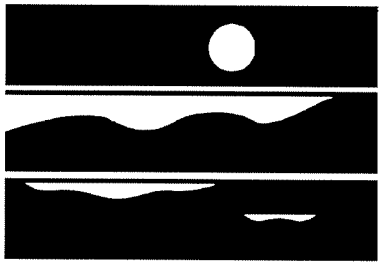

Washington State Pesticide Monitoring Program

Pesticide Residues in Skagit Delta Surficial Aquifer

Pesticides in Ground Water Report No. 8

April 1996

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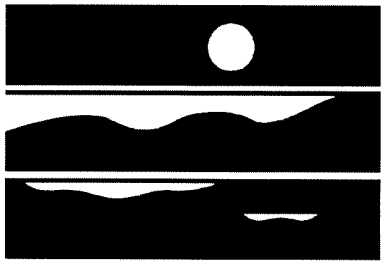

Washington State Pesticide Monitoring Program

Pesticide Residues in Skagit Delta Surficial Aquifer

Pesticides in Ground Water Report No. 8

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by
Arthur G. Larson

Environmental Investigations and Laboratory Services Program
Olympia, Washington 98504-7710

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Abstract

Twenty-seven wells were sampled near Mt. Vernon, Washington for pesticides and nitrate+nitrite as N. Field measurements of water temperature, pH, and specific conductance were also made. Wells were located in the Skagit Delta Surficial Aquifer underlying the Skagit River delta.

Nine pesticides were detected in the initial samples: **dacthal (DCPAs), atrazine, prometon, bromacil, 3,5-dichlorobenzoic acid, dicamba, 4-nitrophenol, pentachlorophenol, and total xylenes**. However, only atrazine, prometon, and bromacil were confirmed by the verification sampling. Pesticides were detected in 11 of the 27 study wells, with more than one pesticide found in three wells.

Concentrations of all pesticides were below the Maximum Contaminant Level (MCL) or Lifetime Health Advisory Level set by the EPA for public drinking water. In two wells, the nitrate+nitrite as N concentration exceeded the 10.0 mg/L drinking water standard for nitrate. Eight wells also had specific conductance values greater than the 700 µmhos/cm MCL for drinking water

Acknowledgments

I thank the owners of the wells for allowing me to sample and for providing background information on their wells.

Thanks to Norm Olson, Bob Carrell, and Dickey Huntamer at Manchester Laboratory for their analyses of the pesticides. I also thank Stuart Magoon at the laboratory for his quality assurance review of the data.

Peer review was provided by Denis Erickson, Larry Goldstein, and Bill Yake of the Environmental Investigations and Laboratory Services Program and by Dave Garland of the Water Quality Program, Northwest Regional Office.

David Nash of the Washington State Department of Health reviewed all results for health implications and wrote health consults explaining these implications. These consults were mailed to well owners

Finally, thanks to Joan LeTourneau for formatting and proofing this report.

Introduction

During August 1994, 27 wells were sampled near Mt. Vernon, Washington for pesticides and nitrate+nitrite as nitrogen. Wells were located in the Skagit Delta Surficial Aquifer underlying the flood plain at the mouth of the Skagit River. Mt. Vernon, the major population center in Skagit County, started as an agricultural and logging community in the late 1800s. The Skagit River flood plain and delta were cleared of forests during the 1880s and 1890s. First crops were oats and hay, grown to feed the horses working in the logging camps. As the logging industry declined and moved further inland, the dairy industry and farming began to thrive on the bottom lands of the Skagit delta.

The study area includes the farm lands between Mt. Vernon to the east, Puget Sound to the west, highway 20 to the north, and Conway to the south (Figure 1). These lands, within the original flood plain of the Skagit River, are now protected by dikes and levees. The area is level to nearly level alluvial bottom lands, most of it less than 10 feet above sea level. The land is artificially drained by ditches and canals which are protected from flooding by tide gates with drainage pumped over the dikes into the Skagit River when necessary.

The area is best known for its tulip farms and the spring tulip festival. Other crops, in addition to bulbs and cut flowers (tulips and daffodils), include strawberries and caneberries, a wide variety of vegetables (peas, corn and broccoli were noted), and a large acreage of potatoes. Turf grass is also grown commercially, and several dairies are still active within the study area. Farming is still the major activity on the Skagit delta outside the residential areas surrounding Mt. Vernon and Burlington.

Background

Agricultural chemicals, specifically pesticides, are used throughout Washington. Although pesticides are used extensively on farmlands, they are also applied in the urban and forest environment. Population growth and increasing urbanization are placing increasing demands on the ground-water resource. At the same time, the effect of pesticide use on the state's ground-water quality is largely unknown.

