Ecological Risks

Water: Environmental Threats Related to Point and Nonpoint Source Discharges To Water.

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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 are 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.

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.

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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 ɔle 1. Contaminants assessed as part of the 2010 human health risk evaluation.

ːTAMINANT	PRIMARY EXPOSURE	HUMAN HEALTH EFFECTS	SEVERITY SCORE*
-	FISH	SUSPECTED CARCINOGEN	
ːLDRIN	FISH	SUSPECTED CARCINOGEN, LIVER ENLARGEMENT NEUROTOXIC EFFECTS	
HA-BHC	FISH & SHELLFISH	SUSPECTED CARCINOGEN	
ː	FISH & SHELLFISH	SUSPECTED CARCINOGEN, CHLOROACNE LIVER DYSFUNCTION, NEUROPATHIC DISORDERS SUSPECTED FETOTOXIC	
)XIN	FISH	SUSPECTED CARCINOGEN	
ːCINOGENIC PAH	SHELLFISH	SUSPECTED CARCINOGEN	
ːENIC	FISH & SHELLFISH	SKIN CANCER, NEUROTOXIC	
'OSULFAN	FISH	NEUROTOXIC	6
ɔRIN	FISH	SUSPECTED TERATOGEN, NEUROTOXIC SUSPECTED FETOTOXIN	7, 6 6
ːMIUM	FISH & SHELLFISH	KIDNEY DAMAGE, POTENTIAL FETOTOXIC	3, 6
ːD	FISH & SHELLFISH	HEMOTOXIC, NEUROTOXIC, REPRODUCTIVE DISORDERS HIGH RISK TO CHILDREN AND PREGNANT MOTHERS	4, 6 5, 6
ːCURY (METHYL)	FISH & SHELLFISH	NEUROTOXIC	6, 3
ːLYTIC SHELLFISH POISON	SHELLFISH	NEUROTOXIC	6, 3
ːIO PARAHAEMOLYTICUS	SHELLFISH	GASTROENTERITIS	4

ːEVERITY 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).

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:
>
> $(0.62 * x * 3)+(0.36 * x * 6)+(0.02 * x * 24) = 1.2$ million user trips
>
> so. $x = \sim 300{,}000$ 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,

ble 3. Fishing public in Washington State (Jones & Stokes, 1988)

tal Fishermen (16 yrs & older)	1,122,300
tal Days Fishing	19,565,100
Average per Fisherman	17
ate-Resident Fishermen	982,300
Freshwater	705,300
Saltwater	562,800
pes 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.

ITAMINANT	FISH CONCENTRATION MAXIMUM	FISH CONCENTRATION AVERAGE	SHELLFISH CONCENTRATION MAXIMUM	SHELLFISH CONCENTRATION AVERAGE	FISH CONSUMPTION RISK MAXIMUM	FISH CONSUMPTION RISK AVERAGE	SHELLFISH CONSUMPTION RISK MAXIMUM	SHELLFISH CONSUMPTION RISK 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
3	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
OSULFAN	0.03	0.001	--	--	0.41	0.002	--	--
RIN	0.005		--	--	0.01	--	--	--
MIUM	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.

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