WASHINGTON STATE DEPARTMENT OF ECOLOGY

Washington State Agricultural Chemicals Pilot Study

Final Report

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Washington State Agricultural Chemicals Pilot Study

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WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

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EXECUTIVE SUMMARY

The Washington State Agricultural Chemicals Pilot Study provides reconnaissance information on the presence and concentration of pesticides in Washington's ground water. The study consists of sampling ground water from three areas, each considered vulnerable to ground water contamination from agricultural chemicals. The study areas range in size from 6.5 to 34 square miles and are located in Whatcom, Franklin, and Yakima Counties. Twenty-seven shallow wells in each study area were tested for 46 pesticides.

The findings of the Pilot Study, based on two sampling events from each study area, indicate that pesticide residues have migrated to shallow ground water in these areas. Of the 81 wells sampled, 23 wells showed at least one pesticide during the initial sampling. All occurrences were verified with only three exceptions during the second sampling round. The pesticides detected and the number of detections by study area are listed as follows (verification occurrences are in parentheses):

Study Area	Pesticide	Number of Detections
Whatcom County:	1,2-Dichloropropane	9(9)
	Dibromochloropropane	1(1)
	Ethylene Dibromide	2(1)
	Carbofuran	1(0)
	Prometon	2(2)
Franklin County:	DCPAs (dacthal and/or diacid metabolite)	7(7)
	1,2-Dichloropropane	2(2)
	Bromacil	1(1)
Yakima County	Atrazine	1(0)

The number of pesticide detections is highly variable between study areas. Nearly all detections were observed in the Whatcom and Franklin study areas. A single detection was observed in the Yakima study area during initial sampling, but was not observed during verification sampling.

Drinking water standards, Maximum Contaminant Levels (MCLs), have not been established by EPA for the eight detected pesticides; however, MCLs have been proposed for five of the pesticides. Observed concentrations exceeded proposed MCLs in five wells for 1,2-dichloropropane, one well for ethylene dibromide, and one well for dibromochloropropane. All wells that exceeded proposed MCLs are located in the Whatcom County study area. Lifetime drinking water health advisories have been calculated by EPA for five of the detected pesticides that are not known or suspected carcinogens. None of the observed concentrations exceeded lifetime drinking water health advisories.

Nitrate/nitrite (as nitrogen) was detected in 61 of the 81 wells sampled at concentrations ranging from 0.10 to 24.4 mg/L. The primary MCL of 10 mg/L was exceeded in 18 wells. Eleven of these 18 wells were located in the Franklin County study area and seven were located in the Whatcom County study area.

INTRODUCTION

The use of agricultural chemicals in Washington State is widespread. However, the effects of these chemicals on the state's ground water quality are largely unknown. As of 1986, 17 pesticides had been found in the ground water of **23** states as the result of agricultural uses (Cohen, ***et*** al., 1986). In Washington, ethylene dibromide (EDB), a soil fumigant used to control nematodes, has been found in drinking water wells in Skagit, Thurston, and Whatcom Counties (DSHS, 1985). The 1987 Washington State Legislature funded the Department of Ecology to begin investigating the effects of agricultural chemicals on ground water quality in Washington. The Agricultural Chemicals Pilot Study is an initial step toward defining these effects.

Objectives

Objectives of the Agricultural Chemicals Pilot Study are as follows:

Primary objective:

- To provide information on the presence and concentration of pesticide residues in ground water resulting from normal pesticide usage in selected areas of Washington State.

Secondary objectives:

- To evaluate the effectiveness of potential indicator parameters (nitrate/nitrite, total phosphorous, total organic carbon, total organic halogens, potassium, and dissolved solids) for identifying wells to be tested for pesticides.

- To correlate, where possible, site conditions and pesticide usage with any observed ground water contamination.

METHODS

Study Area Selection Process

To provide a statewide perspective, three agriculturally diverse and geographically separated study areas were chosen. Small study areas (6.5 to 34 square miles) were chosen to allow hydrogeologic characterization and to provide a sufficient density of wells to define ground water quality.

On a statewide basis, general locations for potential study areas were identified using EPA's designation of areas vulnerable to pesticide contamination (U.S. EPA, 1986). Final selection of the study areas was based on review of statewide, regional, and local geologic and hydrogeologic reports, county soil reports, well log reports, as well as information from local health departments, regional Ecology offices, and the Washington State University Cooperative Extension Service. The three study areas selected (shown in Figure 1) are located in Whatcom, Franklin, and Yakima Counties. Characteristics considered for selecting these areas were as follows:

- Presence of irrigated agriculture.
- Variety of crop types.
- Shallow ground water (less than 50 feet).
- Unconfined aquifer with porous media flow.
- Permeable, well-drained surficial soils.
- Available well information and an adequate number of shallow wells for sampling.
- Known occurrence of ground water contamination from agricultural chemicals.

Well Selection Criteria

Twenty-seven wells were selected for sampling in each study area. Criteria used to select wells were as follows:

- Proximity to fields where agriculture chemicals could have been applied.
- Ease of access.
- Availability of well construction information and stratigraphic logs.

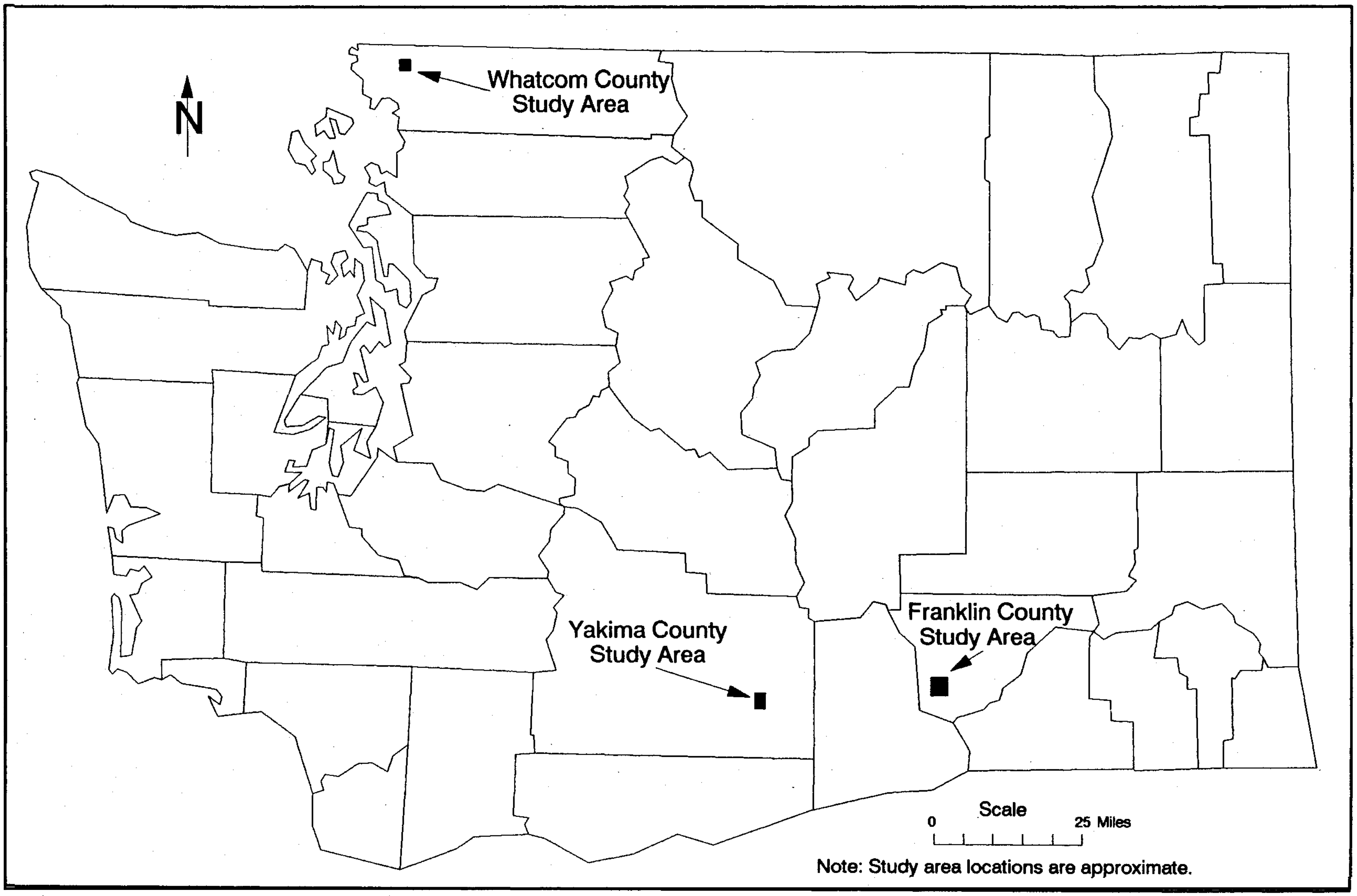


Figure 1: Agricultural Chemicals Pilot Study; Study Area Locations

- Shallow well intake interval: that is, depth interval from which the well draws water.

- Well diameter: smaller well diameters were preferred because of the shorter purging time required prior to sampling.

- Age of well: newer wells were selected because of improved well construction practices in recent years and less time for deterioration of casing and well seal materials.

- Availability of information about previous samples from the well; particularly if data indicated contamination.

- Distribution of well locations: a spatial distribution that fairly represented shallow ground water quality for the study area.

- Position relative to potential point sources: selected wells were remote from potential point sources such as pesticide mixing areas.

Land Use

Land use for each of the study areas was determined by reviewing existing information on crops, agricultural chemical uses, and irrigation practices. Information sources included county WSU Cooperative Extension agents and publications, chemical manufacturing representatives, and aerial photographs. Crop acreage for Whatcom and Yakima County study areas was estimated from aerial photographs using an acreage template. Crop acreage for the Franklin County study area was estimated using Agricultural Stabilization and Conservation Service 1988 lists of certified crops.

Sampling and Analysis

The initial round of sampling was conducted between August and October 1988. Eighty-one wells were sampled of which 67 were domestic wells, two were public water supply wells, seven were irrigation wells, and five were piezometers originally constructed for water-level measurements. Verification sampling was conducted in May 1989 at the **23** wells where pesticides were detected in the first sampling round.

Most samples were obtained using existing installed pumps and piping. Sampling protocols were as follows:

- Water levels were obtained prior to and during purging.

- Wells were pumped until indicator parameters of temperature, specific conductance, and pH stabilized. A minimum of three casing volumes were purged from the well prior to sampling.

- Samples were obtained as close to the wellhead as possible before the water entered pressure tanks or was treated.

- All samples were stored on ice (4°C) prior to delivery to the appropriate laboratory. Pesticide samples were received by the laboratory within 72 hours of collection.

- Five U.S. Bureau of Reclamation piezometers in the Franklin study were purged and sampled using teflon bailers. All bailers were precleaned with sequential washes of hot tap water/LiquiNox detergent, deionized water, 10% nitric acid, methylene chloride, and acetone, then allowed to air dry and wrapped in aluminum foil until used.

Table 1 lists the 46 pesticides targeted for analysis. Most of these pesticides were derived from EPA's list of leachable pesticides which have properties conducive to migration through soil to ground water (Cohen, 1985). Originally, 36 leachable pesticides (which are now or have been registered for use in Washington State) were targeted for analysis (U.S. EPA, 1986). Three of these--butylate, disulfoton, and maleichydrazide--could not be detected reliably with the analytical methods used. EDB, DBCP, and 2,4-D were added to the target list because of their known use in Washington State and mobility in the subsurface. Aldicarb sulfoxide and aldicarb sulfone were targeted because they are readily formed metabolites of aldicarb. An additional eight pesticides were added to the target list because laboratory test methods could identify them with little additional effort or cost.

Target analytes other than pesticides are listed in Table 2.

Indicator parameters [nitrate/nitrite-N, total phosphorus, potassium, total dissolved solids (TDS), total organic carbon (TOC), and total organic halides (TOH)] were sampled at each well. These data were collected to identify potential indicators of pesticide contamination in wells. Major cations/anions and trace metals were measured in six wells in Whatcom County and Franklin County study areas and eight wells in Yakima County study area. These data are used to define the general ground water quality of the study areas. The laboratory support for the Pilot Study is summarized in Table 3.

Table 1. Target Pesticides, Analytical Methods, and Reporting Limits for the Agricultural Chemicals Pilot Study

Pesticide	Chemical Group	Analytical Method*	Reporting Limit, µg/L
Alachlor	Acetanilide	NPS 1	1.0
Ametryn	Triazine	NPS 1	0.30
Atrazine	Triazine	NPS 1	0.20
Bromacil	Uracil	NPS 1	2.2
Carboxin	Carboxanilide	NPS 1	1.0
Cycloate	Carbamate	NPS 1	0.40
Diphenamid	Acetamide	NPS 1	0.40
Fenamiphos	Organophosphate	NPS 1	0.30
Hexazinone	Triazine	NPS 1	0.30
Metolachlor	Acetamide	NPS 1	1.5
Metribuzin	Triazine	NPS 1	0.40
Prometon	Triazine	NPS 1	0.30
Propazine	Triazine	NPS 1	0.20
Simazine	Triazine	NPS 1	0.80
Tebuthiuron	Substituted Urea	NPS 1	0.40
Terbacil	Uracil	NPS 1	3.50
Acifluorfen	Organic Acid	NPS 3	0.20
Bentazon	Benzothiadiazole	NPS 3	0.50
Chloramben	Benzoic Acid	NPS 3	0.50
Dalapon	Aliphatic Acid	NPS 3	5.0
DCPAs (dacthal and/or diacid metabolite)	Phthalic Acid	NPS 3	0.20
Dicamba	Benzoic Acid	NPS 3	0.20
Dichlorprop	Phenoxy Compound	NPS 3	0.50
Dinoseb	Organic Acid	NPS 3	2.5
Pentachlorophenol	Chorinated Hydrocarbon	NPS 3	0.20
Picloram	Organic Acid	NPS 3	1.0
Silvex	Phenoxy Compound	NPS 3	0.20
2,4-D	Organic Acid	NPS 3	0.50
2,4-DB	Phenoxy Compound	NPS 3	2.0
2,4,5-Trichlorophenoxyacetic Acid	Phenoxy Compound	NPS 3	0.20
3,5-Dichlorobenzoic Acid	Organic Acid	NPS 3	0.60
4-Nitrophenol	(metabolite)	NPS 3	5.0
5-Hydroxy Dicamba		NPS 3	0.20
Aldicarb	Carbamate	NPS 5 & EPA 531	1.5
Aldicarb Sulfone	(metabolite)	NPS 5 & EPA 531	1.0
Aldicarb Sulfoxide	(metabolite)	NPS 5 & EPA 531	1.0
Baygon	Carbamate	NPS 4 & EPA 632	1.1
Carbofuran	Carbamate	NPS 4 & EPA 632	0.50
Cyanazine	Carbamate	NPS 4 & EPA 632	0.80
Diuron	Carbamate	NPS 4 & EPA 632	0.50
Methomyl	Carbamate	NPS 4 & EPA 632	0.50
Oxamyl	Carbamate	NPS 4 & EPA 632	0.60
Propham	Carbamate	NPS 4 & EPA 632	0.50
Dibromochloropropane	Halogenated Hydrocarbon	EPA 504 (Modified)	0.01
Ethylene Dibromide	Halogenated Hydrocarbon	EPA 504 (Modified)	0.01
1,2-Dichloropropane	Halogenated Hydrocarbon	EPA 501	0.20

* NPS 1 - Determination of N and P-containing pesticides by GC with N detector.
NPS 3 - Determination of chlorinated acids by GC with electron capture detector.
NPS 4 - Determination of pesticides in water by HPLC with UV detector.
NPS 5 - Measurement of N-Methyl Carbomoyloximes and N-Methyl Carbamates by direct aqueous injection HPLC with post column derivitization.

Sources: USEPA (1984), USEPA (1987), and Montgomery Laboratories (1988)
NPS = National Pesticide Survey

Table 2. Non-Pesticide Parameters, Analytical Methods, and Method Detection Limits

Parameter	Method of Analysis*	Reference	Method Detection Limit	
Field Parameters:				
Water Level	Slope Indicator Well Probe	NA	0.05	feet
pH	Beckman pH Meter	NA	0.05	S.U.
Specific Conductance	Beckman RC-15C Conductivity Bridge	NA	10	umhos/cm
Temperature	Precision Thermometer	NA	0.1	°C
Indicator Parameters:				
Total Dissolved Solids (TDS)	EPA #160.1	USEPA(1983)	10	mg/L
Nitrate/Nitrite-N	EPA #353.2	"	0.01	mg/L
Total Phosphate	EPA #365.1	"	0.001	mg/L
Potassium	EPA #200.7	"	0.01	mg/L
Total Organic Halides (TOH)	EPA #450.1	"	5	μg/L
Total Organic Carbon (TOC)	Std Methods #505	APHA(1985)	0.1	mg/L
Major Cations:				
Sodium	EPA #200.7	USEPA(1983)	0.01	mg/L
Calcium	EPA #200.7	"	0.01	mg/L
Magnesium	EPA #200.7	"	0.01	mg/L
Major Anions:				
Chloride	Std Methods #429	APHA (1985)	0.1	mg/L
Carbonate	Std Methods #406C	"	1	mg/L
Bicarbonate	Std Methods #406C	"	1	mg/L
Sulfate	Std Methods #429	"	0.1	mg/L
Metals (Total Recoverable):				
Arsenic	EPA #206.2	U.S.EPA(1983)	0.2	μg/L
Cadmium	EPA #200.7	"	0.2	μg/L
Chromium	EPA #200.7	"	5	μg/L
Copper	EPA #200.7	"	5	μg/L
Iron	EPA #200.7	"	10	μg/L
Lead	EPA #239.2	"	5	μg/L
Manganese	EPA #200.7	"	10	μg/L
Mercury	EPA #245.1	"	0.06	μg/L
Nickel	EPA #200.7	"	10	μg/L
Selenium	EPA #270.2	"	1	μg/L
Zinc	EPA #200.7	"	5	μg/L

* Huntamer (1986)

NA= Not Applicable

Table 3. Laboratory Support for the Agricultural Chemicals Pilot Study

Laboratory	Analytes
Montgomery Laboratories, Pasadena, CA	Pesticides
Columbia Analytical Services, Inc. Longview, WA	Trace metals and major cations (Initial Sampling)
Aquatic Research, Seattle, WA	Total phosphorus and nitrate/nitrite (Initial Sampling)
Ecology/EPA Region X Laboratory Manchester, WA	Major anions, TOC, TOH, TDS, mercury (Initial Sampling)
	Indicator parameters (except TOH) and lead (verification sampling)
Sound Analytical Services, Inc. Tacoma, WA	TOH (verification sampling)

Quality Assurance

Pesticides

A major emphasis of the Pilot Study was to report reliable water quality results. For initial sampling, the level of effort (the ratio of QA samples to total samples) for assessing precision and accuracy for pesticide analyses was about 25 percent. For the verification sampling, the level of effort was about 50 percent. Goals for the precision and accuracy of the data were ± 30 percent. In addition to method blanks and standard EPA contract laboratory instrument calibration requirements, quality assurance (QA) procedures included analysis of the following sample types: field duplicates and replicates, transport blanks, transfer blanks, standard samples (prepared reference samples), and matrix spikes. Field duplicates are identified samples collected simultaneously from the same well. Duplicates help define analytical precision and accuracy. Field replicates are independent samples collected from the same well at different times. Replicates, combined with duplicate data, are used to define the representativeness of a sample for the sampling period. Transport blanks show whether target analytes may have been introduced to samples during collection, transport, or analysis. Transfer blanks are used to determine if target analytes have been introduced to samples from sampling equipment. Matrix spikes and matrix spike duplicates are used to define analytical precision and accuracy. The results of the quality assurance samples are listed in Tables B-1 through B-5 in Appendix B.

All pesticide results underwent two quality assurance reviews: a review by quality assurance staff within Montgomery Laboratories and a second independent review by Dr. Roger McGinnis of Ecology and Environment, Inc. of Seattle, Washington. Usefulness of the pesticide results is based on criteria outlined in "Laboratory Data Validation Functional Guidelines for Evaluating Organics and Pesticides/PCB Analysis" (USEPA R-582-2-2-01) modified to include requirements of the NPS Method 1, NPS Method 3, USEPA Method 601, and USEPA Method 504. In general, the quality of the pesticide data is excellent and the results are considered acceptable for use except where flagged with qualifiers which modify the usefulness of individual values. Data qualifications are discussed below.

The carbofuran detection (2.4 μg/L) in Whatcom County study area may be biased slightly high because matrix spike recovery exceeded QC limits (50-150%) by seven percent. One DCPAs (dacthal and/or diacid metabolite) detection (0.28 μg/L) is estimated because recovery of an internal standard was about five percent below QC limits (80-120%). The NPS Method 3 results for one sample in Yakima County study area were rejected because surrogate compound recovery was 0%. For the verification sampling round, the reporting limits for EDB and DBCP are 0.25 μg/L and 0.02 μg/L respectively because interferences were detected in laboratory method blanks. All positive results for EDB in the verification round are estimates because matrix spike and laboratory control sample solutions and volumes were not documented. Also, during verification sampling 1,2-dichloropropane results less than 0.5 μg/L are estimates because the lowest concentration for calibration curve was 1.0 μg/L.

The reporting limits for aldicarb (1.5 μg/L), aldicarb sulfone (1.0 μg/L), and aldicarb sulfoxide (1.0 μg/L) and carbamates (baygon, 1.1 μg/L; carbofuran, 0.5 μg/L; cyanazine, 0.8 μg/L; diuron, 0.5 μg/L; methomyl, 0.5 μg/L; oxamyl, 0.6 μg/L; propham, 0.5 μg/L) are estimates for some samples in all study areas either because matrix spike or laboratory control sample recoveries exceeded QC limits or instrument responses were poor at low concentrations. The detection limits for bromacil (2.2 μg/L), fenamiphos (0.3), and chloramben (0.5) are estimates for some Franklin County study area samples because of low matrix spike recoveries.

Standard Samples (Prepared Reference Samples)

In the absence of standard reference samples for the pesticides of interest, two separate samples of known concentration of selected pesticides were prepared and tested by Oregon State University (OSU) and submitted to Montgomery Laboratories for analysis. These samples provide an estimate of the analytical precision and accuracy of the pesticide analyses. The pesticides that were tested were simazine and terbacil (NPS Method 1), dicamba and picloram (NPS Method 3) and carbofuran (NPS Method 4 and EPA 632). The sample results are shown in Table B-4 of Appendix B. The Relative Percent Difference (RPD, the percentage of the difference of two values divided by the mean of those values) of measured concentrations ranged from 0 to 103%. The smaller the RPD, the better the agreement of the sample results. The RPDs for terbacil, dicamba, and picloram were less than 50% for both samples. In the first standard sample, carbofuran was not detected by Montgomery Laboratory. As a result of this finding, subsequent carbamate samples for Franklin and Yakima County study areas were confirmed using Method 531. The RPD for carbofuran in the second reference sample was 29%.

Simazine was detected by Montgomery Laboratories at a concentration two times higher than OSUs calculated and measured concentrations. In general, the results from the standard samples show that the pesticide data are of good quality.

Conventionals and Trace Metals

Manchester Laboratory staff reviewed quality control and laboratory quality assurance results for all non-pesticide results. In addition, accuracy and precision of results were evaluated based on field quality assurance samples that included transport blanks, field duplicates, and replicates. Quality assurance results for conventional parameters and trace metals are shown in Tables B-6 through B-8 in Appendix B. Qualifications of the results are discussed in the following paragraphs.

The analytical precision for most of the trace metals is within 10% based on RPDs for duplicate samples. Exceptions to this were cadmium, lead, and selenium results for the initial sampling in Whatcom County and Franklin County study areas with RPDs that exceeded 100%. Selenium and mercury were detected in the Franklin County study area transport blank and all positive results are flagged with a "B" and are not considered reliable. All lead concentrations less than 10 $\mu g/L$ for the verification sampling are flagged with a "B" and are not considered reliable because lead was detected in the transport blank at 1.9 $\mu g/L$.

The analytical precision for conventional pollutant measurements is within 15% based on RPDs for duplicate samples. Precision of nitrate/nitrite and TOX results were about 30% for the Whatcom County Study area initial sampling. All TOC data for the Franklin County and Yakima County study areas are rejected because of defective sample bottles. All positive TOX data for Franklin County study are flagged with a "B" because concentrations of the transport blank samples were 8 $\mu g/L$ for the initial sampling and 20 $\mu g/L$ for verification sampling.

Precision of replicate samples is generally within 10% for both trace metals and conventionals with the exception of cadmium, lead, and selenium. This suggests that sampling procedures were consistent and that results are probably representative of site conditions during the sampling period.

RESULTS

WHATCOM COUNTY STUDY AREA

Location and Physiography

The Whatcom County study area is located in the western part of the county about 12 miles north of Bellingham and three miles west of Lynden (Figure 2). It occupies an area of 6.5 square miles in Sections 14, 15, 21, 22, 23, and the northern halves of Sections 26, 27, and 28 in Township 40 North, Range 2 East.

It is located in the Puget Sound lowland on the southern margin of the Lynden Terrace, a broad, flat-lying outwash plain about one mile north of the Nooksack River. The study area slopes gently to the south with a maximum elevation of about 100 feet at the north and a minimum elevation of about 60 feet to the south. The boundaries of the study area coincide with the boundaries of a previous study area related to EDB ground water contamination (Black and Veatch,1986).

Geology

The regional geology is a product of multiple glacial advances and retreats during the Pleistocene Epoch and subsequent reworking of these deposits. In general, the geology consists of alternating layers of sand and gravel outwash deposits sandwiched between till or glaciomarine drift deposits. Two geologic units crop out in the study area: 1) Outwash Sand and Gravel deposited during the most recent glacial event, the Fraser Glaciation (Easterbrook, 1971) and 2) peat deposited by organic infilling of paleo-drainages (Easterbrook, 1976). The Outwash Sand and Gravel crops out over most of the study area and consists predominately of well sorted sand. The peat deposits only occur near the south margin of the study area. A third geologic unit, the Bellingham Glaciomarine Drift, crops out in the upland one and a half miles north of the study area. The Bellingham Glaciomarine Drift consists of moderately consolidated mixtures of clay, silt, sand and gravel and was deposited by glacial debris raining down from floating glacial ice. It is significant because it probably underlies the Outwash Sand and Gravel unit in the study area.

