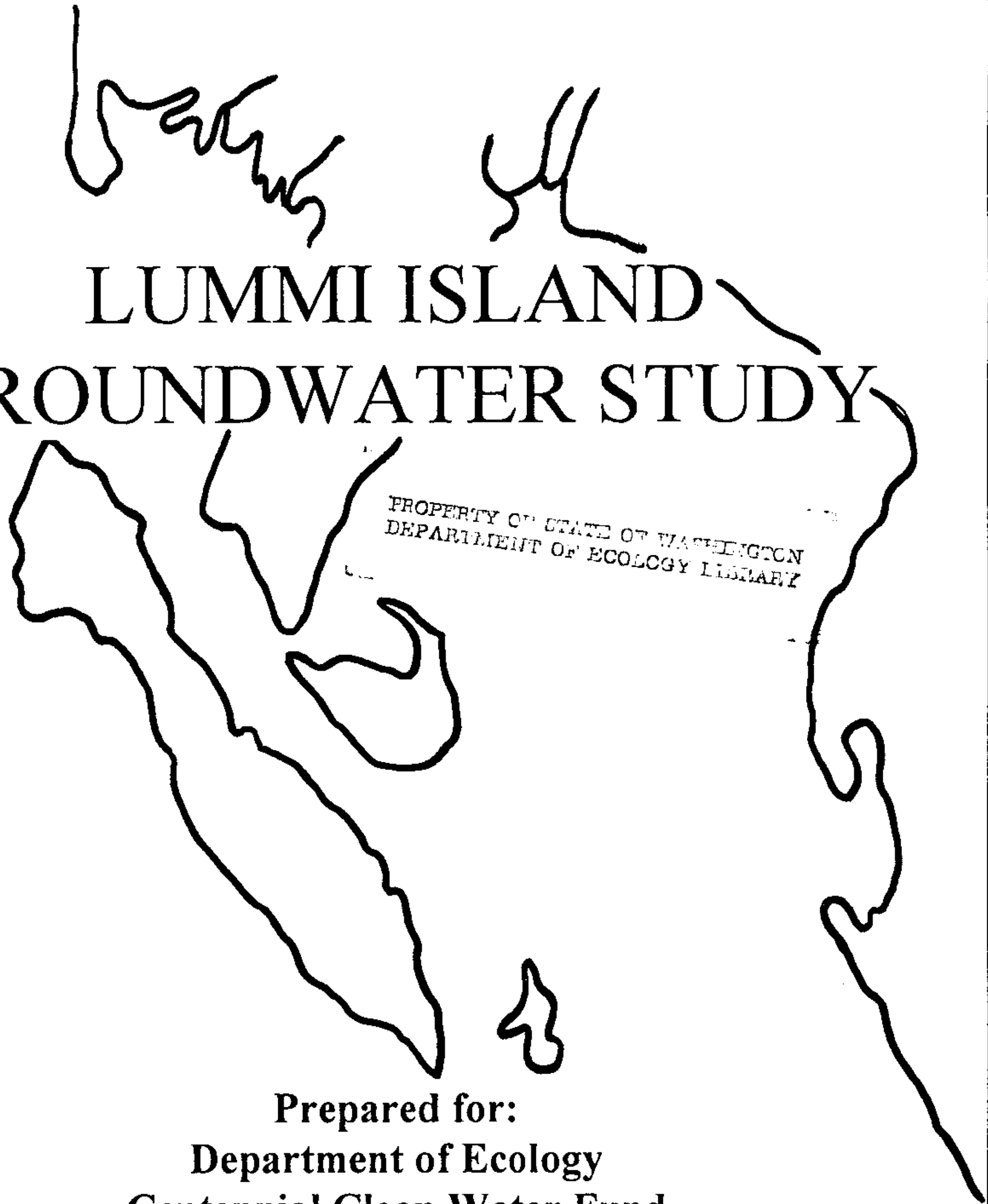
LUMMI ISLAND GROUNDWATER STUDY



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LUMMI ISLAND GROUNDWATER STUDY
Final Report

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1 INTRODUCTION

The Lummi Island groundwater study was developed through the cooperative efforts of Whatcom County and Island residents in 1989. The study grew out of concerns with arsenic and saltwater intrusion, identification of recharge areas, results of previous studies, and recommendations in the Lummi Island Plan.

1.1 AUTHORIZATION AND FUNDING

Whatcom County was the lead agency in developing a grant proposal under Ecology's Centennial Clean Water Fund program. The grant was obtained in 1989 and work began in 1990. This report was written by the Whatcom County Health Department (WCHD) and Planning Department (WCPD) with assistance from the State Department of Ecology (Ecology) and Department of Health (DOH).

1.2 BACKGROUND

Lummi Island supports a permanent population of 620 people (1990 Census). There are a total of 559 homes on the Island with 287 providing homes for the permanent residents and 249 providing homes on a seasonal basis.

There are 19 public water systems on the Island. Sixteen of these systems rely on groundwater and supply water to about 500 people. Three of these systems use surface water and supply about 364 people with water. The Island has many permanent and seasonal residents which rely on private water systems however it is unclear what percentage comes from surface water and what percentage comes from groundwater. Tables 1 and 2 provide additional details on drinking water systems on Lummi Island.

Previous studies and reports have identified specific concerns associated with the long-term use of groundwater for drinking water purposes. These concerns include:

- <u>Arsenic</u>

  Arsenic has been found in public and private water supply wells on the Island. Concentrations found range between undetectable and over 0.330 ppm. The current maximum contaminant level established in the Safe Drinking Water Act is 0.05 ppm. This level is currently under review by EPA and may be lowered due to concerns carcinogenicity. Inorganic arsenic is found in most ground water supplies in the U.S. but concentrations typically average 0.001 ppm, considerably lower than those found on Lummi Island. The source of the arsenic on Lummi Island, whether natural or associated with human activity, has not been determined conclusively.

- Saltwater Intrusion

Saltwater intrusion, as evidenced by chloride concentrations exceeding 100 mg/liter, has been identified as a potential problem in some shoreline areas on Lummi Island. A 1984 study identified one area of concern along the northeast shoreline between Migley Point and the Community of Lummi Island (Diou and Sumioka, 1984). Subsequent monitoring by Ecology in 1988 and 1989 identified additional seawater affected wells along the northeast shoreline and near Village Point (Ecology, 1990). Although existing data did not suggest a wide-spread chloride contamination, continual study and evaluation is needed. In addition, proactive steps to ensure that intrusion does not become widespread may be necessary, if population growth accelerates on the Island in the next 50 years.

Ecology Water Resources Program administers the water rights of the State. Ecology is currently implementing a Seawater Intrusion Policy (Appendix H) when reviewing water right permit applications on Lummi Island. All ground water right applications on Lummi Island are reviewed for the potential to induce seawater intrusion.

In general, unless the applicant can show that the withdrawal will not increase seawater intrusion , water right applications are denied if:

* The chloride level within the proposed well is greater the 99 mg/l.

or

* The proposed well is within a minimum of 1/2 mile of an existing well with a chloride level greater than 99 mg/l.

If a water right permit is issued, further chloride testing is required as a condition of the permit. Depending on the results of this chloride testing, withdrawal of ground water under the permit may be limited or other action required.

Facilitated by the State's Growth Management Act, Ecology can notify the County when water is not available for proposed building projects or subdivisions and this notice would result in the County denying permits for the projects. To date the County has not received notification from Ecology that water is not available for a project on Lummi Island. This Ecology notification that water is not available applies to all wells, including those that are exempt from the water right permit process.

- <u>Other Kinds of Contamination</u>

  Individual incidents of contamination from old fuel tanks or other non-point sources have been indicated by Island residents, but not investigated in this study.

1.3 PURPOSE OF THE STUDY

The purpose of the study was twofold:

1) <u>Groundwater Monitoring</u>

   To obtain data to assist in evaluating current groundwater quality and contribute to the identification of any trends.

2) <u>Public Information and Education</u>

   To work with Island residents providing them with hands-on experience and educational materials about Lummi Island groundwater: where it comes from, how it can become degraded and what can be done to protect it.

2. GROUNDWATER MONITORING

The ground water monitoring portion of the Lummi Island study included data collection and data analysis.

2.1 DATA COLLECTION

Data collection included locating and compiling historic data as well as collection of new data. This new data was obtained by volunteers under the direction of Whatcom County Health Department (WCHD) and Ecology staff. A volunteer group of individuals was selected and trained in preparation for the monitoring work which began in 1991. The volunteers collected the following types of information using the procedures detailed:

<u>Water Levels</u>

Static water levels were collected to gain information on ground water flow direction and to establish a baseline for ranges and trends in aquifer storage. Static water levels were measured monthly by the volunteers in 35 wells in accordance with the Data Collection Guidelines developed by Ecology. Water levels were reported in tenths of feet from consistent points on the casing and qualified if not static. Volunteers were assigned groups of wells in order to increase consistency in data collection. The study did not include surveying of the wellheads and therefore accurate well head elevations are not available at this time. One problem identified was the apparent lack of USGS bench marks on the Island.

TABLE 1

Table 1. Provides a breakdown on the relative numbers of the population which relies on surface water versus groundwater.

POPULATION:

620 Total Permanent Residents
238 are on Public Systems
382 are on Private Systems

? Total Seasonal Residents
628 are on Public Systems
? are on Private Systems

Note: It is difficult to determine how many seasonal residents exist on Lummi Island. Census data indicates that there are 249 seasonal homes with an average of 2.16 residents/home for a total of 538. Public water system records indicate that there are 628 seasonal residents using public water systems alone. The public water system estimates were used to compile data which follows.

PUBLIC WATER SUPPLY:

Total Number of Systems - 19
16 (74 %) Rely on Groundwater
3 (16 %) Rely on Surface Water

Total Population Served - 866
502 (58 %) Rely on Groundwater
364 (42 %) Rely on Surface Water

Total Permanent Population Served - 238
184 (72 %) Rely on Groundwater
54 (18 %) Rely on Surface Water

Total Seasonal Population Served - 628
318 (51 %) Rely on Groundwater
310 (49 %) Rely on Surface Water

PRIVATE WATER SYSTEM.

Total Population Served - 328
Number relying on groundwater and surface water is unknown

HOMES:

559 Total Number of Homes
287 (51%) support a Permanent Population
249 (44%) support a Seasonal Population

TABLE 2

SYSTEM NAME	NUMBER OF CONNECTIONS		POPULATION SERVED		SOURCE of SUPPLY
	Permanent	Seasonal	Permanent	Seasonal	
1. LISECC	163		25	300	Surface
2. Miller Water Association	4		10		Well
3. Bakers Water System	4		6	10	Spring
4. Beach Club Condominium	4	18	4	30	Well
5. Beach Elementary School	1		40		Well
6. Georgia View Association	6		4	15	Well
7. Hilltop Water Owners Association	27	1	27	44	Well
8. Isle Aire Beach Inc.	33		20	90	Well
9. Loganita Lodge		1	3	10	Well
10. Lummi Island Post Office	1				Well
11. Lummi Point Water Association	15	15	45	50	Well
12. Ridge Water Association	5		10	15	Well
13. Salvation Army - Camp Lummi		1		24	Well
14. Sunny Hill Water System	1		3		Well
15. Sunrise Cove Water System	9		23		Surface
16. Marine View Estates	8		4	15	Well
17. Nettles Short Plat	2		6		Well
18. Sunset Beach	1	5	4	15	Well
19. Tuttle Lane Water	5		4	10	Well
TOTAL ---->			238	628	

Arsenic and Chloride

Arsenic and chloride samples were taken from 18 wells on a bi-monthly basis. Criteria used to select the wells were availability of a well log, owner's permission and well accessibility, geographic distribution and previous arsenic and chloride sample results. The intent was to chose wells in areas that had not been previously sampled and to continue sampling other wells to examine seasonal variation or other trends in sample results. Wells were chosen in clusters to allow comparison of water level measurements to examine ground water flow direction. Each well was given an identification number to assist in ensuring that the results remained confidential.

Water samples for analysis were collected in accordance with the Data Collection Guidelines drafted by Ecology. Stabilization of conductivity and temperature readings was used to establish adequate purging of the casing. Readings were reported on a Water Sampling Record Form. Samples were transported by mail to the laboratory and Chain of Custody records were kept.

Samples were analyzed at Laucks Laboratory in Seattle for arsenic and chloride. Arsenic was analyzed using EPA method 7061 and 206.3 with a detection level of 0.005 milligrams per liter (mg/l). Chloride was analyzed using EPA method 325.3 with a detection level of 1.0 mg/l. Well owners were sent written notice when an arsenic result exceeded the Maximum Contaminant Level (MCL) for the first time.

Precipitation

Approximately daily precipitation measurements, with more consistent monthly totals, were taken at 3 locations on the Island . The stations are located on the north west coast, the north east coast, and midland on the north end of the island.

Tidal Effects Study

A one day tidal effects sampling study was conducted in 3 Lummi Island wells. June 30, 1992 was chosen for the sampling because of its relatively extreme tidal range of 12.2 feet (from tide tables). The purpose of the tidal study was to examine the relationship between tidal stage and pumping on chloride and arsenic results. A reconnaissance field trip to determine study wells was conducted on 5/21/92.

2.2 DATA ANALYSIS

<u>Sources of Ground Water Quality Data</u>

There are three sources of ground water data considered in this study: 1) Well samples collected in 1983 and 1984 by the Whatcom County Health District/Department (WCHD) after they recognized the occurrence of arsenic. 2) Health Department data also includes arsenic data from private well owners applying for building permits after approximately July 1990; 3) Ecology's follow-up ground water sampling for arsenic, chloride, and specific conductance in 1988-1989; 4) And finally, two years of arsenic, chloride, and water level data contributed by this citizen initiated Centennial study for selected wells from 1991-1992. The compiled ground water data from these three sources is contained in Appendix E. Chloride data from an earlier study entitled " The Water Resources of Northern Lummi Island" (Robinson & Noble, 1978), was not included in this analysis.

<u>Arsenic Data Analysis</u>

Except for arsenic data collected during the one-day tidal effects test done in connection with this study, the ground water arsenic data collected during this study and an interpretive report are contained in Appendix B. In summary the data show that 8 of the 24 wells sampled exceeded the drinking water MCL for arsenic of 50 ug/l. Two of the 24 wells showed levels of arsenic exceeding 25 ug/l, which is half the MCL for arsenic. While the arsenic data collected to date clearly establish the presence of arsenic contamination in ground water on Lummi Island, the quantity, seasonal variation, and limited time span of the data do not provide an adequate basis for trend analysis.

<u>Chloride Data Analysis</u>

Chloride data for Lummi Island ground water was compiled by the WCHD and is found in Appendix E. This compilation includes data from this sampling , but not the data from Robinson and Noble (1978). The data includes sample results from a total of 75 Lummi Island wells and were collected by various parties as described above under <u>Sources of Data</u>. The chloride results were summarized by subdivision into categories based on Ecology's Seawater Intrusion Policy contained in Appendix H. The <u>highest</u> chloride reading measured for the well was used to determine its category. Duration of pumping is not accounted for or documented in this data compilation.

Chloride level	Ecology Risk Level	Number of wells
<25 mg/l	background	50
25-100 mg/l	low risk	16
100-250 mg/l	medium risk	2
>250 mg/l	high risk	7

The above data indicate that 88% of the study wells have background or low risk chloride levels and 12% were at medium or high risk levels.

In a effort to identify possible trends, average annual chloride readings were calculated for wells with 3 or more chloride samples per year from 1991-1992. These annual chloride averages are found in Table 3. Comparing 1991 to 1992, 9 wells showed an increase in average annual chloride detected and 7 wells showed a decrease or no change in average annual chloride level.

Average annual chloride data for a period of 4 years was available for two of the study wells. Table 4 shows that chloride levels in these wells remained below the background level of 25 mg/l over the four year period.

It has not been determined whether the degree of average annual chloride change is significant. Annual averages of 3-5 samples may not be representative of long term ground water quality. There are many variables such as changes in pumping rate, seasonal water level changes, or precipitation levels which could effect the chloride level in individual wells. The value of this data is the establishment of a baseline for future investigations of chloride levels on the Island.

The previous single sampling in May 1978 by Robinson and Noble was not adequate for comparison or use in trend analysis. Future studies and perhaps monitoring wells would be necessary to determine: the aquifers potentially affected by seawater intrusion, the areal extent of medium and high risk areas, the location of the zone of mixing of fresh and saline ground waters, whether the mixing zone is moving inland due to increased water demand, whether any of the chloride levels over 250 mg/l can be attributed to localized upconing due to overpumping.

Water level and precipitation data analysis

Precipitation was observed at 3 stations on the northern half of the island and data is found in Appendix G. Without the benefit of a formal statistical analysis, data from the 3 stations does not seem to indicate a large difference in precipitation pattern over the northern portion of the island as shown in Table 5. Comparing this data with readings from the Bellingham

TABLE 3

AVERAGE ANNUAL CHLORIDE IN SELECTED LUMMI ISLAND WELLS 1988-1992					
			CHLORIDE IN MG/L		
WELL ID	1988	1989	1990	1991	1992
37/1-4F1*				18.2	19
37/1-4G2*				14	16
37/1-5A1*				22.5	20
37/1-5C1*				43.6	46
37/1-5R1*				20.4	21.3
37/1-8A1*				13.2	13.5
37/1-9G3*				10.2	10.3
37/1-9J1*				45.6	39.3
37/1-10L2*				6.6	6.6
37/1-15E1*				16	14
37/1-15G1*				9.6	12.3
37/1-15H2*				9.2	9.3
38/1-32A1*				44.8	44.4
38/1-32B1*	18.5	17.3		18.8	14.5
38/1-32J1*	16.4	19.8		20	19.1
38/1-32P1*				20.2	25.4
* DENOTES WELLS SAMPLED IN GRANT STUDY					

AVERAGE ANNUAL CHLORIDE LEVEL FOR SELECTED WELLS 1991 and 1992

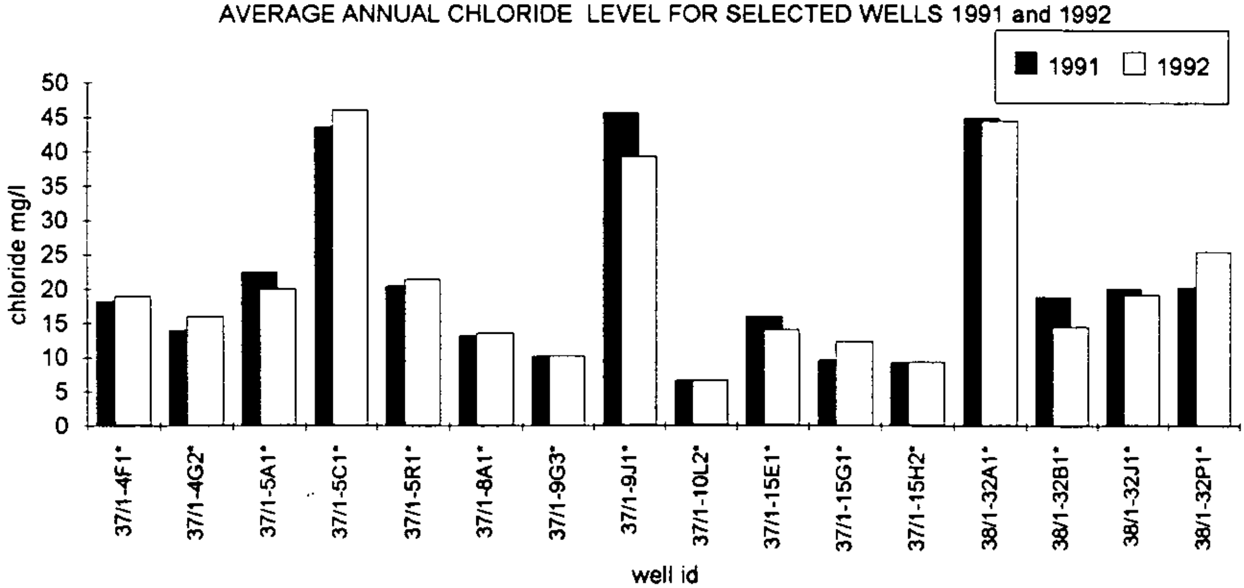


TABLE 4

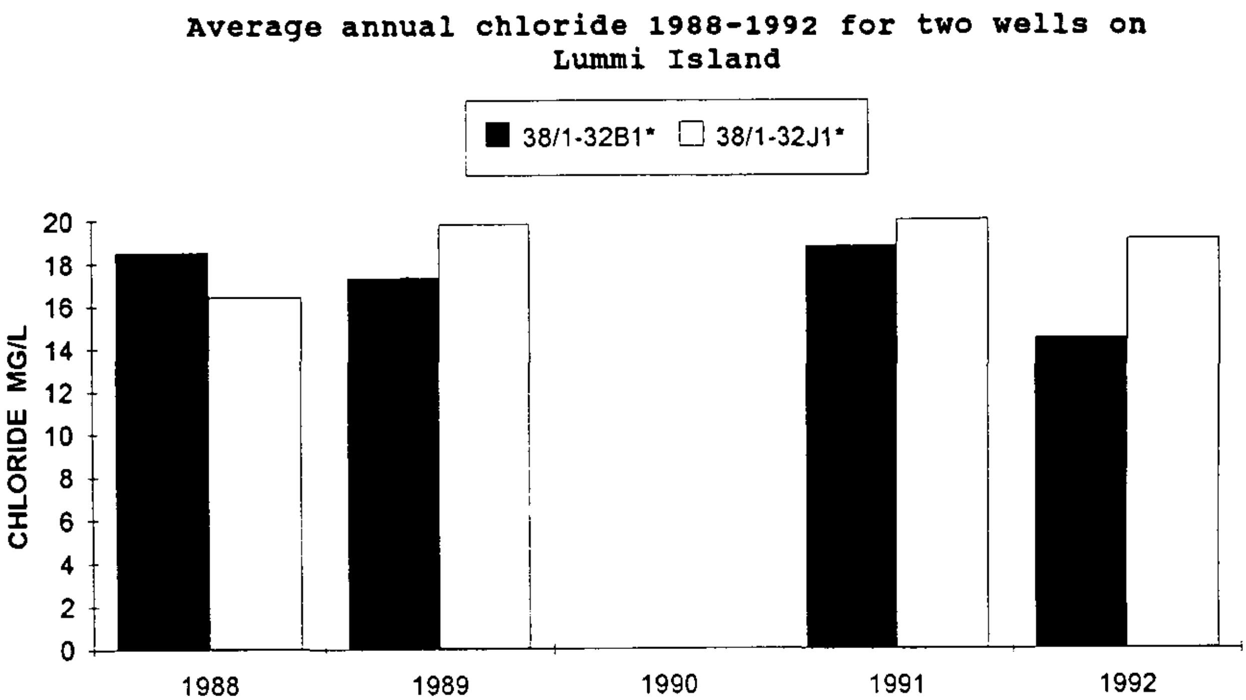
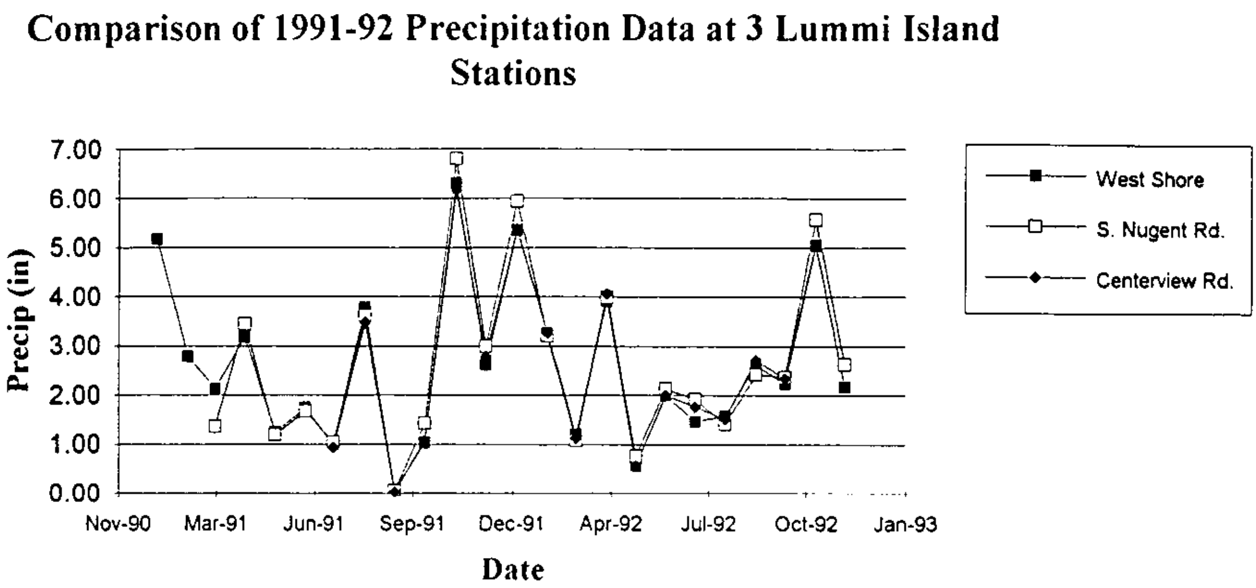

Average annual chloride 1988-1992 for two wells on Lummi Island
38/1-32B1*
38/1-32J1*
CHLORIDE MG/L
20
18
16
14
12
10
8
6
4
2
0
1988
1989
1990
1991
1992

TABLE 5



Comparison of 1991-92 Precipitation Data at 3 Lummi Island Stations
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Precip (in)
Nov-90
Mar-91
Jun-91
Sep-91
Dec-91
Apr-92
Jul-92
Oct-92
Jan-93
Date
West Shore
S. Nugent Rd.
Centerview Rd.

Airport during the same time period would be a first step in determining whether historical records from the Bellingham Airport would be useful or relevant to future water budget calculations.

Water level data collected by the volunteers is found in Appendix F. An analysis of water levels and precipitation was not made due to staff time constraints. However, this water level data will be useful in establishing a base line for future comparisons. Selected water levels and arsenic levels are graphed and briefly discussed in Appendix B.

Both the precipitation and water level data may be useful additions to the water budget developed for the Island by Robinson and Noble (1978). The Robinson and Noble (1978) study also included a rough estimate of the permanent population and housing density they thought was sustainable with no water resources management plan. They suggested that a permanent population of up to 2380 - 3333 was a preferred conservative population figure supportable by the water resources on the island without any resource management. The current permanent population of Lummi Island is 620 based on 1990 census figures.

In addition to population figures, the number of new wells drilled on the Island can be partial measure of increased water demand on the Island. County Health Department records of Ecology's water well reports show the following number of water well reports on file for Lummi Island:

1988-	3
1989-	2
1990-	3
1991-	11
1992-	13
1993-	4

No conclusions or projections on water availability can be made from this study. Further studies are necessary to develop a more precise water budget and to examine water level and precipitation trends.

2.3 GENERAL COMMENTS

There were a number of tasks identified in the Groundwater Monitoring section that were modified or deleted throughout the course of the project after discussion with the Department of Ecology grant administrator. These tasks were determined to be unfeasible or of little benefit to achieving the study purpose. They included: determination of well elevations, development of a questionnaire, locating runoff sites and recording observations, and compilation of water use data from electrical meter readings of well pumps.

3 EDUCATION AND PUBLIC INVOLVEMENT

Information and educational materials were provided to Island residents through the community newsletter, two community meetings, and the development of an informational pamphlet.

3.1 COMMUNITY NEWSLETTER

The Lummi Island Community Club Newsletter is published on a monthly basis with the exception of one month during the summer. Informational articles were prepared by Whatcom County and submitted to the newsletter for publication. A total of 9 articles were published covering the following topics:

1. The Lummi Island Groundwater Study
2. What is Groundwater?
3. Possible Health Effects of Arsenic in Lummi Island Groundwater
4. How Groundwater Can Become Contaminated
5. On-site Septic Systems
6. Seawater Intrusion -What is it? Is it Happening on Lummi Island?
7. Seawater Intrusion - Reducing the Risk of Seawater Intrusion
8. Groundwater Protection
9. Study Results

The articles are included in Appendix C.

3.2 COMMUNITY MEETINGS

Two community meetings were held to inform Island residents about the study and study results. The first meeting was held at the end of October 1991. The meeting was attended by 35 - 40 people. Discussions centered on the study, upcoming drinking water legislation, and general groundwater information. Presenters were from the State Department of Health and Whatcom County Health Department.

The second public meeting was held on July 21, 1993. The purpose of this meeting was to inform Island residents about the study results. Forty one people attended the meeting. Staff from the WCHD, Ecology, and DOH presented the results. Nearly all participants requested a copy of the final report.

3.3 PAMPHLETS

One pamphlet was prepared during the grant. It covered general information about the study and general groundwater protection. A copy of the pamphlet is included in Appendix D.

APPENDIX A

Appendix A

Effect of Tidal Fluctuations on Ground Water Quality

Lummi Island Field Study

Introduction

This report describes and summarizes the tidal effects studies conducted in selected Lummi Island water wells on May 21 and June 30, 1992.

The tidal effects tests at Lummi Island consisted of documenting tidal effects on water levels in two wells on May 21, 1992, and all-day water-level monitoring and sampling at tidal extremes in three wells on June 30, 1992. Well sampling involved identifying the time of low tide effect as indicated by water levels in each well, then pumping and frequent sampling of the well pumpage for a period of about one hour. Following the low tide sampling interval, well pumps were shut off and water levels observed in order to identify the high tide water level effect in each well. The low tide pumping and sampling procedure was repeated at the high tide extreme in the three study wells. Six to twelve samples were collected from each of the three study wells during both low and high tide sampling intervals. A total of 67 water samples were collected from the three study wells during the tidal effects sampling test. Five samples were eliminated due to expected redundancy based on field conductivity results. The remaining 62 water samples were submitted to labs for analysis of chloride and arsenic.

Background

Lummi Island is one of many places in coastal Washington where aquifers are affected by seawater (Dion and Sumioka, 1984). As population increases in the Puget Sound region, increased demand for ground water from coastal aquifers may induce seawater to flow toward the pumping wells. This migration of saline water into freshwater aquifers is known as seawater intrusion. Seawater intrusion has been identified in many areas of coastal Washington and is expected to become more severe in areas of anticipated high growth such as Puget Sound. County and state agencies are currently developing testing requirements for regulation of new wells and water systems in order to minimize this problem.

An increase in chloride concentration in a freshwater aquifer is a reliable indicator of the first stages of seawater intrusion. Of all the major ions occurring in seawater, chloride is least affected by the chemical processes seawater undergoes as it passes through soil and sediments (Revelle, 1941). Seawater contains approximately 35,000 mg/L dissolved solids including 19,000 mg/L chloride. Uncontaminated ground waters in Washington coastal areas typically contain less than 10 mg/L chloride. Wells in several shoreline areas of Lummi Island have chloride concentrations exceeding 100 mg/L. Consequently, these areas are considered to be affected by seawater intrusion.

In addition to areas of localized seawater intrusion, Lummi Island has areas of arsenic-contaminated ground water. The problem of arsenic in Lummi Island well water was reported in 1983-84 sampling results obtained by the Bellingham-Whatcom County Health Department. The Northwest Regional Office of the Department of Ecology conducted a reconnaissance sampling of wells for arsenic in well water at northern Lummi Island during 1988-1990 (Ecology, 1990). The Ecology sampling results indicated that the arsenic problem was fairly widespread and is focused near the northern and eastern shore areas of northern Lummi Island. The source of the arsenic is not known with certainty, but it is believed to be naturally derived from the geologic materials penetrated by well drilling. Naturally occurring arsenic in ground water has been documented in other areas of Puget Sound (Frost, 1991) and sulphide minerals typically associated with arsenic are found at Migley Point.

