportionate to the level of erosion occurring and include; loss of soil fertility and in extreme cases, smothering of immature crops. This latter impact occurs when wind or water born soils are deposited on immature plants.

Soil fertility is impacted because many plant nutrients adhere to soil particles. When these particles are borne away in an erosion process the nutrients are lost and will probably have to be replaced by use of chemical fertilizers. This process has implications for the long term sustainability of agriculture in Washington State, a fact which is readily recognized by the SCS and the Washington State Department of Agriculture.

<u>SENSITIVITY</u>

The highly productive agricultural land of eastern Washington is also highly sensitive to erosion. This fact is illustrated by exhibit 3, a map which shows the per cent of land in eastern Washington counties planned for erosion control. Plans include expansion of CRP participation and other techniques (source; SCS, 1989).

Agricultural land are also sensitive to a number of other threats such as misuse of chemicals, air pollution (e.g. airborne contaminants) and water pollution. These threats are analyzed in other components of the Washington Environment 2010 Project.

PRODUCTIVITY/UNIQUENESS

Each acre of irrigated cropland in Washington State produces, on average, about $750.00 of commodities annually. Thus, Washington State cropland is considered highly productive and unique.

Highly productive cropland, however is being lost and replaced with less productive/unique land. This issue is explored in more detail in the following section on " Conversion ."

UNCERTAINTY

The rates of erosion are well documented and certain. The data used in this analysis is the best and most recent available.

CONVERSION

DESCRIPTION OF FINDINGS

Conversion of agricultural lands to other uses is a threat equal to or greater than erosion.

Conversion is occurring throughout Washington State. While estimates of the rates of conversion to urban uses vary, in 1983 the SCS estimated that 20,000 acres of rural land (e.g. cropland, pasturland and forestland) were converted to nonfarm uses each year between 1977 and 1982. The following table illustrates this trend in terms of the rural land subset of all cropland (e.g. irrigated and dryland).

Trends in Cropland (acres)*

	1967	1977	1982
Irrigated	1,356,158	1,772,000	1,653,400
Nonirrigated	6,780,110	6,179,000	6,140,000
Total	8,136,268	7,951,000	7,793,400

*(source; "Washington's Soil and Water:

Condition and Trends"
USDA, SCS, Spokane Wa. Undated)

Additionally, in 1983, the SCS projected a statewide rate of cropland to conversion at 10% per year.

SEVERITY

Fortunatley, the 1983 SCS projections have not materialized.

More recent estimates of the conversion rates on crop land, forest land and pasturland are provided in the preliminary, unpublished results of the 1987 National Resource Inventory, as prepared by the SCS and provided by James F. McClinton of the SCS's Spokane office.

During the period 1982-1987 approximatley 23,000 acres per year were converted from rural to urban uses. Of this total 5%, or 1,350 acres per year were agricultural and pasturland. The remaining lands were forestland.

The trend in urbanization is illustrated by the SCS 1987 National Resource Inventory Preliminary Results shown below;

Statewide Urban Land Base 1977........973,000 acres
Statewide Urban Land Base 1982......1,073,100 acres
Statewide Urban Land Base 1987......1,207,200 acres.

The additional 234,000 acres of urban land created during the decade resulted from conversion of cropland, forestland and pasturland. This represents a mere 8% loss of rural land for the decade.

Clearly then, the majority of land being converted to urban uses is forest land. Similarly, it appears that the conversion of crop land and pasturland is a trend that was overestimated in the past and a threat that is currently controlled.

REVERSIBILITY

Conversion, in the context of this risk assessment, means urbanization. Land placed in CRP for example is not included in the definition of conversion because CRP land remains in farm use.

As a result, conversion is considered to constitute an irreversible, permanent loss of agricultural land within the the planning horizon of Washington Environment 2010.

SCALE OF IMPACTS

The impact of conversion on the state's agricultural land base is best illustrated by the rate of conversion shown above. Converted lands are generally lost to the agricultural commodities production process permanently.

SENSITIVITY

Productive agricultural land is highly sensitive to conversion.

Agricultural land is also highly vulnerable to conversion because it often is found in river valleys or at river mouths that have been developed as ports or rail transportation corridors in previous decades. Once urban infrastructure penetrates agricultural land, experience has shown that conversion follows. Examples include the Green River Valley in King County, the Port of Vancouver in Clark County, and the urbanization of the Spokane Valley in Eastern Washington.

PRODUCTIVITY/UNIQUENESS

Highly productive agricultural land is a unique resource that is essentially irreplaceable. There is, however, one caveat that must be added to this statement.

Despite the ongoing loss of cropland in Washington State, the number of acres under production during the period 1967-1982 remained nearly constant at about 8,000,000.

This phenomenon is explained by the fact that, as prime cropland (e.g.river valleys) is converted to urban use it is replaced by conversion of pasturland, rangeland and woodland to crop production. Irrigation has played a major role in creating this replacement opportunity.

Because most of the replacement land that could be productively converted to cropping had been converted by 1982 and conversion pressures continue to build, it is expected that the total agricultural land base will shrink over time. Additionally, the unit cost of production on converted marginal land may be higher than production costs on prime farmland. This set of circumstances has significant implications for the sustainability of agriculture, Washington farm economics and the future role agriculture in the Washington State economy.

UNCERTAINTY

Conversion data used has a high degree of confidence and is the most recent available.

Bibliography

Multi-Year Plan, 1983 and 1987 Updates, U.S. Dpartment of Agriculture, Soil Conservation Service, 1983 & 1987

Protecting Our Resources, Washington State Conservation Report, Washington State Conservation Commission, 1982

Washington's Soil and Water: Conditions and Trends, United States Department of Agriculture, Soil Conservation Service, Spokane,Wa., Undated

1987 National Resource Inventory Data, Preliminary Results 3/89, unpublished

Telephone conversation, Mr. James F. McClinton, Soil Conservation Service, Spokane

REPORT OF ACTIVE CRP CONTRACTS - BY PRACTICE - AS OF APRIL 1989

COUNTY	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14	TOTALS Acres/ Contracts
ADAMS															
Farms	547			34				3		3					
Acres	157,689.7			633.6				6.1		330.9					158,660.3
															615
ASOTIN															
Farms	83		1	2						3					
Acres	23,991.3		6.5	1,047.0						215.3					25,260.1
															93
BENTON															
Farms	85														
Acres	32,765.5														32,765.5
															100
CHELAN															
Farms	4														
Acres	401.1														401.1
															4
COLUMBIA															
Farms	60		4	1						10					
Acres	13,954.2		346.2	29.1						1,051.5					15,381.0
															68
DOUGLAS															
Farms	433	1		7		2			1	14					
Acres	151,756.9	1.0		568.0		108.0			20.0	1,558.0					154,011.9
															495
FERRY															
Farms	9		5	1						6					
Acres	1,416.2		208.0	51.2						294.6					1,970.0
															16
FRANKLIN															
Farms	144			5											
Acres	64,878.9			3,651.0											68,529.9
															174
GARFIELD															
Farms	63									18					
Acres	11,916.1									675.5					12,591.6
															71
GRANT															
Farms	207			4											
Acres	60,998.5			2,097.7											63,096.2
															223
KITTITAS															
Farms	9								1						
Acres	1,523.3								51.0						1,574.3
															11
KLICKITAT															
Farms	169	4	2	12		9				58			1		
Acres	37,892.9	2,775.1	79.1	527.6		280.7				3,483.4			2.3		45,041.1
															232
LINCOLN															
Farms	517	1	2	72			1			26					
Acres	84,194.5	488.3	160.1	8,563.3			1.0			971.3					94,378.5
															623

REPORT OF ACTIVE CRP CONTRACTS - BY PRACTICE - AS OF APRIL 1989

COUNTY	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14	TOTALS Acres/ Contracts
OKANOGAN															
Farms	87			1						21					
Acres	15,874.4			29.6						1,834.6					17,738.6
															106
PEND OREILLE															
Farms	2									2					
Acres	153.4									43.9					197.3
															2
SPOKANE															
Farms	238		9	6	1					59	1				
Acres	29,309.3		370.4	291.5	5.8					2,471.4	3.0				32,451.4
															288
STEVENS															
Farms	56		2							20					
Acres	4,137.1		43.0							846.4					5,026.5
															65
WALLA WALLA															
Farms	172	2		3			4	24					1		
Acres	95,156.5	1,192.0		7.4			572.0	190.5					13.6		97,132.0
															202
WHITMAN															
Farms	153			14						15					
Acres	16,704.1			1,037.2						1,197.7					18,939.0
															173
YAKIMA															
Farms	54	1				1									
Acres	30,977.6	334.2				625.7									31,937.5
															62
WASHINGTON STATE TOTALS															
Farms	3,092	9	25	162	1	12	5	27	2	255	1	0	2	0	3593
Acres	835,691.5	4,790.6	1,213.3	18,534.2	5.8	1,014.4	573.0	196.6	71.0	14,974.5	3.0	0	15.9	0	877,083.8
															3623

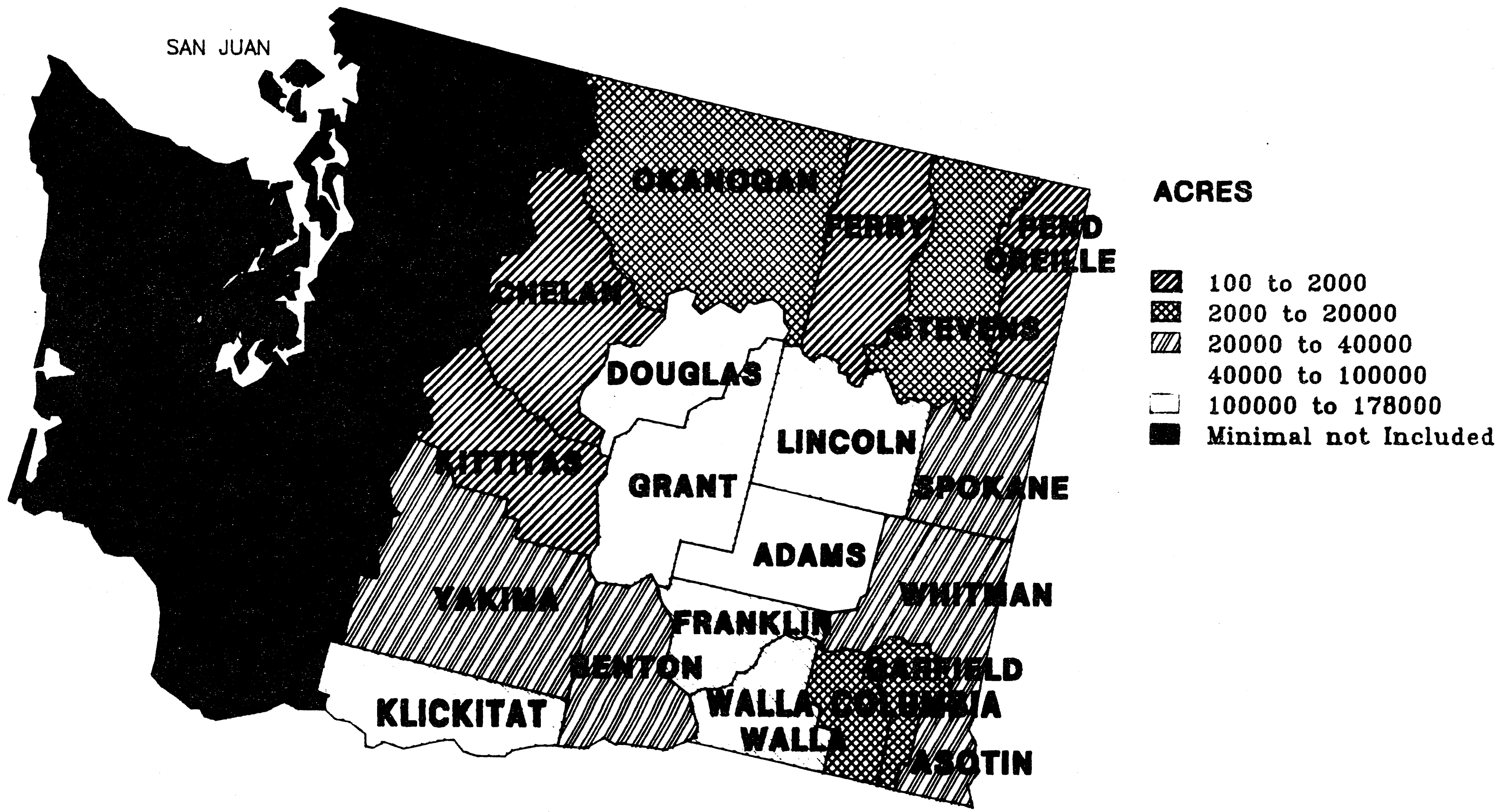
CRP PRACTICES AVAILABLE

CP1 Establishment of Permanent Introduced Grasses and Legumes
CP2 Establishment of Permanent Native Grasses
CP3 Tree Planting
CP4 Permanent Wildlife Habitat
CP5 Field Windbreak Establishment
CP6 Diversions
CP7 Erosion Control Structure
CP8 Grass Waterways
CP9 Shallow Water Areas For Wildlife
CP10 Vegetative Cover - Grass - Already Established
CP11 Vegetative Cover - Trees - Already Established
CP12 Wildlife Food Plots
CP13 Vegetative Filter Strips
CP14 Bottomland Hardwood Wetland Establishment

WASHINGTON

ACREAGE IN CRP

(Eastern Washington Counties Signups 01-08)

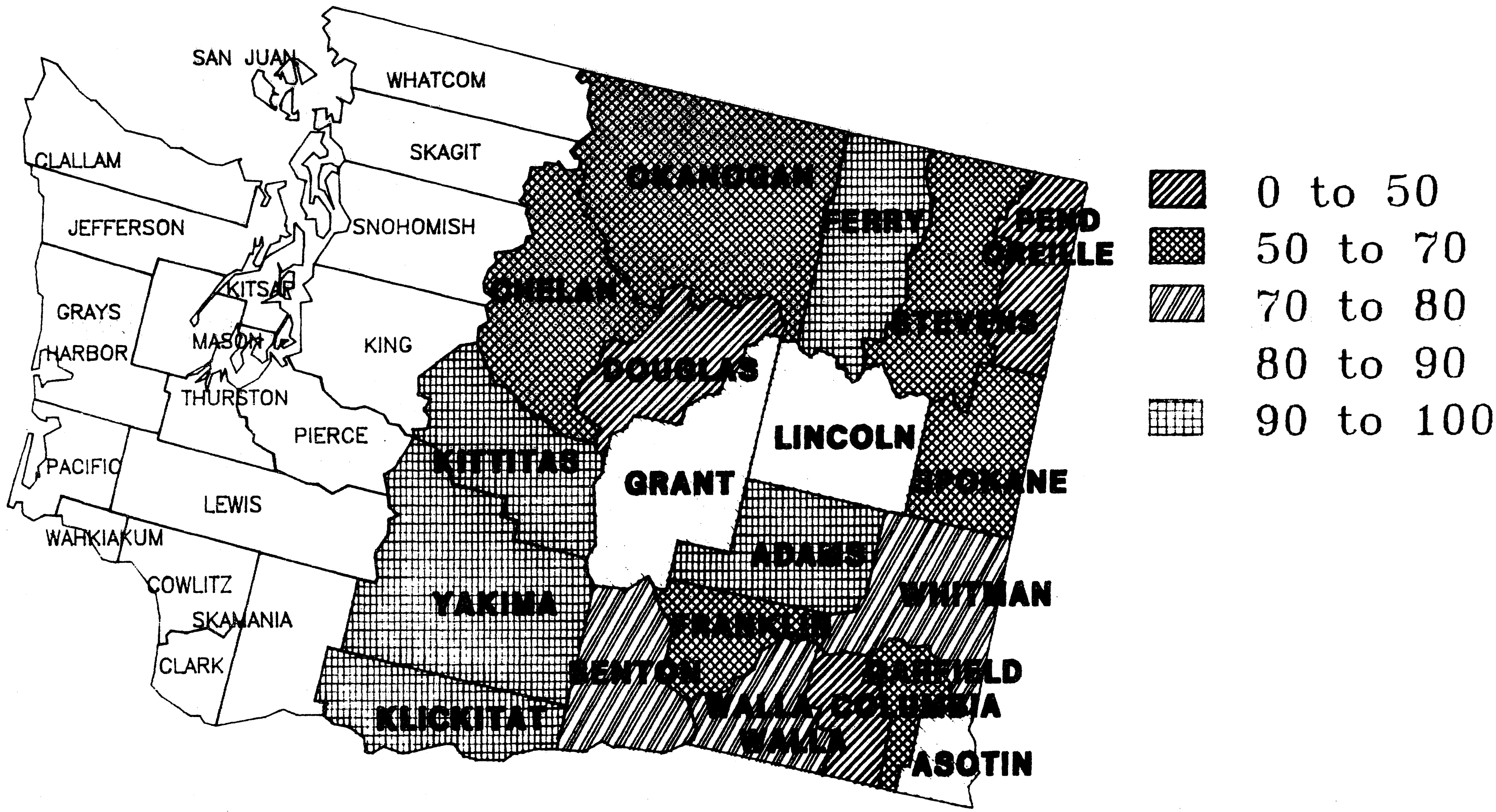


April 1989

USDA, Soil Conservation Service

FOOD SECURITY ACT

PERCENT OF HIGHLY ERODIBLE ACRES PLANNED



April 1989

USDA, Soil Conservation Service

THE STATE OF THE ENVIRONMENT REPORT

VOLUME III
Part 23

Risk Evaluation Reports for Pesticides (Not Covered Elsewhere)

ENVIRONMENT 2010

State of Washington
October, 1989

INTRODUCTION

The following is a series of brief reports on the major human health and ecological risks associated with pesticide use that are not included in other Washington Environment 2010 risk analyses. Specifically, these reports focus on the following types of pesticides-related risks:

- Human health risks to Washingtonians associated with ingesting foods that are contaminated with pesticide residues;
- Human health risks to Washingtonians due to exposure to aerial drift of pesticides;
- Human health risks associated with household use of pesticides;
- Ecological risks associated with pesticide use in the state of Washington - primarily impacts on fish and wildlife.

Other potentially significant pesticides-related risks are addressed in other Washington Environment 2010 risk reports. Specifically, the human health and ecological risks associated with pesticide contamination of surface and ground water are addressed in the reports on point and nonpoint source water pollution (reports number seven and eight, respectively.)

Some pesticide-related risks are not addressed by Washington Environment 2010. Most notably, the risks to pesticide exposures, and therefore are not included here. The Technical Advisory Committee (TAC) decided early in this effort that risks due to occupational exposures to an environmental threat were outside the scope of the project.

What follows is a series of separate but brief reports on each of the four types of pesticide-related risks listed above - pesticide residues on food, aerial drift, household use of pesticides, and impacts on fish and wildlife. The reports vary in substance due to wide gaps in available data, and in style due to varying authorship.

PESTICIDE RESIDUES IN AND ON FOOD

INTRODUCTION

Pesticides, used to help protect crops from insects, weeds, diseases and other pests, are potentially dangerous substances whose use requires careful regulation. They are effective because they are toxic to target organisms, or because they otherwise disturb the natural processes necessary for the organisms' survival. Some are toxic only to the target pests for which they are intended, and pose little or no threat to other life forms, such as humans. Many, however, can harm nontarget species (NAS, 1987).

Pesticides are widely used to treat crops, pastureland, and harvested fruits and vegetables. The amount and types of pesticides used varies by region. For example, oats grown in the northern plains require little or no pesticides, while vegetables grown in the humid regions of the country (e.g., the south) might require 20 or more pesticide applications in a single growing season (NAS, 1987).

Pesticides are widely used in food production in Washington. Pesticide is the broad term encompassing all products used to mitigate pests and to regulate plant growth. Herbicides are used to limit weed competition for moisture, nutrients, and sunlight. Insecticides and fungicides are used to mitigate damage or destruction of crops from insects and disease. In some cases, insecticides and/or fungicides are used post-harvest to protect the food commodity from damage or spoilage while in transit or storage. Desiccants and defoliants are used in some crops to aid in harvest. Other plant growth regulators are used in a few crops to aid cultural practices or to produce a uniformly marketable crop without losses that would occur if the crop were not treated. Some crops are subject to damage by rodents or birds; rodenticides, repellents, or other vertebrate controls are used to prevent such damage.

Not every food crop is treated with pesticides and most treatments are made in response to an identified presence of a pest. The major exceptions to this are some fungicides that must be applied prior to a significant attack by the organism or herbicides that are most effective when applied prior to germination or emergence of the weeds. Even under these conditions, the fungicide or herbicide is normally applied only where the organisms or weeds are likely to occur. This is important since the safety of pesticide residues allowed to remain on or in the food is evaluated on treatment of 100 percent of the crop.

The main source of pesticides in food is the application of pesticides to the crop or to the land prior to planting the crop. Drift from nearby applications may also result in pesticide residues in crops nearing harvest. In a few cases with pesticides with particularly long half-lives in soil, there may be a carryover to subsequent crops. In imported commodities, legal uses in the country of origin may not have been approved in the United States.

Another source of pesticides in food includes post-harvest treatment to prevent attack of insects or organisms that cause spoilage or destroy the commodity while in storage. In the case of animals or animal products used as sources of food, the source of pesticide contamination usually is from residues in the animal feed or pesticides used to control pests on the animal.

Because pesticides can cause harm to nontarget species--e.g., if high levels of pesticide residues remain in or on foods consumed by humans--careful regulation is necessary. The focal point of the current regulatory system is the registration process, which requires U.S. EPA approval of all pesticide uses under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). EPA registration of a pesticide is required by law before the pesticide can be sold in the U.S.; use of the pesticide inconsistent with the registered label is illegal.

The registration process is linked to the tolerance-setting process. The EPA will not register a pesticide for use on a food crop until it establishes the amount of pesticide residue that can safely remain on food. These residues, known as pesticide tolerances, are enforced by the federal Food and Drug Administration (FDA), the United States Department of Agriculture and, in Washington, the Department of Agriculture.

No attempt will be made to outline in detail the scientific tests required for establishment of tolerances, but a brief description of the procedure follows.

EPA uses animal tests to identify short- and long-term risks associated with residues in food. The tolerance, if granted, is established at the minimum level to reflect the maximum residue that may occur as a result of the proposed use of a pesticide. Studies are performed to establish a no observed effect level (NOEL) or a cancer risk estimate if the pesticide has oncogenic potential. An oncogen is measured against a negligible risk of one in one million in lieu of a NOEL. Based on the NOEL, an acceptable daily intake (ADI) (now called a reference dose) is proposed with a safety factor built in. Typically, this safety factor is a hundred times the NOEL.

Pesticides from all sources are compared with the ADI in considering whether additional tolerances are established. Tolerances are set at the lowest level necessary to accommodate the maximum treatment allowed for a crop.

In short, an elaborate regulatory framework--intended to protect U.S. consumers from unacceptably high levels of pesticide residues in foods--is in place. There is a disagreement, however, over the effectiveness of that framework, and over the level of risk to consumers posed by pesticide residues. Some scientists believe that the existing regulatory system adequately protects human health, and that the risks posed by pesticide residues on foods in this country are negligible. Others believe that the system is inadequate, and that the risks of eating foods with pesticide residues are significant.

Analysis of State-Specific Data

Accurate pesticide use statistics are not available in Washington, so they must be extrapolated from crop data to establish major food uses of pesticides in Washington. First we must examine the major agricultural commodities in Washington, based on the 1987 value of production. Apples were the number one crop, produced on 135,000 acres; wheat ranked number two, being produced on 2,100,000 acres; and potatoes ranked number three, produced on 124,000 acres. The type of pesticide used varies with the crop; tree fruit crops rate high in insecticide and fungicide use, and grain crops higher in herbicide use.

Some sampling of food products--testing for pesticide residues--is done in Washington by both the U.S. FDA and the state's Department of Agriculture. The results of that sampling over the last several years--particularly in the cases in which residue tolerances have been exceeded--are reviewed here as well.

During the years 1984-1988, the regional FDA laboratory analyzed 2,656 foods and animal feeds and 86, or 3.2 percent, were found violative related to residues (see Table 1). 32 of the violative findings were on compliance samples which were not random and which would bias the findings to a higher violation rate. Not all of the FDA samples were of Washington produce; they also include samples taken of commodities from other areas.

The violations represent residues over the established tolerance, or pesticides not registered on that specific crop even though it may be registered on other crops with tolerances at the level found. Twenty different pesticide ingredients were involved in the 86 violations and all but one had tolerances established or pending on the crop in question or other crops. The most common pesticide active ingredient found in violation was malathion (19) which has tolerances on a wide variety of crops. Twelve of the 86 samples were crop screenings or by-products of commodity processing which were destined for animal feeds.

In 1988, the Washington State Department of Agriculture tested 1,128 foods, of which 170, or 15 percent, tested positive for chemical residues. All tested within tolerance (see Table 2). In 958 of the samples, or 84.9 percent of the foods tested, no pesticides were found at the detection level.

Table 3 gives the national picture of 1987 FDA analyses of domestic produce, which would include the samples previously presented in this report for Washington. They reported 6,503 foods analyzed, of which 58 percent had no detectable residues and less than 2 percent were in violation of tolerances. Table 4 gives the results of analyses of 7,989 import samples during the sample period with 58 percent finding no detectable levels and less than 6 percent found to be violative because of pesticide residues.

In addition to regulatory sampling, FDA performs total diet studies four times each year. These studies compare actual analyses of foods, based on representative diets as normally prepared and eaten, with the ADIs. In general, these results in 1987 indicate that pesticide residues in the foods we eat are significantly below established ADIs and are, in fact, for most pesticides, less than than 1 percent of established ADIs.

FDS in its 1987 report on pesticide residues in foods states: "Total Diet Study results show that dietary pesticide intakes are many fold lower than safety levels established by WHO." WHO refers to the World Health Organization. This FDS report found no pesticide residues in over 50 percent of the samples.

It appears, then, that only a small percentage of the food products sampled in Washington State have pesticide residues that are in violation of regulatory tolerances. In addition, nationwide sampling by the U.S. FDA indicates that only a small percentage of all foods sampled exceed residue tolerances. This suggests that the risks to Washingtonians from pesticide residues are relatively low, if the following assumptions are correct.

- That federal and state sampling is adequately representative of all food products consumed in the state;

- That residues in concentrations lower than the established tolerances do not pose a risk;

- That exposures to those residues that do exceed established tolerances are prevented once detected.

CONCLUSIONS

It is very difficult to draw concrete conclusions from the information an analysis provided here. It is clear that there is considerable disagreement, even among scientists, over the level of human health risk associated with ingestion of pesticide residues in and on food.

This report provides a review of sampling data in Washington State which shows only a small percentage of foods sampled to be in violation of EPA-established residue tolerances. It is difficult to draw conclusions about actual risk from this data, however, without knowing more about the representativeness of the sampling procedures.

In short, much better data are required for an accurate assessment of the risks posed by pesticide residues on food consumed in Washington State. Such an assessment would require:

- More and better data on actual pesticide residues (i.e., concentrations of pesticides) found on foods consumed by Washingtonians; and

- Data on who is consuming which crops (i.e., how many people, what subpopulations), how much they are consuming, and over what period of time.

It is clear that some pesticides are toxic and harmful. In addition, there is toxicological data--based on animal studies--demonstrating that tumors and/or cancer can be induced in test animals at elevated dose levels. It is also clear that food consumers are, at some time, exposed to some pesticide residues on their food. That is illustrated by thef act that residues are often detected on sampled foods--albeit usually at levels below established tolerances.

What is not known with certainty is who is exposed, to which pesticides are they exposed, how often and for what period of time are they exposed. More data and further analysis are necessary to accurately answer these questions.

Table 1

FDA SAMPLES 1984 - 1988
WASHINGTON STATE

YEAR	SAMPLES/YEAR	VIOLATIVE SAMPLES Compliance	Surveillance	Total
1988	498	13	4	17
1987	177	1	0	1
1986	745	12	25	38
1985	475	4	15	19
1984	761	1	10	11
Total:	2,656	32	55	86

VIOLATIVE SAMPLES BY PRODUCT

Product Name	Total Count
Whole grain, wheat	8
Wheat flour, enriched, bromated	1
Cranberries	1
Strawberries	2
Apples	14
Apricots	10
Cherries	1
Peaches	1
Watermelon	4
Garbanzo beans/chickpeas	1
Field peas	1
Lentils	2
Cucumbers	2
Cabbage	1
Romaine Lettuce	1
Parsley	2
Parsnip	3
Potato	3
Radish	1
Red Beet	1
Hops	2
Diet Spec N.E.C. for animals	1
Wheat grain for animals	3
Animal feeds, N.E.C.	13
Potato by-product for animals	1
N.E.C. by-product for animals	2
N.E.C. by-product for animals	4
Total Violative Samples:	86

Table 2

1988 PESTICIDE SAMPLES

Product	# Samples	Pesticide Found	Action
Apples	100	44 diphyenylamine	NAI
		7 daminozide	NAI
		5 dioxathion	NAI
		1 dursban	NAI
		1 endosulfan	NAI
		58	
Apricots	9	2 endosulfan	NAI
Asparagus	60	1 chlorpyrifos	NAI
Barley-human use	4		
Beans	15		
Beets	10		
Blackberries	1		
Blueberries	7		
Broccoli	4		
Cabbage	11		
Carrots	17		
Cauliflower	9		
Cherries	22	4 parathion	NAI
Corn - human use	20		
Cucumbers	7		
Eggs	29		
Feeds - animal	202	58 malathion	NAI
		16 methyl chloropyrifos	NAI
Flour	13	9 malathion	NAI
Garlic	7		
Grapes & juice	10		
Honey	31		

Table 2 (contd.)

Lentils	8		
Lettuce	26		
Mint & mint oils	27		
Mixes - bread, cake	5		
Onions	49		
Peas	30	1 parathion	NAI
Peaches	11		
Pears	33	1 endosulfan	NAI
Peppers	4		
Plums	6		
Potatoes	146	11 CIPC	NAI
Radishes	10		
Raspberries	15		
Rhubarb	19		
Spinach	6	1 endosulfan	NAI
Squash	15		
Strawberries	17	2 vinclozolin	NAI
Tomatoes	5		
Watermelon	2		
Wheat	21	6 malathion	NAI
Miscellaneous foods	85	3 malathion	NAI
		2 diphenylamine	NAI
		1 CIPC	
		DDE	
		TDE - organic	
		DDT	

1128 samples tested
170 chemical residues
15% all NAI

Table 3

1987 U.S. FDA
Analysis of Domestic Samples by
Commodity Group in 1987

Commodity Group	Total No. of Samples	Percent Samples with No Residues Found	Percent Samples Violative Over Tol.	Percent Samples Violative No Tol.
A. Grains and Grain Products				
Bakery and cereal products/ snack foods	16	31	0	6
Corn, popcorn	72	49	4	0
Grain products	22	59	0	0
Other whole grains	10	20	0	0
Rice	63	46	6[a]	8
Soybeans	19	68	0	0
Wheat	123	29	7	0
Total	325	41	5[a]	2
B. Milk/Dairy Products/Eggs				
Butter/butter products	15	33	0	0
Cheese/cheese products	97	66	0	0
Eggs	302	91	0	0
Ice cream/ice cream products	14	43	0	0
Milk & cream	419	71	0	0
Total	847	76	0	0
C. Fish/Seafoods/Other Meats				
Fish & shellfish	499	27	5[a]	<1
Other meats	4	50	0	0
Total	503	27	5[a]	<1
D. Fruits				
Blackberries	3	67	0	0
Blueberries	21	57	0	0
Boysenberries	5	100	0	0
Cranberries	20	0	0	0
Grapes	127	72	0	0
Raspberries	12	83	0	0
Strawberries	305	18	2	<1
Other berries	13	85	0	0
Grapefruit	14	29	0	0
Oranges	62	24	0	0
Other citrus fruit	12	17	0	0
Apples	243	42	0	0
Pears	69	51	0	0
Other core fruits/ mixed fruits	8	12	0	0
Apricots	18	61	0	0
Cherries	84	61	0	0
Nectarines	15	67	0	0
Olivers	32	94	0	0
Peaches	100	49	2	0
Plums and prunes	23	83	0	0
Other pit fruits	5	100	0	0
Papaya	26	100	0	0
Pineapples	19	100	0	0
Other tropical fruits	5	100	0	0
Cantaloup	51	61	0	0
Honeydew	22	65	0	0
Watermelon	70	91	0	1
Other vine fruits	21	67	0	0
Other fruits	11	55	0	36
Fruit jams & toppings	9	33	0	0
Fruit juices	14	86	0	0
Fruits, dried or paste	19	37	0	0
Total	1458	50	<1	<1
E. Vegetables				
Bean sprouts	15	100	0	0
Blackeyed peas	3	33	0	0
Corn	78	92	0	0
Garden/green/sweet peas	55	85	0	0
String beans	59	71	0	3
Other beans, peas, & corn	38	82	3	0
Cucumbers	62	66	0	0
Eggplant	28	68	0	4
Okra	4	75	0	25

Table 3 (Contd.)