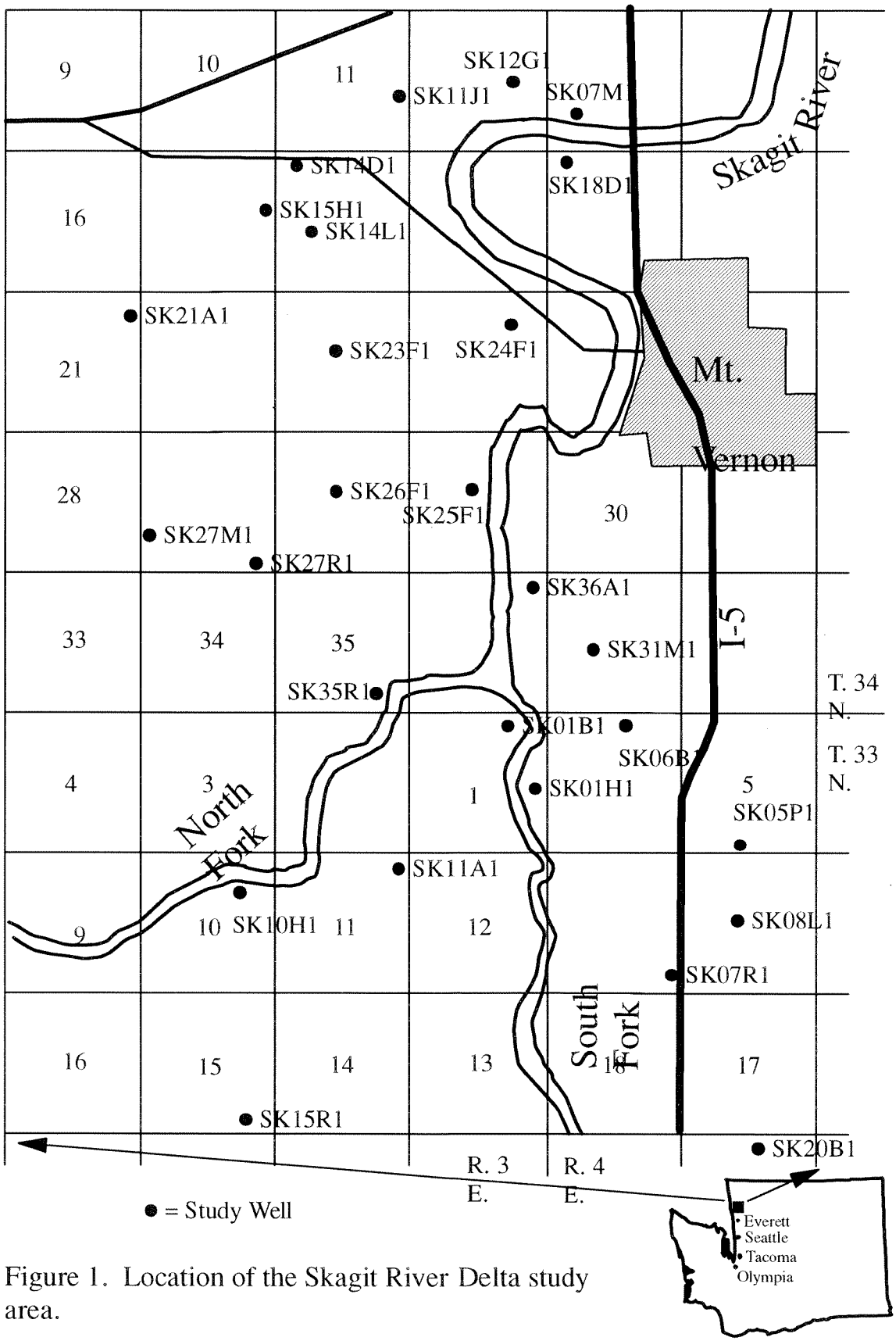

Figure 1. Location of the Skagit River Delta study area.

Purpose

Sampling of the Skagit Delta Surficial Aquifer is part of ongoing efforts to monitor pesticides in ground water, statewide. It provides data on the occurrence and concentration of pesticides in ground water where agriculture is interspersed with residential and industrial development.

Skagit Delta Aquifer

The Skagit Delta Surficial Aquifer is located in the flood plain and delta of the Skagit River near its terminus with Puget Sound. The aquifer is bounded on the west by the Padilla Bay - Swinomish Channel - Skagit Bay arms of Puget Sound, and on the east by the relatively abrupt uplands east of Mt. Vernon and the Interstate 5 corridor. The aerial extent of the aquifer is confined to the valley formed by flood and meander channels cut by the Skagit River since the end of Vashon glaciation. The aquifer is bound by Bay View Ridge to the north and extends south to the mouth of the South Fork channel of the Skagit. The aquifer is unconfined, with a shallow water table, and is hydraulically connected to the Skagit River and Puget Sound. Although most of the land surface is diked against flooding, the aquifer probably receives significant recharge from the river during flood events, especially the early fall storms. The aquifer discharges to the river during low summer flows.

The climate of the Skagit delta is maritime with wet, mild winters and dry summers. Winter snow is common, but any accumulation is rare, usually melting within a few days. The average temperature is about 40 degrees F. during the winter and 63 degrees F. in summer. Annual precipitation is 32 inches at Mt. Vernon (SCS, 1989). Because of light summer rainfall, farmers must irrigate to insure that crops will grow actively. Irrigation is primarily from ground water.

Hydrogeology

The water table is shallow, generally within 10 feet of the land surface. The aquifer is hydraulically connected with the network of ditches that web its surface. Along with recharge from precipitation, the aquifer receives water from the Skagit River and infiltration of excess irrigation water. The water table, controlled by the level of the Skagit River and sea level, does not fluctuate greatly. Heavy precipitation soon results in surface flooding and rapid runoff of excess ground water via drainage ditches. Likewise, summer discharge is impeded by the controlling water level of Puget Sound. The salinity of the aquifer probably fluctuates more than its water level.

The study area encompasses only a small portion of the aquifer between Mt. Vernon and Puget Sound. Because of high salinity, few wells are located within the nearest one-mile of Puget Sound, and no wells were selected for sampling in this area.

Soils

Major soils of the Skagit River delta include the Skagit-Sumas-Field soil series associations (SCS, 1989). These very deep, poorly drained to moderately well drained, level soils are formed on flood plains and deltas. A large part of the study area is covered by the Skagit silt loam. This deep, poorly drained flood plain soil has been extensively altered by tile and open ditch drainage and protection from flooding. Typically, the surface layer is very dark grayish brown and dark brown silt loam about 12 inches thick. The upper eight inches of the underlying material is gray silt loam, grading to a very fine sandy loam at five feet and greater. Permeability is moderate and available water capacity is high. The effective rooting depth is limited by a seasonal high water table that is at a depth of six to 24 inches from November to March. During the growing season, the water table is lowered to a depth of about 36 to 60 inches.