To some extent, areas of arsenic-contaminated ground water on Lummi Island coincided with areas most affected by seawater intrusion. Proximity of these areas to the Lummi Island shoreline and the fact that many of the contaminated wells have tide-affected water levels suggested that an investigation of tidal effects and ground water quality could better define the relationship between the chloride and arsenic contamination.

In 1990, a Lummi Island citizen group, the Ground Water Committee of the Lummi Island Community Club, obtained state Centennial Clean Water Grant funding to perform a two-year ground water quality monitoring program. This short term field study of tidal effects on ground water is one of the tasks included in the two-year Lummi Island grant study.

Field Setting

Lummi Island is an elongate island located in the Strait of Georgia in western Whatcom County. The southern portion of the island is mostly mountainous and extremely steep bedrock with elevations from sea level to the 1,665 elevation Lummi Peak. The northern portion of the island is predominantly made up of unconsolidated sedimentary deposits with local exposures of the underlying bedrock. The topography of northern Lummi Island is relatively low lying and gently rolling, with elevations ranging from sea level to 362 feet (Robinson & Noble, 1978). The northern portion of Lummi Island constitutes the study area for this tidal effects field study and the associated two-year ground water monitoring program (Figure 1).

The locations of the three wells monitored and sampled during the tidal effects test on June 30, 1992 are shown in Figure 1. Two of the observation well sites, 38/1-29Q2 (29Q2) and 37/1-15E1 (15E1), are located at the extreme north and south ends of the northern Lummi study area. The third well, 37/1-4J4 (4J4), is located on the east shore about 2 miles south of Point Migley and a quarter mile north of the Lummi ferry dock (Figure 1).

Study Methods

Of the 35 wells measured during the two-year Lummi Island ground water monitoring program, three wells provided advantageous characteristics for a sampling study of tidal effects on local ground water quality. Three domestic wells were selected for monitoring and sampling during the Lummi tidal effects test. The wells were selected on the basis of accessibility, observed tidal influence, and detectable arsenic and chloride in historical water samples. A well selection reconnaissance was conducted on May 21, 1992, and the tidal effects sampling test was conducted in three wells on June 30, 1992.

The three wells selected for the sampling study are known as wells 29Q2, 4J4, and 15E1. Well 29Q2 is located on Point Migley at the very northern tip of Lummi Island, and is about 250 feet from the beach at elevation 35 feet above sea level. Well 29Q2 is accessible for water-level measurement through a removable well cap and was sampled from a garden hose leading from the house. Since no well log was available for well 29Q2, details of construction for the well are unknown. The well 29Q2 intake is believed to be completed in fractured bedrock and below sea level in elevation. Well 4J4 is 6 inches in diameter, 94 feet deep, and open hole below 24 feet in sandstone. The well is accessible for water-level measurement through a removable well cap and was sampled from an outdoor tap at the house. Static water level in well 4J4 was 25.5 feet below top of casing at the time of construction on August 14, 1989. Well 15E1 is 6 inches in diameter, 207 feet deep, and open hole at the bottom one foot in a sand and coarse gravel aquifer zone. Static water level in well 15E1 was 74 feet below top of casing at the time of construction on June 1, 1977. Water well reports for wells 4J4 and 15E1 are shown in Appendix A-1. No well report was available for well 29Q2.

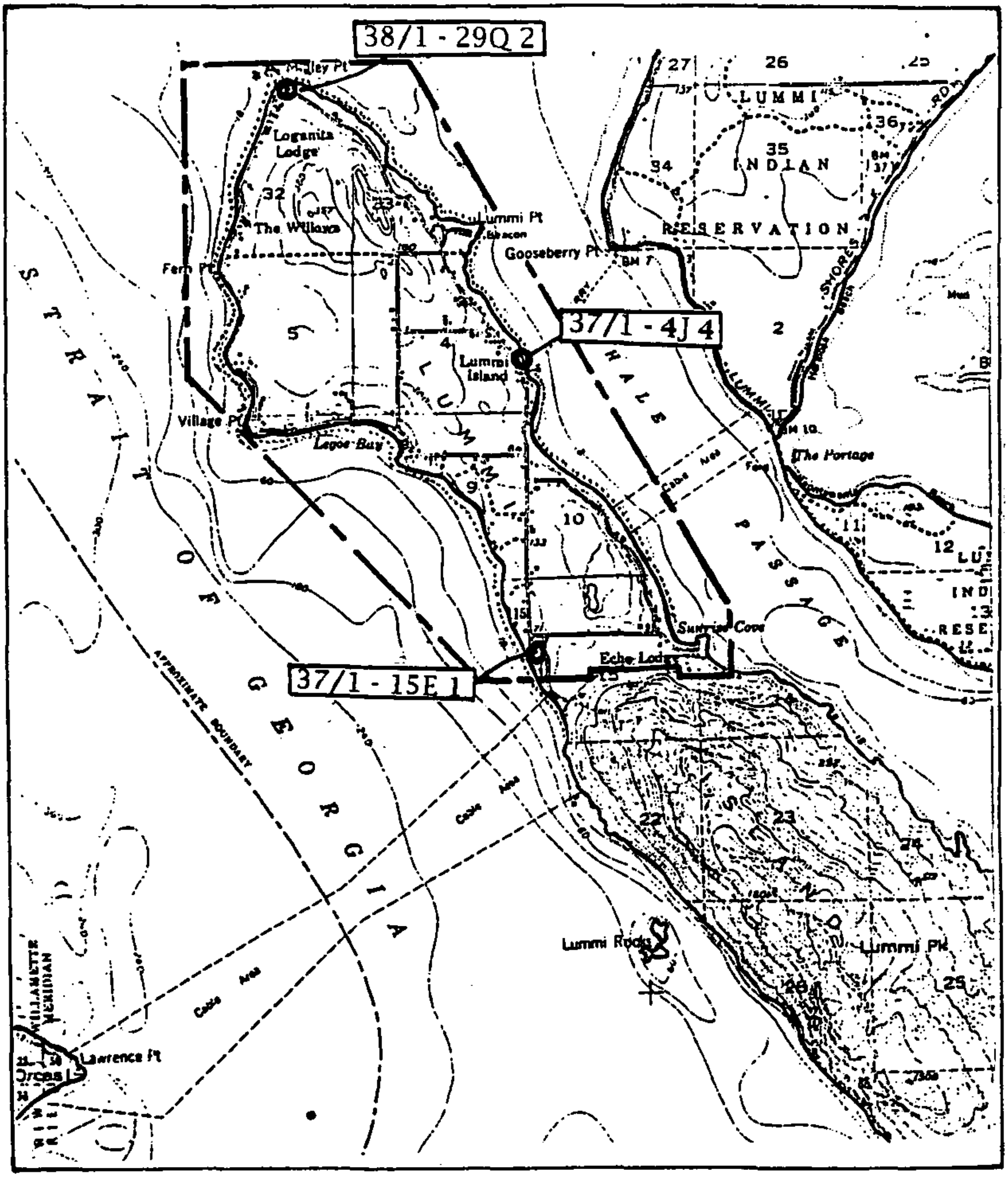


Figure 1. Lummi Island tidal effects study well locations.

May 21, 1992 Tidal Effects Reconnaissance

On May 21, 1992, water levels were measured in 2 wells over a 7-hour period in order to verify that water levels were tide affected and to determine well tidal efficiencies and lag times. According to Port Townsend tide tables corrected for Point Migley, a high tide of 6.4 feet occurred at 7:21 AM on May 21 followed by a -0.8 foot low tide at 2:33 PM. The maximum high tide effects were not observable in either well during the May 21 reconnaissance, so tidal efficiencies could not be accurately determined for the wells. Low tide effects occurred in both wells at approximately 3:40 PM which yielded an approximate 1 hour lag time for both wells relative to the predicted time of low tide at Point Migley.

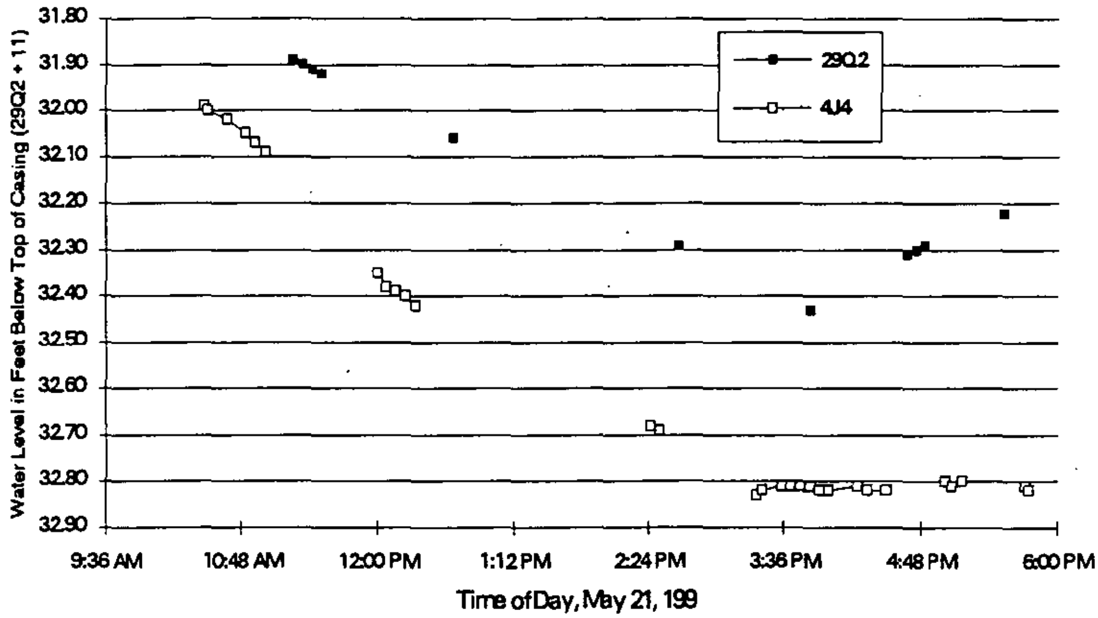


Figure 2. Tide affected water levels in Lummi Island wells, May 21, 1992.

Figure 2 shows tide affected water levels in two Lummi Island wells, 29Q2 and 4J4, during a 7-hour reconnaissance on May 21, 1992. An additional third well, 15E1, located at the southwestern corner of the study area, was selected for the tidal effects sampling study to take place on June 30, 1992.

June 30, 1992 Tidal Effects Test

Water levels in all three observation wells were monitored throughout the day on June 30th from about 9:50 AM to 10:00 PM. When water levels indicated low tidal effect in the wells, the well pumps were turned on for approximately 1 hour and well pumpage was frequently sampled during pumping. Low tide sampling was followed by approximately 8 hours of water level observation until high tide effects were observed in the wells. The same pumping and sampling procedure used at the low tidal extreme was followed during the high tidal extreme for the three Lummi observation wells.

Tidal range at Point Migley on June 30, 1992 was predicted by tide tables to be about 12.2 feet. From a -3.2 foot low tide at 11:18 AM at Point Migley, a steadily incoming tide was predicted to reach a 9.0 foot high tide at 7:41 PM in the evening. Arrangements were made with two of the well owners to avoid using water during the day of the test so that wells would not have to be pumped other than for the pumping/sampling cycles of the tidal survey. Well 15E1 was pumped the morning of the test and was still in water-level recovery at the beginning of the low tide pumping.

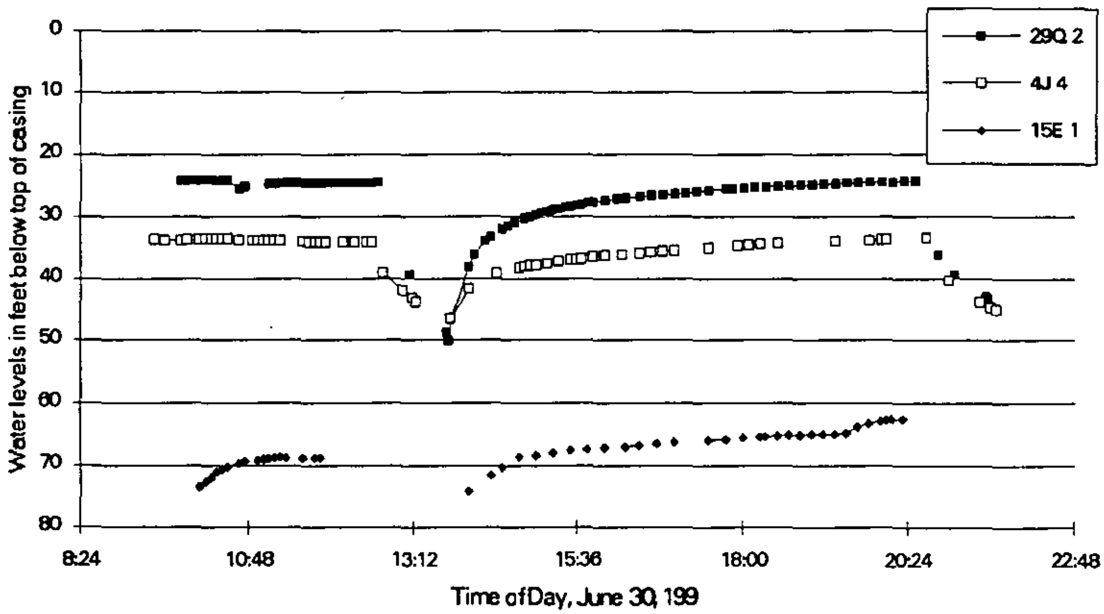


Figure 3. Water levels in Lummi Island wells, June 30, 1992.

Results of water level measurements in the three domestic monitoring wells used on June 30, 1992 are shown in Figure 3. Influences from pumping and tidal effects on ground water levels are apparent in all three well hydrographs. Water level recoveries were slow following the low tide pumping in all three wells such that none of the wells had recovered significantly above the low tide pre-pumping level by the 8:30 PM high tidal effect. Wells 29Q2 and 4J4 showed effects from pumping in nearby wells but the interference was not significant enough to affect test results. Minimum water levels due to pumping drawdown during sampling intervals are not plotted in Figure 3.

Samples were collected in I-Chem liter 'cubitainers' and 1 liter Nalgene bottles and were analyzed for arsenic, chloride, and specific conductance. Sample containers were numbered consecutively from 1 to 72. Even numbered samples from well 29Q2 and odd numbered samples from wells 4J4 and 15E1 were analyzed at Ecology's Environmental Laboratory in Manchester, Washington. To help recognize and eliminate potential lab error, the alternate samples were delivered to Lauck's Testing Laboratory in Seattle for analysis. Sample analysis results are summarized by tables for each well and tidal stage in Appendix A-2. Complete lab analysis reports are included in Appendix A-3.

Low Tide Sampling

As shown in Figure 3, measurements taken from 9:30 AM to 12:30 AM showed the water levels in wells 29Q2 and 4J4 were gradually declining and leveling off corresponding to the earlier low tide in adjacent Hale Passage. The water level in well 15E1 was still recovering from being pumped that morning. Pumping for the low tide sampling in well 15E1 commenced at 11:49 AM. Low tide pumping began at 12:40 PM in wells 29Q2 and 4J4. Low tide pumping was maintained for 70 minutes in wells 29Q2 and 4J4 and for 113 minutes in well 15E1. The low tide pumping discharge rates in wells 29Q2 and 4J4 remained relatively constant at 6.4 and 12 gpm, respectively. Well discharge in 15E1 was increased from 6 gpm to 12 gpm when a hose was unkinked 28 minutes into low tide pumping at 12:17 PM.

Low tide sampling results for the northernmost well 29Q2 and duration of pumping at each sample grab are shown in Table 1, and plotted in Figure 4.

Well 29Q2
Low Tide Sampling 6/30/92

Time	Pumping Duration (min.)	Sample Number	Chloride mg/L low tide	Arsenic ug/L low tide
12:42 PM	0	pump on		
12:55	8	2	120	374
13:05	23	4	120	350
13:15	33	6	110	349
13:25	47	8	110	316
13:35	57	10	95	290
13:45	67	12	100	304
13:48	70	pump off		

Table 1. Sample results from low tide pumping well 29Q2, June 30, 1992.

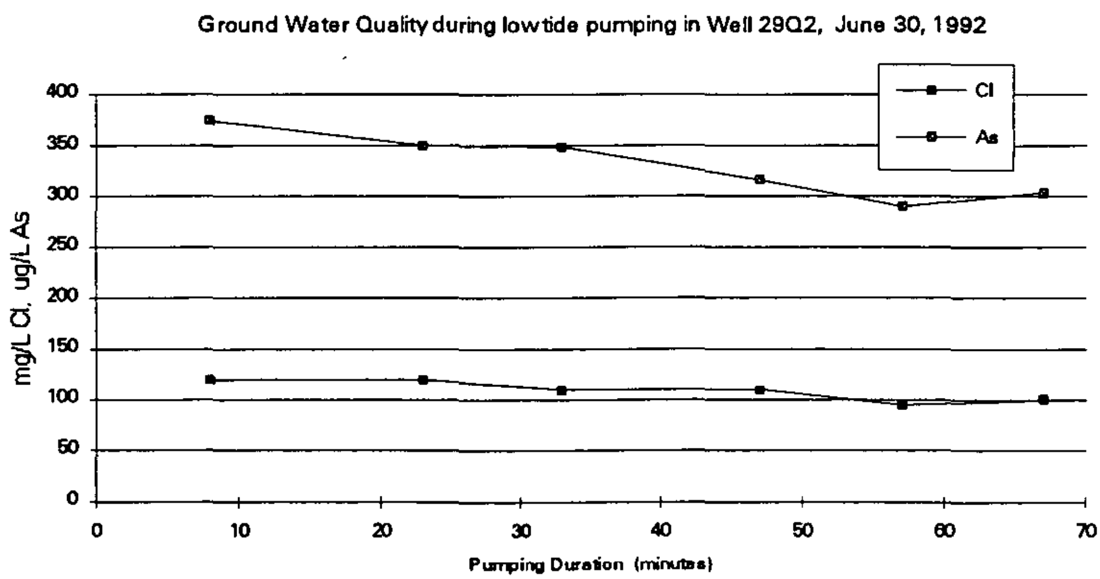


Figure 4. Arsenic and chloride in water samples from well 29Q2, low tide pumping, June 30, 1992.

A total of 12 samples were taken during the low tide pumping of well 29Q2. The six odd-numbered sample results were rejected for the purpose of analysis, however, because the arsenic values were anomalous with even-numbered samples and were inconsistent with historical arsenic results from the well (Appendix A-2). Sample results from the low tide pumping in well 29Q2 indicate that chloride decreased slightly from 120 mg/L in the sample taken 8 minutes after pump start to 100 mg/L in the last sample taken after 67 minutes of pumping. Arsenic in well 29Q2 also decreased according to the same samples from 374 to 304 ug/L.

Low tide sampling results from 4J4 and 15E1 are shown in Figures 5 and 6, respectively.

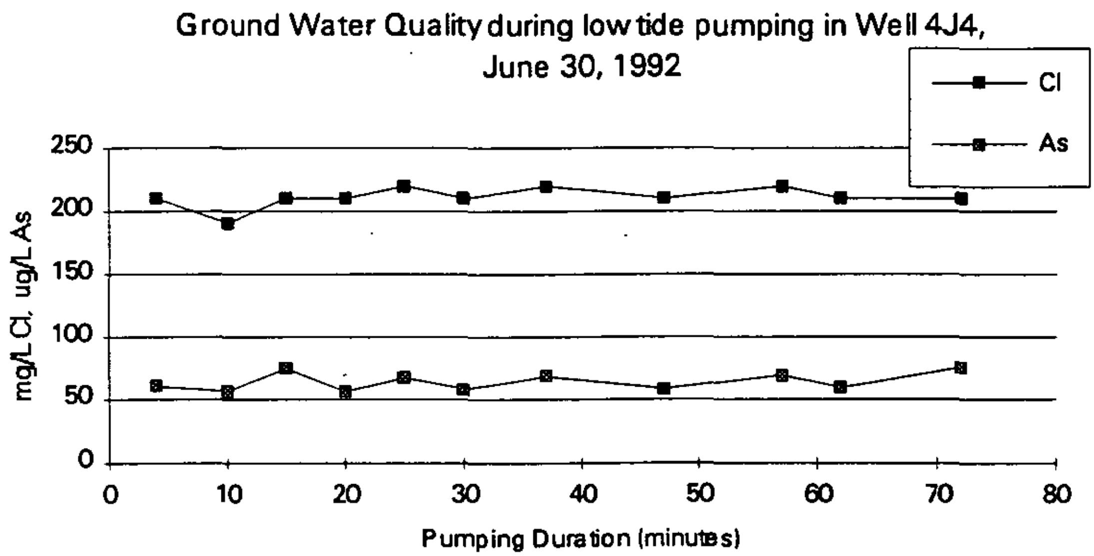


Figure 5. Arsenic and chloride in water samples from well 4J4, low tide pumping, June 30, 1992.

Low tide samples from well 4J4 showed relatively consistent results for arsenic and chloride. Arsenic samples from well 4J4 ranged from 56 to 75 ug/L and chloride ranged from 190 to 220 mg/L during low tide sampling. Complete sample results are listed in summary tables in Appendix A-2 and data are included in Appendix A-3.

The most interesting low tide sampling results were from well 15E1, plotted below in Figure 6.

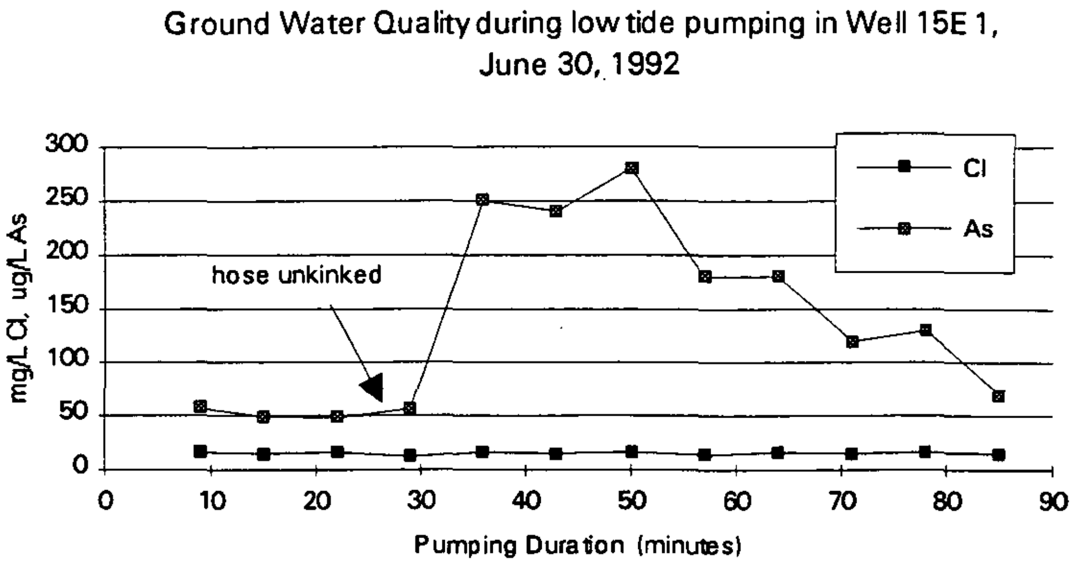


Figure 6. Arsenic and chloride in water samples from well 15E1, low tide pumping, June 30, 1992.

Pumping for the low tide sampling in well 15E1 commenced at 11:49 AM and pumping was maintained for 113 minutes. The pumping discharge rate in well 15E1 was increased from 6 gpm to 12 gpm when a hose was unkinked 28 minutes into low tide pumping at 12:17 PM. As shown in Figure 6, the timing of the increase in well discharge coincided with a dramatic increase in arsenic concentrations in samples collected after 30 minutes of pumping. Arsenic in samples rose from 56 ug/L at 12:18 PM(at 29 minutes of pumping) to 250 ug/L at 12:25 PM(at 36 minutes of pumping). Arsenic in low tide samples from well 15E1 reached a maximum of 280 ug/L at 12:39 PM (50 minutes pumping) and fell off to 69 ug/L in the last sample collected at 13:42 PM (85 minutes pumping). These increases in well discharge and arsenic concentrations were accompanied by a drop in pumping water level in well 15E1 from 88.68 feet below top of well at 12:06 PM (17 minutes of pumping) to 108.00 feet at 1.13 PM(84 minutes pumping).

Water level measurements in all three study wells showed slow recovery following low tide pumping and water levels continued to gradually rise coinciding with the incoming tide (Figure 3). At about 8:30 PM, the rate of recovery and tide-effected water level rise in the wells was decreasing as water levels began to express the earlier high tide in the saltwater surrounding Lummi Island.

High Tide Sampling

High tide pumping in all three wells commenced between 8:25 PM and 8:42 PM and total pumping time ranged from 63 to 85 minutes. High tide sampling results for well 29Q2 and duration of pumping at each sample grab are shown in Table 2 and plotted in Figure 7.

Well 29Q2
High Tide Sampling 6/30/92

Time	Pumping Duration (min.)	Sample Number	Chloride mg/L high tide	Arsenic ug/L high tide
20:30 PM	0	pump on		
20:40 PM	10	14	140	452
20:50 PM	20	16	140	465
21:00 PM	30	18	130	410
21:10 PM	40	20	120	358
21:20 PM	50	22	110	334
21:30 PM	60	24	110	329
21:35 PM	65	pump off		

Table 2. Sample results from high tide pumping in well 29Q2, June 30, 1992.

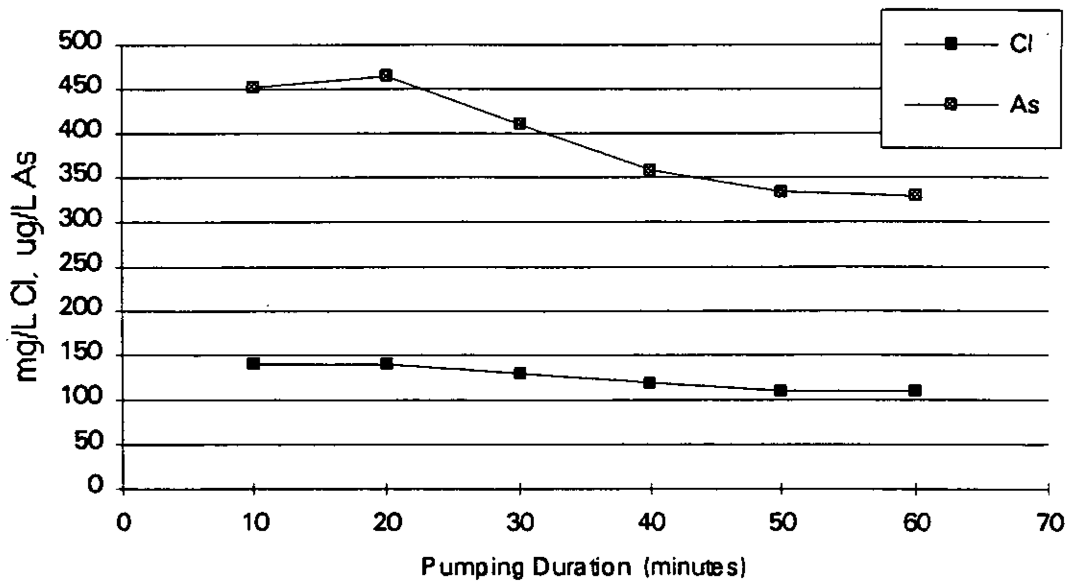


Figure 7. Arsenic and chloride in water samples from well 29Q2, high tide pumping, June 30, 1992.

As in the low tide pumping cycle, a total of 12 samples were taken during the high tide pumping cycle at well 29Q2. Again, the six odd-numbered sample results were rejected because the arsenic values were anomalous with even-numbered samples which were more consistent with historical results from well 29Q2(Appendix A-2). Sample results from the high tide pumping indicate that chloride in discharge from well 29Q2 steadily decreased from 140 mg/L in the sample taken 10 minutes after pump start to 110 mg/L in the last sample taken after 1 hour of pumping. Arsenic in the well 29Q2 high tide samples increased from 452 ug/L at 10 minutes of pumping to 465 ug/L at 20 minutes of pumping. From this maximum arsenic value of 465 ug/L, arsenic in high tide samples from well 29Q2 gradually dropped to 329 ug/L in the last sample taken after 1 hour of pumping.

High tide sampling results from wells 4J4 and 15E1 are shown in Figures 8 and 9, respectively.

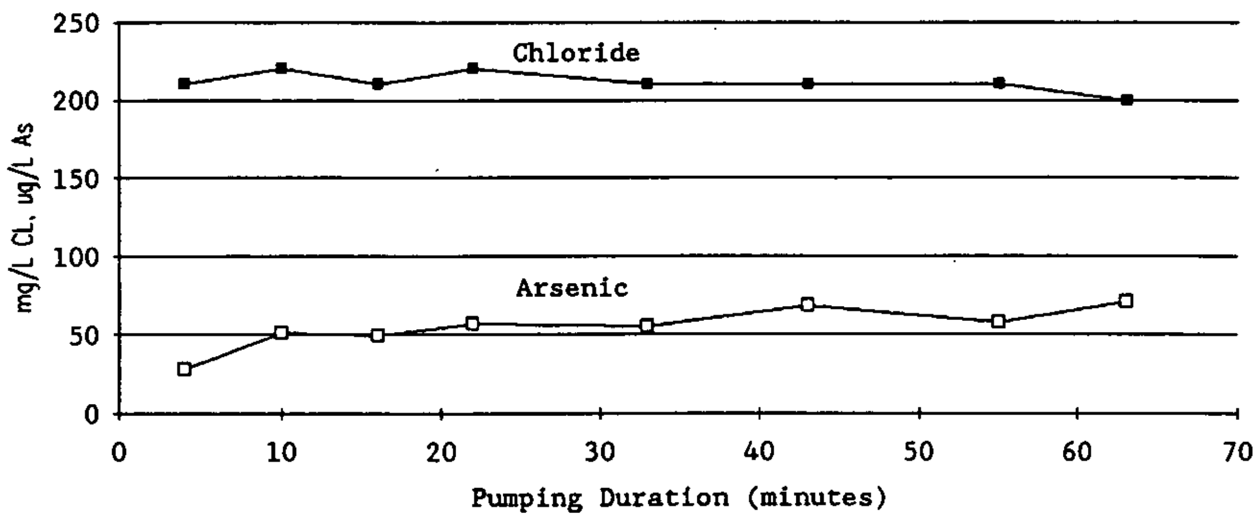


Figure 8. Arsenic and chloride in water samples from well 4J4, high tide pumping, June 30, 1992.