Commodity Group	Total No. of Samples	Percent Samples with No Residues Found	Percent Samples Violative Over Tol.	Percent Samples Violative No Tol.
Peppers	98	64	0	0
Pumpkins	5	20	0	20
Squash	109	71	0	3
Tomatoes	260	83	0	3
Artichokes	30	63	0	0
Asparagus	56	100	0	0
Bamboo sprouts	2	0	0	0
Broccoli	159	83	0	0
Broccoli raab	10	80	0	0
Brussels sprouts	9	100	0	0
Cabbage	114	82	0	0
Cauliflower	107	96	0	0
Celery	87	18	0	0
Chinese cabbage	27	63	0	22
Collards	41	44	0	7
Dandelion greens	10	30	0	20
Endive/chicory	30	70	0	3
Kale	44	36	0	20
Lettuce	494	34	2	2
Mustard greens	44	39	2	11
Parsley	25	36	0	20
Spinach	82	35	5[a]	7
Swiss chard	15	73	0	7
Turnip greens	35	23	14	3
Other leaf/stem vegetables	59	63	0	8
Mixed vegetables	2	100	0	0
Mushroom/truffle products	20	90	0	0
Carrots	107	61	1	0
Leeks	5	100	0	0
Onions	77	75	0	5
Parsnips	20	30	20	0
Potatoes	281	62	0	0
Radishes	30	87	0	0
Red beets	30	77	0	7
Rutabagas	9	67	0	0
Sugar beets	15	93	0	0
Sweet potatoes	55	69	0	0

Commodity Group	Total No. of Samples	Percent Samples with No Residues Found	Percent Samples Violative Over Tol.	Percent Samples Violative No Tol.
Turnips	28	61	0	0
Others	16	94	0	0
Vegetable juice	5	100	0	0
Vegetables with sauce	66	70	0	0
Other vegetable-related products	20	65	0	0
Total	3080	63	<1[a]	2
F. Other				
Spices and flavorings	29	62	0	24
Peanuts	27	44	0	0
Pecans	19	100	0	0
Walnuts	19	79	0	0
Sunflower seeds	18	78	0	6
Other nuts, seeds, & related products	12	100	0	0
Refined vegetable oil	16	62	0	0
Vegetable oil seed stock	23	65	0	0
Other vegetable oil products	9	56	0	0
Alcoholic beverages	25	48	0	0
Bottled spring or mineral water	11	100	0	0
Other waters and soft drinks	10	100	0	0
Chocolate & cocoa products	3	100	0	0
Food sweeteners	8	25	0	12
Other food products	61	43	0	0
Total	290	63	0	3
A-F Total	6503	58	1[a]	1

[a] Includes samples that have both residue(s) over tolerance and residue(s) with no tolerance.

Table 4

Analysis of Import Samples by
Commodity Group in 1987

Commodity Group	Total No. of Samples	Samples with No Residues Found	Percent Samples Violative Over Tol.	Percent Samples Violative No Tol.
A. Grains and Grain Products				
Bakery and cereal products/ snack foods	44	77	0	0
Corn, Popcorn	1	100	0	0
Grain products	31	68	0	3
Other whole grains	6	33	0	17
Pasta products	45	76	0	9
Rice	20	85	0	0
Wheat	6	67	0	0
Total	153	74	0	4
B. Milk/Dairy Products Eggs				
Butter/butter products	1	100	0	0
Cheese/cheese products	230	85	0	1
Eggs & egg products	34	50	0	3
Milk & cream	1	0	0	0
F____ & imitation milk	4	100	0	0
Total	270	80	0	1
C. Fish/Seafoods/Other Meats				
Fish & shellfish	197	78	0	<1
Other meats	15	20	0	47
Total	212	74	0	4
D. Fruits				
Blackberries	15	53	0	0
Blueberries	31	77	0	0
Boysenberries	7	29	0	0
Cranberries	4	25	0	0
Grapes	451	30	0	13
Raspberries	65	38	0	3
Strawberries	329	40	0	12
Other berries	40	10	0	12
Grapefruit	10	80	0	0
Lemons	57	23	0	32
Limes	27	93	0	0
Oranges	43	37	0	0
Tangerines	29	45	0	0
Other citrus fruits	9	78	0	22
Apples	161	51	0	
Pears	110	41	0	2
Other core fruits/mixed fruits	9	78	0	0
Apricots	14	36	0	0
Cherries	7	43	0	0
Nectarines	24	42	0	0
Olives	9	100	0	0
Peaches	58	41	0	0
Plums and prunes	21	43	0	0
Other pit fruits	15	87	0	0
Bananas	154	68	0	0
Mangoes	41	63	0	22
Papaya	15	93	0	7
Pineapples	75	85	0	1
Plantains	17	94	0	0
Other tropical fruits	92	87	0	0
Cantaloup	266	39	<1	6
Honeydew	108	33	<1	2
Watermelon	154	69	0	<1
Bitter melons	59	81	0	3
Other vine fruits	20	60	0	0
Other fruits	15	33	0	7
Fruit jams & toppings	17	82	0	0
Fruit juices	55	89	0	0
Fruits, dried or paste	87	85	0	0
Total	2720	51	<1	6
E. Vegetables				
Blackeyed peas	83	69	0	16
Corn	28	100	0	0
Garden/green/sweet peas	170	62	<1	4

Table 4 (contd.)

Commodity Group	Total No. of Samples	Samples with No Residues Found	Percent Samples Violative Over Tol.	Percent Samples Violative No Tol.
Mung beans	17	59	0	0
String beans	145	59	0	1
Other beans, peas, & corn	130	65	0	28
Cucumbers	224	38	2	1
Eggplant	199	43	0	9
Okra	148	75	0	8
Peppers	825	38	2	7
Pumpkins	5	80	0	0
Squash	454	64	<1	2
Tomatoes	721	35	<1	<1
Other fruits used as vegetables	31	74	0	3
Artichokes	10	90	0	0
Asparagus	76	96	0	1
Bamboo sprouts	10	100	0	0
Broccoli	110	60	0	1
Broccoli raab	9	89	0	0
Brussels sprouts	57	63	2	0
Cabbage	23	91	0	0
Cauliflower	30	87	0	0
Celery	19	11	0	5
Chinese cabbage	9	89	0	0
Endive/chicory	113	78	0	6
Kale	5	60	0	0
Lettuce	31	48	3	6
Parsley	4	75	0	25
Spinach	15	33	0	0
Other leaf/stem vegetables	56	71	0	16
Mixed vegetables	8	63	0	0
Mushroom/truffle products	38	84	3	5
Carrots	32	59	0	0
Leeks	5	100	0	0
Onions	88	76	0	0
Potatoes	27	93	0	4
Radishes	42	90	0	0
Red beets	2	100	0	0
Shallots	23	100	0	0

Commodity Group	Total No. of Samples	Percent Samples with No Residues Found	Percent Samples Violative Over Tol.	Percent Samples Violative No Tol.
Sweet potatoes	5	80	0	20
Turnips	4	75	0	0
Other ______ vegetables	72	92	0	0
Vegetable juice	7	71	0	0
Vegetables, dried or paste	106	76	8	0
Vegetables with sauce	37	62	0	0
Other vegetable-related products	12	75	0	0
Total	4265	55	<1	4
F. Other				
Whole coriander	97	68	0	19
Whole fennel	20	50	0	0
Other whole spices	35	66	0	11
Ground spices	10	60	0	0
Other spices and flavorings	17	59	0	6
Peanuts	13	31	0	0
Other nuts & related products	28	96	0	4
Sesame seeds	11	100	0	0
Other seeds & related products	12	75	0	0
Refined vegetable oil	4	75	0	0
Other vegetable oil products	6	50	0	33
Alcoholic beverages	3	100	0	0
Beverage cases	13	85	0	0
Coffee & tea	52	85	0	2
Bottled spring or mineral water	7	86	0	0
Other waters and soft drinks	2	100	0	0
Chocolate & cocoa products	11	91	0	0
Food sweeteners	14	93	0	0
Other food products	14	57	0	0
Total	369	73	0	7
A-F Total	7989	56	<1	5

REFERENCES

Washington Agricultural Statistics Service, 1988. Washington Agricultural Statistics 1987-1988. Washington Agricultural Statistics Service, Olympia, WA, 124 pages.

Miller, G., 1989. Computer print of pesticide residue findings in samples taken in Washington by Food and Drug Administration, Bothell, WA.

Washington State Department of Agriculture, 1989. 1988 Pesticide Samples. Washington State Department of Agriculture, Olympia, WA.

Food and Drug Administration Pesticide Program, 1988. Residues in Food - 1987. Food and Drug Administration, Washington, D.C.

AERIAL DRIFT OF PESTICIDES

WASHINGTON ENVIRONMENT 2010

HUMAN HEALTH RISKS ASSOCIATED WITH PESTICIDE DRIFT in WASHINGTON STATE

INTRODUCTION/BACKGROUND

Pesticides, whether they are insecticides, herbicides, rodenticides or fungicides, are widely used in the state of Washington. Both the agricultural and forest economies depend on pesticides for crop protection and vegetative management. While use is targeted for specific purposes, the application procedures potentially cause nontarget areas, including the public and nearby residents, to be exposed to pesticides. Off-target deposition is a function of several complex variables including micrometeorologic conditions, the dynamics of spray droplet behavior, the physical properties of the spray formulation and the application methods selected.(1)

That pesticides drift is well documented in the state of Washington. There are records of paraquat drifting over several surrounding farms and homes from aerial applications.(2) Long-term studies of atmospheric drift of 2,4-D in the lower Yakima Valley have been conducted in order to assess injury to sensitive crops and plants by herbicides which have drifted in the atmosphere. Their "drift" is known to be a "fairly common and serious agricultural problem."(3) For example, grape growers have noted that damage to their grapes reflect symptoms caused by herbidices used with other crops in the region. Unfortunately, from the perspective of public health, the studies of drift that have been conducted are aimed at the agricultural damage rather than any human health implications.

If 2,4-D were the only pesticide of concern, conducting a risk assessment on the health aspects of drift might be somewhat simplified. However, it is one of possibly hundreds of pesticides registered for use in the state. The variables which have been studied for 2,4-D may or may not be applicable to the other pesticides. Furthermore, the fact that pesticides are being registered for use does not provide evidence for the extent, duration, or frequency of their actual applications. Thus, it is extremely difficult to know to which pesticides the public may be exposed. Appendix 1 includes a list of those pesticides which EPA Region X documents as some of the major ones used in the region.(4) Unfortunately, any risk assessment for the health risk associated with drift must be based on reliable information documenting use levels. Such data are not available.

When pesticide drift occurs, the public can potentially be exposed to pesticides through several direct and indirect pathways in the environment, as shown in Figure 1. There are innumerable variables which can impact what, if any, exposure occurs from these various pathways. Unfortunately, at the present time, there are no data available to substantiate the levels of pesticides to which the public are being exposed through these various pathways.

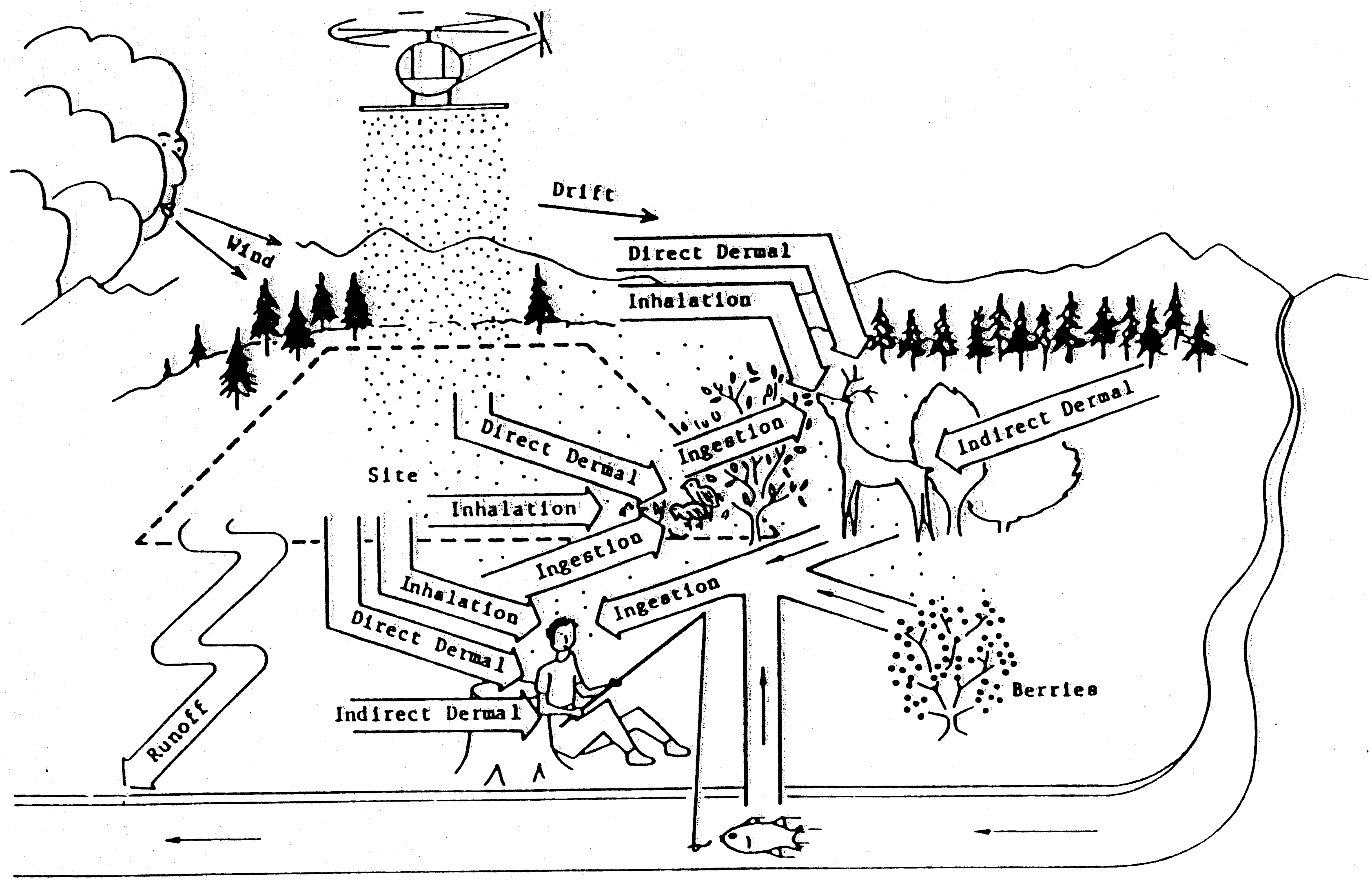


Figure 1 - Routes of Exposure to Herbicides in Spraying Operations

(From: U.S. Dept. of Agriculture, 1987, DEIS, Managing Competing and Unwanted Vegetation.)

Since pesticides include natural and synthetically derived chemicals that are specifically developed to destroy some type of biological or botonical agent, there is great suspicion that such compounds will also have serious human repercussions. Instructions for use and disposal carry the message that pesticides may be hazardous to health.(5) Bodily insult may occur from having skin contact with a pesticide or by inhaling or ingesting it. The injury may be an acute reaction or a chronic effect that may take years to develop, like cancer. In addition, these chemicals may cause systemic, neurological, gastrointestinal, immunological, or mutagenic toxicity. While groups of similar pesticides may affect the body similarly, there is no general effect common to all pesticides. Laboratory studies of the pesticides attempt to establish the hazards associated with each route of entry. However, with very few of the hundred or more pesticides potentially in use is there real human exposure data regarding doses received and the production of either cancer or noncancer effects.

A qualitative risk assessment, looking at the quality of research data available for the toxicity of 16 herbicides being considered for use by the Forest Service was recently conducted by the University of Washington.(6) It is revealing to note how marginal and/or inadequate the data were considered for the judgment calls which have to be made for toxicity. (See Figure 2.0) Such problems associated with a hazard analysis are magnified when dealing with the numbers of chemicals potentially being used in the state. The attempt to define the hazard is complicated even more when the potential for interactions among the pesticides is considered, as it must be if drift is the issue of interest. Having no common, specific symptom on which to focus also complicates the problem of documenting health effects among the public exposed to pesticide drift.

These and several other problems associated with analyzing the health effects associated with pesticide drift present serious limitations to any effort at quantifying the risks in this state.

ANALYTICAL APPROACH AND DATA SOURCES

A quantitative risk assessment must consider four basic elements:

- The hazard - Does the particular pesticide cause specific adverse health impacts?
- The exposure - What are the levels, sources and times of exposure to the pesticide?
- The dose-response - Given any exposure, what dose will the body receive and what will be the likelihood that an adverse reacton will occur?
- The risk characterization -- Given the data above, what estimates can be made for the magnitude of risks for the populations at risk.

The problem of pesticide drift must be recognized as a real problem, with a definite potential for impact on human health. However, at the present time, it is felt inappropriate to conduct a quantitative risk assessment in the state, for the following reasons:

Figure 2.0

Table IV–23

Quality of Information on 16 Herbicides by Type of Toxicity

Chemical	Effect: Systemic	Cancer	Reproductive	Developmental	Neurologic	Immunologic
Amitrole	M	M	I	A	I	I
Asulam	M	A	M	M	I	I
Atrazine	M	M	M	M	M	I
Bromacil	M	M	M	M	I	I
2,4–D	A	M	A	M	A	M
2,4–DP	A	M	M	A	I	I
Dalapon	M	M	I	M	I	I
Dicamba	I	M	M	A	I	I
Diuron	I	I	I	M	I	I
Fosamine	M–I	I	I	I	I	I
Glyphosate	M–I	M	M	A	I	I
Hexazinone	M	A	M	M	I	I
Picloram	A	M	M	M	I	I
Simazine	M	I	M	A	I	I
Tebuthiuron	M–I	M	M	M–I	I	I
Triclopyr	M–I	M	M	A	I	I

Quality of Data:
I = Inadequate information available for evaluating toxicity.
M–I = Marginal but usable information available for evaluating toxicity – widely varying results provide an unstable assessment.
M = Marginal but usable information available for evaluating toxicity – additional studies may significantly change assessment.
A = Adequate information available – more studies unlikely to change assessment.

Source: U.S.D.A.. DEIS: Managing Competing and Unwanted Vegetation

REGARDING THE HAZARD

While there is evidence that pesticides can cause cancer and other noncancer effects, at this time data are insufficient to document to which pesticides the public may be most exposed through the phenomenon of pesticide drift. While the research is available that 2,4-D does drift, any assessments conducted with only that pesticide would not necessarily be representative of the hazard from pesticide drift occurring in the state. It may or may not be the most frequent offender. It may or may not cause health impacts similar to other pesticides in the state. Thus, it may or may not be an indicator of the extent or nature of the hazard.

In addition, inert ingredients used in the formulation of pesticides may be of concern in drift exposure. Pesticide formulations, and hence the presence of such compounds, tend to be proprietary information. Nonetheless, EPA has identified approximately 1,200 chemicals as inert ingredients in pesticide formulations.(7) Some of these include chemicals previously identified as carcinogens, reproductive toxins, and neurotoxins. The list includes asbestos, benzene, carbon tetrachloride, formaldehyde, lead, pentachlorophenol, and trichlorethylene.(6) Until the actual chemicals and hence the types of hazards associated with pesticide drift are documented, it is unrealistic to quantify a population risk.

REGARDING THE EXPOSURE

There are many variables which impact the exposure assessment and there could be many estimates for public exposure. The type, duration, and frequency of various pesticide applications are not known. Aerial applications certainly cause drift, but there can also be drift from ground spraying under the right conditions. Available studies do not provide the scientific exposure levels on which an exposure assessment can be calculated. Some of the variables to exposure which influence this factor are:

1. Different formulations of pesticides can have different volatility categories, reflecting different vapor pressures for the compounds.(3)

2. Weather conditions and wind patterns can affect the exposure patterns, and hence the populations impacted. For example, high-volatile formulations of 2,4-D were found to be most widespread when there were unsettled weather conditions, and they were frequently affected by fronts or low pressure systems with cloudy skies and showers or more general rain. In contrast, the occurrence of low-volatile 2,4-D was scattered and could not be related to particular weather or other factors.(3)

   A study of airborne residues of two herbicides in Canada noted that the onset of rainy periods correlated with significant levels of triallate being released into the atmosphere.(8) They noted that airborne herbicide residues were highest during and following their application, provided soil moisture conditions were conducive to vapor activity, after which the residues declined to low levels.(8) They also noted that when soil moisture conditions were dry during and following applications, airborne residues corresponded to rainfall events over the remaining growing season. They concluded that vapor transport was a major route for the dissipation of the herbicides under study, with soil water being the limiting factor. Thus the level and source of the pesticide exposure due to drift is extremely difficult to calculate over time. The presence of one recently sprayed pesticide may very well be found in conjunction with the airborne residues of pesticides sprayed at a different time and place.

Studies of wind patterns at Badger Mountain during a recent paraquat drift investigation found that wind conditions constantly fluctuated. It also appeared that wind at different elevations could be moving in different directions. This could markedly influence ultimate destinations and depositions of drift.

3. A complicating variable associated with drift is the consideration of not only what occurs at the time of application, but what might also be released at later times. This brings up the concern of short-term versus long-term exposure data. It also points out that while pesticide drift may be a concern because of public exposure due to ingestion of vegetation exposed during the application process, the concern of inhalation of airborne residuals released over time may also be a problem. There are no data to document exposure levels from either source at the present time.

4. Another confounding variable in assessing exposure is that the public has a multitude of other exposures which may complicate the assessment. Personal habits, such as cigarette smoking, and work place exposures to other toxic agents could significantly alter reactions to any drift exposure.

5. Another unknown exposure variable is the distance pesticides may be transported by drift. Evidence exists that drift can extend from several feet to several miles. One study of drift from aerial applications of insecticides to coniferous seed orchards in other states found drift deposits from 60 to 210 meters downwind. The study also noted large amounts of spray deposited within a 15 meter zone surrounding orchards.(11) A better transport model must be made available in order to estimate the populations actually exposed to drift.

FINDINGS

At this time, no quantitative risk assessment can be done for the human health risks associated with pesticide drift. There is a substantial body of information which must be gathered before such an assessment is possible.

The potential severity of the health end points associated with any pesticide drift could be substantial, ranging over a wide range of possible health effects, including mortality and teratogenicity.

It is a fact that pesticide drift occurs. The actual health effects associated with drift are unknown at the present time.

QUALITATIVE RESULTS

Three studies of health effects associated with drift should be noted. The first was conducted by DSHS in 1980 in response to complaints about reproductive outcomes in Ashford, Washington.(10) The public was concerned that forest and roadside spraying with the phenoxy herbicides, 2,4-D and 2,4,5,-T were causing reproductive problems. In a six-month period, ten conceptions had resulted in only one normal term livebirth. The study found that only 1.32 percent of the area within ten miles of Ashford had been treated with herbicides/pesticides in the years 1977-1979. In addition, there was no history of personal exposure to pesticides or any agents related to fetal loss. The study concluded that the various, different pregnancy outcomes had different etiologies. While no cause for the situation could be elucidated, herbicide/pesticide exposures were not implicated.

A second study was a quantitative and qualitative risk assessment that included an assessment of public exposure to pesticide drift, done as part of a Draft Environmental Impact Statement for Vegetative Management in the Forest Services' Pacific Northwest Region.(6) In that effort, several assumptions were made to assess the impacts of 16 herbicides. A nearby resident was assumed to have exposure from direct dermal contact due to drift over two square feet of unprotected skin and to eat 400 grams (less than one pound) of vegetables contaminated by drift. The assumption was also made that one quart of water contaminated by drift would be consumed, and that the resident entered a sprayed area with secondary skin contact from sprayed vegetation. Nearly all the calculated exposure was due to eating the vegetables and drinking the water. Drift deposition was derived from actual measurements, which were adjusted for application rates. Guidelines for aerial spraying in forest areas were assumed to be followed. Wind direction was assumed directly toward the targets of concern. No allowance was made for herbicide degradation. Assumed distances from the helicopter to vegetables was 600 feet, while the distance to water was assumed to be 50 feet. Lifetime exposure assumed that the resident received the dose calculated once per year for 40 years. It also assumed a one-time accident exposure. A substantial appendix in the DEIS described the quantitative risk assessment in detail. A few results have been excerpted and are shown in Appendix 2 of this document. With the assumptions given in the DEIS, it was generally concluded that the public had a large margin of safety and that the risk for health effects from drift were minimal. Unfortunately, there were several uncertainties regarding the data since the quality of the scientific data base on which the calculations had to be based was questioned in several instances. Nonetheless, the assessment in the DEIS demonstrates the complexity of attempting such a risk assessment and provides data of interest even though they are not directly applicable to the issue at hand.

The third study is the recently completed Badger Canyon Report which was conducted in response to complaints from Tri-Cities area residents about illnesses from the aerial application of pesticides.(12) Pesticide drift over wide areas had been documented in 1988 and the study evaluated the relationship between the health complaints and pesticide usage in the Badger Canyon area. The study found that, based on the toxicologic profiles of the pesticides of greatest concern, the health risks from drift should be extremely low. In addition, environmental samples did not detect pesticide residues at levels likely to be associated with adverse health effects. However, increases in general symptoms such as cough, sore throat and anxiety were seen among the population at highest risk. Two families in the area continue to experience illnesses which have been attributed to pesticide exposure. However, since there were several limitations to the study, the available data proved inconclusive. The data did not prove or disprove a cause-effect relationship between pesticide applications and reported illnesses in the area.

UNCERTAINTY

There can be no specific conclusions drawn regarding pesticide drift and health effects in Washington. The entire issue is entangled with uncertainties.

ANATOMY OF RISK

Since both urban and rural areas may be subjected to pesticide use, pesticide drift is a statewide problem. However, the agricultural areas are perhaps of greater interest because of the typical use of aerial spraying.

The numbers and types of sources, pesticide formulations, and exposure pathways are all complex. Multiple effects are possible, although none have been documented to date.

There is an increasing use of pesticides, perhaps reflecting the conversion of grazing and idle farmland to cropland with irrigation.(4) This indicates that the issues associated with pesticide drift need to be addressed. Before appropriate risk management can be implemented, better monitoring and data collection must be initiated in order to adequately define the risks. Specifically needed are:

1. Adequate documentation and record keeping of the quantity and type of pesticide use in the state;

2. Established monitoring programs for environmental and health information; and

3. Models developed for data extrapolation for information such as drift distances.

The recently passed House Bill 2222, relating to pesticide use, is an important step in assessing the health impacts of pesticides applied in the state. Noteworthy among the provisions of this bill are the requirements for increased reporting, unbiased health investigations of all suspected human cases of pesticide poisoning, and increased education for health care providers regarding pesticide poisonings. These, coupled with new record-keeping requirements, should begin to provide the needed framework for documenting any health impacts from pesticide use, including drift.

REFERENCES

1. Miller, Conrad O. M. 1980. "A Mathematical Model of Aerial Deposition of Pesticides from Aircraft." Environmental Science and Technology: Vol. 14, No. 7. July 1980, pp 824ff.

2. Briggs, Calvin. 1988. "Paraquat Drift Investigation." Washington State Department of Agriculture.

3. Pack, Merrill R., and Elmer Robinson. 1981. "Final Report: Atmospheric Drift of 2,4-D in the Lower Yakima Valley-1980." Washington State Department of Agriculture.

4. Environmental Protection Agency. 1989. "Draft. Human Health Risk Assessment: Pesticide Use and Application."

5. Office of Environmental Health Programs. 1988. "Toxic Substances Fact Sheet: Pesticides." State of Washington: DSHS.

6. United States Department of Agriculture. 1987. Draft Environmental Impact Statement: Managing Competing and Unwanted Vegetation: Volume 1 Narrative and Volume 2 Appendices. Forest Service: Pacific Northwest Region.

7. United States Department of Agriculture. 1988. Memorandum to Regional Foresters, Station Directors, and Area Director. "Inert Ingredients in Pesticide Formulations."

8. Grover, R., L. A. Kerr, K. E. Bowren, and S. U. Shan. 1988. "Airborne Residues of Traillate and Trifluralin in Saskatchewan," Bull. Environ. Contam. Toxicol. 40:683-688.

9. Frank, R., R. A. Campbell, and G. J. Sirons. 1985. "Forestry Workers Involved in Aerial Application of 2,4-Dichlorophenoxyacetic Acid (2,4-D): Exposure and Urinary Excretion." Archives of Environmental Contamination and Toxicology. 14:427-435.

10. Milham, Samuel. 1980. "Investigation of Reproductive Experience in Ashford, Washington." Washington State Department of Social and Health Services: Epidemiology Section.

11. Barry, John W., Patricia A. Kenney, Robert B. Ekblad, Larry A. Barber. 1983. "Drift from Aerial Application to Coniferous Seed Orchards." Presentation at the 1983 Joint Technical Session American Society of Agricultural Engineers and National Agricultural Aviation Association. Reno, Nevada. Dec. 5, 1983.

12. Sagerser, Carl, et al. 1989. Badger Canyon Report. Washington State Department of Social and Health Services, Division of Health.

APPENDIX 1

CHARACTERISTICS OF MAJOR PESTICIDES USED IN REGION 10

Pesticide/ LD50 Value	Type	Registered uses/other uses	Extent of use	Application Method	Toxity Human	Human Health Concerns	Controlability	Data Gaps
Paraquat LD50 150 mg/kg (MH)	Contact Herbicide	Cropland, non-cropland, forestry, ornamental		Broadcast, band, direct spray	•TMRC - .1134 Mg/day .42% of MPI •Toxicity Category I		Since it is a herbicide it will affect plants assoc. w/grasslands cured by adequate labeling.	Environmental fate 90 day inhalation Residue chemistry (storage stability of paraquat in animal tissue).
Atrazine LD50 1780 mg/kg (M)	Herbicide	Crops, mostly corn	656,619 lbs/yr		•Low order of toxicity. (Category III). •However, there are data gaps - •TMRC - .233 mg/day. •1070% of API of .375 mg/kg	•Food - which tolerance for atrazine residues that have been established constitute about 62% of average diet •TMRC is only about 10% of the ADI		Environmental fate chemistry data to assess chemical characteristics. Animal metabolism studies
2-4-D LD50 LD50 375-805 mg/kg (M)	Herbicide	Crops, cereal, sugarcane, forests, lawns - also used to delay preharvest.	4,813,-729 lbs/yr	Direct Spray	•TMRC - .15 mg/kg - 12% of ADI and .125mg/kg	Clinical signs observed in workers exposed dermally or orally include vomiting, diarrhea, hyperthermia	Surveillance monitoring should concentrate on crops treated near harvest, use in irrigation water/ditchs	Env. fate residue chemistry product chemistry ecological effects.
Dursban/Lorsban Chlorpyrifos LD50 96-270 mg/kg (M)	Insecticide	Food crops, animals, cattle sheep, turkey, dogs, lawn & storage bins		By ground equip., aircraft for corn & aquatic non-crop areas.	•Category II on basis of acute oral effects. •Category III for dermal toxicity.	Most human exposures occur through inhalation and dermal exposure		Full tolerance assessmnt has not been completed because of data gaps
Methyl Parathion LD50 a-25 mg/kg (H)	Insecticide (organo-phosphate)	Terrestrial food crops tobacco, ornamental forestry aquatic, rice	153,613 lbs/yr	Ground equip. or aircraft (foliarly applied)	•Toxicity Category I - because of data gaps. PAD 1.0015 mg/kg/day. TMRC is 800% PAD 1.		Endangered Species labeling is req.	
Strichnine LD50 .7-112 mg/kg	Rodenticide	Crops, orchards & vineyards		Above ground dyed baits	•Toxicity Category I			
Alachlor LD50 1800 mg/kg (M)	Herbicide	Corn, Soybean	635,607 lbs/yr	Preemergence, postemergence by broadcast band appl. 15 or more gals. per acre.	•TMRC - .033 mg/day. 1.5kg diet. No ADI supported by valid data for alachlor.	•General population not exposed. Exposure is to production workers, pesticide applicants and ag. workers has oxygen potential.		Dietary exp. to general public

CHARACTERISTICS OF MAJOR PESTICIDES USED IN REGION 10

..ticide/ ..0 Value	Type	Registered uses/other uses	Extent of use	Application Method	Toxicity Human	Human Health Concerns	Controlability	Data Gaps
..athion ..0 "1000" ..5 mg/kg(M)	Insecticide	Homes, crops, grain treatment	120,301 lbs/yr	Spray	•TMRC - .1014 mg/kg/day - 507 PAD I			Plant & animal metabolism, storage stability toxicological testing
..rboryl ..0 .9-5 ../kg	Insecticide	Crops, aquatic uses pets.	716,050 lbs.yr		•TMRC - 5.48 mg/mg/kg. MPI - 6mg/day. •ADI = .1 mg/kg.	Insufficient data suggests that carboryl is not oncogenic in experimental animals.		Residue data hydolysis study photo dugradation soil metabolism
..dicarb ..50 .9-5 ../kg	Insecticide	Cotton, potatoes sugar beets, peanuts & soybeans.		Ground (broadcast & band), aerial	•TMRC Potatoes: .0815mg = more than 437% of the ADI or .003 mg/kg b.u. •All commodities have tolerance levels of .0244 mg/day/60% ADI.			Groundwater contaminants
..iazinon ..050 300-400 ..g/kg	Insecticide	Crops, rangeland pastures, turf, golf courses.	165,184 lbs/yr	Ground, (broadcast & band), aerial.	•Extremely toxic toxic to all animals. (Categ I.)	Highly toxic to humans; effect re: central nervous system.		
Ethyl Parathion	Insecticide	Crops	630,833 lbs/yr		•TMRC .59 mg/day and is 192% of ADI. However, for infants and children up to 12 yrs ratio increases to 291 - 575%.		Standard required labeling statemnts which govern use of parathion in areas of endang. species	Not determined whether Parathion causes risk to aquatic invarbrates or fish due to insufficient field data, g.w. contaminants, persistence in environment.
Tributyltin TBT LD50 10,000 mg/kg (L)	Biocide	Anti foulant in in paints used on ships, docks piling						Insufficient data accumulation of TBT in aquatic sediments & tissue of aquatic organisms
Picloram/ Tordan LD50 [illegible]	Herbicide	Forests pasture rangelands					Requires cautionary label statements in use of picloram in very permeable areas	The established tolerances for picloram are not supported by the data now available

CHARACTERISTICS OF MAJOR PESTICIDES USED IN REGION 10

'esticide/ .D50 Value	Type	Registered uses/other uses	Extent of use	Application Method	Toxicity Humane	Human Health Concerns	Controlability	Data Gaps
ilyphosate .D50 4300 ıg/kg	Herbicide	Terrestrial food, non food crops, aquatic food & non food crop.			°Low acute toxicity. Category III for oral, dermal eye I and Category IV for primary skin irritation. °TRMC 1.4238 mg/day - 1.5ks diet. Occupies 23.73% ADI.			Ocogenic studies sub chronic feeding studies, photo degradation study
'elpar/Garlon	Herbicide	Non-cropland, X-mas trees, plantation, drainage, ditch banks.			°Category III.		Endangered plants grow with alfalfa.	