A second major soil type is the Sumas silt loam. This very deep, poorly drained soil is formed in alluvium on flood plains and deltas. Drainage has been altered by tiling, ditching, and diking. Typically, the upper six inches of the surface layer is very dark grayish brown silt loam and the lower seven inches is very dark grayish brown silty clay loam. The upper three inches of the underlying material is gray silt loam, the next 14 inches is gray loamy sand, and the lower part to a depth of 60 inches or more is dark gray coarse sand. The effective rooting depth is limited by a seasonal high water table that is at a depth of 12 to 36 inches from November to April.

Another very deep, but moderately well drained soil found in the study area is the Field silt loam. This soil is formed in recent alluvium with an admixture of volcanic ash. Typically the surface layer is dark brown silt loam 13 inches thick. The upper eight inches of the underlying material is olive silt loam, the next 19 inches is grayish brown and dark gray, stratified fine sand and loamy fine sand, and the lower part to a depth of 60 inches or more is gray and dark gray, stratified fine sand and very fine sandy loam. The soil is subject to brief periods of flooding from November to March.

Methods

To select appropriate wells for sampling, I searched the well-log files located at Ecology's Northwest Region Office in Bellevue. I selected well logs based on shallow depth, high water table, and location within the aquifer. Although well logs were useful for the selection of a few wells, most wells were located and selected after a door-to-door survey in areas of interest.

Criteria used in the well selection included:

- Water pumped only from the Skagit Delta Surficial Aquifer
- Location of the well away from aquifer boundaries and from wells already selected
- A shallow well (<100 ft.)
- Ease of collecting a representative water sample
- The owner's permission to sample

Wells

I selected 27 wells for sampling the Skagit Delta Surficial Aquifer: 11 domestic, 14 irrigation, and two unused wells. Wells were located in a 25 square-mile area along the Skagit River between Mt. Vernon and the Swinomish Channel which connects Padilla Bay and Skagit Bay (Figure 1). Several wells were located on Fir Island.

Several of the study wells were shallow, driven wells (sand points). Wells ranged from 11 to 108 feet deep with a median depth of 30 feet. Water entered unscreened wells through the well bottom. Screens, when present, usually allowed water to enter the well over the deepest four to five feet. The depth to water in all wells was less than 20 feet. The type of well, surface elevation, total depth, and depth to water for the individual wells are presented in Appendix A.

Sampling Schedule

Initial sampling occurred in August 1994. Wells in which pesticides were detected were resampled in May 1995 (verification sampling), to confirm the initial analyses.

Sampling Procedures

Before sampling, I purged all wells until the temperature, pH, and specific conductance had stabilized and at least three casing volumes of water had been removed. I used an Orion model 250A meter for pH and temperature measurements, and a Beckman type RB-5 meter to measure specific conductance. When the well had an installed pump, I purged and sampled from an existing faucet located as close to the well as possible and upstream of any pressure tanks, where feasible. Several wells (without installed pumps) were purged and sampled with a portable centrifugal pump. New tubing was attached to the portable pump at each well, but the pump itself was simply rinsed and not decontaminated between wells. Pesticides were detected in three of the wells sampled with the portable pump (SK05P1, SK07R1, SK12G1), but different pesticides were found in each well.

Samples were collected in pre-cleaned, organic-free glass bottles and stored on ice until delivery to the lab. Carbamate samples were preserved with a monochloroacetic acid buffer. No field blanks were collected.

Analytes Tested

Ground water was analyzed for 131 pesticides and pesticide-breakdown products (Appendix B) and for nitrate+nitrite as nitrogen. The list included most of the pesticides on the U. S. Environmental Protection Agency's (EPA) list of leachable pesticides which have properties conducive to migration through soil to ground water (Cohen, 1985).

Nitrate was tested to investigate any link between elevated concentrations and pesticide detections.

Samples were analyzed by the Ecology/EPA Manchester Laboratory.

Quality Assurance

The quality of the results is generally good. The qualitative and quantitative accuracy, validity, and usefulness of data were independently reviewed by Stuart Magoon of the Ecology/EPA Manchester Laboratory (Appendix C).

Results

Pesticides

In the initial sampling, pesticides were detected in 11 of the 27 study wells, with more than one pesticide found in three of the 11 wells. Pesticides detected were **dacthal (DCPA), atrazine, prometon, bromacil, 3,5-dichlorobenzoic acid, dicamba, 4-nitrophenol, pentachlorophenol,** and **total xylenes**. Of these, atrazine, prometon, and bromacil were confirmed in verification sampling. The concentrations of detected pesticides are presented in Table 1, including results of both initial and verification sampling.

Table 1. Concentrations of pesticides detected in the Skagit Delta Surficial Aquifer (µg/L).

Site ID	Dacthal (DCPA)	Atrazine	Prometon	Bromacil	3,5,-Dichloro-benzoic Acid	Dicamba	4-Nitro-phenol	Penta-chlorophenol (PCP)	Total Xylenes
SK05P1									0.1J/ns
SK07R1					0.035J/U	0.025J/U			
SK11J1								0.013J/U	
SK12G1				0.019J/0.57					
SK14D1	0.056/U	0.12/0.16	0.037J/0.29						
SK15H1				0.03J/0.082J			0.6/U	0.013J/U	
SK15H1 D				0.02J/ns			0.71/U	0.014J/U	
SK18D1							1.2/ns		
SK24A1								0.015J/U	
SK25F1							1.5J/U	0.014J/U	
SK27M1								0.069/ns	
SK35R1								0.014J/U	

ns = not sampled for verification.
/ = initial followed by verification sample (initial/verification).
D = field duplicate sample.
U = not detected.
J = analyte detected but value is an estimate.

Eight of the nine pesticides detected are herbicides. 3,5-Dichlorobenzoic acid is a by-product from the degradation of other chlorinated pesticides. Three of the eight herbicides, pentachlorophenol (PCP), 4-nitrophenol, and total xylenes are also commonly used for other purposes. PCP is a common insecticide used to treat wood (often poles and fence posts), 4-nitrophenol is used to make other chemicals and has been reported to be used as a fungicide, and xylene is a component of numerous industrial chemicals including petroleum products.