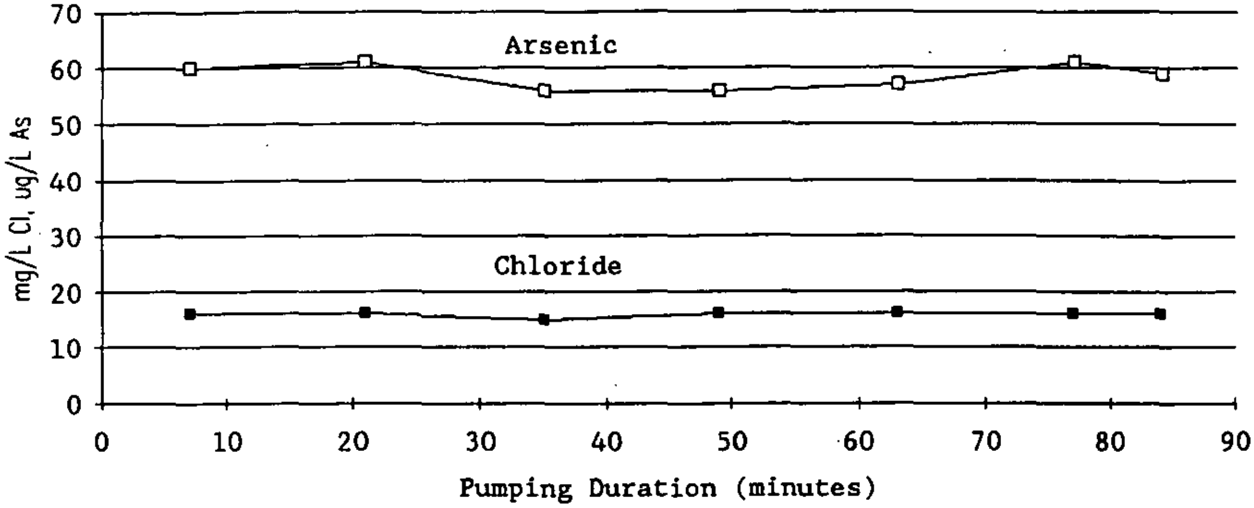


Figure 9. Arsenic and chloride in water samples from well 15E1, high tide pumping, June 30, 1992.

Discussion

Chloride contamination in the three domestic wells used in this study was most severe in well 4J4. Water samples from well 4J4 for both low and high tide pumping averaged 210 mg/L chloride. Low and high tide samples from well 29Q2 averaged 115 mg/L of chloride, and samples from well 15E1 were least affected with average chloride concentration of 15 mg/L.

The sample result curves in Figures 4 through 9 indicate that the salinity of pumpage is not significantly affected by tidal stage and does not appear to be very sensitive to the cumulative pumping duration. If anything, chloride went slighly down in wells as pumping duration increased. This was the case in well 29Q2 during high tide pumping (Figure 7).

The small difference between chloride sample results from well 29Q2 at high and low tide (Tables 1 & 2) may be due to tidal influence on the transition zone. If the saline zone of transition between fresh ground water and seawater migrates vertically and/or horizontally with tidal fluctuations, higher salinity ground water would be expected around the well screen during high tide. However, chloride concentrations in all three study wells were not significantly different for the high and low tide pumping cycles.

Arsenic contamination was most severe in well 29Q2, averaging 360 ug/L and reaching a maximum of 465 ug/L arsenic during high tide sampling. Most samples from wells 4J4 and 15E1 ranged from 28 to 75 ug/L arsenic. The exceptions to this range were seven samples from well 15E1 collected during the low tide pumping. The seven samples from well 15E1 with elevated arsenic are associated with the timing of an increase in well discharge from 6 to 12 gpm. The low tide sampling results from well 15E1 suggest a relationship between arsenic concentration and well discharge rate. Since the increase in discharge was accompanied by a drop in pumping level in well 15E1, the elevated arsenic in well water may have resulted from the removal of water level head at one or more arsenic contaminated fractures or wet zones in the well bore. A drop in pumping level past the depth of such zones or fractures would result in an increase in flow from these zones into the well. According to established principles of well hydraulics, the increased discharge rate in well 15E1 caused enlargement of the area of pumping influence on water levels, or water pressures, around the well. The larger area of influence causes ground water at further distances from the well to flow toward the well and contribute to well discharge. The larger area of influence due to the discharge increase may have intercepted an arsenic contaminated area which then contaminated well 15E1. A third possible explanation of the higher arsenic in well 15E1 pertains to pumping influence on the water in the well bore below the pump, or on ground water directly below the bottom of the well. If higher density contaminated water is present beneath the well pump, an increase in discharge could cause the underlying contaminated water to flow toward and into the well pump. This pumping influence on the area below wells is called `upconing'.

In summary, the Lummi tidal effects test documented water level conditions and water quality characteristics in some detail for the three monitored domestic wells. The following conclusions and recommendations are derived from consideration of the test results.

Conclusions

For the Lummi Island wells involved in tidal effects testing, chloride concentration in well pumpage did not appear to be a function of tidal stage. A single sample collected near the end of a pumping test is sufficient to estimate the short term severity of seawater intrusion in Lummi Island wells.

Arsenic contaminated ground water which exceeds the State Drinking Water Standard of 50 ug/L arsenic is fairly widespread throughout northern Lummi Island. The source of arsenic contamination is still unknown but does not appear to be related to tidal stage during pumping or chloride concentration in well pumpage. The flare-up in arsenic concentration during the low tide sampling of well 15E1 indicates a relationship between arsenic contamination and well pumping rate. The severity of arsenic contamination may be a local phenomenon directly related to site specific geology and ground water chemistry. A single sample collected near the end of a constant rate pumping test is sufficient to indicate the severity of arsenic contamination in Lummi Island wells. If pumping discharge rate of a Lummi Island well is increased, additional sampling is necessary to characterize the severity of arsenic contamination under the new rate.

Single domestic well pumps such as those in the three wells used in this study have limited capacity to impose pumping stress on aquifers. Only limited pumping stress was possible during this tidal effects field study due to small capacity well pumps in domestic wells. The water quality changes in well 15E1 associated with changes in discharge rate suggests that future well testing should involve larger capacity pumps with adjustable discharge rates.

Recommendations

More study is needed to determine whether Lummi Island ground water arsenic contamination is related to chloride concentrations in well pumpage or is due to other independent influences on ground water quality.

Additional pumping tests should be conducted to better define the relationship between well discharge and arsenic contamination. These tests should be performed on existing arsenic contaminated wells using large capacity (10 - 50 gpm) pumps with adjustable pumping rates.

A study similar to this one should be performed with the first sampling cycle run during high tide followed by low tide pumping.

Special gelogic borings with concurrent rock and water sampling should be done in order to identify the source of arsenic contamination. Better definition of the source of arsenic may result in recommendations for future Lummi Island well construction. These recommendations may include completing drinking water wells at specified depths and/or casing wells across certain arsenic bearing stratum.

References

1. Dion, N.P. and S.S. Sumioka. 1984. Seawater Intrusion Into Coastal Aquifers in Washington, 1978. U.S.Geological Survey Water-Supply Bulletin 56, 13 pp., 14 plates.

2. Ecology, Washington Department of, 1990. Lummi Island Ground Water Quality Survey, unpublished data, Northwest Regional Office NonPoint Unit.

3. Frost, Floyd, 1991. Seasonal Study of Arsenic in Ground Water, Snohomish County, Washington. Washington State Department of Health and Snohomish Health District, 35 pp.

4. Reilly, T.E., M.H. Frimpter, D.R. LeBlanc, and A.S. Goodman. 1987. Analysis of Steady-State Salt-Water Upconing with Application at Truro Well Field, Cape Cod, Massachusetts. Ground Water. v. 25, no. 2, pp.194-206.

5. Revelle, Roger. 1941. Criteria for Recognition of Sea Water in Ground Waters. Transactions American Geophysical Union, vol. 22, pp. 593-597.

6. Robinson & Noble, Inc., (Roland G. Schmidt). 1978. The Water Resources of Northern Lummi Island. For Whatcom County Planning Commission, June 1978, 30 pp.

Appendix A-1

Water Well Reports

37/1 - 4/J

File Original and First Copy with Department of Ecology
Second Copy—Owner's Copy
Third Copy—Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. 022631

Water Right Permit No. ______

OWNER: Name 37/1 - 4J 4 Address N Nugent Lummi , Is.

(2) LOCATION OF WELL: County Whatcom NE ¼ SE ¼ Sec 4 T 37 N., R 1E W.M.

(2a) STREET ADDDRESS OF WELL (or nearest address) 2231 N Nugent Rd.

(3) PROPOSED USE: XX Domestic ☐ Irrigation ☐ DeWater Industrial ☐ Test Well ☐ Municipal ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) ______

Abandoned ☐ New well XX Deepened ☐ Reconditioned ☐ Method: Dug ☐ Cable XX Rotary ☐ Bored ☐ Driven ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 6 inches. Drilled 94 feet. Depth of completed well 94 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 6 " Diam. from +1 ft. to 24 ft.
Welded XX ______ " Diam. from ______ ft. to ______ ft.
Liner installed ☐
Threaded ☐ ______ " Diam. from ______ ft. to ______ ft.

Perforations: Yes ☐ No XX
Type of perforator used ______
SIZE of perforations ______ in. by ______ in.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.

Screens: Yes ☐ No XX
Manufacturer's Name ______
Type ______ Model No. ______
Diam. ______ Slot size ______ from ______ ft. to ______ ft.
Diam. ______ Slot size ______ from ______ ft. to ______ ft.

Gravel packed: Yes ☐ No XX Size of gravel ______
Gravel placed from ______ ft. to ______ ft.

Surface seal: Yes XX No ☐ To what depth? 18+ ft.
Material used in seal Bentonite clay
Did any strata contain unusable water? Yes ☐ No XX
Type of water? ______ Depth of strata ______
Method of sealing strata off ______

(7) PUMP: Manufacturer's Name Fairbanks Morse
Type: Submergible H.P. 1/2

(8) WATER LEVELS: Land-surface elevation above mean sea level ______ ft.
Static level 25'-6" ft. below top of well Date 8/14/89
Artesian pressure ______ lbs. per square inch Date ______
Artesian water is controlled by ______ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes XX No ☐ If yes, by whom? driller
Yield: 10 gal./min. with 15'-2" ft. drawdown after 3 hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test 8/14/89
Bailer test ______ gal./min. with ______ ft. drawdown after ______ hrs.
Airtest ______ gal./min. with stem set at ______ ft. for ______ hrs.
Artesian flow ______ g.p.m. Date ______
Temperature of water ______ Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
Top soil	0	1
Sand & gravel	1	5
Sand , gravel & hardpan	5	11
Big boulders,four	7	14
Blue clay	11	22
Sandstone	22	94
water app 2 gpm	65	
WATER 10+ GPM	84	

RECEIVED
OCT 25 1989
DEPARTMENT OF ECOLOGY
NORTHWEST REGION

Work started 8/7/89, 19__. Completed 8/14/89, 19__

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME Livermore & Son,Inc. (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address 6053 Portalway , Farndale
(Signed) [signature] (WELL DRILLER) License No. 272
Contractor's Registration No. Livers*199JG Date 8/14/89, 19__

(USE ADDITIONAL SHEETS IF NECESSARY)

1495 S. Nugent

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Application No. 37/01-15F

Permit No.

(1) OWNER: Name 37/1 - 15E 1 ER Address 1495 S. NUGENT LUMMI

(2) LOCATION OF WELL: County WHATCOM ~~NE SW~~ SW NW ¼ Sec. 15 T. 37 N., R. 1E W.M.

Bearing and distance from section or subdivision corner

(3) PROPOSED USE: Domestic [X] Industrial [ ] Municipal [ ] Irrigation [ ] Test Well [ ] Other [ ]

(4) TYPE OF WORK: Owner's number of well (if more than one)....
New well [X] Method: Dug [ ] Bored [ ]
Deepened [ ] Cable [X] Driven [ ]
Reconditioned [ ] Rotary [ ] Jetted [ ]

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 207 ft. Depth of completed well 207 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: ______" Diam. from ______ ft. to ______ ft.
Threaded [ ] ______" Diam. from ______ ft. to ______ ft.
Welded [X] 6" Diam. from 0 ft. to 207 ft.

Perforations: Yes [ ] No [X]
Type of perforator used
SIZE of perforations ______ in. by ______ in.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.

Screens: Yes [ ] No [X]
Manufacturer's Name
Type ______ Model No. ______
Diam. ______ Slot size ______ from ______ ft. to ______ ft.
Diam. ______ Slot size ______ from ______ ft. to ______ ft.

Gravel packed: Yes [X] No [ ] Size of gravel PEA
Gravel placed from 206 ft. to 207 ft.

Surface seal: Yes [X] No [ ] To what depth? ______ ft.
Material used in seal BENTONITE
Did any strata contain unusable water? Yes [ ] No [ ]
Type of water? ______ Depth of strata ______
Method of sealing strata off ______

(7) PUMP: Manufacturer's Name ______
Type: ______ H.P. ______

(8) WATER LEVELS: Land-surface elevation above mean sea level.... ft.
Static level 74 ft. below top of well Date ______
Artesian pressure ______ lbs. per square inch Date ______
Artesian water is controlled by ______ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes [ ] No [X] If yes, by whom? ______
Yield: ______ gal./min. with ______ ft. drawdown after ______ hrs.
" " " "
" " " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test 6-1-77
Bailer test 10 gal./min. with 35 ft. drawdown after 1.05 hrs.
Artesian flow ______ g.p.m. Date 6-1-77
Temperature of water ______ Was a chemical analysis made? Yes [ ] No [X]

(10) WELL LOG: 37/1-15E

Formation: *Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.*

MATERIAL	FROM	TO
RED CLAY & ROCKS	0	16
HARD GREY CLAY	16	137
HARD SANDY CLAY	137	149
HARDPAN	149	157
HARD CLAY	157	200
COARSE SAND W/WATER	200	205
COARSE GRAVEL	205	207
FINE SAND	207	

SET PUMP AT 190'
PUMP 5 GPM

Work started 4-16 1977 Completed 5-1-77 19

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME STAR DRILLING SERVICE (Person, firm, or corporation) (Type or print)

Address 3930 CLIFFSIDE DR. BLHM.

[Signed] Herman L. Lehnert (Well Driller)

License No. 266 Date 6-1-77 19

(USE ADDITIONAL SHEETS IF NECESSARY)

Appendix A-2

Ground Water Sampling Summary

Lummi Island Tidal Effects Study

Ground Water Sample Summary

Last Modification - 4/21/93

38/1 - 29Q 2 6/30/92

Low Tide

Time	Pumping Time (min.)	Samp. No.	Cl mg/L ow tid	As ug/L low tide
12:42	0		pump on	
12:47	5	1	130	5
12:55	8	2	120	374
13:00	18	3	110	7
13:05	23	4	120	350
13:10	28	5	100	310
13:15	33	6	110	349
13:20	42	7	110	18
13:25	47	8	110	316
13:30	52	9	100	27
13:35	57	10	95	290
13:40	62	11	95	5
13:45	67	12	100	304
13:48	70		pump off	

38/1 - 29Q 2 6/30/92

High Tide

Time	Pumping Time (min.)	Samp. No.	Cl mg/L high tid	As ug/L high tide
20:30	0		pump on	
20:35	5	13	140	5
20:40	10	14	140	452
20:45	15	15	130	5
20:50	20	16	140	465
20:55	25	17	130	5
21:00	30	18	130	410
21:05	35	19	120	5
21:10	40	20	120	358
21:15	45	21	100	5
21:20	50	22	110	334
21:25	55	23	100	5
21:30	60	24	110	329
21:35	65		pump off	

37/1 - 4J 4 6/30/92

Low Tide

Time	Pumping time (min.)	Samp. No.	ow tid mg/L Cl	low tide ug/L As
12:38	0		pump on	
12:42	4	25	210	60
12:48	10	26	190	56
12:53	15	27	210	74
12:58	20	28	210	56
13:03	25	29	220	67
13:08	30	30	210	58
13:15	37	31	220	68
13:25	47	32	210	58
13:35	57	33	220	69
13:40	62	34	210	59
13:50	72	35	210	75
13:50	72		pump off	

37/1 - 4J 4 6/30/92

High Tide

Time	Pumping time (min.)	Samp. No.	high tid mg/L Cl	high tide ug/L As
20:42	0		pump on	
20:46	4	36	210	28
20:52	10	37	220	51
20:58	16	38	210	49
21:04	22	39	220	57
21:15	33	40	210	55
21:25	43	41	210	68
21:37	55	42	210	58
21:45	63	43	200	71
21:45	63		pump off	

Ground Water Sample Summary

37/1 - 15E 1 6/30/92

Low Tide

Time	Pumping Time (min.)	Samp. No.	Cl mg/L ow tid	As ug/L low tide
11:49	0		pump on	
11:57	9	49	16	57
12:04	15	50	15	49
12:11	22	51	16	48
12:18	29	52	12	56
12:25	36	53	16	250
12:32	43	54	15	240
12:39	50	55	16	280
12:46	57	56	14	180
12:53	64	57	16	180
13:00	71	58	15	120
13:07	78	59	16	130
13:14	85	60	15	69
13:42	113		pump off	

37/1 - 15E 1 6/30/92

High Tide

Time	Pumping Time (min.)	Samp. No.	Cl mg/L high tid	As ug/L high tide
20:25	0		pump on	
20:32	7	61	16	60
20:46	21	63	16	61
21:00	35	65	15	56
21:14	49	67	16	56
21:28	63	69	16	57
21:42	77	71	16	61
21:49	84	72	16	59
21:50	85		pump off	

Appendix A-3

Lab Analysis Reports

WASHINGTON STATE DEPARTMENT OF ECOLOGY
ENVIRONMENTAL INVESTIGATIONS AND LABORATORY SERVICES
MANCHESTER LABORATORY

August 7, 1992

TO: Project Officer

FROM: Despina Strong D

SUBJECT: Lummi Tidal Study

SAMPLE RECEIPT:

The samples from the Lummi Tidal Study project were received by the Manchester Laboratory on 7/1/92 in good condition.

HOLDING TIMES:

All analyses were performed within the specified holding times for chloride.

PROCEDURAL BLANKS:

The procedural blanks associated with these samples showed no detectable levels of analytes.

SPIKED SAMPLE ANALYSIS:

Spiked sample analysis was performed on one sample per batch. All spike recoveries were within the acceptable limits of +/- 25%.

PRECISION:

Duplicate sample analysis was performed on two samples in the batch. The %RPD was within the acceptable windows for water analysis (10%).

SUMMARY:

The data generated by the analysis of the above referenced samples can be used without qualification.

If you have any questions about the results or the methods used to obtain these results please call me at SCAN 744-4737.

Laucks 84 years
Testing Laboratories, Inc.
940 South Harney St., Seattle, WA 98108 (206) 767-5060 FAX 767-5063
Chemistry, Microbiology, and Technical Services

CLIENT : WA State Dept. of Ecology

Certificate of Analysis

Work Order # 92-07-625

TESTS PERFORMED AND RESULTS:

Analyte	Units	53 25	55 26	57 27	59 28
Chloride (Method 325.3)	mg/L	16.	16.	16.	16.

Analyte	Units	61 29	63 30	65 31	67 32
Chloride (Method 325.3)	mg/L	16.	16.	15.	16.

Analyte	Units	69 33	71 34	72 35
Chloride (Method 325.3)	mg/L	16.	~~34.~~ 16.	16.

Laucks 84 years

Testing Laboratories, Inc.

940 South Harney St., Seattle, WA 98108 (206) 767-5060 FAX 767-5063

Chemistry, Microbiology, and Technical Services

CLIENT : WA State Dept. of Ecology

Certificate of Analysis

Work Order # 92-07-625

TESTS PERFORMED AND RESULTS: field samp. no.

Analyte	Units	#2 01	4 02	6 03	8 04
Chloride (Method 325.3)	mg/L	120.	120.	110.	110.

Analyte	Units	10 05	12 06	14 07	16 08
Chloride (Method 325.3)	mg/L	95.	100.	140.	140.

Analyte	Units	18 09	20 10	22 11	24 12
Chloride (Method 325.3)	mg/L	130.	120.	110.	110.

Analyte	Units	25 13	27 14	29 15	31 16
Chloride (Method 325.3)	mg/L	210.	210.	220.	220.

Analyte	Units	33 17	35 18	37 19	39 20
Chloride (Method 325.3)	mg/L	220.	210.	220.	220.

Analyte	Units	41 21	43 22	49 23	51 24
Chloride (Method 325.3)	mg/L	210.	200.	16.	16.

WASHINGTON STATE DEPARTMENT OF ECOLOGY
ENVIRONMENTAL INVESTIGATIONS AND LABORATORY SERVICES
MANCHESTER LABORATORY

July 27, 1992

TO: Project Officer

FROM: Despina Strong

SUBJECT: Lummi Arsenic Data

SAMPLE RECEIPT:

The samples from the Lummi project were received by the Manchester Laboratory on 7/1/92 in good condition.

HOLDING TIMES:

All analyses were performed within the specified holding times for metals analysis.

INSTRUMENT CALIBRATION:

Instrument calibration was performed before each analytical run and checked by initial calibration verification standards and blanks. Continuing calibration standards and blanks were analyzed at a frequency of 10% during the run and again at the end of the analytical run. All initial and continuing calibration verification standards were within the control limits of +/- 10%.

PROCEDURAL BLANKS:

The procedural blanks associated with these samples showed no detectable levels of analytes.

SPIKED SAMPLE ANALYSIS:

Spiked sample and duplicate spiked sample analysis were performed on one sample in the batch. All spike recoveries were within the acceptable limits of +/- 25% for water sample analysis.

PRECISION DATA:

The duplicate results of the spiked and duplicate spiked sample were used to calculate precision related to the analysis of these samples. The % RPD for all parameters was well within the +/- 20% window for duplicate analysis.

STANDARD REFERENCE MATERIAL:

Standard reference material or external verification standards were all within the windows established for each parameter.

SUMMARY:

The data generated by the analysis of the above referenced samples can be used without qualification.

If you have any questions about the results or the methods used to obtain these results please call me at SCAN 744-4737.

*** Lab Analysis Report ***

==> Transaction #: 07241041 Laboratory: (WE) Ecology, Manchester Lab

Work Group: (38) Metals - ICP Scan

Instrument: (ICP) ICP, Jarrell-Ash AtomComp 1100 (DOE)

Method: (EP1-200.7) Inductively Coupled Plasma Atomic Emissions Analysis

Chemist: (AGH) Hedley, Art DOE Hours Worked:

Project: DOE-381Y LUMMI TIDAL STUDY Prg Ele#: F2545

Prj Off: Garland, Dave DOE Analysis Due: 920701 Revised Due:

*** Sample Records in Transaction ***

Parameter Form File: ICP381002 Title: ICP Scan, Water Total

Seq#	Sample #	QA	Date/Time	Description	Alternate Keys		
01	92278293	LBK1	920630	27			
02	92278293	LBK2	920630	27			
03	92278280		920630	2			
04	92278281		920630	4			
05	92278282		920630	6			
06	92278283		920630	8			
07	92278284		920630	10			
08	92278285		920630	12			
09	92278286		920630	14			
10	92278287		920630	16			
11	92278288		920630	18			
12	92278289		920630	20			
13	92278290		920630	22			
14	92278291		920630	24			
15	92278292		920630	25			
16	92278293		920630	27			
17	92278294		920630	29			
18	92278295		920630	31			
19	92278296		920630	33			
20	92278297		920630	35			
21	92278298		920630	37			
22	92278299		920630	39			
23	92278300		920630	41			
24	92278301		920630	43			
25	92278302		920630	49			
26	92278303		920630	51			
27	92278304		920630	53			
28	92278305		920630	55			
29	92278306		920630	57			
30	92278307		920630	59			
31	92278308		920630	61			
32	92278309		920630	63			
33	92278310		920630	65			
34	92278311		920630	67			
35	92278312		920630	69			
36	92278313		920630	71			

(Continued next page)

37	92278314		920630	72
38	92278293	LMX1	920630	27
39	92278293	LMX2	920630	27

Record Type: TRNIN1 Date Verified: 7/24/92 By: [signature]
Transaction Status: New Transaction...First Printing...Unverified.
Processed: 24-JUL-92 10:50:35 Status: N Batch: (In CUR DB)

Transaction #: 07241041 (38) Metals - ICP Scan
Proj Code : DOE-381Y LUMMI TIDAL STUDY PE # : F2545

Blank ID:			EWPB 28.09	EWPB 28.10			
Sample Number:			92278293	92278293	92278280	92278281	92278282
Sample Description:			27	27	2	4	6
Matrix:			Water-Tot	Water-Tot	Water-Tot	Water-Tot	Water-Tot
Units:							
% Slds:							
QA Code:			LBK1	LBK2			
Date Extract:							
Date Analyzd:			920718	920718	920718	920718	920718
1 Aluminum	Al-Total	ug/l					
2 Antimony	Sb-Total	ug/l					
3 Arsenic	As-Total	ug/l	30U	30U	374	350	349
4 Barium	Ba-Total	ug/l					
5 Berylium	Be-Total	ug/l					
6 Boron	B -Total	ug/l					
7 Cadmium	Cd-Total	ug/l					
8 Calcium	Ca-Total	mg/l					
9 Chromium	Cr-Total	ug/l					
10 HexChrom	Cr6Total	ug/l					
11 Cobalt	Co-Total	ug/l					
12 Copper	Cu-Total	ug/l					
13 Iron	Fe-Total	ug/l					
14 Lead	Pb-Total	ug/l					
15 Mgnsium	Mg-Total	mg/l					
16 Mangnese	Mn-Total	ug/l					
17 Molybdnm	Mo-Total	ug/l					
18 Nickel	Ni-Total	ug/l					
19 Potssium	K -Total	mg/l					
20 Selenium	Se-Total	ug/l					
21 Silicon	Si-Total	ug/l					
22 Silver	Ag-Total	ug/l					
23 Sodium	Na-Total	mg/l					
24 Strntium	Sr-Total	ug/l					
25 Thallium	Tl-Total	ug/l					
26 Tin	Sn-Total	ug/l					
27 Titanium	Ti-Total	ug/l					
28 Tungsten	W -Total	ug/l					
29 Vanadium	V -Total	ug/l					
30 Zinc	Zn-Total	ug/l					
31 Zircnium	Zr-Total	ug/l					

Transaction #: 07241041 (38) Metals - ICP Scan
Proj Code : DOE-381Y LUMMI TIDAL STUDY PE # : F2545

Sample Number:			92278283	92278284	92278285	92278286	92278287
Sample Description:			8	10	12	14	16
Matrix:			Water-Tot	Water-Tot	Water-Tot	Water-Tot	Water-Tot
Units:							
% Slds:							
QA Code:							
Date Extract:							
Date Analyzd:			920718	920718	920718	920718	920718
1 Aluminum	Al-Total	ug/l					
2 Antimony	Sb-Total	ug/l					
3 Arsenic	As-Total	ug/l	316	290	304	452	465
4 Barium	Ba-Total	ug/l					
5 Berylium	Be-Total	ug/l					
6 Boron	B -Total	ug/l					
7 Cadmium	Cd-Total	ug/l					
8 Calcium	Ca-Total	mg/l					
9 Chromium	Cr-Total	ug/l					
10 HexChrom	Cr6Total	ug/l					
11 Cobalt	Co-Total	ug/l					
12 Copper	Cu-Total	ug/l					
13 Iron	Fe-Total	ug/l					
14 Lead	Pb-Total	ug/l					
15 Mgnsium	Mg-Total	mg/l					
16 Mangnese	Mn-Total	ug/l					
17 Molybdnm	Mo-Total	ug/l					
18 Nickel	Ni-Total	ug/l					
19 Potssium	K -Total	mg/l					
20 Selenium	Se-Total	ug/l					
21 Silicon	Si-Total	ug/l					
22 Silver	Ag-Total	ug/l					
23 Sodium	Na-Total	mg/l					
24 Strntium	Sr-Total	ug/l					
25 Thallium	Tl-Total	ug/l					
26 Tin	Sn-Total	ug/l					
27 Titanium	Ti-Total	ug/l					
28 Tungsten	W -Total	ug/l					
29 Vanadium	V -Total	ug/l					
30 Zinc	Zn-Total	ug/l					
31 Zircnium	Zr-Total	ug/l					

*** Lab Analysis Report ***

Transaction #: 07241041 (38) Metals - ICP Scan
Proj Code : DOE-381Y LUMMI TIDAL STUDY PE # : F2545

Sample Number:			92278288	92278289	92278290	92278291	92278292
Sample Description:			18	20	22	24	25
Matrix:			Water-Tot	Water-Tot	Water-Tot	Water-Tot	Water-Tot
Units:							
% Slds:							
QA Code:							
Date Extract:							
Date Analyzd:			920718	920718	920718	920718	920718
1 Aluminum	Al-Total	ug/l					
2 Antimony	Sb-Total	ug/l					
3 Arsenic	As-Total	ug/l	410	358	334	329	60P
4 Barium	Ba-Total	ug/l					
5 Berylium	Be-Total	ug/l					
6 Boron	B -Total	ug/l					
7 Cadmium	Cd-Total	ug/l					
8 Calcium	Ca-Total	mg/l					
9 Chromium	Cr-Total	ug/l					
10 HexChrom	Cr6Total	ug/l					
11 Cobalt	Co-Total	ug/l					
12 Copper	Cu-Total	ug/l					
13 Iron	Fe-Total	ug/l					
14 Lead	Pb-Total	ug/l					
15 Mgnsium	Mg-Total	mg/l					
16 Mangnese	Mn-Total	ug/l					
17 Molybdnm	Mo-Total	ug/l					
18 Nickel	Ni-Total	ug/l					
19 Potssium	K -Total	mg/l					
20 Selenium	Se-Total	ug/l					
21 Silicon	Si-Total	ug/l					
22 Silver	Ag-Total	ug/l					
23 Sodium	Na-Total	mg/l					
24 Strntium	Sr-Total	ug/l					
25 Thallium	Tl-Total	ug/l					
26 Tin	Sn-Total	ug/l					
27 Titanium	Ti-Total	ug/l					
28 Tungsten	W -Total	ug/l					
29 Vanadium	V -Total	ug/l					
30 Zinc	Zn-Total	ug/l					
31 Zircnium	Zr-Total	ug/l					

*** Lab Analysis Report ***

Transaction #: 07241041 (38) Metals - ICP Scan

Proj Code : DOE-381Y LUMMI TIDAL STUDY PE # : F2545

		92278293	92278294	92278295	92278296	92278297
Sample Number:		92278293	92278294	92278295	92278296	92278297
Sample Description:		27	29	31	33	35
Matrix:		Water-Tot	Water-Tot	Water-Tot	Water-Tot	Water-Tot
Units:						
% Slds:						
QA Code:						
Date Extract:						
Date Analyzd:		920718	920718	920718	920718	920718
1 Aluminum	Al-Total ug/l					
2 Antimony	Sb-Total ug/l					
3 Arsenic	As-Total ug/l	74P	67P	68P	69P	75P
4 Barium	Ba-Total ug/l					
5 Berylium	Be-Total ug/l					
6 Boron	B -Total ug/l					
7 Cadmium	Cd-Total ug/l					
8 Calcium	Ca-Total mg/l					
9 Chromium	Cr-Total ug/l					
10 HexChrom	Cr6Total ug/l					
11 Cobalt	Co-Total ug/l					
12 Copper	Cu-Total ug/l					
13 Iron	Fe-Total ug/l					
14 Lead	Pb-Total ug/l					
15 Mgnsium	Mg-Total mg/l					
16 Mangnese	Mn-Total ug/l					
17 Molybdnm	Mo-Total ug/l					
18 Nickel	Ni-Total ug/l					
19 Potssium	K -Total mg/l					
20 Selenium	Se-Total ug/l					
21 Silicon	Si-Total ug/l					
22 Silver	Ag-Total ug/l					
23 Sodium	Na-Total mg/l					
24 Strntium	Sr-Total ug/l					
25 Thallium	Tl-Total ug/l					
26 Tin	Sn-Total ug/l					
27 Titanium	Ti-Total ug/l					
28 Tungsten	W -Total ug/l					
29 Vanadium	V -Total ug/l					
30 Zinc	Zn-Total ug/l					
31 Zircnium	Zr-Total ug/l					