Hydrogeology

Two hydrogeologic units have been identified in the study area and are designated as the Outwash Aquifer and the Aquitard. The Outwash Aquifer is the principal aquifer in the study area and also the target aquifer for the Pilot Study. It consists of the Outwash Sand and Gravel deposits. The geometry of the Outwash Aquifer and its relationship with the underlying Aquitard are shown on hydrogeologic profiles A-A' and B-B', Figure 3. It is continuous beneath the study area and ranges in saturated thickness from about 20 to 40 feet. It is unconfined with the depth to the water table ranging from three to 25 feet, but usually less than ten feet. The specific capacity of wells in the study area range from about two to 30 gallons per minute per foot. Transmissivity estimated from specific capacity data of six wells in the study

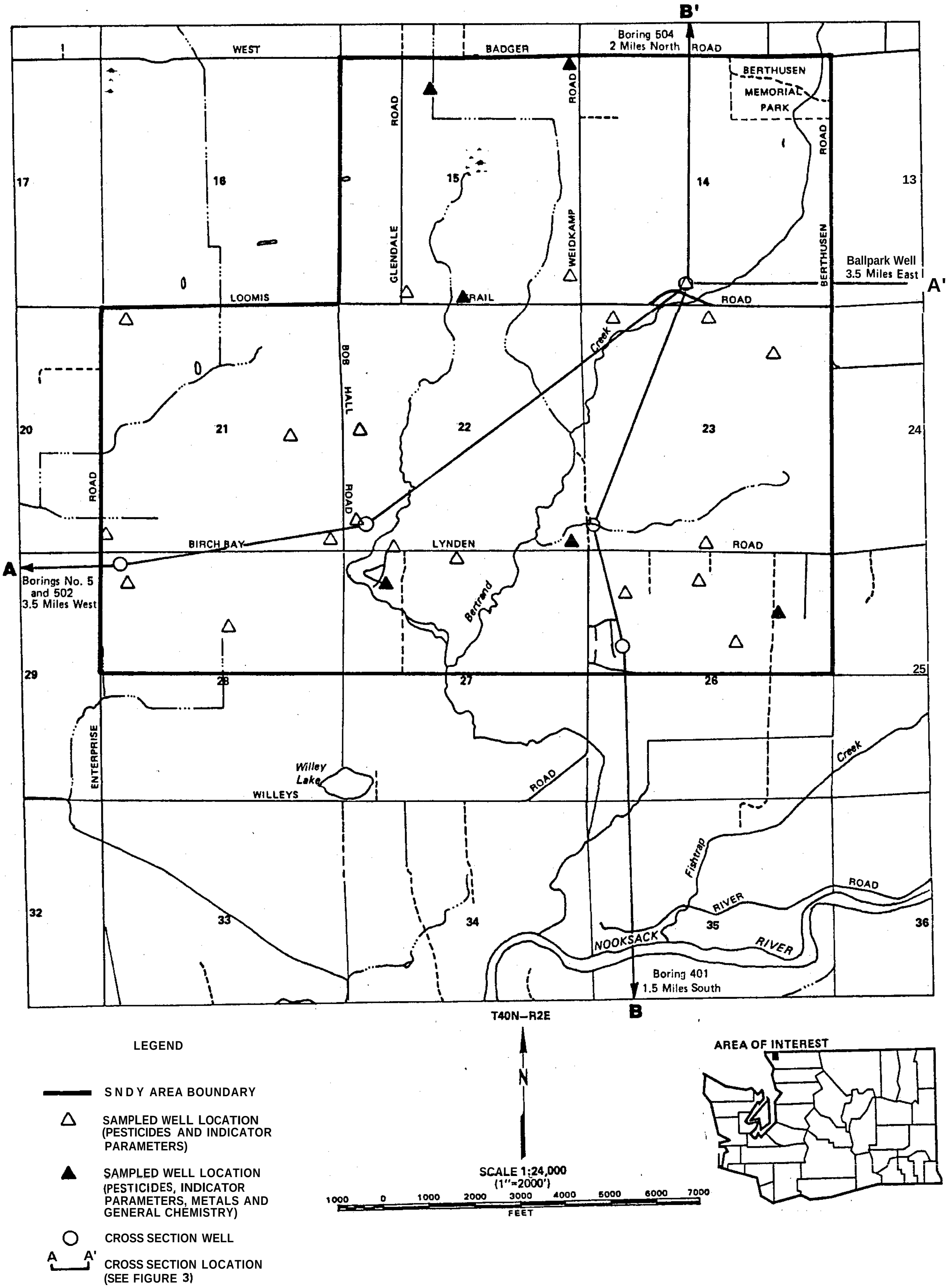


FIGURE 2: WHATCOM COUNTY STUDY AREA; WELL LOCATION MAP

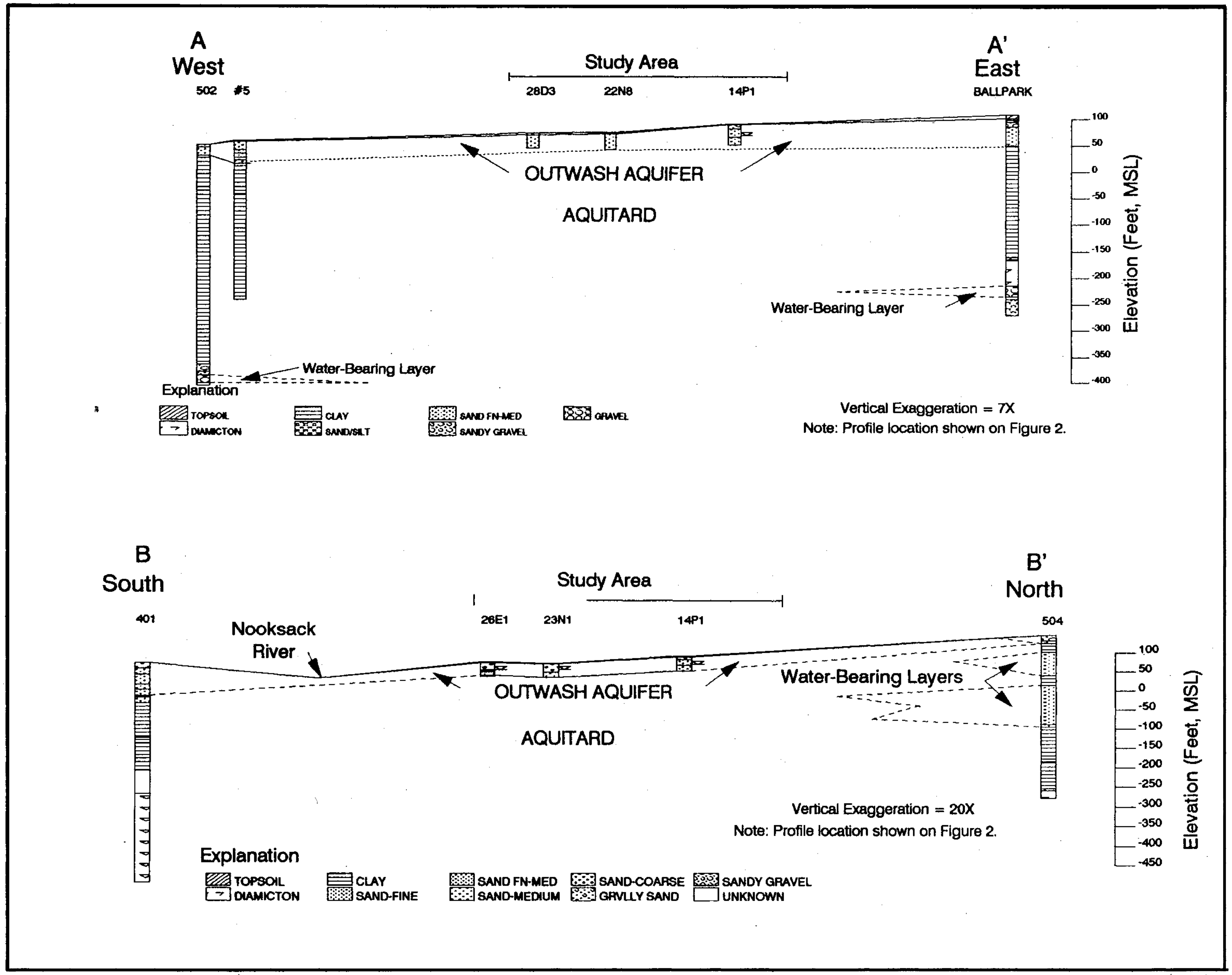


Figure 3: Whatcom County Study Area; Hydrogeologic Profiles

area (Bradbury, 1985) ranges from 2,900 to 31,000 gallons per day per foot. These transmissivity values correspond to hydraulic conductivities of about 30 to 200 feet/day.

The ground water flow pattern within the Outwash Aquifer is shown in the Water Table Contour Map (Figure 4). This map is based on water levels obtained from about 100 wells on March 20-21, 1987 (Creahan, 1987). The direction of ground water flow is generally toward the Nooksack River to the south. Because the aquifer is shallow and unconfined, the ground water flow pattern is likely to be affected locally by seasonal variations due to pumping and irrigation and surface water interactions. Creahan reports that water levels in September were generally about three to five feet lower than March water levels, but the pattern and hydraulic gradients remained essentially the same.

Alternate ground water sources for water supply have not been identified beneath the study area. Wells completed in water-bearing zones beneath the Outwash Aquifer have low yields or poor water quality due to high salinity (URS, 1986). Although deep water-bearing zones have been reported north of the study area (Boring 504, Figure 3), an exploration for the Berthusen Road Water Association in the northeast portion of the study area did not encounter significant quantities of water to a depth of 320 feet (Carr, 1984).

About 200 water supply wells have been identified in the study area and all are completed in the Outwash Aquifer. Nearly all of these wells serve either domestic supplies or are used for irrigation. Most of the older wells and, in particular, wells used for irrigation are constructed of 24- to 36-inch diameter concrete casings. The newer private wells are constructed with 6- to 8-inch steel casing.

Primary surface drainage in the area is Bertrand Creek, an ungaged stream that discharges to the Nooksack River about one mile to the south. Numerous small creeks and irrigation trenches are also present within the study area that drain to the south and southwest. The surface water and the Outwash Aquifer are hydraulically interconnected. The water table contour map (Figure 4) shows that Bertrand Creek strongly affects the water table contours.

Ground Water Quality

Pesticides

The approximate locations of wells sampled in the Whatcom County study area are shown in Figure 2. All wells sampled are completed in the Outwash Aquifer. Twenty-one of the wells are used for domestic purposes, three are for irrigation, two are public supplies, and one is not used. The pesticide results are summarized in Table 4. Of the 27 wells tested during the initial sampling round, 12 showed at least one pesticide with a total of fifteen detections. Five different pesticides were detected: 1,2-dichloropropane, dibromochloropropane (DBCP), ethylene dibromide (EDB), carbofuran and prometon. Previous studies had shown the presence of EDB in the study area. As of December 1986, 37 samples from 27 wells had been tested for EDB by the Department of Social and Health Services (DSHS) or Western Washington

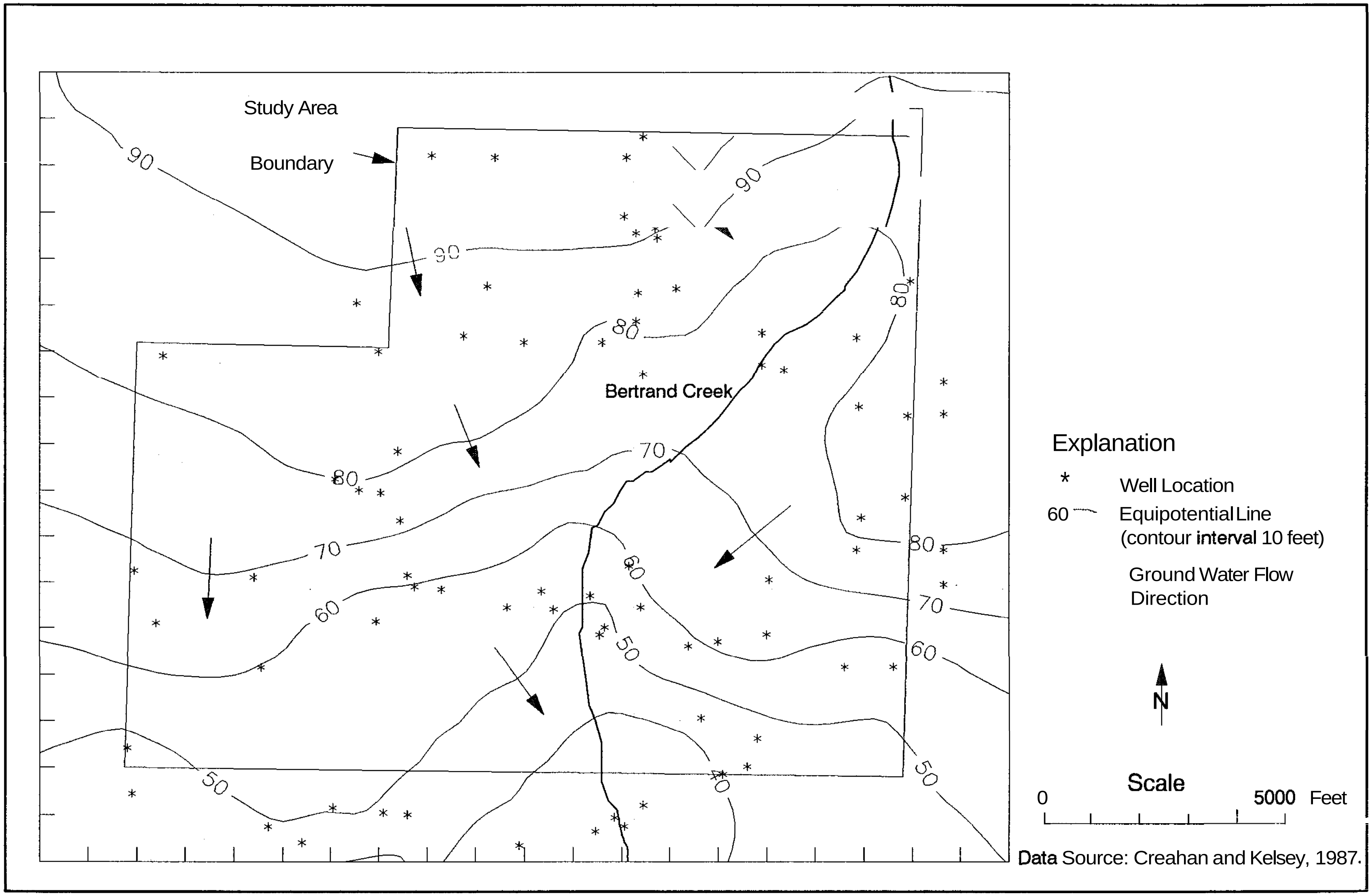


Figure 4: Whatcom County Study Area; Water-Table Contour Map March 1987

Table 4. Summary of Pesticide Results for the Whatcom County Study Area (Numbers in parentheses are verification sampling results.)

	Number of Detections	Detection Frequency	Concentration Mean (μg/L)	'Concentration Range Study Area (μg/L)
1,2-Dichloropropane	9(9)	33	6.9(5.6)	0.3-24(0.4-20)
Dibromochloropropane	1(1)	3.7	0.36(0.3)	NA
Ethylene Dibromide	2(1)	7.4	1.5(1.6)	0.02-2.95(NA)
Carbofuran	1(0)	3.7	2.4(NA)	NA
Prometon	2(2)	7.4	0.55(3.5)	0.5-0.6(0.9-6.0)

* Mean and range of detected concentrations
NA = Not applicable

University (DSHS, 1985 and Mayer, 1986). Of these wells, ten showed measurable concentrations of EDB that ranged from .013 to 6.2 μg/L. The pesticide with the highest detection frequency during the Pilot Study was 1,2-dichloropropane which was detected in nine of the 27 wells. Verification sampling confirmed all pesticide detections observed during the initial sampling round with the exception of carbofuran and one occurrence of EDB. The EDB occurrence that was not confirmed was reported previously at 0.02 μg/L which was below the detection limit (0.25 μg/L) during verification sampling (See Quality Assurance section). Nearly all concentrations observed during the initial sampling round were similar to concentrations observed during the verification sampling. One exception was prometon which was detected at one well during the initial sampling at a concentration of 0.5 μg/L, but during verification sampling the concentration was 6.0 μg/L.

Nitrate

Nitrate/nitrite-N was observed in 26 of 27 wells sampled in the initial sampling and in all 12 wells sampled during the verification sampling. The mean nitrate/nitrite-N for 27 wells in August was 6.7 mg/L and for 12 wells in May, the mean was 11.0 mg/L. The concentration of nitrate/nitrite-N exceeded the Maximum Contaminant Level (MCL) of 10 mg/L in seven wells in the initial sampling and four wells in the verification sampling.

Major Cations/Anions and Trace Metals

Six wells were sampled to define the general ground water quality of the Outwash Aquifer. These samples were tested for major cations and anions and trace metals. The results, listed in Table 5, show that the ground water quality, in general, is good and is dominated by calcium and bicarbonate ions. Zinc was detected in all samples with concentrations ranging from 5.0 to 78.8 μg/L. Copper was detected in five of the six wells at concentrations ranging from 5.7 to 77.5 μg/L. None of these concentrations exceed primary or secondary Maximum Contaminant Levels (MCLs) for public water systems (Department of Health, 1989). Lead was detected in one well at a concentration of 50 μg/L which is the same concentration as the primary MCL. This well was resampled during the verification sampling and lead was not detected (level of detection was 1.0 μg/L).

Table 5. Major Cations/Anions and Trace Metals, Whatcom County Study Area.

Well ID:	15A1	15C1	15Q1	22R2	26A4	27D2
Major Cations and Anions						
Sodium	4.3	10.4	6.3	6.4	11.1	17.3
Potassium	1.8	1.6	0.82	0.50	16.1	1.2
Calcium	25.0	29.3	22.4	17.3	26.7	15.2
Magnesium	5.7	12.7	6.37	4.5	9.50	4.50
Iron	0.02	8.19	0.11	ND	ND	0.011
Manganese	0.01	0.34	0.04	ND	ND	ND
Carbonate (as $CaCO_3$)	ND	ND	ND	ND	ND	ND
Bicarbonate (as $CaCO_3$)	8	47	26	36	43	40
Sulfate	7.7	86	21	17	31	15
Chloride	13	18	14	10	25	16
NO, $+NO_2$-N	24.4	0.3	9.6	3.8	10.4	7.9
Trace Metals (µg/L)						
Arsenic	ND	0.67B	0.2B	0.21B	0.3B	1.7
Cadmium	ND	ND	0.3	0.2	0.3	0.2
Chromium	ND	ND	ND	ND	ND	ND
Copper	ND	8.9	5.7	6.6	78	8.3
Lead	ND	ND	50	5.4	ND	5.0
Mercury	ND	ND	ND	ND	ND	ND
Nickel	ND	ND	ND	ND	ND	ND
Selenium	ND	ND	ND	ND	ND	1.1
Zinc	47	79	6.6	21	5.0	11

ND = Not detected
B = Analyte detected in the transport blank and sample..

Notes: Major anions and cations are total values.
Trace metals are total recoverable values.

Soils

The properties of the major soil types for the Whatcom County study area are described in Table 6. Figure 5 shows the distribution of soil types grouped by similar texture, permeability,

Table 6. Properties of Whatcom County Study Area Soils

Name	Depth (in.)	Texture*	Permea-bility**	High Water Table (ft.)	Organic Content (%)	% Study Area
Loams:						
Edmonds-	0-11	1	m	1.0-2.5	3- 9	27
Woodlyn	11-18	1	r			
	18-37	ls	m			
	37-60	s	vr			
Laxton	0-23	1	m	2.5-3.5	3- 9	10
	23-32	ls	r			
	32-60	s	vr			
Tromp	0-20	1	m	2.5-2.5	3- 9	33
	20-26	sl	mr			
	26-46	s	r			
	46-60	s	vr			
Silt Loam:						
Hale	0-26	sil	m	2.0-4.0	3- 9	8
	26-60	s	vr			
Sandy Loams:						
Lynden	0-18	sl	mr	>6.0	3- 9	8
	18-60	s	vr			
Lynnwood	0-36	sl	mr	>6.0	1- 2	3
	18-60	s	r			
Puyallup	0-19	sl	mr	>6.0	3- 9	5
	19-60	s	r			
Muck:						
Fishtrap	0.19	muck	m	0.5-1.5	40-90	3
	19-60	s	vr			
Pangbom	0-60	muck	m	0.5-1.5	40-90	3

* Texture (USDA)
sil = silt loam
cl = clay loam
s = sand or sandy
1 = loam or loamy

References:
Soil Conservation Service (1989a)
Poulson and Flannery (1953)

** Permeability
vs = very slow (<0.06 in/hr)
s = slow (0.06- 0.2 in/hr)
ms = moderately slow (0.2 - 0.6 idhr)
m = moderate (0.6 - 2.0 in/hr)
mr = moderately rapid (2.0 - 6.0 in/hr)
r = rapid (6.0 - 20.0 in/hr
vr = very rapid (>20.0 in/hr)

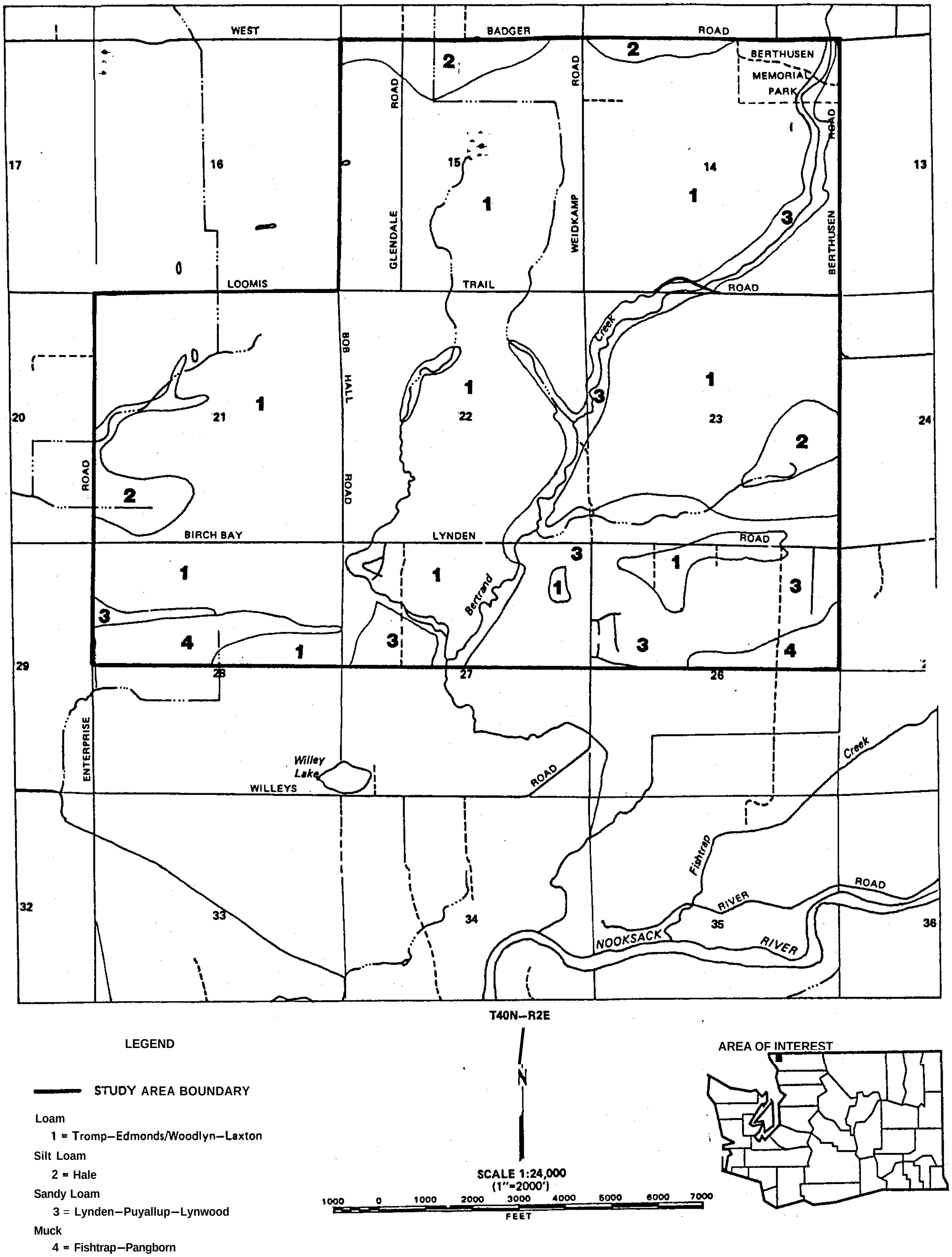


FIGURE 5: WHATCOM COUNTY STUDY AREA; SOILS MAP

seasonal high water-table depth, and organic content. In general, the soils are derived from sandy and silty glacial outwash deposits (Poulson and Flannery, 1953). Loam soils cover 70% of the study area, sandy loams cover 16%, and silt loams and muck soils comprise the remainder. Most of the soils are well drained with lesser amounts imperfectly drained. Poorly drained organic soils occur in low areas along the southern boundary of the study area associated with paleo-drainage channels. About 85% of the study area has soils with a seasonal high water table of four feet or less.

Crops and Irrigation

In general, the farms in Whatcom County are small averaging about 90 acres. Major crops grown and estimated acreage are listed in Table 7. The distribution of crops in 1988 is shown in Figure 6. Raspberries and strawberries are the dominant cash crop. Forages (silage, pasture, green chop or hay) cover one-third of the study area. Row crops may be grown in rotations of seed potatoes, wheat and green peas, or green peas, snap beans and corn. Blueberries are grown in the poorly drained areas. There are six dairies, five active and one inactive, and a small nursery in the study area. About 27% of the study area is woodland, residential or used for dairies.

All higher value crops (berries, seed potatoes, peas, and beans) are irrigated in the study area. During the summer, the water deficit between rainfall and crop needs is about 17 inches (MacConnell, 1989). The most common type of irrigation used is the "travelling big gun." Water pressure moves the system's large reels with attached hoses, spraying a path of water over 200 feet wide. Drip irrigation is used on raspberries by some growers.

Table 7. Whatcom County Study Area Crop Acreage (Approximate)

Crop	Percent of Area
forages	31
raspberries	25
seed potatoes/wheat/peas	6
strawberries	6
peas/beans/corn	4
nursery	1

Note: About 27% of the study area is woodland, residential, or dairies.

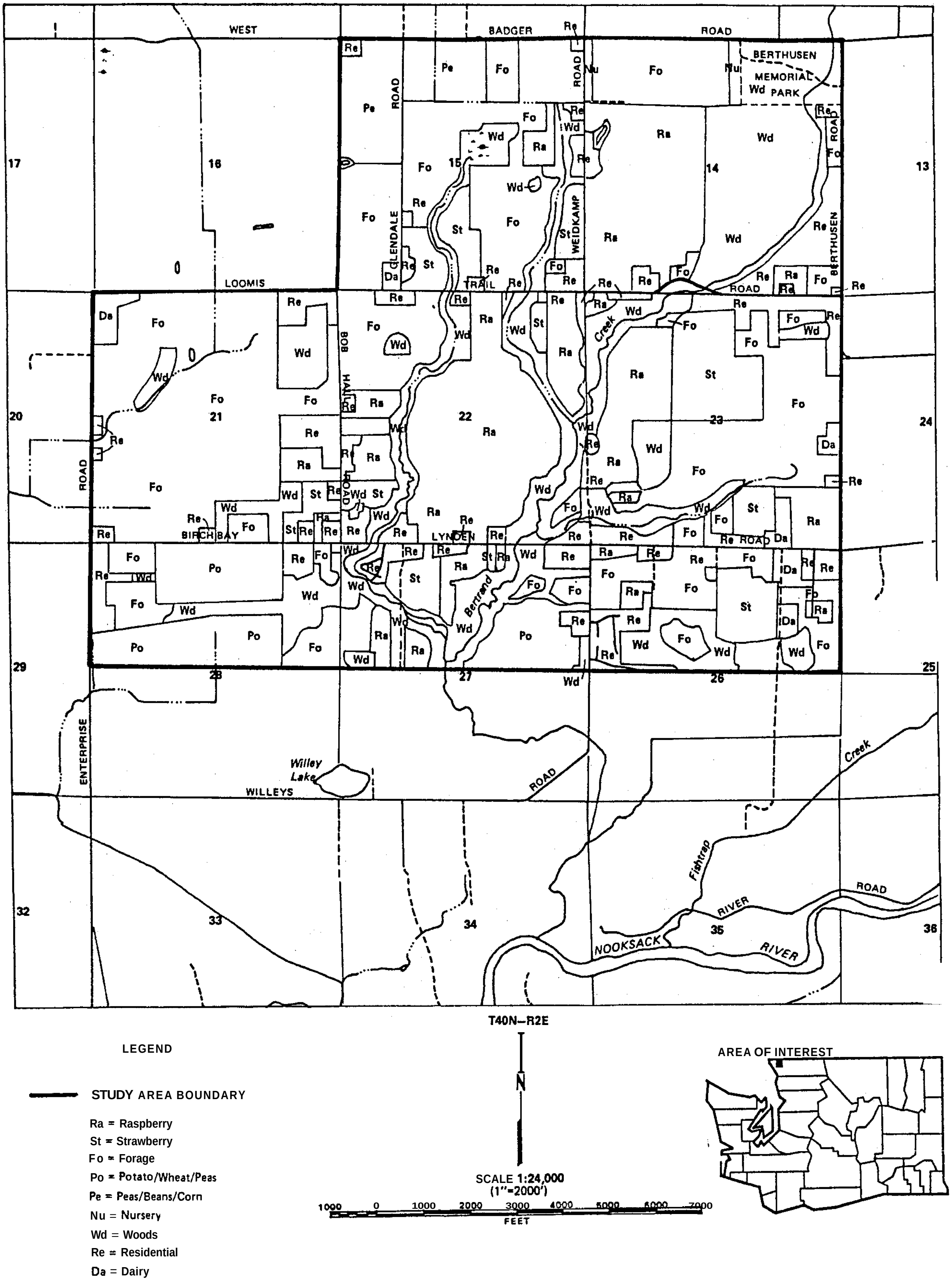


FIGURE 6: WHATCOM COUNTY STUDY AREA; LAND-USE MAP

Agricultural Chemicals Usage

Pesticides

Many of the target pesticides analyzed in the Pilot Study have been used in the Whatcom County study area. However, no records of specific information on actual application rates, locations, times, and formulations used are readily available. Table 8 summarizes the pesticide use for the study area and is based on three sources: 1) interviews with Whatcom County pesticide dealers on sales in the county in 1985, 2) interviews with WSU Cooperative Extension agents (MacConnell, 1989 and U.S. EPA, 1986), and 3) WSU Cooperative Extension spray guides and publications. The first two sources are probably most useful for estimating actual pesticide use. Pesticide use for major study area crops is discussed below.

Soil fumigation for nematodes is common prior to planting major cash crops such as raspberries and seed potatoes. Ethylene dibromide (EDB), which was detected in two study area wells, was used as a soil fumigant on berries, seed potatoes and nurseries in the area before it was banned by EPA in 1984 (MacConnell, 1989). Since that time, the use of dichloropropene (1,3-DCP, Telone) has replaced EDB use. Dichloropropene use was common on berries before 1983 as well (Timblin, 1989). 1,2-dichloropropane (1,2-DCP), the most frequently detected pesticide in study area wells, has been associated in the past with dichloropropene use. About 25-30% 1,2-DCP was present in dichloropropene products sold by DOW Chemical before 1962 and by Shell before 1986. The current level of 1,2-DCP occurring in dichloropropene formulations is 500 ppm (0.05%) or less (Toohey, 1989). It is not known whether the occurrences of 1,2-DCP in the study area ground water are related to past or present uses. Dibromochloropropane (DBCP), a soil fumigant was detected in one study area well. The EPA in 1979 suspended the registration of pesticide products containing DBCP and in 1985 issued an intent to cancel all registrations for pesticide products containing DBCP. Carbofuran, a currently used insecticide-nematocide, was detected in one study area well.

Dinoseb (Dinitro) was used on berries, seed potatoes, and legumes in the area before it was banned for most uses nationwide in 1987. Since then, only limited uses have been allowed in the northwest (Smerdon, 1989). Dinoseb has been allowed for use in the area on raspberries through 1989 and on peas through 1988. Metribuzin (Lexone, Sencor) and metolachlor (Dual) have replaced dinoseb use on seed potatoes while metribuzin may be used as a replacement for dinoseb on peas (Wraspir, Howard, 1989).

Methomyl was used on raspberries during the 1983 growing season only. Although recommended for use on seed potatoes and legumes by extension references, methomyl use is rare in the area (MacConnell, 1989). Although EPA listed dacthal as used on berries and nurseries in Whatcom County and oxamyl (Vydate) as used on strawberries, they are rarely applied (MacConnell, 1989).