APPENDIX 2

EXCERPTS FROM U.S.D.A.

DEIS MANAGING COMPETING AND UNWANTED VEGETATION, 1987

Table IV–24

Estimated Level of Confidence that No Adverse Human Health Effects Will Occur

Based on Public Exposure from Routine-Realistic Aerial Spraying** (Combined Exposures for a Nearby Resident)

	Effect:		
Chemical	Systemic	Reproductive	Developmental
Amitrole	U	*	M
Asulam	H	H	H
Atrazine	M	M	M
Bromacil	H	H	H
2,4–D	M	M	M
2,4–DP	H	H	H
Dalapon	H	*	H
Dicamba	*	H	M
Diuron	*	*	H
Fosamine	H	*	*
Glyphosate	H	H	H
Hexazinone	H	H	H
Picloram	H	H	H
Simazine	M	M	M
Tebuthiuron	H	H	H
Triclopyr	M	H	H

Quality of Data:
U = Uncertain, M = Moderate, H = High.
* Not calculated due to inadequate data.
** Exposures as estimated in LAI risk assessment (Appendix D).

Table IV–27

Comparison of Cancer Hazards for 16 Herbicides

	Worst Case—Nearby Resident			Worst Case—Applicator	
Chemical	Animal LOEL (ug/kg)	Lifetime** Average Daily Exposure (ug/kg)	LOEL HERP	Lifetime*** Average Daily Exposure (ug/kg)	LOEL HERP
Amitrole	2,500	0.019	0.0008	0.077	0.0031
Asulam	750,000	0.024	0.000003	4.7	0.0006
Atrazine	3,500	0.039	0.001	12.	0.34
Bromacil	250,000	0.035	0.00001	15.	0.006
2,4–D	45,000	0.018	0.00004	4.7	0.01
2,4–DP	25,000	0.019	0.00008	4.9	0.02
Dalapon	N/A	0.044	—	15.	—
Dicamba	125,000	0.013	0.00001	0.96	0.0008
Diuron	*	0.054	—	15.	—
Fosamine	*	0.048	—	12.	—
Glyphosate	32,000	0.022	0.00007	5.9	0.02
Hexazinone	N/A	0.027	—	4.2	—
Picloram	380,000	0.011	0.000003	0.19	0.00005
Simazine	*	0.029	—	7.7	—
Tebuthiuron	N/A	0.022	—	5.9	—
Triclopyr	1,200– 30,000	0.032	0.003– 0.0001	7.7	0.64– 0.026

* = Not calculated due to inadequate data.
N/A = No positive rodent data.
** = Lifetime exposure for a "nearby resident" is represented by one routine-realistic exposure per year for 40 years plus one accidental exposure (routine-realistic and accidental exposures for residents are calculated in LAI – Appendix D).
*** = Lifetime exposure for a backpack sprayer is estimated by 15 routine-realistic exposures per year for a working life of 40 years (routine realistic backpack applicator exposure is calculated in LAI – Appendix D).

Table 4-12
Doses to Example People in
Routine-Realistic Exposure Scenarios

Herbicide	Aerial					Truck (row)					Backpack				
	Hiker	Berry-picker	Hunter	Fisher-man	Nearby Resident	Hiker	Berry-picker	Hunter	Fisher-man	Nearby Resident	Hiker	Berry-picker	Hunter	Fisher-man	Nearby Resident
Amitrole	1	1	1	1	1	-1	0	0	0	0	0	0	0	0	0
Asulam	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Atrazine	1	2	1	2	1	0	0	0	0	0	0	1	0	1	1
Bromacil	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1
2,4-D	1	1	1	1	1	0	0	0	0	0	0	1	0	0	0
2,4-DP	1	1	1	1	1	0	0	0	0	0	0	1	0	0	0
Dalapon	1	2	1	1	1	0	0	0	0	0	0	1	1	0	1
Dicamba	0	1	1	1	1	-1	0	-1	-1	0	-1	0	0	-1	0
Diuron	-	-	-	-	-	0	0	0	1	0	0	1	1	1	1
Fosamine	1	1	1	1	1	0	0	0	0	0	0	1	0	0	1
Glyphosate	1	1	1	1	1	0	0	0	0	0	0	1	0	0	0
Hexazinone	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Picloram	0	1	1	1	1	-1	-1	-1	-1	0	-1	0	0	0	0
Simazine	1	2	1	1	1	0	0	0	0	0	0	1	0	0	0
Tebuthiuron	0	1	1	1	1	0	0	0	0	0	0	1	0	0	0
Triclopyr	1	1	1	1	1	0	0	0	0	0	0	1	0	0	0

DOSE LEVELS
- - not used
- 2 0.1 mg/kg
- 1 0.01 mg/kg
- 0 0.001 mg/kg
- -1 0.0001 mg/kg

Table 5-11

Lifetime Cancer Risk[d]--Exposed Public
Realistic Aerial, 40 Acres by Helicopter

Routes of Exposure	Exposures per Lifetime	Risk from Exclusive Use of:							
		2,4-D	2,4-DP	Asulam	Bromacil	Picloram	Amitrole	Glyphosate	Atrazine
For a Single Exposure									
Dermal, Spray	1	10^{-11}[b]	10^{-10}	10^{-12}	—[c]	10^{-14}	10^{-11}	10^{-13}	10^{-10}
Vegetation Contact									
Hiker	1	10^{-13}	10^{-12}	10^{-14}	—	10^{-16}	10^{-13}	10^{-15}	10^{-12}
Picker	1	10^{-9}	10^{-8}	10^{-10}	—	10^{-12}	10^{-9}	10^{-11}	10^{-8}
Drinking Water	1	10^{-9}	10^{-8}	10^{-10}	—	10^{-10}	10^{-7}	10^{-11}	10^{-8}
Eating Berries	1	10^{-9}	10^{-8}	10^{-10}	—	10^{-11}	10^{-7}	10^{-11}	10^{-8}
Eating Vegets.	1	10^{-9}	10^{-8}	10^{-10}	—	10^{-10}	10^{-7}	10^{-11}	10^{-8}
Eating Deer	1	10^{-10}	10^{-9}	10^{-11}	—	10^{-12}	10^{-8}	10^{-12}	10^{-9}
Eating Fish	1	10^{-10}	10^{-9}	10^{-10}	—	10^{-11}	10^{-7}	10^{-12}	10^{-8}
Combined Routes of Exposure									
Hiker	1	10^{-9}	10^{-8}	10^{-10}	—	10^{-10}	10^{-7}	10^{-11}	10^{-8}
Berry Picker	1	10^{-9}	10^{-8}	10^{-9}	—	10^{-10}	10^{-7}	10^{-11}	10^{-8}
Hunter	1	10^{-9}	10^{-8}	10^{-10}	—	10^{-10}	10^{-7}	10^{-11}	10^{-8}
Fisherman	1	10^{-9}	10^{-8}	10^{-10}	—	10^{-10}	10^{-7}	10^{-11}	10^{-8}
Resident	1	10^{-9}	10^{-8}	10^{-10}	—	10^{-10}	10^{-6}	10^{-11}	10^{-8}
For 30 Exposures									
Dermal, Spray	30	10^{-10}	10^{-9}	10^{-10}	—	10^{-12}	10^{-9}	10^{-12}	10^{-9}
Vegetation Contact									
Hiker	30	10^{-12}	10^{-11}	10^{-12}	—	10^{-14}	10^{-11}	10^{-14}	10^{-11}
Picker	30	10^{-8}	10^{-7}	10^{-8}	—	10^{-10}	10^{-7}	10^{-9}	10^{-6}
Drinking Water	30	10^{-8}	10^{-7}	10^{-8}	—	10^{-9}	10^{-5}	10^{-10}	10^{-7}
Eating Berries	30	10^{-8}	10^{-7}	10^{-9}	—	10^{-9}	10^{-6}	10^{-10}	10^{-7}
Eating Vegets.	30	10^{-8}	10^{-7}	10^{-8}	—	10^{-9}	10^{-5}	10^{-10}	10^{-7}
Eating Deer	30	10^{-9}	10^{-8}	10^{-9}	—	10^{-10}	10^{-6}	10^{-11}	10^{-8}
Eating Fish	30	10^{-8}	10^{-7}	10^{-9}	—	10^{-9}	10^{-6}	10^{-10}	10^{-6}
Combined Routes of Exposure									
Hiker	30	10^{-8}	10^{-7}	10^{-8}	—	10^{-9}	10^{-5}	10^{-10}	10^{-7}
Berry Picker	30	10^{-7}	10^{-6}	10^{-8}	—	10^{-9}	10^{-5}	10^{-9}	10^{-6}
Hunter	30	10^{-8}	10^{-7}	10^{-8}	—	10^{-9}	10^{-5}	10^{-10}	10^{-7}
Fisherman	30	10^{-7}	10^{-7}	10^{-8}	—	10^{-9}	10^{-5}	10^{-10}	10^{-6}
Resident	30	10^{-7}	10^{-6}	10^{-8}	—	10^{-9}	10^{-5}	10^{-9}	10^{-6}

[a]Cancer risks shown in this Table were calculated based on a variety of assumptions that tend to overestimate risks as explained in Section 5.

[c]Not used in aerial application.

[b]All of these numbers shown exponentially are to be interpreted as follows:

[c]Not used in aerial application.

10^{-7} means 1 out of 10 million individuals exposed to a given herbicide via a given exposure scenario.

10^{-8} means 1 out of 100 million individuals,

10^{-9} means 1 out of 1 billion individuals, etc.

Table 5-12

Lifetime Cancer Risk[a]--Exposed Public
Large Aerial, 400 Acres by Fixed Wing, Worst Case

Routes of Exposure	Exposures per Lifetime	Risk from Exclusive Use of: 2,4-D	2,4-DP	Asulam	Bromacil	Picloram	Amitrole	Glyphosate	[Atrazine]
For a Single Exposure									
Dermal, Spray	1	10^{-8}[b]	10^{-8}	10^{-9}	—[c]	10^{-10}	10^{-8}	10^{-10}	[10^{-7}]
Vegetation Contact									
Hiker	1	10^{-10}	10^{-9}	10^{-11}	—	10^{-12}	10^{-10}	10^{-12}	[10^{-9}]
Picker	1	10^{-8}	10^{-7}	10^{-9}	—	10^{-10}	10^{-7}	10^{-10}	[10^{-7}]
Drinking Water	1	10^{-8}	10^{-8}	10^{-9}	—	10^{-9}	10^{-6}	10^{-10}	[10^{-8}]
Eating Berries	1	10^{-8}	10^{-8}	10^{-9}	—	10^{-9}	10^{-6}	10^{-10}	[10^{-8}]
Eating Vegets.	1	10^{-8}	10^{-7}	10^{-9}	—	10^{-9}	10^{-6}	10^{-10}	[10^{-7}]
Eating Deer	1	10^{-9}	10^{-8}	10^{-10}	—	10^{-10}	10^{-7}	10^{-11}	[10^{-9}]
Eating Fish	1	10^{-9}	10^{-8}	10^{-10}	—	10^{-10}	10^{-6}	10^{-11}	[10^{-7}]
Combined Routes of Exposure									
Hiker	1	10^{-8}	10^{-7}	10^{-9}	—	10^{-9}	10^{-6}	10^{-10}	[10^{-7}]
Berry Picker	1	10^{-8}	10^{-7}	10^{-8}	—	10^{-9}	10^{-6}	10^{-9}	[10^{-7}]
Hunter	1	10^{-8}	10^{-7}	10^{-9}	—	10^{-9}	10^{-6}	10^{-10}	[10^{-7}]
Fisherman	1	10^{-8}	10^{-7}	10^{-9}	—	10^{-9}	10^{-6}	10^{-10}	[10^{-7}]
Resident	1	10^{-8}	10^{-7}	10^{-9}	—	10^{-9}	10^{-6}	10^{-10}	[10^{-7}]
For 30 Exposures									
Dermal, Spray	30	10^{-7}	10^{-6}	10^{-8}	—	10^{-9}	10^{-6}	10^{-9}	[10^{-6}]
Vegetation Contact									
Hiker	30	10^{-9}	10^{-8}	10^{-9}	—	10^{-11}	10^{-8}	10^{-10}	[10^{-8}]
Picker	30	10^{-7}	10^{-6}	10^{-7}	—	10^{-9}	10^{-6}	10^{-8}	[10^{-6}]
Drinking Water	30	10^{-7}	10^{-6}	10^{-8}	—	10^{-8}	10^{-4}	10^{-9}	[10^{-6}]
Eating Berries	30	10^{-7}	10^{-6}	10^{-8}	—	10^{-8}	10^{-5}	10^{-9}	[10^{-6}]
Eating Vegets.	30	10^{-7}	10^{-6}	10^{-7}	—	10^{-8}	10^{-4}	10^{-9}	[10^{-6}]
Eating Deer	30	10^{-8}	10^{-7}	10^{-9}	—	10^{-9}	10^{-5}	10^{-10}	[10^{-7}]
Eating Fish	30	10^{-7}	10^{-6}	10^{-8}	—	10^{-8}	10^{-5}	10^{-9}	[10^{-6}]
Combined Routes of Exposure									
Hiker	30	10^{-7}	10^{-6}	10^{-7}	—	10^{-8}	10^{-4}	10^{-8}	[10^{-6}]
Berry Picker	30	10^{-6}	10^{-5}	10^{-7}	—	10^{-7}	10^{-4}	10^{-8}	[10^{-5}]
Hunter	30	10^{-7}	10^{-6}	10^{-7}	—	10^{-8}	10^{-4}	10^{-8}	[10^{-6}]
Fisherman	30	10^{-7}	10^{-6}	10^{-7}	—	10^{-8}	10^{-4}	10^{-8}	[10^{-5}]
Resident	30	10^{-6}	10^{-5}	10^{-7}	—	10^{-7}	10^{-4}	10^{-8}	[10^{-6}]

[a]Cancer risks shown in this Table were calculated based on a variety of assumptions that tend to overestimate risks as explained in Section 5.

[b]All of these numbers shown exponentially are to be interpreted as follows:
- 10^{-7} means 1 out of 10 million individuals exposed to a given herbicide via a given exposure scenario.
- 10^{-8} means 1 out of 100 million individuals,
- 10^{-9} means 1 out of 1 billion individuals, etc.

[c]Not used in aerial application.

Table 5-2

Lowest Margins of Safety for the General Public Under the Routine Scenarios

Herbicide	Routine-Realistic Scenarios	Routine-Worst Case[a] Scenarios
Amitrole	All right-of-way and most backpack MOS's are greater than 50, except eating vegetables (41), and residents (32). Most MOS's for aerial application are less than 50, including the following that are less than 10: berrypicker (8), hunter (9), fisherman (9), and residents (6).	Many of the right-of-way and 2 of the backpack MOS's are less than 50. Most of the aerial MOS's are less than 50, including the following that are less than 10: drinking water (2), eating berries (2), eating vegetables (1), eating bird (4), eating fish (4), hiker (1), berrypicker (1), hunter (1), fisherman (1), and resident (-1).
Asulam	All situations 8,000 or greater.	All situations greater than 860.
Atrazine	All situations greater than 310.	All situations greater than 50 except for berrypickers (44), for the 400-acre aerial application.
Bromacil	All situations are greater than 2,200.	All situations are 700 or greater.
2,4-D	All situations greater than 150.	All right-of-way and backpack MOS's are greater than 380. All aerial MOS's are greater than 10 with the following situations having MOS's of 10 to 50: vegetation contact by picker (38), eating vegetables (48), hiker (43), berrypicker (17), hunter (32), fisherman (36) and resident (23).
2,4-DP	All situations 990 or greater.	All situations greater than 120.
Dalapon	Greater than 1,100 in all situations.	All situations greater than 100 except berrypicker (72).

[a]A margin of safety of 50 was chosen as the cutoff to report values in this table for ease of comparison. It was not intended to indicate what would be considered low or high risk.

Table 5-2 (Cont.)

Herbicide	Routine-Realistic Scenarios	Routine-Worst Case[a] Scenarios
Dicamba	Greater than 1000 in all situations.	All situations greater than 100 except for berrypickers (47), hunters (85), fishermen (95), and residents (60) for 400-acre aerial application.
Diuron	Greater than 180 in all situations.	All MOS's 77 or greater in all situations.
Fosamine	All greater than 2,600.	All 99 or greater.
Glyphosate	All greater than 1,500.	All 95 or greater.
Hexazinone	All greater than 1,200.	All greater than 150.
Picloram	All greater than 3,400.	All greater than 150.
Simazine	All greater than 390.	All greater than 50 except for berrypickers (48) in 400-acre aerial application.
Tebuthiuron	All greater than 2,500.	All MOS's 99 or greater.
Triclopyr	All greater than 390.	All situations greater than 50 except for vegetation contact by berrypicker (29), and the multiple routes for hiker (42), berrypicker(15), hunter (32), fisherman (36), and resident (25) in the 400-acre aerial application.

[a]A margin of safety of 50 was chosen as the cutoff to report values in this table for ease of comparison. It was not intended to indicate what would be considered low or high risk.

HOUSEHOLD USE OF PESTICIDES

INTRODUCTION

The time and resource constraints within which this report was produced prevented a thorough investigation of the use of pesticides in Washington homes, and the risks associated with those uses. Nonetheless, the Technical Advisory Committee (TAC) recognizes the potential importance of such exposures, especially vis-a-vis acute effects (e.g., headaches, burns). Therefore, for informational purposes, excerpts from a 1988 U.S. EPA report titled "Human Exposure to Pesticides Used In and Around the Household" are included here.

EXCERPTS FROM EPA REPORT

By far the principal exposure of the general population of the United States to pesticides occurs in the home. Studies have shown that about 90 percent of all U.S. households use pesticides (Kiel *et al.*, 1969; von Rumker *et al.*, 1972; EPA, 1979; Savage *et al.*, 1981). A national survey conducted by the U.S. Environmental Protection Agency during 1976-77 (EPA, 1979), revealed of the 90.7 percent of the U.S. households that used pesticides, 83.7 percent used them inside the house, 21.4 percent in the garden, and 28.7 percent on the lawn. Twelve of the 14 most commonly used pesticides were insecticides. Over 90 percent of the households used disinfectants (antimicrobials), 35.8 percent used moth repellants and 26 percent were treated with termiticides.

Herbicides are unlikely to be used inside the home. However, several are commonly used for lawn care and may enter the home *via* intrusion of outdoor air or be carried in on soil particles.

A wide variety of pesticide products are available "off the shelf" for use by the homemaker. These include preparations for flies, roaches, ants, and spiders within the home, flea and tick sprays and shampoos for pets, insecticides for use on house plants and home gardens, insecticides and fungicides for lawn treatment, and a variety of herbicides for weed and crabgrass control. While most homemakers do not consider disinfectants to be pesticide products, most use them routinely as kitchen and bathroom cleaners, room deodorizers, or laundry aids. Many homemakers and landlords utilize professional pest control services for routine indoor treatments or lawn care. In many parts of the country, especially in the southern states, pre- or post-construction treatment for termite protection is essential.

Misuse of household pesticides does occur. During 1976-77, EPA estimated that exposure to pesticides around the home resulted in 2.5 million reported incidences of headache, nausea, dizziness, and eye or skin irrigations (1979). Exposure to pesticides in the home accounted for 75 percent of all pesticide-related injuries treated in hospital emergency rooms in 1981 (Reinert, 1984). However, of greater concern is potential chronic health effects that may derive from long-term, residential exposures.

The typical resident of the U.S. spends the large majority of time indoors, mostly inside his or her own domicile. For full-time homemakers and small children, this amounts to over 21 hours/day inside the home (Robinson, 1977), with another 2.5 hours inside other buildings (stores, offices, etc.) or in transit vehicles. Even when employed, urban dwellers spend about the same amounts of time indoors, 63 percent of it at home and 28 percent at work. Most meals are also taken in the home. Consequently, at least 90 percent of our daily cumulative exposure to pesticides occurs at home.

Some pesticides, such as termiticides, may persist in the home environment for many months or years after application. Chlordane, a popular termiticide used until 1988, has been found to be very effective for up to 23 years after treatment. Even nonpersistent pesticides may last much longer indoors where they are protected from sunlight, water, and other factors which hasten their degradation.

ROUTE OF EXPOSURE

Air

Of the several possible routes of exposure to household pesticides, the air route may be the most significant. In addition to the periodic introduction of pesticides into household air by direct application, there are often sources which continually emit vapors into the living space. These include intrusion of termiticides from the foundations of the dwelling (Leidy et al., 1985), evaporation of residues from crack and crevice treatments (Wright and Jackson, 1976), emissions from impregnated pest control strips often used inside kitchen cabinets (Leary et al., 1974; Jackson and Lewis, 1981), vapors from moth repellants and room deodorizer (Wallace, 1987), and contamination from house dusts and soils tracked into the home (Lewis and Lee, 1976).

At any given time, the air inside of the average dwelling in the U.S. contains several kinds of pesticides at levels that are typically 10 to 100 times higher than those found in the air immediately surrounding outdoor air (Lewis and Lee, 1976; Lewis and MacLeod, 1982; Lewis et al., 1986). A 1985 study of nine households selected from three census regions of Jacksonville, Florida (Lewis et al., 1986, 198) reported a total of 24 of 33 commonly-used pesticides in indoor air at concentrations ranging from 0.002 to 15 ug/m^3. Simultaneous personal monitoring of one or more occupants of each household showed that 81 percent of the total respiratory exposures occurred inside their own homes. Note that the use of household pesticides might be more prevalent in Florida and other southern states than it is elsewhere.

Dermal

Many pesticides may be absorbed through the skin. The efficiency of dermal penetration depends on the chemical type, concentration, and physical form of the pesticide product. While some pesticides (especially organophosphates) have been shown to penetrate the dermis readily (Honeycutt et al., 1985), the EPA assumes, for the purpose of exposure assessment, 10 percent dermal absorption for liquid and spray formulations and 1 percent absorption for granular forms and dusts (Jensen, 1984).

The average homemaker may receive dermal exposures to pesticides when spraying insecticides inside the home, shampooing pets with flea and tick preparations, mixing emulsifiable concentrates for ornamental, lawn or garden applications, and the application of insecticides, herbicides, and fungicides in the yard. Despite label instructions to the contrary, many users do not wear gloves or other protective clothing during these operations. On the other hand, an increased use of lawn care professionals could be reducing the number of people exposed.

Comparatively little dermal exposure data for household pesticide use has been collected to date. It is hoped that sufficient information will be obtained from EPA's current nonoccupational pesticide exposure study to determine the relative importance of chronic vs acute exposures in the home.

House Dust

House dust and the pollutants carried with it may be potentially important contributors to exposure through inhalation, ingestion and skin penetration, especially for small children. Dust can be both a medium for the transfer of pesticides from sources inside and outside the house to people and a medium for their accumulation. Starr et al. (1974) first tested house dust for pesticides in 28 homes of farmers and pesticide formulators in Colorado. He found that the concentrations of organochlorine pesticides were typically in the 10 to 100 ppm range. Klemmer et al. (1975) found arsenic in house dust from 61 homes in Hawaii that had been treated with arsenical pesticides. Arsenic levels ranged from 1 to 1100 ppm.

Toddlers (under age 5) have only about 20 percent of the body weight of an adult, yet ingest 2.5 times as much dust (Hawley, 1985). Therefore, the potential health risk to child is about 12 times that to adults. Some research has suggested that dust ingestion may represent 1,000 times the exposure from inhalation to long-lived soil contaminants by young children (Roberts et al., 1985). For body-stored pollutants, childhood intake may represent a major source of the total adult body burden. There have been several studies that have shown house dust to have significant mutagenicity (Roberts et al., 1986). However, it has been impossible to accurately estimate the risks associated with these exposures because house dust sampling methodology has been inadequate, especially for organics, and insufficient data have been obtained on simultaneous air and dermal exposures, the latter of which is also very difficult to measure.

Diet

The U.S. EPA sets tolerances for pesticide residues in food under the Federal Food, Drug and Cosmetic Act of 1954. The Delaney Clause found in this FDC Act (Section 409) prohibits potentially oncogenic substances in food, which applies to 90 percent of all fungicides, 60 percent of herbicides, and 30 percent of insecticides (NRC, 1987). Despite the law, it has not been possible to eliminate all pesticide residues from produced commercially here and abroad. These residues are generally considered to account for the major exposure to pesticides in the general U.S. population.

Most home gardeners use pesticides, primarily insecticides, on the crops they grow. While the variety of pesticides used by home gardeners is comparatively limited, it is not possible to assess the relative residue levels which may be found in home-grown food compared to that bought in the market place. Many home gardeners may not follow proper application instructions, and residues may not be efficiently removed by usual washing procedures. For the average U.S. resident, however, the total quantity of pesticides ingested from commercial food sources from the U.S. and abroad probably far outweighs that received from home-grown produce.

Prepared and stored food may also become contaminated from pesticides used within the home. This may occur from spray deposition during treatment (Jackson and Wright, 1975), or by diffusion of pesticide vapors into packaged and open foodstuffs stored in kitchen cabinets and pantries (Yeo, 1969). The relative importance of such contributions to food contamination is not known.

For the purpose of comparing the importance of the relative routes of exposure to pesticides used around the household, information collected by the Food and Drug Administration is its Total Diet Surveys may be used. Using data collected by the FDA from eight market baskets analyzed between April 1982 and April 1984 and assuming an average volume to 20 m^3/day, some preliminary estimates of food intake vs. inhalation exposure has been made for participants of the spring 1987 NOPES program conducted by EPA (Immerman et al., 1988). In Jacksonville, Florida, food was estimated to be the primary source of exposure for 13 pesticides and inhalation for five. Corresponding numbers for Springfield, Massachusetts were 17 and two. Data on the seven pesticides responsible for the highest estimated total exposure are given in Table III. It should be noted that several of the most important pesticides found in air are not monitored in food (e.g., o-phenylphenol, propoxur and dichlorvos). It is likely that inhalation is the major exposure route for these pesticides. Since summertime levels are substantially higher than those in the spring (see Tables I and II), the relative contribution of inhalation exposure should be increased in summer. For those pesticides found most frequently and in highest concentrations in household air (see Table I), inhalation appears to be the major route of exposure for all except diazinon.

CONCLUSIONS

It is difficult to draw hard conclusions in the absence of state-specific exposure information. It is clear from the EPA report, excerpted above, that some exposures to household pesticides such as termiticides, insecticides, and herbicides are likely. The vast majority of U.S. household use some such chemicals. And, while they are used in relatively small amounts in private homes, the uses are not well-regulated.

In addition, there are a number of pathways - inhalation of air, dermal exposure, ingestion or inhalation of household dust, and dietary exposure - by which household pesticides can pose risks.

Again, what is missing is an accurate portrait of exactly who in the state is being exposed to household pesticides, and at what levels. In lieu of such information, we can only conclude that household use of pesticides is a potential source of additional human health risk, the magnitude of which cannot be determined given currently available data.

Table I Major Pesticides Found in the EPA Non-Occupational Pesticide Exposure Study, Jacksonville, Florida, 1986-87

	Summer 1986		Spring 1987	
Pesticide	% of Households	Mean Air Concentration ug/m^3	% of Households	Mean Air Concentration ug/m^3
Chlordane	60.8	0.32	53.6	0.24
Chlorpyrifos	100.0	0.37	88.3	0.20
Diazinon	83.2	0.42	82.9	0.11
Dichlorvos	32.9	0.13	14.0	0.09
Heptachlor	45.9	0.16	59.1	0.15
Ortho-Phenylphenol	85.1	0.10	83.5	0.07
Propoxur	98.0	0.53	93.1	0.22

Table II Major Pesticides Found in the EPA Non-Occupational Pesticide Exposure Study, Springfield, Massachusetts, Spring 1987

Pesticide	% of Households	Mean Air Concentration ug/m^3
Chlordane	50.4	0.199
Chlorpyrifos	28.9	0.010
Diazinon	16.4	0.048
Dichlorvos	1.7	0.004
Heptachlor	13.7	0.029
Ortho-Phenylphenol	91.1	0.044
Propoxur	48.9	0.027

Table III Estimates of Relative Contributions of Air and Diet to Exposure to Pesticides Commonly Used Around the Household, Spring 1987

Pesticide	Jacksonville, Florida Mean Intake, (ug/day) Air*	Food	Total	% from Air	Springfield, Massachusetts Mean Intake, (ug/day) Air*	Food	Total	% from Air
Malathion	0.20	4.70	4.90	4	0.01	4.63	4.64	< 1
Chlordane	3.81	0.07	3.88	98	5.06	0.07	5.13	99
Chlorpyrifos	3.66	0.14	3.80	96	0.15	0.14	0.29	52
Heptachlor	2.63	<0.01	2.63	100	0.64	<0.01	0.64	100
Diazinon	2.25	0.59	2.84	79	0.20	0.59	0.79	25
Carbaryl	0.02	1.68	1.70	1	<0.01	1.71	1.71	< 1
Captan	0.01	1.37	1.38	< 1	<0.01	1.47	1.47	< 1

*Based on 24-hour mean air concentrations determined with personal air samplers times 20 m^3 inhaled air/day.

ECOLOGICAL RISKS DUE TO PESTICIDE USE (i.e., IMPACTS ON FISH AND WILDLIFE

INTRODUCTION

(NOTE: The following information is taken largely from a draft report produced in 1988 by the U.S. EPA Seattle office.)

Pesticides are both beneficial and hazardous. The very aspect that makes them beneficial also makes them hazardous. Because pesticides are toxic compounds intended to kill living organisms, both target and nontarget species are affected.

Pesticide use is extensive and its impacts pervasive. With an estimated 3.5 billion pounds applied each year in the U.S. to agricultural lands, residential and business properties and marine facilities, there is not an ecosystem that escapes its effects.

There are many kinds of pesticides used in Washington for the control of pests. They include:

- insecticides
- herbicides
- nematocides
- fungicides
- rodenticides

Herbicides are the most heavily used type of pesticide in the Northwest; insecticide use is increasing.

Sources

Agricultural use of pesticides, which includes animal and crop farming, silviculture, and range and pasture grazing, is the predominant source. Marine and fishing industries are significant users, as well as residential and business property owners.

Receptors

Aside from the target species, pesticides affect nontarget plant and animal species, including endangered species. Pesticides also affect entire communities and ecosystems - terrestrial, and aquatic (marine and fresh water).

Pathway

Nontarget organisms are exposed to pesticides through direct and indirect routes. Organisms are directly exposed to pesticides from inhalation, dermal absorption, and ingestion.

Indirect exposure results from ingesting tainted food and water.

Approach

We gathered information on acute and chronic species level effects and ecosystem level effects from two major sources. General effects information was obtained from EPA registration standards documents and from literature review. Washington-specific information was obtained from the EPA STORET data base and a U.S. Fish and Wildlife Contaminant Survey data base.

The STORET database contains data from several agencies. It is a composite of water, sediment, and tissue samples taken from stations throughout EPA Region 10 and tested for a variety of contaminants.

The information provided by the U.S. Fish and Wildlife Contaminant Survey data base, which tracks fish and wildlife kills by location and cause of mortality, is limited because it tracks only those "kills" reported by other agencies. It is not based on a mandatory reporting requirement.

Findings

Table 1 displays the data obtained from EPA's STORET data base. The table lists the percent of water, tissue, and sediment samples that contained measurable amounts of pesticides. These samples were taken at sampling stations throughout the Northwest over a period of years. The attached maps identified the locations where two of these pesticides (malathion and 2,4-D) were detected.

Table 2 presents the data obtained from the U.S. Fish and Wildlife Service's Contaminant Survey. The table lists by location, bird kill incidences reported in Washington and the cause or suspected cause of mortality.

Ecological Impacts - Species Level Effects

Nontarget fish, wildlife, insect and plant species are directly and indirectly exposed to pesticides. Exposure to pesticides may result in acute and chronic effects, depending on species susceptibility, dose, duration of exposure, and exposure pathway. The following is a discussion of the types of effects that can result from exposure of nontarget species to pesticides.