Transaction #: 07241041 (38) Metals - ICP Scan
Proj Code : DOE-381Y LUMMI TIDAL STUDY PE # : F2545

Sample Number:			92278298	92278299	92278300	92278301	92278302
Sample Description:			37	39	41	43	49
Matrix:			Water-Tot	Water-Tot	Water-Tot	Water-Tot	Water-Tot
Units:							
% Slds:							
QA Code:							
Date Extract:							
Date Analyzd:			920718	920718	920718	920718	920718
1 Aluminum	Al-Total	ug/l					
2 Antimony	Sb-Total	ug/l					
3 Arsenic	As-Total	ug/l	51P	57P	68P	71P	57P
4 Barium	Ba-Total	ug/l					
5 Berylium	Be-Total	ug/l					
6 Boron	B -Total	ug/l					
7 Cadmium	Cd-Total	ug/l					
8 Calcium	Ca-Total	mg/l					
9 Chromium	Cr-Total	ug/l					
10 HexChrom	Cr6Total	ug/l					
11 Cobalt	Co-Total	ug/l					
12 Copper	Cu-Total	ug/l					
13 Iron	Fe-Total	ug/l					
14 Lead	Pb-Total	ug/l					
15 Mgnsium	Mg-Total	mg/l					
16 Mangnese	Mn-Total	ug/l					
17 Molybdnm	Mo-Total	ug/l					
18 Nickel	Ni-Total	ug/l					
19 Potssium	K -Total	mg/l					
20 Selenium	Se-Total	ug/l					
21 Silicon	Si-Total	ug/l					
22 Silver	Ag-Total	ug/l					
23 Sodium	Na-Total	mg/l					
24 Strntium	Sr-Total	ug/l					
25 Thallium	Tl-Total	ug/l					
26 Tin	Sn-Total	ug/l					
27 Titanium	Ti-Total	ug/l					
28 Tungsten	W -Total	ug/l					
29 Vanadium	V -Total	ug/l					
30 Zinc	Zn-Total	ug/l					
31 Zircnium	Zr-Total	ug/l					

Transaction #: 07241041 (38) Metals - ICP Scan
Proj Code : DOE-381Y LUMMI TIDAL STUDY PE # : F2545

Sample Number:	92278303	92278304	92278305	92278306	92278307
Sample Description:	51	53	55	57	59
Matrix:	Water-Tot	Water-Tot	Water-Tot	Water-Tot	Water-Tot
Units:					
% Slds:					
QA Code:					
Date Extract:					
Date Analyzd:	920718	920718	920718	920718	920718
1 Aluminum Al-Total ug/l					
2 Antimony Sb-Total ug/l					
3 Arsenic As-Total ug/l	48P	250	280	180	130P
4 Barium Ba-Total ug/l					
5 Berylium Be-Total ug/l					
6 Boron B -Total ug/l					
7 Cadmium Cd-Total ug/l					
8 Calcium Ca-Total mg/l					
9 Chromium Cr-Total ug/l					
10 HexChrom Cr6Total ug/l					
11 Cobalt Co-Total ug/l					
12 Copper Cu-Total ug/l					
13 Iron Fe-Total ug/l					
14 Lead Pb-Total ug/l					
15 Mgnsium Mg-Total mg/l					
16 Mangnese Mn-Total ug/l					
17 Molybdnm Mo-Total ug/l					
18 Nickel Ni-Total ug/l					
19 Potssium K -Total mg/l					
20 Selenium Se-Total ug/l					
21 Silicon Si-Total ug/l					
22 Silver Ag-Total ug/l					
23 Sodium Na-Total mg/l					
24 Strntium Sr-Total ug/l					
25 Thallium Tl-Total ug/l					
26 Tin Sn-Total ug/l					
27 Titanium Ti-Total ug/l					
28 Tungsten W -Total ug/l					
29 Vanadium V -Total ug/l					
30 Zinc Zn-Total ug/l					
31 Zircnium Zr-Total ug/l					

Transaction #: 07241041 (38) Metals - ICP Scan
Proj Code : DOE-381Y LUMMI TIDAL STUDY PE # : F2545

Sample Number:		92278308	92278309	92278310	92278311	92278312
Sample Description:		61	63	65	67	69
Matrix:		Water-Tot	Water-Tot	Water-Tot	Water-Tot	Water-Tot
Units:						
% Slds:						
QA Code:						
Date Extract:						
Date Analyzd:		920718	920718	920718	920718	920718
1 Aluminum Al-Total	ug/l					
2 Antimony Sb-Total	ug/l					
3 Arsenic As-Total	ug/l	60P	61P	56P	56P	57P
4 Barium Ba-Total	ug/l					
5 Berylium Be-Total	ug/l					
6 Boron B -Total	ug/l					
7 Cadmium Cd-Total	ug/l					
8 Calcium Ca-Total	mg/l					
9 Chromium Cr-Total	ug/l					
10 HexChrom Cr6Total	ug/l					
11 Cobalt Co-Total	ug/l					
12 Copper Cu-Total	ug/l					
13 Iron Fe-Total	ug/l					
14 Lead Pb-Total	ug/l					
15 Mgnsium Mg-Total	mg/l					
16 Mangnese Mn-Total	ug/l					
17 Molybdnm Mo-Total	ug/l					
18 Nickel Ni-Total	ug/l					
19 Potssium K -Total	mg/l					
20 Selenium Se-Total	ug/l					
21 Silicon Si-Total	ug/l					
22 Silver Ag-Total	ug/l					
23 Sodium Na-Total	mg/l					
24 Strntium Sr-Total	ug/l					
25 Thallium Tl-Total	ug/l					
26 Tin Sn-Total	ug/l					
27 Titanium Ti-Total	ug/l					
28 Tungsten W -Total	ug/l					
29 Vanadium V -Total	ug/l					
30 Zinc Zn-Total	ug/l					
31 Zircnium Zr-Total	ug/l					

Transaction #: 07241041 (38) Metals - ICP Scan
Proj Code : DOE-381Y LUMMI TIDAL STUDY PE # : F2545

Sample Number:			92278313	92278314	92278293	92278293
Sample Description:			71	72	27	27
Matrix:			Water-Tot	Water-Tot	Water-Tot	Water-Tot
Units:					% Recov	% Recov
% Slds:						
QA Code:					LMX1	LMX2
Date Extract:						
Date Analyzd:			920718	920718	920718	920718
1 Aluminum	Al-Total	ug/l				
2 Antimony	Sb-Total	ug/l				
3 Arsenic	As-Total	ug/l	61P	59P	95	95
4 Barium	Ba-Total	ug/l				
5 Berylium	Be-Total	ug/l				
6 Boron	B -Total	ug/l				
7 Cadmium	Cd-Total	ug/l				
8 Calcium	Ca-Total	mg/l				
9 Chromium	Cr-Total	ug/l				
10 HexChrom	Cr6Total	ug/l				
11 Cobalt	Co-Total	ug/l				
12 Copper	Cu-Total	ug/l				
13 Iron	Fe-Total	ug/l				
14 Lead	Pb-Total	ug/l				
15 Mgnsium	Mg-Total	mg/l				
16 Mangnese	Mn-Total	ug/l				
17 Molybdnm	Mo-Total	ug/l				
18 Nickel	Ni-Total	ug/l				
19 Potssium	K -Total	mg/l				
20 Selenium	Se-Total	ug/l				
21 Silicon	Si-Total	ug/l				
22 Silver	Ag-Total	ug/l				
23 Sodium	Na-Total	mg/l				
24 Strntium	Sr-Total	ug/l				
25 Thallium	Tl-Total	ug/l				
26 Tin	Sn-Total	ug/l				
27 Titanium	Ti-Total	ug/l				
28 Tungsten	W -Total	ug/l				
29 Vanadium	V -Total	ug/l				
30 Zinc	Zn-Total	ug/l				
31 Zircnium	Zr-Total	ug/l				

Laucks 84 years
Testing Laboratories, Inc.
940 South Harney St., Seattle, WA 98108 (206) 767-5060 FAX 767-5063

Chemistry, Microbiology, and Technical Services

CLIENT: Martin Lutz
4325 Graler Place
Lummi Island, WA 98262

Certificate of Analysis

Work Order# : 92-07-086
DATE RECEIVED : 07/01/92
DATE OF REPORT: 07/20/92

ATTN : Martin Lutz

Work ID : Lummi Is. Ground Water Study
Taken By : Client
Transported by: Hand Delivered
Type : Water

SAMPLE IDENTIFICATION:

	Sample Description	Collection Date
01	#1	06/30/92
02	#3	06/30/92
03	#5	06/30/92
04	#7	06/30/92
05	#9	06/30/92
06	#11	06/30/92
07	#13	06/30/92
08	#15	06/30/92
09	#17	06/30/92
10	#19	06/30/92
11	#21	06/30/92
12	#23	06/30/92
13	#26	06/30/92
14	#28	06/30/92
15	#30	06/30/92
16	#32	06/30/92
17	#34	06/30/92
18	#36	06/30/92
19	#38	06/30/92
20	#40	06/30/92
21	#42	06/30/92
22	#50	06/30/92

Lauckss 84 years
Testing Laboratories, Inc.
940 South Harney St., Seattle, WA 98108 (206) 767-5060 FAX 767-5063
Chemistry, Microbiology, and Technical Services

CLIENT : Martin Lutz

Certificate of Analysis

Work Order# : 92-07-086

SAMPLE IDENTIFICATION:

	Sample Description	Collection Date
23	#52	06/30/92
24	#54	06/30/92
25	#56	06/30/92
26	#58	06/30/92
27	#60	06/30/92

cc: Dave Garland
NW Regional Office Ecology
3190 160th Ave. S.E.
Bellevue, WA 98008-5452

FLAGGING:

The flag "U" indicates the analyte of interest was not detected, to the limit of detection indicated.

cc: N.W. Regional Office of Ecology
ATTN: Dave Garland
3190 160th Ave S.E.
Bellevue, WA 98008-5452

Lancks 84 years
Testing Laboratories, Inc.
940 South Harney St., Seattle, WA 98108 (206) 767-5060 FAX 767-5063
Chemistry, Microbiology, and Technical Services

CLIENT : Martin Lutz

Certificate of Analysis

Work Order # 92-07-086

TESTS PERFORMED AND RESULTS:

Analyte	Units	FIELD SAMPLE NO. #1 / 01	#3 / 02	#5 / 03	#7 / 04
Arsenic (Method 206.3)	mg/L	0.005 U	0.007	0.31	0.018
Chloride (Method 325.3)	mg/L	130.	110.	100.	110.

Analyte	Units	#9 / 05	#11 / 06	#13 / 07	#15 / 08
Arsenic (Method 206.3)	mg/L	0.027	0.005 U	0.005 U	0.005 U
Chloride (Method 325.3)	mg/L	100.	95.	140.	130.

Analyte	Units	#17 / 09	#19 / 10	#21 / 11	#23 / 12
Arsenic (Method 206.3)	mg/L	0.005 U	0.005 U	0.005 U	0.005 U
Chloride (Method 325.3)	mg/L	130.	120.	100.	100.

Analyte	Units	#26 / 13	#28 / 14	#30 / 15	#32 / 16
Arsenic (Method 206.3)	mg/L	0.056	0.056	0.058	0.058
Chloride (Method 325.3)	mg/L	190.	210.	210.	210.

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Testing Laboratories, Inc.

940 South Harney St., Seattle, WA 98108 (206) 767-5060 FAX 767-5063

Chemistry, Microbiology, and Technical Services

CLIENT : Martin Lutz

Certificate of Analysis

Work Order # 92-07-086

TESTS PERFORMED AND RESULTS:

Analyte	Units	#34 17	#36 18	#38 19	#40 20
Arsenic (Method 206.3)	mg/L	0.059	0.028	0.049	0.055
Chloride (Method 325.3)	mg/L	210.	210.	210.	210.

Analyte	Units	#42 21	#50 22	#52 23	#54 24
Arsenic (Method 206.3)	mg/L	0.058	0.049	0.056	0.24
Chloride (Method 325.3)	mg/L	210.	15.	12.	15.

Analyte	Units	#56 25	#58 26	#60 27
Arsenic (Method 206.3)	mg/L	0.18	0.12	0.069
Chloride (Method 325.3)	mg/L	14.	15.	15.

Lauck's 84 years
Testing Laboratories, Inc.
940 South Harney St., Seattle, WA 98108 (206) 767-5060 FAX 767-5063
Chemistry, Microbiology, and Technical Services

Quality Control Report
Method Blanks for Work Order 9207086

Blank Name	Samples Verified	Test Description	Result	Units	Control Limit
B070792_HY_W02	1-12	Arsenic by gaseous hydride AA	0.0050 U	mg/L	0.010
B070792_HY_W03	13-27	Arsenic by gaseous hydride AA	0.0050 U	mg/L	0.010
B071492_CL_W01	1-20	Chloride by Hg(NO3)2 titrimetry	1.0 U	mg/L	2.0
B071492_CL_W02	21-27	Chloride by Hg(NO3)2 titrimetry	1.0 U	mg/L	2.0

A method blank can validate more than one analyte on more than one work order. The method blanks in this report may validate analytes not determined on this work order, but nonetheless determined in the associated blank.

Because they validate more than one work order, method blank results are not always reported in the same concentration units used for sample results.

* = blank exceeds control limit

*** Lab Analysis Report ***

Transaction #: [illegible] Seq #: [illegible]
(10) Gen Inorg/Phys-Specified
(WE) Ecology, Manchester Lab
Project: (DOE-381Y) LUMMI TIDAL STUDY F2545 DPG
Param: (95 S) Cond@25C Meter umho/cm

QA Code: ( ) Normal Data
Instrument: (CONDUC) Conductivity Meter #XXXXXXX
Method: (EP1-120.1) Conductance, Specific
Chemist: (GAD) Davis, Greg DOE Hours Worked:
Lab Prep: ( ) Unspecifed
Matrix: (10) Water-Total Date Preprd:
Units: (03) umho/cm Date Anlyzd: 920707

Line	Sample #	Result	Sample Location/Description	#Days to Anl
1	92 278280	1980	2	920630 (7)
2	92 278281	1920	4	920630 (7)
3	92 278282	1720	6	920630 (7)
4	92 278283	1750	8	920630 (7)
5	92 278284	1560	10	920630 (7)
6	92 278285	1550	12	920630 (7)
7	92 278286	2250	14	920630 (7)
8	92 278287	2220	16	920630 (7)
9	92 278288	2050	18	920630 (7)
10	92 278289	1960	20	920630 (7)
11	92 278290	1770	22	920630 (7)
12	92 278291	1680	24	920630 (7)
13	92 278292	1190	25	920630 (7)
14	92 278293	1410	27	920630 (7)
15	92 278294	1450	29	920630 (7)
16	92 278295	1470	31	920630 (7)
17	92 278296	1440	33	920630 (7)
18	92 278297	1410	35	920630 (7)
19	92 278298	1410	37	920630 (7)
20	92 278299	1400	39	920630 (7)
21	92 278300	1340	41	920630 (7)
22	92 278301	1340	43	920630 (7)
23	92 278302	581	49	920630 (7)
24	92 278303	582	51	920630 (7)
25	92 278304	578	53	920630 (7)
26	92 278305	578	55	920630 (7)
27	92 278306	581	57	920630 (7)
28	92 278307	579	59	920630 (7)
29	92 278308	579	61	920630 (7)
30	92 278309	579	63	920630 (7)
31	92 278310	582	65	920630 (7)
32	92 278311	581	67	920630 (7)
33	92 278312	578	69	920630 (7)
34	92 278313	582	71	920630 (7)
35	92 278314	582	72	920630 (7)

Record Type: TRNIN2 Date Verified: 7-8-92 By: G. Thomas
Transaction Status: New Transaction...First Printing...Unverified.
Processed: 8-JUL-92 13:28:17 Status: N Batch: (In CUR DB)

APPENDIX B

APPENDIX B

LUMMI ISLAND GROUNDWATER QUALITY INVESTIGATION 1989 - 1993
ARSENIC CONTAMINATION OF GROUNDWATER SUPPLIES

Ginny Stearn, DOH

Executive Summary:

Twenty four wells on Lummi Island were monitored for arsenic, other water quality parameters, and water level between March 1991 and January 1993. The wells were located on the northern half of the island and were part of an on-going groundwater investigation carried out by the island residents, Whatcom County Health Department, and the Department of Ecology. Of the 24 wells, 10 showed levels of arsenic > 25 ug/l (ppb). Of the 10 with elevated arsenic, 8 had concentrations in excess of the federal Safe Drinking Water Act (SDWA) maximum contaminant level (MCL) of 50 ug/l. Most of the wells showing the elevated arsenic concentrations were located along the northeast side of the island. Further analysis showed that all but one of the wells exceeding the MCL were completed in bedrock (sandstone).

There is evidence to suggest that the pattern of arsenic contamination is linked to the depth of well completion (bedrock v.s. drift) and may be fault controlled. Four of the wells, located along the central spine of the island, show an inverse relationship between arsenic concentration and water level and may trace a major water bearing fracture zone in the bedrock.

The arsenic contaminated wells are located in the northeastern area of the island. In this area, wells completed in the underlying bedrock may require periodic testing to insure a safe potable supply of drinking water.

Introduction:

The purpose of this report is to describe the occurrence, possible causes, and implications of arsenic contamination of groundwater on the northern half of Lummi Island. The data used in the preparation of this report was collected under the auspices of the Lummi Island CCWF grant between 1989 to 1993.

Background information on the history and scope of the investigation can be found in the grant report prepared by Whatcom County for the Centennial Clean Water Fund. This report does not attempt to reproduce that discussion. This report looks solely at the issue of arsenic in groundwater and the potential implications for drinking water supplies.

As a part of the ground water investigation, 24 wells were selected across the northern half of the island. These were monitored monthly for water levels and bi-monthly for a variety of water quality parameters including arsenic. The sampling was conducted by island residents under protocols developed by Ecology and the County for the grant and the study.

Background:

Lummi Island has had a history of elevated arsenic levels in wells located on the northern half of the island. This has been documented in previous informal investigations by both the Whatcom County Health Department (WCHD)(WCHD, 1993) and the Department of Ecology's Northwest Regional Office (Ecology, 1990). The historical data shows an apparent trend of elevated arsenic levels on the north-northeast side of the island. Early data was sporadic. Repeat monitoring was generally limited to confirmation samples and further limited to those wells with elevated arsenic or chlorides. Goals of the current study include the expansion of the existing database on arsenic, identify patterns of seasonality and occurrence, as well provide information on potential sources of the contamination. The commonly suspected source of the contamination was naturally occurring minerals in the bedrock. Hydrology of the northern half of the island suggested a potential source in or along fracture zones in bedrock or near contact zones with mafic base rock. However, early data did not include details of well construction, lithology, water levels, or depth. As a result many questions concerning the nature and extent of the contamination remained.

Naturally occurring arsenic contamination has been documented in other areas of Washington (Goldstein, 1988)(Frost, 1991)(Ficklind et al., 1989). However most of these areas have been linked with igneous or metamorphic bedrock. Although Lummi Island does have areas of both igneous and metamorphic outcrops, these have not been typically associated with the island's ground water resources. The aquifers on the island are generally considered to be either unconsolidated glacial drift or the sandstone bedrock that underlies most of the north half of the island (Schmidt, 1978)(Easterbrook, 1973). The question of the arsenic source is examined in this report.

Study Area:

A complete description of the study area and its drinking water resources has been described in the project report as well as the companion report, "Effects of Tidal Fluctuations on Ground Water Quality, Lummi Island Field Study" (Garland, 1993). Earlier reports such as the "Lummi Island Plan" (Whatcom County Planning, 1978), and "The Water Resources Of Northern Lummi Island"

(Schmidt 1978) provide an excellent overview of the study area physiography and hydrology. These reports identify the north half of the island as the dominant groundwater production zone. The southern half of the island is composed of shallow bedrock with no significant useable groundwater resources.

The northern half of the island has two distinct aquifer materials. The oldest and deepest aquifer is the Chuckanut Sandstone. The fractured greywacke sandstone is overlain in many areas of the island by a mantle of unconsolidated glacial drift. Both aquifers are unconfined and exhibit a high degree of continuity. All recharge to the aquifers is derived from rainfall on the island. Water yield from the glacial material is substantially higher than for the sandstone. However, the drift material can be locally thin and shallow, and in some cases, not provide sufficient quantity to meet year round domestic needs.

The Data:

A summary of study well characteristics can be found in Appendix B-1. In addition to general location and field number, this table provides an estimate of well depth, a qualitative description of arsenic concentration (> MCL, > 1/2MCL, or << MCL), and an estimation of lithology at the completion depth (bedrock y/n). The last column identifies whether or not water level information was available. Wellhead elevations were not collected for the study wells. As such, depth had to be measured as "feet below the top of the well" as opposed to a referenced elevation. In some cases, the depth of the well had to be inferred from the water level measurements. The values in the parentheses give an estimate of the minimum depth of the well.

Appendices B-1 and B-2, profile the water levels and arsenic concentrations for the ten wells that showed elevated arsenic levels. Appendix B-4 contains hydrographs for 7 of the wells that have both arsenic and water level measurements. Not all of the wells had complete arsenic and/or water level information. The lack of elevation data for the wellhead makes quantitative comparisons between the wells impossible without the standard reference to sea level or some other datum. Comparison of the shape and period found in the hydrographs is at the present time the only way to identify linked wells.

The location of the study wells are plotted on the map in Appendix B-5. Wells that showed arsenic concentrations > 50 ug/l are shown in red. Those with concentrations >25 ug/l but <50 ug/l are marked in yellow. The remaining wells had arsenic concentrations < 25 ug/l. Previous water quality monitoring within the study area, had identified a number of domestic wells with elevated arsenic. These were primarily located along eastern shore (near the Beach Store, post office and school,) and along the northern most tip of the island. Appendix B-6 shows the location of these wells along with the CCWF wells that had elevated arsenic concentrations. The historical data generally corresponds with the new study findings.

Arsenic and Groundwater Quality:

Arsenic in groundwater on Lummi Island raises a number of questions for the residents and the local and state health departments. They include:

* Is the source of contamination natural or human caused?

* Is there a way to predict where the elevated arsenic levels may occur?

* Are there health concerns associated with the levels of arsenic being detected on Lummi? (Appendix B-7)

* What actions might be taken to reduce public risks?

These questions form the basis of this report. The nature of the contaminant source leads to the identification of a conceptual model that helps predict where the risk of contamination is highest. In order to do that however, the contamination itself needs to be characterized.

Based on the study results, it can be seen that the contaminated wells are located in a zone that runs south from Point Migley, though Richardson Mountain and diagonally towards the narrowest portion of the island (near the ferry dock and post office). The highest concentrations are found at the northern end of the island. The maps in Appendix B-5 and B-6 show an area marked with the shaded boundary. Outside this area, arsenic concentrations are generally at or near the detection level. It should be noted even inside of the area, there are a number of wells without high arsenic. Many of these appear to be finished in the bedrock. This means that while all but one of the high arsenic wells are completed in bedrock, not all bedrock wells show high arsenic.

Arsenic was a common pesticide in the 40's and 50's. It was used on orchards, poultry, row crops, and sheep. This could have been a potential source of the arsenic on the island given its rural character, mixed land-use, and semi-agricultural history. However, two factors argue against a human or anthropogenic source of the arsenic. These factors are that:

1) The incidents of contamination show no apparent correlation with land use or land development, and

2) None of the shallow glacial drift wells have shown elevated levels of arsenic.

If the arsenic had come from a surface activity, it would have to migrate through the shallow aquifer to impact the deep bedrock wells. This would be expected to leave some residual concentrations in the upper aquifer. To date, this does not appear to be the case. Furthermore, many of the contaminated wells are located in relatively undisturbed portions of the island. In fact, there is more developed land outside of the northeastern area than inside. The fact that none of the wells completed in the shallow aquifer have shown arsenic contamination, suggests that the arsenic source is located within the aquifer and not at land surface.

The arsenic in the aquifer could occur in a number of ways. Arsenic is a common constituent of the igneous and metamorphic rocks that make up the Cascades. The most common mineral form is as arsenopyrite. The Chuckanut sandstone is composed of greywacke and conglomerates derived from the ancestral Cascades. The sands that washed down from the Cascades and formed the Chuckanut formation may have locally concentrated deposits of arsenopyrite.

Arsenic and Drinking Water Wells

An evaluation of the water quality data for wells within the northeastern area shows that arsenic levels between adjacent wells can vary tremendously. Within the northeastern area, the concentration ranges from near 50 ug/l to concentrations in excess of 350 ug/l. Even within a well, the contaminant level can vary significantly over time. At least two of the wells in the northeastern area show arsenic levels varying by 10 to 20 times over their minimum concentration within a year. While some wells show high degree of variation, other remain virtually constant over the same period. This, coupled with the fact that other wells located within the area show no contamination, suggests a contaminant source that is localized by some hydrologic or geologic factor.

Usually when groundwater is produced from an unconsolidated bedrock, it generally flows through weathered zones and/or fracture zones within the rock. These conditions can create locally productive aquifers. However, unlike unconsolidated aquifers, the productivity in the aquifer will vary from fracture to fracture and produces a highly heterogeneous pattern of water levels. Fracture patterns tend to be linear and reflect gross surface geology in areas of large scale faulting. Wells linked along a fracture zone will exhibit similar characteristics in terms of hydraulic head and water levels. Where the groundwater flow is primarily limited to a weathered zone in the bedrock, water levels tend to respond more like an unconsolidated aquifer with smooth water table surfaces and area homogeneity.

The geologic structure of Lummi Island has been shaped by episodes of large scale faulting. The southern half of the island was faulted in place next to the northern half (Schmidt, 1978) (Easterbrook, 1973) (Cheney, 1987). The geologic history of much of the island suggests major fault activity under its northern half. Cheney described a number of major fault lines surrounding Lummi in his paper, "Major Cenozoic Faults in The Norther Puget Lowland of Washington". Of particular interest is a proposed extension of the Skagit fault along the northeast shore of the island. Whenever this type of activity occurs it is generally accompanied by significant fracture zones. Such fracture zones generally run parallel with the major faults.

Lummi Island appears to have both fractured flow and weathered zone flow occurring within the sandstone aquifer. As a general rule, the monitoring data for the bedrock aquifer indicates that the greatest annual fluctuation in water levels is found in the deepest wells. The intermediate wells also located in the bedrock (weathered zone) have less pronounced water level fluctuations. Water levels in the drift aquifer, generally shows the lowest amount of variability. In fact, analysis of the water level information for the study wells indicates that stability of the water levels over the year is one of the best indicators of the glacial drift aquifer.

Among the bedrock wells that showed high arsenic, water level fluctuations were not homogeneous. However there are four wells within the northeastern area that showed similar patterns of water level change. These wells (4, 6, 22, & 24) not only showed significant water level changes, but also showed an inverse relationship between arsenic and water level. When water levels were high, arsenic was low. Conversely, when water levels were low, arsenic levels tended to be high. Wells 4, 24, and 22 are aligned along a northwest trend down the spine of the northeastern area and parallels the northeast coast line. Well 6 (arsenic concentration >25 ug/l), although not on the same line, could be plotted on a parallel line just outside the northeastern area.

Arsenic Vulnerability:

When taken together the above factors suggest that the arsenic contamination on Lummi is naturally occurring within the bedrock aquifer, and is likely fault or fractured controlled. At the present time, arsenic occurrence is defined by existing water quality records. This empirical approach to vulnerability, is conservative. Not all of the wells located in the area, show arsenic contamination. However, out of all of the wells on the island, wells located within this area have the highest potential to have elevated arsenic. This is especially true for wells that are completed in the bedrock aquifer.

Lummi Island is not the first community to encounter arsenic water quality problems. Snohomish County also has areas with naturally occurring arsenic that has contaminated water supplies (Frost, 1991). A copy of the executive summary from the Snohomish County investigation can be found in Appendix B-8. The key points of its recommendations revolve around initial sampling and repeat sampling when arsenic detected.

Looking at the water quality records for the contaminated wells suggests that a single sample may not be able to identify a contaminated source. Many of the wells that currently have problems have had months, where the test result were considerably below the MCL. There were other months in the same year when the concentration could be considerably over the SDWA MCL. In the Lummi Island study, wells 24 and 22 had recorded samples was close to the detection limits, however within the same year other samples were as high as 6 times the MCL (range 10 - 300 ug/l).

This is a problem not only for public drinking water supplies but also for individual supplies. Most individual water supplies or very small public systems are required to test for inorganic contaminants only when the well is brought on line or at the time a property transfer takes place. With no regular on-going monitoring, an individual may never know if they are exposed to high arsenic levels. Multiple or repeat testing is the most effective prevention and public education tool available.

However, there additional methods that could be used to better refine the area where arsenic is most likely to occur. One piece of information that is missing from this investigation is wellhead elevation. This could be very useful in pinning down problem areas, or defining fault traces. With the wellhead elevation, the existing water levels could be used to construct water table maps and to correlate water level changes between wells. This in turn could be used be used to link wells along connected fracture zones.

Arsenic and Public Health:

Eight wells in the study detected arsenic at concentrations in excess of the MCL of 50 ug/l. The contaminant level is based primarily on the concern for chronic exposure. Appendix B-7 contains the Washington State Department of Health Fact Sheet on Arsenic in Drinking Water. It summarizes the general concerns for arsenic, background information about health risks, and a cursory discussion of treatment options.

At the present time EPA is considering reducing the MCL for arsenic in public drinking water because of increased concerns for its potential carcinogenicity. Estimates of the new MCL are as low as 2 ug/l. There is still quite a bit of discussion on the subject on the and until a federal change goes into effect the 50 ug/l MCL still stands. The primary route of exposure for arsenic in water is ingestion via drinking water, and food preparation. Showering and inhalation are not considered significant routes of exposure for most persons.

Public water supplies, those systems serving more than 2 residences or a business, must monitor for arsenic. When arsenic concentrations below the MCL are detected in a public water supply, the State Department of Health (DOH) recommends additional quarterly or semi-annual monitoring with one sample to be taken in August or September. Public water supplies that exceed the MCL are required to do the following:

1) Collect 3 additional samples from the same sample point within 30 days. If the average of all four samples exceeds the MCL, a violation is confirmed. (WAC 246-290-320 (3)(b).

2) Notify DOH and consumers served by the water system. (WAC 246-290-320 (1)(b).

3) Determine the cause of the contamination and take corrective action as directed by the DOH. (WAC 246-290-320 (1)(b). Such action may include increased monitoring for arsenic, seeking another source of water, blending with another source of supply, and/or treatment of existing source.

There are five methods of arsenic removal listed on the fact sheet. Of these, coagulation/filtration and lime softening generally require a level of operational skills beyond most very small water systems or individual well owners (Fox, 1989) (Hathaway & Rubel, 1987)(AWWA, 1983). This type of treatment generally requires a trained operator and regular maintenance of the treatment system. Larger public systems may be required to consider one of these treatment options. A third alternative would be one that consider dilution. By blending the high arsenic source with a low arsenic source, a safe and potable source can be produced that meets EPA and the State's standards.

In addition to the three methods described above there are three small scale-technologies that can also be used to reduce arsenic in the water an individual drinks. The three main methods available to individuals and small systems vary in efficiency based on the arsenic concentration in the source, the pH of the water, and the desired rate of water treatment. These methods include:

1) Activated alumina ion exchange,

2) reverse osmosis, and

3) anion exchange.