Dacthal is used to control perennial and annual weeds such as crabgrass, foxtail, horsetail, and chickweed. Bromacil is a herbicide used for general weed and brush control in non-crop areas. It is particularly useful against perennial grasses. Atrazine and prometon are triazine herbicides. Prometon is non-selective and used for total vegetation control and brush control in noncrop areas. Atrazine is selective and used to control weeds on crop and pasture lands. Dicamba is a herbicide used to control broadleaf weeds in corn, sorghum, grains, asparagus, and on pasture, range land, and non-crop areas.

Dacthal was detected in 1 well (SK14D1) during the initial sampling at a concentration of 0.056 µg/L. It was not detected in the verification sample.

Atrazine was detected in one well (SK14D1) during the initial sampling at a concentration of 0.12 µg/L. It was again detected in the verification sample at a concentration of 0.16 µg/L

Prometon was detected in one well (SK14D1) during the initial sampling at a concentration of 0.037 µg/L. The concentration was low enough, however, that only an estimated value was reported. It was also found in the verification sample, but at a higher concentration (0.29 µg/L) that was quantifiable.

The above three herbicides were found in the same well. Well SK14D1 is a shallow irrigation well used for domestic lawn and garden watering. The well is hand dug, 12" in diameter, and lined with concrete rings It is physically located inside a garage structure with a depth to water about 11 feet below the garage floor. The design and shallow nature of the well make it susceptible to contamination from chemicals stored in the garage; however, nothing out of the ordinary was noted during the sampling.

Bromacil was detected in two wells (SK12G1 and SK15H1) at concentrations of 0.019 and 0.03 µg/L. A duplicate sample was collected from SK15H1, the concentration was 0.02 µg/L Concentrations were low enough in the initial samples that only estimated values were reported. Bromacil was also detected in the verification samples from both wells. The concentration in SK12G1 was 0.57 µg/L, great enough to be quantified. However, the concentration (0.082 µg/L.) in SK15H1 was again low enough that only an estimated value was reported.

Well SK12G1 is a 10 inch in diameter irrigation well used to irrigate nearby fields. The well is located about 100 feet from the nearest field. The well is 48 feet deep, but the depth to water is only 13 feet. SK15H1 is an old 3 foot in diameter, hand dug, concrete ringed irrigation well. It is located within a pea field. Although the well is unsealed at the surface, this is of little consequence since the depth to water is only 10 feet.

3,5-Dichlorobenzoic Acid was found in one well (SK07R1) at an estimated concentration of 0.035 µg/L. **Dicamba** was also detected in this same well at an estimated concentration of 0.025 µg/L. Concentrations of both pesticides were low enough that they could not be accurately quantified and only estimated values were reported. Neither pesticide was detected in the verification sample.

4-Nitrophenol was detected in three wells: SK15H1, SK18D1, and SK25F1. A duplicate sample was collected from SK15H1 and concentrations were 0.6 and 0.71 µg/L. The concentration in well SK18D1 was 1.2 µg/L and in SK25F1 it was 1.5 µg/L (estimated value). 4-Nitrophenol was not detected in the verification sample from either SK15H1 or SK25F1. The quantification limit for the verification analyses was 0.07 µg/L. The owner of well SK18D1 was concerned about legal ramifications and did not allow resampling.

Xylene was detected in one well (SK05P1) at an estimated concentration of 0.1 µg/L (the quantification limit was 3 µg/L). The well was partially dismantled during the verification sampling and could not be resampled. The usual source of xylene in water is petroleum products. Although xylene biodegrades rapidly in soils, it may be stable in ground water. Billions of pounds of xylene are produced and consumed in the U.S. each year.

Pentachlorophenol (PCP) was detected in six wells (SK11J1, SK15H1, SK24A1, SK25F1, SK27M1, and SK35R1). Concentrations ranged from an estimated 0.013 µg/L to a quantifiable 0.069 µg/L. The quantification limit for PCP was 0.019 µg/L. PCP was not detected in the verification samples (no verification sample collected for SK27M1).

I suspect that five of the six initial PCP detections were caused by field or laboratory contamination. All five of these samples were collected on the final sampling run of the initial sampling, were analyzed by the lab on the same day, and were below the quantification level. They include five of the seven wells sampled on the last day of field sampling. These wells were scattered throughout the study area, eliminating the possibility of local contamination. The only quantifiable concentration of PCP was found in the sample from well SK27M1 collected one week prior to these final five. Unfortunately, the owner had pulled his irrigation pump from this well prior to verification sampling, and no verification sample was collected. It is suspicious that PCP was detected in the last few samples collected during the study, but not detected in the verification samples collected from these wells. PCP was not detected, however, in any of the laboratory blanks analyzed with these samples. Therefore, I cannot confirm laboratory contamination. The PCP data have been accepted.

Nitrate + Nitrite as N

Nitrate+nitrite as N was detected in 13 of the 27 wells sampled. Initial concentrations ranged from 0.02 to 22.0 mg/L (Table 2). The quantification limit was 0.01 mg/L. The maximum concentration of nitrate+nitrite as N occurred in well SK11J1: 22.0 mg/L (initial) and 26.2 mg/L (verification). This well and one other had a nitrate+nitrite as N concentration greater than the MCL (10.0 mg/L) for public drinking water.

Nine of the 13 wells with detected nitrate also had detected pesticides. Only two wells in which pesticides were detected had nitrate+nitrite as N concentrations below the quantification level. The well with the greatest nitrate+nitrite as N concentration had one detected pesticide (PCP); the well with the next greatest nitrate concentration had no detected pesticides. Thus, although pesticides are more likely to be found where nitrate is detected, the connection is not definitive.