Exposure to pesticides can result in acute effects to nontarget species either through direct mortality of the organism or significant impairment such that mortality occurs from another source such as a predator. Exposure to diazinon has resulted in large bird kills. Carbaryl has been associated with the devastation of honey bee populations, and has been a particular problem in Idaho. (One granule of Carbaryl (Sevin) can kill an entire bee hive.) Exposure to Carbofuron, used to control insects on corn and wheat fields, resulted in the death of 500 Canadian geese on May 23. Insecticides can be lethal to aquatic juvenile life stages of many insect species (e.g. dragonflies, mayflies).

Chronic effects occur over time and while not causing immediate mortality to the individual, they can eventually result in reduced populations. Exposure to pesticides can result in a range of effects from teratogenic and oncogenic effects to changes in behavior. The following are examples of chronic effects resulting from exposure to pesticides by nontarget species.

- Malathion is believed to be responsible for weakening the defense of breeding grounds by sharp-tailed grouse, which leads to the predation of the clutch.

- Birds dosed with methyl parathion display much lower activity levels than unaffected birds. Changes in activity levels may threaten the ability of wildlife to find food, escape predators or migrate successfully.

- Reduced parenting was reported in song birds exposed to organophosphate.

- Parathion exposure has been associated with lack of nest attentiveness in laughing gulls resulting in a fledging success rate 30 percent below normal.

- Organophosphates and carbamates are associated with delayed neurotoxicity in mammals.

- Phenoxy herbicides are associated with teratogenicity in mammals.

While the following examples of acute and chronic effects are not necessarily Washington specific or associated with the major pesticides in Washington, the species affected and the pesticides used are all present in northwestern states.

Ecological Impacts - Ecosystem Level Effects

Acute and chronic effects of pesticides on individual organisms within an ecosystem can result in adverse effects on the system itself. Such effects can cause a reduction or alteration of species diversity; alterations to the food chain which in turn can change the energy flow and nutrient cycling; reduced habitat quality through changes to the physical resources; and impair the stability and resiliency of the ecosystem.

Pesticides contaminate both aquatic and terrestrial ecosystems in Washington. Aquatic ecosystems, both marine and freshwater, are contaminated by pesticides through direct application (i.e. biocides, tributyltin) and indirectly through surface water runoff and drift.

EPA estimated that nationally, 10 percent of the pesticides applied via air or mist blower methods will reach adjacent aquatic ecosystems. When pesticides are applied by airplane to forest ecosystems there is unavoidable contamination of the streams, ponds, and estuaries within the forest.

Terrestrial ecosystems are exposed to pesticides through direct application and indirectly by drift. The majority of terrestrial pesticides use is for agriculture, silviculture, and rangelands. Nationally, it has been estimated that there are 33 pesticides registered for use on rangelands, 137 pesticides registered for use on forest lands, and the large majority of the active ingredients in the 600 pesticides registered for use on crop lands.

Croplands, forest and rangeland ecosystems also provide habitat for most of our wildlife species. The following are examples of adverse pesticide effects on these ecosystems:

- Herbicides degrade wildlife habitat by destroying the vegetation that provides a food base and cover for wildlife.
- Pesticides can destroy organisms that are an integral part of the structure and function of a terrestrial ecosystem (i.e., soil microbes, predators, pollinators).
- Pesticides may cause the release of a secondary pest from the constraints of natural enemies and thus potentially alter the food chain or habitat structure.

Pesticides not only have immediate lethal effects on organisms but they also produce harder to measure chronic effects. The incremental effects of pesticides on individual organisms accumulate and ultimately impact entire ecosystems. The EPA Unfinished Business report concluded that the adverse effects from pesticides were reversible. However, it would take many generations for a population to be restored, for a habitat to become viable again, and for a food chain to stabilize. Restoration of an ecosystem to its original structure may never occur; a different ecosystem may result instead. Even if reversal to an original state were possible, it is not likely to occur since it would require elimination of pesticides use.

Table 1
STORET Data

Pesticide	Water Samples	Tissue Samples	Sediment
Malathion	3% (33 of 990)		.5% (1 of 221)
Altrazine	.5% (1 of 195)		
2,4-D	13% (116 of 915)	50% (12 of 24)	3.8% (5 of 131)
Carbaryl (Sevin)		13% (3 of 24)	
Diazinon	7% (72 of 979)		
Methyl Parathion	0.7% (7 of 941)		
Ethyl Parathion	4.3% (20 of 461)		

E

Table 2

U.S. Fish and Wildlife Contaminant Survey
Data From 1982 through 1987
(Reported bird kill incidences and actual or suspected cause)

Location Of Incident	# Killed	Species Killed	Cause or Suspected Cause
Ilwaco, WA	8	Mallard	Diazinon
Yakima, WA	30	C. Goose, Robin Humming bird, Sparrow	"
Bellevue, WA	9	Mallard	"
Lk. Meridian, WA		Mallard, C. Goose, Duck	"
Lk. Sawyer, WA	35	C. Goose	"
Keyport Naval Stn.	33	A. Widgeon, C. Goose	"
King Co., WA	25	Gadwall, A. Widgeon	"
Tacoma, WA	10	Mallard, G. Gull Peregrine Falcon Rock Dove	Strychnine

THE STATE OF THE ENVIRONMENT REPORT

VOLUME III
Appendix A

Draft Economic Damages
Risk Evaluation Reports

ENVIRONMENT 2010

State of Washington
October, 1989

WASHINGTON ENVIRONMENT 2010

FINAL DRAFT ECONOMIC DAMAGE

RISK ASSESSMENTS

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July 10, 1989

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CONTENTS

ECONOMIC EFFECTS OF AMBIENT AIR POLLUTION WASHINGTON 2010

RCG/Hagler, Bailly, Inc.
July 6, 1989

Final Draft

1.0 INTRODUCTION

This paper provides Washington 2010 with estimates of current and projected economic risks associated with ambient air pollution in Washington. Estimated economic effects are intended to provide quick estimates of the likely magnitude of the potential economic damages associated with ambient air pollution in Washington. The results are not expected to be precise, but to be useful for the overall ranking of environmental problems being addressed in the Washington 2010 project.

Economic effects are developed for human health and materials damage effects associated with particulate matter, carbon monoxide, ozone, and toxic air pollutants. Economic measures associated with the cost of illness and lost income due to cancer cases are estimated for toxic air pollution. These estimates are based on work performed by Johnson (1989).

2.0 PM_{10} HEALTH EFFECTS

Epidemiological studies that have covered fairly wide geographic areas in the U.S. have found an association between ambient particulate matter levels and restricted activity days and human mortality rates. There is also some evidence that particulate matter is associated with a greater frequency of emergency room visits, with higher rates of chronic respiratory disease, and with adverse effects on lung function. Some of these latter health effects may actually underlie the observed association with restricted activity days. The biological pathways for these effects are not well understood, but it is believed that particulate matter affects human health via the respiratory system.

Restricted activity days are days on which an individual's normal activities are restricted to some extent due to illness. This includes confinement to bed and days missed from work as well as minor activity restrictions.

2.1 Methodology

1. Based on results reported in previous State and Comparative Risk projects, we suggest the following procedure for estimating the number of restricted activity days currently associated with particulate matter in Washington:

   $$\text{Annual restricted activity days} = \sum_{j=1}^{J} .073*(TSP_j-75)*POP_j$$

   where:

   TSP_j = annual average TSP in $\mu g/m^3$ in location j
   POP_j = total population in location j

   Restricted activity days were calculated based on work performed by Ostro (1983) using TSP data. The coefficient in the damage function is the annualized derivative with respect to TSP in Ostro's regression equation. The equation assumes that no health effects will occur above the old Federal Standard for TSP.

2. To estimate increased mortality due to elevated particulates, the methodology requires an estimate of background TSP levels for the state of Washington and the following equation:

   Change in Annual Deaths/100,000=.0881*.0125*.55*365*change in TSP

   To estimate change in mortality due to TSP associated with different monitored TSP concentrations:

   [Predicted mortality using monitored data]-[predicted mortality using background TSP concentration]

2.2 Health and Economic Estimates

Statewide health effects were estimated for annual restricted activity days and annual deaths following the procedures outlined above. Results of these calculations are shown in Table 1.

Table 1 summarizes health effects by Air Quality Control Region and County. If more than one air quality data point per county was recorded, these were averaged to develop one value. It was assumed that 80 percent of the population of each county was exposed to the estimated TSP concentration (Johnson, 1989).

3.0 CARBON MONOXIDE HEALTH EFFECTS

It was not possible to estimate economic effects associated with carbon dioxide air pollution in Washington. However, economic effects are unlikely to be significant when compared to the economic effects associated with other air pollutants.

When carbon monoxide (CO) enters the respiratory system, it attaches to hemoglobin and forms carboxyhemoglobin, reducing the oxygen carrying capacity of the blood. CO's affinity for hemoglobin is much greater than that of oxygen and when present in significant amounts can result in a significant reduction in oxygen carried to body tissue. Individuals believed to be at higher risk of ill effects for exposures to ambient CO levels that occur in urban areas include people with heart disease, with chronic respiratory disease, with chronic anemia, and fetuses.

3.1 Methodology

For this screening level risk assessment, we used the federal primary standard for CO and the pollution standard index levels for CO as thresholds with regard to ambient CO levels. Individuals living in areas where these levels are exceeded can be presumed to be at some elevated risk of experiencing a CO related health effect on days when the CO standard is exceeded. The types of health effects likely to occur can be identified, but the magnitude of the risk for the exposed individual will remain unspecified. The outcome of this calculation is the number of people at elevated risk of each type of health effect and the number of days in the year that this elevated risk occurs. The incidence of these health effects is unspecified.
Health risks are calculated using the following thresholds:

CO 8-hour Average Exceeds	Pollution Standard Index	Health Risk
9 ppm (federal standard)	100	10% of population at moderate risk of increased angina pain
		90% of population at low risk of mild symptoms
15 ppm	200	10% of population at high risk of increased angina pain
		90% of population at moderate risk of mild symptoms

3.2 Assumptions

1. That the 10%-90% population ratio adequately defines the population with coronary heart disease.

2. Mild symptoms in the general population include reduced vigilance and the reduced capacity for strenuous exercise.

3.3 Health Effects

Health effects of CO are listed in Table 2.

4.0 OZONE

Health effects due to elevated exposures to ozone include irritation of the human respiratory system. There is some evidence that exposure to ozone is associated with higher rates of respiratory illness. Ozone is also believed to aggravate chronic respiratory diseases. Chronic exposure to elevated ozone concentrations may contribute to the development of chronic respiratory diseases, although the evidence is not conclusive. Health effects estimates will be made for annual asthma attacks and annual respiratory restricted activity days.

4.1 Health Effects

State-wide ozone health effects are summarized in Table 3.
Annual asthma attacks are predicted based on the following equation:

$$\text{annual asthma attacks} = \sum_{j=1}^{J} .00029 * DAYS_j * .04 * POP_j$$

The coefficient represents the per person risk having an asthma attack on a standard exceedance day, and was derived by:

(# of cases/population @ risk)/# of exceedance days

Respiratory restricted activity days were calculated in the same manner, assuming that 96% of the population is affected during an ozone exceedance day by the following equation:

$$ARRAD = \sum_{j=1}^{J} .00092*DAYS_j*.96*POP_j$$

where:

$DAYS_j$ = the number of days/year on which daily high ozone exceeds .12 ppm in location j

POP_j = total population in location j

5.0 MATERIALS DAMAGE

Materials damage caused by air pollution has been widely recognized as a source of economic loss in some urban and, to a lesser extent, some rural areas. Chamber and field studies have demonstrated that materials damage can take a number of forms, including the surface erosion, blistering, and discoloration of paint; the corrosion and tarnishing of metals; the fading, soiling, and reduction of the tensile strength of fabrics; and the soiling and erosion of building stone, marble, and concrete. All of these effects also occur, to some extent, in unpolluted atmospheres as the result of natural environmental conditions, such as moisture, temperature, and wind fluctuations.

Numerous economic studies have been performed estimating economic losses from materials damage and soiling. Economic effects have been related to the reduced service life of a material, the decreased usefulness of damaged materials, increasing costs of more expensive substitute materials, losses caused by the use of inferior substitute products, and expenses incurred for the protective maintenance and rehabilitation of sensitive materials. Increased maintenance and cleaning costs (as well as amenity losses) caused by soiling or damage to monuments and works of art have also been included in materials damage estimates. Evaluation of damage estimates from economic studies should be guided by the completeness of the materials inventory at risk, the adequacy of the physical damage function describing the response of materials to air pollution, and the economic model used to value the predicted effects.

Four criteria air pollutants have been associated with materials damage: particulate matter, nitrogen dioxide, ozone, and sulfur dioxide. The most significant materials damage effects associated with sulfur dioxide are believed to be due to sulfate caused damages. These damages are not considered in this report due to their association with acid deposition. Current acid deposition levels in Washington are unlikely to cause significant damage. Statewide damage estimates are based on the following approaches and are summarized in Tables 1-4.

5.1 PM_{10}

Particulate matter has been identified as causing soiling and discoloration effects on a wide variety of materials, including paint, structural metals, and other building materials. The primary effect is considered to be the soiling of surfaces. This soiling has economic impacts through increased cleaning costs and by reducing the useful life of affected materials. Economic damages related to particulate matter soiling have been estimated for households and two manufacturing industries.

5.1.1 Methodology

1. Household Damages. Mathtech (1983) estimated annual household damages as \$.82/μg change in the annual geometric mean total of particulates. They also used 10 $\mu g/m^3$ as an approximate background estimate for TSP. Background in Washington may be above or below this value. Using this approach, annual household soiling damages due to TSP are:

   AHSD = .82*HHj*(TSPj-10)

   where:

   HHj = the number of households living in area j

   TSPj= the annual geometric mean TSP concentration in the area

2. Manufacturing Sector Damages. Mathtech also estimated a model to calculate damages in the manufacturing sector. Estimates were made for two industries: fabricated structural metal products and metal working machinery. Mathtech estimated that national damages were approximately \$3.3 million due to current levels of TSP. If we assume that these costs are largely passed on to consumers, this implies average per capita damages of \$14. To estimate damages in Washington multiply \$14 by the population.

5.2 Nitrogen Dioxide

The primary materials damage effect associated with nitrogen dioxide is dye fading. The EPA estimated that the national cost of dye fading due to nitrogen dioxide is \$280 million/year, or 1.20 per capita. To estimate damages in Washington, multiply \$1.20 by the population.

5.3 Ozone

Elastomers are the most vulnerable material to ozone damage. The EPA estimated that annual damage to automobile and truck tires was about $200 million, or $.85/person. To calculate Washington damages, multiply this value by the state's population.

6.0 NON-CANCER HEALTH CARE COSTS

Health care costs include direct medical costs and lost productivity due to inability to conduct normal work activities. The financial impact does not reflect the full social economic impact because it does not reflect pain and discomfort of the individual, lost ability to conduct non-work activities such as recreation, and the inconvenience and concern of friends and families. Cost of illness measures do not include damages associated with mortality. We propose estimating average costs for three health endpoints described earlier in the health effects section:

- Restricted Activity Day
- Asthma Attack
- Respiratory Restricted Activity Day

Restricted Activity Day

Restricted activity days are days on which an individual's normal activities are restricted due to illness. This includes confinement to bed and days missed from work as well as other minor restrictions in activity. Rowe et al. (1986) cite evidence that about one-third of all restricted activity days involve days missed from work. The average daily full-time wage in the U.S. is about $95. Rowe et al. suggest that the medical costs associated with the types of restricted activity days likely to be caused by air pollution might be expected to average about $5 per day. Thus, the average financial cost of a restricted activity day would be:

.33*$95+5=approximately $35

Asthma Attack

Rowe et al. (1986) estimate the direct medical costs associated with an average asthma attack as $10. Assuming that asthma attacks are equivalent to restricted activity days, one third of all asthma attacks will involve a lost day from work. The average cost of an asthma attack is:

.33*$95+10=approximately $40

Respiratory Restricted Activity Day

Direct medical costs associated with restricted respiratory activity days are likely to be minimal and can be reasonably assumed to be zero. Assuming that one-tenth of all respiratory restricted activity days involve a day missed from work, the average cost for a restricted respiratory activity day is $10.

7.0 CANCER CASES DUE TO TOXIC AIR POLLUTANTS

Economic effects due to annual cancer cases associated with toxic air pollutant exposures are based on estimates of the direct and indirect costs of cancer cases estimated by Hartunian, et al. (1981).

Direct costs represent the average hospitalization costs and nonhospital costs, such as physician services, private nursing, nursing home and attendant care, drugs, physical therapy, special equipment and prosthetics, and other miscellaneous services. These costs were estimated as $9,704 for the average lost per cancer patient in 1975 dollars. These costs are $29,112 1988 dollars, using the Index of Medical Prices deflator (DOL, 1988).

Indirect costs represent economic effects associated with foregone productivity or earnings as a result of cancer. Hartunian, et al. estimated the average foregone earnings for all cancer sites as being $25,334 per capita. Converting to 1988 dollars using the GNP Implicit Price deflator, foregone productivity equals $55,734 per cancer case. Total damages per cancer case are $84,846.

7.1 Uncertainty

Hartunian, et al. performed sensitivity analyses over basic analytic assumptions in their analysis and concluded that errors in the direct costs (medical costs) of up to 5 percent are possible if these assumptions are incorrect. They reported that potential errors in the forgone earnings estimates could be as large as 13 percent. Thus, total damage estimates could over or underpredict the "true" damage estimates by as much as 18 percent. Per capita cancer damages could range between $69,573 and $100,118.

7.2 Toxic Air Pollutant Economic Damages

Johnson (1989) estimated that exposure to toxic air pollutants in Washington results in an excess of 15 cancers annually. This results in economic damages of $1,272,690.

8.0 VISIBILITY DEGRADATION

Visibility effects are an important component of the impact of atmospheric pollutants. Small particles and gases can form plumes, layered and regional haze, and changing visibility or visual air quality (VAQ). VAQ is not bought and sold, but evidence suggests that people prefer better, rather than degraded VAQ. Clean air and scenic views can add value to a property in urban and residential environments. To reach scenic overlooks, people drive and hike considerable distances. They may also spend time viewing scenery when it is obstructed by air pollution.

Estimating economic measures of changes in VAQ is complex. The analyst must relate changes in emissions and atmospheric conditions to changes in characteristics (visual range, clarity, color, etc.), determine what changes are of most concern, determine or assume a change in attitudes or behavior due to the change in VAQ, and then use an economic method to value the change in VAQ.

No studies estimating the value of VAQ have been performed in the state of Washington. However, numerous studies performed in the eastern United States, the southwest, and in California and Oregon suggest that economic damages associated with reductions in visibility may be very significant.

A study performed by Crocker (1986) estimating the value of visibility improvements in Oregon may be the most useful indication of the potential values associated with visibility degradation in Washington.

Crocker obtained willingness to pay estimates for visibility improvements at the Pittock Mansion in Portland and at several campsites and trailheads in the Central Oregon Cascades. For the secure provision of an 82 kilometer visual range during the summer of 1985 throughout the Portland area, Portland respondents were willing to make a one-time payment of $49.26. For a secure provision of a 309 kilometer visual range throughout their stay Central Oregon Cascade recreationists were willing to pay an average of $2.08 per day.

9.0 REFERENCES

Crocker, T. 1986. Unpublished Report to the Oregon Department of Environmental Quality, February 18.

Johnson, D. 1989. Washington Environment 2010 Ambient Air Draft Report, Washington Department of Ecology.

Hartunian, N.S., C.N. Smart, and M.S. Thompson. 1981. The Incidence and Economic Costs of Major Health Impairments, Lexington Books, D.C. Heath and Company, Lexington, Massachusetts, Toronto.

Mathtech. 1983. Benefits Analysis of Alternative Secondary National Ambient Air Quality Standards for Particulate Matter, Final Report prepared for the U.S. EPA OAQPS, Research Triangle Park, NC.

Ostro, B.D. 1983. "Urban Air Pollution and Morbidity: A Retrospective Approach." Journal of Urban Economics 20 (July): 21-38.

Table 1a Health and Welfare Effects of Particulate Matter by County for 1988

Air Quality Control Region County	Population 1988	TSP ug/cu.m. annual geometric mean 1987	HEALTH EFFECTS: RESTRICTED ACTIVITY DAYS [1]	HEALTH EFFECTS: CHANGE IN ANNUAL DEATHS/ 100,000 [2]	HEALTH EFFECTS: CHANGE IN ANNUAL DEATHS [3]	WELFARE EFFECTS: RESTRICTED ACTIVITY DAYS [4]	WELFARE EFFECTS: ANNUAL HOUSEHOLD SOILING DAMAGE [5]	WELFARE EFFECTS: MANUFACTURING SECTOR DAMAGE [6]
Olympic-Northwest	593,000							$8,302,000
San Juan	9,600							$134,400
Island	53,400							$747,600
Clallam	54,400							$761,600
Jefferson	18,600							$260,400
Mason	36,800							$515,200
Grays Harbor	63,400							$887,600
Thurston	149,300							$2,090,200
Pacific	17,600							$246,400
Skagit	70,800							$991,200
Whatcom	119,100							$1,667,400
Puget Sound	2,548,400							$35,677,600
Snohomish	409,500							$5,733,000
Kitsap	177,300							$2,482,200
King	1,413,900	79	330,287	1	10	$11,560,046	$24,150,479	$19,794,600
Pierce	547,700	82	223,900	1	7	$7,836,492	$9,761,874	$7,667,800
Portland	363,900							$5,094,600
Lewis	57,400							$803,600
Wahkiakum	3,500							$49,000
Cowlitz	80,500							$1,127,000
Clark	214,500							$3,003,000
Skamania	8,000							$112,000
South Central	415,800							$5,821,200
Kittitas	25,000							$350,000
Yakima	186,300	79	43,520	1	1	$1,523,189	$3,182,145	$2,608,200
Klickitat	16,600							$232,400
Benton	104,100							$1,457,400
Franklin	35,500							$497,000
Walla Walla	48,300							$676,200

Table 1a (cont.) Health and Welfare Effects of Particulate Matter by County for 1988

Air Quality Control Region County	Population 1988	TSP ug/cu.m. annual geometric mean 1987	HEALTH EFFECTS: RESTRICTED ACTIVITY DAYS [1]	HEALTH EFFECTS: CHANGE IN ANNUAL DEATHS/ 100,000 [2]	HEALTH EFFECTS: CHANGE IN ANNUAL DEATHS [3]	WELFARE EFFECTS: RESTRICTED ACTIVITY DAYS [4]	WELFARE EFFECTS: ANNUAL HOUSEHOLD SOILING DAMAGE [5]	WELFARE EFFECTS: MANUFACTURING SECTOR DAMAGE [6]
Northern	150,600							$2,108,400
Chelan	49,700							$695,800
Douglas	24,100							$337,400
Okanogan	31,700							$443,800
Ferry	6,100							$85,400
Stevens	30,200							$422,800
Pend Oreille	8,800							$123,200
Eastern	493,300							$6,906,200
Grant	52,600							$736,400
Adams	14,000							$196,000
Lincoln	9,700							$135,800
Spokane	354,100	93	380,502	3	12	$13,317,559	$7,310,548	$4,957,400
Whitman	39,000							$546,000
Columbia	4,100							$57,400
Garfield	2,400							$33,600
Asotin	17,400							$243,600
TOTAL	4,565,000		978,208	6	30	$34,237,286	$44,405,046	$63,910,000

[1] Restricted activity days = sum of .073*(TSPj-75)*POPj; where: TSPj = annual average TSP inug/cu.m. in location j a POPj is the total population in location j.
[2] Change in annual deaths/100,000 = .0881*.0125*.55*365*(TSPj-75); with TSP as defined in [1].
[3] Change in annual deaths = (change in annual deaths/100,000)*POPj/100,000; with POPj as defined in [1]
[4] Welfare effect of each restricted activity day is estimated to be $35.
[5] Annual household soiling damage = .82*HHj*(TSPj-10); where: HHj is the number of households living in area j (POPj and TSPj is the annual geometric mean TSP concentration in the area.
[6] Manufacturing Sector Damage = $14 per person.

Table 1b Health and Welfare Effects of Particulate Matter
by County for 2010

Air Quality Control Region County	Population 2010	TSP ug/cu.m. annual geometric mean 1987	HEALTH EFFECTS: RESTRICTED ACTIVITY DAYS [1]	HEALTH EFFECTS: CHANGE IN ANNUAL DEATHS/ 100,000 [2]	HEALTH EFFECTS: CHANGE IN ANNUAL DEATHS [3]	WELFARE EFFECTS: RESTRICTED ACTIVITY DAYS [4]	WELFARE EFFECTS: ANNUAL HOUSEHOLD SOILING DAMAGE [5]	WELFARE EFFECTS: MANUFACTURING SECTOR DAMAGE [6]
Olympic-Northwest	789,238							$11,049,332
San Juan	13,879							$194,306
Island	87,635							$1,226,890
Clallam	63,570							$889,980
Jefferson	28,381							$397,334
Mason	49,027							$686,378
Grays Harbor	53,007							$742,098
Thurston	229,385							$3,211,390
Pacific	16,989							$237,846
Skagit	95,253							$1,333,542
Whatcom	152,112							$2,129,568
Puget Sound	3,636,577							$50,912,078
Snohomish	671,151							$9,396,114
Kitsap	267,778							$3,748,892
King	1,947,596	79	454,958	1	14	$15,923,545	$33,266,410	$27,266,344
Pierce	750,052	82	306,621	1	9	$10,731,744	$13,368,474	$10,500,728
Portland	449,487							$6,292,818
Lewis	62,291							$872,074
Wahkiakum	1,666							$23,324
Cowlitz	84,168							$1,178,352
Clark	292,751							$4,098,514
Skamania	8,611							$120,554
South Central	426,803							$5,975,242
Kittitas	25,000							$350,000
Yakima	224,814	79	52,517	1	2	$1,838,079	$3,839,993	$3,147,396
Klickitat	17,211							$240,954
Benton	82,092							$1,149,288
Franklin	30,609							$428,526
Walla Walla	47,077							$659,078

Table 1b (cont.) Health and Welfare Effects of Particulate Matter by County for 2010

Air Quality Control Region County	Population 2010	TSP ug/cu.m. annual geometric mean 1987	HEALTH EFFECTS: RESTRICTED ACTIVITY DAYS [1]	HEALTH EFFECTS: CHANGE IN ANNUAL DEATHS/ 100,000 [2]	HEALTH EFFECTS: CHANGE IN ANNUAL DEATHS [3]	WELFARE EFFECTS: RESTRICTED ACTIVITY DAYS [4]	WELFARE EFFECTS: ANNUAL HOUSEHOLD SOILING DAMAGE [5]	WELFARE EFFECTS: MANUFACTURING SECTOR DAMAGE [6]
Northern	170,773							$2,390,822
Chelan	63,149							$884,086
Douglas	33,270							$465,780
Okanogan	30,477							$426,678
Ferry	6,100							$85,400
Stevens	30,811							$431,354
Pend Oreille	6,966							$97,524
Eastern	540,374							$7,565,236
Grant	71,551							$1,001,714
Adams	15,834							$221,676
Lincoln	9,089							$127,246
Spokane	382,833	93	411,377	3	12	$14,398,196	$7,903,753	$5,359,662
Whitman	34,721							$486,094
Columbia	4,100							$57,400
Garfield	1,789							$25,046
Asotin	20,457							$286,398
TOTAL	6,013,253		1,225,473	6	37	$42,891,564	$58,378,630	$84,185,528

[1] Restricted activity days = sum of .073*(TSPj-75)*POPj; where: TSPj = annual average TSP inug/cu.m. in location j a POPj is the total population in location j.
[2] Change in annual deaths/100,000 = .0881*.0125*.55*365*(TSPj-75); with TSP as defined in [1].
[3] Change in annual deaths = (change in annual deaths/100,000)*POPj/100,000; with POPj as defined in [1]
[4] Welfare effect of each restricted activity day is estimated to be $35.
[5] Annual household soiling damage = .82*HHj*(TSPj-10); where: HHj is the number of households living in area j (POPj and TSPj is the annual geometric mean TSP concentration in the area.
[6] Manufacturing Sector Damage = $14 per person.

Table 2 Health Effects of Carbon Monoxide
by County for 1988 and 2010

Air Quality Control Region County	Population 1988	Population 2010	CO 8-hr avg. number of days > 9ppm 1987	CO 8-hr avg. number of days > 15ppm 1987	1988 MODERATE RISK OF INCREASED ANGINA PAIN [1] Person-Days	1988 LOW RISK OF MILD SYMPTOMS [2] Person-Days	1988 HIGH RISK OF INCREASED ANGINA PAIN [3] Person-Days	1988 MODERATE RISK OF MILD SYMPTOMS [4] Person-Days	2010 MODERATE RISK OF INCREASED ANGINA PAIN [1] Person-Days	2010 LOW RISK OF MILD SYMPTOMS [2] Person-Days	2010 HIGH RISK OF INCREASED ANGINA PAIN [3] Person-Days	2010 MODERATE RISK OF MILD SYMPTOMS [4] Person-Days
Olympic-Northwest	593,000	789,238										
San Juan	9,600	13,879										
Island	53,400	87,635										
Clallam	54,400	63,570										
Jefferson	18,600	28,381										
Mason	36,800	49,027										
Grays Harbor	63,400	53,007										
Thurston	149,300	229,385										
Pacific	17,600	16,989										
Skagit	70,800	95,253										
Whatcom	119,100	152,112										
Puget Sound	2,548,400	3,636,577										
Snohomish	409,500	671,151	3	0	98,280	884,520	0	0	161,076	1,449,686	0	0
Kitsap	177,300	267,778	1	0	14,184	127,656	0	0	21,422	192,800	0	0
King	1,413,900	1,947,596	2.6	0	294,091	2,646,821	0	0	405,100	3,645,900	0	0
Pierce	547,700	750,052	7	0	306,712	2,760,408	0	0	420,029	3,780,262	0	0
Portland	363,900	449,487										
Lewis	57,400	62,291										
Wahkiakum	3,500	1,666										
Cowlitz	80,500	84,168										
Clark	214,500	292,751	4	0	68,640	617,760	0	0	93,680	843,123	0	0
Skamania	8,000	8,611										
South Central	415,800	426,803										
Kittitas	25,000	25,000										
Yakima	186,300	224,814	4	0	59,616	536,544	0	0	71,940	647,464	0	0
Klickitat	16,600	17,211										
Benton	104,100	82,092										
Franklin	35,500	30,609										
Walla Walla	48,300	47,077										

Table 2 (cont.) Health Effects of Carbon Monoxide by County for 1988 and 2010

Air Quality Control Region County	Population 1988	Population 2010	CO 8-hr avg. number of days > 9ppm 1987	CO 8-hr avg. number of days > 15ppm 1987	1988 MODERATE RISK OF INCREASED ANGINA PAIN [1] Person-Days	1988 LOW RISK OF MILD SYMPTOMS [2] Person-Days	1988 HIGH RISK OF INCREASED ANGINA PAIN [3] Person-Days	1988 MODERATE RISK OF MILD SYMPTOMS [4] Person-Days	2010 MODERATE RISK OF INCREASED ANGINA PAIN [1] Person-Days	2010 LOW RISK OF MILD SYMPTOMS [2] Person-Days	2010 HIGH RISK OF INCREASED ANGINA PAIN [3] Person-Days	2010 MODERATE RISK OF MILD SYMPTOMS [4] Person-Days
Northern	150,600	170,773										
Chelan	49,700	63,149										
Douglas	24,100	33,270										
Okanogan	31,700	30,477										
Ferry	6,100	6,100										
Stevens	30,200	30,811										
Pend Oreille	8,800	6,966										
Eastern	493,300	540,374										
Grant	52,600	71,551										
Adams	14,000	15,834										
Lincoln	9,700	9,089										
Spokane	354,100	382,833	19.8	2	560,894	5,048,050	56,656	509,904	606,407	5,457,667	61,253	551,280
Whitman	39,000	34,721										
Columbia	4,100	4,100										
Garfield	2,400	1,789										
Asotin	17,400	20,457										
TOTAL	4,565,000	6,013,253			1,402,418	12,621,758	56,656	509,904	1,779,656	16,016,903	61,253	551,280

[1] 10% of population at moderate risk of increased angina pain when CO 8-hr. avg. exceeds 9 ppm.
[2] 90% of population at low risk of mild symptoms when CO 8-hr. average exceeds 9 ppm.
[3] 10% of population at high risk of increased angina pain when CO 8-hr. avg. exceeds 15 ppm.
[4] 90% of population at moderate risk of mild symptoms when CO 8-hr. average exceeds 15 ppm.