Table 8. Pesticide Use on Whatcom Study **Area** Crops

Chemical	Crop	Sold in the region (1985)'	Use in area WSU Cooperative Extension Agent[2]	EPA[3]	Recommended by WSU Cooperative Extension Spray Guides and Handbook8
alachlor	corn	yes	no	yes	yes
	potatoes		Small Quantity	no	no
	nursery		no	yes	yes
aldicarb	potatoes	yes	no	yes	yes
	nursery		no	yes	yes
atrazine	corn	yes	yes	yes	yes
carbofuran	berries	yes	no	yes	yes
	corn		no	yes	yes
	potatoes		no	yes	yes
	nursery		no	yes	yes
dacthal	berries	yes	no	yes	no
	nursery		no	yes	no
dalapon	corn	no	no	yes	yes
dicamba	corn	yes	Small Quantity	yes	no
dichloro-	berries	yes	yes	yes	yes
propene	potatoes		yes	yes	yes
	nursery		yes	no	no
dinoseb	berries	yes	yes	yes	no
	legumes		yes	yes	Before 1987188
	potatoes		yes	yes	Before 1987188
diphenamid	berries	yes	no	no	yes
	nursery		no	yes	yes
diuron	berries	yes	no	no	yes
fenamiphos	berries	yes	no	no	yes
methomyl	potatoes	yes	rare	yes	yes
	legumes		rare	yes	yes
	raspberries		1983	yes	no
metolachlor	potatoes	yes	yes[4]	no	yes
	legumes		no	yes	yes
	nursery		no	yes	yes
metribuzin	potatoes	yes	yes[4]	yes	yes
	legumes		yes[4]	yes	yes
oxamyl	berries	no	no	yes	no
	potatoes		rare	no	yes
simazine	berries	yes	no	yes	yes
	nursery		no	yes	yes
terbacil	berries	yes	no	yes	yes

References: 'Norton (1987)
[2]MacConnell (1988)
[3]EPA (1986)
[4]Wrasper (1989), Howard (1989)
[5]Burrill (1988), Capizzi (1988), Koespell (1988), Cooperative Extension (1988d)

Insecticides tested for in the Pilot Study are not considered economical for use on wheat or forages in Whatcom County (MacConnell, 1989). Atrazine (Aattrex) is the most common herbicide used on corn and may be applied to the small amounts of hay grown in the area (MacConnell, 1989).

The WSU Cooperative Extension does not recommend aldicarb (Temik) for use in Whatcom County. However, it has been used in the area in the past when planting seed potatoes (Wraspir, 1989). Small amounts of alachlor may be used on study area seed potatoes (MacConnell, 1989). Prometon, which was detected in two study area wells, is not widely used (MacConnell, 1989).

Fertilizer Use

Commercial nitrogen fertilizer is used alone or in combination with manure on many study area crops. Recommended fertilizer types and rates for all crops vary depending on the results of soil tests. Formulations vary by vendor and application practices differ among individual operators. Recommended nitrogen fertilizer use for four of the major study area crops is outlined in Table 9.

Table 9. Recommended Nitrogen Fertilizer Use for Whatcom County Study Area.

Crop	Rate	Method/Remarks	Timing
Raspberry	60 lb/A	To soil surface or banded along rows	1/2 after planting, 1/2 in late June. Established crop: March or early April. At or soon after planting.
Strawberry	30-45 lb/A	Broadcast	After harvest in established crop.
Sweet Corn	75 lb/A	Banded	
	or 35 lb/A	plowed and	
	40 lb/A	banded	
Pasture	30-45 lb/A		When establishing fields April through September
	30 lb/A		in established fields

Reference: WSU Cooperative Extension (1975a,b)(1976a,b)
Note: Not from actual records of chemical use

Dairy farms in the area often use irrigation devices to spread animal wastes on their fields. The Whatcom County Conservation District estimates annual nitrogen application by dairies at 196 pounds per acre. The Conservation District recommends a 180 day on-farm storage facility during the October to March rainy season because many fields are unsuited for winter applications due to high runoff potential and seasonally high water tables. Waste application is encouraged during the growing season between April and September; however, wastes are often spread year-round.

FRANKLIN COUNTY STUDY AREA

Location and Physiography

The Franklin County study area is located in the south portion of the county about ten miles north of Pasco (Figure 7). It consists of nearly all of Township 10 North, Range 29 East and the south one-third of Township 11 North, Range 29 East, an area of about **34** square miles. It is bounded by the Columbia River on the west and Glade North Road on the east.

The elevation ranges from 875 feet in the north to about 450 feet in the south. The relief is moderate and undulating. Numerous irrigation canals cross the study area.

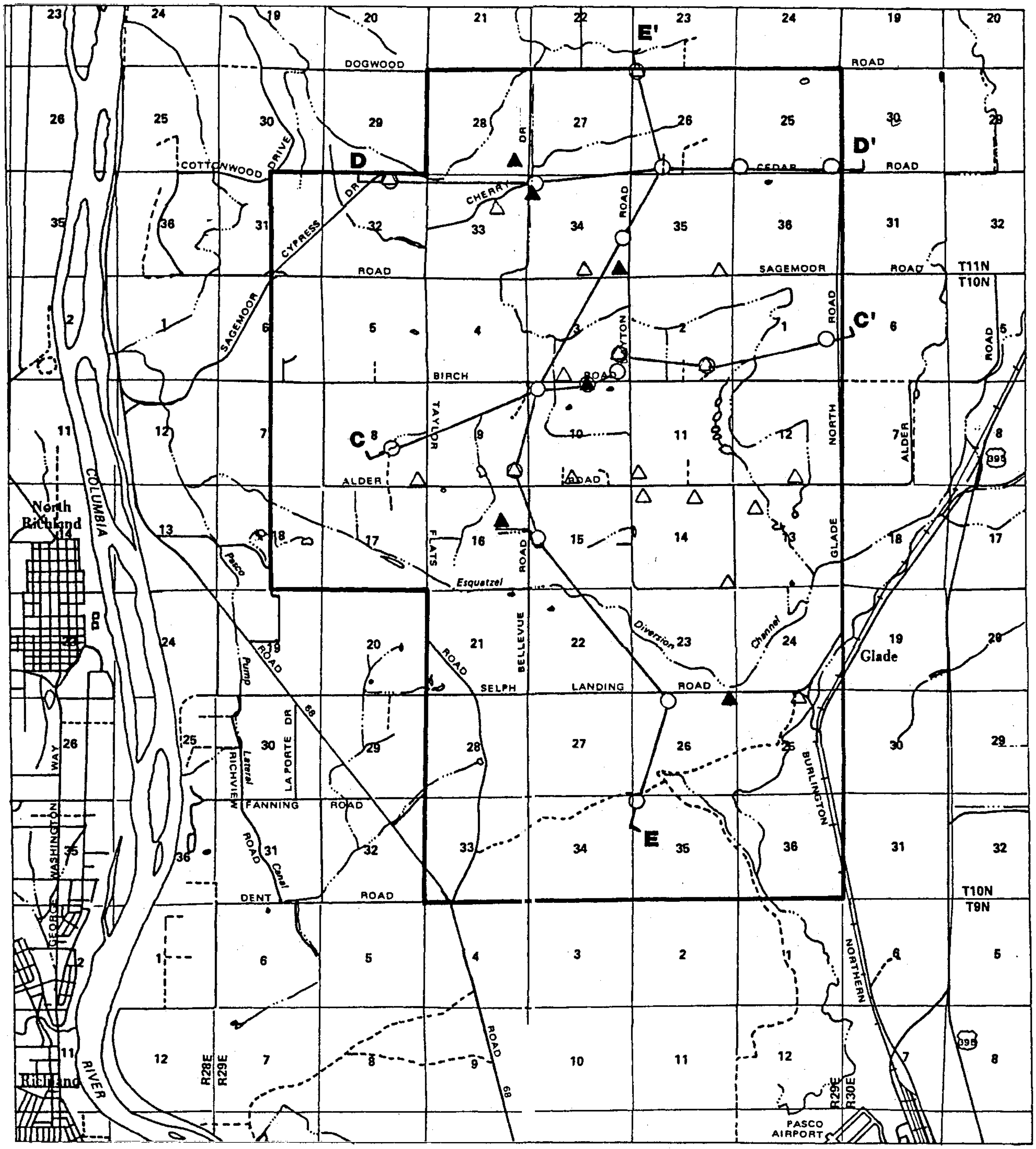
Geology

Franklin County lies within the Pasco Basin, a structural and topographic basin within the Columbia Plateau. The Columbia Plateau is underlain by the Columbia River Basalt Group, a volcanic complex formed by repeated extrusions of lava between six to 17.5 million years ago. Thickness of the Columbia River Basalt Group may exceed 15,000 feet locally. Tectonic warping combined with fluvial and lacustrine processes have resulted in the deposition of sedimentary deposits on the Columbia River Basalt Group.

Seven geologic units listed in Table 10 have been identified within the study area (Myers, ***et*** al., 1979; Campbell ***et*** al., 1979; Grolier and Bingham, 1971; Walters and Grolier, 1960; Brown, R.E., 1979).

Table 10. Franklin County Study Area Geologic Units

Geologic Unit	Description
Alluvium	Primarily stream deposits of silt, sand and gravel in floodplains, terraces and valley bottoms
Dune Sand Active Stabilized	Fine to medium sand. Volcanic ash horizon common with stabilized dunes
Pasco Gravels (Hanford Formation)	Pleistocene deposits associated with catastrophic floods Variable texture, predominantly sand and coarse gravel
Ringold Formation	Tertiary fluvial and some lacusterine deposits Two facies: 1) Sand, silt, clay facies, and 2) Conglomerate facies
Saddle Mountains Basalt	The uppermost basalt unit of the Columbia Basalt River Group



LEGEND

STUDY AREA BOUNDARY

△ Sampled Well Location (Pesticides and Indicator Parameters)

▲ Sampled Well Location (Pesticides, Indicator Parameters, Metals and General Chemistry)

○ Cross Section Wells

C ⌊__⌋ C′ Cross Section Location (See Figure 8 & 9)

N

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(1″=5208′)

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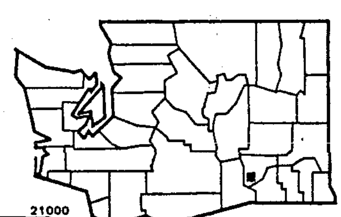


FIGURE 7: FRANKLIN COUNTY STUDY AREA; WELL LOCATION MAP

The distribution of each unit within the study area is discussed below.

The Saddle Mountains Basalt is continuous beneath the study area. It consists of fine-grained to aphanitic basalt with frequent jointing and splintery columns (Grolier and Bingham, 1971). Sedimentary interbeds are common. The thickness ranges from 600 to 800 feet and is overlain by about 200 feet of sedimentary deposits (Drost and Whiteman, 1986). The Ringold Formation unconformably overlies the Saddle Mountains Basalt and consists of two facies: a conglomeratic facies and an overlying sand, silt, and clay facies. The conglomeratic facies may be continuous beneath the study area. The sand, silt, clay facies is exposed at the surface of the northern two-thirds of the study area.

The Pasco Gravels unit was deposited by catastrophic release(s) of water from ice-dammed lake(s) during the last major Pleistocene glaciation about 13,000 years ago. The unit unconformably overlies the Ringold Formation and crops out in the southern one-third of the study area. The thickness ranges up to 100 feet (Grolier and Bingham, 1971). Dune sand deposits occur predominately in the southwest portion of the study area. Alluvium is associated with the Esquatzel Coulee drainage in the southeastern portion of the study area.

Regional Hydrogeology

For conceptual purposes, four regional aquifer systems have been identified within the Columbia Plateau: three within the Columbia River Basalt Group and one within the overlying sedimentary deposits (Bauer, *et al.*,1985). The uppermost saturated sedimentary deposits represent the target aquifer for the Pilot Study. Two aquifers have been identified within the sedimentary aquifer system and are discussed below in the Study Area Hydrogeology. The regional ground water flow direction in the sedimentary aquifer system is toward the Columbia and Snake Rivers to the southeast and south (Bauer, *et* al., 1985).

Study Area Hydrogeology

Two aquifers, designated for this report as the Upper Aquifer and the Lower Aquifer, have been identified within the sedimentary aquifer system. The geometry and interrelationship of the two aquifers is shown in cross sections Figures 8 and 9. The Upper Aquifer consists of hydraulically connected units of alluvium, dune sand, Pasco Gravels, and sandy facies of the upper Ringold Formation. Grain size ranges from fine sand to coarse gravel. The aquifer is recharged primarily by irrigation water. The USGS has estimated that about 90% of the recharge to ground water is from infiltrated irrigation water and 10% is from precipitation (Ebbert, 1990a). Since the 1950s the water table has risen as much as 100 feet locally due to irrigation. The Upper Aquifer appears to underlie most of the study area but does not appear to be continuous (Well T11N/R29E 26P1, See North-South' Cross Section, Figure 11). Brown (1979) designated the northeast comer of the study area as perched and hydraulically separated from the water table aquifer. The hydraulic properties of the Upper Aquifer are expected to be highly variable considering the heterogeneity of the units comprising it. Likewise, Brown (1979) estimated the transmissivity of the Upper Aquifer from specific capacity data. In the northern two-thirds of the study area, where the Upper Aquifer consists of the sand, silt, clay of the Ringold Formation, the transmissivities range from less than 800 up to 10,000 gallons per day per foot (gpd/ft). In the southern one-third, where the Upper Aquifer consists of Pasco Gravels, the transmissivity ranges from 50,000 to greater than 500,000 gpd/ft.

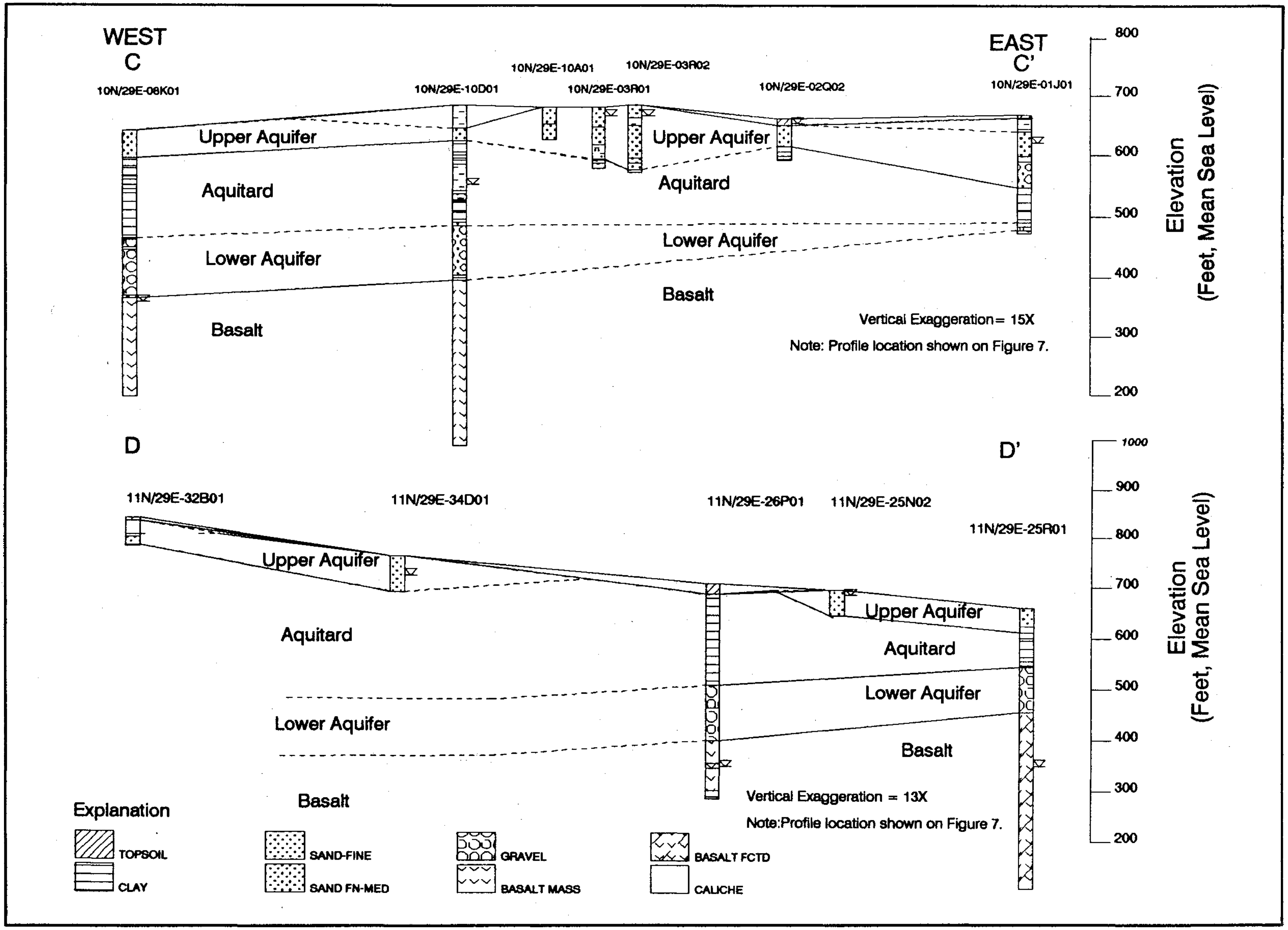


Figure 8: Franklin County Study Area; West-East Hydrogeologic Profiles

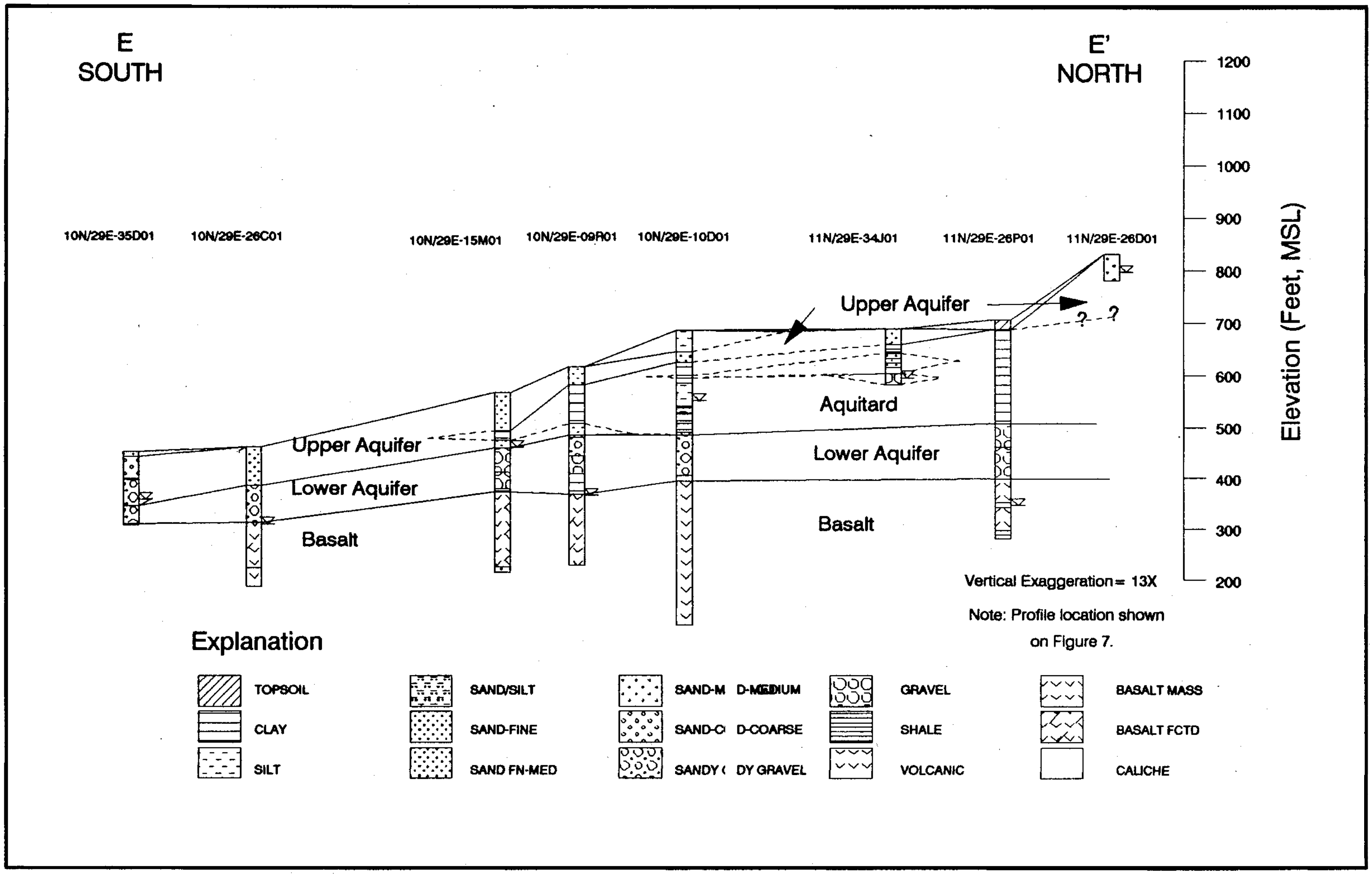


Figure 9: Franklin County Study Area; South-North Hydrogeologic Profile

The ground water flow pattern in the Upper Aquifer is shown in Figure 10. This figure was constructed using water levels obtained by Ecology in September 1988. In general, the ground water flow direction is toward the south. Because the Upper Aquifer is shallow and unconfined, flow patterns are influenced seasonally by pumping and irrigation and are probably more complex than shown in Figure 10.

The Lower Aquifer consists of the conglomerate facies of the Ringold Formation. The aquifer material consists of well-rounded pebbles and cobbles set in a sand matrix which is commonly cemented. Only one well completed in the Lower Aquifer was sampled during the Pilot Study. The transmissivity of the Lower Aquifer is generally low and usually provides only sufficient quantities of water for private supplies (Brown, 1979).

The Upper Aquifer and Lower Aquifer are separated by a silt/clay aquitard that continuously underlies the northern half of the study area. The maximum thickness of the aquitard is 200 feet but it pinches out to the south (Figure 9). Where the aquitard is not present, the Upper Aquifer and Lower Aquifer are hydraulically connected.

A well inventory compiled from USGS and Ecology Eastern Regional Office files identified about 100 water supply wells within the study area and near vicinity. Nearly all of these wells serve either domestic supplies or are used for irrigation. Five wells serve public water supplies. About 30 wells are completed in the Upper Aquifer. Eleven of these shallow wells are observations wells installed by the Bureau of Reclamation in the 1950s to monitor water table responses to irrigation. None of the public wells were completed in the Upper Aquifer.

Ground Water Quality

Pesticides

The location of wells sampled in the Franklin County study area are shown in Figure 7. Twenty-two of the wells are private water supplies and five are USBR piezometers. None of the wells sampled was a public water supply well.

During the initial sampling round, ten occurrences of pesticides were observed in ten wells. Pesticide results are summarized in Table 11. Three different pesticide residues were identified: DCPAs (dacthal and/or its diacid metabolite), 1,2-dichloropropane, and bromacil. All results were confirmed during verification sampling. DCPAs, which had the highest detection frequency, were observed in seven wells. The test method used, NPS 3, could not differentiate dacthal from its diacid metabolite, tetrachloroterephthalicacid. Concentrations during the initial sampling ranged from 0.26 to 1.08 μg/L with a mean of 0.7 μg/L. Concentrations during the verification sampling round ranged from 0.2 to 0.9 μg/L with a mean of 0.6 μg/L. All occurrences of DCPAs were in wells completed in the Upper Aquifer and were distributed uniformly over the northern two-thirds of the study area. 1,2-dichloropropane was detected in two wells at concentrations of 0.4 and 0.8 μg/L. Verification sampling confirmed the initial sampling results with concentrations of 0.3 and 0.9 μg/L. The lower concentration was observed in a well completed in the Upper Aquifer. The higher concentration was observed in a well completed in the Lower Aquifer. The occurrence of the 1,2-dichloropropane in the deeper aquifer suggests that significant vertical migration of the 1,2-dichloropropane may have occurred. Bromacil was detected in one well, a USBR piezometer, at a concentration of 14.9 μg/L. The concentration observed during verification sampling was 12 μg/L.

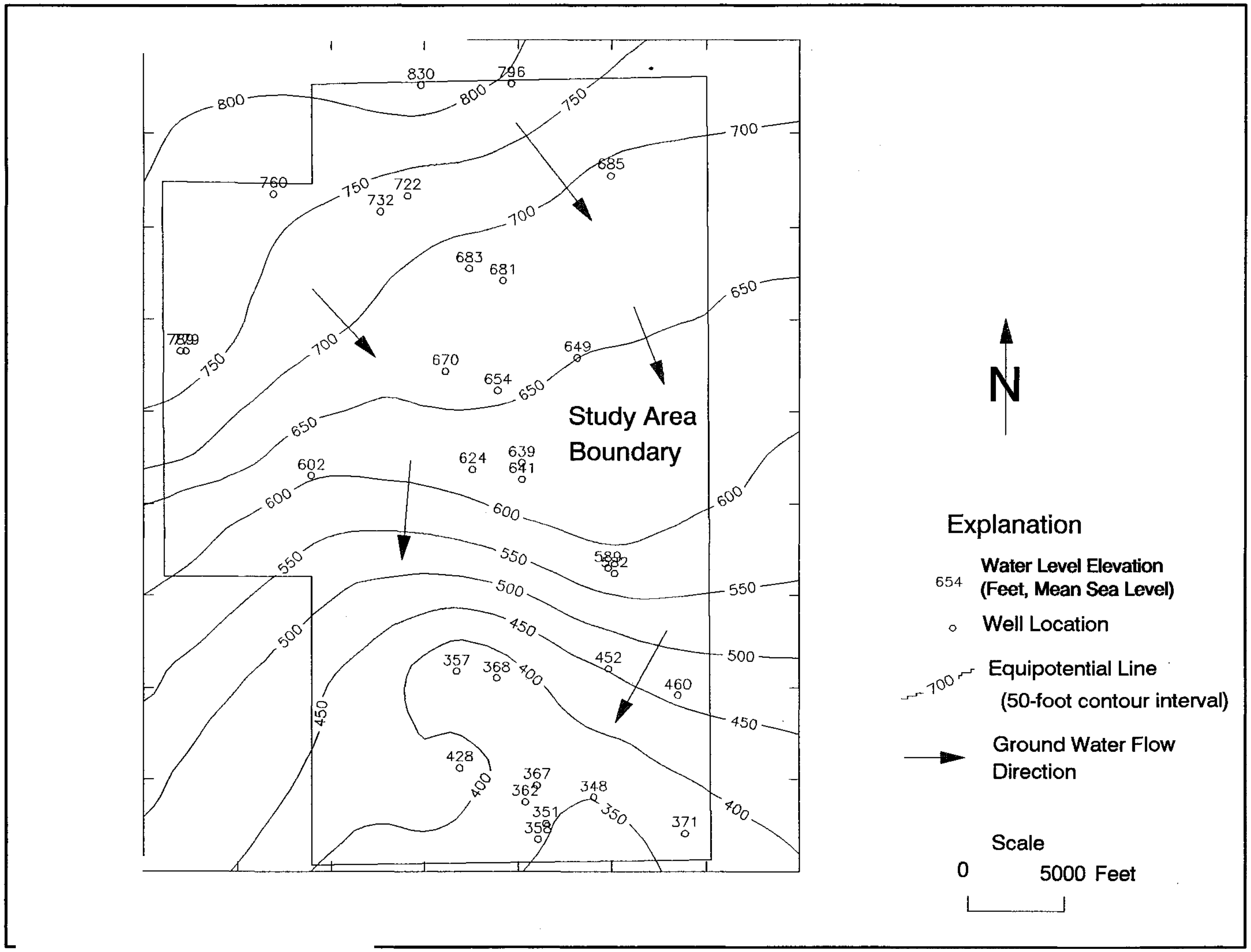


Figure 10: Franklin County Study Area Water-Table Contour Map September 1988

The USGS tested 14 wells and four subsurface drains in the Benton-Franklin Counties ground water study for about 40 pesticides. All of the subsurface drains and five of the wells had detectable concentrations of pesticides. The pesticides that have been detected with concentrations in parentheses are dicamba (two occurrences at .O1 μg/L), picloram (.03 μg/L), atrazine (two occurrences at 0.1 and 0.2 μg/L) and aldicarb sulfone (0.09 μg/L).

Table 11. Summary of Pesticide Results for the Franklin County Study Area (Numbers in parentheses are verification sampling results.)

	Number of Detections	Detection Frequency	Concentration Mean (μg/L)	Concentration Range Study Area (μg/L)
DCPAs(dacthal and/or diacid metabolite)	7(7)	26.0	0.7(0.6)	0.3-l.l(O.2-0.9)
1,2-Dichloropropane	2(2)	7.4	0.6(0.6)	0.4-0.8(0.3-0.9)
Bromacil	1(1)	3.7	14.9(12)	NA

Nitrate

In Franklin County study area, all 27 wells had detectable concentrations of nitratelnitrite-N. The concentrations ranged from 0.5 to 18.8 mg/L with a mean of 8.1 mg/L. Verification sampling of the ten wells with pesticides showed nitratelnitrite-N concentrations that ranged from 0.4 to 15.3 mg/L with a mean of 6.0 mg/L. The well completed in the Lower Aquifer showed nitrate/nitrite-N concentrations during both sampling rounds of 11.5 and 12.2 mg/L.

Eleven of the 27 wells (41%) sampled during the initial sampling exceeded the MCL of 10 mg/L. Three of the ten wells (30%) sampled during the verification sampling exceed the 10 mg/L MCL.

Nitrate concentrations exceeding 5 mg/L have been reported for wells completed in both unconsolidated deposits and basalt in the Pasco Basin (Turney, 1986a). The concentration of nitrate ranged up to 23.0 mglL for 29 wells sampled for the USGS Benton-Franklin Counties study (Ebbert, 1988). Four of the public supply wells completed in unconsolidated deposits showed nitrate concentrations that ranged from 6 to 21 mg/L (DSHS, 1988).