All three of these treatment technologies lend themselves to point-of-use treatment devices which treat water only as needed. Generally speaking, these devices are used within a home to provide treatment at the cooking and drinking water faucets only. This type of treatment is not expected to provide complete treatment of all in-house water use. By addressing the ingestion pathway and reducing arsenic intake, the overall risk and arsenic exposure can be reduced and controlled.

The design, construction, and operation of any treatment system serving a public water system is subject to review and approval by DOH. DOH generally does not approve <u>point-of-use</u> type treatment devices on public water systems and discourages such devices on private water systems unless there is no feasible alternative. This position is based on the difficulty and cost for completing the necessary design studies and pilot studies; difficulties encountered by homeowners to properly monitor, operate, and maintain such devices; concerns for a false sense of security by the homeowner or subsequent homeowner when a residence is sold.

<u>Conclusions:</u>

The following summary can be made concerning the arsenic contamination on Lummi Island.

* There is evidence of arsenic contamination in Lummi Island groundwater.

* The arsenic source appears to be in the aquifer itself, derived from naturally occurring accumulations of arsenic (arsenopyrite) in the sandstone aquifer.

* Contamination seems to be linked to ground water movement along major fault lines and fracture zones. Mapping these and identifying the associated water table, will improve the conceptual model for predicting arsenic vulnerability.

* Based on the water quality record, contamination appears to be limited primarily to wells completed in the sandstone, located along the northeast side of the north half of the island. This area runs southeast from Point Migley through Richardson Mountain diagonally towards the narrowest portion of the island in the vicinity of the Post office and the

ferry dock.

* Deep wells within this area with a history of significant water level variation should be considered a high risk and subject to repeat monitoring over time (multiple samples in first year repeat sampling every 1 to 3 years.

* Contaminated wells within this area have significant seasonal variation in arsenic levels over a year. Systems under the MCL for part of the year may be well over the MCL at other times of the year.

* All water wells on the island that detect arsenic at or near 20 ug/l should be scheduled for a minimum of one follow-up sample.

* Further investigation should include the identification of wellhead levels, water table maps, and well correlations.

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APPENDIX B-1: LUMMI ISLAND CCWF STUDY WELLS SUMMARY TABLE

LOCATION	DOH#	DEPTH	ARSENIC	BEDROCK	H2O LVL
37/1-4D1	1	122	>MCL	YES	
37/1-4E1	2	69	<<MCL	NO	
37/1-4F1	3	77	<<MCL	NO	YES
37/1-4G2	4	227	>MCL	YES	YES
37/1-4J4	5	94	>MCL	YES	YES
37/1-5A1	6		>1/2MCL	Yes	YES
37/1-5C1	7	158	<<MCL	YES	YES
37/1-5R1	8	(>65)	<<MCL	No	YES
37/1-8A1	9		<<MCL	No	YES
37/1-9C6	10	(>65)	>1/2MCL	No	YES
37/1-9G3	11	94	<<MCL	?	YES
37/1-9J1	12	(>85)	<<MCL	?	YES
37/1-10L1	13		<<MCL	No	
37/1/10L2	14	(>180)	<<MCL	YES	YES
37/1-10M1	15	(>110)	<<MCL	YES	YES
37/1-15E1	16	207	>MCL	NO?	YES
37/1-15G1	17	86	<<MCL	NO	YES
37/1-15H2	18	45	<<MCL	NO	
38/1-29Q2	19	(>50)	>MCL	Yes	YES
38/1-32A1	20	101	<<MCL	YES	
38/1-32B1	21	(>140)	>MCL	YES	YES
38/1-32J1	22	100	>MCL	YES	YES
38/1-32P1	23	73	<<MCL	?	
38/1-33N5	24	(>105)	>MCL	YES	YES

APPENDIX B-2: SELECTED WATER LEVELS FOR CCWF STUDY WELLS

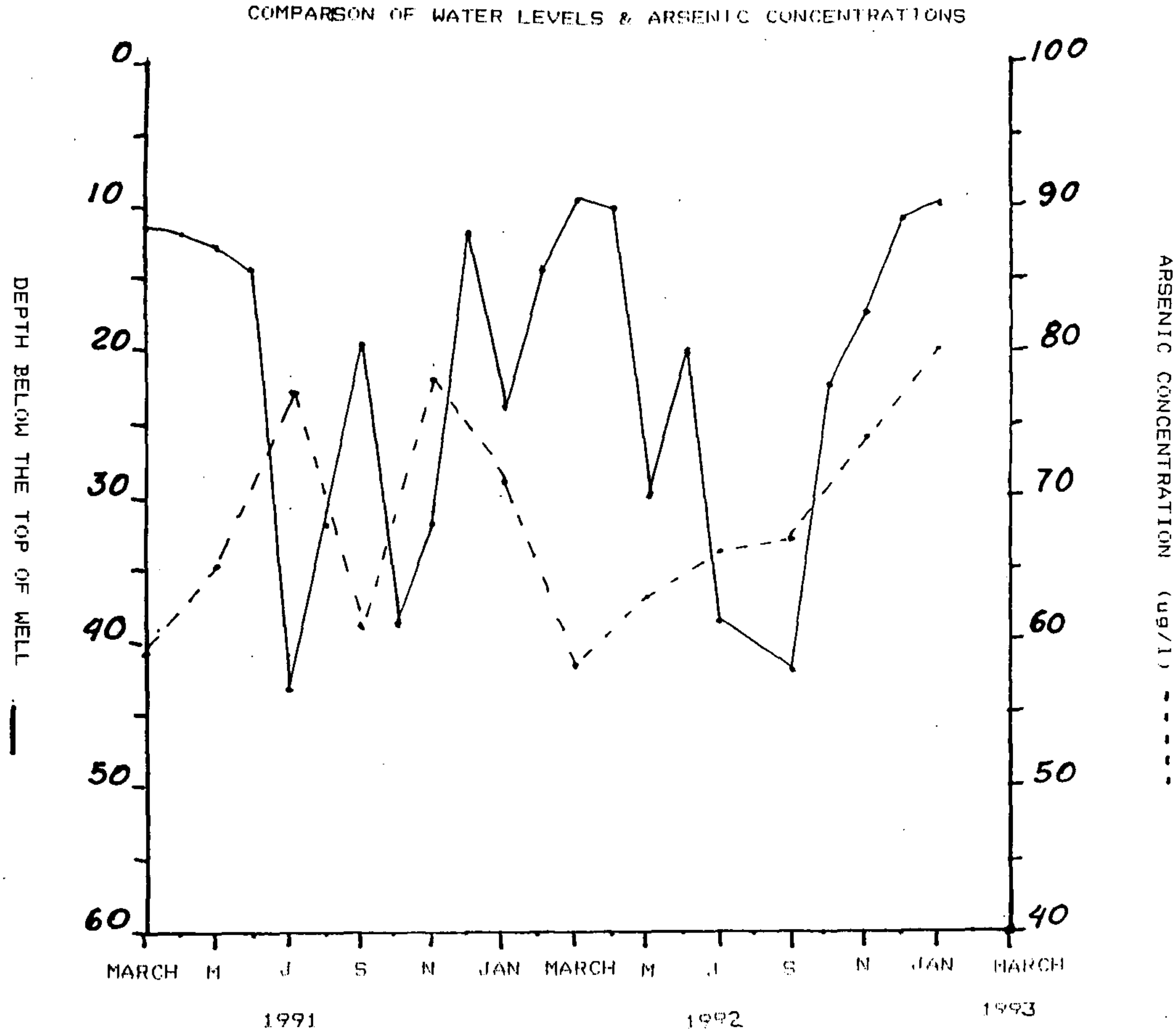
DATE	#4	#5	#6	#10	#16	#19	#21	#22	#24
3/91	11.5	30.5	23.8		67.9		123	4.78	32.9
4/91	11.9	31.3	25.8		67.6	20.4	110	4.16	36.4
5/91	12.7	31.9	28.6		66.2	21.1	112	10.4	31.3
6/91	14.9	32.6	33.8		70.9	23.6	115	17.4	43.1
7/91	43.4	33.4	46.3		65.5	28.2	138	26.5	31.3
8/91	32.1	35.0	36.8	58.5	66.1	27.3	110	37.9	
9/91	19.5	34.3	44.0	64.5	67.2	26.8	82.6	69.2	106
10/91	38.7	34.5	42.6	59.3	66.8	28.4	57.8	76.6	>85
11/91	31.9	33.2	45.1	63.5	66.6	26.1	57.4	67.4	86.3
12/91	11.9	33.1	42.6	63.5	65.8	24.9	57.4	43.1	106
1/92	24.0	32.1	32.2	61.7	65.3	20.9	56.7	38.7	
2/92	14.8	30.0	26.3	59.6	65.9	19.6	58.9	24.3	
3/92	9.6	30.1	25.7	66.0	74.7	19.4	55.9	6.12	
4/92	10.3	31.3	37.9	60.1	68.3	20.9	56.2	11.8	
5/92	29.3	31.2	27.9	62.2	67.2	21.3	73.8	14.2	
6/92	19.9	33.9	38.1	59.9	67.0	22.3	138	22.3	
7/92	38.9		37.2	61.7	67.0		69.3	32.9	
8/92	40+		37.7		69.0		91.4	39.1	
9/92	42.0	34.8	40.8	59.4	65.4		59.9	76.1	
10/92	22.5	37.9	39.5	59.1	66.6		60.3		
11/92	17.5	31.5	38.8	62.7	65.7		59.5		
12/92	11.1	30.7		62.5			57.8		
1/93	10.4	31.1	32.7	69.9	67.2		57.1	69.7	

DEPTH IS MEASURED IN FEET BELOW TOP OF WELL.

APPENDIX B-3: ARSENIC CONCENTRATIONS (ug/L) FOR SELECT CCWF WELLS

DATE	#1	#4	#5	#6	#10	#16	#19	#21	#22	#24
3/91	76	59	105			44		140	15	24
5/91		64	66	14		47		140	39	32
7/91	61	77	84	37		53		130	140	27
9/91	60	61	27	26		48		140	300	120
11/91	35	78	48	33	23	48			300	43
1/92	62	71	39	16	26	57		160	200	
3/92		58	80	9	21	45		63	15	
5/92		63	110	10	23	48		180	38	
7/92		66	33	23	23	52	370	140	160	
9/92		67	42	27	23	59	320	150	280	
11/92		74	16	20	24	51		140	300	
1/93		80	87	18	22	49		170	280	

APPENDIX B-4: ARSENIC AND WATER LEVELS FOR DOH WELL #4



DOH WELL #4

Department of Health
Environmental Health

Office of Toxic Substances Fact Sheet

Revised January 1993

ARSENIC IN DRINKING WATER

WHAT IS ARSENIC?

- Arsenic is a mineral commonly found in the environment. It may be present in small amounts in plants and animals, including humans.

ENVIRONMENTAL SOURCES AND USES

- Although arsenic may be found as the pure element, it is more commonly found combined with other elements as arsenic ores. Ore deposits, mining activities, and industrial and manufacturing processes can be sources of contamination of ground and surface waters. Infiltration of ocean water, which contains arsenic, into fresh water aquifers can also be a source of arsenic in drinking water. The Environmental Protection Agency (EPA) estimates that most ground and surface waters contain less than 5 parts per billion (ppb) of arsenic. Arsenic-containing mineral deposits have been reported to be the cause of well water contamination and human arsenic toxicity in Washington State.

- Because of its highly toxic nature, arsenic was once used in pesticide products to control insects, rodents, weeds, and wood decaying organisms.

- Historically, Fowler's solution and other arsenic containing medicines were used for the treatment of psoriasis, syphilis, and parasitic diseases. Arsenic is also found in some homeopathic and folk remedy preparations.

- Arsenic is used to increase hardening and heat resistance in glassware and ceramics.

ARSENIC AND HEALTH

Several studies have indicated that arsenic is an essential element in some animal species. However, there is no evidence that arsenic is beneficial to humans.

Non-Cancer Health Effects - The immediate health effects expected from consuming drinking water with arsenic levels over 10 parts per million (ppm) are primarily gastrointestinal. Symptoms can also include abdominal pain, forceful vomiting, cramps in the legs, restlessness, and muscle spasms. Prolonged exposure to such drinking water may result in cardiovascular, liver, kidney, and peripheral nerve damage.

At lower levels of water contamination (1-10 ppm) symptoms may include less severe gastrointestinal problems. Short-term health effects are unlikely for people exposed to drinking water containing less than 1 ppm of arsenic.

Persons exposed to arsenic have also been observed to have papery nails with white transverse ridges.

Cancer Health Effects - It has been known for many years that chronic inhalation of arsenic causes lung cancer in smelter and pesticide workers. Also, the use of Fowler's solution for the treatment of psoriasis and other diseases has been shown to be the cause of arsenic induced skin cancer. In 1968, a study in Taiwan implicated skin cancer with the ingestion of drinking water containing high amounts of arsenic. Population studies in Mexico, Chile, and India have also associated skin cancer with the consumption of drinking water containing high amounts of arsenic.

Unlike most skin cancers, arsenic induced skin cancer often occurs on parts of the body not exposed to the sun. The abnormal pigmentation consists of irregular bronze or slate-gray staining of the skin or pale areas where the normal skin color is lost. The minimum arsenic level at which symptoms occur varies among the general population.

Recent published reports (1992), using the Taiwanese data and data from other countries, have shown a strong association between liver, lung, bladder, and kidney cancer and the ingestion of drinking water containing high amounts of arsenic. The lowest drinking water concentration of arsenic in the Taiwanese study was 0.170 ppm.

Arsenic does cross the placenta, and has the potential to cause damage to the exposed fetus. Data is not available for humans, but animals given amounts of arsenic much greater than those in the above drinking water studies caused malformations and fetal death in hamsters.

There is no evidence that dermal exposure from bathing in arsenic-contaminated water is harmful.

REGULATIONS IN DRINKING WATER

The present maximum contaminant level for arsenic in public drinking water supplies is 50 ppb. In light of the most recent studies, EPA is restudying the arsenic issue in drinking water and plans to submit a regulatory proposal in late 1993. Although private wells are not regulated, it is recommended that they be tested if they are located in areas of known naturally occurring high arsenic concentrations. Significant seasonal variations in arsenic levels have been observed in some areas. For this reason, any well water testing positive for arsenic should be retested according to the recommendations of the local or state health department. Known mining sites that contain arsenic are generally in the Cascade corridor and in the northern half of Washington State.

TREATMENT OF WATER

Depending upon the chemical form of arsenic, the following technologies are available for removing arsenic from water.

- **Coagulation/filtration** - This method uses conventional treatment processes to coagulate the arsenic. The treated water is then filtered to remove the precipitate.

- **Lime softening** - Adding lime increases the alkalinity of the water and causes the arsenic to precipitate.

- **Activated alumina ion exchange** - This method removes arsenic from waters by adsorption onto alumina.

- **Reverse osmosis** - This technology utilizes pressure to force water through a membrane filter leaving the arsenic behind.

- **Anion exchange** - Arsenic is adsorbed onto a resin and then eluted with sodium chloride.

As with any treatment process, proper operational and maintenance of the system is essential for effective treatment. In addition, the potentially hazardous waste produced by such a treatment system must be disposed of properly.

FOR MORE INFORMATION

About the health effects associated with arsenic in drinking water or other environmental exposures to arsenic please contact:

- Your Local County Health Agency

- Washington State Department of Health
  Office of Toxic Substances - (206) 586-5403
  Division of Drinking Water - (206) 753-9674
  Northwest Drinking Water Operations - (206) 464-7670
  Southwest Drinking Water Operations - (206) 753-4152
  Eastern Drinking Water Operations - (509) 456-3115

- Additional copies of this fact sheet can be obtained from:

  Washington State Department of Health
  Office of Toxic Substances
  P.O. Box 47825
  Olympia, Washington 98504-7825
  (206) 586-5403

Washington State Department of Health

EXECUTIVE SUMMARY

A series of arsenic poisonings near Granite Falls in Snohomish County was reported to the Washington State Department of Health in early 1987. Initial investigation revealed the source of arsenic exposure to be contaminated well water. A coordinated investigation by the Snohomish Health District, the Washington Department of Health, the Washington Department of Ecology and the U.S. Environmental Protection Agency was begun to evaluate the extent of the contamination, human health effects, and options for control. A large number of wells in eastern Snohomish County were tested, residents were interviewed, and sources of contamination, both natural and man-made, were investigated.

Of particular interest was the issue of seasonality in groundwater arsenic concentration. A study in Oregon found considerable seasonal variation in arsenic. If similar variation occurred near Granite Falls, it was feared that one-time testing of well water would not identify all contaminated wells.

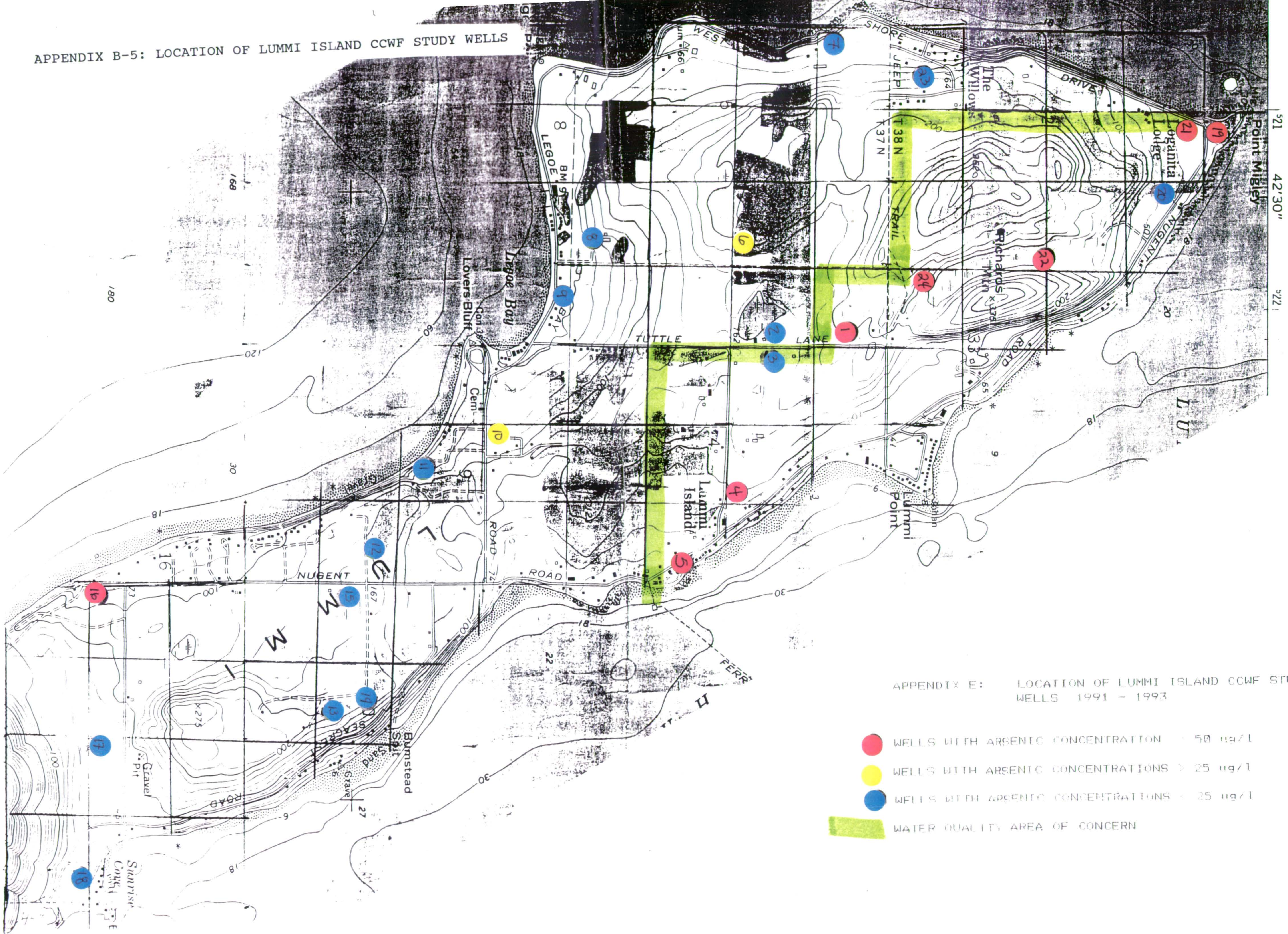
A 12-month study of groundwater was conducted in selected wells. The following recommendations for ground water users in Snohomish County are based on the results of this seasonal study. The recommendations may be revised with further investigations or analysis of data.

1) If an arsenic analysis of well water yields a concentration above the detection limit of 0.01 mg/l, an additional sample should be collected and analyzed to confirm that arsenic is detectable in the water.

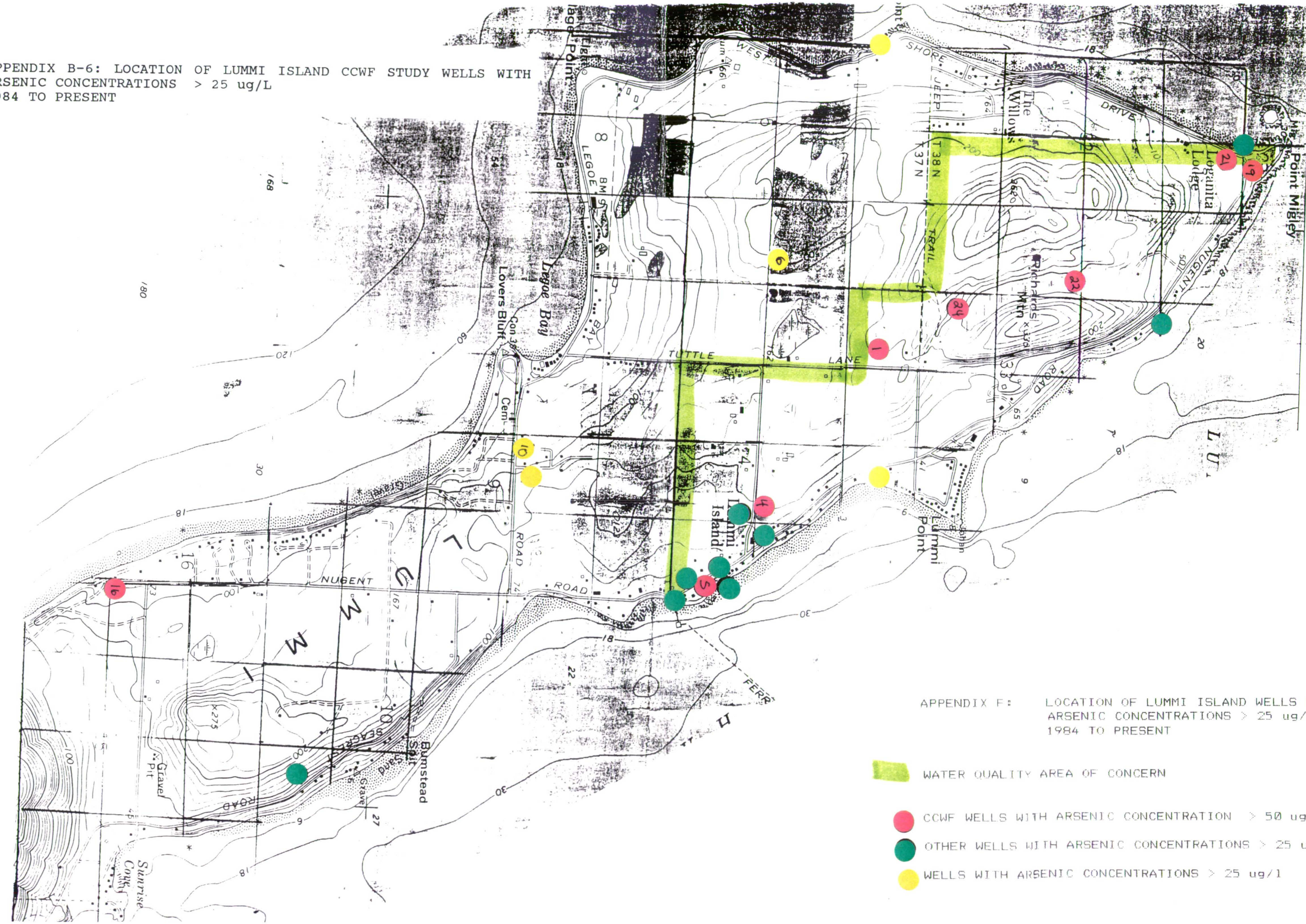
2) If either an initial or repeat analysis is between 0.02 mg/l and 0.05 mg/l, a seasonal set of samples should be analyzed to determine if variability over a year's period could cause arsenic concentrations to exceed the MCL. The seasonal set of samples should include at least four samples spaced across a year, or approximately every three months.

3) If an initial or repeat analysis is greater than 0.05 mg/l, the well water can be considered to exceed the MCL for at least part of the year. Additional samples, preferably on a monthly basis, may be collected to better delineate the variability about the MCL, and determine the time period during which arsenic concentration is likely to be unacceptably high.

APPENDIX B-5: LOCATION OF LUMMI ISLAND CCWF STUDY WELLS



APPENDIX B-6: LOCATION OF LUMMI ISLAND CCWF STUDY WELLS WITH ARSENIC CONCENTRATIONS > 25 ug/L
1984 TO PRESENT



APPENDIX F: LOCATION OF LUMMI ISLAND WELLS WITH ARSENIC CONCENTRATIONS > 25 ug/l
1984 TO PRESENT

WATER QUALITY AREA OF CONCERN

CCWF WELLS WITH ARSENIC CONCENTRATION > 50 ug/l

OTHER WELLS WITH ARSENIC CONCENTRATIONS > 25 ug/l

WELLS WITH ARSENIC CONCENTRATIONS > 25 ug/l

APPENDIX C

WATER WATCHERS: THE LUMMI ISLAND GROUNDWATER STUDY — Sue Blake

This is the first in a series of ten articles covering many aspects of groundwater here on Lummi Island. The articles are funded through a grant from the Department of Ecology, Centennial Clean Water Fund, as part of the Lummi Island Groundwater Study.

In 1989 a concerned group of Lummi Islanders worked with Whatcom County to develop a study and education program about groundwater on the Island. The study grew out of concerns with arsenic and saltwater intrusion, identification of recharge areas, results of previous studies, and recommendations in the Lummi Island Plan. One of the major objectives of the study is to focus on developing a more consistent water quality data base and to educate Island residents about groundwater issues.

Since then, grants have been obtained from the State Department of Ecology to carry out the study and education work. A group of dedicated volunteers has been working since March 1991 to collect information on rainfall, and arsenic and chloride levels, and water levels from carefully selected wells.

In subsequent articles, a summary of the results of the study will be provided (specific well sites will be kept anonymous), along with preliminary information on the possible sources of contamination, health issues, and what individuals can do to keep the water clean. We would also like to dedicate several articles to answering specific questions which Island residents may have about water. Please send your questions to:

Lummi Island Groundwater Study
Whatcom County Health Department
Attention: Sue Blake
PO Box 935
Bellingham, WA 98227

GRANGE NEWS — Lois Peterson for Donna Granger

Donna, our normal correspondent, had knee surgery on May 11, home again May 16th. The regular Grange meeting was May 6 hostessed by June and Tom Doyle.

Plans for the May 23rd Flea Market were finalized. Card-table size space will be $5.00 and large size

WATER WATCHERS: WHAT IS GROUND WATER?

Sue Blake

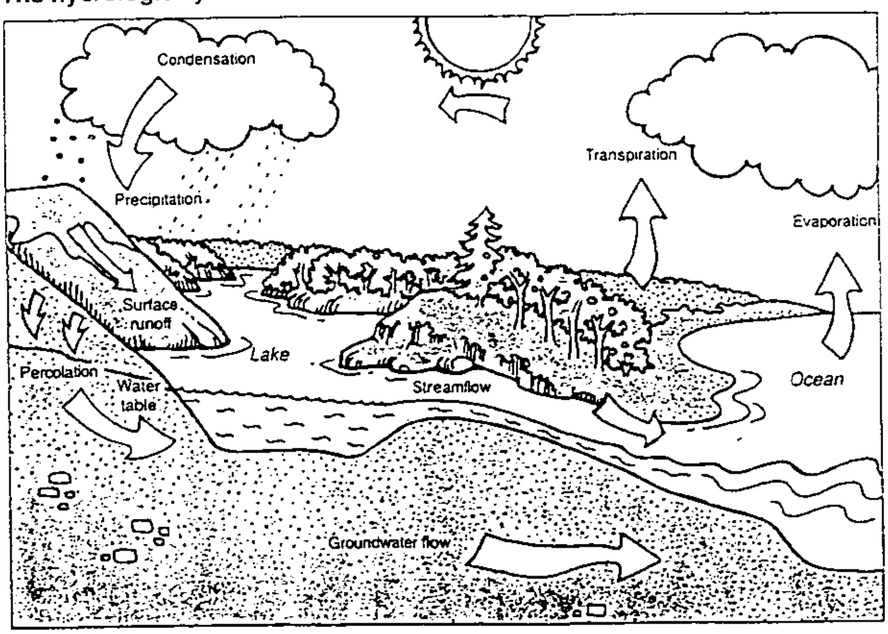
This is the second in a series of ten articles covering many aspects of ground water here on Lummi Island. The articles are funded through a grant from the Department of Ecology, Centennial Clean Water Fund, as part of the Lummi Island Ground Water Study.

Many residents on Lummi Island depend on ground water for their drinking water supply. Unlike surface water such as lakes, streams and rivers, ground water lies unseen, hidden beneath the surface of the earth. Ground water is found where water fills the innumerable tiny spaces between particles of sand and gravel, or cracks in rocks. Many wells on Lummi Island obtain ground water from fractured sandstone. If enough ground water gathers in one area, it can supply wells and springs.

Ground water does not stay underground forever. It moves continuously, but very slowly, through the ground as part of a cycle called the hydrologic cycle. The hydrologic cycle describes a series of changes as water constantly circulates from the air, to the surface and subsurface areas of the earth, back to the surface then the air where the cycle is repeated. On Lummi Island, the cycle includes movement toward the saltwater.

It can sometimes take thousands of years to complete this cycle. Along the way water can be exposed to a wide variety of materials which can alter its quality. Some of these materials can contaminate the ground water. Arsenic and salt are examples of contaminates found in some of the ground water on Lummi Island. Once contaminated, ground water can be very difficult, and sometimes impossible to clean.Subsequent articles will examine more closely the kinds of activities which can contaminate ground water and actions that each of us can take to keep it clean.

The hydrologic cycle



WILDLAND FIRE

Another fire. This time up in Scenic Estates over the hillside. Again, we relied on numerous local people for assistance. Everyone pitched in from shoveling and laying hoselines to getting drinking water and helping with cleanup You know who you are and we thank you for your help and support. This fire was stopped just in time. If it had gotten out of hand, there's no telling how far or how long it would have burned.

Our thanks to the Lummi Islanders who have volunteered their time and energies in helping us with our summer fire-fighting efforts. The public response to five (midweek) fire alarms has been outstanding. Please pay attention to the burning ban notices and adhere to them.

-- Dave Lapof and Janet Evans, LIFD

POSSIBLE HEALTH EFFECTS OF ARSENIC IN LUMMI ISLAND GROUNDWATER

-- Sue Blake

Inorganic arsenic is found in most ground water supplies in the US, typically averaging .001 ppm (parts per million) Arsenic occurs in the earth's crust in concentrations averaging 2 ppm. It is concentrated in shales, clays, coals, iron and manganese ores. Arsenic is also a component of insecticides and herbicides and can be found in foods produced using these chemicals. Arsenic occurs naturally in some foods.