Table 3 Health and Welfare Effects of Ozone
by County for 1988 and 2010

Air Quality Control Region County	Population		Ozone # of days > .12 ppm	HEALTH EFFECTS: ANNUAL ASTHMA ATTACKS [3]		HEALTH EFFECTS: ANNUAL RESPIRATORY RESTRICTED ACTIVITY DAYS [4]		WELFARE EFFECTS: ANNUAL ASTHMA ATTACKS [3]		WELFARE EFFECTS: ANNUAL RESPIRATORY RESTRICTED ACTIVITY DAYS [4]		MATERIALS DAMAGE [5]	
	1988	2010	1987	1988	2010	1988	2010	1988	2010	1988	2010	1988	2010
Olympic-Northwest	593,000	789,238										$504,050	$670,852
San Juan	9,600	13,879										$8,160	$11,797
Island	53,400	87,635										$45,390	$74,490
Clallam	54,400	63,570										$46,240	$54,035
Jefferson	18,600	28,381										$15,810	$24,124
Mason	36,800	49,027										$31,280	$41,673
Grays Harbor	63,400	53,007										$53,890	$45,056
Thurston	149,300	229,385										$126,905	$194,977
Pacific	17,600	16,989										$14,960	$14,441
Skagit	70,800	95,253										$60,180	$80,965
Whatcom	119,100	152,112										$101,235	$129,295
Puget Sound	2,548,400	3,636,577										$2,166,140	$3,091,090
Snohomish	409,500	671,151										$348,075	$570,478
Kitsap	177,300	267,778										$150,705	$227,611
King	1,413,900	1,947,596	1	13	18	999	1,376	$525	$723	$9,990	$13,761	$1,201,815	$1,655,457
Pierce	547,700	750,052										$465,545	$637,544
Portland	363,900	449,487										$309,315	$382,064
Lewis	57,400	62,291										$48,790	$52,947
Wahkiakum	3,500	1,666										$2,975	$1,416
Cowlitz	80,500	84,168										$68,425	$71,543
Clark	214,500	292,751										$182,325	$248,838
Skamania	8,000	8,611										$6,800	$7,319
South Central	415,800	426,803										$353,430	$362,783
Kittitas	25,000	25,000										$21,250	$21,250
Yakima	186,300	224,814										$158,355	$191,092
Klickitat	16,600	17,211										$14,110	$14,629
Benton	104,100	82,092										$88,485	$69,778
Franklin	35,500	30,609										$30,175	$26,018
Walla Walla	48,300	47,077										$41,055	$40,015

Table 3 (cont.) Health and Welfare Effects of Ozone by County for 1988 and 2010

Air Quality Control Region County	Population		Ozone # of days > .12 ppm	HEALTH EFFECTS: ANNUAL ASTHMA ATTACKS [3]		HEALTH EFFECTS: ANNUAL RESPIRATORY RESTRICTED ACTIVITY DAYS [4]		WELFARE EFFECTS: ANNUAL ASTHMA ATTACKS [3]		WELFARE EFFECTS: ANNUAL RESPIRATORY RESTRICTED ACTIVITY DAYS [4]		MATERIALS DAMAGE [5]	
	1988	2010	1987	1988	2010	1988	2010	1988	2010	1988	2010	1988	2010
Northern	150,600	170,773										$128,010	$145,157
Chelan	49,700	63,149										$42,245	$53,677
Douglas	24,100	33,270										$20,485	$28,280
Okanogan	31,700	30,477										$26,945	$25,905
Ferry	6,100	6,100										$5,185	$5,185
Stevens	30,200	30,811										$25,670	$26,189
Pend Oreille	8,800	6,966										$7,480	$5,921
Eastern	493,300	540,374										$419,305	$459,318
Grant	52,600	71,551										$44,710	$60,818
Adams	14,000	15,834										$11,900	$13,459
Lincoln	9,700	9,089										$8,245	$7,726
Spokane	354,100	382,833										$300,985	$325,408
Whitman	39,000	34,721										$33,150	$29,513
Columbia	4,100	4,100										$3,485	$3,485
Garfield	2,400	1,789										$2,040	$1,521
Asotin	17,400	20,457										$14,790	$17,388
TOTAL	4,565,000	6,013,253		13	18	999	1,376	$525	$723	$9,990	$13,761	$3,880,250	$5,111,264

[1] Annual asthma attacks = sum of .00029*DAYSj*.04*POPj, where: DAYSj is the number of days/year on which daily high ozone exceeds .12 ppm in location j, and POPj = total population in location j.
[2] Annual respiratory restricted activity days = sum of .00092*DAYSj*.96*POPj, with DAYSj and POPj as defined in [1].
[3] Welfare effect of each asthma attack is $40.
[4] Welfare effect of each respiratory restricted activity day is $10.
[5] Welfare effects of materials damage is estimated to be $0.85 per person.

Table 4 Welfare Effects of
Nitrogen Dioxide by AQCR and County

Air Quality Control Region County	Population 1988	Population 2010	MATERIALS DAMAGE [1] 1988	MATERIALS DAMAGE [1] 2010
Olympic-Northwest	593,000	789,238	$711,600	$947,086
San Juan	9,600	13,879	$11,520	$16,655
Island	53,400	87,635	$64,080	$105,162
Clallam	54,400	63,570	$65,280	$76,284
Jefferson	18,600	28,381	$22,320	$34,057
Mason	36,800	49,027	$44,160	$58,832
Grays Harbor	63,400	53,007	$76,080	$63,608
Thurston	149,300	229,385	$179,160	$275,262
Pacific	17,600	16,989	$21,120	$20,387
Skagit	70,800	95,253	$84,960	$114,304
Whatcom	119,100	152,112	$142,920	$182,534
Puget Sound	2,548,400	3,636,577	$3,058,080	$4,363,892
Snohomish	409,500	671,151	$491,400	$805,381
Kitsap	177,300	267,778	$212,760	$321,334
King	1,413,900	1,947,596	$1,696,680	$2,337,115
Pierce	547,700	750,052	$657,240	$900,062
Portland	363,900	449,487	$436,680	$539,384
Lewis	57,400	62,291	$68,880	$74,749
Wahkiakum	3,500	1,666	$4,200	$1,999
Cowlitz	80,500	84,168	$96,600	$101,002
Clark	214,500	292,751	$257,400	$351,301
Skamania	8,000	8,611	$9,600	$10,333
South Central	415,800	426,803	$498,960	$512,164
Kittitas	25,000	25,000	$30,000	$30,000
Yakima	186,300	224,814	$223,560	$269,777
Klickitat	16,600	17,211	$19,920	$20,653
Benton	104,100	82,092	$124,920	$98,510
Franklin	35,500	30,609	$42,600	$36,731
Walla Walla	48,300	47,077	$57,960	$56,492

Table 4 (cont.) Welfare Effects of
Nitrogen Dioxide by AQCR and County

Air Quality Control Region County	Population 1988	Population 2010	MATERIALS DAMAGE [1] 1988	MATERIALS DAMAGE [1] 2010
Northern	150,600	170,773	$180,720	$204,928
Chelan	49,700	63,149	$59,640	$75,779
Douglas	24,100	33,270	$28,920	$39,924
Okanogan	31,700	30,477	$38,040	$36,572
Ferry	6,100	6,100	$7,320	$7,320
Stevens	30,200	30,811	$36,240	$36,973
Pend Oreille	8,800	6,966	$10,560	$8,359
Eastern	493,300	540,374	$591,960	$648,449
Grant	52,600	71,551	$63,120	$85,861
Adams	14,000	15,834	$16,800	$19,001
Lincoln	9,700	9,089	$11,640	$10,907
Spokane	354,100	382,833	$424,920	$459,400
Whitman	39,000	34,721	$46,800	$41,665
Columbia	4,100	4,100	$4,920	$4,920
Garfield	2,400	1,789	$2,880	$2,147
Asotin	17,400	20,457	$20,880	$24,548
TOTAL	4,565,000	6,013,253	$5,478,000	$7,215,902

[1] Materials Damage is $1.20 per person.

ECONOMIC EFFECTS OF INDOOR AIR POLLUTION
WASHINGTON 2010

RCG/Hagler, Bailly, Inc.

July 6, 1989

Final Draft

1.0 INTRODUCTION

This paper provides Washington 2010 with estimates of the current economic risks associated with indoor air pollution in Washington. Estimated economic effects are intended to provide quick estimates of the likely magnitude of the potential economic damages associated with indoor air pollution in Washington. The results are not expected to be precise, but to be useful for the overall ranking of environmental problems being addressed in the Washington 2010 project.

Indoor air pollution has been associated with economic effects through two principal pathways: human health damages and materials damage. This analysis includes quantitative estimates of the medical cost of illness and lost productivity due to predicted annual cancer cases associated with indoor air pollution. It does not consider economic damages associated with acute and chronic non-cancer health effects due to the absence of estimated incidence numbers and the variability of chronic and acute health end points associated with indoor air pollutants. Because large numbers of persons are at risk of acute and chronic health effects associated with indoor air pollution, specifically environmental tobacco smoke, nitrogen dioxide, volatile organic compounds, formaldehyde, and biological organisms (Jacobs, 1989), health economic damage estimates based on annual cancer cases are likely to underestimate the actual economic damages associated with health effects.

Materials damage caused by indoor air pollution has been widely recognized as a source of economic loss in large metropolitan areas. Economic effects associated with indoor air pollution have been associated with expenses incurred for increased protective maintenance and cleaning in industrial and electronic industries, the reduced service life of materials, the decreased usefulness of materials, and damage to certain paints and dyes used in fine art. Leather books and other rare documents may also be damaged by high levels of indoor air pollution.

While numerous studies of economic damages associated with materials damage associated with ambient (outdoor air pollution) have been performed, we have not been able to locate studies quantifying economic damage due to materials damage associated with indoor air pollution. It is also difficult to estimate the possible magnitude of these damages in Washington. Materials damage economic effects may range from relatively small values to potentially significant damages in certain industries, libraries, and laboratories.

2.0 CANCER ECONOMIC EFFECTS

Economic effects due to annual cancer cases associated with indoor air pollutant exposures are based on estimates of the direct and indirect costs of cancer cases estimated by Hartunian, et al. (1981).

Direct costs represent the average hospitalization costs and nonhospital costs, such as physician services, private nursing, nursing home and attendant care, drugs, physical therapy, special equipment and prosthetics, and other miscellaneous services. These costs were estimated as $9,704 for the average cancer patient in 1975 dollars. These costs are $29,112 1988 dollars, using the Index of Medical Prices deflator (DOL, 1988).

Indirect costs represent economic effects associated with foregone productivity or earnings as a result of cancer. Hartunian, et al. estimated the average foregone earnings for all cancer sites as being $25,334 per capita. Converting to 1988 dollars using the GNP Implicit Price deflator, foregone productivity equals $55,734 per cancer case. Total damages per cancer case are $84,846.

2.1 Uncertainty

Hartunian, et al. performed sensitivity analyses over basic analytic assumptions in their analysis and concluded that errors in the direct costs (medical costs) of up to 5 percent are possible if these assumptions are incorrect. They reported that potential errors in the forgone earnings estimates could be as large as 13 percent. Thus, total damage estimates could over or underpredict the "true" damage estimates by as much as 18 percent. Per capita cancer damages could range between $69,573 and $100,118.

2.2 Annual Cancer Economic Damages

Estimated annual cancer damages are summarized in Table 1. These damages are based on incidence values calculated by Jacobs (1989).

3.0 REFERENCES

Jacobs, C. 1989. Washington Environment 2010 Indoor Air Pollutants Other than Radon Draft Report, Washington Department of Agriculture.

Hartunian, N.S., C.N. Smart, and M.S. Thompson. 1981. The Incidence and Economic Costs of Major Health Impairments, Lexington Books, D.C. Heath and Company, Lexington, Massachusetts, Toronto.

Table 1 Annual Cancer Economic Damage Associated with Indoor Air Pollution

Pollutant	Exposure Conditions	Annual Cancer Incidence Lower Bound Upper Bound	Damage/Case	Total Welfare Damages
Environmental Tobacco Smoke	Exposure (0.45-2.27 mg tar/day) at home for 62% of population	64	$84,846	$5,430,144 *
		321	$84,846	$27,235,566 *
Benzo(a)pyrene	462,806 households with woodstoves used for 3 to 6 months (456 to 912 hours) at 4.7 ng/cu.m./day	4	$84,846	$339,384 *
		7	$84,846	$593,922
	462,806 households with fireplaces used for 3 to 6 months (273 to 547 hours) at 11.4 ng/cu.m/day	5	$84,846	$424,230
		10	$84,846	$848,460 *
Volatile Organic Compounds	4,565,000 people exposed to average conditions based on TEAM study	16	$84,846	$1,357,536 *
		33	$84,846	$2,799,918 *
Formaldehyde	274,731 mobile home residents exposed to HUD mobile home standard (500 ug/cu.m.) and average level (525 ug/cu.m.)	22	$84,846	$1,866,612
		23	$84,846	$1,951,458
	274,731 mobile home residents exposed to low to high levels (150-1500 ug/cu.m)	7	$84,846	$593,922 *
		66	$84,846	$5,599,836 *
	4,036,153 residents of conventional homes exposed to low to high levels (7-4350 ug/cu.m.)	4	$84,846	$339,384
		2,445	$84,846	$207,448,470
Asbestos	986,745 children aged 5-19 exposed to avg levels (200 ng/cu.m.) and a range (10-1950 ng/cu.m.) of asbestos for 200 days @ 8 hrs/day where 10% of student area in school contains asbestos and 66% of surface area is damaged	<1	$84,846	$0 *
		17	$84,846	$1,442,382 *

* These estimates were used in the calculation of the upper and lower bound economic risk estimates. Incidence data were taken from Jacobs (1989).

ECONOMIC EFFECTS OF RADIOACTIVE RELEASES WASHINGTON 2010

RCG/Hagler, Bailly, Inc.

July 6, 1989

Final Draft

1.0 INTRODUCTION

This paper provides Washington 2010 with estimates of the current economic risks associated with radioactive releases in Washington. Estimated economic effects are intended to provide quick estimates of the likely magnitude of the potential economic damages associated with radioactive releases in Washington. The results are not expected to be precise, but to be useful for the overall ranking of environmental problems being addressed in the Washington 2010 project.

Human health and ecological risks associated with radioactive releases in Washington are described in Stohr (1989a). Statewide economic damage estimates associated with annual cancer cases attributable to radioactive releases are based on Stohr's estimates of cancer risk. It was not possible to estimate economic losses due to ecosystem damages associated with radioactive releases, however, noted ecosystem damages at Hanford are probably creating economic losses associated with existence and option values at the site.

Economic damages have been reported near a number of hazardous waste facilities across the United States. These damages have been documented in hedonic property value studies, which attempt to measure the value of environmental amenities across housing markets. There have been no property value studies conducted in the vicinity of Hanford. However, a strong property value gradient exists, with property values decreasing with increasing distance from the site. Apparently the perceived risk associated with health effects due to radioactive release at Hanford is less important in the housing market than commuting time to and from the site. In addition, the sites that are perceived to be most threatening to public health are at least 8 to 10 miles away from residential areas (Nessie, 1989). There is no evidence of property value decrements being associated with any of the remaining types of facilities analyzed by Stohr (Stohr, 1989b).

Stohr (1989b) expressed concern that the economic value of the 560 square mile Hanford Reservation, once returned to the State, is dependent on its quality. Severely contaminated land will not possesses the same potential for beneficial, if any, economic uses as unpolluted land with the same general characteristics. Consequently, one source of economic damage associated with radioactive releases from the site will be the forgone use value of contaminated land.

It has not been possible to estimate economic losses associated with the withdrawal of potentially productive lands from Washington's economy. Precise estimates of this damage will not be possible prior to site remediation. However, irrigated agricultural land in Benton County is currently selling for approximately $1,200 to $1,400 per acre (McClinton, 1989). There are 358,400 acres on the Hanford site.

Stohr (1989b) also indicated that there have been an increasing number of requests from foreign countries for Department of Social and Health Service certification of wheat and grape export crops grown in the Hanford area. Despite negative results, ie., crops were not contaminated in DSHS inspections, increasing requests for certification are an indication that the fear of radioactive contamination is increasing. Stohr (1989b) estimates that 20 requests for certification have been received.

If real or perceived radioactive contamination associated with the Hanford site leads to fewer crop exports and sales from agricultural suppliers in the Hanford vicinity, economic damages could be very significant.

Uranium mining and mills located on the Spokane Indian Reservation have produced radioactive tailings waste that cover about 250 acres. Economic effects associated with these facilities have not been included in this analysis.

2.0 QUANTIFIED ECONOMIC EFFECTS ASSOCIATED WITH CANCER CASES

Economic effects due to annual cancer cases associated with radioactive releases are based on estimates of the direct and indirect costs of cancer cases estimated by Hartunian, et al. (1981).

Direct costs represent the average hospitalization costs and nonhospital costs, such as physician services, private nursing, nursing home and attendant care, drugs, physical therapy, special equipment and prosthetics, and other miscellaneous services. These costs were estimated as $9,704 for the average cancer patient in 1975 dollars. These costs are $29,112 1988 dollars, using the Index of Medical Prices deflator (DOL, 1988).

Indirect costs represent economic effects associated with foregone productivity or earnings as a result of cancer. Hartunian, et al. estimated the average foregone earnings for all cancer sites as being $25,334 per capita. Converting to 1988 dollars using the GNP Implicit Price deflator, foregone productivity equals $55,734 per cancer case. Total damages per cancer case are $84,846.

2.1 Uncertainty

Hartunian, et al. performed sensitivity analyses over basic analytic assumptions in their analysis and concluded that errors in the direct costs (medical costs) of up to 5 percent are possible if these assumptions are incorrect. They reported that potential errors in the forgone earnings estimates could be as large as 13 percent. Thus, total damage estimates could over or underpredict the "true" damage estimates by as much as 18 percent. Per capita cancer damages could range between $69,573 and $100,118.

2.2 Annual Cancer Economic Damages

Calculated damages are based on health risk impacts estimated by Stohr (1989a,c) in Table 2 and are summarized in Table 1.

Table 1
Economic Effects Associated with Radioactive Releases

Potential Source	Annual Cancer Deaths in Exposed Pop.	Annual Cancer Cases in Exposed Pop.	Economic Damages
Atmospheric Weapons Testing	0.9	1.8	$152,722
Nuclear Naval Facilities	<0.1	<0.2	<$16,969
Hanford Defense Production Facilities	<0.1	<0.2	<$16,969
Commercial Nuclear Reactors	<0.1	<0.2	<$16,969
Uranium Mining and Milling	<0.1	<0.2	<$16,969
Commercial Low Level Waste Disposal	<0.1	<0.2	<$16,969
Others	<0.1	<0.2	<$16,969

3.0 REFERENCES

Hartunian, N.S., C.N. Smart, and M.S. Thompson. 1981. The Incidence and Economic Costs of Major Health Impairments, Lexington Books, D.C. Heath and Company, Lexington, Massachusetts, Toronto.

McClinton, J. 1989. Personal communication, Soil Conservation Service, Spokane, Washington, June 19.

Nessie, R. 1989. Personal communication, Battelle, Washington, D.C., June 19.

Stohr, J. 1989a. Human Health and Ecological Risks Associated with Radioactive Releases, Washington Environment 2010, Washington Department of Ecology, June 15.

Stohr, J. 1989b. Personal communication with K. Rokstad, Washington Department of Ecology.

Stohr, J. 1989c. Personal communication, Washington Department of Ecology.

ECONOMIC EFFECTS OF INDOOR RADON
WASHINGTON 2010

RCG/Hagler, Bailly, Inc.
July 6, 1989

Final Draft

1.0 INTRODUCTION

This paper provides Washington 2010 with estimates of the current economic risks associated with indoor radon pollution in Washington. Estimated economic effects are intended to provide quick estimates of the likely magnitude of the potential economic damages associated with radon air pollution in Washington. The results are not expected to be precise, but to be useful for the overall ranking of environmental problems being addressed in the Washington 2010 project.

Radon exposures have been associated with respiratory tissue damage and lung cancer. Economic effects associated with radon exposures include the cost of illness and lost productivity associated with lung cancer cases and the costs of radon mitigation in homes. This analysis quantifies economic damages associated with annual predicted cancer cases, but does not quantitatively address the costs of radon monitoring or mitigation programs due to the lack of available data in Washington.

2.0 ECONOMIC DAMAGES

Economic effects due to annual cancer cases associated with indoor radon exposures are based on estimates of the direct and indirect costs of cancer cases estimated by Hartunian, et al. (1981).

Direct costs represent the average hospitalization costs and nonhospital costs, such as physician services, private nursing, nursing home and attendant care, drugs, physical therapy, special equipment and prosthetics, and other miscellaneous services. These costs were estimated as $9,704 for the average cancer patient in 1975 dollars. These costs are $29,112 1988 dollars, using the Index of Medical Prices deflator (DOL, 1988).

Indirect costs represent economic effects associated with foregone productivity or earnings as a result of cancer. Hartunian, et al. estimated the average foregone earnings for all cancer sites as being $25,334 per capita. Converting to 1988 dollars using the GNP Implicit Price deflator, foregone productivity equals $55,734 per cancer case. Total damages per cancer case are $84,846.

2.1 Uncertainty

Hartunian, et al. performed sensitivity analyses over basic analytic assumptions in their analysis and concluded that errors in the direct costs (medical costs) of up to 5 percent are possible if these assumptions are incorrect. They reported that potential errors in the forgone earnings estimates could be as large as 13 percent. Thus, total damage estimates could over or underpredict the "true" damage estimates by as much as 18 percent. Per capita cancer damages could range between $69,573 and $100,118.

2.2 Estimated Damages

Webber (1989) estimated that total statewide cancer deaths could range form between 78-441 per year in 1988, and 100-559 per year in 2010 due to residential radon exposure. Table 1 summarizes economic damages associated with these estimates.

Table 1

1988 Economic Damages Associated with Annual Cancer Deaths

Deaths	Economic Damages/Case	Total Damages
78	$69,573	$5,426,694
	$84,846	$6,617,988
	$100,118	$7,809,204
441	$69,573	$30,681,693
	$84,846	$37,417,086
	$100,118	$44,152,038

2010 Economic Damages Associated with Annual Cancer Deaths

Deaths	Economic Damages/Case	Total Damages
100	$69,573	$6,957,300
	$84,846	$8,484,600
	$100,118	$10,011,800
559	$69,573	$38,891,307
	$84,846	$47,428,914
	$100,118	$55,965,962

For 1988, economic damages may range between a lower bound of approximately 5 million dollars and an upper bound of approximately 44 million dollars. For 2010, using 1988 dollars, the range of damages is approximately 7 million to 56 million dollars. It should be noted that 2010 damages assume no changes in current practice regarding residential radon mitigation. If testing and mitigation became more widespread, predicted economic damages associated with cancer cases would decline. The decrease in cost of illness and lost productivity measures would more than offset the cost of testing and residential mitigation programs.

3.0 REFERENCES

Hartunian, N.S., C.N. Smart, and M.S. Thompson. 1981. The Incidence and Economic Costs of Major Health Impairments, Lexington Books, D.C. Heath and Company, Lexington, Massachusetts, Toronto.

Webber, J. 1989. Indoor Radon: Comparative Risks for Washington State, Washington Department of Energy, March 24.

ECONOMIC EFFECTS OF GLOBAL WARMING AND OZONE DEPLETION IMPACTS WASHINGTON 2010

RCG/Hagler, Bailly, Inc.

July 6, 1989

Final Draft

1.0 INTRODUCTION

This paper summarizes information on economic economic effects of global warming and atmospheric ozone depletion provided in the report on Human Health and Ecological Risks (Canning et al., 1989). The Canning et al. report is a comprehensive review of studies on the risk of ecological, human health, and economic effects of global warming.

Almost all of the available information is national or global in scope. Information specific to Washington State or the Pacific Northwest is unavailable or at best quite generalized.

The estimates of global warming and ozone depletion impacts are characterized by a high degree of uncertainty. This uncertainty is reflected in conflicting estimates of the types and magnitudes of potential impacts. In fact, the damaging effects of one impact are often estimated to be off-set by beneficial effects of another impact. The lack of information and uncertainty make quantitative analyses impossible at this time. Canning et al. estimate that information required to conduct quantitative analyses may be available in two to five years.

2.0 ECONOMIC EFFECTS

The economic effects of global warming and ozone depletion impacts are identified for agriculture, energy, fisheries, forestry, and coastal resources. The types of climate impacts addressed include, increased temperatures, increased concentration of CO_2, changes (uncertain) in precipitation amounts and timing, rises in sea level, and decreased stratospheric ozone concentrations.

Agricultural Economic Effects

Although climate changes will impact agricultural resources, the net economic effects are uncertain. Increased temperatures will tend to shift crop zones to the north and increase plant evapotranspiration. The effect shifting crop zones and crop substitutions is uncertain and will depend on other factors such as soil type, water availability and the ability to shift to other crops (it is difficult to shift some types of agriculture such as orchards). Increased evapotranspiration, for some crops, may be off-set by improved plant water use efficiency resulting from the increased concentrations of CO_2. The type and magnitude of agricultural impacts will depend in large part on the changes in hydrology, that is, the change in quantity and timing of water. Studies on the agricultural impacts of climate change have reported effects ranging from a slight increase in economic welfare to a net loss of $10 billion annually (Adams et al. 1988). The same study estimates that agricultural land use will increase in the Pacific states with an increase in gross revenues of as much as 30 percent. Decreased levels of stratospheric ozone are estimated to decrease crop yields. Adams and Rowe (1989) estimated that a 15 percent decrease in stratospheric ozone would result in a $2.6 billion annual economic loss to the U.S.

Energy Economic Effects

Global warming will likely affect Washington's energy system by changing the balance of supply and demand. Changes in climate may affect the source or reliability of electricity supply and the quantity and timing of demand. Washington has the largest hydropower generating system in the nation. In 1987, 94 percent of the electricity generated in the state was from hydropower. Because of the reliance on hydropower, the supply system is very sensitive to fluctuations in water supply. Model impacts vary in their predictions of changes in the amount, timing and type of precipitation. The type of precipitation is important because snowpack smooths the timing of the available runoff. Increases in temperature could reduce the snowpack and thus increase the variation in streamflow.

Studies of climate related changes in demand in Washington indicate that with an increase in temperature, demand will probably decrease in the winter with only a slight increase in summer (air conditioning). An U.S. Environmental Protection Agency electricity demand study estimated that with a 4.5 degree increase in temperature, average electricity demand in the Northwest may decrease by 0-5 percent and peak demand may decrease by 0-10 percent.

Net economic effects of energy in Washington by be positive or negative. The primary factor determining the effects is the change in the hydrologic cycle. Reductions in rainfall or snowpack associated with higher temperatures may cause electricity costs to rise as other, more expensive, generation units are required. Increases in precipitation and snowpack could reduce electricity costs. At the same time, demand may decrease as winter heating needs are reduced.

Fishery Economic Effects

The magnitude and timing of the impacts and economic effects of ozone depletion, climate change and rising sea level on fisheries is unknown, however, the impacts are forecast to cause economic losses. A depletion of ozone and associated increase in ultra violet radiation is projected to have substantial impacts on the survival and development fish and shellfish eggs and larvae. A reduction in fish and shellfish resources would affect the welfare of sport and commercial fisheries. Climate change could impact fisheries through increases in temperature and changes in precipitation. An increase in the temperature of ocean waters could lead to the loss of the Pink, Sockeye, Chum, and Chinook Salmon fisheries, as these fish species are currently close to the southern boundary of their range (Finn, 1989). Sea level rise could result in loss of habitat as current intertidal areas become inundated and shorelines become steeper. Sea level rise could result in the loss of intertidal clams, surf smelt, and juvenile Pacific salmon. These losses would cause significant economic damage (Finn, 1989). The combined effects of the impacts are expected to reduce the fishery economic welfare.

Forestry Economic Effects

Forestry economic effects are uncertain, however, several climatological factors may contribute to losses in welfare. Increased temperatures may create heat stress and reduce the ability to have sufficient chilling to enable overwintering. Changes in precipitation and evapotranspiration requirements may impact tree growth. Changes in CO_2 concentrations may also affect tree growth, both positively and negatively. The net economic effects of forestry resources are unknown.

Sea Level Rise

Although there has been considerable national effort to address sea level rise impacts and effects, there is little current information available (a state study is underway). The types of impacts expected from a rise in sea level include: property losses, beach and cliff erosion, wetland losses, flooding, increased costs of sea walls, and sea water intrusion on fresh water supplies. There are no estimates for these losses but they are projected to be significant.

3.0 REFERENCES

Canning, Douglas J., Katharine P. Bauer, Bonnie B. Bunning, Candace Jacobs, Mary Lou Mills, and Jeffery Weber. 1989. Global Warming and Ozone Depletion: Comparative Risks for Washington State, Global Warming Subcommittee, Environment 2010 Project, Draft, June.

Finn, E. 1989. Personal communication, Department of Fisheries, Olympia, WA.

ECONOMIC EFFECTS OF POINT AND NONPOINT SOURCE DISCHARGES TO WATER WASHINGTON 2010

RCG/Hagler, Bailly, Inc.
July 7, 1989

Final Draft

1.0 INTRODUCTION

This report provides Washington 2010 with estimates of the current economic risks associated with point and nonpoint source discharges to water in Washington. Estimated economic effects are intended to provide quick estimates of the likely magnitude of the potential economic damages associated with point and nonpoint source discharges in Washington.

The US EPA's Unfinished Business Report ranked nonpoint source discharges to surface water as the second most important environmental economic risk evaluated. Discharges from POTWs were considered to be the third most important risk and point source discharges were considered to be the eighth most important economic risk. Consequently, point and nonpoint source discharges are, together, one of the most important, if not the most important source of economic damages nationally. It is not unreasonable to assume that risks associated with these stresses are equally significant in Washington.

Point and nonpoint source water pollution have been associated with economic losses due to:

- the loss of recreational opportunities for fishing, swimming and boating;
- the closure and/or decline in the harvest of commercial fish and shellfish;
- property value losses due to aesthetic degradation;
- increased treatment or alternative supply costs due to contaminated drinking water;
- reduced suitability of surface water for non-human consumptive uses;
- loss of non-use values associated with Washington river bodies; and
- the direct and indirect costs of illness due to ingestion of contaminated fish and shellfish and full body immersion in polluted water.

This report estimates economic damages associated with:

- the cost of illness due to cancer cases, it was not possible to estimate the costs of illness associated with other health endpoints related to point and nonpoint pollution;
- soil erosion;
- lost recreational opportunity in Puget Sound; and
- lost recreational opportunity due to nonpoint and point sources.

2.0 ECONOMIC EFFECTS ASSOCIATED WITH CANCER CASES

Economic effects due to annual cancer cases associated with point and nonpoint source pollution are based on incidence estimates developed by Singleton, et al. (1989) and estimates of the direct and indirect costs of cancer cases estimated by Hartunian, et al. (1981).

Singleton, et al. estimated that nonpoint and point source water pollution in Washington are likely to cause 2.38 additional cancer cases annually in the MEI and recreational populations. Values at the lower end of the range are considered to be more likely. These bounding estimates were multiplied by the direct and indirect costs of cancer cases.

Direct costs represent the average hospitalization costs and nonhospital costs, such as physician services, private nursing, nursing home and attendant care, drugs, physical therapy, special equipment and prosthetics, and other miscellaneous services. These costs were estimated as $9,704 for the average cancer patient in 1975 dollars. These costs are $29,112 1988 dollars, using the Index of Medical Prices deflator (DOL, 1988).

Indirect costs represent economic effects associated with foregone productivity or earnings as a result of cancer. Hartunian, et al. estimated the average foregone earnings for all cancer sites as being $25,334 per capita. Converting to 1988 dollars using the GNP Implicit Price deflator, foregone productivity equals $55,734 per cancer case. Total damages per cancer case are $84,846.

Estimated economic damages associated with annual cancer cases equal $210,933.

2.1 Uncertainties

Hartunian, et al. performed sensitivity analyses over basic analytic assumptions in their analysis and concluded that errors in the direct costs (medical costs) of up to 5 percent are possible if these assumptions are incorrect. They reported that potential errors in the forgone earnings estimates could be as large as 13 percent. Thus, total damage estimates could over or underpredict the "true" damage estimates by as much as 18 percent. Per capita cancer damages could range between $69,573 and $100,118.

3.0 ECONOMIC LOSSES ASSOCIATED WITH SOIL EROSION

Soil erosion from farmland and other lands increases sediment, nutrient, and pesticide loadings in surface waters. Sediments, nutrients, and pesticides cause sedimentation problems in reservoirs, affect aquatic plant and animal life, affect the quality of wetland and riparian habitats, reduce recreation opportunities, and may be related to human health effects.

Ribaudo (1986) estimated the offsite damages due to water caused erosion for each of the Farm Production Regions and the U.S. His estimates do not include damages caused by wind erosion. Based on his calculations, erosion causes $2.02 (1983 dollars) of damages per ton of soil loss in the Pacific Region.

Total Washington sheet and rill erosion from all sources was estimated in the 1982 NRI (SCS, 1985) as 53,810,600 tons per year. To calculate economic damages:

$2.36(1988 $) * 53,810,600 = $126,993,016.

Note that Ribaudou's estimate of damages per acre has been converted to 1988 dollars using the GNP implicit price deflator. This damage estimate includes estimated damages to recreational fishing, water storage facilities, flood damage, drainage ditches and irrigation canals, water treatment facilities, municipal and industrial water uses, electric power plants, and irrigated agriculture.

4.0 PUGET SOUND

Pollution reaches Puget Sound through numerous point and nonpoint source discharges. The principal known sources are municipal and industrial point source discharges, stormwater runoff, pesticides from nonpoint sources, and unpermitted discharges of wastewater. The accumulation of pollutants in Puget Sound results in economic damages resulting from reduced recreational, commercial, and property values.