Field Measurements

The water temperature, pH, and specific conductance of study wells are shown in Table 2. Values showed little seasonal variation between the initial sampling in August 1994 and the verification sampling in May 1995. The temperature of ground water averaged 12.4° C during the initial sampling and was cooler by about 0.8° C during the verification sampling. The average initial pH was 7.1, similar to the pH during verification sampling. The average specific conductance was about 550 µmhos/cm during the initial sampling, with little change noted during verification.

Samples from eight wells equaled or exceeded the MCL (700 µmhos/cm) for specific conductance of public drinking water. This included water from both the shallowest and deepest wells (11 and 108 feet, respectively).

Influence of Well Depth and Location

Pesticides were not detected in the seven deepest wells, ranging from 55 to 108 feet, even though the water levels in these wells averaged less than eight feet. The average depth of wells in which pesticides were detected was 23 feet; the deepest was 48 feet. It appears that pesticides are restricted to the upper 50 feet of the aquifer.

Table 2. Nitrate + nitrite as nitrogen (mg/L), temperature (°C), pH, and specific conductance (µmhos,cm) of ground water.

Site ID	Nitrate	Temperature	pH	Conductance
SK01B1	U	11.8	8.2	950
SK01H1	U	12.2	6.5	500
SK05P1	6.3	ns	ns	ns
SK06B1	U	12.1	7.9	900
SK07M1	12.7	11.1	6.2	360
SK07R1	U	12.5/10.8	6.9/6.9	900/990
SK08L1	8.8	ns	ns	ns
SK10H1	U	12.4	6.73	220
SK11A1	U	15.0	6.8	1000+
SK11J1	22J/26.2	13.5/12.3	7.1/6.9	480/500
SK12G1	0.5	12.0/12.4	6.4/6.6	550/600
SK14D1	6.3	13 4/12.5	6.2/6.4	310/310
SK14L1	1.9	12.5	6.4	340
SK15H1	2.1J/2.0Ja	13.2/10.9	6.7/7.6	380/420
SK15R1	U	12.1	7.7	1000+
SK18D1	6.6J	11.8	6.9	400
SK20B1	U	12.1	8.2	300
SK21A1	U	12.2	6.4	390
SK23F1	U	11.8	6.8	370
SK24A1	0.04J	13.2/13.8	6.6/6.5	340/300
SK25F1	5.1J	12.4	6.2	410
SK26F1	U	11.2	7.2	800
SK27M1	0.1	14.2	7.2	1000+
SK27R1	UJ	12.2	8.1	800
SK31M1	U	11.6	7.5	540
SK35R1	UJ	11.8/11.7	8.2/8.7	200/180
SK36A1	0.02	11.9	7.6	395

U - not detected above the detection limit of 0.01 mg/L.
J - stored at an incorrect temperature, qualified as an estimate.
/ - initial followed by verification sample (initial/verification).
a - field duplicate samples.
ns - not sampled.

A similar relationship was found between well depth and nitrate concentrations. Nitrate was not detected in six of the seven deepest wells just mentioned. It was detected in only one well greater than 50 feet in depth (SK36A1 = 65 feet deep) but at a concentration (0.02 mg/L) just above the quantification limit. The average depth of wells without detected nitrate was 53 feet, but included wells as shallow as 11 feet.

Wells with detected nitrate ranged from 12 to 65 feet deep. However the two deepest nitrate detections, at 48 feet and 65 feet, had nitrate+nitrite as N concentrations of only 0.05 mg/L and 0.02 mg/L, respectively. Excluding these two deeper wells, the average depth of wells with detected nitrate was 20 feet. The wells with the two greatest nitrate concentrations were 22 and 25 feet deep.

An inverse relationship was noted with specific conductance. The average conductance of the seven wells greater than 50 feet in depth was 711 µmhos/cm. The average conductance of wells less than 50 feet deep was 492 µmhos/cm. These results may reflect the greater salinity expected with depth in an aquifer bounded by seawater.

Although over half of the pesticide detections were located in the northern portion of the study area, there is no apparent relationship between pesticide detections and location within the study area. Similarly, there is no relationship between well location and elevated nitrate concentration.

Health Concerns

The Environmental Protection Agency (EPA) has set Maximum Contaminant Levels (MCLs) or Lifetime Health Advisory Levels (LHALs) -- concentrations considered protective of non-cancer health effects -- for all of the detected pesticides except 3,5-dichlorobenzoic acid. None of the pesticide concentrations exceeded these levels of concern.

- EPA has set a LHAL for dacthal (DCPAs) at 4,000 µg/L. The one detection in this study was about 1/100,000 of this value.

- The MCL for atrazine in drinking water is 3.0 µg/L. Atrazine was detected in one well at a concentration of about 5% of the MCL.

- The LHAL for prometon is 100 µg/L, 350 times greater than the concentration found in this study.

- Bromacil was detected at 0.6% of the 90 µg/L LHAL.

- 3,5-dichlorobenzoic acid is not listed for regulation in drinking water by EPA.

- The LHAL for dicamba is 200 µg/L. The concentration found in this study was 1/10,000 of this value.

- EPA has set the MCL for 4-nitrophenol at 60 µg/L. The maximum concentration found in this study was about 2.5% of the MCL.

- The LHAL for xylene is 400 µg/L. The detected concentration was 0.1 µg/L.

- The MCL for pentachlorophenol is 1 µg/L. The maximum concentration found in this study was about 7% of the MCL.

The MCL for public drinking-water systems for nitrate as N is 10.0 mg/L. The nitrate+nitrite as N concentration exceeded 10 mg/L in two wells, and 5.0 mg/L (1/2 the MCL) in seven wells.

Specific conductance in eight wells equaled or exceeded the 700 µmhos/cm secondary drinking water standard.