Conventionals and Trace Metals

Six water quality samples obtained during the Pilot Study were tested for major cations and anions and trace metals. The results of these analyses are shown in Table 12. The major cations present in all samples are calcium and sodium. The major anion is bicarbonate at concentrations ranging from 160 to 326 mg/L. Ground water in the unconsolidated deposits in the Pasco Basin is a calcium bicarbonate type and ground water in the basalt is a sodium bicarbonate type (Turney, 1986).

Table 12. Major Cations/Anions and Trace Metals, Franklin County Study Area.

Well ID:	10/29-26A1	10/29-10A1	10/29-16A2	11/29-28R2	11/29-34D2	11/29-34R1
Major Cations and Anions (mg/L)						
Sodium	33.1	97.2	59.8	49	36.0	NT
Potassium	2.53	7.75	5.61	1.14	7.02	1.41
Calcium	48.2	68.7	60.7	66.8	33.4	37.8
Magnesium	29	21.7	24.5	33.2	9.89	26
Iron	13.1	0.02	0.02	0.43	ND	0.35
Manganese	0.71	ND	ND	ND	ND	ND
Carbonate(as $CaCO_3$)	ND	ND	ND	ND	ND	ND
Bicarbonate(as $CaCO_3$)	160	326	246	160	174	190
Sulfate	81	89	87	150	37	74
Chloride	48	22	29	39	9.5	30
NO, $+NO_2$-N	9.2	16.3	12.9	11.9	1.2	3.7
Trace Metals (µg/L)						
Arsenic	4.7	7.5	7.0	2.0	13.3	1.6
Cadmium	ND	0.1	0.3	ND	ND	ND
Chromium	21.9	ND	ND	ND	ND	ND
Copper	ND	ND	ND	ND	ND	ND
Lead	13.0	ND	36.0	ND	ND	ND
Mercury	0.10B	0.21B	0.16B	0.13B	0.10B	0.13B
Nickel	25.7	ND	ND	ND	ND	ND
Selenium	7.1B	1.1B	1.3B	2.0B	ND	6.6B
Zinc	30.3	77.1	49.8	53.2	5.0	9.3

ND = Not detected
NT = Not tested
B = Analyte detected in the transport blank and sample.

Notes: Major anions and cations are total values.
Trace metals are total recoverable values.

Arsenic was detected is all samples at concentrations ranging from 1.6 to 13.3 $\mu g/L$. Zinc was detected in all wells at concentrations ranging from 5.0 to 77.1 $\mu g/L$. Mercury and selenium detections are unreliable because both metals were detected in the transport blank.

Soils

The soils in the Franklin County study area are coarse textured with low organic content (Soil Conservation Service, 1989b). The properties of the major soil types are shown in Table 13 and their distribution over the study area is shown in Figure 11. Loamy fine sands cover 93% of the study area. Soil permeability ranges from moderate to rapid, becoming very rapid with depth in some horizons. In general, the soils provide moderate to low attenuation of potential organic contaminants. All soils have seasonal high water tables deeper than six feet and are commonly well drained to excessively drained.

Table 13. Properties of Franklin County Area Soils.

Name	Depth (in.)	Texture* (USDA)	Permea-bility**	Organic Content (%)	% study area
Loamv fine sand					
Burbank	0-30	ls	r	0.5-1	<1
	30-60	vgls	vr		
Quincy	0-60	fs	r	0.5-1	85
Royal	0- 5	fsl	r	0.5-1.0	6
	5-60	fs	mr		
Verv fine sandv loams					
Hezel	0- 7	lfs	I	<0.5	<1
	7-18	Is			
	18-60	sil			
Sagehill	0-19	vfsl	mr	0.5-2.0	4
	19-60	sil	ms		
Sagemoor	0- 9	sil	ms	1.0-2.0	1
	9-19	vfsl	mr		
	19-60	vfsl & sil	ms		
Warden	0-19	vfsl	m	1.0-3.0	1
	19-40	sil			
	40-60	vfsl			
Loamv coarse sand					
Winchester	0- 8	lcs	mr	0.5-1.0	2
	8-60	CS	vr		
Fine sandv loam***					
Timmerman	0-16	fsl	mr	0.5-1.0	<1
	16-60	cs	vr		

Note: All soils have seasonal high water tables greater than six feet.

*Texture (USDA)
- sil = silt loam
- cl = clay loam
- s = sand or sandy
- g = gravelly
- 1 = loam or loamy
- f = fine
- c = coarse
- v = very

**Permeability
- vs = very slow (<0.06 in/hr)
- s = slow (0.06 - 0.2 in/hr)
- ms = moderately slow (0.2 - 0.6 in/hr)
- m = moderate (0.6 - 2.0 in/hr)
- mr = moderately rapid (2.0 - 6.0 in/hr)
- r = rapid (6.0 - 20.0 in/hr)
- vr = very rapid (>20.0 in/hr)

***Not shown in Figure 7.

References: Soil Conservation Service (1989b)

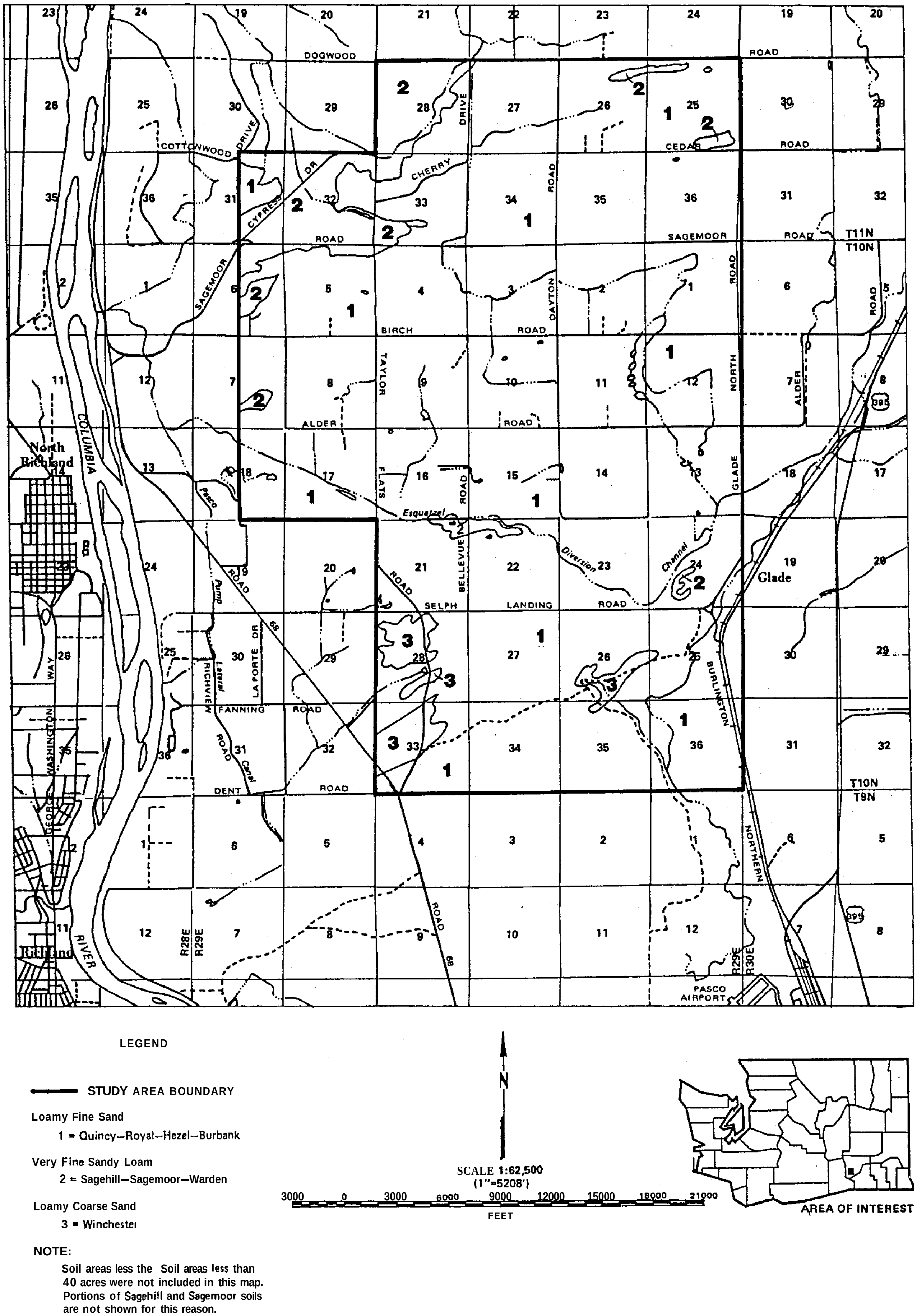


FIGURE 11: FRANKLIN COUNTY STUDY AREA; SOILS MAP

Crops and Irrigation

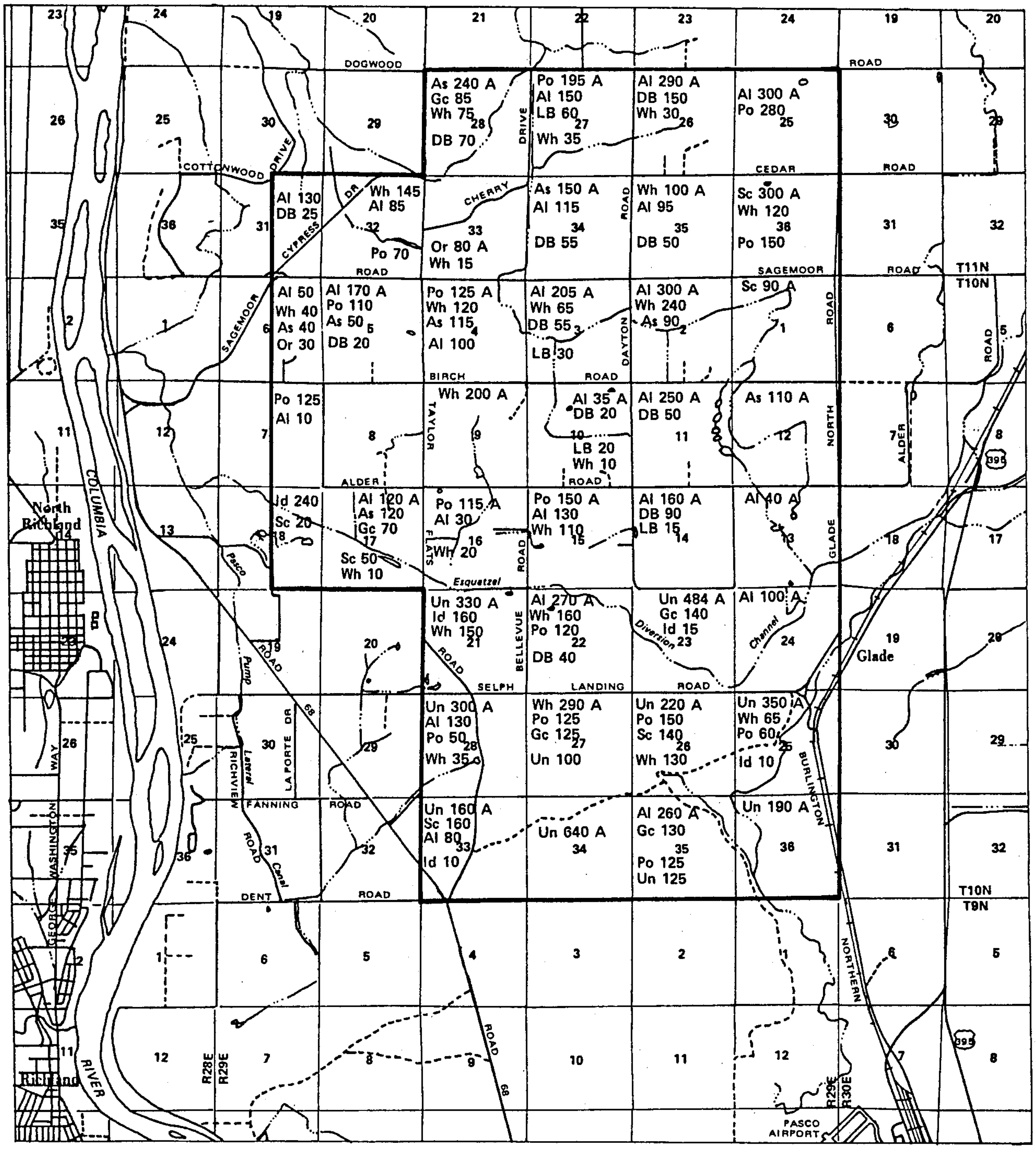
The crops and estimated acreage of each are listed in Table 14. The distribution of the crops by acres per section are shown in Figure 12. Acreage for each crop was estimated using Agricultural Stabilization and Conservation Service (ASCS) lists of certified crops. About 30% of the crops grown in the area are not certified with ASCS in 1988. Alfalfa, winter wheat, potatoes, asparagus, and field corn are the main crops grown in the area (Ford, 1989). Minor crops include dry and lima beans, barley, carrots, Sudan grass hay, onions, melons, squash, grass seed, alfalfa seed, and clover seed (Sorensen, 1989). Small stonefruit and apple orchards, strawberries, and grapes are grown in the north part of the study area. There is a limited amount of livestock; however, beef cattle may be grazed in winter (Sorensen, 1989).

Table 14. Franklin County Study Area Crop Acreage (approximate)

Crop	Percent of Area
alfalfa	15
uncultivated	11
wheat	10
potatoes	9
asparagus	5
idle	5
corn (sweet)	4
beans (dry)	3
corn (grain)	3
beans (lima)	2
minor crops	2
fruit crops	1

Note: 30% of the crops in the study area are not certified with the Agricultural Stabilization and Conservation Service

Annual rainfall in the Columbia Basin ranges from 6-10 inches (WSU Cooperative Extension, 1988b). This factor, combined with the well drained soil, increases the need for irrigation. Water for irrigation is supplied mainly from surface water sources. Ground water sources are used only in the south part of the study area. About 50% of the cultivated areas are irrigated with center-pivot systems. These systems supply water in circular paths above the crop through sprinkler heads or nozzles. About 40% of the irrigation systems are wheel-line (irrigation pipe with sprinklers moved by wheels), handline (similar to wheel-line except moved by hand) and solid set (buried pipes with sprinkler heads above ground) sprinklers. Rill (furrow) systems (partial flooding of soil surface by water sent through rows or furrows) make up about 10% of the irrigation systems (Holmes, 1989).



LEGEND

STUDY AREA BOUNDARY

Al = Alfalfa
Wh = Wheat
Po = Potatoes
As = Asparagus
Sc = Sweet Corn
Gc = Grain Corn
DB = Dry Beans
LB = Lima Beans
Or = Orchard
Id = Idle
Un = Uncultivated

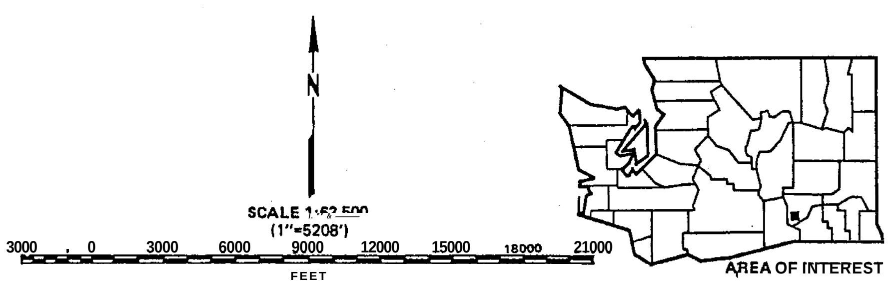


FIGURE 12: FRANKLIN COUNTY STUDY AREA; LAND-USE MAP

Agricultural Chemical Usage

Pesticides

Many of the target pesticides analyzed in the Pilot Study have been used in the Franklin County study area. However, no records of specific information on actual application rates, locations, times, and formulations used are readily available. Table 15 summarizes the pesticide use for the study area. Table 15 is based on four sources: 1) inquiries with Franklin County pesticide dealers on what was sold in the county in 1985, 2) interviews with WSU Cooperative Extension agents, 3) a statewide U.S. EPA survey of Cooperative Extension agents (U.S. EPA, 1986), and 4) WSU Cooperative Extension spray guides and publications. The first two sources are probably most useful for estimating actual pesticide use. Pesticide use for major study area crops is discussed below.

Carbofuran, hexazinone, methomyl, and metribuzin are used on alfalfa in the area (Ford, 1989). Sorensen (1989) reports that aldicarb, dichloropropene, methomyl, and metribuzin (often in combination with alachlor) are used on potatoes in the study area. According to Sorensen, dichloropropene is used as a soil fumigant for carrots grown fresh for market in the study area. 1,2-dichloropropane (1,2-DCP) detected in two area wells is a contaminant in the manufacture of dichloropropene (See Whatcom County Agricultural Chemical Usage in this report).

Ford also reports that diuron and metribuzin and small amounts of chloramben, dicamba, and methomyl are used on asparagus in the area. EPA lists picloram as being used on asparagus in the county.

Alachlor, atrazine, cyanazine, dicamba, methomyl, metholachlor and small amounts of 2,4-D are used on corn in the area (Ford and Sorensen, 1989). Alachlor, bentazon, and metolachlor are used on beans in the area and bentazon is used on peas.

Extension references and Sorensen included dacthal for use on onions in the area. DCPAs (dacthal and metabolites) were detected in seven area wells, although reportedly dacthal is not widely used. Extension references report that dacthal is used on squash and melons.

Bromacil, detected in one USBR monitoring well, is not widely used in the area. Also Frederickson (1989) reported that during the fall of 1987, diuron was used on the edging of all oiled roads in the study area.

Fertilizer

Nitrogen is a major production cost for most crops in the Columbia Basin (WSU Cooperative Extension, 1988b). Nitrogen is applied at planting in granular form and throughout the growing season in liquid form through irrigation systems (Sorensen, 1989). Table 16 summarizes the nitrogen use associated with the major crops in the region using center-pivot irrigation systems (WSU Cooperative Extension, 1988b). This information is considered to be representative of actual usage at well-managed farms in the Columbia Basin. In general, the nitrogen fertilizer applications range from about 50 to 150 pounds per acre.

Table 15. Pesticide **Use** on Franklin Study **Area** Crops

Chemical	Crop	Sold in the Region (1985)[1]	Use in area WSU Cooperative Extension Agent[2]	EPA[3]	Recommendedby WSU Cooperative Extension Spray Guides and Handbooks[4]
alachlor	corn	yes	yes	yes	yes
	legumes		yes	yes	yes
aldicarb	potatoes	yes	yes	yes	yes
atrazine	corn	yes	yes	yes	yes
bentazon	corn	yes	no	yes	yes
	legumes		yes	yes	yes
carbofuran	alfalfa	yes	yes	yes	yes
	corn		no	yes	yes
	grapes		Not Addressed	yes	yes
	potatoes		no	yes	yes
	wheat		no	no	yes
carboxin	wheat	yes	Small Quantity	yes	no
chloramben	asparagus	yes	Small Quantity	no	yes
	legumes		no	yes	yes
	melonlsquash		no	no	yes
cyanazine	corn		yes	yes	yes
dacthal	legumes	yes	no	yes	yes
	melon/squash		no	yes	yes
	onions		yes	yes	yes
dalapon	asparagus	no	no	yes	yes
	corn		no	no	yes
	legumes		no	yes	yes
	orchards		Not Addressed	yes	yes
	potatoes		no	no	yes
dicamba	asparagus	yes	Small Quantity	yes	yes
	corn		yes	yes	yes
	roadside		yes[S]	Not Addressed	Not Addressed
	wheat		Small Quantity	yes	yes
dichloro-propene	potatoes	yes	yes	yes	yes
	carrots		yes	yes	yes
	onions		no	yes	yes
diphenamid	orchards	yes	Not Addressed	yes	yes
diuron	alfalfa		no	yes	yes
	asparagus		yes	yes	yes
	grapes		Not Addressed	yes	yes
	orchards		Not Addressed	yes	yes
	roadside		yes[S]	Not Addressed	Not Addressed
fenamiphos	grapes	no	Not Addressed	yes	yes
hexazinone	alfalfa	yes	yes	yes	yes
methomyl	alfalfa	yes	yes	yes	yes
	asparagus		Small Quantity	yes	yes
	carrots		no	yes	yes
	corn		yes	yes	yes
	grapes		Not Addressed	yes	yes

Table 15. Pesticide Use on Franklin Study Area Crops

Chemical	Crop	Sold in the Region (1985)[1]	Use in area WSU Cooperative Extension Agent[2]	EPA[3]	Recommended by WSU Cooperative Extension Spray Guides and Handbooks[4]
methomyl	melon/squash		no	yes	yes
	potatoes		yes	yes	yes
	wheat		Small Quantity	yes	yes
metolachlor	corn	yes	yes	yes	yes
	legumes		yes	yes	yes
	orchards		Not Addressed	yes	yes
	potatoes		no	yes	yes
metribuzin	alfalfa	yes	yes	yes	yes
	asparagus		yes	yes	yes
	legumes		no	no	yes
	potatoes		yes	yes	yes
oxamyl	orchards		Not Addressed	yes	yes
	potatoes		no	yes	yes
picloram	asparagus	yes	no	yes	no
propham	alfalfa	yes	no	yes	yes
	legumes		no	yes	yes
simazine	alfafa	yes	no	yes	yes
	asparagus		no	yes	yes
	grapes		Not Addressed	yes	yes
	orchards		Not Addressed	yes	yes
terbacil	alfafa	yes	no	yes	yes
	asparagus		no	yes	yes
	orchards		Not Addressed	yes	yes
2,4-D	corn	yes	Small Quantity	no	yes
	grapes		Not Addressed	no	yes
	orchards		Not Addressed	no	yes
	roadside		yes[5]	Not Addressed	Not Addressed

References:

[1]Ebbert (1987)
[2]Ford (1989), Sorenson (1989)
[3]EPA (1986)
[4]Burrill (1988), Capizzi (1988), Koespell (1988), WSU Cooperative Extension (1988c)(1988f)
[5]Frederickson (1989)

Table 16. Average Amount of Nitrogen Fertilizer Used on Columbia Basin Crops Under Center-Pivot Irrigation

Crop	Form	Pounds Per Acre
Fall potatoes following alfalfa	Dry Liquid	150 210
Alfalfa establishment following wheat or barley	Dry	0-20
Winter wheat	Dry or liquid	100-150
Grain corn	Dry or liquid	150-200
Processed sweet corn	Dry Liquid	50 250
Dry beans	Dry	50
Spring barley	Dry Liquid	100 60
Carrots	Dry Liquid	75-100 125

Note: These are the total, actual amounts applied per acre by producers considered to be representatives of well managed farms in the Columbia Basin region. Refer to text for general application times in the study area.

Reference: WSU Cooperative Extension (1988b).

YAKIMA COUNTY STUDY AREA

Location and Physiography

The Yakima County study area (Figure 13) is located in the southeastern portion of the county about three miles southwest of Sunnyside. It occupies Sections 3-5, 8-10, 15-17, the northern half of Section 23, and the western halves of Sections 2, 11 and 14, of Township 9 North, Range 22 East, an area of about 9-1/2 square miles. The study area is bounded by the Yakima River on the west and south, Snipes Mountain on the north, and Midvale Road on the east.

The physiography consists of two generally flat-lying terraces that gently slope to the south. The upper terrace occupies the northeastern one-third of the study area and stands about 25 feet above the lower terrace. The lower terrace represents the floodplain of the Yakima River prior to the river being dammed.

Geology

The Yakima Valley lies within the Columbia Plateau, a major physiographic province formed by repeated extrusions of lava between six to 17.5 million years ago. The thickness of the volcanic sequence, the Columbia River Basalt Group, may exceed 15,000 feet locally. Tectonic warping combined with fluvial and lacustrine processes have resulted in the deposition of sedimentary deposits on the Columbia River Basalt Group. The thickness of sedimentary deposits is about 200 feet in the Sunnyside area (Drost and Whiteman, 1986).

Five geologic units occur in the study area: alluvium, loess deposits, catastrophic flood slack-water sediments, Tertiary fluvial deposits (Ringold Formation) and basaltic flows of the Columbia River Basalt Group with sedimentary interbeds (Campbell, 1977 and 1979). The Saddle Mountains Basalt unit, the uppermost basalt unit of the Columbia River Basalt Group, and sedimentary interbeds of the Ellensburg Formation underlie the study area and crop out at Snipes Mountain. The Ringold Formation (possibly correlative with the uppermost Ellensburg Formation (Campbell, 1977)) consists of Tertiary fluvial sediments with some lacustrine deposits and uncomformably overlies the Columbia River Basalt Group. The detailed lithology of the Ringold has not been defined near Sunnyside but commonly consists of three units: an upper well-bedded silt and sand; a well-sorted, variably-cemented sand and gravel; and a lower silt-clay unit which is usually blue but can be green, brown or tan (Geoscience Research Consultants, 1978). The upper unit of the Ringold Formation crops out at Peanut Hump east of the study area.

Catastrophic flood slack-water sediments, associated with glacial meltwater, consist of sand and gravel and underlie the upper terrace in the northeastern half of the study area. Loess deposits, consisting of wind-blown silt and fine sand derived from glacial meltwater plains during the Pleistocene Epoch, mantle the terrace deposits. Alluvium, consists of silt, sand, and gravel, and underlies the modem floodplain of the Yakima River and lower terrace in the south western half of the study area.

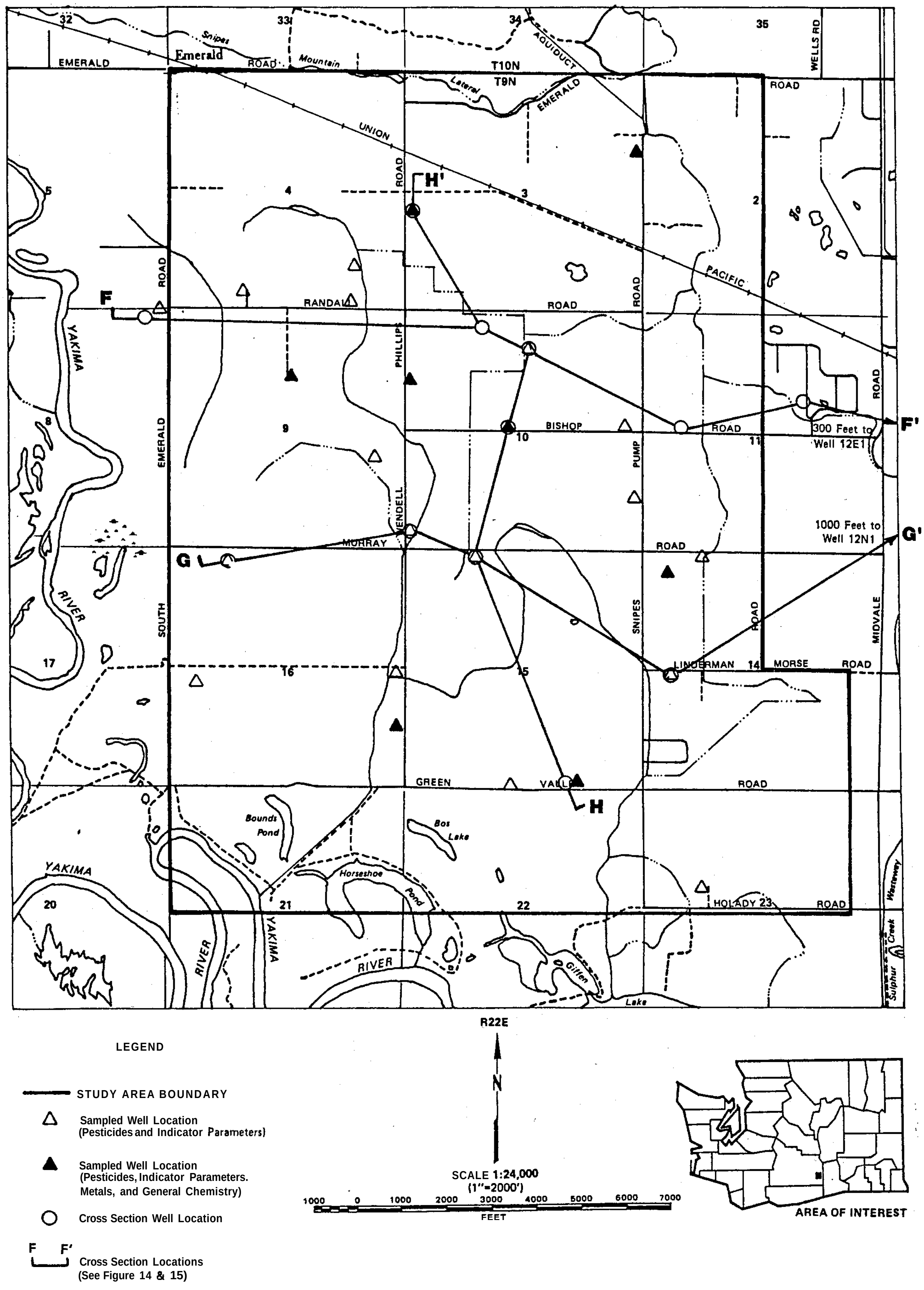


FIGURE 13: YAKIMA COUNTY STUDY AREA; WELL LOCATION MAP

Regional Hydrogeology

For conceptual purposes, four regional aquifer systems have been identified within the Columbia Plateau: three within the Columbia River Basalt Group and one within the overlying sedimentary deposits. The aquifer within the uppermost portions of the sedimentary deposits is the target aquifer for the Pilot Study. It consist of alluvium, catastrophic flood deposits, and the Ringold Formation.