4.1 Lost Recreational Opportunity In Puget Sound

According to the Puget Sound Water Quality Authority (1988), Puget Sound represents an "invaluable recreational resource for residents and tourists alike." Economic benefits of the sound derive from people's desire to live near the water and the high participation by Washington residents involved in fresh or saltwater recreation. The western Puget Sound/Olympic Peninsula region is the most important recreation region in the state, and was visited by approximately 28 percent of all state vacationers in 1986.

Recent estimates made by the Washington Department of Trade and Economic Development cited in PSWQA (1988) indicate that resident and nonresident travelers spent approximately $2.7 billion in the counties bordering Puget Sound. Table 1 summarizes tourist expenditures and travel generated employment estimates for counties adjacent to the Puget Sound. Travel related employment accounted for 54,825 jobs, or 73 percent of all the travel related employment in the state. Participation in recreational boating, fishing, and shellfishing is partially dependent on the water quality of Puget Sound. Unfortunately, no estimates of recreation economic damages associated with point and non-point source water pollution in Puget Sound have been performed using local data (Richter, 1989).

The US EPA (1987) estimated economic damages associated with the lost recreational opportunity in Puget Sound to range between $24 and $73 million dollars (1988). This estimate was based on an analysis of the economic value of recreation in Long Island Sound. The simple extrapolation of these values to the Puget Sound is very uncertain and doesn't take into account numerous factors including differences in: recreational activities, species distribution, beach swimming patterns, present water quality, and the sensitivity of recreational activities to changes in water quality. The EPA damage estimate may significantly underestimate economic damages related to reduced recreation participation and enjoyment in Puget Sound. However, research necessary to establish this conclusion has not yet been performed.

4.2 Lost Commercial Fishery in Puget Sound

Commercial fishing in the Sound is an important part of the local economy as well as a significant contributor to Washington's fishing industry. According to the PSWQA, fishing provides benefits to both Indian and non-Indian communities. The PSWQA estimated the five year average commercial catch value as 47.92 million dollars. The commercial fish and shellfish industries have been affected by point and nonpoint pollution in the Sound. Significant areas of the Sound have been restricted for commercial shellfish, see Table 2. These closures have caused significant economic damages, especially in local areas. However, it has not been possible to estimate the value of these damages in this report due to data and time constraints.

5.0 LOST RECREATIONAL OPPORTUNITY ON SURFACE WATER

The US EPA (1987) estimated recreational damages associated with discharges from nonpoint, POTW, and point sources to surface waters across the U.S. To develop estimates of economic losses in Washington using this data, total U.S. damage estimates were divided by the U.S. population to develop per capita damage estimates. Washington damage estimates were derived by multiplying 1988 per capita damage estimates by the state population. These damages and calculations are summarized in Table 3. This estimate should not be added to estimates for recreational damages for Puget Sound to avoid double counting. In addition, these estimates may double count recreational damages estimated in the soil erosion damage estimate.

6.0 REFERENCES

Hartunian, N. C. Smart, and M. Thompson. 1981. The Incidence and Economic Costs of Motor Vehicle Impairments, A Comparative Analysis of Cancer, Motor Vehicle Injuries, Coronary Heart Disease and Stroke, D.C. Heath and Company.

PSWQA, 1988. State of the Sound Report, Seattle, WA, May.

Ribaudo, M.O. 1986. "Reducing Soil Erosion: Offsite Benefits." USDA, Economic Research Service, Agricultural Economic Report Number 561, Washington, D.C. September.

Richter, J. 1989. Personal communication, Puget Sound Water Quality Authority, Seattle, WA.

SCS. 1985. 1982 National Resource Inventory Tables. Soil Conservation Service, USDA, Denver, CO, January.

Singleton, L., et al. 1989. Health and Ecological Effects Related to Point and Nonpoint Source Discharges to Water, Washington 2010 Project, Washington Department of Ecology, June 15.

U.S. EPA. 1987. Unfinished Business: A Comparative Assessment of Environmental Problems, Appendix IV, Welfare Risk Workgroup, Washington, D.C., February.

Table 1
Tourist Expenditures and Travel-Generated Employment Estimates by County, 1986

County	Expenditures ($1,000,000)	Employment (Number of Jobs)
Clallam	40.0	960
Island	13.0	370
Jefferson	12.8	325
King	1,700.0	38,600
Kitsap	33.0	1,000
Mason	13.5	375
Pierce	680.0	6,550
San Juan	32.0	720
Skagit	35.0	700
Snohomish	85.0	2,200
Thurston	55.0	1,575
Whatcom	55.0	1,450
TOTAL	$2,754.3	54,825
OTHER COUNTIES	755.0	19,795
STATE TOTAL	$3,509.3	74,620

Source: PSWQA (1988) p.75

Table 2
Classification Status of Puget Sound Commercial Shellfish Areas(1)

Area	Product(s)[2]	Growers	A	CA	R	P[3]	Source(s)[4]
Clallam County							
Dungeness Bay	Clams/Oysters	2	1183	0	0	0	
Sequim Bay	Clams/Mussels/Oysters	5	3080	0	0	337	Marina/Nonpoint
South Point	Clams/Oysters	1	5	0	0	0	
Island County							
Holmes Harbor	Mussels/Oysters	3	2994	0	0	0	
Penn Cove	Mussels	3	0	439	0	1020	STP/Nonpoint/Urban
Island/Snohomish Counties							
Port Susan	NA		0	0	6120	2250	Animal Waste/STP
Jefferson County							
Big Beef Harbor	Oysters	1	408 (includes Seabeck area)				
Brinnon	Clams/Oysters	3	295	0	0	0	
Dabob Bay	Clams/Oysters	8	5895	0	0	0	
Discovery Bay	Clams	5	9139	0	0	0	
Dosewallips State Park	Clams/Oysters	1	0	0	180	0	Nonpoint
Duckabush	Oysters	1	0	0	214	0	Nonpoint
Fisherman Harbor	Clams/Oysters	1	0	40	100	0	Boating
Fulton Creek	Oysters	1	90	0	0	0	
Hadlock Bay	Clams	1	40	0	0	100	Marina/STP/Nonpoint
Jackson Cove	Oysters	1	4	0	0	0	
Kilisut Harbor	Clams/Oysters	4	1112	0	0	0	
Mats Mats Bay	Oysters	1	15	0	0	0	
Nordland	Clams/Oysters	1	10	0	0	0	
Oak Bay	NA	-	367	0	0	0	
Quilcene Bay	Clams/Oysters	5	918	0	0	204	Nonpoint
Sylopash	Clams/Oysters	1	612	0	0	0	
Squamish Bay	Clams	1	82	0	0	0	
Thorndyke Bay	Clams	1	245	0	0	0	
Triton Cove	Clams/Oysters	1	204	0	0	0	

NOTE: (1). Classifications are current as of 1/1/89 and are subject to change throughout the year.
(2). NA = Not active; the area is not currently being used to grow commercial shellfish.
(3). Numbers provided represent the amount of acres that have been classified in the area. The actual acreage currently being used commercially within the classified area varies. A= Approved; CA= Conditionally Aproved; R= Restricted; P= Prohibited. (see page 3 for definitions of these classifications).
(4). "Sources" refers to contamination sources that have been identified in the area. "Nonpoint" refers to urban runoff, failing on-site systems, and other indirect sources of contamination. "STP" refers to municipal sewage treatment plants.

Table 2 (cont.)

Area	Product(s)[2]	Growers	A	CA	R	P[4]	Source(s)[3]
King County							
Northeast Vashon Island	Clams/Oysters	1	143	0	0	0	
Kitsap County							
Agate Pass	Clams	1	122	0	0	0	
Crystal Springs, Bainbridge	Clams	1	5	0	0	0	
Liberty Bay	Clams/Oysters	1	0	260	0	2417	Nonpoint/Animal Waste/Marinas
Misery Point	Oysters	1	40	0	0	0	
Nellita	Oysters	1	5	0	0	0	
Port Blakely	Oysters	1	1	0	0	0	
Port Gamble, Klallam Reservation	Clams		286	0	0	0	
Port Madison, Suquamish Reservation	Clams		80	0	0	0	
Port Orchard Passage	Clams	1	2183	0	0	0	
Raft Island	Oysters	1	10	0	0	0	
Seabeck	Oysters	4	(see Big Beef Harbor)			600	Marina
Mason County							
Annas Bay	Clams/Oysters	4	979	0	0	0	
Beacon Point	Oysters	1	6	0	0	0	
Case Inlet - North Bay	Clams/Oysters	7	1387	0	0	0	
Hamma Hamma River Delta	Clams/Oysters	3	520	0	0	0	
Hammersley Inlet	Clams	3	20	0	0	0	
Hartstene Island	Clams/Oysters	5	846	0	0	194	STP
Jorsted Creek	Oysters	1	10	0	0	0	
Lilliwaup	Clams/Oysters	4	153	0	0	0	
Lynch Cove	Clams/Oysters	1	0	0	0	634	Nonpoint
Oakland Bay	Clams/Oysters	5	0	0	820	1224	Ind./Munic. STPs
Pickering Passage	Clams/Oysters	4	30	0	0	0	
Sisters Point	Clams/Oysters	1	6	0	0	0	
Skookum Inlet	Clams/Mussels/Oyster	14	2907 (includes Totten)		0	0	
Squaxin Island	Clams/Oysters	1	979	250	5	0	Marina/Boating
Stretch Island	Clams/Oysters	2	15	0	0	0	
Sunbeach - Lynch Cove	Clams/Oysters	4	16.5	0	0	0	
Tahuya	Oysters	2	27	0	0	0	
Totten Inlet - North Side	Clams/Oysters	18	2907 (includes Skookum)				
Waketickeh Creek	Oysters	1	50	0	0	0	
Pierce County							
Case Inlet - Rocky Bay	Oysters	1	See Case Inlet				
Filucy Bay	Clams/Oysters	1	0	60	0	0	Nonpoint/Marina
Glen Cove	NA	-	0	0	0	80	Nonpoint/Marina
Oro Bay - Anderson Island	Clams/Mussels/Oysters	1	45	0	0	0	

Table 2 (cont.)

Area	Product(s)[2]	Growers	A	CA	R	P[4]	Source(s)[3]
Pierce/Kitsap Counties							
Carr Inlet - Burley Lagoon	Clams/Oysters	1	0	0	480	0	Nonpoint/Animal Waste
Carr Inlet - Minter Bay	Clams/Oysters	1	0	0	0	93	Nonpoint
Case Inlet - Vaughn Bay	Oysters	2	see Case Inlet				
San Juan County							
Hunter Bay - Lopez Island	Mussels	1	1	0	0	0	
MacKaye Harbor - Lopez	Clams/Oysters	1	1	0	0	0	
Shoal Bay - Lopez	Clams	1	1.5	0	0	0	
Ship Bay - Orcas Island	Oysters	1	140	0	0	0	
Westcott Bay - San Juan	Clams/Mussels/Oysters	1	255	0	0	0	
Skagit County							
Samish Bay	Clams/Oysters	7	2424	0	0	0	
Similk Bay	NA	-	2616	0	0	0	
Sinclair Island	Clams	1	80	0	0	0	
Skagit/Island/Snohomish Counties							
Skagit Bay	NA		5374	0	2878	0	Nonpoint
Snohomish County							
Fidalgo Island	Clams	1	10	0	0	0	
Thurston County							
Eld Inlet	Clams/Oysters	8	31	602	0	0	Nonpoint/Animal Waste
Henderson Inlet	Clams/Oysters	1	450	150	0	163	Nonpoint
Jarrell Cove	NA	-	0	0	0	43	Marina/Boating
Nisqually Flats	Oysters	1	520	0	0	0	
Totten Inlet - South Side	Clams/Oysters	8	See Totten Inlet - Mason County				
Whatcom County							
Drayton Harbor (Semiahmoo)	Clams/Oysters	1	150	0	0	500	Nonpoint
Lummi Bay	Oysters	1	2487	0	0	1332	STPs/Nonpoint
Portage Bay	Oysters	1	510	0	0	0	

Source: DSHS (1989)

Table 3 Recreation Economic Damages Associated with Nonpoint and Point Source Discharges to Surface Water

Environmental Problem	US Estimate (billions) ($1986)	Per Capita ($1986)	Per Capita ($1988)	Total Washington Damages
Discharges from Nonpoint Sources to Surface Waters	3.7	$15.35	$16.54	$75,527,253
Discharges from Point Sources to Surface Waters	3.3	$13.69	$14.76	$67,362,144
			Total	$142,889,397

ECONOMIC EFFECTS ASSOCIATED WITH HYDROLOGIC DISRUPTIONS WASHINGTON 2010

RCG/Hagler, Bailly, Inc.
July 6, 1989

Final Draft

1.0 INTRODUCTION

This paper provides Washington 2010 with estimates of the current economic risks associated with hydrologic disruptions. Estimated economic effects are intended to provide quick estimates of the likely magnitude of the potential economic damages associated with hydrologic disruptions in Washington. The results are not expected to be precise, but to be useful in the overall ranking of environmental problems being addressed in the Washington 2010 project.

Ecological effects associated with hydrologic disruptions in Washington have been estimated by Wildrick (1989). Wildrick described seven different source activities that cause hydrologic disruptions. These are:

- dam construction and operation;
- surface water withdrawal;
- ground water withdrawal;
- construction of flood control devices;
- dryland agricultural practices;
- livestock grazing; and
- urban development.

These sources of hydrologic disruption are associated with numerous aquatic and terrestrial impacts that may cause a wide variety of potential economic damages. Principal impacts identified in Wildrick include:

- fish mortality and loss of aquatic habitat;
- decreased slope stability and increased soil erosion; and
- loss of riparian habitat.

This paper provides estimates of economic losses associated with the loss of salmon based on data contained in NPPC (1986) and ICF (1988); with soil erosion based on SCS (1985) RPI data and research performed by the USDA Economic Research Service; and with the loss of an acre of riparian habitat based on data contained in Meyer, et al. (1986). It was not possible to estimate total economic damages associated with riparian habitat loss due to the lack of available data describing the quantity of lost riparian habitat in Washington.

2.0 ECONOMIC EFFECTS ASSOCIATED WITH SALMON LOSSES

Hydrologic disruptions ranging from those caused by dam construction to urban development have caused direct mortality, reduction in habitat, reduction in food fish habitat, and other effects that have combined to significantly reduce the salmon population in Washington. A two step analysis was used to estimate the economic effects associated with damage to commercial and recreation salmon fishing in the State.

- First, the estimated total loss of Columbia River Basin salmon and steelhead cited in the Compilation of Information on Salmon and Steelhead Losses in the Columbia River Basin (NPPC 1986) was used to establish ratios of fish populations prior to and subsequent to development of the Columbia River Basin assuming different catch efficiency bases. According to the NPPC report, the predevelopment run, assuming a 67% catch rate, was approximately 3.75 times larger than the current run size.

- Second, the current value of the commercial and recreation salmon fishery, expressed as net economic value, was taken from ICF (1988). ICF estimated that the net economic value of the commercial salmon fishery in Washington was $1,439,448 in 1988. The estimated net economic value of the recreational fishery was $41,125,702. The current, 1988, total net economic value of the salmon fishery was estimated to be $42,565,150. By multiplying this value by the ratio developed in the previous step we estimated a hypothetical total value of the predevelopment salmon fishery value. This value is approximately $159.6 million. To estimate damages, we subtracted the current net economic value from this "predevelopment" value. Annual damages are approximately $117 million.

This estimate is quite speculative, assuming a linear relationship between increases in supply and net economic value of the fishery. This assumption is likely to be very conservative and result in an overestimate of the calculated damages. Use of the NPPC report to estimate statewide salmon population loss is also uncertain. Its use could lead to an overestimate of economic damages due to the extensive hydrologic modification in the Columbia River Basin. On the other hand, mitigation of hydrologic modification in the Columbia River Basin has been extensive and additional hatcheries have recently increased the salmon run. The Basin also has less urban development than other river basins in Washington. Consequently, it is difficult to estimate the direction of the bias in this estimate from these sources. Unfortunately, there is currently no available data that would allow the estimation of salmon run decrement for other river basins in Washington (Lincoln, 1989).

It should be noted that net economic value estimates prepared by ICF do not include the value of the salmon fishery to Indian people, nor those values associated with steelhead. Neither data source addressed the loss of other fish species. The Indian fishery constitutes approximately 50% or the total annual recreational and commercial salmon catch. Consequently, the economic damages associated with the decline in this fishery would also be considerable. Total economic damages may be underestimated by approximately 50% (Lincoln, 1989).

3.0 ECONOMIC LOSSES ASSOCIATED WITH SOIL EROSION

Soil erosion from farmland and other lands increases sediment, nutrient, and pesticide loadings in surface waters. Sediments, nutrients, and pesticides cause sedimentation problems in reservoirs, affect aquatic plant and animal life, affect the quality of wetland and riparian habitats, reduce recreation opportunities, and may be related to human health effects.

Ribaudo (1986) estimated the offsite damages due to water caused erosion for each of the Farm Production Regions and the U.S. His estimates do not include damages caused by wind erosion. Based on his calculations, erosion causes $2.02 (1983 dollars) of damages per ton of soil loss in the Pacific Region.

Total Washington sheet and rill erosion from all sources was estimated in the 1982 NRI as 53,810,600 tons per year. To calculate economic damages:

$2.36(1988 $) * 53,810,600 = $126,993,016.

Note that Ribaudou's estimate of damages per acre has been converted to 1988 dollars using the GNP implicit price deflator. This damage estimate includes estimated damages to recreational fishing, water storage facilities, flood damage, drainage ditches and irrigation canals, water treatment facilities, municipal and industrial water uses, electric power plants, and irrigated agriculture.

Because Ribaudou's estimate of total damages associated with soil erosion includes damages due to recreational fishing losses, the soil erosion damage estimate should not be added to the salmon damage estimate to avoid double counting of recreational fishing damages.

4.0 ECONOMIC LOSSES ASSOCIATED WITH THE LOSS OF RIPARIAN HABITAT

Meyer, et al. (1986) estimated the annual per acre recreation and aesthetic value of riparian habitat as being $3,625 based on the results of a study evaluating the value of riparian habitat along the Sacramento River in California. Economic damages associated with the loss of riparian habitat could be partially estimated if the current annual loss of riparian habitat in Washington were known.

5.0 REFERENCES

ICF. 1988. Economic Impacts and Net Economic Values Associated with Non-Indian Salmon and Sturgeon Fishing, A Report to the State of Washington Department of Community Development, March.

Lincoln, R. 1989. Personal communication, Department of Fisheries, Olympia, WA.

Meyer, P., et al. 1986. Calculation of Environmental Costs and Benefits Associated with Hydropower Development in the Pacific Northwest, prepared for the Bonneville Power Administration, Portland, Oregon, April.

NPPC. 1986. Compilation of Information on Salmon and Steelhead Losses in the Columbia River Basin, Northwest Power Planning Council, Portland, Oregon, March.

Ribaudo, M.O. 1986. "Reducing Soil Erosion: Offsite Benefits." USDA, Economic Research Service, Agricultural Economic Report Number 561, Washington, D.C. September.

SCS. 1985. 1982 National Resource Inventory Tables. Soil Conservation Service, USDA, Denver, CO, January.

ECONOMIC RISKS ASSOCIATED WITH ACTIVE HAZARDOUS WASTE SITES WASHINGTON 2010

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Final Draft

1.0 INTRODUCTION

This paper provides Washington 2010 with qualitative estimates of the current economic risks associated with active hazardous waste sites in Washington. As noted by Hughes (1989), "a quantitative measure of (human health and ecosystem) risks posed by active hazardous waste sites in the State of Washington is not possible with the currently available data." This analysis is constrained by similar limitations. The principal economic damages associated with active hazardous waste sites in the U.S. EPA's Unfinished Business Report (U.S. EPA 1987) were property value decrements and the loss of ground water use and option values. Groundwater use values are most likely associated with costs due to replacement or treatment of drinking water supplies contaminated by hazardous waste. Ground water option value is an economic measure of the value of future uses that would be forgone as a result of contamination.

2.0 PROPERTY VALUE DECREMENTS

Health risk beliefs of homeowners near hazardous waste sites may influence property values near those sites. Unfortunately, no studies of property value decrements associated with active hazardous waste sites have been conducted in Washington. However, four studies have reported evidence suggesting that proximity to hazardous waste sites can influence residential property values.

Schulze, et al. (1986) and McClelland, et al. (1989) used statistical techniques to evaluate declines in property values of residences surrounding the Operating Industries Inc (OII) Landfill in the Los Angeles metropolitan area. The site received both municipal and hazardous waste. Methane gas had migrated from the site creating health and property risks as well as odor problems. In addition, vinyl chloride was present at the site.

Schulze, et al. related the sales prices of properties surrounding the OII site and properties distant from the landfill to a variety of factors related to property values, for example, size of home, number of rooms, number of bathrooms, etc. Multiple regression analysis was used to estimate the extent to which the sales prices of homes were reduced by virtue of being located near the landfill.

Schulze, et al. reported that the property values of homes located within 1,000 feet of the site were estimated to be reduced by about $10,000. Sales prices of homes beyond this distance did not appear to be influenced by the landfill.

In a reanalysis of the same data, McClelland, et al. reported that housing prices in the vicinity of the landfill were approximately $4,793 lower after the closure of the landfill due to resident's concerns about possible health effects associated with the site. In the 4100 homes near the site, McClelland, et al., estimated the depression in property values to be about $40.2 million before the site was closed and to be about $19.7 million after closure.

In a similar study conducted by Smith and Desvouges (1986) in the Boston area, homeowners were willing to pay $300 to $500 per mile for a location more distant from a hazardous waste landfill. Michaels, et al. (1987) also reported that the mean willingness to pay for an increase of 0.8 miles in distance from CERCLA sites in the Boston area was approximately $69.

While there is little or no data regarding the effect of active hazardous waste sites in Washington on property values, there is considerable data available regarding the effect of the public's risk perception of the Midway Landfill on residential property values. In 1985, methane migrated from the landfill site to a residential neighborhood adjacent to the landfill. Some of the methane rose to the surface of the ground and entered a number of residences in the area. The City of Seattle responded by taking measures to contain the methane in the landfill and initiated the "Good Neighbor Program" to protect the value of residential properties in the vicinity of the landfill. The city also commissioned a study to evaluate the effect of proximity to the landfill on housing prices prior to the mid-1985 methane migration incident.

Haslerig (1985) concluded that between 1977 and 1984, that "areas near the landfill held their residential values at the same levels as the comparable study areas (neighborhoods) which are well out of the landfill's sphere of influence." However, housing values of homes participating in the Good Neighbor Program fell to approximately 84% of comparable fair market prices in 1986 (Robinson, 1989). By 1988, housing values in the affected neighborhood recovered to 100% of comparable fair market prices.

These and other data suggest that simple proximity to the Midway Landfill was not sufficient to depress property values prior to the widespread television, radio, and regional news coverage of the methane migration problem in mid-1985. While property values did diminish significantly, by 16%, in 1986 they appear to have recovered following successful remediation of the offsite methane migration (Anderson, 1989).

There have been no property value studies conducted in the vicinity of Hanford. However, a strong property value gradient exists, with property values decreasing with increasing distance from the site. Apparently the perceived risk associated with health effects due to the large number or active hazardous waste sites at Hanford is less important in the housing market than commuting time to and from the site. In addition, the sites that are perceived to be most threatening to public health are at least 8 to 10 miles away from residential areas (Nessie, 1989).

3.0 GROUND WATER LOSSES

No comprehensive estimates of the costs arising from the contamination of drinking water supplies around active hazardous waste sites was available. However, ground water has been contaminated at a number of landfills in Washington, and substantial costs have been incurred in supplying alternative drinking water to affected residences and in restoring contaminated aquifers.

4.0 CONCLUSION

While it has not been possible to estimate the economic damages associated with active hazardous waste sites in Washington, available data suggests that these damages could be substantial. Option values associated with contaminated ground water could be very significant, as ground water remediation technologies are unlikely to restore contaminated aquifers to their unpolluted condition.

The U.S. EPA Unfinished Business Report concluded that economic risks associated with active hazardous waste sites were moderate to significant, ranking 11th out of 23 environmental problems.

5.0 REFERENCES

Anderson, R. 1989. Personal communication, Seattle Engineering Department, Seattle, WA.

Haslerig, K. 1985. Market Study, Residential Values Midway Landfill and Vicinities, Draft Report prepared for the Seattle Engineering Department, Seattle, WA, December 12.

Knudson, J. 1989. Human Health and Ecological Risks Associated with Active Hazardous Waste Sites, Washington Environment 2010, Washington Department of Ecology, Olympia, WA.

McClelland, G., et al. 1989. "The Effect of Risk Beliefs on Property Values: A Case Study of a Hazardous Waste Site," in press.

Michaels , G., et al. 1987. "Market Segmentation and Valuing Amenities with Hedonic Models: A Case of Hazardous Waste Sites," unpublished.

Nessie, R. 1989. Personal communication, Battelle, Washington, D.C., June 19.

Robinson, L. 1989. Personal communication, Seattle Engineering Department, Seattle, WA.

Schulze, W., et al. 1986. "A Case Study of a Hazardous Waste Site: Perspectives from Economics and Psychology," report to the Office of Policy, Planning, and Evaluation, U.S. EPA, Cooperative Agreement CR812054-02-1.

Smith, K. and W. Desvouges. 1986. "The Value of Avoiding a LULU: Hazardous Waste Disposal Sites," The Review of Economics and Statistics, May, 293-299.

U.S. EPA. 1987. Unfinished Business: A Comparative Assessment of Environmental Problems, Appendix IV, Welfare Risk Work Group, February.

ECONOMIC RISKS ASSOCIATED WITH INACTIVE HAZARDOUS WASTE SITES WASHINGTON 2010

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1.0 INTRODUCTION

This paper provides Washington 2010 with estimates of the current economic risks associated with inactive hazardous waste sites in Washington. Estimated economic effects are intended to provide quick estimates of the likely magnitude of the potential economic damages associated with inactive hazardous waste sites in Washington. The results are not expected to be precise, but to be useful for the overall ranking of environmental problems being addressed in the Washington 2010 project.

Inactive hazardous waste sites have been associated with economic effects through a number of different pathways. This analysis evaluates effects associated with the direct health care costs and foregone earnings associated with annual cancer cases estimated by Blum (1989a); damage to residential property values near inactive hazardous waste sites; Washington residents willingness to pay for clean-up of inactive hazardous waste sites; and the replacement of contaminated drinking water supplies. The estimates of Washington state residents' willingness to pay to clean up inactive hazardous waste sites are based on a study performed in Colorado. Consequently, these estimates are highly uncertain and should only be used to suggest that Washington residents may be willing to pay significant amounts to clean up existing inactive hazardous waste sites in Washington. These damage estimates should not be added to damages calculated for cancer cases or property value decrements to avoid double counting damages. Other potential economic effects associated with inactive hazardous waste sites not evaluated in this analysis include: the loss of ground water option value, habitat loss, and lost recreational opportunities.

2.0 CANCER ECONOMIC EFFECTS

Economic effects due to annual cancer cases associated with inactive hazardous waste sites are based on incidence estimates developed by Blum (1989a) and estimates of the direct and indirect costs of cancer cases estimated by Hartunian, et al. (1981). Incidence estimates developed by Blum are subject to considerable uncertainty and were intended for use only within the Washington 2010 project.

Blum estimated that all inactive hazardous waste sites in Washington are likely to have a cumulative upper bound incidence of between 1 and 10 cancer cases per year. Values at the lower end of the range are considered to be more likely. These bounding estimates were multiplied by the direct and indirect costs of cancer cases.

Direct costs represent the average hospitalization costs and nonhospital costs, such as physician services, private nursing, nursing home and attendant care, drugs, physical therapy, special equipment and prosthetics, and other miscellaneous services. These costs were estimated as $9,704 for the average cancer patient in 1975 dollars. These costs are $29,112 1988 dollars, using the Index of Medical Prices deflator (DOL, 1988).

Indirect costs represent economic effects associated with foregone productivity or earnings as a result of cancer. Hartunian, et al. estimated the average foregone earnings for all cancer sites as being $25,334 per capita. Converting to 1988 dollars using the GNP Implicit Price deflator, foregone productivity equals $55,734 per cancer case. Total damages per cancer case are $84,846.

Best estimate damages associated with annual cancer cases range from a lower bound of $84,846 to an upper bound of $848,846.

2.1 Uncertainties

Hartunian, et al. performed sensitivity analyses over basic analytic assumptions in their analysis and concluded that errors in the direct costs (medical costs) of up to 5 percent are possible if these assumptions are incorrect. They reported that potential errors in the forgone earnings estimates could be as large as 13 percent. Thus, total damage estimates could over or underpredict the "true" damage estimates by as much as 18 percent. Per capita cancer damages could range between $69,573 and $100,118.

Accounting for these uncertainties, damages could range from a lower bound of $69,573 to $1,001,180.

3.0 PROPERTY VALUE DECREMENTS

Health risk beliefs of homeowners near inactive hazardous waste sites may influence property values near those sites. Unfortunately, no studies of property value decrements associated with inactive hazardous waste sites have been conducted in Washington. However, four studies have reported evidence suggesting that proximity to hazardous waste sites can influence residential property values.

Schulze, et al. (1986) and McClelland, et al. (1989) used statistical techniques to evaluate declines in property values of residences surrounding the Operating Industries Inc (OII) Landfill in the Los Angeles metropolitan area. The site received both municipal and hazardous waste. Methane gas had migrated from the site creating health and property risks as well as odor problems. In addition, vinyl chloride was present at the site.

Schulze, et al. related the sales prices of properties surrounding the OII site and properties distant from the landfill to a variety of factors related to property values, for example, size of home, number of rooms, number of bathrooms, etc. Multiple regression analysis was used to estimate the extent to which the sales prices of homes were reduced by virtue of being located near the landfill.

Schulze, et al. reported that the property values of homes located within 1,000 feet of the site were estimated to be reduced by about $10,000. Sales prices of homes beyond this distance did not appear to be influenced by the landfill.

In a reanalysis of the same data, McClelland, et al. reported that housing prices in the vicinity of the landfill were approximately $4,793 lower after the closure of the landfill due to resident's concerns about possible health effects associated with the site. In the 4100 homes near the site, McClelland, et al., estimated the depression in property values to be about $40.2 million before the site was closed and to be about $19.7 million after closure.

In a similar study conducted by Smith and Desvouges (1986) in the Boston area, homeowners were willing to pay $300 to $500 per mile for a location more distant from a hazardous waste landfill. Michaels, et al. (1987) also reported that the mean willingness to pay for an increase of 0.8 miles in distance from CERCLA sites in the Boston area was approximately $69.

While there is little or no data regarding the effect of active hazardous waste sites in Washington on property values, there is considerable data available regarding the effect of the public's risk perception of the Midway Landfill on residential property values. In 1985, methane migrated from the landfill site to a residential neighborhood adjacent to the landfill. Some of the methane rose to the surface of the ground and entered a number of residences in the area. The City of Seattle responded by taking measures to contain the methane in the landfill and initiated the "Good Neighbor Program" to protect the value of residential properties in the vicinity of the landfill. The city also commissioned a study to evaluate the effect of proximity to the landfill on housing prices prior to the mid-1985 methane migration incident.

Haslerig (1985) concluded that between 1977 and 1984, that "areas near the landfill held their residential values at the same levels as the comparable study areas (neighborhoods) which are well out of the landfill's sphere of influence." However, housing values of homes participating in the Good Neighbor Program fell to approximately 84% of comparable fair market prices in 1986 (Robinson, 1989). By 1988, housing values in the affected neighborhood recovered to 100% of comparable fair market prices.

These and other data suggest that simple proximity to the Midway Landfill was not sufficient to depress property values prior to the widespread television, radio, and regional news coverage of the methane migration problem in mid-1985. While property values did diminish significantly, by 16%, in 1986 they appear to have recovered following successful remediation of the offsite methane migration (Anderson, 1989).

Blum (1989b) estimated that 31 inactive hazardous waste sites with a high potential for health damages were cited in urban areas. If we assume that a potential range of damages to property values from these 31 inactive hazardous waste sites ranges from a lower bound of $69 to an upper bound of $4,793 for properties within 1 mile of the site and if we could obtain a distribution of properties within 1 mile of each of the 31 sites, then an estimate of property value damage could be developed.

It was not possible to estimate the number of residences within a 1 mile radius from each of the 31 sites as they were not identified and because of time and resource constraints. However, it was possible to estimate the number of residences within a mile radius of a number of urban municipal landfills. For 6 urban municipal landfills, residences within this radius ranged from 15 to 4509 (see Table 1). The average number of homes within a one mile radius for these six landfills is approximately 945.

If we assume that this distribution can be used to characterize the proximity of residences to inactive hazardous waste sites, property value damages can be derived by multiplying $69 by the estimated average number of homes within a one mile radius times 31 waste sites to obtain a lower bound. Upper bound damages can be calculated by multiplying $4,793 by the average number of homes within one mile by 31 waste sites. Lower bound damages are approximately $2 million while upper bound damages are approximately $140 million.

3.1 Uncertainties

The range of property value damages is highly uncertain for two principal reasons. First, none of the property value damage studies were conducted in Washington. The average property values in the Los Angeles are and in Boston are likely to be higher than in Washington. Consequently, these estimates may overstate the property value damages. Secondly, the range of homes near the urban sites is highly uncertain.