Conclusions

- Nine pesticides were detected in ground water from the Skagit Delta Surficial Aquifer: **dacthal (DCPA), atrazine, prometon, bromacil, 3,5-dichlorobenzoic acid, dicamba, 4-nitrophenol, pentachlorophenol, and xylene**. However, the presence of only three of these pesticides was confirmed by the verification sampling; the vertification sample for xylene was not collected.

- None of these pesticides was detected above concentrations established by the EPA for health protection.

- No impairment of water use is indicated based on concentrations of pesticides.

- Pesticides were not detected in the seven deepest wells, ranging from 55 to 108 feet. Pesticide detections were limited to well depths less than about 50 feet.

- In two of the 27 study wells, the nitrate+nitrite as N concentration exceeded the 10.0 mg/L drinking water standard. Seven wells had concentrations greater than 5 mg/L. Like pesticides, elevated nitrate concentrations were restricted to the shallow wells (<50 feet).

- Eight wells had specific conductance values greater than or equal to the 700 µmhos/cm MCL for public drinking water. Unlike nitrate, specific conductance generally increased with well depth. Pesticides were detected in only two of these wells.

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Appendices

Appendix A. Skagit Delta Surficial Aquifer study wells.				
Site ID	Water Use	Ground Elevation (ft)	Well Depth (ft)	Depth to Water (ft)
SK01B1	Domestic	15	55	10
SK01H1	Domestic	12	UN	UN
SK05P1	Irrigation	8	20	7
SK06B1	Domestic	8	108	5
SK07M1	Domestic	25	30	<20
SK07R1	Irrigation	5	11	4
SK08L1	Irrigation	5	12	<20
SK10H1	Domestic	10	28	UN
SK11A1	Irrigation	10	35	6
SK11J1	Domestic	22	20	<20
SK12G1	Irrigation	25	48	14
SK14D1	Irrigation	16	20	11
SK14L1	Irrigation	16	UN	<20
SK15H1	Irrigation	15	20	11
SK15R1	Not in use	4	77	5
SK18D1	Domestic	25	25	<20
SK20B1	Domestic	25	36	<20
SK21A1	Irrigation	11	60	7
SK23F1	Not in use	15	37	10
SK24A1	Irrigation	20	20	<20
SK25F1	Irrigation	22	15	<15
SK26F1	Irrigation	11	30	10
SK27M1	Irrigation	5	22	<20
SK27R1	Domestic	10	84	UN
SK31M1	Domestic	15	103	9
SK35R1	Domestic	10	29	UN
SK36A1	Irrigation	15	65	UN
UN = Unknown				

Appendix B. Target pesticides.

Pesticide	Method	Quantification Limit (µg/L)
1,2-Dibromo-3-Chloropropane (DBCP)	EPA 504	0.02
1,2-Dibromoethane (EDB)	EPA 504	0.02
1,2-Dichloropropane	EPA 846	1.0
1-Naphthol	EPA 531.1	1.0
2,3,4,5-Tetrachlorophenol	EPA 615	0.02
2,4,5-T	EPA 615	0.01
2,4,5-TB	EPA 615	0.01
2,4,5-TP (Silvex)	EPA 615	0.01
2,4,5-Trichlorophenol	EPA 615	0.02
2,4,6-Trichlorophenol	EPA 615	0.02
2,4-D	EPA 615	0.03
2,4-DB	EPA 615	0.06
3,5-Dichlorobenzoic Acid	EPA 615	0.03
3-Hydroxycarbofuran	EPA 531.1	0.50
4-Nitrophenol	EPA 615	0.07
5-Hydroxydicamba	EPA 615	0.02
Abate (Temephos)	EPA 1618	0.75
Acifluorfen (Blazer)	EPA 615	0.03
Alachlor	EPA 1618-N	0.20
Aldicarb	EPA 531.1	1.0
Aldicarb Sulfone	EPA 531.1	1.0
Aldicarb Sulfoxide	EPA 531.1	2.0
Ametryn	EPA 1618-N	0.08
Atraton	EPA 1618-N	0.25
Atrazine	EPA 1618-N	0.08
Azinphos Ethyl	EPA 1618	0.13
Azinphos Methyl (Guthion)	EPA 1618	0.15
Baygon (Propoxur)	EPA 531.1	1.0
Benefin	EPA 1618-N	0.13
Bentazon	EPA 615	0.11
Bolstar (Sulprofos)	EPA 1618	0.06
Bromacil	EPA 1618-N	0.50
Bromoxynil	EPA 615	0.01
Butachlor	EPA 1618-N	0.29
Butifos (DEF)	EPA 1618	0.12
Butylate	EPA 1618-N	0.13
Carbaryl	EPA 531.1	2.0
Carbofuran	EPA 531.1	2.0
Carbophenothion	EPA 1618	0.08
Carboxin	EPA 1618-N	0.92
Chloramben	EPA 615	0.02
Chlorothalonil (Daconil)	EPA 1618-N	0.20
Chlorpropham	EPA 1618-N	0.42
Chlorpyrifos	EPA 1618	0.06
Cis-1,3-Dichloropropene	EPA 846	1.0
Coumaphos	EPA 1618	0.10
Cyanazine	EPA 1618	0.10
Cycloate	EPA 1618-N	0.13
Dacthal (DCPA)	EPA 615	0.01
Dalapon (DPA)	EPA 615	0.05
Demeton-O	EPA 1618	0.05
Demeton-S	EPA 1618	0.06

Appendix B. Continued.