The regional ground water flow direction in the sedimentary deposits is toward the Yakima River. In the Sunnyside area, the flow is thought to be toward the south and southeast (Bauer *et* al., 1985) or southeast and southsoutheast (Kinnison and Sceva, 1963).

Study Area Hydrogeology

Three hydrogeologic units significant to the study have been identified beneath the study area based on published geologic reports and well log reports. These units are an Upper Aquifer that consists of two hydraulically-connected units, a sand unit which overlies a gravel unit, and an underlying silt-clay Aquitard. The geometry of the units is shown in hydrogeologic cross-sections Figures 14 and 15. The upper aquifer is continuous beneath the study area and represents the target aquifer for this study. The upper sand unit, which ranges in thickness from about 50 to 70 feet, consists of alluvium and catastrophic flood slack-water sediments. The gravel unit ranges in thickness from 10 to 60 feet. Under most of the study area the two units appear to be hydraulically connected. However, at one location (Well 14M1, Figure 14), a silt unit, about ten feet thick appears to occur between the two units. The hydraulic conductivity of the gravelly facies of the Upper Aquifer, based on specific capacity data (Bradbury and Rothschild, 1985) of ten wells, is estimated to range from 400 to 2000 feet per day. None of the wells completed in the sand facies had sufficient data to estimate hydraulic conductivity.

The ground water flow pattern in the Upper Aquifer, based on water levels obtained in October 1988 (Figure 16), show that ground water flows southward and southwestward toward the Yakima River. Because the Upper Aquifer is shallow and unconfined, the flow pattern will be influenced seasonally by pumping and irrigation.

The silt-clay aquitard, probably the lower Ringold Formation, appears to be continuous beneath the study area; however, the geologic control is poor. The low permeability of the aquitard acts as a hydraulic barrier between the Upper Aquifer and the underlying basalt. Occasional water-bearing sand layers are present within the unit, but they do not appear to be continuous. The maximum observed thickness is about 400 feet (Well 08A1, Figure 14).

In nearby Toppenish Creek Basin, the USGS divided the sedimentary deposits into two hydrogeologic units: young valley fill and old valley fill which may be separated by the Touchet Beds, a lacusterine silt, clay and sand unit (USGS, 1975 and Skrivan, 1987). The upper sand unit of the Upper Aquifer may coincide with the young valley fill. The gravel unit of the Upper Aquifer may represent the upper portion of the older valley fill. The Touchet Beds appear to be absent beneath most of the study area.

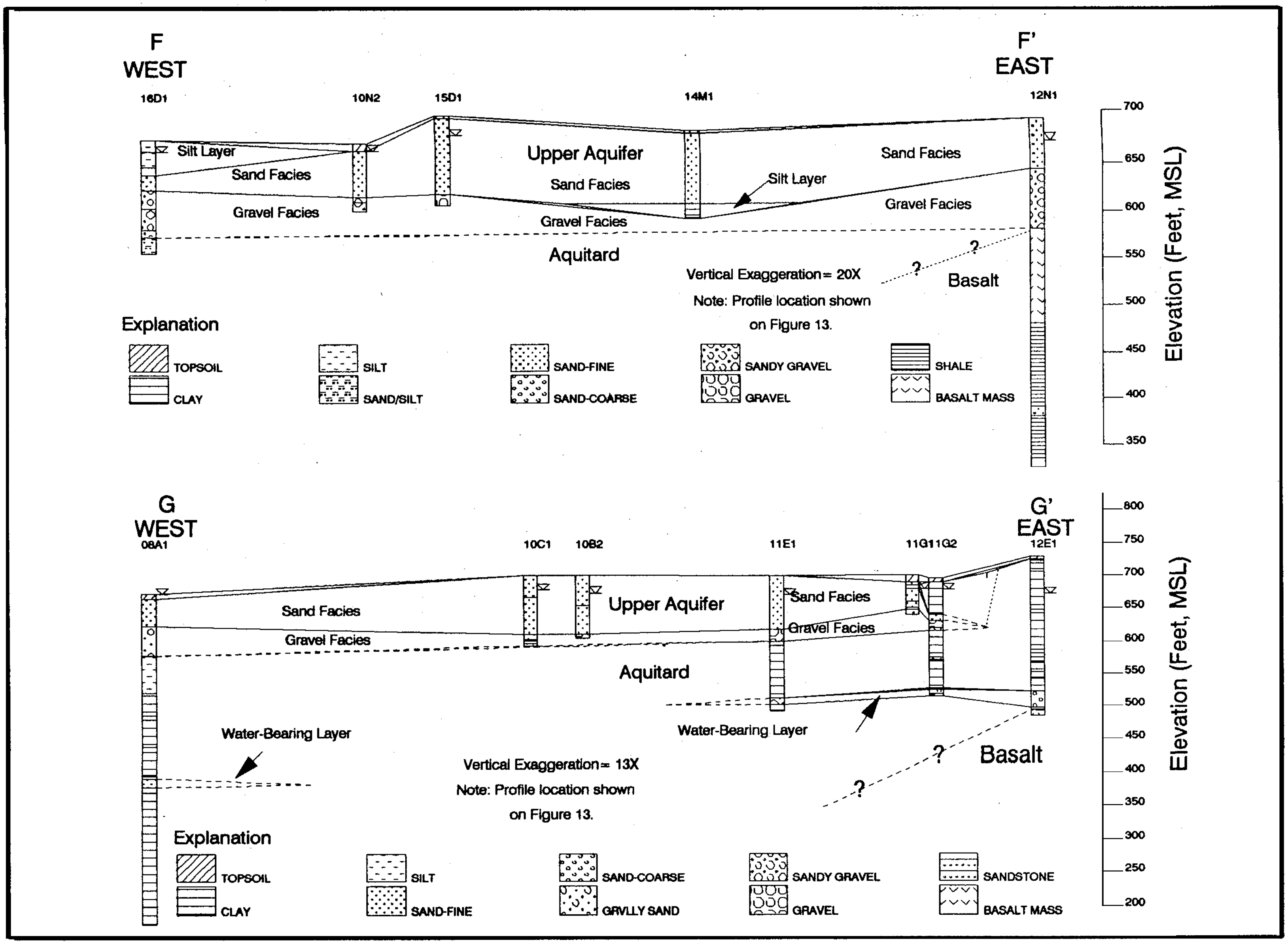


Figure 14: Yakima County Study Area; West-East Hydrogeologic Profiles

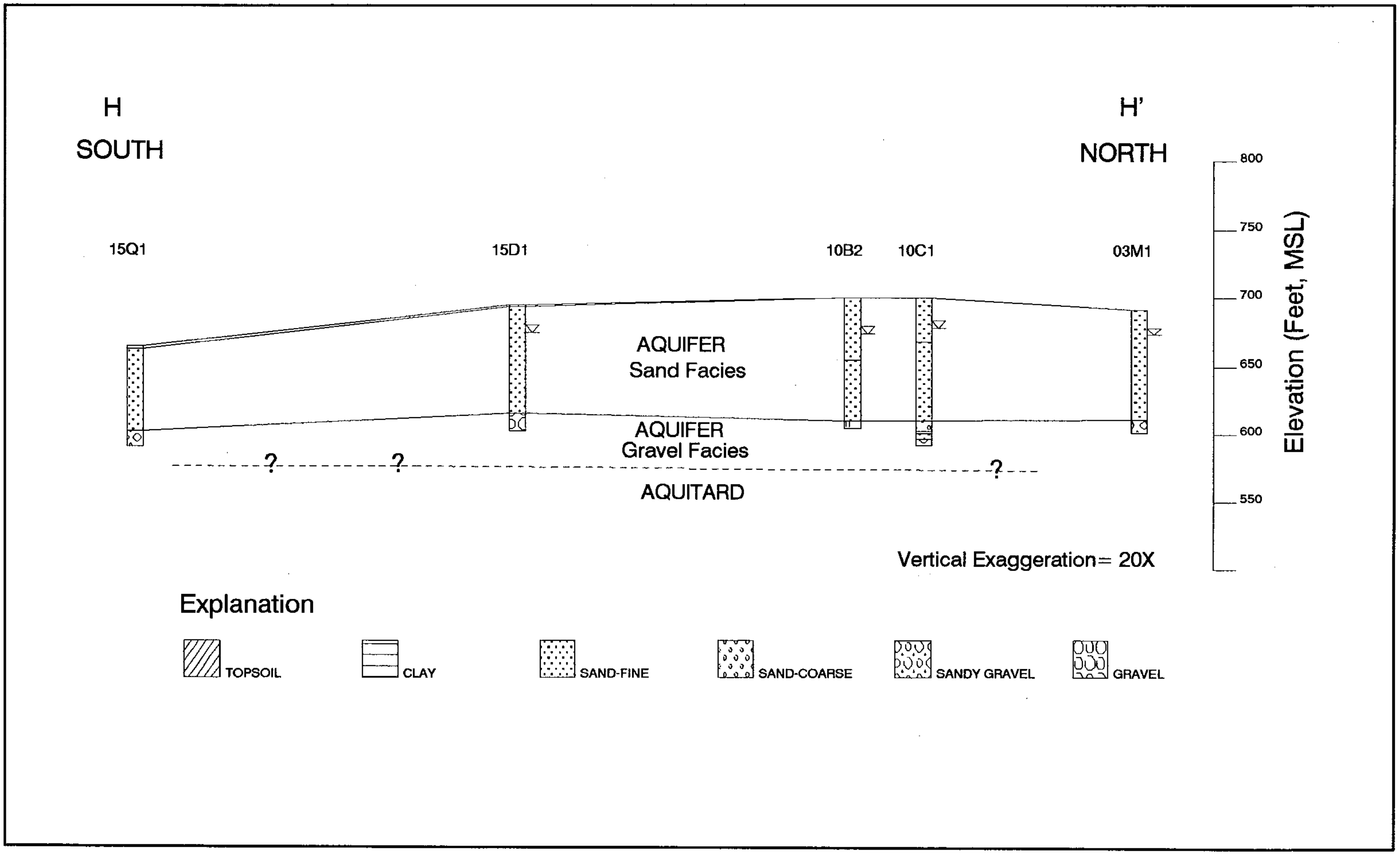


Figure 15: Yakima County Study Area; South-North Hydrogeologic Profile

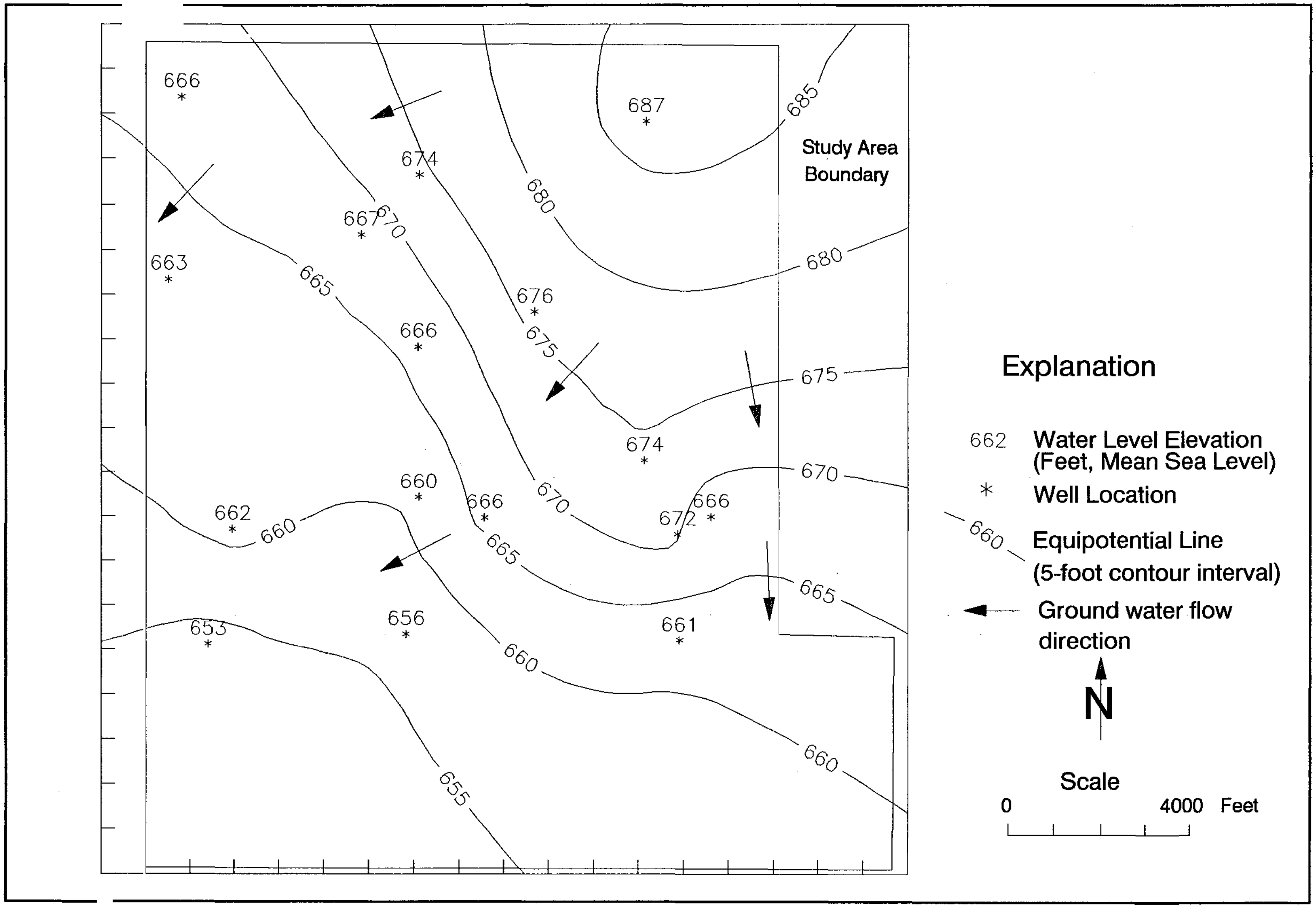


Figure 16: Yakima County Study Area; Water-Table Contour Map
October 1988

A well inventory, consisting of a compilation of well logs from Ecology's Central Regional Office files and a reconnaissance well survey conducted July 20-22, 1988, identified about 80 wells in the vicinity. Because all water use in the area is supplied by wells, many more wells are known to exist in the area that were not identified in the inventory. Most of the wells are used for irrigation or domestic water use.

Ground Water Quality Results

Pesticides

The location of the wells sampled in the Yakima County study area are shown in Figure 13. Twenty-five of the sampled wells are used for domestic water supplies and two are irrigation wells. Eight of the wells were sandpoints completed in the upper portions of the aquifer; most of the remainder of the wells were completed at depths exceeding 90 to 100 feet below the water table. None of the wells sampled serve public water supplies.

Atrazine was observed in one well in the Yakima County study area during the initial sampling at a concentration of 0.4 μg/L. Atrazine was not observed in the verification sample. The well in which atrazine was detected was a shallow well point located adjacent to and downgradient of a corn field.

The low detection frequency of pesticides in the Yakima County study area may be a function of the large saturated thickness of the target aquifer, and the depth of completion (greater than 90 feet) of most of the sampled wells.

Nitrate

Eight wells of the 27 wells (30%) sampled in the Yakima County study area showed detectable concentrations of nitrate/nitrite-N. The concentrations ranged from less than 0.01 to 6.2 mg/L with a mean concentration of 0.7 mg/L. No wells exceeded the MCL of 10 mg/L. Turney (1986) reported concentrations of nitrate-N in the sedimentary deposits commonly ranged from 1 to 5 mg/L in the Lower Yakima River basin. In the study are nitrate/nitrite-N concentrations are somewhat higher in shallow wells. Of the 27 wells sampled, nine wells are completed above a depth of 50 feet. The mean nitrate concentration for wells completed above 50 feet was 1.6 mg/L and the mean concentration for wells completed below 50 feet was 0.3 mg/L.

Conventionals and Trace Metals

Eight samples were tested for major cations and anions and trace metals. The results of these analyses are shown in Table 17. The major cations present in study area ground water are calcium, magnesium and sodium. Usually calcium and magnesium are dominant; but in one well, sodium was detected at concentration 145 mg/L. The major anion is bicarbonate which ranged in concentration from 160 to 328 mg/L. Turney (1986) reported that ground water in the sedimentary deposits is usually a calcium bicarbonate type and ground water in the basalt is a calcium-sodium bicarbonate type. Sulfate is present in concentrations ranging from 8.4 to 98 mg/L. Iron and manganese are common especially in the wells completed in the deeper gravelly facies. The concentrations of iron ranged from 0.01 to 0.79 mg/L. The secondary MCL for iron is 0.3 mg/L which was exceeded in one of the wells. Manganese which was

Table 17. Major **Cations/Anions** and Trace Metals, Yakima County Study Area, October 1988.

Well ID:	03H1	03M1	09B1	10E1	10F1	14D1	15Q2	16J2
Major Cations and Anions (mg/L)								
Sodium	23.9	42.1	15.7	28.3	7.7	27.0	145	16.9
Potassium	3.47	6.18	1.46	5.50	7.23	5.83	8.50	3.97
Calcium	49.9	37.8	83.2	29.8	68.0	39.2	44.2	32.6
Magnesium	26.1	15.5	25.7	11.2	22.6	15.4	16.2	10.1
Iron	0.01	ND	0.28	0.23	0.01	0.79	0.27	0.18
Manganese	0.02	0.06	0.20	0.50	ND	0.51	0.44	0.29
Carbonate(as $CaCO_3$)	ND	ND	ND	ND	ND	NT	NT	NT
Bicarbonate(as $CaCO_3$)	243	219	328	162	283	220	360	160
Sulfate	48	43	27	23	8.4	12	98	13
Chloride	11	10	10	14	3.7	4.2	3.4	3.5
NO, $+NO_2$-N	2.6	0.25	5.5	ND	6.2	ND	0.10	ND
Trace Metals (μg/L)								
Arsenic	9.6	10.5	5.8	5.1	6.1	6.7	11.7	2.0
Cadmium	0.2	ND	ND	ND	ND	ND	0.2	ND
Chromium	ND	ND	ND	ND	ND	ND	ND	ND
Copper	ND	ND	ND	11.0	ND	6.0	ND	ND
Lead	ND	ND	ND	ND	ND	ND	ND	ND
Mercury	ND	ND	ND	ND	ND	0.11	0.09	0.08
Nickel	ND	ND	ND	ND	ND	ND	ND	ND
Selenium	ND	ND	ND	ND	ND	ND	ND	ND
Zinc	9.4	ND	14	26	16	61	5	18

ND = Not detected
NT = Not tested

Notes: Major anions and cations are total values.
Trace metals are total recoverable values.

detected in seven of the wells ranged in concentration from 0.02 to 0.51. Turney (1986) reported an elevated manganese concentration (.3 mg/L) in the area. The secondary MCL for manganese is 0.05 mg/L which was exceeded in six of the wells. Many of the wells in the study area treat their drinking water to remove objectionable concentrations of iron and manganese. Zinc was observed in seven of the wells at concentrations that ranged from 5.0 to 61 μg/L.

Soils

The soils in the Yakima County study area are sandy, strongly alkaline, with some salt and water accumulation problems. The properties of study area soils are summarized in Table 18. The distribution of soils grouped by texture, permeability, and depth to seasonal high water table is shown in Figure 17. Silt loams cover 60% of the study area and loamy fine sands cover about 37% (Lenfesty and Reedy, 1985). The seasonal high water table is deeper than six feet for 70% of the area soils. The Clemen-Hezel-Quincy loamy fine sands, which are very deep and somewhat excessively drained, occur in the northeast half of the study area. The southwest half is dominated by silt loams which are very deep, somewhat poorly drained and artificially drained, and associated with the modem flood plain of the Yakima River. In some of the silt loams, alkali deposits have formed. In general, the organic contents of all study area soils are low averaging less than two percent. The properties of the soils are generally conducive to the migration of soluble constituents.

Crops and Irrigation

Crops and estimated percent acreage for the Yakima County study area are listed in Table 19. The distribution of crops and land use practices is shown in Figure 18. Alfalfa and hops which cover about 37% of the study area are the most common crops grown in the area. Row crops (wheat, silage corn or vetch) are also grown and cover about 12% of the area. Concord grapes, apple and cherry orchards occur in the northern half of the study area. Four feedlots and three dairies are also present.

Due to low precipitation, all crops in the study area are irrigated during the growing season. Average precipitation recorded in the Sunnyside area between 1951-1978 was 6.5 inches (Lenfesty and Reedy, 1985). Over half of this amount occurs between November and February. The most common irrigation systems are rills (furrows) and wheel-line sprinklers. Rill systems consist of partial flooding of the soil surface by water sent through furrows or rows. Rill irrigation is commonly used for hops because of the low cost, abundant water supply, and reduced occurrence of downy mildew infestations (WSU Cooperative Extension, 1985). Rills are also used to irrigate grapes. Conventional furrow systems in Washington are estimated to have less than 50% application efficiency; over half of the water applied is not used by the crop (WSU Cooperative Extension, 1985). Wheel-line systems are used to irrigate alfalfa, asparagus, and row crops. Wheel-line sprinkler systems consist of irrigation pipe raised on wheels with sprinklers at set intervals along the length of the pipe. Water is spread in a straight path over the field. Two center-pivot systems are also present in the area. Center-pivot systems consist of sprinkler pipe supported above the crop by towers on wheels at fixed spacings. Water is supplied in circular paths at uniform rates through sprinkler heads of nozzles (Washington Conservation Commission, 1988).

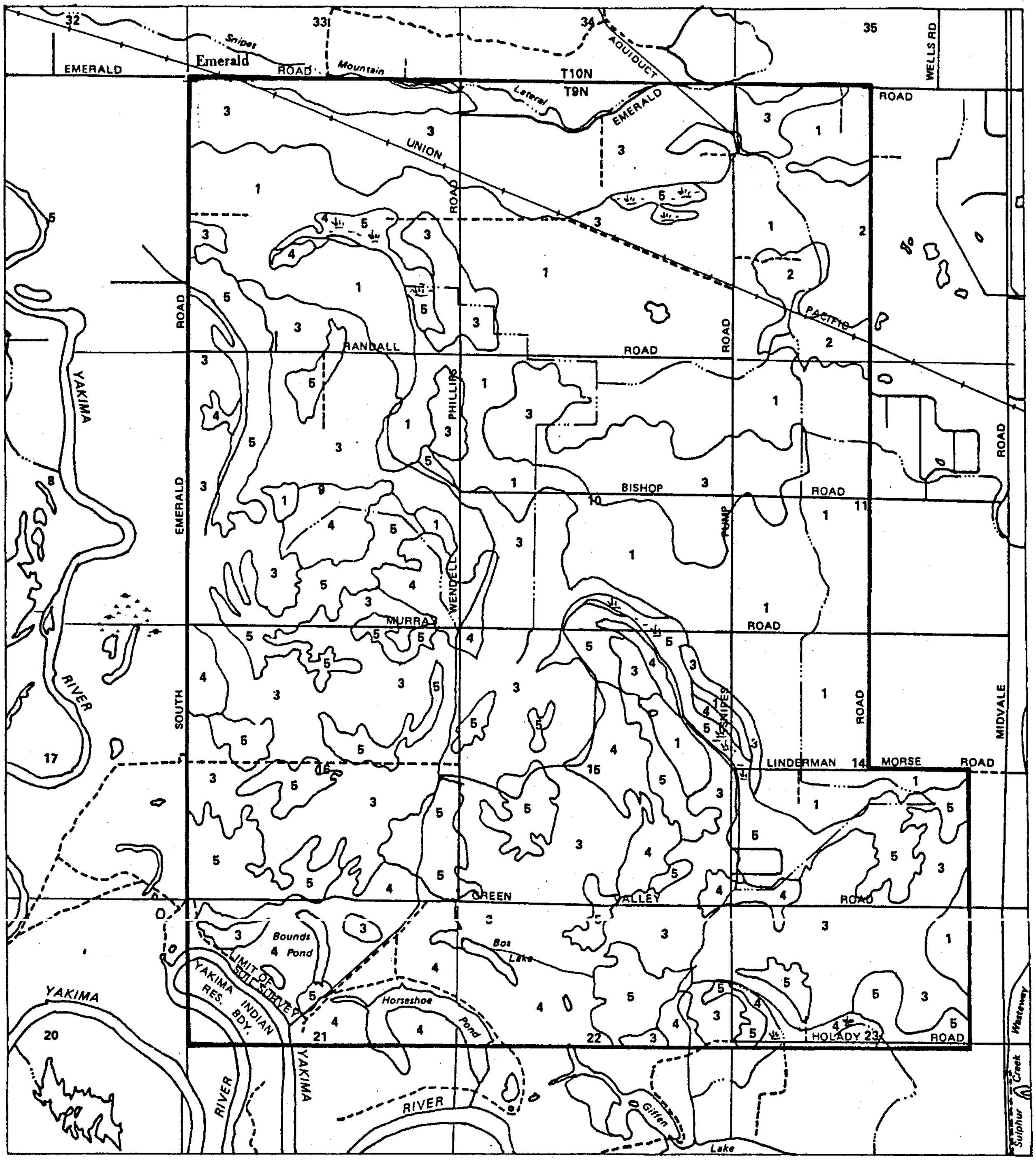
Table 18. Properties of Yakima County Study Area Soils

Name	Depth (in.)	Texture*	Permea-bility**	Seasonal High Water Table (ft.)	Organic Content (%)	% Study Area
Loamy Fine Sands:						
Clemen	0-10	vfsl	m	>6.0	1-2	
	10-60	sl & sil				
Hezel	0-22	lfs	r	>6.0	<.5	35
	22-60	vfsl/sil	ms			
Quincy	0-20	lfs	r	>6.0	.5-1	
	20-60	s				
Wanser	0-57	lfs	r	3.5-5.0 Jan-Jun	.2-.4	2
	57-60	s				
Silt Loam:						
Esquatzel	0-60	sil	m	>6.0	1-2	
Warden	0-5	sil	m	>6.0	.5-1	40
	5-19	sil				
	19-60	sil,l,vfsl				
Harwood	0-30	sil	m	>6.0	1-2	<1
Burke-Wiehl	30-60	hardpan	vs			
Fiander	0-2	sil	s	2.0-3.0 Jun-Dec	1-3	
	2-25	cl				10
	25-50	sil				
	50-60	lvfs				
Kittitas	0-41	sil	ms	1.5-3.5 Jun-Nov	2-5	
	41-60	fsl				
Outlook	0-60	sil	m	2.0-4.0 May-Dec	1-2	
Sinloc	0-45	sil	m	1.5-3.5 May-Oct	.5-1	
	45-60	lfs	r			10
Umapine	0-60	sil	m	2.0-4.0 Nov-Jun	.5-1	
Zillah	0-42	sil	m	2.5-4.0 Apr-Nov		
	42-60	ls	r			

*Texture (USDA)
- sil = silt loam
- cl = clay loam
- s = sand or sandy
- l = loam or loamy
- v = very
- f = fine
- c = coarse
- g = gravelly

**Permeability
- vs = very slow (<0.06 in/hr)
- s = slow (0.06- 0.2 in/hr)
- ms = moderately slow (0.2 - 0.6 in/hr)
- m = moderate (0.6 - 2.0 in/hr)
- mr = moderately rapid (2.0 - 6.0 in/hr)
- r = rapid (6.0 - 20.0 in/hr)
- vr = very rapid (>20.0 in/hr)

Reference: Lenfesty and Reedy (1985)



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LEGEND

STUDY AREA BOUNDARY

Loamy Fine Sands
1 = Clemen–Hezel–Quincy
2 = Wanser

Silt Loarnr
3 = Esquatzel–Warden
4 = Fiander–Kittitar
5 = Outlook–Sinloc–Urnapine–Zillah

Wetlands

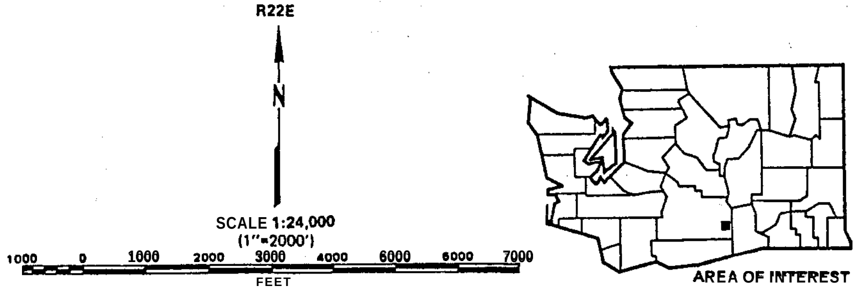

FIGURE 17: YAKIMA COUNTY STUDY AREA; SOILS MAP

Table 19. Yakima County Study Area Crop Acreage (Approximate)

Crop	Percent of Area
pasture	22
alfalfa	19
hops	18
uncultivated	16
row crops	12
grapes	9
orchards	2
livestock	2

Agricultural Chemicals Usage

Pesticides

Many of the target pesticides analyzed in the Pilot Study have been used in the Yakima County study area. However, no records of specific information on actual application rates, locations, times, and formulations used are readily available. Table 20 summarizes the pesticide use for the study area. Table 20 is based on four sources: 1) three Yakima County pesticide dealers, 2) an interview with a local pesticide consultant (Whitener, 1989), 3) a statewide U.S. EPA survey of WSU Cooperative Extension agents (U.S. EPA, 1986), and 4) WSU Cooperative Extension spray guides and publications. The first two sources are probably most useful for estimating the pesticides used locally. Pesticide use for major study area crops is discussed below.

Metribuzin and hexazinone (Velpar) use on alfalfa is common, while simazine, terbacil and 2,4-DB may be used to a limited extent (Whitener, 1989).

Dinoseb was used on hops before 1987 (WSU Cooperative Extension, 1985, and Whitener, 1989). According to Whitener, dichloropropene, a soil fumigant, is applied yearly in the lower Yakima area before planting hops, mint, and potatoes.