The arsenic levels detected so far in the Lummi Island Groundwater Study wells range from less than .005 ppm to .370 ppm. Up to 25 ppm arsenic has been detected in drinking water in other parts of Washington where there are naturally occurring arsenic deposits. The current maximum contaminant level established by the Environmental Protection Agency (EPA) for arsenic in public drinking water is .05 ppm. This level is presently under review by EPA and may be changed.

The immediate health effects expected from drinking water with arsenic levels OVER 10 ppm are primarily gastrointestinal. Symptoms can include abdominal pain, forceful vomiting, cramps in the legs, restlessness, and spasms. Prolonged exposure to such drinking water may result in peripheral nerve damage, skin problems, and respiratory symptoms.

At lower levels of arsenic from 1-10 ppm symptoms will include less severe gastrointestinal problems and changes in the fingernails and toenails. Prolonged exposure may result in skin problems such as abnormal skin pigmentation, skin thickening, and possible skin cancer. The abnormal pigmentation consists of irregular bronze or slate-gray staining of the skin of pale areas where the normal skin color is lost. These changes occur mainly in areas with little exposure to the sun. The minimum arsenic level at which symptoms occur varies among the general population.

Short-term health effects are unlikely for people exposed to drinking water containing less than 1 ppm. The primary concern is skin cancer from long-term exposure. There is NO evidence that bathing in arsenic contaminated water is harmful.

In 1984, a State Department of Health Epidemiologist, Len Paulozzi stated in a report that on Lummi Island it is probably true that there is a small risk of skin pigmentation changes, a smaller risk of skin thickenings, and an even smaller risk of skin cancer. At the absolute worst, the risk of skin cancer is about 1 in 7 after consuming two liters of water contaminated with 0.3 ppm of inorganic arsenic every day for 70 years.

The Whatcom County Health Department does not know of any cluster of arsenic-related symptoms in the Lummi Island population at this time. However, a thorough epidemiological study has not been conducted on the Island.

LUMMI ISLAND COMMUNITY CLUB BOARD OF DIRECTORS - 1992

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This Newsletter is the publication of the Lummi Island Community Club and is published deci-annually. All subscriptions are on a calendar year basis, January to December. Subscription fee is $4.00 for Lummi Island addresses and $6.00 for off-Island addresses. Canadian addresses are $10.00 U.S. funds. LICC membership is limited to residents and property owners of Lummi Island and is $1.00 per family household (18 years and older). Write to LICC, P.O. Box 163, Lummi Island WA 98262, or call Paul Davis, Treasurer and Editor at (206) 758-2414 for information about subscriptions, dues, or advertising.

LICC
P.O. Box 163

BULK RATE POSTAGE PAID
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WATER WATCHERS: HOW GROUND WATER CAN BECOME CONTAMINATED -- Sue Blake

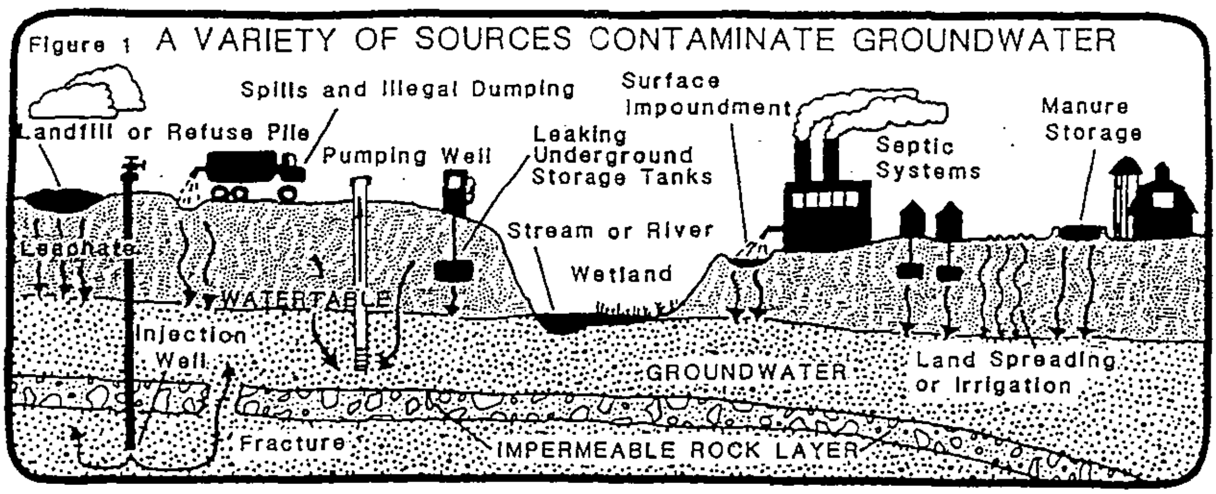
This is the fourth in a series of nine articles covering many aspects of ground water here on Lummi Island. The articles are funded through a grant from the Department of Ecology, Centennial Clean Water Fund, as part of the Lummi Island Ground Water Study.

Pure water is tasteless and odorless. A molecule of water contains only hydrogen and oxygen atoms. Water is never found in a pure state in nature. As it moves through the hydrologic cycle it may pick up many things, including microorganisms, gases, inorganic and organic materials. Although some of these materials are found in water naturally, some are the result of our actions.

Any addition of unwanted materials to ground water caused by human activities is considered to be contamination. It is often assumed that contaminants left on or under the ground will stay there. This has been shown to be wishful thinking. Ground water often spreads the effects of dumps and spills far beyond the site of the original contamination as it moves slowly through its cycle. Because contaminants can move at different rates through the ground, it may be days, months, or years before a contaminant is detected in a well.

Ground water contaminants come from two categories of sources: *POINT* sources and distributed, or *NON-POINT* sources. Solid waste handling sites, underground gasoline storage tanks, septic tanks, and accidental spills are examples of point sources. Infiltration from farm land or home lawns treated with pesticides and fertilizers are examples of non-point sources. All of these potential sources can be found on Lummi Island. Because of their widespread use, septic tanks can pose a particular threat if not properly installed and maintained. A future article will be devoted exclusively to septic tanks.

If enough contaminants are present, ground water can become unsuitable for use or may require expensive treatment before it can be used. It is almost always much cheaper and safer for public health, to prevent water from becoming contaminated than to rely on treatment to remove the contaminants. Some contaminants are impossible to remove. Other consequences of having a contaminated water supply familiar to some residents of Lummi Island include problems getting a building permit or bank loan. Future articles will focus on simple actions that each of us can take to prevent ground water from becoming contaminated.



WATER WATCHERS: ON-SITE SEPTIC SYSTEMS

- - Sue Blake

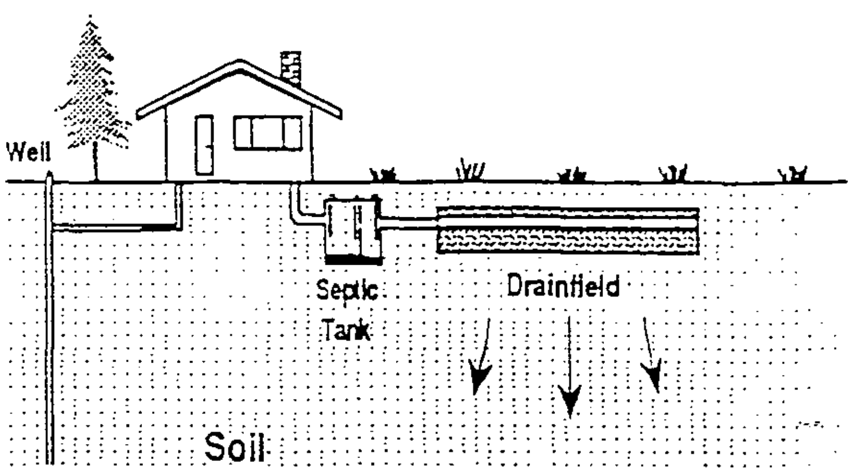
This is the fifth in a series of nine articles covering many aspects of ground water here on Lummi Island. The articles are funded through a grant from the Department of Ecology, Centennial Clean Water Fund, as part of the Lummi Island Ground Water Study.

Household waste water from toilets, baths, laundry and kitchens can be disposed of in two basic ways: through sewer systems which transport the waste to a larger regional treatment system, or through on-site septic systems. All homes and residences on Lummi Island use on-site systems to dispose of their household waste water. Homeowners must use special care to make sure that their systems are properly designed and maintained to prevent ground water in the area from becoming contaminated. This is particularly important since many residents on the Island depend on ground water for drinking.

Most septic systems are made of a septic tank and drainfield; they work together to treat the more than 100,000 gallons of household waste water that flows through them each year. The septic tank collects the solid portion while the drainfield provides additional treatment and acts to disburse the water ("leachate"). If septic tanks are not properly maintained, solids may pass into the drainfield causing odors, plugging, backup into the home, or a breakout of waste water onto the surface of the land. Once this happens, correcting the problem can be expensive and can cause ground water contamination.

Even properly designed and maintained systems can contaminate ground water if care is not taken. Most systems are not designed to remove the wide variety of contaminants which they receive. We use many things on a daily or periodic basis that are washed down drains and may eventually contaminate ground water supplies. These include harsh detergents and cleansers, grease, oil, paint thinners, and antifreeze, which many homeowners put in toilets to prevent freezing. Typical leachate from systems can contain bacteria, viruses, organic contaminants, metals and nutrients such as nitrogen (about 40-60 mg/l).

Despite the potential from septic systems to contaminate ground water supplies, there are some simple things home owners can do to minimize the possible impacts. Practice water conservation to prevent system overload. Avoid using chemicals and materials that won't break down. Don't use septic tank additives. Know when to maintain your system; a general rule of thumb is every three years but your local Health Department (676-6724) can provide you with more specific information.



(206) 758-2651

2825 West Shore Drive,

WATER WATCHERS: SEAWATER INTRUSION - Is it happening on Lummi Island? - - Sue Blake

This is the sixth in a series of nine articles covering many aspects of ground water here on Lummi Island. The articles are funded through a grant from the Secretary of Ecology, Centennial Clean Water Fund, as part of the Lummi Island Ground Water Study.

Seawater intrusion is the movement of seawater into fresh water aquifers. Ground water on Lummi Island discharges underground toward the sea. There is a zone where seawater and fresh water mix. If this zone of mixing moves landward, the ground water in wells near the coast may show small increases of sodium chloride (salt). A chloride level of 100 milligrams per liter indicates seawater intrusion. Most people notice a salty taste in the water when chloride exceeds 250 mg/l.

So far in the Lummi Island Ground Water Study wells, the chloride levels range from 6 mg/l to 250 mg/l. Two of the 21 wells sampled during the current study had chloride results exceeding 100 mg/l. Both affected wells are located near the coast.

The causes of seawater intrusion. Decreases in ground water levels may cause saltwater intrusion. Reduced precipitation or less ground water recharge due to urban development can lower the groundwater level over time. Lower ground water levels can cause the mixing zone to move landward. Rising sea level due to global climate patterns can also cause saltwater intrusion because this also moves the mixing zone landward.

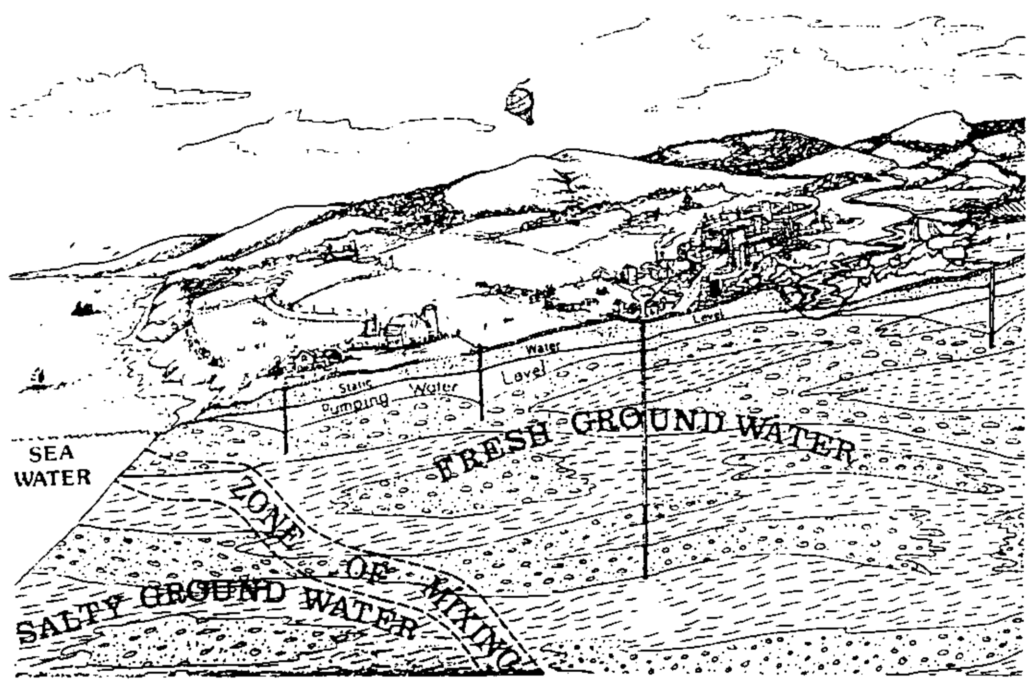
Pumping a well can cause a local decline in the ground water level in the immediate vicinity of the pumped well and may cause local seawater intrusion or affect the quality of the water at nearby well sites.

Problems with saltwater intrusion. Seawater intrusion can cause aesthetic, health, agricultural, and environmental problems for users of ground water. Salty tasting water is unpalatable to most people and can become a health problem for individuals with a history of heart disease or those put on a sodium restricted diet by their doctors. Salty water is detrimental to most plants and can have detrimental effects on wetlands and estuaries of coastal environments.

NEXT MONTH'S ARTICLE: The next article will discuss ways to reduce the risk of saltwater intrusion in Lummi Island.

Seawater Intrusion and the Hydrologic System

The diagram below illustrates the connection between multiple water wells, the hydrologic system, and seawater intrusion. All components of the hydrologic system: the sea, surface water, ground water, precipitation, recharge, and discharge are integrally connected. When a change occurs in one part of the hydrologic system (as through pumping from wells or a long term drought) it affects the others. Seemingly easy solutions to seawater intrusion such as completing wells above sea level or locating wells further from shore will not necessarily be of value. The well in question may not be directly affected by intrusion but it may be contributing to intrusion of the aquifer.



WATER WATCHERS: SEAWATER INTRUSION - Is it happening on Lummi Island? - - Sue Blake

This is the seventh in a series of nine articles covering many aspects of ground water here on Lummi Island. The articles are funded through a grant from the Secretary of Ecology, Centennial Clean Water Fund, as part of the Lummi Island Ground Water Study.

Reducing the Risk of Saltwater Intrusion. In last month's article we described the possible causes of saltwater intrusion on Lummi Island which stem from a lowering of the ground water level. Lower ground water levels cause the seawater/fresh water mixing zone to move landward and create the potential for seawater intrusion. Activities which can cause a lowering of the groundwater level include a reduction in the amount of fresh water recharge and pumping and withdraw rates which exceed the rate of recharge.

For example, development projects which include impervious surfaces, such as paved driveways and roads, prevent rainwater from draining directly through the soil into the groundwater. Water generated from impervious surfaces is usually collected in a drainage "ditch" and may discharge directly into the sea without having a chance to be fully absorbed on the land. Drainage swales are an alternative which allow water to slowly drain into the soil, usually near the area where the water was collected. This issue of drainage and recharge is currently under consideration by the County Council in their review of proposed Development Standards.

Pumping a well or wells can also cause a local decline in the ground water level in the immediate vicinity of the wells. Careful monitoring and management of the withdraw rate and use of devices such as flow restrictors, timers, and storage systems could help prevent seawater intrusion.

Reducing the demand for water through conservation practices could also help protect the resource. The State Departments of Health and Ecology, along with the Washington Water Utilities Council, have developed Interim Guidelines for Public Water Systems Regarding Water Use Reporting, Demand Forecasting Methodology, and Conservation Programs. A water conservation plan is required of a new or expanding public water system in Whatcom County either as an element of a State Department of Health mandated water system plan or possibly as a condition of a water right permit granted by the State Department of Ecology. Conservation measures include things like leak detection, meter-based rate setting to encourage conservation, low flow fixture plumbing codes and retrofit kits, and low water use landscaping.

THANK YOU FROM RUTH WALTERS

Leon and I felt so blessed to have been able to spend our last years together on this beautiful island

GLENN SCHULER - - ed

We have just received word of the death of long-time Island resident Glenn H. Schuler who has been living in Alaska with his wife Wanda since July 1991. We will have a complete notice about Glenn and his life in next month's *NEWSLETTER.*

WATER WATCHERS: KEEPING GROUND WATER CLEAN - - Sue Blake

This is the eighth in a series of nine articles covering many topics of ground water here on Lummi Island. The articles are funded through a grant from the Department of Ecology, Centennial Clean Water Fund, as part of the Lummi Island Ground Water Study.

As with any limited resource, ground water must be carefully managed to protect its quality for present and future uses. Some of the tips that each of us can follow at home to help ensure clean water are listed below.

Household/Yard Hazardous Waste

☆ Read product labels, buy the least toxic products, and use them sparingly.
☆ Dispose of unwanted toxic products at the Household Hazardous Waste Facility operated year-round by the City of Bellingham. Call 676-6850 for information.
☆ Try alternatives like borax for bleach, baking soda for cleaners, and vinegar and water for windows.

Solid Waste - "Garbage"

☆ Recycling can reduce your household waste by 60%. Newspapers, glass, cans, oil, and paper are only a few of the materials that can be recycled; for more information call the recycling hotline at 676-5723.
☆ Compost yard clippings and table scraps for adding to your garden.
☆ Dispose of the rest of your waste properly - make sure it is taken to a permitted solid waste facility. Do not bury it on your property.

Septic Systems

☆ Check your tank at least every three years, have it pumped as needed (usually every 3 to 5years).
☆ Avoid chemicals and materials that won't break down. Septic system additives are not recommended.
☆ Keep vehicles, roads and heavy equipment away from the drainfield, as well as runoff from roofs, driveways and patios.

Only by working together and taking responsibility for our own actions, can we ensure clean water for ourselves and future generations. If you would like additional information on what you can do to keep water clean, contact your local or State Health Departments or the Department of Ecology.

Island Properties

So much for theories!

Several months ago I wrote an article to reassure you that your property taxes wouldn't go up proportionately with your change in assessed value. Well, guess what — they very nearly did! So, I called our Whatcom County Assessor and said, "What happened?", and he explained it to me.

As you will note from the following table, rates declined for each taxing district except Fire District and Other. The increase in the Fire District was due to the ballot issue we passed in the last election. The increase in Other was due partially to a ballot issue we passed for the emergency services portion of the Fire District and partially to a new tax passed by the county council called a Conservation Futures levy. In addition, of course, there was the new Flood Control assessment which is a minimum of $5.00 per property (the highest I have seen is $90.00). These were the new taxes.

The other major factor that prevented a decline in tax rates was an increase in the amount of the new Ferndale School District bond and levy over the prior one.

While a 6% ceiling on increases in taxes collected applies to most taxing districts' budgets, there are some like schools and fire districts that we can increase more than that if we vote to do so, and we did.

One other factor to remember is that when property taxes are lowered for one owner due to an exemption for open space, senior status, religious use, government acquisition, etc., they go up for everyone else. The taxes due on exempt properties do not vanish — they are added to those not exempt.

So the bottom line is that if we want the services, we have to pay the bills.

Property Taxes by Taxing District

	1992	1993
State School	4.73	4.302
Local School	4.01	3.884
County	1.70	1.609
Road	2.20	2.172
Port	.50	.471
Fire District	.66	1.13
Library	.48	.478
Cemetery	.06	.038
Other	.109	.263
Flood Control		$5 and up
Total	14.40722	14.35051

Talk to you next month-

Rich & Lylene Johnson

Rich & Lylene Johnson

"Your lifestyle specialists."

If you have questions regarding any Whatcom County property, call us at 758-7290 or 647-6477

APPENDIX D

APPENDIX E

WELL ID LOCATION	DEPTH	WELL LOG	BEDROCK	DATE SAMPLED	CHLORIDE	ARSENIC	
	ft.				mg/l	ug/l	
37/1-4 1	116.00	YES	NO	4/17/89	18.00	3.00	
37/1-4 2	290.00	YES	YES	3/24/89	44.00	19.00	
37/1-4A1	150.00	YES	YES	8/13/91	39.00	21.00	
37/1-4B1	78.00	YES	YES	10/9/90	13.50	32.00	
37/1-4D1*	122.00	YES	YES	3/7/89	16.00	76.00	
				7/11/89	15.00	61.00	
				9/14/92	14.00	60.00	
				11/11/92	14.00	35.00	
				1/19/93	14.00	62.00	
37/1-4E1*	69.00	YES	NO	1/29/92	12.23	23.00	
				9/14/92	13.00	12.00	
				11/9/92	14.00	16.00	
				1/18/93	15.00	14.00	
37/1-4P1				1/31/89	20.00	17.00	
37/1-4F1*	77.00	YES	NO	3/6/91	20.00	5.00	u
				5/6/91	19.00	5.00	u
				7/8/91	17.00	5.00	u
				9/9/91	18.00	5.00	u
				11/3/91	17.00	1.00	u
				1/6/92	18.00	5.00	u
				3/12/92	20.00	5.00	u
				5/4/92	19.00	5.00	u
37/1-4G1		YES	YES	10/9/90	16.10	20.00	
37/1-4G2*	227.00	YES	YES	3/6/91	7.00	59.00	
				5/6/91	13.00	64.00	
				7/8/91	20.00	77.00	
				9/9/91	16.00	61.00	
				11/3/91	14.00	78.00	
				1/6/92	15.00	71.00	
				3/12/92	13.00	58.00	
				5/5/92	14.00	63.00	
				7/5/92	22.00	66.00	
				9/14/92		67.00	
				11/9/92		74.00	
				1/18/93		80.00	
37/1-4H1		NO		8/10/84		99.00	
37/1-4J1	75.00	YES		4/25/88	24.00		
37/1-4J2		NO		2/23/84	15.00	u	
				8/10/84		130.00	

WELL ID LOCATION	DEPTH	WELL LOG	BEDROCK	DATE SAMPLED	CHLORIDE	ARSENIC	
	ft.				mg/l	ug/l	
				9/6/88	45.00	177.00	
				11/7/88	20.00	76.00	
				3/7/89	20.00	79.00	
				7/11/89	20.00	103.00	
				12/7/89	21.00	71.00	
37/1-4J3	58.00	YES	YES	4/25/88	270.00		
				7/5/88	510.00	28.00	
				9/6/88	880.00		
				11/7/88	2200.00		
				3/8/89	187.00	74.00	
				7/11/89	387.00	54.00	
				9/7/89	1250.00	42.00	
				12/7/89	304.00	281.00	
				10/9/90	1160.00	16.00	
37/1-4J4*	94.00	YES	YES	9/7/89	964.00	54.00	
				12/7/89	256.00	17.00	
				3/6/91	120.00	105.00	
				5/6/91	90.00	66.00	
				7/8/91	210.00	84.00	
				9/9/91	250.00	27.00	
				11/3/91	220.00	48.00	
				1/6/92	180.00	39.00	
				3/11/92	87.00	80.00	
				5/5/92	95.00	110.00	
				7/5/92	200.00	33.00	
				9/14/92	340.00	42.00	
				11/9/92	470.00	16.00	
				1/18/93	240.00	87.00	
37/1-4K1		NO		8/10/84		182.00	
				7/5/88	850.00	114.00	
				9/6/88	320.00		
				3/7/89	144.00	139.00	
37/1-4K2	45.00	NO		3/23/88	12.00	40.00	
				4/25/88	12.00	48.00	
				11/7/88	11.00	50.00	u
	150.00	YES	YES	12/7/89	12.00	80.00	
37/1-4J5	114.00	YES	YES	2/28/84		306.00	
				8/10/84		338.00	
				4/25/88	120.00	319.00	
				7/5/88	100.00	266.00	
				9/6/88	110.00		
				11/7/88	110.00	476.00	
				3/7/89	90.00	441.00	
				7/11/89	100.00	384.00	
				12/7/89	109.00	322.00	
				7/22/92		289.00	

WELL ID LOCATION	DEPTH	WELL LOG	BEDROCK	DATE SAMPLED	CHLORIDE	ARSENIC	
	ft.				mg/l	ug/l	
37/1-4K4		NO		7/11/89	62.00	3.00	
37/1-4K5		NO		4/15/84		33.00	
				7/5/88	9.00	28.00	
				7/11/89	8.00	40.00	
				9/7/89	8.00		
37/1-4K6	60.00	NO		10/9/90	28.30	17.00	
37/1-4N1	153.00	YES	YES	9/7/89	18.00	1.00	u
37/1-4Q1	105.00	YES	YES	2/23/84		30.00	
37/1-4R1	134.00	YES	YES	1/1/92	17.90	32.00	
37/1-5 1	163.00	YES	YES	9/19/91	74.00	50.00	
37/1-5 2	85.00	YES	YES	2/25/91	32.00	100.00	u
37/1-5 3	181.00	YES	NO	2/25/91	22.00	10.00	u
37/1-5A1*				5/8/91	19.00	14.00	
				7/11/91	24.00	37.00	
				9/12/91	22.00	26.00	
				11/3/91	25.00	33.00	
				1/6/92	20.00	16.00	
				3/14/92	19.00	9.00	
				5/4/92	19.00	10.00	
				7/6/92	22.00	23.00	
				9/14/92		27.00	
				11/9/92		20.00	
				1/18/93		18.00	
37/1-5C1*	158.00	YES	YES	3/6/91	40.00	20.00	
				5/6/91	47.00	20.00	
				7/8/91	40.00	20.00	
				9/9/91	46.00	20.00	
				11/3/91	45.00	22.00	
				1/6/92	45.00	23.00	
				3/3/92	45.00	16.00	
				5/4/92	57.00	19.00	
				7/6/92	42.00	22.00	
				9/15/92	42.00	11.00	
				11/10/92	45.00	17.00	
				1/18/93	46.00	11.00	
37/1-5D1	65.00	YES	YES	3/23/88	33.00		
				4/25/88	30.00		
37/1-5D2		NO		4/25/88	37.00		
				9/6/88	36.00		

WELL ID LOCATION	DEPTH	WELL LOG	BEDROCK	DATE SAMPLED	CHLORIDE	ARSENIC	
	ft.				mg/l	ug/l	
				11/7/88	35.00		
37/1-5L1	258.00	YES	YES	2/23/84			u
				3/23/88	20.00		
37/1-5L2	350.00	NO		3/23/88	21.00		
37/1-5P1	353.00	YES	YES	2/23/84			u
37/1-5R1*				3/6/91	22.00	8.00	
				5/6/91	20.00	10.00	
				7/8/91	20.00	15.00	
				9/9/91	20.00	11.00	
				11/3/91	20.00	10.00	u
				1/6/92	22.00	11.00	
				3/11/92	21.00	11.00	
				5/7/92	21.00	9.00	
				9/12/92		5.00	
				11/8/92		9.00	
				1/17/93		9.00	
37/1-8 1	99.00	YES	NO	2/20/90	253.00	1.00	
37/1-8A1*				3/6/91	12.00	5.00	u
				5/6/91	13.00	5.00	u
				7/8/91	13.00	6.00	
				9/9/91	14.00	6.00	
				11/3/91	14.00	10.00	u
				1/6/92	14.00	6.00	
				3/11/92	13.00	5.00	u
37/1-8C1				7/5/88	2300.00	1.00	u
37/1-8C2	99.00	YES	NO	2/20/90			
37/1-8C3				3/7/89	40.00		
37/1-9A1	76.00	YES	NO	12/4/83			u
				3/23/88	13.00	12.00	
				7/5/88	18.00	20.00	
37/1-9B1		NO		3/23/88	16.00	25.00	
37/1-9C6*				11/3/91	16.00	23.00	
				1/6/92	18.00	26.00	
				3/13/92	18.00	21.00	
				5/1/92	18.00	23.00	
				7/5/92	17.00	23.00	
				9/16/92		23.00	
				11/15/92		24.00	
				1/17/93		22.00	

WELL ID LOCATION	DEPTH	WELL LOG	BEDROCK	DATE SAMPLED	CHLORIDE	ARSENIC	
	ft.				mg/l	ug/l	
37/1-9D1		NO		3/23/88	16.00	15.00	
				9/07/89	16.00		
37/1-9G1	224.00	YES	YES	2/23/84			u
37/1-9G2	62.00	YES	NO	2/23/84			u
37/1-9G3*	94.00	NO		3/6/91	12.00	5.00	u
				5/6/91	10.00	5.00	u
				7/8/91	9.00	5.00	u
				9/9/91	10.00	5.00	u
				11/3/91	10.00	10.00	u
				1/6/92	10.00	5.00	u
				3/13/92	10.00	5.00	u
				5/1/92	11.00	5.00	u
37/1-9J1*				3/6/91	40.00	5.00	u
				5/6/91	47.00	5.00	u
				7/8/91	47.00	5.00	u
				9/10/91	47.00	5.00	u
				11/3/91	47.00	10.00	u
				1/6/92	40.00	5.00	u
				3/11/92	40.00	5.00	u
				5/7/92	41.00	5.00	u
				7/8/92	40.00	5.00	u
				9/12/92	36.00		
				11/8/92	39.00		
37/1-9R1	123.00	YES	NO	8/15/85		32.00	
				11/7/88	14.00	50.00	u
37/1-10D1	220.00	YES	NO	6/16/84			u
37/1-10D2	166.00	YES	YES	3/23/88	13.00	2.00	
	225.00	YES	YES	3/23/88	17.00	47.00	
				11/7/88	18.00	50.00	u
				3/7/89	16.00	82.00	
				7/11/89	17.00	42.00	
37/1-10E1	8.00	NO	NO	3/23/88	22.00	3.00	
37/1-10E2		NO		3/23/88	12.00	3.00	
37/1-10L1*				3/6/91	7.00	5.00	u
				5/6/91	6.00	5.00	u
37/1-10L2*				5/8/91	6.00	5.00	u
				9/10/91	8.00	6.00	
				11/3/91	6.00	10.00	u
				1/6/92	6.00	6.00	
				3/3/92	7.00	5.00	u
				5/4/92	7.00	5.00	u

WELL ID LOCATION	DEPTH	WELL LOG	BEDROCK	DATE SAMPLED	CHLORIDE	ARSENIC	
	ft.				mg/l	ug/l	
				9/16/92		5.00	u
				11/11/92		5.00	u
				1/19/93		5.00	u
37/1-10M1*				7/8/92	13.00	5.00	u
				9/12/92	15.00	5.00	u
				11/8/92	14.00	5.00	u
				1/17/93	15.00	5.00	u
37/1-15E1*	207.00	YES	NO	3/6/91	17.00	44.00	
				5/6/91	16.00	47.00	
				7/8/91	16.00	53.00	
				9/9/91	16.00	48.00	
				11/3/91	15.00	48.00	
				1/3/92	8.00	57.00	
				3/11/92	16.00	45.00	
				5/7/92	17.00	48.00	
				7/8/92	15.00	52.00	
				9/12/92		59.00	
				11/8/92		51.00	
				1/17/93		49.00	
37/1-15G1*	86.00	YES	NO	3/6/91	10.00	5.00	u
				5/6/91	10.00	5.00	u
				7/8/91	9.00	5.00	u
				9/9/91	10.00	5.00	u
				11/3/91	9.00	10.00	u
				1/6/92	19.00	5.00	u
				3/11/92	9.00	5.00	u
				5/7/92	9.00	5.00	u
37/1-15H1	89.00	NO		3/23/88	8.00	6.00	
37/1-15H2*	45.00	YES	NO	3/6/91	10.00	5.00	u
				5/6/91	9.00	5.00	u
				7/8/91	8.00	5.00	u
				9/10/91	10.00	5.00	u
				11/3/91	9.00	10.00	u
				1/6/92	9.00	5.00	u
				3/11/92	9.00	5.00	u
				5/7/92	11.00	5.00	u
				7/8/92	8.00	5.00	u
37/1-16H1				9/6/88	15.00		
37/1-23		NO		2/23/84			u
38/1-29Q1	103.00	YES	YES	8/27/84		47.00	
				9/07/89	49.00	85.00	
38/1-29Q2*				7/11/89	113.00	270.00	
				7/6/92	130.00	370.00	