Pesticide	Method	Quantification Limit (µg/L)
Di-allate (Avadex)	EPA 1618	0.30
Diazinon	EPA 1618	0.07
Dicamba	EPA 615	0.01
Dichlobenil	EPA 1618-N	0.10
Dichlorprop	EPA 615	0.03
Dichlorvos (DDVP)	EPA 1618	0.07
Diclofop Methyl	EPA 615	0.06
Dimethoate	EPA 1618	0.06
Dioxathion	EPA 1618	0.13
Diphenamid	EPA 1618-N	0.25
Disulfoton (Di-Syston)	EPA 1618	0.05
Diuron	EPA 1618	0.10
EPN	EPA 1618	0.08
Eptam	EPA 1618-N	0.13
Ethalfluralin (Sonalan)	EPA 1618-N	0.13
Ethion	EPA 1618	0.06
Ethoprop	EPA 1618	0.07
Fenamiphos	EPA 1618	0.12
Fenarimol	EPA 1618-N	0.25
Fenitrothion	EPA 1618	0.06
Fensulfothion	EPA 1618	0.08
Fenthion	EPA 1618	0.06
Fenvalerate	EPA 1618	0.31
Fluridone	EPA 1618-N	0.67
Fonofos	EPA 1618	0.05
Hexazinone	EPA 1618-N	0.13
Imidan	EPA 1618	0.09
Ioxynil	EPA 615	0.01
MCPA	EPA 615	1.7
MCPP	EPA 615	1.7
MGK264	EPA 1618-N	0.59
Malathion	EPA 1618	0.07
Metalaxyl	EPA1618	0.50
Methiocarb	EPA 531.1	1.0
Methomyl	EPA 531.1	1.0
Methyl Chlorpyrifos	EPA 1618	0.06
Methyl Paraoxon	EPA 1618	0.15
Methyl Parathion	EPA 1618	0.06
Metolachlor	EPA 1618-N	0.25
Metribuzin	EPA 1618-N	0.08
Mevinphos	EPA 1618	0.08
Molinate	EPA 1618-N	0.22
Napropamide	EPA 1618-N	0.25
Norflurazon	EPA 1618-N	0.13
Oxamyl (Vydate)	EPA 531.1	2.0
Oxyfluorfen	EPA 1618-N	0.22
Parathion	EPA 1618	0.07
Pebulate	EPA 1618-N	0.20
Pendimethalin	EPA 1618-N	0.13
Pentachlorophenol	EPA 615	0.004
Permethrin	EPA 1618	0.16

Appendix B. Continued.

Pesticide	Method	Quantification Limit (µg/L)
Phenothrin	EPA1618	0.16
Phorate	EPA 1618	0.06
Phosphamidan	EPA 1618	0.20
Picloram	EPA 615	0.02
Profluralin	EPA 1618	0.20
Prometon (Pramitol 5p)	EPA 1618-N	0.08
Prometryn	EPA 1618-N	0.08
Pronamide (Kerb)	EPA 1618-N	0.25
Propachlor (Ramrod)	EPA 1618-N	0.17
Propargite	EPA 1618	0.16
Propazine	EPA 1618-N	0.08
Propetamphos	EPA 1618	0.17
Resmethrin	EPA 1618	0.16
Ronnel	EPA 1618	0.06
Simazine	EPA 1618-N	0.08
Sulfotepp	EPA 1618	0.05
Tebuthiuron	EPA 1618-N	0.08
Terbacil	EPA 1618-N	0.42
Terbutryn (Igran)	EPA 1618-N	0.08
Tetrachlorvinphos (Gardona)	EPA 1618	0.17
Trans-1,3-Dichloropropene	EPA 846	1.0
Treflan (Trifluralin)	EPA 1618-N	0.13
Triadimefon	EPA 1618-N	0.22
Triallate	EPA 1618-N	0.22
Tributylphosphorotrithioite(Folex),(Merphos)	EPA 1618	0.13
Trichlopyr (Garlon)	EPA 615	0.03
Vernolate	EPA 1618-N	0.13
Xylene, Total	EPA 846	1.0

Appendix C. Quality Assurance Review

Analyses were conducted at the Ecology/EPA Manchester Laboratory. The qualitative and quantitative accuracy, validity, and usefulness of data were reviewed by Stuart Magoon of Manchester Laboratory. Laboratory quality control (QC) followed standard Manchester guidelines and included laboratory blanks, surrogate spikes, and pesticide matrix spikes. The relative percent difference (RPD) was used to estimate analytical precision. The RPD is the ratio of the difference and the mean of duplicate (or replicate) samples expressed as a percentage.

In addition to laboratory QC samples, a single duplicate sample was collected for field quality assurance (QA). A duplicate sample consisted of an identical sample submitted to the laboratory with different sample identification (from site SK15H1). Because of the preponderance of below quantification limit results, duplicate and replicate samples are usually not useful in determining precision of pesticide analyses. However, bromacil, 4-nitrophenol, and pentachlorophenol were detected in these duplicates. Although positively detected, bromacil and pentachlorophenol concentrations were below the quantification limit and were reported as estimated values with the "J" qualifier. 4-nitrophenol was reported at 0.60 and 0.71 µg/L. Nitrate-nitrite as N was detected at 2.1 and 2.0 mg/L in the duplicates

In general, the quality of the results is good. Specific comments on each laboratory method follow:

Chlorinated herbicides by EPA Method 1658 and 515.1: All samples were extracted and analyzed within recommended holding times. No target compounds were detected in the laboratory blanks. Surrogate spike recoveries for 2,4,6-tribromophenol ranged from 26% to 119% for the initial samples except for three samples which had 8%, 9%, and 0% recovery. Results for these three samples were given the "J" qualifier because of low surrogate recoveries. Surrogate recoveries for the verification samples ranged from 82% to 112%. No recovery limits have been established for this method.

A matrix spike and a matrix spike duplicate were collected during the initial sampling. No matrix spike was collected during verification. Most of the compounds in the matrix spikes had recoveries between 19% and 122% except for dalapon at 2% and 4% recovery. All dalapon results were given the "J" qualifier. The relative percent differences (RPD) ranged from 8.9% to 67%. No matrix spike recovery limits or RPD have been established for this method. Dinoseb was not recovered at all and the data was not acceptable and all results were rejected. With one exception, no special problems were encountered with these analyses and the data are acceptable for use as qualified.