Whitener stated that alachlor, atrazine, cyanazine (Bladex), dicamba, diuron, and metolachlor may be used on grain corn in the area. Atrazine was detected in one study area well during the initial sampling round, but was not detected during the verification sampling round. Also, dicamba is used on wheat in the area.

Dinoseb, diuron, fenamiphos, and 2,4-D are used on grape crops. EPA also listed methomyl and dinoseb as pesticides used on grapes in Yakima County. Diuron, dalapon, oxamyl, simazine, terbacil, and 2,4-D are used on various orchard crops (Whitener, 1989).

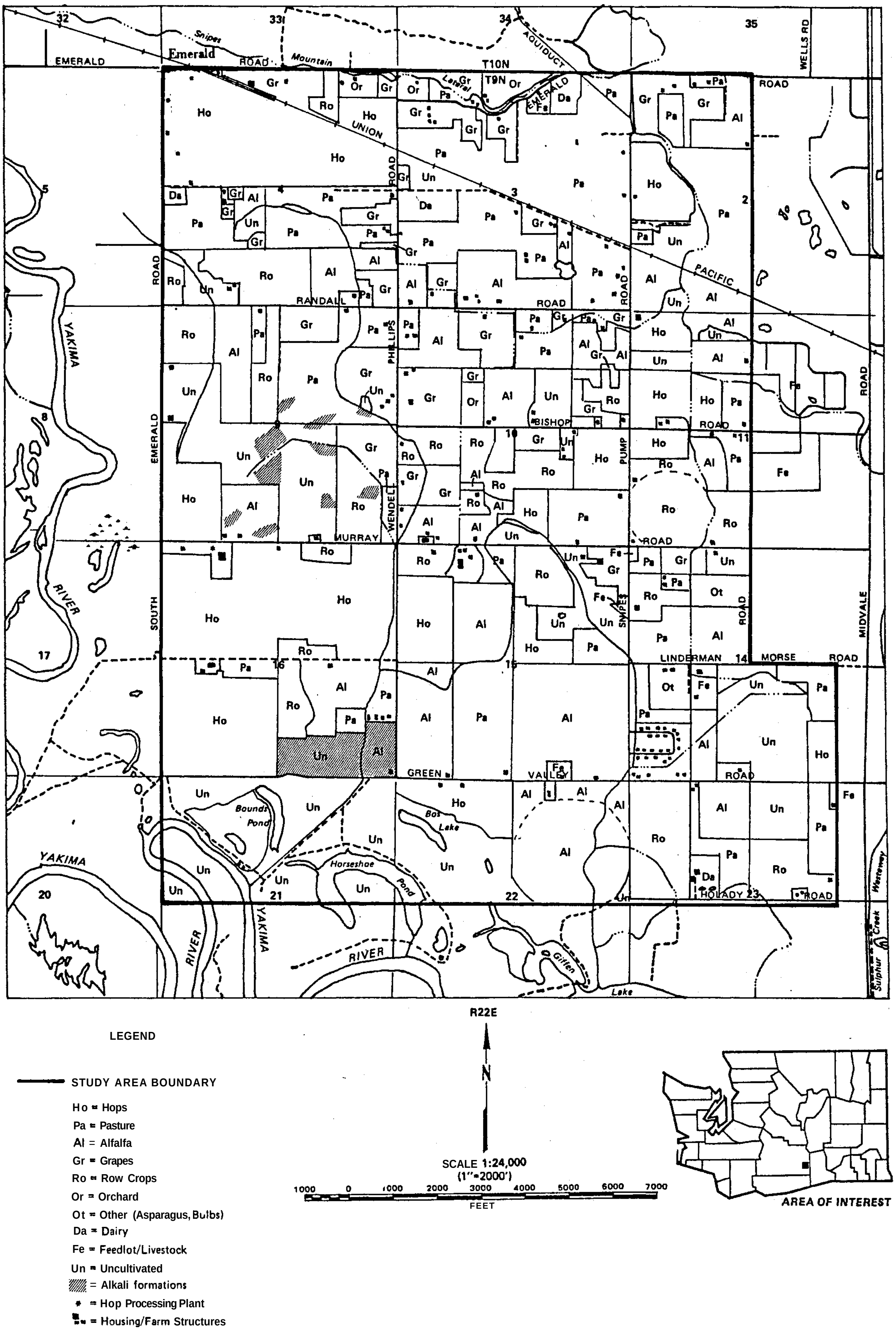

FIGURE 18: YAKIMA COUNTY STUDY AREA; LAND-USE MAP

Fertilizers

The major study area crop on which nitrogen fertilizer is used is hops (Whitener, 1989). About 120 pounds per acre of dry granular commercial nitrogen is applied to established hops fields annually and 240 pounds per acre may be applied to new plants. In addition, manure is added to about 80% of the hops fields (Whitener, 1989). Nitrogen fertilizers are commonly applied in the spring or may be split between spring and fall.

Nitrogen fertilizers are applied similarly to orchards. The application rates are variable, but commonly range from 75 to 100 pounds of total product per acre. Applications are usually made annually, but may be split between spring and fall (Whitener, 1989).

Nitrogen fertilizer use on winter wheat is similar to practices in Franklin County (Willett, 1989). The application rate is about 100 pounds of nitrogen per acre which is applied at planting in granular form and throughout the growing season in liquid form.

Table 20. Pesticide Use on Yakima County Study Area Crops

Chemical	Crop	Sold in the Region (1988)	Pesticide Consultant[1]	EPA[2]	Recommended by WSU Cooperative Extension Spray Guides and Handbooks[3]
alachlor	corn	yes	yes	yes	yes
atrazine	corn	yes	yes	yes	yes
bentazon	corn	yes	no	yes	yes
carbofuran	alfafa	no	no	yes	yes
	corn		no	yes	yes
	grapes		no	NA	yes
	wheat		no	no	yes
chloramben	asparagus	no	no	no	yes
cyanazine	corn	yes	yes	no	yes
dalapon	asparagus	yes	yes	no	yes
	orchards		yes	no	yes
dicamba	asparagus	yes	yes	yes	yes
	corn		yes	no	yes
	wheat		yes	yes	yes
dichloro-propene	hops	yes	yes	no	no
dinoseb	grapes	no	yes	NA	NA
	hops		no	no	yes
	orchards		no	yes	no
diphenamid	orchards	no	no	no	yes
diuron	alfalfa		no	yes	yes
	asparagus		yes	yes	yes
	corn		yes	yes	no
	grapes		yes	NA	yes
	orchards		yes	yes	yes

Table 20. (continued).

Chemical	Crop	Sold in the Region (1988)	Pesticide Consultant'	EPA[2]	Recommended by WSU Cooperative Extension Spray Guides and Handbook2
fenamiphos	grapes	yes	yes	NA	yes
hexazinone	alfalfa	yes	yes	no	yes
methomyl	alfalfa	yes	no	yes	yes
	asparagus		no	yes	yes
	corn		no	no	yes
	grapes		no	NA	yes
	hops		no	yes	no
	orchards		no	yes	no
	wheat		no	yes	yes
metolachlor	corn		no	yes	yes
	orchards		no	no	yes
metribuzin	alfalfa		yes	yes	yes
	asparagus		yes	yes	yes
oxamyl	orchards	yes	yes	yes	yes
propham	alfalfa	no	rare	yes	yes
simazine	alfafa	yes	SQ	yes	yes
	asparagus		yes	yes	yes
	grapes		no	NA	yes
	orchards		yes	yes	yes
terbacil	alfafa	yes	SQ	yes	yes
	asparagus		yes	yes	yes
	orchards		yes	yes	yes
2,4-D	alfalfa	yes	SQ	no	no
	corn		no	no	yes
	grapes		yes	NA	yes
	orchards		yes	no	yes

'Whitener (1989)
[2]USEPA (1986)
[3]Burrill (1988), Capizzi (1988), Koespell (1988), Cooperative Extension (1988e) (1988f)

Notes: NA = Not Addressed
SQ = Small Quantity

Pesticides

Eighty-one wells were sampled during initial sampling. In 23 of the 81 wells (27 percent), at least one pesticide was detected. All 23 wells with pesticide detections were resampled the following spring. With the exception of three instances, the verification sampling confirmed the findings of the initial sampling.

Pesticide results for each study area are shown in Table 21. The numbers in parentheses are results from the verification sampling. The frequency of pesticide detection varied between the study areas. The results for each of the study areas are discussed individually in the Results section of this report.

Table 21. Summary of Pesticide Results for the Agricultural Chemicals Pilot Study (Numbers in parentheses are verification sampling results.)

	Number of Detections	Detection Frequency	Concentration* Mean (µg/L)	Concentration Range* Study Area (µg/L)
Whatcom County				
1,2-Dichloropropane	9(9)	33	6.9(5.6)	0.3-24(0.4-20)
Dibromochloropropane	1(1)	3.7	0.36(0.3)	NA
Ethylene Dibromide	2(1)	7.4	1.5(1.6)	0.02-2.95(NA)
Carbofuran	1(0)	3.7	2.4(NA)	NA
Prometon	2(2)	7.4	0.55(3.5)	0.5-0.6(0.9-6.0)
Franklin County				
DCPAs(Dacthal and metabolites)	7(7)	26.0	0.7(0.6)	0.3-1.1(0.2-0.9)
1,2-Dichloropropane	2(2)	7.4	0.6(0.6)	0.4-0.8(0.3-0.9)
Bromacil	1(1)	3.7	14.9(12)	NA
Yakima County				
Atrazine	1(0)	3.7	0.4(ND)	NA

*Mean and range of detected pesticides. NA= Not applicable

Status and Health Advisories of Detected Pesticides

The classification, uses, and regulatory status of the eight pesticides detected during the Agricultural Chemicals Pilot Study are listed in Table 22. The use of all detected pesticides, with the exception of dacthal, is either canceled or restricted in Washington. Use of ethylene dibromide was canceled by U.S. EPA in 1984. Dibromochloropropane was canceled voluntarily except for use on pineapples in Hawaii in 1977. Use of 1,2-DCP was canceled in 1979, but is still present as a contaminant in the manufacture of 1,3-dichloropropene. (See Whatcom County Pesticide Use section in this report.) Atrazine, bromacil, carbofuran, and prometon were declared "state restricted use" pesticides in April 1989 because of their potential to contaminate ground water. These "state restricted use" pesticides are subject to recordkeeping requirements and can be applied only by a certified applicator or someone under their direct supervision.

Table 22. Classification, Use, and Status of Detected Pesticides

Pesticide Name	Classification	Use	Status
1,2-Dichloropropane	Halogenated Hydrocarbon	Fumigant	Canceled*
Atrazine	Triazine	Herbicide	Restricted**
Bromacil	Uracil	Herbicide	Restricted**
Carbofuran	Carbamate	Insecticide	Restricted**
Dacthal	Phthalic Acid	Herbicide	
Dibromochloropropane	Halogenated Hydrocarbon	Fumigant	Canceled*
Ethylene Dibromide	Halogenated Hydrocarbon	Fumigant	Canceled*
Prometon	Triazine	Herbicide	Restricted**

*Use of these pesticides has been canceled in the United States.

**Declared "state restricted use" due to ground water concerns:
can only be applied by a certified applicator or by someone under their supervision.

Maximum Contaminant Levels (MCLs) have not yet been established by **EPA** for any of the pesticides found during this study. However, proposed MCLs and/or lifetime drinking water health advisories have been calculated by **EPA.** These are listed in Table **23.** MCLs are enforceable public drinking water standards. They are the maximum permissible concentration of a contaminant in water which is delivered to any user of a public water system. MCLs are established by considering health effects, treatment technology, national costs, and limitations of laboratory methods. Lifetime drinking water advisories are not enforceable and are calculated based on toxicity information. They are not calculated for contaminants that are known or suspected carcinogens.

Table 23. Proposed Drinking Water Standards and Health Advisories for Pesticides Detected in the Pilot Study.

Pesticide	Proposed MCL (µg/L)	Lifetime Drinking Water Health Advisory (µg/L)	10-6 Cancer Risk* (µg/L)	Number of Wells with Pesticides Detected	Maximum Observed Concentration (µg/L)
Atrazine	3	3	--	1	0.4
Bromacil	--	90	--	1	14.9
Carbofuran	40	40	--	1	2.4
DCPAs (dacthal and diacid metabolite)	--	3500	--	7	1.1
Dibromochloropropane	0.2(1)**	--	0.03(1)**	1	0.4
1,2-Dichloropropane	5(5)**	--	0.6(6)**	11	24
Ethylene Dibromide	0.05(1)**	--	0.0004(2)**	2	2.95
Prometon	--	100	--	2	6.0

* EPA estimates that if an individual drinks water containing this pesticide at the indicated concentration over his or her entire lifetime, that individual would theoretically have no more than a one-in-a-millionadditional chance of developing cancer as a result of drinking this water.
** Number of occurrences exceeding the listed concentration are in parentheses.
Source: U.S. EPA (1989)

Observed concentrations exceeded the proposed MCL in five wells for 1,2-dichloropropane, one well for dibromochloropropane, and one well for ethylene dibromide. All wells that exceeded proposed MCLs were located in the Whatcom County study area. None of the observed concentrations exceeded lifetime drinking water health advisories.

Nitrate

Nitrate in ground water can result from multiple sources including natural processes. The presence of nitrate in ground water does not necessarily mean that ground water is being contaminated from agricultural practices. Under natural conditions, nitrate concentrations in ground water commonly are low, but they can vary widely depending on soil and vegetative types and climate. Davis and Dewiest (1966) reported "normal" ground water nitrate concentrations ranged from 0.1 to 10 mg/L.

The nitrite/nitrate-N results for each study area are summarized in Table 24. Nitrate/nitrite-N was detected in about three-quarters of the wells tested. Of the 81 wells sampled, 61 wells showed detectable concentrations of nitratelnitrite-N which ranged from 0.10 to 24.4 mg/L.

Table 24. Summary of Nitrate/Nitrite-N Results for the Agricultural Chemicals Pilot Study.

Study Area	Number of Detections	Detection Frequency (Percentage)	Concentration Mean (Range) (mg/L)	Number of Wells With >10 mg/L
Initial Sampling				
Whatcom County	26	96	6.7 (<0.01-24.4)	7
Franklin County	27	100	8.1 (0.5-18.8)	11
Yakima County	8	30	0.7 (<0.01-6.2)	0
Total	61	75	5.2 (<0.10-24.4)	18
Verification Sampling				
Whatcom County	12	100	11.0 (2.5-19.6)	6
Franklin County	10	100	6.0 (0.4-15.3)	3
Yakima County	1	100	3.4 (NA)	0
Total	23	100	8.5 (0.4-19.6)	9

The number of occurrences of nitrate/nitrite-N in each study area was variable. Detectable concentrations of nitrate/nitrite-N were observed in nearly all wells in the Whatcom and Franklin County study areas, whereas eight wells in the Yakima County study area showed detectable concentrations of nitratelnitrite-N. In the Whatcom County study area, seven wells exceeded the 10 mg/L standard. In the Franklin County study area, eleven wells exceeded the standard, and in the Yakima County study area, all concentrations were below 10 mg/L.

Reliable historical nitrate data for the study areas are limited. For the Franklin County study area wells sampled in the early 1950s prior to the importation of irrigation water show nitrate concentrations less than 1 mg/L (Ebbert, 1990b). In the Whatcom County study area, one well located about six miles east of the study area showed a nitrate concentration of 2.2 mg/L in 1960 (Turney, 1986b). It is not known whether this concentration is representative of conditions prior to any development. In the Yakima County study area, Turney (1986c) reported a well located about two miles east of the area was sampled in 1961 and showed a concentration of 0.5 mg/L. Turney also reported that two wells located about six miles north of the area were sampled in 1970 and showed concentrations of 0.2 and 0.4 mg/L.

The observed nitrate concentrations in the Whatcom County and Franklin County study areas are substantially higher than the historical concentrations. Also, six wells in the Yakima County study area exceed 2 mg/L nitrate/nitrite as N. Because agriculture is the primary land use in each of these study areas, it is likely that agricultural practices are the primary source of the elevated nitrate observed in the wells.

Indicator Parameters

A secondary objective of the Pilot Study is to evaluate indicator parameters that could be used to identify wells for pesticide testing. The ideal indicator parameter would have a strong positive correlation with pesticide occurrences, give repeatable and reliable results, and be inexpensive. Six potential indicator parameters were selected for the Pilot Study: potassium, total phosphorous, total organic halogens (TOH), total organic carbon (TOC), nitratelnitrite-N, and total dissolved solids. The indicator parameter results are listed by individual well in Tables A-4 through A-6 in Appendix A. Summary statistics are shown in Tables 25, 26, and 27. A concentration of one-half the level of detection was assigned to all non-detect results for calculating summary statistics.

Table 25 shows summary statistics for indicator parameter results for all wells based on whether pesticides were detected. In general, mean and median concentrations for nitrate/nitrite-N and TOH appear to be higher in wells with pesticides. The mean concentration for nitratelnitrite-N in wells with pesticides was 6.75 mg/L and for wells without pesticides was 4.58 mg/L. For TOH the mean concentration for wells with pesticides was 11.1 mg/L, but for wells without pesticides the mean concentration was 7.2 mg/L. Total phosphorus concentrations appear to be higher in wells without pesticides. Other indicator parameter concentrations are similar whether the wells had pesticides or not.

Table 26 lists summary statistics of indicator results for all wells for each study area. The study areas are listed in order of pesticide detection frequency highest to lowest. Nitrate/nitrite-N and TOH concentrations are higher in the study areas of higher pesticide detection frequency. Nitratelnitrite-N is 0.7 mg/L in the Yakima County study area (detection frequency 3.7%) and is 8.1 mg/L in Franklin County study area (detection frequency - 37%) and 6.7 mg/L in Whatcom County study area (detection frequency - 44%). The mean TOH concentration is 3.1 mg/L in the Yakima County Study Area and 9.7 and 12.2 mg/L in Franklin County and Whatcom County Study Areas, respectively. Potassium and total phosphorus appear to be higher in areas with lower frequency of pesticide detection.

Table 25. Summary Statistics for Indicator Parameter Results - Wells with Pesticides versus Wells without Pesticides

		Potassium	Total Phosphorus	Total Organic Halogen	Total Organic Carbon	NO_3/NO_2-N	Total Dissolved Solids
Wells without Pesticides							
Arithmetic Mean	=	4.6	0.16	7.2	4.7	4.6	345
Std. Dev.	=	3.3	0.26	8.0	2.7	5.5	155
Median	=	4.4	0.06	3.0	3.8	2.5	305
Geometric Mean	=	3.3	0.05	4.9	4.2	0.5	309
± 1 Std. Dev.	=	1.4-8.1	0.008-0.28	2.2-11.0	2.6-6.6	1.3-11.5	190-502
Sample Size	=	58	58	58	15	58	58
Wells with Pesticides							
Arithmetic Mean	=	3.9	0.03	11.1	3.7	6.8	278
Std. Dev.	=	4.2	0.08	8.3	1.8	4.6	167
Median	=	2.0	0.01	8.5	3.8	5.7	210
Geometric Mean	=	2.4	0.01	8.5	3.3	4.6	236
± 1 Std. Dev.	=	0.8-6.6	0.003-0.04	4.0-17.9	1.9-5.6	1.6-12.9	135-415
Sample Size	=	23	23	23	12	23	23

Table 26. Summary Statistics for Indicator Parameter Results, Initial Sampling - All Wells by Study Area

	Potassium	Total Phosphorus	Total Organic Halogen	Total Organic Carbon	NO_3/NO_2-N	Total Dissolved Solids
Whatcom County Study Area						
(Pesticide Detection Frequency= 44%)						
Arithmetic Mean =	3.1	0.011	12.2	4.3	6.7	188
Std. Dev. =	4.4	0.014	10.7	2.4	5.3	114
Median =	1.2	0.006	8.0	3.8	5.2	180
Geometric Mean =	1.5	0.006	8.7	3.7	3.9	170
± 1 Std. Dev. =	0.5-44	0.003-0.017	3.5-21.6	2.2-6.2	0.9-17.7	113-254
Sample Size =	27	27	26	27	27	27
Franklin County Study Area						
(Pesticide Detection Frequency= 37%)						
Arithmetic Mean =	4.6	0.12	9.7	--	8.1	476
Std. Dev =	3.5	0.34	7.0	--	5.0	126
Median =	3.7	0.017	8.0	--	7.8	460
Geometric Mean =	3.5	0.024	7.5	--	6.0	556
± 1 Std. Dev. =	1.6-7.5	0.005-0.106	3.3-17.1	--	2.3-15.3	414-745
Sample Size =	27	27	26	--	27	27
Yakima County Study Area						
(Pesticide Detection Frequency= 3.7%)						
Arithmetic Mean =	5.5	0.24	3.1	--	0.7	332
Std. Dev. =	1.8	0.13	2.1	--	1.6	113
Median =	5.8	0.21	2.5	--	0.005	290
Geometric Mean =	5.1	0.20	2.8	--	0.04	315
± 1 Std. Dev. =	3.4-7.9	0.11-0.38	1.9-4.0	--	0.004-0.43	227-437
Sample Size =	27	27	27	--	27	27

Table 27. Summary Statistics for Indicator Parameter Results by Study Area, Initial Sampling - Wells with Pesticides vs Wells without Pesticides

		Potassium	Total Phosphorus	Total Organic Halogen	Total Organic Carbon	NO_3/NO_2-N	Total Dissolved Solids
Whatcom County Study Area							
(Pesticide Detection Frequency = 44%)							
Wells without Pesticides							
Mean	=	2.7	0.013	12.1	4.7	6.2	210
Std. Dev.	=	4.1	0.013	11.7	2.7	5.9	145
Median	=	1.2	0.006	7.0	3.8	4.6	180
Sample Size	=	15	15	15	15	15	15
Wells with Pesticides							
Mean	=	3.5	0.010	12.5	3.7	7.4	161
Std. Dev.	=	4.8	0.015	8.9	1.8	4.4	41
Median	=	1.2	0.005	10.0	3.9	6.8	165
Sample Size	=	12	12	11	12	12	12
Franklin County Study Area							
(Pesticide Detection Frequency = 37%)							
Wells without Pesticides							
Mean	=	4.5	0.16	9.3	--	9.0	476
Std. Dev.	=	3.6	0.42	6.5	--	5.0	106
Median	=	3.7	0.019	7.8	--	9.2	470
Sample Size	=	17	17	16	--	17	17
Wells with Pesticides							
Mean	=	4.7	0.045	10.4	--	6.6	428
Std. Dev.	=	3.3	0.089	7.3	--	4.6	149
Median	=	3.7	0.010	8.0	--	6.1	425
Sample Size	=	10	10	10	--	10	10
Yakima County Study Area							
(Pesticide Detection Frequency = 3.7%)							
Wells without Pesticides							
Mean	=	5.7	0.24	3.1	--	0.7	338
Std. Dev.	=	1.6	0.14	2.2	--	1.6	111
Median	=	5.9	0.20	2.5	--	0.0	295
Sample Size	=	26	26	26	--	26	26
Wells with Pesticides							
Mean	=	1.6	0.23	2.5	--	0.6	190
Std. Dev.	=	--	--	--	--	--	--
Median	=	--	--	--	--	--	--
Sample Size	=	1	1	1	--	1	1

Table 27 lists summary statistics for indicator parameters by study area and by wells with and without pesticides. For the Whatcom County study area there appears to be little difference in concentrations between wells with or without pesticides. Nitrate/nitrite-N is slightly higher in wells with detected pesticides. For Franklin County study area, the nitratelnitrite-N concentrations are higher in wells without pesticides. This is counter to the general trends discussed above for nitrate/nitrite-N. Also, mean and median concentrations for total phosphorus are higher in wells without pesticides. Other indicators appear to be similar for wells with or without pesticides. In the Yakima County study area, only one well had a detectable pesticide and there is insufficient information for comparison.

The distributions for the indicator parameter concentrations and logarithms of indicator parameter concentrations were tested for normality using the Kolmogorov-Smirnov goodness of fit method (Zar, 1984). With the exception of potassium, all indicator sample distributions were determined to be non-normal. Therefore, a non-parametric significance test, the Mann-Whitney Test, was used to compare indicator concentrations in wells with pesticides against concentrations in wells with no pesticides detected. The Mann-Whitney Test is a rank sum statistical test that can be used for comparing unequal sample sizes. The calculated T values and the lower and upper critical values for $p=0.05$ and $p=0.10$ are listed for Whatcom and Franklin County study areas in Table 28. The Yakima County study area had only one pesticide occurrence and was not tested. The results show that there is no statistical difference between indicator parameter concentrations for wells with pesticides compared to wells without pesticides at the 95% or 90% confidence interval.

In summary, Tables 25 and 26 show that nitrate and TOH concentrations appear to be higher in the study areas with higher pesticide detection frequencies. This suggests that nitrate and TOH may be useful for identifying general areas where pesticides may have migrated to ground water. However, as shown by the Mann-Whitney Test, none of the indicator parameters can be used to reliably identify specific wells that may have pesticide contamination.

Data Limitations

Limitations of the Pilot Study results should be considered when interpreting findings. Limitations of the Pilot Study results are summarized as follows:

- The relative susceptibility and vulnerability of the ground water of Washington State has not been defined in a comprehensive or consistent manner. For this discussion "susceptibility" is the potential for ground water contamination based on physical properties of the soil and aquifer, whereas "vulnerability" is potential for ground water contamination as a function of susceptibility combined with land-use. Study areas selected for this project are considered to be vulnerable to ground water contamination from agricultural chemicals based on limited data. It is not known whether these areas represent the most vulnerable conditions or to what extent these areas are representative of ground water vulnerability for other areas of the state.

Table 28. Mann-Whitney Calculations for Indicator Parameter Results

Indicator Parameter	Nnp	Np	W	T	a = 0.05 Lower T(a/2)	a = 0.05 Upper T(1-(a/2))	a = 0.10 Lower T(a/2)	a = 0.10 Upper T(1-(a/2))
Whatcom County Study Area								
Potassium	15	12	177	98	50	130	56	124
Phosphorus	15	12	156	77	50	130	56	124
TOH	15	11	161	95	45	120	51	114
TOC	15	12	152	74	50	130	56	124
Nitrate	15	12	190	112	50	130	56	124
TDS	15	12	156	78	50	130	56	124
Franklin County Study Area								
Potassium	17	10	143	88	46	124	52	118
Phosphorus	17	10	126	71	46	124	52	118
TOH	16	10	140	84	43	117	49	111
TOC	--	--						
Nitrate	17	10	119	64	46	124	52	118
TDS	17	10	121	66	46	124	52	118

Where:
- Nnp = Number of wells without pesticides.
- Np = Number of wells with pesticides.
- W = Rank sum of indicator parameters with pesticides.
- T = Mann-Whitney test statistic. T=W-[Np(Np+1)/2]
- T(a/2) = Lower critical value from tables.
- T(1-(a/2)) = NpNnp-T(a/2)
- a = Level of significance, as shown.

Hypothesis: Concentrations of indicator parameters in wells with pesticides are equal to concentrations of indicator parameters in wells without pesticides.

The hypothesis can be rejected when T exceeds the range of T(a/2) and T(1-(a/2)).

Reference: NCASI(1985)

Pesticide use information for each of the study areas was limited or unavailable. In particular, information on formulations used, and amounts and timing of pesticide applications was not available for specific areas as well as information to accurately estimate quantities of specific pesticides applied within study areas based on known patterns of pesticide use. This prevented optimal selection of sampling wells and analytes of concern.

- Samples were obtained from water-supply wells using existing pumps and plumbing. Water-supply well intakes are commonly installed within the most productive portions of aquifers which may not be the portion of the aquifer most susceptible to contamination. Also, pumps used for water supply are commonly not optimal for sampling ground water and can be responsible for altering water quality samples (for instance, stripping volatile organics or increasing concentrations of some metals).

- Samples probably represent the quality only of the water in close proximity to the well intake.

- Sampled wells are widely spaced and were not selected based on specific agricultural practices.

- The pesticide results represent only two sampling events. Ground water quality of shallow, unconfined aquifers underlying agricultural areas is likely to change both seasonally and over the long-term.

CONCLUSIONS

1. Pesticide residues were detected in shallow ground water in all three study areas. Twenty-three of 81 wells sampled showed at least one pesticide occurrence. However, the detection frequency between study areas is highly variable. Twenty-two of the wells with pesticides were observed in the Whatcom County and Franklin County study areas and one occurrence was observed in the Yakima County study area. Verification sampling confirmed the initial sampling results except for three occurrences. The single pesticide detection in the Yakima County study area was not observed during the verification sampling.

2. Eight different pesticides were detected in Pilot Study wells: 1,2-dichloropropane, DCPAs (dacthal and/or diacid metabolite), ethylene dibromide, prometon, atrazine, bromacil, carbofuran, and dibromochloropropane. The use of 1,2-dichloropropane, dibromochloropropane, and ethylene dibromide has been canceled in the United States, although 1,2-dichloropropane is present as a contaminant in a currently used pesticide. Atrazine, bromacil, carbofuran, and prometon are declared state "restrictive use" pesticides which are subject to recordkeeping requirements and can only be applied by certified applicators or by someone under their supervision. The degree that this classification will protect ground water is unknown. Dacthal is not subject to any special restrictions.

3. Concentrations from the initial sampling exceeded the proposed MCLs in five wells for 1,2-dichloropropane, one well for dibromochloropropane, and one well for ethylene dibromide. Concentrations from the verification sampling round exceeded the proposed MCL in four wells for 1,2-dichloropropane, one well for dibromochloropropane, and one well for ethylene dibromide. All wells that exceeded proposed MCLs were located in the Whatcom County study area. None of the observed pesticide concentrations exceeded lifetime drinking water health advisories calculated for non-carcinogenic contaminants.