4.0 WILLINGNESS TO PAY FOR INACTIVE HAZARDOUS WASTE SITE CLEAN-UP

Energy and Resource Consultants, now RCG/Hagler, Bailly, Inc., conducted a survey for the State of Colorado Attorney General's Office in 1985 to evaluate attitudes of Colorado residents toward the clean-up of inactive hazardous waste sites in the state. The results of this work provide a rough estimate of Colorado residents willingness to pay for clean-up of inactive hazardous waste sites. If we assume that Washington residents value clean-up of hazardous waste sites in a similar fashion, the Colorado results can be used to indicate the potential magnitude of Washington's residents willingness to pay for inactive hazardous waste site clean-up.

The results of the survey reported that the average annual willingness to pay for site clean-up throughout Colorado was $187, adjusted to 1988 dollars. To estimate the number of households in Washington, we divided the state population of 4,565,000 by 2.65, the average number of persons per household in Washington. The resulting estimate of Washington households is 1,722,641. Total willingness to pay to clean-up sites could be approximately $322.1 million.

The survey used to collect data for this study included human health risks as a reason that respondents might be willing to pay for clean-up. Therefore, damage estimates based on total willingness to pay of respondents include the value of human health damages and non-health related damages. These estimates should not be added to human health or property value damages estimated earlier in order to avoid double counting. This estimate is useful as an indication that Washington residents may be willing to pay substantial amounts to clean-up inactive hazardous waste sites in Washington and should not be interpreted as providing an accurate estimate of economic damages associated with inactive hazardous waste sites in Washington.

5.0 GROUND WATER LOSSES

No comprehensive estimates of the costs arising from the contamination of drinking water supplies around inactive hazardous waste sites was available. However, ground water has been contaminated at a number of landfills in Washington, and substantial costs have been incurred in supplying alternative drinking water to affected residences and in restoring contaminated aquifers. The following cases suggest the potential magnitude of the economic costs due to groundwater contamination associated with landfills in Washington and are not necessarily representative of the 800 inactive hazardous waste sites listed in Blum (1989a).

- **Hobart Landfill** Located in King County, the Hobart landfill is sited over a very shallow aquifer, which rises seasonally, resulting in the saturation of refuse in the lower portion of the landfill. The resulting groundwater contamination caused the replacement of 4 wells sited in the aquifer and the construction of an 8 mile water supply pipeline at a cost of approximately $1.8 million. Construction of a slurry wall to prevent leaching from the landfill is estimated to cost $4 million (Kirnan, 1989).

- **Colbert Landfill** Located in Spokane, contamination of 2 aquifers has resulted in 25 homes being removed from individual wells and being provided water by the Whitworth Water District at a cost of $1.5-$2 million. Approximately 10 to 15 other wells are reported to have water quality problems related to the landfill (Blum, 1989)

- **North Side Landfill** Also located in Spokane, groundwater contamination from the North Side Landfill has resulted in the contamination of 15 private wells. Residences served by these wells were provided Spokane water, which required the installation of approximately 2 miles of pipe (Cummings, 1989)

- **City of Tacoma Landfill** As a result of groundwater contamination related to the Tacoma Landfill, 5 wells have been taken out of service. The cost of providing alternative water supplies was approximately $60,000. Construction of a liner to prevent further groundwater contamination is estimated to cost $20 million (Jorgensen, 1989).

6.0 CONCLUSIONS

It has not been possible to present a credible estimate of the total economic damage associated with inactive hazardous waste sites in Washington due to the numerous gaps and uncertainties in the available data. However, it is likely that economic damages associated with these sites are large. Note that the U.S. EPA ranked the economic effects associated with inactive hazardous sites 7th out of 23 environmental threats.

7.0 REFERENCES

Anderson, R. 1989. Personal communication, Seattle Engineering Department, Seattle, WA.

Blum, M. 1989a. Human Health and Ecological Risks Associated with Inactive Hazardous Waste Sites, Washington Environment 2010, Washington State Department of Ecology.

Blum, M. 1989b. Personal communication, Washington Department of Ecology, Olympia, WA.

Cummings, D. 1989. Personal communication, Washington Department of Ecology, Olympia, WA.

Energy and Resource Consultants. 1986. "A Survey of Colorado Residents Attitudes About Cleaning Up Hazardous Waste Site-Problems in Colorado," prepared for the Colorado Attorney General's Office, Denver, CO, April 6.

Hartunian, N. C. Smart, and M. Thompson. 1981. The Incidence and Economic Costs of Motor Vehicle Impairments, A Comparative Analysis of Cancer, Motor Vehicle Injuries, Coronary Heart Disease and Stroke, D.C. Heath and Company.

Haslerig, K. 1985. Market Study, Residential Values Midway Landfill and Vicinities, Draft Report prepared for the Seattle Engineering Department, Seattle, WA, December 12.

Jorgensen, T. 1989. Personal communication, City of Tacoma, Tacoma, WA.

Kirnan, K. 1989. Personal communication, King County Solid Waste Department.

McClelland, G., et al. 1989. "The Effect of Risk Beliefs on Property Values: A Case Study of a Hazardous Waste Site," in press.

Michaels , G., et al. 1987. "Market Segmentation and Valuing Amenities with Hedonic Models: A Case of Hazardous Waste Sites," unpublished.

Robinson, L. 1989. Personal communication, Seattle Engineering Department, Seattle, WA.

Schulze, W., et al. 1986. "A Case Study of a Hazardous Waste Site: Perspectives from Economics and Psychology," report to the Office of Policy, Planning, and Evaluation, U.S. EPA, Cooperative Agreement CR812054-02-1.

Smith, K. and W. Desvouges. 1986. "The Value of Avoiding a LULU: Hazardous Waste Disposal Sites," The Review of Economics and Statistics, May, 293-299.

U.S. EPA. 1987. Unfinished Business: A Comparative Assessment of Environmental Problems, Appendix IV, Welfare Risk Work Group, February.

Table 1

Number of Residences within One, Two, and Three Mile Radii of Six Urban Non-Hazardous Landfills

Land Fill	One Mile Radius	Two Mile Radius	Three Mile Radius
Cashmere	1,000	1,200	1,400
Aberdeen	25	525	575
Tacoma	4,509	17,981	68,000
Rudey	15		
Terrace Heights	100	300-500	500-600
Grandview	25-30	400	1,000

ECONOMIC RISKS ASSOCIATED WITH NON-HAZARDOUS WASTE SITES WASHINGTON 2010

RCG/Hagler, Bailly, Inc.
July 6, 1989

Final Draft

1.0 INTRODUCTION

This paper provides Washington 2010 with estimates of the current economic risks associated with non-hazardous waste sites in Washington. Estimated economic effects are intended to provide quick estimates of the likely magnitude of the potential economic damages associated with non-hazardous waste sites in Washington. The results are not expected to be precise, but to be useful for the overall ranking of environmental problems being addressed in the Washington 2010 project. The scope of this analysis is limited to municipal landfills.

Non-hazardous waste sites have been associated with economic effects through a number of different pathways. This analysis evaluates effects associated with the direct health care costs and foregone earnings associated with annual cancer cases estimated by Knudson (1989); foregone earnings associated with deaths attributable to methane explosions; damage to residential property values near non-hazardous waste sites; and the replacement of contaminated drinking water supplies. Other potential economic effects associated with non-hazardous waste sites not evaluated in this analysis include: non-cancer health effects; the loss of ground water option value, habitat loss, and lost recreational opportunities, and the loss of producer surplus attributable to the loss of commercial fishing.

2.0 CANCER ECONOMIC EFFECTS

Economic effects due to annual cancer cases associated with non-active hazardous waste sites are based on incidence estimates developed by Knudson (1989) and estimates of the direct and indirect costs of cancer cases estimated by Hartunian, et al. (1981). Incidence estimates developed by Knudson are subject to considerable uncertainty. Readers interested in a discussion of the derivation of and uncertainties surrounding these risk estimates should refer to Knudson (1989).

Knudson estimated that all non-hazardous waste sites in Washington are likely to result in 0.01 annual excess cancer cases in the exposed population of 690 individuals. This cancer risk estimate was multiplied by the direct and indirect costs of cancer cases.

Direct costs represent the average hospitalization costs and nonhospital costs, such as physician services, private nursing, nursing home and attendant care, drugs, physical therapy, special equipment and prosthetics, and other miscellaneous services. These costs were estimated as $9,704 for the average cancer patient in 1975 dollars. These costs are $29,112 1988 dollars, using the Index of Medical Prices deflator (DOL, 1988).

Indirect costs represent economic effects associated with foregone productivity or earnings as a result of cancer. Hartunian, et al. estimated the average foregone earnings for all cancer sites as being $25,334 per capita. Converting to 1988 dollars using the GNP Implicit Price deflator, foregone productivity equals $55,734 per cancer case. Total damages per cancer case are $84,846.

Best estimate damages associated with annual cancer cases are $848.

2.1 Uncertainties

Hartunian, et al. performed sensitivity analyses over basic analytic assumptions in their analysis and concluded that errors in the direct costs (medical costs) of up to 5 percent are possible if these assumptions are incorrect. They reported that potential errors in the forgone earnings estimates could be as large as 13 percent. Thus, total damage estimates could over or underpredict the "true" damage estimates by as much as 18 percent. Per capita cancer damages could range between $69,573 and $100,118.

Accounting for these uncertainties, damages could range from a lower bound of $695 to $1,001.

3.0 METHANE CAUSED MORTALITY COSTS

Knudson estimated that methane migration would cause 0.004 sudden deaths per year. Hartunian, et al. (1981) provided estimates of the direct medical costs and foregone earnings associated with motor vehicle accident fatalities. Expressed as 1988 dollars, the sum of these cost is $324,892. If we assume that the costs associated with the medical treatment and foregone earnings loss due to motor vehicle accidents are similar to those for accidental explosions, economic damages can be expressed as the sum of the fatality incidence and the economic costs. The resulting economic damages are approximately $1,300.

4.0 PROPERTY VALUE DECREMENTS

Health risk beliefs of homeowners near non-hazardous waste sites may influence property values near those sites. Unfortunately, no studies of property value decrements associated with non-hazardous waste sites have been conducted in Washington. However, four studies have reported evidence suggesting that proximity to hazardous waste sites can influence residential property values.

Schulze, et al. (1986) and McClelland, et al. (1989) used statistical techniques to evaluate declines in property values of residences surrounding the Operating Industries Inc (OII) Landfill in the Los Angeles metropolitan area. The site received both municipal and hazardous waste. Methane gas had migrated from the site creating health and property risks as well as odor problems. In addition, vinyl chloride was present at the site.

Schulze, et al. related the sales prices of properties surrounding the OII site and properties distant from the landfill to a variety of factors related to property values, for example, size of home, number of rooms, number of bathrooms, etc.. Multiple regression analysis was used to estimate the extent to which the sales prices of homes were reduced by virtue of being located near the landfill.

Schulze, et al. reported that the property values of homes located within 1,000 feet of the site were estimated to be reduced by about $10,000. Sales prices of homes beyond this distance did not appear to be influenced by the landfill.

In a reanalysis of the same data, McClelland, et al. reported that housing prices in the vicinity of the landfill were approximately $4,793 lower after the closure of the landfill due to resident's concerns about possible health effects associated with the site. In the 4100 homes near the site, McClelland, et al., estimated the depression in property values to be about $40.2 million before the site was closed and to be about $19.7 million after closure.

In a similar study conducted by Smith and Desvouges (1986) in the Boston area, homeowners were willing to pay $300 to $500 per mile for a location more distant from a hazardous waste landfill. Michaels, et al. (1987) also reported that the mean willingness to pay for an increase of 0.8 miles in distance from CERCLA sites in the Boston area was approximately $69.

While there is little or no data regarding the effect of active non-hazardous waste sites in Washington on property values, there is considerable data available regarding the effect of the public's risk perception of the Midway Landfill on residential property values. In 1985, methane migrated from the landfill site to a residential neighborhood adjacent to the landfill. Some of the methane rose to the surface of the ground and entered a number of residences in the area. The City of Seattle responded by taking measures to contain the methane in the landfill and initiated the "Good Neighbor Program" to protect the value of residential properties in the vicinity of the landfill. The city also commissioned a study to evaluate the effect of proximity to the landfill on housing prices prior to the mid-1985 methane migration incident.

Haslerig (1985) concluded that between 1977 and 1984, that "areas near the landfill held their residential values at the same levels as the comparable study areas (neighborhoods) which are well out of the landfill's sphere of influence." However, housing values of homes participating in the Good Neighbor Program fell to approximately 84% of comparable fair market prices in 1986 (Robinson, 1989). By 1988, housing values in the affected neighborhood recovered to 100% of comparable fair market prices.

These and other data suggest that simple proximity to the Midway Landfill was not sufficient to depress property values prior to the widespread television, radio, and regional news coverage of the methane migration problem in mid-1985. While property values did diminish significantly, by 16%, in 1986 they appear to have recovered following successful remediation of the offsite methane migration (Anderson, 1989).

Knudson (1989) estimated that 10 non-hazardous waste sites are sited in urban areas. If we assume that a potential range of damages to property values from these non-hazardous waste sites ranges from a lower bound of $69 to an upper bound of $4,793 for properties within 1 mile of the site and if we could obtain a distribution of properties within 1 mile of each of the sites, then an estimate of property value damage could be developed.

For six urban municipal landfills, residences within this radius ranged from 15 to 4,509 (see Table 1). The average number of homes within a one mile radius for these six landfills is approximately 945. If we assume that this distribution can be used to characterize the proximity of residences to non-hazardous waste sites, property value damages can be derived by multiplying $69 by the estimated average number of homes within a one mile radius times ten non-hazardous waste sites to obtain a lower bound. Upper bound damages can be calculated by multiplying $4,793 by the average number of homes within one mile by ten non-hazardous urban waste sites. Lower bound damages are approximately $650,000 while upper bound damages are approximately $42.6 million.

4.1 Uncertainties

The range of property value damages is highly uncertain for two principal reasons. First, none of the property value damage studies were conducted in Washington. The average property values in the Los Angeles are and in Boston are likely to be higher than in Washington. Consequently, these estimates may overstate the property value damages. Secondly, the range of homes near the urban sites is highly uncertain. Lastly, there may be property value damage associated with rural non-hazardous waste sites not considered here.

5.0 GROUND WATER LOSSES

No comprehensive estimates of the costs arising from the contamination of drinking water supplies around non-hazardous waste sites was available. However, ground water has been contaminated at a number of landfills in Washington, and substantial costs have been incurred in supplying alternative drinking water to affected residences and in restoring contaminated aquifers. The following cases suggest the potential magnitude of the economic costs due to groundwater contamination associated with landfills in Washington and are not necessarily representative of the non-hazardous waste sites in Washington.

- **Hobart Landfill** Located in King County, the Hobart landfill is sited over a very shallow aquifer, which rises seasonally, resulting in the saturation of refuse in the lower portion of the landfill. The resulting groundwater contamination caused the replacement of 4 wells sited in the aquifer and the construction of an 8 mile water supply pipeline at a cost of approximately $1.8 million. Construction of a slurry wall to prevent leaching from the landfill is estimated to cost $4 million (Kirnan, 1989).

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- **North Side Landfill** Also located in Spokane, groundwater contamination from the North Side Landfill has resulted in the contamination of 15 private wells. Residences served by these wells were provided Spokane water, which required the installation of approximately 2 miles of pipe (Cummings, 1989)

- **City of Tacoma Landfill** As a result of groundwater contamination related to the Tacoma Landfill, 5 wells have been taken out of service. The cost of providing alternative water supplies was approximately $60,000. Construction of a liner to prevent further groundwater contamination is estimated to cost $20 million (Jorgensen, 1989).

6.0 REFERENCES

Anderson, R. 1989. Personal communication, Seattle Engineering Department, Seattle, WA.

Blum, M. 1989. Personal communication, Washington Department of Ecology, Olympia, WA.

Cummings, D. 1989. Personal communication, Washington Department of Ecology, Olympia, WA.

Hartunian, N. C. Smart, and M. Thompson. 1981. The Incidence and Economic Costs of Motor Vehicle Impairments, A Comparative Analysis of Cancer, Motor Vehicle Injuries, Coronary Heart Disease and Stroke, D.C. Heath and Company.

Haslerig, K. 1985. Market Study, Residential Values Midway Landfill and Vicinities, Draft Report prepared for the Seattle Engineering Department, Seattle, WA, December 12.

Jorgensen, T. 1989. Personal communication, City of Tacoma, Tacoma, WA.

Kirnan, K. 1989. Personal communication, King County Solid Waste Department.

McClelland, G., et al. 1989. "The Effect of Risk Beliefs on Property Values: A Case Study of a Hazardous Waste Site," in press.

Michaels , G., et al. 1987. "Market Segmentation and Valuing Amenities with Hedonic Models: A Case of Hazardous Waste Sites," unpublished.

Robinson, L. 1989. Personal communication, Seattle Engineering Department, Seattle, WA.

Schulze, W., et al. 1986. "A Case Study of a Hazardous Waste Site: Perspectives from Economics and Psychology," report to the Office of Policy, Planning, and Evaluation, U.S. EPA, Cooperative Agreement CR812054-02-1.

Smith, K. and W. Desvouges. 1986. "The Value of Avoiding a LULU: Hazardous Waste Disposal Sites," The Review of Economics and Statistics, May, 293-299.

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Land Fill	One Mile Radius	Two Mile Radius	Three Mile Radius
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Aberdeen	25	525	575
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ECONOMIC RISKS ASSOCIATED WITH SUDDEN AND ACCIDENTAL RELEASES WASHINGTON 2010

RCG/Hagler, Bailly, Inc.
July 6, 1989

Final Draft

1.0 INTRODUCTION

This paper provides Washington 2010 with estimates of the current economic risks associated with sudden and accidental releases in Washington. Estimated economic effects are intended to provide quick estimates of the likely magnitude of the potential economic damages associated with these releases in Washington. The results are not expected to be precise, but to be useful for the overall ranking of environmental problems being addressed in the Washington 2010 project.

Sudden and accidental releases have been associated with economic effects through a number of different pathways. Neel (1989) reported that accidental releases in Washington result in human health effects and injuries as well as ecological damages. These effects result in economic damages associated with direct medical costs and foregone earnings, evacuation costs, and numerous potential economic damages linked with ecosystem damages. Ecosystem damages resulting from accidental releases range from relatively minor local effects to widespread and severe short term and potentially long term disruptions of ecosystem structure and function. These disruptions lead to economic losses due to the loss of commercially valuable species or habitat, the loss of recreational habitat and opportunity, the loss of option values associated with the future use of the resource, and the loss of preservation and other non-use values associated with severely damaged ecosystems. This paper discusses economic damages associated with injuries, evacuation costs and the replacement or restoration costs associated with accidental releases documented by the Washington State Department of Ecology. It was not possible to estimate quantitative economic damages associated with evacuations due to the lack of cost data for evacuations in Washington.

2.0 ECONOMIC EFFECTS ASSOCIATED WITH INJURIES AND EVACUATIONS

Neel (1989) estimated that there were approximately 3,000 accidental releases in Washington during 1988. Approximately 750 resulted in potentially significant health effects, while 50 resulted in injury. Neel noted that the majority of injuries resulting from accidental releases are minor, such as burns, headaches, and eye irritations. However, serious injuries and deaths have occurred. Approximately 90% of the reported injuries are serious, with the remaining 10% being more serious. According to Neel, there are no data regarding the chronic health effects associated with accidental releases. Neel (1989) did not estimate the number of accidents or health effects resulting from accidental spills in Washington, consequently it was necessary to assume that 90% of the 50 annual injuries result in minor injuries. To quantify the cost of these 45 minor injuries, we referred to the direct health costs and foregone earnings associated with automobile accidents summarized in Table 1. If the costs are similar for minor injuries, we can assume these 45 injuries cost approximately $602 each. Consequently, total costs associated with the minor injuries are approximately $27,000. For the remaining five injuries, if we assumed they are moderately severe (see Table 1), then damages for these accidents will be approximately $39,000. Total costs associated with medical costs of illness are approximately $66,000.

IEC estimated the economic damages associated with evacuations based on the number of accidental release incidents resulting in evacuations in Colorado, an estimate of the number of people evacuated per event, and the costs associated with evacuation of the area surrounding the Three Mile Island Plant in Pennsylvania. The estimated costs of evacuation ranged from $79 to $454 per person per day. Neel did not report the number of accidental release events responsible for evacuations in Washington in 1988. But data referenced by IEC suggest that costs associated with evaluations could be significant for large urban accidental releases.

3.0 ECONOMIC DAMAGES ASSOCIATED WITH ECOLOGICAL DAMAGES

Table 2 summarizes restoration cost data provided by the Washington State Department of Ecology in numerous damage assessments. Economic costs are based on valuations originally made by Crutchfield (1983) and applied to accidental releases by Department of Ecology staff. Damages reported in Table 1 are reported in 1988 dollars.

Estimated damages range from approximately $400 per event to approximately $150,000. These damages, however, probably significantly underestimate economic losses associated with these resource damages, as the resource damage assessments only consider the cost of restoration and not damages to interrupted service flows following the spill and prior to restoration.

Neel estimated that Washington is likely to have "one large-scale oil spill to marine or estuarine waters once every one to three years. Assuming a frequency of one per year and using costs associated with the 1985 Pt. Angeles spill provides an upper bound estimate of approximately $36,500. If the frequency is assumed to be one event every three years, then annual damages become approximately $12,166.

4.0 REFERENCES

Hartunian, N., et al. 1981. The Incidence and Economic Costs of Major Health Impairments, A Comparative Analysis of Cancer, Motor Vehicle Injuries, Coronary Heart Disease and Stroke, Heath and Company, D.C.

IEC. 1989. Welfare Impacts of Accidental Releases of Hazardous Materials in Colorado, prepared for the CE2000 Project, Department of Natural Resources, Denver, CO.

Kittle, L. 1981. Whatcom Creek Freshwater Resource Damage Assessment, January 7-8, 1981, Department of Ecology, April 7.

Kittle, L. 1984. Touchet River Freshwater Resource Damage Assessment, April 14, 1984, Department of Ecology, December 5.

Kittle, L. 1985. Allen Creek Fishkill and Freshwater Resource Damage Assessment, Department of Ecology, May 29.

Kittle, L. 1986a. Des Moines Creek Freshwater Damage Assessment December 2, 18-20 1985, Department of Ecology, May 1.

Kittle, L. 1986b. Rock Creek Fish Kill and Freshwater Resource Damage Assessment, Department of Ecology, July 29, 1986.

Kittle, L. 1986c. Hall Creek Fish Kill and Freshwater Damage Assessment, Department of Ecology, September 10.

Kittle, L. 1987a. Marine Resource Damage Assessment Report for the ARCO Anchorage Oil Spill, December 21, 1985 into Port Angeles Harbor and the Strait of Juan de Fuca, Department of Ecology, January.

Kittle, L. 1987b. Nelson Creek Freshwater Resource Damage Assessment, December 17, 1986, Department of Ecology, February 9.

Kittle, L. and LeVander, L. 1986a. Des Moines Creek Freshwater Damage Assessment April 9, 1986, Department of Ecology, May 16.

Kittle, L. and LeVander, L. 1986b. Anderson Creek Tributary Freshwater Resource Damage Assessment, May 9-10, 1986, Department of Ecology, July 17.

Kittle, L. and LeVander, L. 1986c. Salmon Creek Freshwater Resource Damage Assessment (FRDA) May 26-June 4, 1986, Department of Ecology, July 31.

Kittle, L. and LeVander, L. 1986d. Unnamed Tributary to Quilceda Creek, Freshwater Resource Damage Assessment, March 13, 1986, Department of Ecology, August 21.

LeVander, L. 1987a. Green/Duwamish River Freshwater Resource Damage Assessment (FRDA) September 28-October 2, 1986, Department of Ecology, January 24.

LeVander, L. 1987b. Tributary to Deer Creek Freshwater Resource Damage Assessment, August 27, 1987. Department of Ecology, November 10.

LeVander, L. 1987c. Little North Creek Freshwater Resource Damage Assessment, May 27, 1987, Department of Ecology, September 28.

LeVander, L. 1987d. Church Creek Freshwater Resource Damage Assessment, May 12, 1987 - June 16, 1987, Department of Ecology, October 12.

LeVander, L. and Kittle, L. 1986. Mill Creek Freshwater Resource Damage Assessment (FRDA) Jun 7-10, 1986, Department of Ecology, July 31.

Neel, S. 1989. Human and Ecological Risks Associated with Sudden and Accidental Releases, Washington Environment 2010.

Table 1
Direct Health Costs and Foregone Earnings Associated with Motor Vehicle Accidents

Severity	Direct Medical Costs per Case (1988 dollars)[a]	Foregone Earnings per Case (1988 dollars)[b]	Total
Fatalities	$3,217	$321,675	$324,892
High Severity	18,290	4,847	23,137
Moderate Severity	6,022	1,820	7,842
Low Severity	2,750	525	3,275
Very Low Severity	528	74	602

[a] All estimates are translated from 1975 to 1986 dollars using the Indexes of Medical Prices and from 1986 to 1988 dollars using the Gross National Product Implicit Price Deflator. The source of both indexes is the U.S. Department of Commerce, Statistical Abstracts of the United States, (U.S. Government Printing Office: 1988). The Index of Medical Prices for 1987 and 1988 was not available at the time of this analysis.

[b] All estimates are translated from 1975 to 1988 dollars using the Gross National Product Implicit Price Deflator from the source cited above.

Source: Hartunian, et al. 1981.

Table 2 Estimated Restoration Costs Associated with Accidental Releases

1981

Location	Source	Material	Amount	Environmental Damage	Resource Lost (original $)	$Year	Resource Lost (1988 $)	Reference
Bellingham	Tank	Oil with 5% to 10% pentachloro-phenol	Unknown	44,769 food and game fish killed	$100,809.48	($1981)	$128,733.71	Kittle, 1981
				Restocking costs	$8,996.87	($1981)	$11,489.00	
				Repropagation costs	$6,111.18	($1981)	$7,803.98	
				Total cost	$115,917.53	($1981)	$148,026.69	

1984

Location	Source	Material	Amount	Environmental Damage	Resource Lost (original $)	$Year	Resource Lost (1988 $)	Reference
Dayton	Truck	Aqua-Ammonia	1,700 gal.	214,016 game and forage fish killed	$204,143.36	($1984)	$232,723.43	Kittle, 1984
Columbia R.	Tanker	Oil	200,000 gal.	6,500+ birds killed vegetation oiled	$43,318.89	($1986)	$46,697.76	Nicholas, 1989

1985

Location	Source	Material	Amount	Environmental Damage	Resource Lost (original $)	$Year	Resource Lost (1988 $)	Reference
Marysville	Dairy farm	Manure	Unknown	18162 food and forage fish killed	$42,247.65	($1985)	$46,810.40	Kittle,1985
					$3,290.00	($1985)	$3,645.32	
				Total cost	$45,537.65	($1985)	$50,455.72	
Des Moines	Pipe	Jet Fuel	63,000 gal.	2,458 fish killed	$4,109.48	($1985)	$4,553.30	Kittle, 1986a
Pt. Angeles	Tanker	ANS Oil	239,000 gal.	4,000 waterbirds killed	$12,573.63	($1985)	$13,931.58	Kittle, 1987a
				12,468 lbs of clams killed	$20,356.40	($1985)	$22,554.89	
				Widespread beach contam.				
				High smelt egg kill				
				Total Cost	$32,930.03		$36,486.47	

Table 2 (cont.) Estimated Restoration Costs Associated with Accidental Releases

1986

Location	Source	Material	Amount	Environmental Damage	Resource Lost (original $)	$Year	Resource Lost (1988 $)	Reference
Packwood	Lumber Co.	"Permatox"	Unknown	3,623 fish killed	$18,402.60	($1986)	$19,838.00	Kittle, 1986c
Near Sea-Tac	Fueling Fac.	Jet Fuel	8,000 gal.	7,000 Coho killed	$597.68	($1986)	$644.30	Kittle & LeVander 1986a
Anderson Crk.	Dairy Farm	Dairy waste	Unknown	Coho & Cutthroat killed	$400.00	($1986)	$431.20	Kittle & LeVander 1986b
Salmon Creek	Manhole	Sewage	Unknown	Six fish species killed	$1,200.00	($1986)	$1,293.60	Kittle & LeVander 1986c
Walla Walla	Unknown	High Alkaline	Unknown	Four fish species killed	$800.00	($1986)	$862.40	LeVander & Kittle 1986
Kent	Pipe	Chlorine	Unknown	16,474 fish killed	$2,435.40		$2,625.36	Kittle, 1986b
Tukwila	Unknown	Unknown	Unknown	2,550 Coho and Chinook Eels, trout & whitefish	$70,821.10	($1986)	$76,345.15	LeVander, 1987a
Pt. Angeles	Tanker	Oil & Diesel	Unknown	162 fish killed	$1,400.00	($1986)	$1,509.20	Kittle, 1987b
Quilceda Crk.	Dairy	Dairy Waste	Unknown	Cutthroat killed	$200.00	($1986)	$215.60	Kittle & LeVander 1986d
Renton	Pipe	Diesel Oil	80,000 gal.	GW contam., Evacuation				Nicholas, 1989
Renton	Pipe	Diesel Oil	90,000 gal.	Aquatic life				Nicholas, 1989

1987

Location	Source	Material	Amount	Environmental Damage	Resource Lost (original $)	$Year	Resource Lost (1988 $)	Reference
Stanwood	Well	Chlorine	Unknown	16267 fish killed Eels, sculpin & mussels	$13,220.38	($1987)	$13,749.20	LeVander, 1987d
Little N. Crk.	Residence	Pesticide	Unknown	2,448 fish killed	$1,104.53	($1987)	$1,148.71	LeVander, 1987c
Edmonds	Construction	Cement	Unknown	2,559 salmon killed	$1,321.51	($1987)	$1,374.37	LeVander, 1987b
Spokane	Tank	Gasoline	70,000 gal.	Aquifer damaged				Nicholas, 1989

Table 2 (cont.) Estimated Restoration Costs Associated with Accidental Releases

1988

Location	Source	Material	Amount	Environmental Damage	Resource Lost (original $)	$Year	Resource Lost (1988 $)	Reference
Spokane	Truck	Diesel Oil	2,950 gal.	Fire Hazard & Traffic				Nicholas, 1989
Republic	Truck	Diesel Oil	1,472 gal.	Unknown				Nicholas, 1989
Grays Harbor	Barge	Bunker C	237,000 gal.	Birds, other				Nicholas, 1989
Anacortes	Barge	Cycle gas	100,000 gal.	Unknown, food chain				Nicholas, 1989
Anacortes	Ship	Crude Oil	4,000 gal.	Unknown, threat to Padilla Bay				Nicholas, 1989
Ballard	Truck	Sodium Cyanide	55 gal.	Evacuation				Nicholas, 1989
Kent	Tank Farm	Acetone	900 gal.	Hospitalization				Nicholas, 1989
Grays Harbor	Barge	Crude Oil	235,000 gal.	10,300 birds 3 sea otters	$68,598.00	($1986)	$73,948.64	Nicholas, 1989

ECONOMIC EFFECTS OF DEGRADATION AND LOSS OF WETLANDS WASHINGTON 2010

RCG/Hagler, Bailly, Inc.
July 6, 1989

Final Draft

1.0 INTRODUCTION

This paper provides Washington 2010 with estimates of the current economic risks associated with the degradation and loss of wetlands. Estimated economic effects are intended to provide quick estimates of the likely magnitude of the potential economic damages associated with the degradation and loss of wetlands in Washington. The results are not expected to be precise, but to be useful in the overall ranking of environmental problems being addressed in the Washington 2010 project.

Estimates of wetland loss used in this paper are taken from Canning, et al. (1989). These estimates are recognized to be very uncertain, as "there is presently no accurate, comprehensive inventory of the nature or extent of Washington's wetlands, nor is there enough quantitative information available at this time to adequately document the nature of the threat to Washington's wetlands or the rate of loss or degradation." (p.1) Recognizing these limitations, Canning, et al. provided estimates of yearly wetland loss based on work performed in the US EPA Region 10 Comparative Risk Analysis. Wetland loss was cited as approximately 800 acres per year.

2.0 VALUE OF WETLAND LOSS AND DEGRADATION

Wetlands have economic value because they satisfy human wants or needs. For example, the wildlife supported by wetlands is valuable because it can be hunted or fished, or because it can be studied or admired, or because people believe that it is better to live in a world where there are still wild animals than to live in a world without them. Thibodeau and Ostro (1981) described and in some cases estimated wetland values associated with the following categories for wetlands in the Charles River Basin in Massachusetts: property value, pollution reduction, recreation and aesthetics, preservation and research, and undiscovered benefits. The use of wetland values derived in the Charles River Basin to describe the value of potential annual wetlands losses in Washington is, of course, highly questionable. However, use of Thibodeau and Ostro's results may provide useful information regarding the potential order of magnitude of the values associated with wetland loss in Washington.

2.1 Property Value

Thibodeau and Ostro estimated property values associated with wetlands by considering values derived from flood control and the increased privacy for property abutting wetlands. As Canning, et al. point out, wetlands provide flood storage and desynchronization of storm water release. Thibodeau and Ostro calculated the value of these functions as $2,000 per acre. Converting to 1988 dollars, this equals $3,371.