In the initial analyses, pentachlorphenol (PCP) was detected in six samples and a duplicate. However, no pentachlorophenol was detected in the verification samples and thus the initial analyses could not be confirmed. There is the possibility that lab contamination may have resulted in the detections of PCP but there is no way to confirm this since PCP was not detected in the two laboratory blanks analyzed with each sample set. Extra precautions were taken with the verification analyses. Precautions included replacing the siphon apparatus with new materials and running an equipment blank on each extraction setup prior to extracting the sample through the same setup. This gave each PCP sample the equivalent of a rinse blank prior to extraction. No pentachlorophenol was detected in the rinse blanks nor in the verification samples

Volatile organics by EPA SW 846 Method 8260: All samples were analyzed within the recommended 14-day holding time. No pesticides were detected in the laboratory blanks, although low levels of the common laboratory solvents acetone and methylene chloride were found. Surrogate recoveries for 1,2-Dichloroethane-D4, D8-Toluene, D4-1,2-Dichlorobenzene, p-Bromofluorobenzene, and Fluorobenzene were within acceptable limits, ranging from 88% to 124% for the initial samples. Matrix spikes were within acceptable limits for both percent recovery and RPD with the exception of the RPD for one matrix spike ran for the final sample set. This spike exhibited higher recoveries than the others, probably caused by an error made in the process of spiking the sample. This does not affect the validity of the data and did not require any additional qualifiers. No analytical problems were encountered in the analysis. The data are acceptable for use as qualified.

Ethylene dibromide(EDB) and dibromochloropropane (DBCP) by EPA Method 504: All samples were extracted and analyzed within the recommended holding times. No target compounds were detected in the laboratory blanks. Surrogate recoveries for methylated Dalapon ranged from 55% to 113%. No recovery limits have been established for this method. Matrix spike recoveries for EDB ranged from 96% to 100%. DBCP recoveries ranged from 100% to 102%. The RPD ranged from 2% to 4.1%. No special problems were encountered in the analysis. The data are acceptable for use without additional qualifiers.

Nitrogen containing pesticides by EPA Method 1618: All samples were extracted within 7 days and extracts were analyzed within the recommended holding time. No target analytes were detected in laboratory blanks. Dimethylnitrobenzene was used as the surrogate compound. No specific nitrogen containing pesticide surrogates were available for this analysis. Surrogate recoveries ranged from 44% to 126% for the initial samples except for two samples which had 5% and 3% recoveries, and 71% to 84% for the verification samples except for one blank which had 25% recovery. No surrogate recovery limits have been established for this method. Matrix spike recoveries for the 9 nitrogen containing compounds spiked in the initial samples, ranged from 91% to 146%, and the RPD from 1.9% to 20%. No matrix spikes were analyzed for the verification

samples. No recommended recovery limits or RPD have been established for this method. No special problems were encountered in the analysis.

Organo-phosphorous pesticides by EPA 1618 Method: All samples were extracted within 7 days and extracts were analyzed within the recommended holding time. No target analytes were detected in the laboratory blanks. Surrogate recovery for triphenyl phosphate (TPP) ranged from 50% to 158%. No recommended recovery limits have been established for this method. Matrix spike recoveries for nine organo-phosphorous pesticide compounds ranged from 92% to 122%, and the RPD ranged from 0% to 6.5%. No recommended recovery limits or RPD have been established for this method. No special problems were encountered in the analysis. The data are acceptable for use as qualified.

Pyrethrin pesticides by modified EPA 1618 Method: All samples were extracted within 7 days and analyzed within the recommended holding time. No target analytes were detected in the laboratory blanks. No specific surrogates were available for this method. Matrix spike recoveries for the pyrethrin, fenvalerate (2 isomer), ranged from 116% to 126% and the RPD was 8.3%. No recommended recovery limits or RPD have been established for this method. No special problems were encountered in the analysis except for two samples which had low surrogate recoveries and were qualified with a "J". One sample contained significant phthalate contamination which interfered with the phenothrin analysis. This analyses was rejected. The remaining data are acceptable for use as qualified.

Sulfur pesticides by modified EPA 1618 Method: All samples were extracted within 7 days and extracts were analyzed within the recommended holding time. The single target analyte, Propargite, was not detected in the laboratory blanks. No specific sulfur pesticide surrogate has been identified for this method, and no matrix spikes were analyzed with these samples. No special problems were encountered in the analysis and the data are acceptable for use as qualified.

Carbamate pesticides by EPA Method 531.1: Samples were preserved in the field at the time of collection and initial samples were analyzed within the recommended 28-day holding time. No target compounds were detected in the laboratory blanks. No surrogate compound is specified for EPA Method 531.1. Since the method calls for direct injection of the sample, recovery is 100%. The compound 4-bromo-3,5-dimethylphenyl N-methylcarbamate (BDMC) is added as a surrogate when samples are extracted and concentrated before analysis but is used as an internal standard in Method 531.1. Consequently no surrogate recovery data are available from this analysis. Matrix spike recoveries for the 11 carbamate pesticides spiked ranged from 53% to 101% and the RPD ranged from 0% to 16%. No recovery or RPD limits have been established for this method. The data are acceptable for use as qualified.

Nitrate+nitrite as nitrogen by EPA Method 353.2: All samples were analyzed within recognized holding times. However, during the storage of eight samples, the refrigeration unit failed over a weekend. Samples were found at 32 degrees C on a Tuesday. The specific length of time the samples were stored at elevated temperature is unknown. The samples were moved to a 4 degree C cold room until repairs were complete. These samples were qualified with the "J" qualifier. The procedural blanks showed no significant levels of nitrate-nitrite. Concentrations of a field duplicate were within 5% and recovery of a single spiked sample was 98.9%.