4. Qualitatively, the Pilot Study results show that pesticides are migrating to shallow ground water in some areas of the state and that additional sampling and studies are needed to define the extent of the problem.

5. Extrapolation of Pilot Study findings to other Washington State aquifers is not justified in a quantitative sense and is beyond the scope of the Pilot Study. The reasons for this are listed as follows: a) The movement of pesticides to and through ground water is a complex process that is affected by numerous site-specific factors including soil and aquifer properties, climatic and irrigation patterns, physical and chemical properties of the pesticides, and application rates and timing of applications; b) the relative vulnerability of study area aquifers to other Washington aquifers is not known; and c) quantities and types of pesticides actually used over Washington aquifers is not known; only qualitative estimates are currently available.

6. 1,2-dichloropropane was detected in 11 wells and was the pesticide with the highest detection frequency. The occurrence of 1,2-dichloropropane in a 168-foot deep well may indicate significant vertical movement of the contaminant.

7. Nitrate/nitrite-N was detected in 61 of the 81 wells sampled. Eighteen of the wells (22%) showed concentrations greater than 10 mg/L, the primary MCL for public water systems. The detection frequency was variable between the study areas. Fifty three of the nitrate/nitrite-N detections were observed in the Whatcom County and Franklin County study areas and eight detections were observed in the Yakima County study area. All exceedances of the MCL occurred in the Whatcom County and Franklin County study areas. Although historic nitrate data is scarce, nitrate concentrations have increased substantially in all three study areas presumably because of agricultural practices.

8. Six potential indicator parameters were evaluated for their correlation with pesticide occurrence. These parameters were nitrate, total organic carbon, total organic halogens (TOH), potassium, total phosphorus, and total dissolved solids. Results suggest that nitrate and TOH may help to identify vulnerable areas for sampling, but none of the indicators showed significant correlations with pesticide occurrence on a well-by-well basis.

RECOMMENDATIONS

1. Pesticide residues were detected in Pilot Study wells with sufficient frequency to justify additional ground water sampling in other areas of Washington. The current base of information, primarily from the Pilot Study, is inadequate to draw conclusions on the extent of pesticide residues in Washington ground water. In the short-term, additional study areas should be identified and sampled similarly to the Pilot Study. Agricultural areas underlain by vulnerable aquifer systems should have priority. Two high priority areas, the Gleed area near Yakima and the Black Sands area near Quincy, were identified during the initial stages of the Pilot Study and will be sampled in 1990. After these two areas are addressed, the basis for identifying subsequent areas should include:

    - Areas characterized by elevated nitrate concentrations in ground water by compiling nitrate data from national (EPA's STORET), state (Department of Health), and county sources.

    - Areas with significant acreage of crops associated with pesticides that were detected in Pilot Study wells such as onions (dacthal and/or diacid metabolite), berries (1,2-dichloropane), and corn (atrazine).

    - Areas designated as vulnerable to ground water contamination by Ecology's vulnerability study (see Recommendation 2).

    - Areas of reported ground water contamination by pesticides, such as certain locations within Thurston and Skagit Counties.

2. The characterization of Washington's aquifers is incomplete and inconsistent on a statewide basis and much of the basic hydrogeologic information in the state is not easily retrievable. This was a major limitation of the Pilot Study for selecting study areas and wells. A program is needed within the state with the long-term objective of compiling all available hydrogeologic information and systematically characterizing Washington State's aquifers. Aquifer characterization includes definition of the lateral and vertical extent, hydraulic properties (hydraulic conductivity, transmissivity, and storage), recharge and discharge rates, flow patterns and directions including seasonal variations, water use, degree of interconnection between aquifers and surface water, and water quality. This information is essential to informed decision-making for future ground water quality and resource issues.

    Also, in the short-term, the relative susceptibility and vulnerability to contamination of the state's ground water needs to be defined comprehensively and consistently. Susceptibility, for this discussion, is a measure for the potential for contamination defined by the physical properties of the aquifer and overlying soils, whereas vulnerability is a function of land-use combined with susceptibility. The Ground Water Vulnerability Study currently being conducted by Ecology is a test project intended to define the relative susceptibility and vulnerability of the ground water in two counties in Washington. Methods developed during the Vulnerability Study should be used to assess susceptibility and vulnerability of ground water statewide.

3. The lack of actual pesticide use information for the pesticides of concern was a major limitation to study area and well selection and interpretation of results for the Pilot Study. The Washington State Department of Agriculture has the authority to require application records to be kept and submitted on request for many categories of applicators/products. Effective April 1989, Chapter 16-228 WAC (Records of Restrictive Use Pesticides) requires applicators to maintain records on use of an additional eighteen pesticides with properties conducive to migration to ground water. However, these data have limited use for future studies if not compiled in a readily available form. Financial support is needed so that this pesticide use information is collected and compiled in a central repository for easy retrieval.

4. Obtaining samples from private wells is necessary for a study of this kind. Well owners who cooperate in this kind of study naturally expect that some level of assistance will be provided if significant health-threatening contamination is identified. We recommend development of a formal policy and identification of a mechanism to provide technical assistance for well owners, in particular private well owners, in areas of known or suspected pesticide contamination from normal agricultural use.

5. At present there is no comprehensive long-term program which assesses ground water contamination by pesticide residues in Washington State. A recent long-term (20 year) planning effort (Ecology, 1990) identified improved monitoring of pesticide residues in the environment as among the highest future priorities. In response to this, Ecology will request that a portion of current revenues be assigned to evaluate pesticide residues in ground water. A part of this long-term response should include the design and implementation of a statewide ambient monitoring network.

6. Additional studies should be conducted in the original three study areas to fill data gaps and provide useful information on pesticide fate and persistence in ground water in Washington. These studies are listed as follows:

   - Define actual pesticide use in all three study areas and compare ground water quality results with actual pesticide use.

   - Define lateral and vertical extent of 1,2-dichloropropane contamination in the Whatcom County study area and conduct parallel efforts with dacthal (and metabolites) in the Franklin County study area.

- Define the persistence of 1,2-dichloropropane in Whatcom County study **area.** This would require time series sampling of contaminated wells; quantification of source applications; installation of monitoring wells; and predictive modeling using soil, aquifer and 1,2-dichloropropane properties.

  Expand the Whatcom County study area and conduct sampling in an area based on hydrogeologic boundaries and agricultural practices.

7. Support and fund research that defines the environmental fate of pesticides under conditions that exist in Washington State.

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APPENDIX A

Table A-1. Whatcom County Study Area Pesticide Results.

Site #	Sit. ID	Date	1,2-Dichloro-propane	Q	Dibromo-chloropropane	Q	EDB	Q	Prometon	Q	Carbofuran	Q
WS01	14P1	08/24/88	0.5		ND		ND		ND		ND	
WS01	14P1	05/23/89	0.9		NT		NT		NT		NT	
WS02	15A1	08/25/88	ND		ND		ND		ND		ND	
WS03	15C1	08/22/88	ND		ND		ND		ND		ND	
WS04	15H1	08/23/88	ND		ND		ND		ND		ND	
WS05	15P1	08/24/88	0.7		ND		ND		ND		ND	
WS05	15P1	05/22/89	0.4	J	NT		NT		NT		NT	
WS06	15Q1	08/24/88	ND		ND		ND		ND		ND	
WS07	15R2	08/25/88	6.7		ND		ND		ND		ND	
WS07	15R2	05/23/89	3.1		NT		NT		NT		NT	
WS08	21D1	08/24/88	ND		ND		ND		ND		ND	
WS09	21J5	08/23/88	ND		ND		ND		0.5		ND	
WS09	21J5	05/22/89	NT		NT		NT		6		NT	
WS10	21N1	08/25/88	ND		ND		ND		ND		ND	
WS11	21R5	08/24/88	14		ND		ND		ND		ND	
WS11	21R5	05/23/89	8.8		NT		NT		NT		NT	
WS12	22E2	08/23/88	0.6		ND		ND		ND		ND	
WS12	22E2	05/22/89	0.4	J	NT		NT		NT		NT	
WS13	22N2	08/24/88	9		0.36		ND		0.6		ND	
WS13	22N2	05/22/89	8.2		0.3	J	ND		1		NT	
WS13	22N2	05/22/89	8		0.3	J	ND		0.9		NT	
WS13	22N2	05/22/89	8.3		0.3	J	ND		0.9		NT	
WS14	22N7	08/22/88	ND		ND		0.02		ND		ND	
WS14	22N7	05/23/89	NT		ND		N D	J	NT		NT	
WS15	22R2	08/23/88	ND		ND		ND		ND		ND	
WS16	23A3	08/25/88	ND		ND		ND		ND		ND	
WS17	23B2	08/24/88	6		ND		ND		ND		ND	
WS17	23B2	05/23/89	6.9		NT		NT		NT		NT	
WS18	23D4	08/22/88	24		ND		ND		ND		ND	
WS18	23D4	05/22/89	20		NT		NT		NT		NT	
WS19	23P4	08/23/88	ND		ND		ND		ND		ND	
WS20	26A4	08/23/88	ND		ND		ND		ND		ND	
WS21	26C1	08/22/88	ND		ND		ND		ND		ND	
WS22	26D2	08/22/88	0.3		ND		ND		ND		ND	
WS22	26D2	05/23/89	1.4		NT		NT		NT		NT	
WS23	26G1	08/22/88	ND		ND		ND		ND		ND	
WS24	27C1	08/25/88	ND		ND		2.95		ND		2.4	J
WS24	27C1	05/23/89	ND		NT		NT		ND		ND	
WS24	27C1	05/23/89	NT		NT		NT		NT		ND	
WS24	27C1	05/23/89	NT		ND		1.52	J	NT		ND	
WS24	27C1	05/23/89	NT		ND		1.72	J	NT		NT	
WS24	27C1	05/23/89	NT		ND		1.5	J	NT		NT	
WS25	27D2	08/22/88	ND		ND		ND		ND		ND	
WS25	27D2	08/22/88	ND		ND		ND		ND		ND	
WS25	27D2	08/24/88	ND		ND		ND		ND		ND	
WS26	28D5	08/23/88	ND		ND		ND		ND		ND	
WS27	28G1	08/25/88	ND		ND		ND		ND		ND	

J= Estimated value. See Quality Aeeurance section for explanation.
ND= Analyte teeted but not detected.
NT= Analyte not tested.

Table A-2. Franklin County Study Area Pesticide Results (ug/L)

Site #	Site Name	Date	DCPAs	1,2-Dichloro-propane	Bromacil
MW30	10/29-01A1	09/21/88	ND	ND	14.9
MW30	10/29-01A1	05/30/89	NT	NT	11
MW30	10/29-01A1	05/30/89	NT	NT	12
MW30	10/29-01A1	05/30/89	NT	NT	12
MW36	10/29-08R1	09/07/88	ND	ND	ND
MW45	10/29-14R1	09/08/88	ND	ND	ND
MW48	10/29-26A1	09/21/88	ND	ND	ND
MW49	11/29-26D1	09/07/88	ND	ND	ND
WS31	10/29-02Q2	09/06/88	0.28 J	ND	ND
WS31	10/29-02Q2	05/31/89	0.2	NT	NT
WS32	10/29-03P1	09/06/88	1.08	ND	ND
WS32	10/29-03P1	05/31/89	0.9	NT	NT
WS32	10/29-03P1	05/31/89	1	NT	NT
WS32	10/29-03P1	05/31/89	0.9	NT	NT
WS33	10/29-03R2	09/06/88	ND	ND	ND
WS34	10/29-04N1	09/20/88	ND	ND	ND
WS35	10/29-08C1	09/20/88	0.26	ND	ND
WS35	10/29-08C1	05/31/89	0.4	NT	NT
WS37	10/29-09R2	09/07/88	ND	ND	ND
WS38	10/29-10A1	09/06/88	ND	ND	ND
WS38	10/29-10A1	09/21/88	ND	ND	ND
WS38	10/29-10A1	09/21/88	ND	ND	ND
WS39	10/29-10Q2	09/07/88	ND	0.8	ND
WS39	10/29-10Q2	05/31/89	NT	0.9	NT
WS39	10/29-10Q2	05/31/89	NT	0.9	NT
WS39	10/29-10Q2	05/31/89	NT	1	NT
WS40	10/29-11N2	09/21/88	ND	ND	ND
WS41	10/29-12Q1	09/06/88	ND	ND	ND
WS42	10/29-13D1	09/22/88	ND	ND	ND
WS43	10/29-14B1	09/08/88	ND	ND	ND
WS44	10/29-14D1	09/07/88	1.04	ND	ND
WS44	10/29-14D1	05/31/89	0.9	NT	NT
WS46	10/29-16A2	09/07/88	ND	ND	ND
WS46	10/29-16A2	09/07/88	ND	ND	ND
WS47	10/29-25B1	09/08/88	ND	0.4	ND
WS47	10/29-25B1	05/31/89	NT	0.3 J	NT
WS50	11/29-28R2	09/22/88	ND	ND	ND
WS51	11/29-32B1	09/22/88	0.65	ND	ND
WS51	11/29-32B1	05/31/89	0.7	NT	NT
WS52	11/29-33G2	09/20/88	ND	ND	ND
WS53	11/29-34D2	09/06/88	1.08	ND	ND
WS53	11/29-34D2	05/31/89	0.7	NT	NT
WS54	11/29-34Q1	09/20/88	ND	ND	ND
WS55	11/29-34R1	09/22/88	ND	ND	ND
WS56	11/29-35R1	09/22/88	0.46	ND	ND
WS56	11/29-35R1	05/31/89	0.5	NT	NT

J= Estimated value.
ND= Analyte not detected.
NT= Analyte not tested.

Table A-3. Yakima County Study Area Pesticide Results

Site #	Site Name	Date	Atrazine
WS60	9/22-03H1	10/03/88	ND
WS61	9/22-03M1	10/03/88	ND
WS62	9/22-04D2	10/03/88	ND
WS63	9/22-04P1	10/04/88	0.4
WS63	9/22-04P1	05/30/89	ND
WS63	9/22-04P1	05/30/89	ND
WS63	9/22-04P1	05/30/89	ND
WS64	9/22-04R2	10/04/88	ND
WS65	9/22-04R3	10/04/88	ND
WS66	9/22-08A2	10/03/88	ND
WS67	9/22-09B1	10/04/88	ND
WS67	9/22-09B1	10/04/88	ND
WS67	9/22-09B1	10/11/88	ND
WS68	9/22-09J1	10/05/88	ND
WS69	9/22-10B2	10/04/88	ND
WS70	9/22-10E1	10/04/88	ND
WS71	9/22-10F1	10/05/88	ND
WS72	9/22-10H1	10/04/88	ND
WS73	9/22-10N1	10/05/88	ND
WS74	9/22-10R1	10/04/88	ND
WS75	9/22-14D1	10/10/88	ND
WS76	9/22-14D2	10/10/88	ND
WS77	9/22-14M1	10/10/88	ND
WS78	9/22-15D1	10/12/88	ND
WS79	9/22-15P1	10/11/88	ND
WS80	9/22-15Q2	10/11/88	ND
WS81	9/22-16D1	10/11/88	ND
WS82	9/22-16J1	10/11/88	ND
WS83	9/22-16J2	10/11/88	ND
WS84	9/22-16M1	10/11/88	ND
WS84	9/22-16M1	10/11/88	ND
WS85	9/22-23E1	10/11/88	ND
WS86	9/22-23J1	10/11/88	ND

ND= Analyte not detected.

Table A-4, Whatcom County Study Area Indicator Parameter Results
(Units=mg/L unless shown otherwise)

Site #	Well ID	Date	K-Total	Q	Total Phosphorus	Q	TOH (ug/L)	Q	TOC	Q	NO3+NO2-N	Q	T D Solid	Q
WS01	14P1	08/24/88	1.25		0.004		8		3.6		8.94		180	
WS01	14P1	05/23/89	1.35		ND		17		5.68		19.6		230	
WS02	15A1	08/25/88	1.77		0.003		ND		2.5		24.45		180	
WS03	15C1	08/22/88	1.6		0.029		6		3.7		0.28		260	
WS04	15H1	08/23/88	1.01		0.003		5		2.9		1.04		140	
WS05	15P1	08/24/88	17.1		0.004		10		7.1		3.63		110	
WS05	15P1	05/22/89	14.4		ND		13		5.55		4.6		110	
WS06	15Q1	08/24/88	0.82		0.004		ND		6.1		9.6		180	
WS07	15R2	08/25/88	6.75		0.004		12		3.8		5.16		150	
WS07	15R2	05/23/89	6.07		ND		12		5.16		15		200	
WS08	21D1	08/24/88	4.69		0.037		11		5.5		1.49		190	
WS09	21J5	08/23/88	0.36		0.008		ND		3.9		1.14		80	
WS09	21J5	05/22/89	0.58		ND		8		3.28		2.5		95	
WS10	21N1	08/25/88	8.03		0.044		15		13		3.92		720	
WS11	21R5	08/24/88	8.29		0.003		18		5.6		11.22		200	
WS11	21R5	05/23/89	5.95		ND		22		3.97		16		220	
WS12	22E2	08/23/88	0.61		0.006		5		5.2		4.32		130	
WS12	22E2	05/22/89	1.34		ND		ND		5.35		6		130	
WS13	22N2	08/24/88	1.71		0.003		20		1.8		10.15		180	
WS13	22N2	05/22/89	1.46		ND		24		4.08		12.8		170	
WS13	22N2	05/22/89	1.45		ND		21		3.56		12.9		190	
WS13	22N2	05/22/89	1.51		ND		26		3.33		12.8		190	
WS14	22N7	08/22/88	0.99		0.005		6		1.3		5.43		140	
WS14	22N7	05/23/89	0.81		0.01		7		4.05		4.6		120	
WS15	22R2	08/23/88	0.5		0.006		15		2.4		3.76		130	
WS16	23A3	08/25/88	0.48		0.004		ND		3.7		ND		90	
WS17	23B2	08/24/88	0.77		0.004		NM		1.6		13.58		210	
WS17	23B2	05/23/89	3.87		ND		22		3.9		17.1		230	
WS18	23D4	08/22/88	0.75		0.058		35		5.2		15.2		200	
WS18	23D4	05/22/89	0.66		0.01		30		4.33		16.2		210	
WS19	23P4	08/23/88	0.76		0.008		ND		7.1		10.34		180	
WS20	26A4	08/23/88	16.1		0.001		9		6.2		10.37		270	
WS21	26C1	08/22/88	0.77		0.004		7		2.2		4.6		140	
WS22	26D2	08/22/88	2.03		0.011		15		3.9		1.66		140	
WS22	26D2	05/23/89	1.93		0.01		13		3.74		9.1		160	
WS23	26G1	08/22/88	1.23		0.006		29		3		4.2		150	
WS24	27C1	08/25/88	1.2		0.006		6		1.7		8.24		210	
WS24	27C1	05/23/89	1.25		ND		9		4.91		8.1		210	
WS25	27D2	08/22/88	1.29		0.021		51		4.1		7.03		190	
WS25	27D2	08/22/88	1.25		0.022		54		5.6		9.67		160	
WS25	27D2	08/24/88	1.1		0.023		35		2		7.05		140	
WS26	28D5	08/23/88	1.21		0.006		7		4.2		5.95		230	
WS27	28G1	08/25/88	0.56		0.017		18		3.8		4.97		120	

ND= Not detected.
Q= Data qualifiers.
NM= Not measured.

Table A-5. Franklin County Study Area Indicator Parameter Results
(Units= mg/L unless shown otherwise,)

Site #	Well ID	Date	K-Total	Q	Total Phosphorus	Q	TOH (ug/L)	Q	TOC	NO3+NO2-N	Q	T D Solid	Q
MW30	10/29-01A1	09/21/88	12		0.311		16	B	NAR	13.58		650	
MW30	10/29-01A1	05/30/89	11.1		0.1		279	B	NAR	15.3		661	
MW36	10/29-08R1	09/07/88	15.9		1.824		NT	B	NAR	10.83		670	
MW45	10/29-14R1	09/08/88	4.41		0.026		17	B	NAR	0.92		310	
MW48	10/29-26A1	09/21/88	2.53		0.136		13	B	NAR	9.18		400	
MW49	11/29-26D1	09/07/88	9.5		0.227		15	B	NAR	11.66		650	
WS31	10/29-02Q2	09/06/88	2.25		0.006		12	B	NAR	11.93		450	
WS31	10/29-02Q2	05/31/89	2.19		0.01		16.3	B	NAR	12.4		440	
WS31	10/29-02Q2	05/31/89	2.48		0.01		12.7	B	NAR	12.2		450	
WS31	10/29-02Q2	05/31/89	2.34		0.01		36.7	B	NAR	12.1		447	
WS32	10/29-03P1	09/06/88	3.94		0.005		9	B	NAR	0.51		300	
WS32	10/29-03P1	05/31/89	3.69		0.01		21.5	B	NAR	0.4		267	
WS33	10/29-03R2	09/06/88	2.81		0.015		27	B	NAR	18.8		540	
WS34	10/29-04N1	09/20/88	3.73		0.017		5	B	NAR	4.36		370	
WS35	10/29-08C1	09/20/88	4.57		0.02		5	B	NAR	8.9		560	
WS35	10/29-08C1	05/31/89	4.16		0.02		49.8	B	NAR	8.5		478	
WS37	10/29-09R2	09/07/88	4.47		0.019		6	B	NAR	9.32		500	
WS38	10/29-10A1	09/06/88	7.35		0.05		19	B	NAR	15.92		650	
WS38	10/29-10A1	09/21/88	8.02		0.05		9	B	NAR	16.6		700	
WS38	10/29-10A1	09/21/88	7.88		NT		NT		NAR	NT		NT	
WS39	10/29-10Q2	09/07/88	3.5		0.008		7	B	NAR	11.52		480	
WS39	10/29-10Q2	05/31/89	3.23		0.01		27.5	B	WAR	12.2		403	
WS40	10/29-11N2	09/21/88	0.65		0.214		ND		NAR	2.43		320	
WS41	10/29-12Q1	09/06/88	2.02		0.005		10	B	NAR	6.7		470	
WS42	10/29-13D1	09/22/88	4.66		0.004		ND		NAR	4.91		460	
WS43	10/29-14B1	09/08/88	2.5		0.005		8	B	NAR	6.12		480	
WS44	10/29-14D1	09/07/88	1.18		0.009		6	B	NAR	0.94		220	
WS44	10/29-14D1	05/31/89	1.3		0.01		34.3	B	NAR	1		266	
WS46	10/29-16A2	09/07/88	5.61		0.01		8	B	NAR	12.2		490	
WS46	10/29-16A2	09/07/88	NM		0.01		7	B	WAR	13.58		470	
WS47	10/29-25B1	09/08/88	2.95		0.01		28	B	NAR	5.05		400	
WS47	10/29-25B1	05/31/89	2.95		0.02		23.4	B	NAR	6.1		377	
WS50	11/29-28R2	09/22/88	1.14		0.017		7	B	NAR	11.93		480	
WS51	11/29-32B1	09/22/88	8.64		0.033		ND		NAR	6.56		650	
WS51	11/29-32B1	05/31/89	3.17		0.05		25.5	B	NAR	2		333	
WS52	11/29-33G2	09/20/88	4.3		0.073		ND		NAR	7.8		450	
WS53	11/29-34D2	09/06/88	7.02		0.041		15	B	NAR	1.19		320	
WS53	11/29-34D2	05/31/89	6.69		0.05		287	B	NAR	0.9		250	
WS54	11/29-34Q1	09/20/88	3.46		0.019		9	B	NAR	16.05		450	
WS55	11/29-34R1	09/22/88	1.41		0.005		ND		NAR	3.67		380	
WS56	11/29-35R1	09/22/88	1.05		0.009		ND		NAR	5.71		250	
WS56	11/29-35R1	05/31/89	1.08		0.02		263	B	NAR	1.6		288	

ND= Not detected.
Q= Data qualifiers described below.
B= Analyte found in the blank as well as the sample.
NAR= No analysis result.
NT= Not tested.

Table A-6. Yakima County Study Area Indicator Parameter Results.
(Units= mg/L unless shown otherwise)

Site #	Well ID	Date	K-Total	Q	Total Phosphorus	Q	TOH(ug/L)	Q	TOC	NO3+NO2-N	Q	T D Solid	Q
WS60	9/22-03H1	10/03/88	3.47		0.043		ND		NAR	2.64		470	
WS61	9/22-03M1	10/03/88	6.18		0.168		ND		NAR	0.25		400	
WS62	9/22-04D2	10/03/88	8.28		0.141		ND		NAR	2.22		460	
WS63	9/22-04P1	10/04/88	1.59		0.232		ND		NAR	0.63		190	
WS63	9/22-04P1	05/30/89	2.05		0.16		13.1	B	NAR	3.4		235	
WS64	9/22-04R2	10/04/88	7.36		0.484		ND		NAR	ND		410	
WS65	9/22-04R3	10/04/88	6.51		0.21		ND		NAR	ND		380	
WS66	9/22-08A2	10/03/88	6.46		0.413		ND		NAR	ND		300	
WS67	9/22-09B1	10/04/88	1.57		0.197		12		NAR	5.91		490	
WS67	9/22-09B1	10/04/88	1.67		0.2		12		NAR	5.88		520	
WS67	9/22-09B1	10/11/88	1.14		0.197		10		NAR	4.6		440	
WS68	9/22-09J1	10/05/88	6.09		0.316		ND		NAR	ND		260	
WS69	9/22-10B2	10/04/88	4.39		0.14		ND		NAR	ND		250	
WS70	9/22-10E1	10/04/88	5.5		0.324		ND		NAR	ND		260	
WS71	9/22-10F1	10/05/88	7.23		0.042		ND		NAR	6.22		400	
WS72	9/22-10H1	10/04/88	7.2		0.132		ND		NAR	2.02		220	
WS73	9/22-10N1	10/05/88	5.76		0.316		ND		NAR	ND		200	
WS74	9/22-10R1	10/04/88	4.64		0.15		ND		NAR	ND		260	
WS75	9/22-14D1	10/10/88	5.83		0.15		ND		NAR	ND		300	
WS76	9/22-14D2	10/10/88	6.17		0.132		ND		NAR	ND		290	
WS77	9/22-14M1	10/10/88	6.35		0.206		ND		NAR	ND		280	
WS78	9/22-15D1	10/12/88	4.86		0.252		ND		NAR	ND		260	
WS79	9/22-15P1	10/11/88	5.52		0.354		ND		NAR	ND		290	
WS80	9/22-15Q2	10/11/88	8.5		0.512		10		NAR	0.1		650	
WS81	9/22-16D1	10/11/88	6.63		0.324		ND		NAR	ND		460	
WS82	9/22-16J1	10/11/88	3.01		0.127		ND		NAR	ND		180	
WS83	9/22-16J2	10/11/88	3.97		0.166		ND		NAR	ND		200	
WS84	9/22-16M1	10/11/88	7.43		0.303		ND		NAR	ND		480	
WS85	9/22-23E1	10/11/88	4.43		0.11		ND		NAR	ND		350	
WS86	9/22-23J1	10/11/88	4.27		0.505		ND		NAR	ND		290	

ND= Not detected.
Q= Data qualifiers described below.
B= Analyte found in the blank as well as the sample.
NAR= No analysis result.

APPENDIX B

Table B-1. Whatcom County Study Area Pesticide Quality Assurance Results.