WELL ID LOCATION	DEPTH	WELL LOG	BEDROCK	DATE SAMPLED	CHLORIDE	ARSENIC	
	ft.				mg/l	ug/l	
				9/15/92	320.00	440.00	
38/1-32 1	101.00	YES	YES	5/30/84			u
38/1-32 2	215.00	YES	YES	11/21/77		10.00	u
				8/10/84			u
38/1-32A1*	101.00	YES	YES	3/6/91	65.00	5.00	u
				5/6/91	61.00	5.00	u
				7/8/91	29.00	5.00	u
				9/9/91	24.00	5.00	u
				1/6/92	50.00	5.00	u
				3/3/92	70.00	5.00	u
				5/4/92	52.00	5.00	u
				9/15/92	27.00		
				11/9/92	23.00		
				1/19/93	29.00		
38/1-32B1*		NO		2/23/84		167.00	
				5/31/84		200.00	
				8/10/84		202.00	
				4/25/88	19.00	172.00	
				7/5/88	18.00	112.00	
				9/6/88	19.00	123.00	
				11/7/88	18.00	141.00	
				3/7/89	16.00	111.00	
				7/11/89	19.00	185.00	
				9/7/89	17.00	160.00	
				12/7/89	17.00	165.00	
				3/6/91	20.00	140.00	
				5/6/91	18.00	140.00	
				7/08/91	19.00	130.00	
				9/9/91	18.00	140.00	
				1/6/92	17.00	160.00	
				3/3/92	17.00	63.00	
				5/4/92	6.00	180.00	
				7/6/92	18.00	140.00	
				9/15/92		150.00	
				11/9/92		140.00	
				1/18/93		170.00	
38/1-32B2	130.00	YES	NO	10/1/91	9.75	46.00	
38/1-32B3	109.00	YES	NO	4/14/84			u
				9/24/91	14.90	11.00	
38/1-32F1		NO		4/25/88	20.00		
38/1-32H1	162.00	YES	YES	8/10/84		133.00	
				9/6/88	18.00	168.00	
				11/7/88	17.00	90.00	
				7/11/89	18.00	116.00	

WELL ID LOCATION	DEPTH	WELL LOG	BEDROCK	DATE SAMPLED	CHLORIDE	ARSENIC	
	ft.				mg/l	ug/l	
				9/7/89	17.00	187.00	
38/1-32H2	110.00	YES	YES	4/6/83	310.00	145.00	
				7/12/83		200.00	
				8/23/83		175.00	
38/1-32J1*	100.00	YES	YES	8/20/84		119.00	
	108.00			3/23/88	17.00	267.00	
				4/25/88	18.00	257.00	
				7/5/88	16.00	67.00	
				9/6/88	17.00	268.00	
				11/7/88	14.00	162.00	
				3/7/89	25.00	52.00	
				7/11/89	18.00	165.00	
				9/7/89	17.00	324.00	
				12/7/89	19.00	19.00	
				3/06/91	27.00	15.00	
				5/06/91	19.00	39.00	
				7/08/91	16.00	140.00	
				9/9/91	16.00	300.00	
				11/3/91	15.00	300.00	
				1/6/92	16.00	200.00	
				3/12/92	27.00	15.00	
				5/04/92	21.00	38.00	
				7/6/92	15.00	160.00	
				9/14/92	20.00	280.00	
				11/9/92	16.00	300.00	
				1/18/93	17.00	280.00	
38/1-32P1*	73.00			2/25/84			u
				3/23/88	19.00		
				9/07/89	35.00	1.00	u
				3/6/91	20.00	5.00	u
				5/6/91	21.00	5.00	u
				7/8/91	14.00	5.00	u
				9/9/91	22.00	5.00	u
				11/3/91	24.00	10.00	u
				1/6/92	26.00	5.00	u
				3/14/92	27.00	5.00	u
				5/4/92	25.00	14.00	
				9/14/92	26.00	5.00	u
				11/9/92	23.00	5.00	u
				1/18/93	22.00	5.00	u
38/1-33N1	22.00	NO	NO	4/25/88	25.00		
38/1-33N2	125.00	NO		4/25/88	25.00		
38/1-33N3	176.00	YES	YES	4/25/88	25.00		
38/1-33N4				8/10/84			u
				4/25/88	21.00		

WELL ID LOCATION	DEPTH	WELL LOG	BEDROCK	DATE SAMPLED	CHLORIDE	ARSENIC	
	ft.				mg/l	ug/l	
				9/6/88	13.00		
				11/7/88	16.00	50.00	u
				3/7/89	18.00		
38/1-33N5*				3/6/91	22.00	24.00	
				5/6/91	26.00	32.00	
				7/8/91	18.00	27.00	
				9/9/91	21.00	120.00	
				11/3/91	15.00	43.00	
38/1-33Q	40.00	YES	NO	8/10/84			u
				3/23/88	13.00		
38/1-33Q2	81.00	YES	NO	3/23/88	7.00		
38/1-33Q3		NO		1/16/84	21.00	21.00	
38/1-33Q4		NO					u
38/1-33Q5	70.00	YES	YES				u
38/1-33Q6		NO					u
38/1-33Q7		NO					u
38/1-33Q8		NO					u
38/1-33Q9		NO					u
38/1-33Q10		NO					u
38/1-33Q11		NO					u
38/1-33Q12		NO		3/23/88	10.00		u

u= <DETECTION LIMIT

J= ESTIMATED VALUE

B= VALUE IS LESS THAN 10 TIMES AMOUNT SEEN IN PROCEDURAL BLANK

* INDICATE GRANT WELL

APPENDIX F

WELL NUMBER, NAME						
37/1-4DI						
Date	Time	Level	Qualifiers	Conduct	Arsenic	Chloride
		Feet		umh/cm	ug/l	mg/l
8/2/92	16:15	37.39				
1/19/93	17:10	42.28	R			
37/1-4E						
Date	Time	Level	Qualifiers	Conduct	Arsenic	Chloride
		Feet		umh/cm	ug/l	mg/l
7/6/92	9:10		P			
	9:37	25.52	R			
8/3/92	10:45	25.86				
9/14/92	10:37	27.35		340		
10/8/92	15:50	26.22				
11/9/92	10:16	26.71	R	320		
12/7/92	13:54	25.74				
1/18/93	10:37	26.02		290		
37/1-4F1						
Date	Time	Level	Qualifiers	Conduct	Arsenic	Chloride
		Feet		umh/cm	ug/l	mg/l
3/6/91	12:40			350	5.u	20
3/11/91	14:33	45.91				
4/11/91	16:51	46.68				
5/6/91	15:44	46.15		350	5.u	19
6/3/91	12:22	46.34				
7/8/91	12:43	46.68		350	5.u	17
8/5/91	11:37	46.55				
9/9/91	10:12	46.65		350	5.u	18
10/7/91	10:37	46.76				
11/3/91	14:01	46.73		330	10.u	17
12/2/91	10:42	46.87				
1/6/92	11:15	46.65		350	5.u	18
2/3/92	11:35	46.94				
3/14/92	11:27	45.45		350		
4/6/92	15:45	46.78				
5/4/92	10:52	46.43		350		
6/9/92	10:43	46.43				
7/6/92	10:40	46.83				
8/3/92	9:40	46.95				
9/14/92	9:28	46.73				
10/8/92	14:52	46.82				
11/9/92	9:08	47.08				
12/7/92	14:37	46.53				

1/18/93	11:32	46.84				
37/1-4F2						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/11/91	14:15	44.46				
4/11/91	16:27	45.38	R			
6/6/91	16:22	44.72				
6/3/91	12:05	44.82				
37/1-4G2						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/6/91	12:58			400	59	7
	13:34			430		
3/11/91	14:51	11.51	U			
4/11/91	17:17	11.90	RR			
5/6/91	11:20	12.70	R	370	64	13
6/3/91	10:28	14.91	R			
7/8/91	15:56	43.35	RR	430	77	20
8/5/91	10:19	32.08	R			
9/9/91	10:31	19.45	R	440	61	16
10/7/91	16:38	38.67				
11/3/91	14:58	31.90	RR	420	78	14
12/2/91	11:55	11.91				
1/6/92	10:08	24.00	RR	430	71	15
2/2/92	14:55	14.83				
3/14/92	10:27	9.63		420		
4/6/92	14:39	10.30				
5/5/92	11:22	29.30		420		
6/8/92	10:38	19.90	R			
7/5/92	14:46	38.88	U	430		
8/3/92	16:32	40+	UU			
9/14/92	14:42	42.00	U	420		
10/13/92	11:20	22.50	R			
11/9/92	14:44	17.50	U	420		
12/8/92	10:42	11.07				
1/18/93	13:41	10.42		410		
37/1-4J3						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/11/91	13:03	27.45				
4/11/91	09:37	28.07				
5/6/91	10:12	28.65	R			
6/3/91	09:32	29.52				
7/8/91	17:10	31.34	R			
8/5/91	09:35	31.72				
10/7/91	15:44	31.36				

11/3/91	12:02	30.77	R			
12/2/91	10:17	29.68				
1/6/92	11:15	29.09				
2/2/92	14:02	26.80				
3/17/92	14:30	27.70				
4/7/92	9:40	28.20				
5/5/92	9:37	28.10				
6/8/92	9:15	30.48				
7/5/92	13:16	30.14				
8/3/92	15:45	32.24				
9/14/92	15:55	31.94				
10/13/92	10:48	34.57				
11/9/92	16:09	29.65				
12/8/92	9:31	27.58				
1/18/93	14:55	27.77				
37/1-4J4						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/6/91	13:57			980	105	120
3/11/91	13:17	30.52				
4/11/91	10:11	31.28				
5/6/91	10:35	31.88	U	810	66	90
6/3/91	09:42	32.61				
7/8/91	16:39	33.42		260	84	210
8/5/91	09:53	35.00				
9/9/91	09:40	34.31		1490	27	250
10/7/91	16:08	34.50	R			
11/3/91	15:30	33.24		1420	48	220
12/2/91	10:26	33.05				
1/6/92	14:26	32.12		1200	39	180
2/2/92	14:18	30.04				
3/14/92	09:55	30.12		770		
4/7/92	9:58	31.33				
5/5/92	9:55	31.24		780		
6/8/92	10:04	33.93				
6/30/92	12:48				56	190
	12:58				56	210
	13:08				58	210
	13:25				58	210
	13:40				59	210
	20:46				28	210
	20:58				49	210
	21:15				55	210
	21:37				58	210
9/14/92	15:29	34.82		1190		
10/13/92	10:35	37.87				

11/9/92	15:40	31.47		>2000		
12/8/92	9:51	30.65				
1/18/93	14:38	31.12		1200		
37/1-4J2						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/11/91	09:50	29.78				
4/11/91	10:29	31.17				
5/6/91	10:58	31.62				
6/3/91	10:08	33.28	P(9:53)			
7/8/91	16:25	37.75	R			
8/5/91	10:03	37.41				
9/9/91	10:15	37.06				
10/7/91	16:17	39.60				
11/3/91	12:50	39.15	R			
12/2/91	11:37	34.22				
1/6/92	11:32	32.09				
2/2/92	14:38	30.16				
3/17/92	14:40	29.36				
4/7/92	09:26	31.84				
5/5/92	10:55	31.24				
6/8/92	10:20	35.78				
7/5/92	14:04	38.93				
8/3/92	16:15	36.95				
9/14/92	15:15	42.90				
10/13/92	11:01	40.30				
11/9/92	15:20	34.79				
12/8/92	10:05	33.40				
1/18/93	14:26	31.12				
37/1-4K6						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/11/91	13:59	12.18	R			
4/11/91	10:51	12.21	R			
5/6/91	11:45	11.39				
6/3/91	11:13	18.69	R			
7/8/91	15:32	14.43	R			
8/5/91	10:45	12.92	R			
9/9/91	10:56	12.17				
10/7/91	16:51	12.60				
11/3/91	13:05	12.79				
12/2/91	12:13	13.23				
1/6/92	11:57	15.72				
2/2/92	15:10	12.69				
3/17/92	14:50	11.94				
4/4/92	10:19	12.19				

5/5/92	11:52	11.37				
6/8/92	10:57	20.95	R			
7/5/92	15:06	12.48				
8/3/92	16:54	15.80	R			
9/14/92	14:58	13.96				
10/13/92	11:48	15.54	R			
11/9/92	15:04	13.33				
12/8/92	11:02	14.42				
1/18/93	14:13	12.72				
37/1-5C1						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/6/91	12:15			390	20	40
3/9/91	14:30	26.32				
4/12/91	12:06	26.79				
5/6/91	14:35	27.20		440	20	47
6/3/91	14:20	28.02				
7/6/91	11:00	28.00	R		20	40
8/6/91	10:40	28.53				
9/9/91	11:25	28.99		450	20	46
10/7/01	10:34	29.59	R			
11/4/91	10:15	30.47	R	430	22	45
12/2/91	12:00	29.58				
1/1/92	13:35	29.74	R		23	45
2/3/92	11:15	29.91				
3/3/92	16:05	29.35		440		
4/8/92	10:32	31.07				
5/4/92	11:00	29.38		460		
6/9/92	15:10	29.22				
7/6/92	14:43	30.04		410		
8/3/92	14:33	29.81				
9/5/92	11:10	30.04				
10/5/92	14:12	30.00				
11/9/92	16:06	30.17		430		
12/7/92	14:20	29.88				
1/18/93	15:40	30.18		410		
37/1-5F						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/9/91	11:30	71.28				
4/12/91	12:22	72.23				
5/6/91	18:10	70.80				
6/3/91	14:25	75.20				
7/6/91	11:42	78.00				
8/6/91	11:10	78.08				
9/9/91	12:00	74.94				

10/7/91	10:00	75.05				
37/1-5A1						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/11/91	09:00	23.94				
4/11/91	14:37	25.85	R			
5/6/91	12:16	28.64	U	320	14	19
6/3/91	11:32	33.80				
7/8/91	12:08	46.29	R	440	37	24
8/5/91	11:02	36.64				
9/9/91	09:25	44.00		430	26	22
10/7/91	09:50	42.57	R			
11/3/91	14:30	45.14		450	33	25
12/2/91	10:03	42.62	R			
1/6/92	10:35	32.23		330	16	20
2/3/92	11:00	26.36				
3/14/92	10:52	25.73		270		
4/6/92	15:10	37.91	R			
5/4/92	10:15	27.95		290		
6/9/92	09:53	38.19				
7/6/92	10:06	37.22	R			
8/3/92	10:06	37.67				
9/14/92	09:48	40.78		430		
10/8/92	15:12	39.48	R			
9/11/92	09:29	38.82		390		
12/7/92						
1/18/93	10:56	32.73		370		
37/1-5H2						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/9/91	16:13	67.08	R			
4/11/91	15:57	27.97	R			
5/6/91	12:36	27.92				
6/3/91	11:44	28.48				
7/8/91	11:45	31.22				
8/5/91	11:16	36.85	R			
9/9/91	09:50	31.98				
10/7/91	10:07	31.47				
11/3/91	13:21	32.15				
12/2/91	10:26	34.31	R			
1/6/92	10:53	30.26				
2/3/92	11:18	28.44				
3/14/92	11:12	25.78				
4/6/62	15:27	30.29	R			
5/4/92	10:33	27.71				
6/9/92	10:23	34.55	R			

7/6/92	10:23	26.80				
8/3/92	10:30	34.60	R			
9/14/92	10:23	40.00				
10/8/92	15:24	35.37				
11/9/92	09:53	42.79				
12/7/92	14:16	34.32				
1/18/93	11:13	37.77	R			
37/1-5R1						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/6/91	12:23			300	8	22
3/10/91	15:35	62.79				
4/13/91	11:39	63.15				
5/6/91	11:12	62.90		270	10	20
6/3/91	13:43	63.13				
7/8/91	15:15	63.13		270	15	20
8/5/91	14:22	63.00				
9/10/91	13:22	63.12		280	11	20
10/7/91	13:45	63.26				
11/5/91	10:27	62.96		270	10	20
12/3/91	09:28	63.35				
1/6/92	14:01	62.86		270	11	22
2/5/92	14:45	63.00				
3/11/92	10:44	63.23		260		
4/7/92	14:16	63.24				
5/7/92	13:43	63.10		260		
6/9/92	15:33	62.83				
7/8/92	10:41	63.27				
8/8/92	10:40	63.15				
9/12/92	16:25	63.20				
10/11/92	13:32	63.31				
11/8/92	14:00	63.97		270		
1/7/93	10:44	62.94		260		
37/1-8A1						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/6/91	12:10			340	5.u	12
3/10/91	15:10	2.96				
4/13/91	11:14	4.47	R			
5/6/91	11:42	3.10		310	5.u	13
6/3/91	13:16	5.24	R			
7/8/91	15:38	3.73		320	6	13
8/5/91	14:41	3.40				
9/10/91	13:50	4.92		320	6	14
10/7/91	14:05	3.72				
11/5/91	10:55	3.09		410	10.u	14

12/3/91	09:56	5.05	R, P			
	11:39	2.91				
1/6/92	14:23	2.55		310	6	14
2/5/92	14:56	2.67				
3/11/92	11:09	2.80		310		
4/7/92	14:34	4.30				
5/7/92	14:04	4.10				
6/9/92	15:47	3.25				
7/8/92	11:00	3.97				
8/8/92	11:00	11.58	R			
9/12/92	16:55	5.95	RR			
10/11/92	13:45	4.20				
11/8/92	14:18	2.90				
1/17/93	11:02	3.40				
37/1-9C6						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
6/7/91	12:42	58.46				
9/11/91	09:09	64.48	R, P			
10/9/91	10:47	59.26	R			
11/3/91	12:18	59.04	R	450	23	16
12/3/91	08:29	63.51	P			
1/5/92	15:32	61.71	P	450	26	18
2/5/92	13:52	59.53	R, P			
3/13/92	09:24	65.95	P	430		
4/11/92	18:19	60.05	R			
5/1/92	09:48	62.21	R	430		
6/12/92	16:45	59.87	R			
7/5/92	15:27	61.68	R	440		
9/16/92	13:20	58.43	R	440		
10/4/92	17:30	59.09	R			
11/15/92	16:57	62.58	R			
12/6/92	15:11	62.53	R			
1/17/93	13:24	59.85	R	410		
37/1-9F						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
4/12/91	18:58	46.90	R			
6/6/91	15:16	46.04				
7/9/91	09:59	45.98				
8/7/91	10:37	46.61				
9/10/91	08:05	57.58	R			
10/10/91	18:01	46.63				
11/3/91	13:00	47.45				
12/3/91	08:49	46.91				
1/5/92	15:01	47.78	R			

2/5/92	14:13	46.69	R			
3/13/92	14:32	49.35	R			
4/11/92	17:53	47.90	R			
5/1/92	10:12	46.78				
	10:24	59.77	P,R			
6/12/92	17:19	47.85				
7/8/92	16:11	47.00				
9/16/92	13:54	45.95				
10/4/92	17:44	46.48				
12/6/92	15:32	47.09				
1/17/93	14:04	47.22				
37/1-9G3						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/6/91	13:15			370	5.u	12
4/12/91	18:39	75.44				
5/6/91	05:35	75.72		350	5.u	10
6/6/91	15:40	75.57				
7/9/91	08:27	75.82		350	5.u	9
8/7/91	10:20	75.60				
9/10/91	07:27	75.26		340	5.u	10
10/9/91	10:27	75.55				
11/3/91	13:20	75.28	R	350	10.u	10
12/3/91	08:14	75.41				
1/5/92	16:08	75.18		350	5.u	10
2/5/92	13:32	75.37				
3/13/92	08:47	74.78		340		
4/11/92	18:35	75.48				
5/1/92	09:09	75.96		320		
6/12/92	16:25	75.32				
7/5/92	15:20	75.73				
9/16/92	14:16	80.53	P			
10/4/92	17:12	75.69				
12/6/92	15:48	75.08				
1/17/93	14:21	75.33				
.						
37/1-9J1						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/6/91	11:12			530	5.u	40
3/10/91	11:20	40.53	R			
4/13/91	10:48	39.52	R			
	13:16	37.57	N			
5/6/91	12:11	34.18	R	510	5.u	47
6/3/91	10:00	35.73	R			
7/8/91	15:58	36.54		530	5.u	47
8/5/91	13:56	36.38	R			

9/10/91	14:15	38.01	R	520	5.u	47
10/7/91	14:29	37.75	R			
11/5/91	10:04	39.12	R	510	10.u	47
12/3/91	11:30	47.60	R			
1/6/92	13:19	51.50	R	490	5.u	40
2/5/92	16:14	54.20				
3/11/92	10:13	62.34	R	430		
5/7/92	13:18	40.53		480		
6/9/92	14:15	41.88				
7/8/92	10:15	45.29	R	480		
8/8/92	10:20	45.45	R			
9/2/92	17:12	50.09				
10/11/92	13:13	47.00				
11/8/92	15:51	49.40		450		
1/17/93	12:27	83.90	R			
37/1-9K						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
5/7/91	14:47	110.20				
6/3/91	10:23	110.39	S			
37/1-10E2						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
5/7/91	15:28	131.18	R			
6/3/91	16:00	132.73				
7/8/91	07:47	130.46				
9/10/91	16:30	131.33				
12/3/91	11:58	130.20				
2/5/92	16:28	130.70				
3/11/92	12:36	131.10				
4/2/92	11:50	131.50				
5/7/92	07:43	132.40				
6/9/92	16:58	130.50				
7/8/92	12:36	131.60				
8/8/92	14:53	131.25				
37/1-10L1						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/10/91	11:05			300		
3/16/91	16:00			300	5.u	6
5/6/91	16:00			300		
37/1-10L2						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
4/17/91	14:00	180.82	R			
5/6/91	15:35	180.70	R			

6/2/91	18:15	182.47	R			
7/7/91	17:00	168.00	R	330	5	6
8/7/91	18:10	184.09	R			
9/10/91	10:40	178.21	RR	320	6	8
10/6/91	19:00	173.88	R			
11/3/91	11:50	140.25	R	320	10.u	6
12/2/91	16:15	159.60	R			
1/5/92	14:10	109.00		320	6	6
2/3/92	15:50	112.50				
3/3/92	13:00	198.52	RR, I	330		
4/4/92	10:25	123.31				
5/4/92	11:00	152.53	R	330		
6/7/92	12:00	164.33	R			
7/6/92	15:27	135.05	R			
8/2/92	17:00	163.46	R			
9/16/92	10:15	122.63		310		
10/14/92	17:05	131.78	R			
11/11/92	10:00	165.00	R			
12/7/92	16:10	136.18	R			
1/19/93	16:25	150.00	RR			
37/1-10M1						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
4/13/91	12:25	46.51	R			
5/6/91	16:25	37.58				
5/7/91	13:40	36.92				
6/3/91	10:47	92.58	R			
7/8/91	16:24	35.05	R			
8/5/91	14:58	110.32				
9/10/91	15:16	65.78	R			
10/7/91	14:52	41.68				
11/5/91	11:16	37.64				
12/2/91	10:22	95.26	R			
1/6/92	14:41	50.60				
2/5/92	15:11	39.10				
3/11/91	11:26	58.30				
4/7/91	14:56	94.96	R			
5/7/92	14:16	40.30				
6/9/92	16:03	49.50	R			
7/8/92	11:16	49.30		280		
8/8/92	11:13	57.53				
9/12/92	17:28	52.04				
10/11/92	14:01	53.63				
11/8/92	15:41	55.85	R	270		
1/17/93	11:15	51.58		280		

37/1-10Q						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
4/14/91	12:50	27.85	R			
5/6/91	18:25	23.86	R			
6/2/91	18:50	33.70	R			
7/7/91	17:40	21.56				
8/7/91	18:30	33.69				
9/10/91	10:15	30.19				
10/6/91	19:30	30.63	R			
11/3/91	12:30	27.58				
12/2/91	15:45	30.42	R			
1/5/92	13:40	23.82	R			
2/3/92	15:15	20.32	R			
3/3/92	11:55	21.46				
4/4/92	10:10	22.87				
5/4/92	10:25	21.03				
6/7/92	12:35	25.42	R			
7/6/92	15:00	29.06	R			
8/2/92	17:20	29.62				
9/14/92	16:35	36.74				
11/11/92	09:40	30.62				
12/7/92	15:50	26.12				
1/19/93	16:15	21.56				
37/1-15E1						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/6/91	12:40			580	44	17
3/10/91	13:00	67.67	R			
4/13/91	13:03	67.57	R			
5/6/91	12:39	66.18		540	47	16
6/3/91	11:49	70.69	R			
7/8/91	16:51	65.52		560	53	16
8/5/91	15:24	66.06	R			
9/10/91	14:39	67.24	R	560	48	16
10/7/91	15:29	65.77	U			
11/5/91	11:45	65.54	U	530	48	15
12/3/91	10:43	65.87				
1/6/92	14:55	65.25		570	57	8
2/5/92	15:29	65.50				
3/11/92	11:45	65.85		510		
4/7/92	15:32	74.74	R			
5/7/92	14:15	68.30		530		
6/9/92	16:17	67.20	R			
6/30/92	10:00		P			
	10:05	73.45				
	10:10	72.65				

	10:10	72.65				
	10:15	72.03				
	10:20	71.10				
	10:25	70.60				
	10:30	70.30				
	10:35	69.88				
	10:40	69.65				
	10:45	69.30				
	10:55	69.18				
	11:00	69.02				
	11:05	68.90				
	11:10	68.76				
	11:15	68.68				
	11:20	68.80				
	11:36	68.75				
	11:44	68.75				
	11:48	68.74				
	11:49	68.74				
	11:49		P			
	11:56	86.19	P			
	12:01	87.60	P			
	12:04				49	15
	12:06	88.68	P			
	12:18				56	12
	12:32				24	15
	12:46				18	14
	13:00				12	15
	13:13	108.00	P			
	13:14				69	15
	13:34	90.00	P			
	13:42	88.45	P	560		
	13:42					
	13:57	76.65				
	14:06	74.20				
	14:12	72.72				
	14:18	71.60				
	14:29	70.30				
	14:46	68.60				
	15:02	68.40				
	15:16	67.90				
	15:30	67.60				
	15:45	67.45				
	16:02	67.15				
	16:16	66.94				
	16:29	66.74				
	16:45	66.51				

	17:15	66.12				
	17:30	65.89				
	17:45	65.73				
	18:01	65.55				
	18:15	65.40				
	18:20	65.36				
	18:25	65.29				
	18:32	65.23				
	18:41	65.16				
	18:45	65.13				
	18:53	65.07				
	19:00	65.03				
	19:05	64.99				
	19:11	64.95				
	19:15	64.91				
	19:20	64.92				
	19:25	64.91				
	19:30	64.87				
	19:35	63.86				
	19:40	63.83				
	19:45	63.50				
	19:50	63.20				
	19:55	63.00				
	20:00	62.80				
	20:05	62.70				
	20:10	62.60				
	20:15	62.50				
	20:20	62.50				
	20:25	62.50	P			
	20:35	80.00	P			
	20:50	95.25	P			
	21:00	100.68	P			
	21:10	103.98	P			
	21:20	97.22	P			
	21:22	95.00	P			
	21:29	90.00	P			
7/8/92	11:44	67.00		560		
8/8/92	11:25	68.95	R			
9/12/92	17:48	65.44				
10/11/92	14:18	66.64				
11/8/92	15:13	65.65		530		
1/17/93	11:37	67.20	R	550		
37/1-15G1						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/6/91	13:00				5.u	10

3/10/91	16:23	45.50				
4/14/91	11:10	45.68	S			
5/6/91	13:08	45.72		240	5.u	47
6/3/91	12:09	46.04				
7/8/91	17:29	45.93	R	250	5.u	9
8/5/91	16:04	45.72	U			
9/10/91	15:34	46.13		250	5.u	10
10/7/91	16:23	46.14	R			
11/5/91	12:24	46.01		230	10.u	9
12/2/91	11:09	46.44				
1/6/92	15:26	46.09		230	5.u	19
2/5/92	15:52	46.00				
3/11/92	12:05	46.18		240		
4/7/92	15:52	46.33				
5/7/92	15:02	46.30		240		
6/9/92	16:44	46.26				
7/8/92	12:11	46.65				
8/8/92	11:55	46.50				
9/12/92	18:27	46.55				
10/11/92	14:48	46.70				
11/8/92	14:48	46.50				
1/17/93	12:03	46.26	R			
37/1-15H2						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/6/91	13:30				5.u	10
3/10/91		0.00	F			
5/6/91	13:30			310	5.u	9
7/8/91	17:48			320	5.u	8
9/10/91	16:00			320	5.u	10
11/5/91	12:50			310	10.u	9
1/6/92	15:40			280	5.u	9
3/11/92	12:20			290		
5/7/92	15:17			300		
7/8/92	12:23			320		
11/8/92	14:36			370		
37/1-16J						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
5/7/91	14:14	64.79	N			
6/3/91	11:26	65.02				
7/8/91	17:09	66.01				
8/5/91	15:38	66.07				
9/10/91	14:57	65.37				
10/7/91	15:53	65.28	U			
11/5/91	12:05	64.05				

12/3/91	10:55	64.80				
1/6/92	15:08	63.84				
2/5/92	15:39	64.20				
3/11/92	11:53	64.53				
4/7/92	15:34	65.83				
5/7/92	14:49	65.90				
6/9/92	16:28	65.08				
7/8/92	11:58	66.29				
8/8/92	11:40	66.38				
9/12/92	18:03	65.12				
10/11/92	14:30	65.25				
11/8/92	14:58	64.35				
1/17/93	11:49	63.60				
38/1-32A1						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/6/91				500	5.u	65
3/6/91		0.00	F			
5/6/91	16:50	3.27		480	5.u	61
7/6/91	09:40	39.15	Bp		5.u	29
8/6/91	12:45	29.99	R			
9/9/91	02:27	22.36		400	5.u	24
10/7/91	11:45	14.13				
11/4/91	10:50	15.09	N			
12/2/91	11:05	4.74				
1/1/92	12:30	10.02	R		5.u	50
2/3/91	01:12	0.95	R			
3/3/92	10:30	0.00	F	510		
	12:17			480		
9/15/92	12:15			420		
11/9/92	15:10			430		
1/19/93	14:55					
38/1-32B1						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/6/91				470	140	20
3/9/91	14:50	122.65	Bp			
4/12/91	11:30	109.79	R, Bp			
5/6/91	15:55	111.64	R, Bp	430	140	18
6/3/91	18:00	115.07	R, Bp			
7/6/91	10:05	137.69	R, Bp		130	19
8/6/91	11:50	110.00	R			
9/9/91	13:40	82.62	R	420	140	18
10/7/91	13:26	57.67	N			
11/4/91	11:55	57.35	N			
12/2/91	11:25	58.45	R			