The second effect of wetlands on land values is the increase in property values in those properties abutting the wetlands open space. Thibodeau and Ostro estimated that property values increased roughly by $150 to $480 per acre of wetland in the Massachusetts study area. Converted to 1988 dollars, from $252 to $809.

2.2 Pollution Reduction Value

Wetlands remove nutrients, sediments, and biological oxygen demand from polluted surface waters. Thibodeau and Ostro estimated the value of this pollution reduction by considering the costs of constructing additional water treatment plants in order to achieve the same level of pollution reduction. For an acre of wetland, the annual cost expressed in 1978 dollars is $1,560. Converted to 1988 dollars, the annual value of one acre of wetland for pollution reduction is approximately $2,629.

2.3 Water Supply Value

Wetlands also provide groundwater recharge and discharge (Canning, et al. 1989). Thibodeau and Ostro estimated the value of the watersupply of wetlands as the difference between the cost of wetland wells and the cost of providing water from the next best source. The estimated difference for the Charles River wetlands was $6,044 per acre per year. Expressed in 1988 dollars, the value of water supply is $10,187.

2.4 Recreation and Aesthetics Value

Wetlands provide numerous recreation, aesthetic, and preservation values. Thibodeau and Ostro estimated these as $3,130 per acre per year. Converted to 1988 dollars, the estimated value of an acre of wetland for recreational purposes is $5,275.

2.5 Unquantified Values

Thibodeau and Ostro qualitatively discussed values associated with the preservation of wetlands for scientific research, with preservation of wetlands solely for the purpose of preserving unique and valued environments and ecological habitats, and with as yet unknown sources of service flows to society. They were unable to derive values for these wetland services. Consequently, their total valuation estimate is likely to underestimate actual damages.

3.0 WETLAND DAMAGES

Estimated damages associated with the loss of Washington Wetlands are presented in Tables 1 and 2.

4.0 REFERENCES

Canning, D., et al. 1989. Wetlands Loss and Degradation: Comparative Risks for Washington State, Washington Department of Ecology, May 19.

Thibodeau, F.R. and B.D. Ostro. 1981. "An Economic Analysis of Wetland Protection," Journal of Environmental Management, 12, 19-30.

Table 1

Annual Economic Damages Associated with the Loss of One Acre of Wetland (1988 $)

Land Value	
Flood Protection	3,371
Property Value	
Lower Bound	252
Upper Bound	809
Pollution Reduction	2,629
Water Supply	10,187
Recreation and Aesthetics	5,275
Total	
Lower Bound	21,714
Upper Bound	22,271

Table 2

Estimated Range of Annual Economic Damages Associated with Predicted Loss of Washington Wetlands

Wetland Loss	Per Acre Damage	Total Damage
800	$21,714	$17,371,200
	$22,271	$17,816,800

ECONOMIC EFFECTS OF NONCHEMICAL IMPACTS ON FOREST LANDS WASHINGTON 2010

RCG/Hagler, Bailly, Inc.
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1.0 INTRODUCTION

This paper provides Washington 2010 with an identification of the economic effects associated with nonchemical impacts on forest lands. There is a wide range in the potential impacts and economic effects of forest lands. In order to estimate economic effects, both impacts and resource values must be quantified. This is a difficult task because of the interrelationships between many of the forest lands uses and impacts and because many forest land resources do not have readily identifiable values. Identification of the types of interrelated uses and resource values is the first step in estimating forest lands economic effects.

2.0 FUNCTIONS, USES AND IMPACTS ON FOREST LANDS

Forest lands serve many functions and uses. Functions of forest lands include: timber production, recreation land, water management, habitat management, and soil conservation. These functions provide a wide range of uses. Forest lands reduce the potential for flooding and increase ground water recharge by slowing runoff. They also reduce the potential for pollution of ground and surface water. Forest lands provide wildlife and plant habitat and help to maintain species diversity. Forest lands can reduce soil erosion by maintaining ground cover and provide fish habitat. Forest lands also provide a buffer for air quality impacts by fixing CO_2 (see Global Warming). Several of the uses of forest land are compatible with each other, and some uses are competing. Forest lands used for timber production provide lumber for harvesting and land for some types of recreation. Forest lands are also used for recreation activities such as hiking, camping, fishing, hunting, and other activities.

The risk assessment report identified several types of nonchemical stresses or impacts on forest lands. The types of stresses and effects are summarized below. The lists of effects are not comprehensive.

Urbanization - Conversion of forest land to nonforest uses. Effects include: reduction in flora and fauna diversity, increase in the potential for flooding, reduction in ground water recharge, increase in potential for water pollution, increased use of remaining forest resources, reduced timber harvest, reduced capability to fix CO_2, and reduced recreation land.

Harvesting Old Growth - Effects include: reduction in the amount of old growth forest, reduction in species diversity, loss of ecosystem structure and function, change in recreation land, temporary increase in erosion, reduction in water supply and quality benefits.

Road Construction - Development and maintenance of forest roads. Effects include: reduction in available forest land, increased soil erosion, increased water runoff and potential for pollution, change in nature of recreation land, and habitat disturbance.

Timber Harvest - Effects include: increased soil erosion and compaction, reduction in species diversity, temporary reduction in flora and fauna habitat, increase/decrease in structural diversity, reduction in water supply and quality benefits.

Reforestation - Artificial forest regeneration practices. Effects include: reduction in genetic diversity, reduction in species diversity, increased soil erosion (site preparation), development of new habitat.

To estimate the economic effects, the forest lands resource impacts must be quantified. Because of the multiple uses of forest lands, the combined impacts of forest land benefits and losses must be considered.

3.0 ECONOMIC EFFECTS

The economic values of forest land resources are measured in different ways. The value of timber harvested can be estimated from its market price. Species diversity, wildlife habitat, water pollution control and other forest lands resources are valued but do not have established market prices. Estimates for some of these non-market resources have been developed, but there is often a wide range in estimates for similar resources. Because of the different type of resource value measurement (market and non-market) and the wide range in non-market value estimates, it is difficult if not impossible to obtain agreement on how forest lands economic effects should be measured and compared.

ECONOMIC EFFECTS OF NONCHEMICAL IMPACTS ON RECREATION LANDS WASHINGTON 2010

RCG/Hagler, Bailly, Inc.
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1.0 INTRODUCTION

This paper provides Washington 2010 with an identification of the types of economic effects associated with non-chemical impacts on recreation lands. Economic effects arise from changes in the use (and the potential for use) and associated values of recreation lands. In order to estimate economic impacts on recreational land, information must be developed on the current recreational land resources, types and levels of use, economic value of uses and impact related changes in use and values. In this paper, types of use, impact effects, and economic values are identified but not quantified because of the wide ranges in types of recreation lands, potential impacts, changes in associated activities and activity values, and because of the lack of sufficient data to quantify these impacts. The information provided can, however, be used to help assess the type and magnitude of specific recreation land impacts.

2.0 RECREATION LAND AND TYPES OF USES

Recreation lands are important to our society in many ways. These lands are used for many purposes including: a wide range of recreational activities (hiking, camping, boating, golfing, picnics, etc.), for aesthetic and habitat purposes (unique resource, vegetation and wildlife preservation), and economic enterprises (timber production, grazing, water storage, etc.). Recreation use may be complimentary or competitive with other uses. For example, timber land provides forest and wildlife habitat desired for many types of outdoor recreation and water storage projects provide boating and fishing opportunities. Another example of recreation land use compatibility is low impact wilderness recreation with endangered species preservation.

One of the first steps in estimating economic effects of recreation land impacts is to estimate changes in the type of recreation activities and level of recreation use attributed to the impact. This is difficult because recreation lands are used for many types of recreation that depend primarily on the specific environmental amenities and location of the land. Because of the diversity of recreation land, aggregating recreation land by resource and type of use can aid in estimating large scale impacts. The Ecological Risk Assessment Report did this by categorizing recreation land into four general land groups by type of land resource (level of development), types of recreational opportunities, and managing organizations (local, state, federal). Recreation lands were identified as:

Urban/Rural Areas - Typically provide developed recreation opportunities (ballfields, picnic grounds, city parks, boat launches, etc.) and are managed by local agencies.

Roaded Areas - Natural and modified areas (dams, clear cuts, etc.) that have moderate evidence of human use and are generally accessible by passenger cars. Recreation activities include: hiking, car camping, fishing, boating, etc. These are usually managed by state or federal agencies and used for fishing, hiking, sight-seeing, etc.

Semi-Primitive Areas - Motorized and non-motorized access. Evidence of human use (campfires, signs, etc.) but low interaction between users (not congested). These areas are typically called backcountry areas and may also be used by off-road vehicles. Activities include: hiking, camping, fishing, wildlife observation, hunting, off-road travel). Management primarily by the U.S. Forest Service. Areas generally for recreation uses, but may be redesignated for other multi-objective uses (timber harvest, grazing, extraction).

Primitive Areas - Essentially unmodified natural areas with low user interaction and where motorized vehicles are prohibited. These are Wilderness areas and are used for backpacking, hiking, scenic and wildlife preservation, etc. These are managed by federal agencies (U.S. Forest Service and U.S. DOI, Bureau of Land Management).

Recreation land uses are not exclusive. Activities such as hiking or camping, may occur in more than one recreation land group. Differences in similar activities between groups may be attributed to differences in the quality of the resource and recreation experience. For example, hiking in primitive areas is considered by some to be a different experience than hiking in semi-private areas near off-road vehicles. Differences in recreational land quality and accessibility are reflected both in the level of use and in the value of use (discussed in the next section).

To estimate economic effects, the change in recreation land use, usually expressed in recreation visitor days (RVD), must be estimated. The U.S. Forest Service and other government agencies estimate RVDs on a regional basis for various types of recreation activities.

It is important to note that recreation land use impacts may be off-setting. For example, providing a road for access into an area may reduce the number of people using that area for backcountry hiking, but may increase the number of people using that area for camping and hunting. All of the changes in use, positive and negative, need to be estimated.

Once the recreation land resource impacts and changes in use have been identified, these changes need to be multiplied by the economic values to estimate the recreation economic impact.

3.0 RECREATION ECONOMIC VALUES

There are two types of economic benefit values used to measure resource impacts. They are called, "use" and "non-use" values. Use value is the amount that people are willing to pay to actually use a resource (participate in the recreation activity), over and above the cost (fees, etc.) of using that resource. That is, the net benefit that they receive from being able to use that resource, in this case recreation land. Non-use value is the amount people are willing to pay, over and above their cost, to preserve recreation land for the future. Non-use includes societies value of land conservation, habitat preservation, protection of endangered species, in short, the value knowing that recreation land is being maintained (existence value) and that one has the option to use that land in the future. Usually, only use values are used in estimating economic impacts, in part, because of the difficulty in obtaining non-use values. However, studies have indicated that non-use values equal or exceed use values.

Below is a sample of average benefit use values from studies for the western United States (Walsh et al., 1988).

Use Activity	Benefit Value per Activity Day (1987 dollars)
Camping	17.23
Picnicking	18.26
Sightseeing & Off-road Driving	20.75
Boating (motorized)	22.12
Big Game Hunting	46.71
Cold Water Fishing (trout)	31.47
Wildlife Observation	23.80

The figures shown are per activity day. When multiplied by the total number of users per day per year, it is evident that recreation land has significant use value. Use values vary with the quality of environmental amenities and substitute sites available. They are higher with better quality recreation land resources and few substitute sites and lower as land quality declines or if more substitute sites are available.

The economic effects of recreation land impacts are equal to the sum of the changes in use times the values for those activities plus the sum of changes in the resource times the non-use values for those changes.

4.0 EXAMPLES OF RECREATION LAND IMPACTS

The most common threats to the ecosystems of the four recreation land groups described above were identified in the Ecological Risk Assessment Report. Congestion (concentrated use), resource extraction (timber harvesting and mining), urbanization/development and road building were identified as having the potential to cause ecological losses or degrade the resources of each of the four recreational land groups. The effect on recreation land would vary with the amount of impact and type of recreation land. Resource extraction or development in urban/rural areas are projected to have minimal impact, whereas the same actions in semi-primitive areas are projected to cause destruction of habitat and loss of land use. Primitive areas, for the most part, are protected from direct impacts, although impacts on adjacent lands could contribute to degradation. Congestion, contributing to over use, is a problem on primitive and other types of recreation lands. In fact, congestion was identified as posing the most serious threat to recreation lands.

One of the difficulties in calculating changes in economic welfare are the tradeoffs in recreation use and value effects. For example, Greenlake is one of the most popular and intensively used parks in the City of Seattle. A three-mile path around the lake is so popular that a public debate has arisen over conflicting uses - some users want to ban bikes and skate boards from the path. The economic effect of banning some uses is two fold. Although there would be fewer users, a reduction in welfare, the other users would have an increase in the value of their recreation, with an offsetting increase in welfare.

In summary, because of the wide ranges in types of recreation lands, potential impacts, changes in associated activities and activity values, and because of the lack of sufficient data to quantify these impacts it is virtually impossible to estimate recreation land economic effects. The information required to develop estimates includes, identification and quantification of land impacts, the current use and change in use of recreation land associated with those impacts, and recreation land use and non-use values.

5.0 REFERENCES

Walsh, Richard G. 1986. Recreation Economic Decisions: Comparing Benefits and Costs, Venture Publishing, Inc., State College, Pennsylvania.

Walsh, Richard G. Donn M. Johnson, and John McKean. 1988. Review of Outdoor Recreation Economic Demand Studies With Nonmarket Benefit Estimates, 1968-1988, Colorado Water Resources Research Institute, Technical Report 54, Colorado State University.

1989. Ecological Risks Associated With Nonchemical Impacts on Recreation Lands, Washington Environment 2010, Draft Report, June.

WELFARE EFFECTS OF NONCHEMICAL IMPACTS ON RANGELANDS WASHINGTON 2010

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Final Draft

1.0 INTRODUCTION

This paper provides Washington 2010 with estimates of the current welfare risks associated with non-chemical impacts on rangelands. Estimated welfare effects are intended to provide quick estimates of the likely magnitude of the potential economic damages associated with nonchemical impacts on Washington rangelands. The results are not expected to be precise, but to be useful in the overall ranking of environmental problems being addressed in the Washington 2010 project.

Nonchemical degradation of rangeland in Washington can be associated with welfare damages resulting from the lost rangeland productivity, the loss of recreation opportunity and aesthetic values, habitat loss, and diminished water quality (Froeming, 1989). This analysis only develops quantitative damage estimates associated with lost rangeland productivity. However, the potential economic damages associated with the remaining damage categories may be substantial. For example, by improving range condition, improved habitat could be provided for both game and non-game wildlife. This increased habitat could result in additional ranch income due to more lease hunting and non-market recreational benefits resulting from increased recreation participation and improving the quality of the recreational experience. Improved habitat may also be related to preservation and other non-market values associated with the protection of rare or endangered species.

2.0 RANGELAND PRODUCTIVITY DAMAGE ESTIMATES

To estimate welfare damages associated with degraded range condition, the analysis used data developed by the Washington State Grazingland Assessment cited by Trefry (1989) and data provided by Froeming (1989). As noted in the Washington State Grazingland Assessment, range condition has a direct bearing on the income of the livestock industry (Harris and Chaney 1984). Harris and Chaney estimated that Washington range production is approximately 33 percent of its potential.

To estimate the effect of this degraded land condition on the livestock industry, we relied on data describing the ecologic/range condition of rangeland in Washington contained in Trefry (1989). This data is summarized in column 2 of Table 1.

The Washington State Range Conservationist (Froeming, 1989) estimated the number of acres necessary to support an Animal unit month (AUM) on rangeland in different ecologic conditions as:

Ecologic Condition	Acres/AUM
Seeding	2
Climax (excellent)	5
Late Seral (good)	8
Middle Seral (fair)	12
Early Seral (poor)	15

An animal unit month is defined as the amount of forage required by one mature cow with calf, or equivalent, for one month. Consequently rangeland in better condition requires less area per AUM.

Froeming (1989) indicated that it would be possible to manage rangeland in a late seral condition while supporting livestock grazing. Consequently, the total area of damaged rangeland is equal to the sum of the middle and early seral acreage, shown in Table 1. To estimate the number of AUMs in the middle and early seral categories, total acreage in each of these categories was divided by the estimate of the acres/AUM provided by Froeming.

To estimate the damage, expressed as diminished AUMs, the total number of AUMs potentially supported on rangeland currently classified as middle and early seral was estimated by first dividing the acres/AUM coefficient for the late seral stage by 8. This provides an estimate of the undamaged range capacity. The difference between the number of AUMs supported by the damaged rangeland assuming a late seral acre/AUM coefficient and middle and early seral coefficients is equal to the rangeland damage expressed as AUMs, see Table 1 for a summary of this data by owner.

Froeming estimated the value of an AUM as being approximately $8.00. Economic damage estimates were developed by multiplying this value by the lost AUMs associated with damaged rangeland, see Table 1. Economic damages expressed in this fashion represent the lost value of forage on the rangeland. For example, $8.00 is the annual cost of renting rangeland to support one AUM.

Damages expressed as the lost value of beef can be developed by assuming that each AUM produces 50 pounds of beef and that beef is worth approximately $0.75 per pound to the rancher at sale (Froeming, 1989), see Table 1.

Summarized, damages expressed as lost AUMs are worth approximately $0.50 per acre, while expressed as lost beef production approximately $2.00. These expressed damages are quite similar to lost beef production damage calculations previously performed by Froeming, where he estimated that improving range condition would increase the return on beef production between $1.50 and $2.50 for the rancher.

3.0 REFERENCES

Froeming, D. 1989. Personal communication, State Range Conservationist, Soil Conservation Service, Spokane, WA.

Harris, G. and M. Chaney. 1984. Washington State Grazing Land Assessment, prepared with the Washington Rangeland Committee and the Washington Conservation Commission.

Trefry, S. 1989. Nonchemical Degradation of Range Land, Washington Environment 2010, Washington State Department of Agriculture, May.

Table 1 Economic Damages Associated with Decreased Range Productivity

Owner	Acres	Ecological Condition	Acre/AUM	Total AUM	Total AUMs Assuming Late Seral [1]	Lost AUMs [2]	Value of Lost AUMs [3]	Lost Beef (pounds) [4]	Value of Lost Beef [5]
BLM	7,493	Climax	5	1,499					
	35,376	Late Seral	8	4,422					
	40,725	Middle Seral	12	3,394	5,091	1,697	$13,575	84,844	$63,633
	59,556	Early Seral	15	3,970	7,445	3,474	$27,793	173,705	$130,279
Total	143,150			13,285		5,171	$41,368	258,549	$193,912
USFS	87,980	Climax	5	17,596					
	158,840	Late Seral	8	19,855					
	418,280	Middle Seral	12	34,857	52,285	17,428	$139,427	871,417	$653,563
	430,280	Early Seral	15	28,685	53,785	25,100	$200,797	1,254,983	$941,238
Total	1,095,380			100,993		42,528	$340,224	2,126,400	$1,594,800
State &	620,070	Climax	5	124,014					
Private	1,183,770	Late Seral	8	147,971					
	1,803,840	Middle Seral	12	150,320	225,480	75,160	$601,280	3,758,000	$2,818,500
	1,916,580	Early Seral	15	127,772	239,573	111,801	$894,404	5,590,025	$4,192,519
Total	5,524,260			550,077		186,961	$1,495,684	9,348,025	$7,011,019
TOTAL	6,762,790			664,355		234,659	$1,877,276	11,732,974	$8,799,730

[1] Total AUMs for Middle and Early Seral calculated using Late Seral acres/AUM.

[2] Lost AUMs = (Total AUMs Assuming Late Seral)-(Total AUMs).

[3] Value of Lost AUMs = $8 per Lost AUM.

[4] Assumes each AUM produces 50 pounds of beef.

[5] Value of beef to farmer at market time is $0.75 per pound.

ECONOMIC EFFECTS OF NONCHEMICAL IMPACTS ON AGRICULTURAL LANDS WASHINGTON 2010

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1.0 INTRODUCTION

This paper provides Washington 2010 with estimates of the current economic risks associated with nonchemical impacts on agricultural lands. Estimated economic effects are intended to provide quick estimates of the likely magnitude of the potential economic damages associated with nonchemical impacts on agricultural lands in Washington. The results are not expected to be precise, but to be useful in the overall ranking of environmental problems being addressed in the Washington 2010 project.

Nonchemical degradation of agricultural lands is defined by Trefry (1989) "as physical modifications of croplands, dairy farm lands and poultry farm lands that result in reduction of agricultural land and wind and waterborne erosion." Economic damages can be expected to occur from both the on and offsite effects of soil erosion and from the conversion of agricultural land to other, principally, urban uses. This analysis focuses on the estimation of both on and off site economic damages associated with soil erosion in Washington. It was not possible to estimate the economic losses associated with the conversion of agricultural land to other uses.

Damage estimates related to rill and sheet erosion are based on 1982 National Resource Inventory data and estimates of U.S. and regional on and offsite economic damages (Colacicco, et al., 1989 and Ribaudo, 1986; 1989). Wind erosion damage estimates are based on Piper (1989).

2.0 ONSITE DAMAGES

Onsite damages caused by soil erosion are the value of reduced yields and increased costs of inputs, such as fertilizers that result from soil losses due to wind and sheet and rill erosion processes. Yields may be reduced due to reductions in water-holding capacity, infiltration rates, nutrient availability, organic matter, and other beneficial topsoil characteristics.

Colacicco, et al. and Alt, et al. (1989) used the Erosion Productivity Impact Calculator and erosion rates from the 1982 NRI data to estimate regional and national damages from soil erosion over the next 100 years. They assumed that future yield losses would occur only on land losing soil at a rate greater than the soils tolerance rate (T-value). Economic damages were developed by quantifying the value of yield and fertilizer losses from soil erosion by simulating price changes in crops and fertilizers and discounting to present (1982) values. This procedure estimated an average value of the onsite loss per ton of cropland and pastureland as being $0.30 in the Pacific Farm Production Region. Specific estimates were not developed for Washington. The Pacific Region includes: California, Oregon, and Washington.

By assuming that the $0.30/ton value is adequate for Washington, estimates of onsite damage can be developed by multiplying this value by the total cropland and pasture erosion noted in the 1982 NRI tables:

(53,663,400 [crop] + 374,900 [pasture])(0.30) = $16,211,490

Converting to 1988 dollars, the estimated present value of onsite erosion in Washington is $19,729,383.

3.0 OFFSITE DAMAGES

3.1 Offsite Sheet and Rill Erosion Damages

Soil erosion from farmland and other lands increases sediment, nutrient, and pesticide loadings in surface waters. Sediments, nutrients, and pesticides cause sedimentation problems in reservoirs, affect aquatic plant and animal life, affect the quality of wetland and riparian habitats, reduce recreation opportunities, and may be related to human health effects.

Ribaudo (1986) estimated the offsite damages due to water caused erosion for each of the Farm Production Regions and the U.S. His estimates do not include damages caused by wind erosion. Based on his calculations, erosion causes $ 2.02 (1983 dollars) of damages per ton of soil loss in the Pacific Region.

Total Washington sheet and rill erosion from all sources was estimated in the 1982 NRI as 53,810,600 tons per year. To calculate economic damages:

$2.36(1988 $) * 53,810,600 = $126,993,016.

Note that Ribaudou's estimate of damages per acre has been converted to 1988 dollars using the GNP implicit price deflator. This damage estimate includes estimated damages to recreational fishing, water storage facilities, flood damage, drainage ditches and irrigation canals, water treatment facilities, municipal and industrial water uses, electric power plants, and irrigated agriculture.

3.2 Offsite Wind Erosion Damages

Low average rainfall, frequent drought, and relatively high wind velocities characterize much of eastern Washington's landscape. These conditions, combined with fine soils and sparse vegetation, make some Washington lands susceptible to wind erosion problems. The Soil Conservation Service estimated that average annual soil erosion on nonfederal land in Washington due to wind was about 18,201,500 tons (SCS, 1985).

Wind erosion creates two types of economic damages: onsite and offsite. Onsite costs are imposed on all farmers and ranchers who own or lease the land exposed to wind erosion. These damages are primarily productivity impacts. Other onsite costs include emergency tillage operations to reduce blowing soil, damage to growing crops, and damage to farm equipment. Offsite damages are particulate-related damages imposed on those who live or work downwind from blowing soil. These damages include increased cleaning and maintenance for businesses and households, damages to nonfarm machinery, and adverse health impacts. According to Piper (1989) onsite damages of wind erosion are only 2.1% to 3.5% of the off site household sector damages in New Mexico. Other data reviewed in Piper (1989) suggest that onsite crop productivity losses in the Western United States are small compared to offsite damages, perhaps less than 5% of the estimated offsite wind erosion damages.

Piper (1989) estimated off-site household damages from all sources of wind erosion in New Mexico. He found that total offsite damages were estimated to be $465.8 million annually, averaging $980 per household per year in 1984 dollars. Converting the household damage estimate to 1988 dollars using the GNP implicit price inflator yields a household damage estimate of $1,107. To estimate per capita Washington damages:

$1107/2.66 people per house hold, or
per capita damages are approximately $425.

Total estimated annual Washington damages due to wind erosion equal $425 x the population of counties identified by the Soil Conservation Service as having significant wind erosion problems. Those counties and their populations are identified in Table 1. Wind erosion damages equal $425 x 304,900; or approximately $129.5 million.

This estimate does not include cost of illness measures for emphysema cases or other health effects potentially attributable to wind erosion. In addition, it does not include damage to non-residential structures or sectors of the economy.

3.3 Uncertainty

This estimate was based on one survey of New Mexico residents to determine the incremental costs of cleaning residential property associated with wind erosion. No other studies of offsite damages associated with wind erosion were located. Using the per household damage estimate calculated for New Mexico to estimate damages in Washington assumes that:

- Washington and New Mexico experience similar wind erosion; and
- Washington and New Mexico residents are equally impacted (damaged) by wind erosion.

This estimate does not include on-site damages or damages to non-residential sectors of the economy. However, Piper (1989) cites evidence that on-site wind erosion damages are small when compared with off-site damages.

4.0 REFERENCES

Alt, K., C.T. Osborn, D. Colacicco. 1989. "Soil Erosion, What Effect on Agricultural Productivity?" USDA, Economic Research Service, Agricultural Information Bulletin Number 556, Washington, D.C. January.

Colacicco, D., T. Osborn, and K. Alt. 1989. "Economic Damage from Soil Erosion." Journal of Soil and Water Conservation, Jan.-Feb., pp: 35-39.

Piper, S. 1989. "Measuring Particulate Pollution Damage from Wind Erosion in the Western United States." Journal of Soil and Water Conservation, Jan-Feb., pp:70-75.

SCS. 1985. 1982 National Resource Inventory Tables. Soil Conservation Service, USDA, Denver, CO, January.

Trefry, S. 1989. Nonchemical Impacts on Agricultural Land, Washington State Department of Agriculture, May.

Table 1
Washington Counties Identified as Having Significant Wind Erosion Problems[1]

County	Population
Douglas	24,100
Grant	52,600
Klickitat	16,600
Benton	104,100
Franklin	35,500
Walla Walla	48,300
Adams	14,000
Lincoln	9,700
Total	304,900

[1] Source: Hans Klaus. 1989. Personal communication, Soil Conservation Service, Spokane, Washington.

Summary Table 2
Final Draft Summary of Economic Damages Associated with Environmental Threats
Analyzed in Washington 2010

Stress	Source of Welfare Damage	Damage Estimate	Scope of Estimate [1]	Uncertainty [2]	Trend [3]	Reversibility [4]
Nonchemical Impacts on Agricultural Lands			3	M	I	2
	Onsite Damage, all erosion	$19,729,383				
	Offsite Damage, sheet and rill erosion	$126,993,016				
	Offsite Damage, wind erosion	$129,500,000				
	Total	$276,222,399				
Not Quantified						
	Conversion					
Point and Nonpoint Source Discharge			2	H	I	2-3
	Cancer Cases	$210,933				
	Erosion Damage	$126,993,016				
	Puget Sound Recreation Loss	$73,000,000				
	Lost Surface Water Recreation	$142,889,397				
	Total *	$270,093,346				
Not Quantified						
	Commercial Fish and Shellfishing Damages					
	Property Value Damage					
	Incremental Cost of Drinking Water Treatment					
	Health Effects					
	Ground Water Contamination					
	Non-Use Values					
Hydrologic Modifications			3	H	N	3
	Salmon Losses	$117,000,000				
	Soil Erosion	$126,993,016				
	Total	$243,993,016				
Not Quantified						
	Loss of Non-Salmon Fisheries					
	Loss of Riparian Habitat					
	Ground Water Effects					
	Non-Use Values					
Ambient Air Pollution			2	H	I	2
	1988					
	TSP, Restricted Activity Days	$34,237,286				
	TSP, Household Soiling Damage	$44,405,046				
	TSP, Manufacturing Sector Damage	$63,910,000				
	O3, Asthma Attacks	$525				
	O3, Respiratory Restricted Activity Days	$9,990				
	O3, Materials Damage	$3,880,250				
	NO2, Materials Damage	$5,478,000				
	Toxic Air Pollutants, Cancer Cases	$1,272,690				
	Total	$153,193,787				
Not Quantified						
	CO, Health Effects					
	Visibility Degradation					
	O3, Forest and Crop Damage					

[1] Scope of estimated welfare damages relative to potential damages. 3 provides broad coverage of welfare damages relative to potential scope of the problem. 2 provides mid-range of coverage. 1 provides small coverage.
[2] Uncertainty in quantitative damage analysis characterized by H=high, M=median, L=low uncertainty.
[3] Trend in problem causing welfare risks characterized by I=increasing, N=no discernible trend, D=decreasing.
[4] Reversibility of welfare risks charcterized by 1=readily reversible, 2=reversible with more difficulty and expense, 3=very difficult to reverse effects.
* Total does not include Puget Sound damages to avoid double counting.

Final Draft Summary of Economic Damages Associated with Environmental Threats
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Stress	Source of Welfare Damage		Damage Estimate	Scope of Estimate [1]	Uncertainty [2]	Trend [3]	Reversibility [4]
Inactive Hazardous Waste Sites				3	H	D	2
	Cancer Cases	LB	$69,573				
		UB	$1,001,180				
	Property Value Decrement	LB	$2,000,000				
		UB	$140,000,000				
	Total	LB	$2,069,573				
		UB	$141,001,180				
Not Quantified							
	Acute and Chronic Health Effects						
	Ground Water Losses						
Non-Hazardous Waste Sites				2	H	D	2
	Methane Mortality		$1,300				
	Cancer Cases	LB	$695				
		UB	$1,000				
	Property Value Decrement	LB	$650,000				
		UB	$42,600,000				
	Total	LB	$651,995				
		UB	$42,602,300				
Not Quantified							
	Acute and Chronic Health Effects						
	Ground Water Losses						
Indoor Air Pollution				1	M	I	2
	Tobacco Smoke Caused Cancer Cases	LB	$5,430,144				
		UB	$27,235,566				
	Benzo(a)pyrene Caused Cancer Cases	LB	$339,384				
		UB	$848,460				
	Volatile Organic Compounds	LB	$1,357,536				
		UB	$2,799,918				
	Formaldehyde Caused Cancer Cases	LB	$593,922				
		UB	$5,599,836				
	Asbestos Caused Cancer Cases	LB	$0				
		UB	$1,442,382				
	Total	LB	$7,720,986				
		UB	$37,926,162				
Not Quantified							
	Materials Damage						
	Indoor Cleaning Costs						
	Acute and Chronic Health Effects						
Loss/Degredation of Wetlands				3	H	I	3
	Wetlands Loss	LB	$17,371,200				
		UB	$17,816,000				
Nonchemical Impacts on Rangelands				2	M	I	1
	Lost AUMs		$1,877,276				
	Lost Beef		$8,799,730				
	Total		$10,677,006				
Not Quantified							
	Recreation Damages						
	Non-Use Values						

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Stress	Source of Welfare Damage		Damage Estimate	Scope of Estimate [1]	Uncertainty [2]	Trend [3]	Reversibility [4]
Indoor Radon				2	L	N	1
	1988 Cancer Cases	LB	$5,426,694				
		UB	$44,152,038				
Not Quantified							
	Testing and Mitigation Cost						
Accidental Releases				2	M	N	1
	Medical Costs of Injury		$66,000				
	Significant Oil Spill		$12,166				
	Total		$78,166				
Not Quantified							
	Mortality Damages						
	Evacuation Costs						
	Non-Use Values						
Radioactive Releases							
	Cancer Cases		$76,361	2	L	D	1
Not Quantified							
	Risks to Agricultural Export						
	Uranium Mining and Milling Site Mitigation						
Global Warming				3	H	I	3
Not Quantified							
	Agricultural Damages						
	Energy Costs						
	Forestry Damages						
	Property Value Damage						
	Fisheries Damage						
	Human Health Effects						
	Non-Use Values						
Active Hazardous Waste Sites				2	L	N	2
Not Quantified							
	Property Value Damage						
	Ground Water Losses						
	Potential Health Effects						
Nonchemical Impacts on Forest Lands				-	H	I	3
Not Quantified							
	Loss of Income and Producer Surplus						
	Erosion Damages						
	Habitat Loss						
	Recreational Use Values						
	Non-Use Values						
Nonchemical Impacts on Recreation Lands				-	M	I	1
Not Quantified							
	Decrease in Recreation Participation						
	Decrease in Quality of Experience						
	Habitat Loss						
	Non-Use Values						

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