Analyte	Test Method	35-8404	35-8405	35-8422	35-8427	35-8430
	Alt. ID	27D2	27D2	27D2	27C1	
	Sample Date	08/22/88	08/22/88	08/24/88	08/25/88	
	Sample Type	Dup	Dup	Rep	Matrix Sp	Transport
1,2-Dichloropropane	EPA 501	ND	ND	ND	84	ND
Ethylene Dibromide	EPA 504 (Modified)	ND	ND	ND	65	ND
Dibromochloropropane	EPA 504 (Modified)	ND	ND	ND	100	ND
Alachlor	NPS 1	ND	ND	ND	NS	ND
Ametryn	NPS 1	ND	ND	ND	NS	ND
Atrazine	NPS 1	ND	ND	ND	NS	ND
Bromacil	NPS 1	ND	ND	ND	68	ND
Carboxin	NPS 1	ND	ND	ND	58	ND
Cycloate	NPS 1	ND	ND	ND	78	ND
Diphenamide	NPS 1	ND	ND	ND	71	ND
Fenamiphos	NPS 1	ND	ND	ND	NS	ND
Hexazinone	NPS 1	ND	ND	ND	65	ND
Metolachlor	NPS 1	ND	ND	ND	NS	ND
Metribuzin	NPS 1	ND	ND	ND	70	ND
Prometon	NPS 1	ND	ND	ND	75	ND
Propazine	NPS 1	ND	ND	ND	77	ND
Simazine	NPS 1	ND	ND	ND	NS	ND
Tebuthiuron	NPS 1	ND	ND	ND	87	ND
Terbacil	NPS 1	ND	ND	ND	NS	ND
2,4,5-Trichlorophenoxyacetic Acid	NPS 3	ND	ND	ND	87	ND
2,4-D	NPS 3	ND	ND	ND	87	ND
2,4-DB	NPS 3	ND	ND	ND	85	ND
3,5-Dichlorobenzoic Acid	NPS 3	ND	ND	ND	79	ND
4-Nitrophenol	NPS 3	ND	ND	ND	NS	ND
5-Hydroxy Dicamba	NPS 3	ND	ND	ND	96	ND
Acifluorfen	NPS 3	ND	ND	ND	25	ND
Bentazon	NPS 3	ND	ND	ND	84	ND
Chloramben	NPS 3	ND	ND	ND	NS	ND
Dalapon	NPS 3	ND	ND	ND	84	ND
DCPAs(Dacthal)	NPS 3	ND	ND	ND	86	ND
Dicamba	NPS 3	ND	ND	ND	87	ND
Dichloroprop	NPS 3	ND	ND	ND	92	ND
Dinoseb	NPS 3	ND	ND	ND	NS	ND
Pentachlorophenol	NPS 3	ND	ND	ND	61	ND
Picloram	NPS 3	ND	ND	ND	76	ND
Silvex	NPS 3	ND	ND	ND	88	ND
Baygon	NPS 4 8 EPA 632	ND	ND	ND	74	ND
Carbofuran	NPS 4 8 EPA 632	ND	ND	ND	157	ND
Cyanazine	NPS 4 & EPA 632	ND	ND	ND	103	ND
Diuron	NPS 4 & EPA 632	ND	ND	ND	90	ND
Methomyl	NPS 4 8 EPA 632	ND	ND	ND	74	ND
Oxamyl	NPS 4 8 EPA 632	ND	ND	ND	56	ND
Propham	NPS 4 8 EPA 632	ND	ND	ND	40	ND
Aldicarb	NPS 5 8 EPA 531	ND	ND	ND	70	ND
Aldicarb Sulfone	NPS 5 8 EPA 531	ND	ND	ND	68	ND
Aldicarb Sulfoxide	NPS 5 8 EPA 531	ND	ND	ND	51	ND

Table B-2. Franklin County Study Area Pesticide Quality Assurance Results

Analyte	Sample No. --------> / Alt. ID -----------> / Sample Date -------> / Sample Type -------> / Test Method	37-8438 / 02Q2 / 09/06/88 / Matrix Sp	37-8439 / 02Q2 / 09/06/88 / MS Dup	Relative Percent Difference	37-8442 / 16A2 / 09/07/88 / Dup	37-8443 / 16A2 / 09/07/88 / Dup	37-8447 / Transport	37-8434 / 10A1 / 09/06/88 / Rep	39-8457 / 10A1 / 09/21/88 / Dup	39-8458 / 10A1 / 09/21/88 / Dup	39-8462 / 28R2 / 09/22/88 / Matrix Sp	39-8463 / 28R2 / 09/22/88 / MS Dup	Relative Percent Difference	39-8455 / 09/21/88 / Transfer
1,2-Dichloropropane	EPA 501	104	109	-4.7	ND	ND	ND	ND	ND	ND	103	88	15.7	ND
Ethylene Dibromide	EPA 504 (Modified)	94	94	0.0	ND	ND	ND	ND	ND	ND	111	104	6.5	ND
Dibromochloropropane	EPA 504 (Modified)	94	94	0.0	ND	ND	ND	ND	ND	ND	108	105	2.8	ND
Alachlor	NPS 1	NS	NS		ND	ND	ND	ND	ND	ND	95	96	-1.0	ND
Ametryn	NPS 1	NS	NS		ND	ND	ND	ND	ND	ND	NS	NS		ND
Atrazine	NPS 1	NS	NS		ND	ND	ND	ND	ND	ND	95	100	-5.1	ND
Bromacil	NPS 1	46	56	-19.6	ND	ND	ND	ND	ND	ND	NS	NS		ND
Carboxin	NPS 1	45	56	-21.8	ND	ND	ND	ND	ND	ND	NS	NS		ND
Cycloate	M 1	75	87	-14.8	ND	ND	ND	ND	ND	ND	NS	NS		ND
Diphenamide	NPS 1	70	82	-15.8	ND	ND	ND	ND	ND	ND	NS	NS		ND
Fenamiphos	NPS 1	NS	NS		ND	ND	ND	ND	ND	ND	89	155	-54.1	ND
Hexazinone	NPS 1	60	74	-20.9	ND	ND	ND	ND	ND	ND	NS	NS		ND
Metolachlor	NPS 1	NS	NS		ND	ND	ND	ND	ND	ND	NS	NS		ND
Metribuzin	NPS 1	69	83	-18.4	ND	ND	ND	ND	ND	ND	NS	NS		ND
Prometon	NPS 1	69	84	-19.6	ND	ND	ND	ND	ND	ND	NS	NS		ND
Propazine	NPS 1	79	90	-13.0	ND	ND	ND	ND	ND	ND	NS	NS		ND
Simazine	[illegible]	NS	NS		ND	ND	ND	ND	ND	ND	NS	NS		ND
Tebuthiuron	NPS 1	73	76	-4.0	ND	ND	ND	ND	ND	ND	NS	NS		ND
Terbacil	NPS 1	NS	NS		ND	ND	ND	ND	ND	ND	NS	NS		ND
2,4,5-Trichlorophenoxyacetic Acid	[illegible]	NS	NS		ND	ND	ND	ND	ND	ND	97	103	-6.0	ND
2,4-D	NPS 3	NS	NS		ND	ND	ND	ND	ND	ND	92	95	-3.2	ND
2,4-DB	NPS 3	NS	NS		ND	ND	ND	ND	ND	ND	96	105	-9.0	ND
3,5-Dichlorobenzoic Acid	NPS 3	NS	NS		ND	ND	ND	ND	ND	ND	86	95	9.9	ND
4-Nitrophenol	NPS 3	53.6	141	-89.8	ND	ND	ND	ND	ND	ND	NS	NS		ND
5-Hydroxy Dicamba	NPS 3	NS	NS		ND	ND	ND	ND	ND	ND	95	100	-5.1	ND
Acifluorfen	NPS 3	NS	NS		ND	ND	ND	ND	ND	ND	68	71	-4.3	ND
Bentazon	NPS 3	NS	NS		ND	ND	ND	ND	ND	ND	93	99	-6.3	ND
Chloramben	NPS 3	1.7	6.2	-113.9	ND	ND	ND	ND	ND	ND	NS	NS		ND
Dalapon	NPS 3	NS	NS		ND	ND	ND	ND	ND	ND	89	100	-11.6	ND
DCPAs(Dacthal)	NPS 3	NS	NS		ND	ND	ND	ND	ND	ND	100	106	-5.8	ND
Dicamba	NPS 3	NS	NS		ND	ND	ND	ND	ND	ND	93	100	-7.3	ND
Dichloroprop	[illegible]	NS	NS		ND	ND	ND	ND	ND	ND	91	99	-8.4	ND
Dinoseb	NPS 3	40.1	93.9	-80.3	ND	ND	ND	ND	ND	ND	NS	NS		ND
Pentachlorophenol	NPS 3	NS	NS		ND	ND	ND	ND	ND	ND	93	110	-16.7	ND
Picloram	[illegible]	NS	NS		ND	ND	ND	ND	ND	ND	82	86	-4.8	ND
Silvex	NPS 3	NS	NS		ND	ND	ND	ND	ND	ND	98	100	-2.0	ND
Baygon	[illegible] 4 & EPA 632	100	16	144.8	ND	ND	ND	ND	ND	ND	260	266	-2.3	ND
Carbofuran	[illegible] 4 6 EPA 632	35	30	15.4	ND	ND	ND	ND	ND	ND	234	249	-6.2	ND
Cyanazine	[illegible] 4 & EPA 632	92	93	-1.1	ND	ND	ND	ND	ND	ND	106	91	15.2	ND
Diuron	NPS 4 & EPA 632	64	66	-3.1	ND	ND	ND	ND	ND	ND	105	85	21.1	ND
Methomyl	NPS 4 6 EPA 632	72	70	2.8	ND	ND	ND	ND	ND	ND	52	49	5.9	ND
Oxamyl	NPS 4 & EPA 632	100	78	24.7	ND	ND	ND	ND	ND	ND	51	64	-22.6	ND
Propham	NPS 4 & EPA 632	35	45	-25.0	ND	ND	ND	ND	ND	ND	108	64	51.2	ND
Aldicarb	NPS 5 6 EPA 531	83	83	0.0	ND	ND	ND	ND	ND	ND	33	40	-19.2	ND
Aldicarb Sulfone	M 5 & EPA 531	101	83	19.6	ND	ND	ND	ND	ND	ND	54	41	27.4	ND
Aldicarb Sulfoxide	M 5 & EPA 531	118	109	7.9	ND	ND	ND	ND	ND	ND	96	79	19.4	ND

Table B-3. Yakim County Study Area Pesticide Quality Assurance Results.

Analyte	Sample NO --------> / Alt. ID ----------> / Sample Date -------> / Sample Type -------> / Test Method	41-8476 / 09B1 / 10/04/88 / Dup	41-8477 / 09B1 / 10/04/88 / Dup	42-8490 / 09B1 / 10/11/88 / Rep	41-8483 / 10F1 / 10/05/88 / Matrix Sp	41-8484 / 10F1 / 10/05/88 / MS Dup	42-8492 / 16M1 / 10/11/88 / Dup	42-8497 / 15Q2 / 10/11/88 / Matrix Sp	42-8498 / 15Q2 / 10/11/88 / MS Dup	42-8502 / Transport
1,2-Dichloropropane	EPA 501	ND	ND	ND	111	120	ND	103	101	ND
Ethylene Dibromide	EPA 504 (Modified)	ND	ND	ND	93	99	ND	97	107	ND
Dibromochloropropane	EPA 504 (Modified)	ND	ND	ND	92	99	ND	93	101	ND
Alachlor	NPS 1	ND	ND	ND	88.9	91.2	ND	NS	NS	ND
Ametryn	NPS 1	ND	ND	ND	NS	NS	ND	79.6	79.6	ND
Atrazine	NPS 1	ND	ND	ND	91.9	94.8	ND	NS	NS	ND
Bromacil	NPS 1	ND	ND	ND	NS	NS	ND	NS	NS	ND
Carboxin	NPS 1	ND	ND	ND	NS	NS	ND	NS	NS	ND
Cycloate	NPS 1	ND	ND	ND	NS	NS	ND	NS	NS	ND
Diphenamide	NPS 1	ND	ND	ND	NS	NS	ND	NS	NS	ND
Fenamiphos	NPS 1	ND	ND	ND	82.2	71.4	ND	NS	NS	ND
Hexazinone	NPS 1	ND	ND	ND	NS	NS	ND	NS	NS	ND
Metolachlor	NPS 1	ND	ND	ND	NS	NS	ND	78.1	78.1	ND
Metribuzin	NPS 1	ND	ND	ND	NS	NS	ND	NS	NS	ND
Prometon	NPS 1	ND	ND	ND	NS	NS	ND	NS	NS	ND
Propazine	NPS 1	ND	ND	ND	NS	NS	ND	NS	NS	ND
Simazine	NPS 1	ND	ND	ND	NS	NS	ND	82.3	82.3	ND
Tebuthiuron	NPS 1	ND	ND	ND	NS	NS	ND	NS	NS	ND
Terbacil	NPS 1	ND	ND	ND	NS	NS	ND	77.3	77.3	ND
2,4,5-Trichlorophenoxyacetic Acid	NPS 3	ND	ND	ND	122	124	ND	NS	NS	ND
2,4-D	NPS 3	ND	ND	ND	108	105	ND	NS	NS	ND
2,4-DB	NPS 3	ND	ND	ND	116	118	ND	NS	NS	ND
3,5-Dichlorobenzoic Acid	NPS 3	ND	ND	ND	98	93	ND	NS	NS	ND
4-Nitrophenol	NPS 3	ND	ND	ND	NS	NS	ND	103	110.0	ND
5-Hydroxy Dicamba	NPS 3	ND	ND	ND	115	117	ND	NS	NS	ND
Acifluorfen	NPS 3	ND	ND	ND	101	84	ND	NS	NS	ND
Bentazon	NPS 3	ND	ND	ND	117	118	ND	NS	NS	ND
Chloramben	NPS 3	ND	ND	ND	NS	NS	ND	13	10	ND
Dalapon	NPS 3	ND	ND	ND	97	99	ND	NS	NS	ND
DCPAs(Dacthal)	NPS 3	ND	ND	ND	102	111	ND	NS	NS	ND
Dicamba	NPS 3	ND	ND	ND	107	99	ND	NS	NS	ND
Dichloroprop	NPS 3	ND	ND	ND	107	111	ND	NS	NS	ND
Dinoseb	NPS 3	ND	ND	ND	NS	NS	ND	76	85	ND
Pentachlorophenol	NPS 3	ND	ND	ND	89	87	ND	NS	NS	ND
Picloram	NPS 3	ND	ND	ND	86	99	ND	NS	NS	ND
Silvex	NPS 3	ND	ND	ND	116	111	ND	NS	NS	ND
Baygon	NPS 4 & EPA 632	ND	ND	ND	251	215	ND	35	50	ND
Carbofuran	NPS 4 8 EPA 632	ND	ND	ND	266	233	ND	77	85	ND
Cyanazine	NPS 4 & EPA 632	ND	ND	ND	91	94	ND	87	80	ND
Diuron	NPS 4 8 EPA 632	ND	ND	ND	97	81	ND	68	48	ND
Methomyl	NPS 4 & EPA 632	ND	ND	ND	48	46	ND	64	43	ND
Oxamyl	NPS 4 8 EPA 632	ND	ND	ND	66	66	ND	29	6	ND
Propham	NPS 4 & EPA 632	ND	ND	ND	73	109	ND	96	68	ND
Aldicarb	NPS 5 & EPA 531	ND	ND	ND	54	64	ND	54	51	ND
Aldicarb Sulfone	NPS 5 & EPA 531	ND	ND	ND	79	75	ND	66	60	ND
Aldicarb Sulfoxide	NPS 5 8 EPA 531	ND	ND	ND	88	82	ND	70	68	ND

Table B-4. Reference Sample Results (ug/L)

SAMPLE #1

Analyte	Test Method	OSU Calculated	OSU Measured	Montgomery Measured	RPD*
Simazine	NPS 1	3.2	2.9	6.6	78
Terbacil	NPS 1	14.0	13.3	10.6	23
Dicamba	NPS 3	0.8	0.76	0.76	0
Picloram	NPS 3	4.0	3.6	2.2	48
Carbofuran	NPS 4	4.0	3.5	Not Detected	--

SAMPLE #2

Analyte	Test Method	OSU Calculated	OSU Measured	Montgomery Measured	RPD*
Simazine	NPS 1	3.7	3.5	11.0	103
Terbacil	NPS 1	9.7	8.7	9.7	11
Dicamba	NPS 3	1.2	1.2	1.2	0
Picloram	NPS 3	5.5	6.7	4.5	39
Carbofuran	NPS 4	3.2	3.5	4.7	29

*RPD=Relative Percentage of the difference of the mean.

Table B-5. Verification Sampling Pesticide Quality Assurance Results

Analyte	Study Area --------> Sample No. --------> Alt. ID -----------> Sample Date -------> Sample Type -------> Test Method	Uhatcan 21-8400 Transport	Whatcom 21-8408 22N2 05/22/89 Dup	Whatcom 21-8409 22N2 05/22/89 Dup	Whatcom 21-8410 22N2 05/22/89 Rep	Whatcom 21-8416 27C1 05/23/89 Dup	Whatcom 21-8417 27C1 05/23/89 Dup	Whatcom 21-8418 27C1 05/23/89 Rep	Whatcom 21-8419 27C1 05/23/89 Matrix Sp	Whatcom 21-8420 27C1 05/23/89 MS Dup	Yakima 22-8423 Transport	Yakima 22-8424 04P1 05/30/89 Dup	Yakima 22-8425 04P1 05/30/89 Dup
1,2-Dichloropropane	EPA 624	ND	8.2	8.0	8.3				94	96	ND		
Ethylene Dibromide	EPA 504(Modified)	ND(0.25J)	ND(0.25J)	ND(0.25J)	ND(0.25J)	*	113R*	1.52J	1.72J*	1.5J*			
Dibromochlorpropane	EPA 504(Modified)	ND(0.02J)	0.3J	0.3J	0.3J	*	73R*	ND(0.02J)	ND(0.02J)	ND(0.02J)			
Alechlor	NPS 1								101	99			
Atrazine	NPS 1	ND	ND	ND	ND	ND			102	101	ND	ND	ND
Brmcil	NPS 1	ND	ND	ND	ND	ND			NS	NS	ND		
Butylate	NPS 1								96	95			
Ethoprop	NPS 1								100	99			
Fenamiphos	NPS 1								128	125'			
Methyl Paraoxon	NPS 1								128	128			
MGK264	NPS 1								96	96			
Prometon	NPS 1	ND	1.0	0.9	0.9	ND			NS	NS	ND		
Stirofos	NPS 1								115	113			
Terbutryn	NPS 1								102	100			
Dacthal	NPS 3										ND		
Carbofuran	NPS 4 and EPA 632	ND(2.0J)				ND	ND	ND	120	110			

Analyte	Study Area --------> Sample No. --------> Alt. ID -----------> Sanple Date -------> Sample Type -------> Test Method	Yakima 22-8426 04P1 05/30/89 Rep	Yakima 22-8427 04P1 05/30/89 Matrix Sp	Yakima 22-8428 04P1 05/30/89 MS Dup	Franklin 22-8429 01A1 05/30/89 Dup	Franklin 22-8430 01A1 05/30/89 Dup	Franklin 22-8431 01A1 05/30/89 Rep	Franklin 22-8432 01A1 05/30/89 Matrix Sp	Franklin 22-8433 01A1 05/30/89 MS Dup	Franklin 22-8438 03P1 05/31/89 Dup	Franklin 22-8439 03P1 05/31/89 Dup	Franklin 22-8440 03P1 05/31/89 Rep	Franklin 22-8442 02Q2 05/31/89 Matrix Sp
1,2-Dichloropropane	EPA 624												
Ethylene Dibromide	EPA 504(Modified)												
Dibromochlorpropane	EPA 504(Modified)												
Alechlor	NPS 1		100	95				97	98				
Atrazine	NPS 1	ND	102	95				98	98				
Brmcil	YPS 1		NS	NS	11	12	12	NS	NS				
Butylate	NPS 1		90	68				74	68				
Ethoprop	NPS 1		99	96				101	102				
Fenamiphos	NPS 1		92	86				104	109				
Methyl Paraoxon	NPS 1		107	103				118	122				
MGK264	NPS 1		89	68				77	80				
Prometon	NPS 1		NS	NS				NS	NS				
Stirofos	NPS 1		104	99				112	114				
Terbutryn	NPS 1		101	97				107	107				
Dacthal	NPS 3									0.9	1.0	0.9	96.7
Carbofuran	NPS 4 and EPA 632												

Table B-5. Verification Sampling Pesticide Quality Assurance Results, Continued.

	Study Area -------->	Franklin	Franklin	Franklin	Franklin	Franklin	Franklin
	Sample No. -------->	22-8443	22-8445	22-8446	22-8447	22-8449	22-8450
	Alt. ID ----------->	02Q2	10Q2	10Q2	1002	25B1	25B1
	Sample Date ------->	05/31/89	05/31/89	05/31/89	05/31/89	06/01/89	06/01/89
	Sample Type ------->	MS Dup	Dup	Dup	Rep	Matrix Sp	MS Dup
Analyte	Test Method						
1,2-Dichloropropane	EPA 624		0.9	0.9	1.0	100	100
Ethylene Dibromide	EPA 504(Modified)						
Dibromochlorpropane	EPA 504(Modified)						
Alachlor	NPS 1						
Atrazine	NPS 1						
Bromacil	NPS 1						
Butylate	NPS 1						
Ethoprop	NPS 1						
Fenamiphos	NPS 1						
Methyl Paraoxon	NPS 1						
MGK264	NPS 1						
Prometon	NPS 1						
Stirofos	NPS 1						
Terbutryn	NPS 1						
Dacthal	NPS 3	91.8					
Carbofuran	NPS 4 and EPA 632						

Table B-6. Whatcom County Study Area Non-Pesticide Quality Assurance Results

Initial Sampling

Analyte	Units	Sample No. / Alt. ID / Sample Date / Sample Type	35-8404 27D2 08/22/88 Dup	35-8405 27D2 08/22/88 Dup	Mean of Dups	Dup RPD*	35-8422 27D2 08/24/88 Rep	Mean Dup and Rep RPD*	35-8430 Transport
Arsenic	ug/L		1.59	1.65	1.62	-3.7	1.70	-1.2	
Cadmium	ug/L		0.36	<0.2	0.23	113.0	<0.2	78.0	
Chromium	ug/L		<5	<5	<5	0.0	<5	0.0	
Copper	ug/L		9.0	10.0	9.5	-10.5	6.0	11.3	
Lead	ug/L		9.9	<5	6.2	119.0	<5	85.1	
Mercury	ug/L		<0.08	<0.08	<0.08	0.0	<0.08	0.0	
Nickel	ug/L		<10	<10	<10	0.0	<10	0.0	
Seleniun	ug/L		2.2	<1	1.4	121.4	<1	94.7	
Zinc	ug/L		12.3	12.7	12.5	-3.2	8.4	9.8	
Calciun	mg/L		15.4	15.2	15.3	1.3	15.10	0.3	
Magnesium	mg/L		4.53	4.48	4.51	1.1	4.49	0.1	
Manganese	mg/L		<0.01	<0.01	<0.01	0.0	<0.01	0.0	
Iron	mg/L		0.011	<0.01	0.01	75.0	<0.01	66.7	
Sodium	mg/L		18.0	18.0	18.0	0.0	15.90	3.1	
Potassiun	mg/L		1.29	1.25	1.3	3.1	1.10	3.6	<0.01
Carbonate as CaCO3	mg/L		<1	<1	<1	0.0	<1	0.0	
Bicarbonate as CaCO3	mg/L		41	40	40.5	2.5	38	1.6	
Sulfate	mg/L		15	15	15.0	0.0	14	1.7	
Choride	mg/L		16	17	16.5	-6.1	14	4.1	
Total Dissolved Solids	mg/L		190	160	175.0	17.1	140	5.6	
Total Organic Halogens	ug/L		51	54	52.5	-5.7	35	10.0	<5
Total Organic Carbon	mg/L		4.1	5.6	4.9	-30.9	1.8	22.9	
Nitrate/Nitrite as N	mg/L		7.03	9.67	8.4	-31.6	7.05	4.2	
Total Phosphorus	mg/L		0.021	0.022	0.02	-4.7	0.023	-1.7	

Verification Sampling

Analyte	Units	Sample No. / Alt. ID / Sample Date / Sample Type	21-8400 Transport	21-8404 15Q1 05/22/89 Dup	21-8405 15Q1 05/22/89 Dup	21-8408 22N2 05/22/89 Dup	21-8409 22N2 05/22/89 Dup	Dup Mean	Dup RPD*	21-8410 22N2 05/22/89 Rep	Mean Dup and Rep RPD*
Lead	ug/L		<1	<1	<1						
Potassiun	mg/L		<0.01			1.460	1.450	1.46	0.2	1.510	-0.9
Total Dissolved Solids	mg/L		NT			170	190	180	-2.8	190	-1.4
Total Organic Halogens	ug/L		<5			24	21	22.5	3.3	26	-3.6
Total Organic Carbon	mg/L		0.23			4.08	3.56	3.82	3.4	3.33	3.4
Nitrate/Nitrite as N	mg/L		NT			12.8	12.9	12.9	-0.2	12.8	0.1
Total Phosphorus	mg/L		NT			<0.01	<0.01	<0.01	0.0	<0.01	0.0

Table B-7. Franklin County Study Area Non-pesticide Quality Assurance Results

Initial Sampling

Analyte	Units	37-8442	37-8443			37-8447	37-8434	39-8457	39-8458			
Alt. ID		16A2	16A2				10A1	10A1	10A1			Dup Mean
Sample Date		09/07/88	09/07/88	Dup	Dup		09/06/88	09/21/88	09/21/88	Dup	Dup	and Rep
Sample Type		Dup	Dup	Mean	RPD*	Transport	Rep	Dup	Dup	Mean	RPD*	RPD*
Arsenic	ug/L	7.0	7.0	7.0	0.0	0.2	8.9	6.9	6.6	6.8	4.4	-6.9
Cadmium	ug/L	0.2	0.4	0.3	-66.7	<0.2	<0.2	<0.2	<0.2	<0.2	0.0	0.0
Chromium	ug/L	<5	<5	<5	0.0	<5	<5	<5	<5	<5	0.0	0.0
Copper	ug/L	<5	<5	<5	0.0	<5	<5	<5	<5	<5	0.0	0.0
Lead	ug/L	<5	72	37.3	186.6	<5	<5	<5	<5	<5	0.0	0.0
Mercury	ug/L	0.16B	0.16B	0.16B	0.0	0.08	0.31B	0.19B	0.13B	--	--	--
Nickel	ug/L	<10	<10	<10	0.0	<10	<10	<10	<10	<10	0.0	0.0
Selenium	ug/L	<1	2.6B	1.6	131.0	2.2	2.2B	1.0B	1.1B	--	--	--
Zinc	ug/L	48	51.6	49.8	-7.2	<5	<5	101	104	102.5	-2.9	52.9
Calcium	mg/L	60.7	60.0	60.4	1.2	<0.01		71.8	70.4	71.1	2.0	
Magnesium	mg/L	24.5	24.3	24.4	0.8	<0.01		22.7	22.2	22.5	2.2	
Manganese	mg/L	<0.01	<0.01	<0.01	0.0	<0.01		<0.01	<0.01	<0.01	0.0	
Iron	mg/L	0.02	0.02	0.02	0.0	<0.01		0.02	0.01	0.015	66.7	
Sodium	mg/L	59.8	59.5	59.7	0.5	0.04		99.7	97.2	98.5	2.5	
Potassiun	mg/L	5.61	5.53	5.57	1.4	0.04		8.02	7.9	8.0	1.5	
Carbonate as CaCO3	mg/L	<1	<1	<1	0.0							
Bicarbonate as CaCO3	mg/L	246	246	246.0	0.0							
Sulfate	mg/L	86	88	87.0	-2.3							
Choride	mg/L	29	29	29.0	0.0							
Total Dissolved Solids	mg/L	490	470	480.0	4.2							
Total Organic Halogens	ug/L	8B	7B	7.5	13.3	8						
Total Organic Carbon	mg/L	3R	3R	--	--							
Nitrate/Nitrite as N	mg/L	12.20	13.58	12.9	-10.7							
Total Phosphorus	mg/L	0.010	0.010	0.010	0.0							

Verification Sampling

Analyte	Units	22-8423	22-8441	22-8442			22-8443		22-8451	22-8452	22-8453
Alt. ID			0292	02Q02			02Q02	Dup Mean	16A2	16A2	16A2
Sample Date			05/31/89	05/31/89	Dup	Dup	05/31/89	and Rep	06/01/89	06/01/89	06/01/89
Sample Type		Transport	Dup	Dup	Mean	RPD	Rep	RPD	Dup	Dup	Rep
Lead	ug/L	1.9							2.2B	6.2B	2.2B
Potassiun	mg/L		2.19	2.48	2.34	-12.4	2.34	-0.1			
Total Dissolved Solids	mg/L		440	450	445	-2.2	447	-0.1			
Total Organic Halogens	ug/L	20	16B	13B	--	--	37B	--			
Total Organic Carbon	mg/L	0.28	20.5	18.3	19.4	11.3	13.2	9.5			
Nitrate/Nitrite as N	mg/L		12.4	12.2	12.3	1.6	12.1	0.4			
Total Phosphorus	mg/L		0.01	0.01	0.01	0.0	0.01	0.0			

Table B-8. Yakima County Study Area Non-Pesticide Quality Assurance Results

Initial Sampling

Analyte	Units	Sample No. Alt. ID Sample Date Sample Type	41-8476 09B1 10/04/88 Dup	41-8477 09B1 10/04/88 Dup	Dup Mean	Dup RPD*	42-8490 09B1 10/11/88 Rep	Dup Mean and Rep RPD*	42-8502 Transport
Arsenic	ug/L		5.8	5.9	5.9	-1.7	5.7	0.6	<0.2
Cadmiun	ug/L		<0.2	<0.2	<0.2	0.0	<0.2	0.0	<0.2
Chromium	ug/L		<5	<5	<5	0.0	<5	0.0	<5
Copper	ug/L		<5	<5	<5	0.0	<5	0.0	<5
Lead	ug/L		<5	<5	<5	0.0	<5	0.0	<5
Mercury	ug/L		<0.08	<0.08	<0.08	0.0	0.1	-50.0	<0.06
Nickel	ug/L		<10	<10	<10	0.0	<10	0.0	<10
Selenium	ug/L		<1	<1	<1	0.0	1.4	-50.0	<1
Zinc	ug/L		15	15	15.0	0.0	13	3.6	<5
Calciun	mg/L		84.4	84.7	84.6	-0.4	80.4	1.3	<0.01
Magnesiun	mg/L		30.8	30.9	30.9	-0.3	29.3	1.3	<0.01
Manganese	mg/L		0.05	0.05	0.1	0.0	0.04	5.6	<0.01
Iron	mg/L		0.02	0.02	0.0	0.0	0.02	0.0	<0.01
Sodium	mg/L		15.7	15.7	15.7	0.0	15.7	0.0	<0.01
Potassiun	mg/L		1.57	1.67	1.6	-6.2	1.14	8.7	<0.01
Carbonate as CaCO3	mg/L		<1	<1	<1	0.0			
Bicarbonate as CaCO3	mg/L		337	337	337.0	0.0	310	2.1	
Sulfate	mg/L		28	29	28.5	-3.5	23	5.3	
Choride	mg/L		10	11	10.5	-9.5	8.8	4.4	
Total Dissolved Solids	mg/L		490	520	505.0	-5.9	440	3.4	
Total Organic Halogens	ug/L		12	12	12.0	0.0	10	4.5	<5
Total Organic Carbon	mg/L		11R	20R	--	--	19R	--	
Nitrate/Nitrite as N	mg/L		5.91	5.88	5.9	0.5	4.60	6.2	
Total Phosphorus	mg/L		0.197	0.200	0.2	-1.5	0.197	0.2	

Verification Sampling

Analyte	Units	Sample No. Alt. ID Sample Date Sample Type	22-8423 Transport
Lead	ug/L		1.9
Potassiun	mg/L		
Total Dissolved Solids	mg/L		
Total Organic Halogens	ug/L		20
Total Organic Carbon	mg/L		0.28
Nitrate/Nitrite as N	mg/L		
Total Phosphorus	mg/L		