11/4/91	11:55	57.35	N			
12/2/91	11:25	58.45	R			
1/1/92	11:55	56.76			160	17
2/3/92	12:35	56.87				
3/3/92	11:38	55.85	R	560		
4/8/92	11:12	56.24	R			
5/4/92	11:45	73.78	R			
6/9/92	14:53	137.98	R			
7/6/92	15:16	69.27		400		
8/3/92	15:20	91.35	R			
9/15/92	11:40	59.89		440		
10/5/92	14:28	60.28				
11/9/92	14:15	59.49	R	530		
12/7/92	13:32	57.83				
1/18/93	14:29	57.11		480		
38/1-32F2						
Date	Time	Level	Qualifiers	Conduct	Arsenic	Chloride
10/5/92	15:17	126.60	N			
11/9/92	16:31	136.48	N			
12/7/92	14:55	126.11	N			
1/18/93	16:25	125.98	N			
38/1-32J						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/6/91	13:30			440	15	
3/14/91	15:37	4.78				
4/13/91	09:57	4.16	R			
5/6/91	14:16	10.40		400	39	19
6/3/91	15:52	17.37	R			
7/8/91	10:03	26.50	R	520	140	16
8/5/91	12:54	37.69	R			
9/9/91	12:12	69.22	R	560	300	16
10/7/91	11:53	76.58	R			
11/3/91	16:15	67.37	R	560	300	15
12/2/91	11:51	43.10	R			
1/6/92	11:45	38.67		520	200	16
2/3/92	13:39	24.28				
3/14/92	12:02	6.12		430		
4/6/92	16:16	11.69				
5/4/92	11:33	14.42		440		
6/9/92	11:12	22.28				
7/6/92	11:25	32.85				
8/3/92	9:14	39.07				
9/14/92	11:22	76.07	R	600		
1/18/93	12:33	89.71		530		

38/1-32P1						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/6/91	12:00			260	5.u	20
3/4/91	14:00	65.12	R	250		
4/3/91	07:40	63.88	N(7:25 - 18:15)			
	08:40	64.16				
	09:40	64.58				
	10:40	65.00				
	11:40	65.40				
	12:40	65.75				
	14:10	65.97				
	14:40	65.99				
	15:10	65.96				
	16:10	65.78				
	17:10	65.42				
	18:10	64.91				
5/6/91	16:51	66.08	R	270	5.u	21
6/3/91	16:21	66.41				
7/8/91	09:18	66.41		260	5.u	14
8/5/91	14:46	64.39				
9/9/91	14:00	65.88		280	5.u	22
10/7/91	17:59	63.72				
11/3/91	12:28	64.79	S	280	10.u	24
12/2/91	09:16	64.67	S			
1/6/92	09:18	63.02		240	5.u	26
2/3/92	13:10	63.43	S			
3/14/92	14:36	64.23		290		
4/6/92	16:40	66.00				
5/4/92	12:05	66.18		290		
6/9/92	11:44	65.38	R			
7/6/92	11:50	64.79				
8/3/92	14:18	64.48				
9/14/92	11:52	65.11		290		
10/8/92	16:34	64.07				
11/9/92	11:37	64.33		270		
12/7/92	15:02	63.06				
1/18/93	10:03	63.43	P	270		
38/1-33L						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/9/91	15:05	20.87	N			
4/13/91	10:15	20.92	N			
5/6/91	09:14	21.62	N			
6/3/91	09:09	22.34	N			
7/8/91	14:55	23.67	N			

8/5/91	09:11	25.14	N			
9/9/91	09:07	24.80	N			
10/7/91	17:25	25.38	N			
11/3/91	11:28	25.60	N			
12/2/91	09:30	23.63	N			
1/6/92	10:03	22.41	N			
2/3/92	11:50	21.25	N			
3/17/92	15:12	21.12	N			
4/7/92	09:00	23.39	N			
5/4/92	09:12	22.81	N			
6/9/92	09:17	23.91	N			
7/6/92	09:03	24.08	N			
8/3/92	09:29	25.37	N			
9/14/92	09:07	26.20	N			
10/8/92	14:38	25.95	N			
11/9/92	08:54	25.18	N			
12/7/92	13:38	23.34	N			
1/18/93	10:18	22.83	N			
38/1-33N						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/6/91	13:20			360	24	22
3/11/91	09:30	32.88				
4/11/91	12:09	35.42				
5/6/91	15:07	31.30		380	32	26
6/3/91	15:09	43.12				
7/8/91	11:13	31.29		390	27	18
9/9/91	10:56	105.76	FR	510	120	21
10/7/91	11:00	> 85				
11/3/91	13:22	86.28	R	390	43	15
12/2/91	11:08	106.43	R			
38/1-33Q2						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
3/9/91	14:30	30.16				
4/11/91	09:19	30.57	R			
5/6/91	09:54	30.35	R			
6/3/91	09:18	30.27				
7/8/91	15:05	30.22				
8/5/91	09:21	30.57				
9/9/91	09:18	30.52				
10/7/91	17:10	30.48				
11/3/91	11:42	30.88				
12/2/91	09:47	30.70				
1/6/92	10:17	30.59				
2/2/92	15:27	30.36				

5/5/92	09:15	30.72				
6/8/92	09:00	31.39				
7/5/92	15:31	31.76				
8/3/92	17:07	31.30				
9/14/92	14:05	31.75				
10/13/92	12:04	31.75				
11/9/92	14:20	31.85				
12/8/92	11:15	31.33				
1/18/93	13:25	31.53				
38/1-29Q2						
Date	Time	Level	Qualifers	Conduct	Arsenic	Chloride
4/12/91	10:32	20.40				
5/6/91	17:30	21.09	R			
6/3/91	03:18	23.57	R, I			
7/6/91	13:10	28.15	R			
8/6/91	12:20	27.27	R			
9/9/91	15:15	26.80	R			
10/7/91	12:08	28.38				
11/4/91	11.35	26.14	R			
12/2/91	11.45	24.85	N			
1/1/92	13:00	20.87	N			
2/3/92	11:40	19.54	N			
3/3/92	11:13	19.37	N			
4/8/92	11:57	20.95				
5/4/92	12:42	21.33				
6/9/92	14:34	22.36				
6/30/92	09:50	24.07				
	09:55	24.08				
	10:00	24.05				
	10:02	24.10				
	10:05	24.11				
	10:10	24.13				
	10:15	24.14				
	10:20	24.16				
	10:25	24.18				
	10:30	24.20				
	10:40	25.63	I			
	10:45	25.18				
	11:05	24.75				
	11:10	24.71				
	11:15	24.68				
	11:20	24.66				
	11:25	24.64				
	11:30	24.63				
	11:35	24.61				

	11:30	24.63				
	11:35	24.61				
	11:40	24.60				
	11:45	24.59				
	11:50	24.59				
	11:55	24.59				
	12:00	24.58				
	12:05	24.58				
	12:10	24.57				
	12:15	24.57				
	12:20	24.57				
	12:25	24.56				
	12:30	24.56				
	12:35	24.56				
	12:40	24.55				
	12:40		P			
	12:47		P	1770	5u	130
	12:55			1690		
	13:00			1630	7	110
	13:05			1630		
	13:08	39.37	P			
	13:10			1500	310	100
	13:15			1460		
	13:20			1510	180	110
	13:25			1530		
	13:30			1470	270	100
	13:35			1340		
	13:40			1330	5u	95
	13:41	48.73	P			
	13:43	50.19	P			
	13:45	46.59	P	1320		
	14:00	38.06				
	14:05	36.09				
	14:15	33.90				
	14:20	33.25				
	14:25	32.51				
	14:30	31.99				
	14:35	31.50				
	14:41	30.98				
	14:45	30.68				
	14:50	30.34				
	14:55	30.00				
	15:00	29.73				
	15:05	29.47				
	15:10	29.20				

	15:15	29.00				
	15:20	28.80				
	15:25	28.60				
	15:30	28.42				
	15:35	28.24				
	15:40	28.08				
	15:45	27.92				
	15:50	27.75				
	16:00	27.50				
	16:10	27.22				
	16:18	27.07				
	16:30	26.82				
	16:40	26.65				
	16:50	26.44				
	17:00	26.26				
	17:10	26.13				
	17:20	25.98				
	17:30	25.84				
	17:45	25.62				
	17:50	25.57				
	18:00	25.45				
	18:10	25.34				
	18:20	25.23				
	18:30	25.13				
	18:40	25.04				
	18:50	24.95				
	19:00	24.86				
	19:10	24.79				
	19:20	24.73				
	19:30	24.65				
	19:40	24.59				
	19:50	24.53				
	20:00	24.48				
	20:10	24.43				
	20:20	24.38				
	20:30	24.35				
	20:30		P			
	20:35		P	1930	5u	140
	20:40			1900		
	20:45	36.15	P	1890	5u	130
	20:50			1860		
	20:55			1845	5u	130
	21:00			1720		
	21:05	39.35	P	1640	5u	120
	21:10			1640		
	21:15			1510	5u	100

	21:20			1470		
	21:25			1450	5u	100
	21:30			1430		
	21:32	42.95	P			
	07:55	43.28	P			
7/6/92	15:46	24.52				
8/3/92	16:40	28.14				
9/15/92	12:38	26.78				
10/5/92	14:50	25.20				
11/9/92	15:24	24.84	N			
12/7/92	14:00	22.48	N			
1/18/93	15:00	21.02	N			
QUALIFIER CODE						
Bp	Broken pipe in system					
F	Flowing well					
I	Suspected interaction from adjacent well drawdown					
N	Well not being used, or pump failure					
P	Pumping well					
R	Rising water level					
RR	Rapidly rising water level					
S	Falling water level					
U	Unstable, fluctuating water level					

APPENDIX G

RAINFALL RECORD (INCHES)

YEAR 1991 LOCATION 2781 W. Shore Dr. OBSERVER Marshall

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1		.08		.02									1
2			.28	.19								.04	2
3		.07	.25	.17		.04							3
4		.13	.15	1.14							.65	.18	4
5		.17		.39	.10						.44		5
6					.05							.87	6
7	.83		.26	.09	.09	.09					.14		7
8	.42	.64		.10	.22	.24		.12			.06		8
9	1.06			.52	.03			.64				.39	9
10			.04	.06				.41					10
11	1.20					.05	.04	.13			.76	.07	11
12		.28	.27			.02		.10			.81		12
13			.01				.22					.34	13
14		.35	.03		.02								14
15	1.19	.09	.26			.04	.39						15
16						.41							16
17	.13	.07				.25					.81		17
18	.13		.31		.24						.24	.27	18
19		.87									.24		19
20		.03									.60		20
21						.36	.08			.30		.06	21
22			.22			.10					.20		22
23													23
24				.16	.26						.26		24
25				.04		.11	.26				.32		25
26				.03	.16					.32			26
27				.02				1.07			.75		27
28				.25				.08				.35	28
29			.04					.21		.28			29
30					.07	.03					.03	.05	30
31	.20							1.02		.13			31
Tot	5.16	2.78	2.12	3.18	1.24	1.74	0.99	3.78	0.05	1.03	6.31	2.62	

Total: 31.00

Heavy Dew

Snow & frozen rain

RAINFALL RECORD (INCHES)

YEAR 1991 LOCATION 3883 Centerview Rd. OBSERVER Evans

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1												.05	1
2												.01	2
3												.06	3
4												.09	4
5					Installed 6/5/91 →						.97	.31	5
6						.01					.11	.46	6
7						.30		.04			.12	.24	7
8						.05		.07			.05	.08	8
9								.67			.01	.29	9
10						.06		.27			.10	.01	10
11								.11			.41	.06	11
12							T	.10			.43	.38	12
13						T	.23	.41			.07		13
14						.01	T				.51	.01	14
15							.34				.01		15
16						.24			.02		.30		16
17						.31					.44		17
18											.30	.13	18
19											.07	.10	19
20						.25					.61	.02	20
21						.17	.07				.22	.04	21
22						.10					.01	.01	22
23													23
24							.18				.17	.08	24
25						.08	.11				.31	.06	25
26								.06			.31	.03	26
27								1.00			.60	.22	27
28								.11	.01		.01	.01	28
29						.01		.13			.02	.04	29
30						.03		↓			.01		30
31								.51		↓			31
Tot							.93	3.48	.03	1.07	6.17	2.79	

RAINFALL RECORD (INCHES)

YEAR 1991 LOCATION 1764 So. Nugent Rd OBSERVER Jerry Brown

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1													1
2				0.28								0.04	2
3				0.07							0.02	0.10	3
4				0.95							0.71	0.65	4
5				0.53	0.16					0.02	0.37	0.39	5
6			0.14	0.03	0.06	0.01					0.02	0.05	6
7			0.07	0.09	0.27	0.38		0.17			0.18	0.09	7
8			0.02	0.03	T			0.01	T		0.06	0.25	8
9				0.86				0.71			0.02	0.01	9
10			0.07	0.15		0.08		0.20			0.84	0.08	10
11			0.33			0.06	0.03	0.12			0.11	0.41	11
12			0.16		0.03						0.52		12
13							0.24		0.03		0.06		13
14						0.04	0.39						14
15			0.02			0.08				0.27	0.40	0.03	15
16					0.06	0.29					0.47	0.02	16
17					0.16						0.19	0.19	17
18											0.52	0.08	18
19			0.33								0.28		19
20						0.46	0.09				0.25	0.04	20
21			0.06			0.08				0.04	T	T	21
22			0.03								0.01		22
23			0.09		0.27					0.28	0.17	0.07	23
24				0.10	0.08	0.08	0.27			0.29	0.37	0.06	24
25				0.05	0.03	0.03					0.32	0.06	25
26				0.03				1.22			0.74	0.24	26
27				0.02				0.04			T	0.02	27
28				0.20				0.17	0.02	0.38	0.07		28
29			0.04	0.05	0.07	0.08	0.01	0.43					29
30								0.55			0.11	0.05	30
31			T							0.15		0.07	31
Tot			1.36	3.44	1.19	1.67	1.03	3.62	0.05	1.43	6.81	3.00	

Heavy Dew

Snow

RAINFALL RECORD (INCHES)

YEAR *1992* LOCATION *2781 W. Shore Dr.* OBSERVER *A. Marshall*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1		.13	.09								.11		1
2		.30	.04								.24		2
3		.07	.13										3
4	.30		.07						.03	.02	.58		4
5	.11		.12				1.18						5
6			.15				.05	.53			.07		6
7							.01	.50			.50	.10	7
8				.93					.84	.05	.32		8
9	.21				.01			.12			.05		9
10	.49	.10					.13					.33	10
11	.54				.32							.07	11
12						.40							12
13	.03			.16					.19	.75			13
14						.76						.13	14
15		.53		.07							.66		15
16	.53		.27	.10							.07		16
17			.13	.79							.05		17
18				.23						.26	.26	.07	18
19													19
20		.73		.03			.04		.34		.62		20
21	.12	.38					.05			.67	.50	.64	21
22				.27				.43		.10		.02	22
23	.47	.82							.18				23
24	.73								.87				24
25	.11								.17	.20			25
26		.20	.03	.13	.02						.54		26
27	.14		.17	.25							.10		27
28	.45			.08		.10							28
29	.23			.86	.22	.73				.15		.81	29
30	.89			.07		.01					.37		30
31										.04			31
Tot	5.35	3.26	1.20	3.91	0.57	2.00	1.46	1.58	2.62	2.24	5.04	2.17	

(orange) Dew

Total: 31.40

RAINFALL RECORD (INCHES)

YEAR 1992 LOCATION 1764 So. Nugent Rd. OBSERVER Jerry Brown

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	.18	.05	.03		.01						.29		1
2	.05	.20	.13	.18						.02	.57		2
3	.22		.07	.23					.03				3
4	.02		.09	.22			1.17		.03	.02		.02	4
5	.02	.02	.14	.06			.42	.40			.13	.02	5
6	.02			.01				.39			.45	.14	6
7							T	.04	.94	.05	.27	.08	7
8	.19	.11			T			.07					8
9	.51	.01			.23						.35	.17	9
10	.71				.11							.20	10
11	.03	.03		.13		.36							11
12		.07				.76			.07	.74			12
13				.05		.10						.25	13
14		.53											14
15	.45		.31	.11								.04	15
16		.05	.11	.92						.03	.38	.22	16
17	.03	.34		.18						.27	.08		17
18	.02	.01								.47	.04	.42	18
19		.17		.03			.08		.41			.20	19
20	.13	.67		.31			.09			.17	.89	.28	20
21	.04	.46						.46		.09	.90		21
22	.55	.21					T		.21	.16		.11	22
23	.66	.17							.73	.05			23
24	.10	.03									.02		24
25	.03	T	.01	.13	.08							.37	25
26	.12		.18	.34							.39		26
27	.48			.05	.32	.09					.15	.09	27
28	.26			.92	.01	.80				.13	.01		28
29	.33	.07		.12		.02				.03	.65		29
30	.67		T			.01				.03		.02	30
31	.11							.05		.11			31
Tot	5.93	3.20	1.07	3.99	0.76	2.14	1.93	1.41	2.42	2.37	5.57	2.63	

Heavy Dew

Snow

Total: 33.42

YEAR 1994

RAINFALL RECORD (INCHES)

LOCATION 3883 Centerview Road, Lummi Island, WA 98262

OBSERVER Charles D. Evans, Margaret N. Evans

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1			.30										1
2	.24	.03											2
3			.17										3
4	.44		.36										4
5													5
6													6
7	.14												7
8													8
9													9
10		.14	.13										10
11		.04											11
12		.13											12
13		.36											13
14	.53												14
15		.26											15
16		.17											16
17	.06	.52											17
18													18
19		.10											19
20													20
21		.18											21
22													22
23	.07												23
24	.05												24
25													25
26		.44											26
27		.08											27
28	.09	.65											28
29													29
30													30
31													31
Tot	1.62	3.10											

RAINFALL RECORD (INCHES)

YEAR 1993 LOCATION 3883 Centerview Road OBSERVER Charles and Maggie Evans

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1												.83	1
2		.03		[illegible]		[illegible]							2
3	.21										.47		3
4	.17			.15	.41	[illegible]						[illegible]	4
5			.39										5
6			.01		.71								6
7				[illegible]	.01							.24	7
8				.53	.11	.02						[illegible]	8
9				[illegible]	.55 ↓	.61		.12					9
10						[illegible]		[illegible]				.77	10
11				[illegible]	[illegible]	[illegible]			.17			.40	11
12							.02					.15	12
13												.01	13
14				[illegible]			[illegible]		.05		.04		14
15		.10				[illegible]						[illegible]	15
16				.13			.28	[illegible]			.54		16
17				.12									17
18													18
19													19
20	.64	[illegible]			.69		.87		.26				20
21	.14	.12		.02	.14		.01	.02		.32	[illegible]		21
22					.24		[illegible]			.39		.03	22
23						.06		[illegible]		.59		.02	23
24	1.31			[illegible]			.04	[illegible]		.29			24
25													25
26						.53 ↓						.02	26
27	.22												27
28	.54			.59	[illegible]					.12	.34		28
29			2.08			.15	.31				.13		29
30				.02	[illegible]		.03		.05		[illegible]	.51	30
31					[illegible]			.02		.07	[illegible]	.40	31
Tot	2.73	0.27	2.48	2.35	[illegible]	2.29	[illegible]	[illegible]	.53	1.78	2.20	3.68	

Year total = 24.97

RAINFALL RECORD (INCHES)

YEAR 1992 LOCATION Centennial Road, Lummi Island OBSERVER Charles Maggie Evans

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	.07	.10	.06	.01	X	00					.24		1
2	.04	.15	.03	[illegible]							.11		2
3	.19	.13	.11	.13					.01	.01			3
4	.07	—	.07	.24			.01				.52		4
5	.13	—	.19	.42			.80						5
6	.00	.02	.00	.03			.62				.06		6
7	.00	—	—	—			.08				.42		7
8	—	—	.00	.03					.83		.29	.12	8
9	.16	.09	—	—		.01		1.01		.04		.14	9
10	.48	.01	—	—			.13					.02	10
11	.63	—	.02	—			—				.40		11
12	.02	.04	—	.12			—			.01	.01	.25	12
13	—	.01	—	—		1.0	—		.19	.77			13
14	.00	—	.03	—		0.15	—				.01	.15	14
15	—	.56	.25	.12			—						15
16	.16	.02	.03	.11			—				.34		16
17	.0	.04	.12	.81			—				.08	.13	17
18	.01	.34	.01	.20			—		.01	.06	.05		18
19	—	.02	.00	—			—			.43			19
20	.01	.35	.00	.02	.25		.04		.30	.01		.43	20
21	.12	.51	.00	.31	—		.08	H-T	.01	.29			21
22	.02	.48	.00				—				.69	.25	22
23	.41	—	.00	.01			.01		.18	.25	.78	.09	23
24	[illegible]	.35	.00	—			—		.49	.10			24
25	[illegible]	—	.00	—			—			.01			25
26	.04	.03	.03	—	.08		—		.17	.11		.26	26
27	.11	—	.18	.36			—				.43	.35	27
28	.49	—	.00	.13		.07	—				.15		28
29	.20	.02	.00	.37	.24	.75	—				.02		29
30	.30		.00	.14		.02	—			.12	.48		30
31	.59		.00				—	.04		.0	—		31
Tot	5.36	3.27	1.13	4.06	0.57	~~1.09~~ 2.00	1.91	1.52	2.92	2.34	5.08	2.19	

.71 (day 24), .10 (day 25)

+.01

Total 5.37

[19.69] [Thru August]

Year Totals 32.02

APPENDIX H

APPENDIX H

4/28/92

WDOE Seawater Intrusion Policy

Preamble

- Groundwater is a finite and precious resource; in many coastal areas of Washington State, it is a critical source of water which cannot be readily replaced.

- Seawater intrusion is both a water resource and a water quality management issue, potentially affecting coastal aquifers throughout Puget Sound, the Strait of Juan de Fuca and the outer coast of Washington. Seawater intrusion poses aesthetic, public health, and environmental risks, as well as economic impact to public resources.

- The technical and economic feasibility of reversing seawater intrusion is uncertain, at best. Therefore, this policy calls for prudent management of the state's water resources via *prevention* of seawater intrusion for areas currently unaffected and *control* (i.e. stabilization and reversal) for areas where the problem has occurred.

- Ecology shall uphold the principles of resource conservation and sustained yield through its administration of water rights (Chapters 90.03 and 90.44 RCW). If a determination cannot be made with available information, Ecology shall direct the applicant to obtain the necessary data in order for the water right application to receive further consideration.

- Seawater intrusion is a complex problem to diagnose and resolve due to the fact that, in many cases, baseline data is lacking or not organized. Furthermore, the effects of seawater intrusion may not be evident where it is caused. Through this policy, Ecology seeks to improve the information base upon which water right decisions are based. In addition, Ecology will evaluate water right applications, to the extent possible, from the perspective of the overall hydrogeologic system.

- Water resource decisions need to be made in coordination with local governments and tribes, especially in consideration of water availability and land use provisions of the Growth Management Act.

I. Policy Purpose

The objectives of this policy are as follows:

1. To provide the Department of Ecology with a common definition of seawater intrusion.

2. To clarify Ecology's authority/role with regard to the seawater intrusion issue (including Chapter 173-150 WAC).

3. To prevent seawater intrusion in areas which are at risk.

4. To stabilize or reverse seawater intrusion in areas where the problem already exists.

5. To guide Ecology's administration of water rights vis-a-vis seawater intrusion.

6. To provide a technically sound and informed basis for decision making.

7. To ensure state/local government consistency with regards to implementation of water availability and planning provisions of the Growth Management Act.

II. Legal and Administrative Authority

The Department of Ecology has clear statutory authority to prevent and control seawater intrusion under the following codes:

- **Water Well Construction Act - Chapter 18.104 RCW**

  Provides the Department of Ecology with authority to establish and enforce well construction and maintenance standards, license well drillers, require reporting of well construction, and restrict well drilling in sensitive areas to protect the groundwater resource.

  Associated regulations:

  Minimum Standards for Construction and Maintenance of Wells - Chapter 173-160 WAC

- **Regulation of Public Ground Waters - Chapter 90.44 RCW**

  Extends prior appropriation doctrine to groundwater withdrawals. Requires a permit for groundwater withdrawals. Stock-watering, lawn or noncommercial garden, and single or group domestic uses (in an amount not to exceed 5,000 gallons per day) are exempt. Establishes Ground Water Management Area Program.

  Associated regulations:

  Ground Water Management Areas and Programs - Chapter 173-100 WAC

Protection of Withdrawal Facilities Associated with Ground Water Rights - Chapter 173-150 WAC

- **Water Pollution Control - Chapter 90.48 RCW**

  Establishes state policy with regards to groundwater quality, i.e. to retain and secure high quality for all waters of the state. Regulations (173-200 WAC) adopted pursuant to this statute define secondary maximum contaminant level (MCL) for chloride at 250 mg/l and provide for the establishment of an early warning value. The groundwater quality standards also articulate an antidegradation policy.

  Associated regulations:

  Water Quality Standards for Ground Waters - Chapter 173-200 WAC

  Water Quality Standards for Surface Waters - Chapter 173-201 WAC

- **Water Resources Act of 1971 - Chapter 90.54 RCW**

  Sets forth fundamentals of water policy to ensure that state waters are protected and fully utilized for the greatest benefit of the people. Broadly defines beneficial uses of water. Prescribes maximum net benefit test to be applied to allocation of water among potential uses and users. Emphasizes water use efficiency and conservation in the management of the state's water resources, recognizing potential to meet future needs.

The purpose of this policy is to supplement, not supersede, these authorities.

In addition to the aforementioned laws and regulations, Ecology has responsibilities or plays an advisory role under the following:

- **State Building Code - Chapter 19.27.097 RCW**

  Requires applicants for a building permit to provide evidence of an "adequate water supply". The county or city may impose conditions on building permits requiring connection to an existing public water system where the existing system is willing and able to provide safe and reliable potable water to the applicant with reasonable economy and efficiency. Under this statute, an application for a water right does not constitute sufficient proof of an adequate water supply. (Note: This amendment to the State Building Code has origins in the Growth Management Act)

Associated regulations:

Ecology may adopt rules to implement this section of the State Building Code.

- **Growth Management Act - Chapter 36.70A RCW**

  Requires state agency actions to be in compliance with local government plans prepared pursuant to the Growth Management Act. In terms of water right administration, Ecology must review and make permit decisions consistent with local government plans which establish urban growth boundaries and capital facilities.

Although Ecology has extensive authority, prevention and control of seawater intrusion will require a concerted effort with other state and local agencies, (especially the Washington Department of Health, local health departments, and planning departments) which have additional statutory and regulatory authorities. Ecology staff shall work in cooperation with these entities.

III. Application of Policy

This policy applies to withdrawals of groundwater in areas where a seawater-intrusion problem has been documented (e.g. through the Ground Water Management Area Program or through studies by the U.S. Geological Survey, Ecology or consultants) or in areas where natural conditions are such that groundwater withdrawals may create or aggravate seawater intrusion. This includes all groundwater systems which interconnected with saltwater bodies. This policy may be applied to coastal aquifers or groundwater supplies within any of the state's 15 coastal counties, especially those counties which are experiencing population increases and development.

This policy is intended to address seawater intrusion which is suspected to be or is caused by human activity only. In some cases, wells have been drilled in such proximity to saline groundwater that intrusion is unavoidable, regardless of steps taken to mitigate the problem. In other cases, seawater intrusion caused by natural processes, such as daily tidal or seasonal climactic changes, is cyclical and/or uncontrollable by human endeavors. In these situations, the only solution is relocation of the well or substitution of another water source.

Ecology's Water Resources Program regional staff shall refer to this policy for guidance in administration and regulation of water rights whenever a seawater intrusion risk has been identified.

IV. Definition of Related Terms

For purposes of this policy, a number of terms have been so defined:

Adaptive Management - A flexible management system which is applicable in situations where there is a lack of information or certainty about the causes or effects of a particular action or process. Essentially, hypotheses are tested and results evaluated. Management techniques are then adjusted to achieve the desired result.

Aquifer - Geologic materials capable of yielding a sufficient amount of groundwater to wells or springs for commercial or domestic purposes.

Ground Water Basin - a ground water reservoir that is more or less separate from neighboring ground water reservoirs. The ground water reservoir consists of an aquifer or system of aquifers that has reasonably well-defined geologic and/or hydrologic boundaries and more or less definite areas of recharge and discharge.

Public-Water System - Any water-supply system intended to provide water for human consumption or other domestic uses, including source, treatment, storage, transmission, and distribution facilities where water is furnished to more than one single-family residence or facilities, or is made available to the public for human consumption or domestic use. [1]

Saline Contamination - Occurrence of chloride in groundwater supplies at concentrations which exceed the specified maximum contaminant levels set forth by the U.S. Environmental Protection Agency.

Seawater Intrusion - Also known as "salt-water intrusion" is the infiltration of marine salt water into fresh water aquifers, resulting in chloride concentrations above background levels.

Single-Domestic Wells - Wells which are used to withdraw less than 5,000 gallons of water per day for single domestic use, including irrigation of up to 1/2 acre of non-commercial garden and/or lawn.

V. Problem Definition

Seawater intrusion, also known as "salt-water intrusion" is the movement of marine seawater into freshwater aquifers or other geologic formations capable of yielding groundwater. If

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[1] Source: State Board of Health - *Drinking Water Regulations* (September, 1989).

unchecked, seawater intrusion can lead to saline contamination of coastal groundwater supplies.

Seawater intrusion can be caused or exacerbated by human activity, i.e. via increased consumption of groundwater or a reduction of aquifer recharge. In coastal areas, growing consumption of groundwater associated with economic development and increasing population are increasing the risk of contamination of groundwater by seawater. Global warming and associated sea level rise are expected to compound the problem.

Increasing levels of chloride and specific conductivity are indicators of seawater intrusion. The Department of Ecology's Ground Water Quality Standards establish chloride as a secondary chemical contaminant at levels of 250 mg/l or more.

VI. Establishment of Risk Categories

For purposes of this policy, seawater intrusion risk shall be defined by water quality and hydrogeologic factors which are intended to guide the Department of Ecology's administration of water rights.

Since all wells within an island or coastal setting generally contribute to seawater intrusion to some degree, seawater intrusion risk is hereby approached from an areal perspective wherever possible. Where the ground water basin cannot be defined due to lack of hydrogeologic information, a minimum 1/2-mile radius will be used to delineate the ground water basin. These areas will be categorized as low, medium or high risk areas according to the following criteria. (Note: Where two or more risk areas overlap, the higher risk will take precedence. In island settings, all water wells will be assumed to be included in one of the risk categories.)

The risk categories and criteria for each are as follows:

Low-Risk Areas

a. A history of chloride analyses from the water well showing concentrations $\geq$25 mg/l and < 100 mg/l (existing systems); or

b. Chloride concentrations from a test well $\geq$25 mg/l and < 100 mg/l based upon a state certified lab test; or

c. Located within a ground water basin[2] where chloride concentrations are ≥25 mg/l and <100 mg/l.

Medium-Risk Areas

a. A history of chloride analyses from a water well showing concentrations ≥100 mg/l but <200 mg/l (existing systems); or

b. State certified lab tests from test well showing chloride concentrations ≥100 mg/l but <200 mg/l; or

c. Located within a ground water basin[3] with chloride concentrations ≥100 mg/l but <200 mg/l; or

d. Chloride concentration levels which are ≥25 mg/l but <100 mg/l, yet show evidence of an increasing trend as indicated through yearly monitoring or an aquifer test.

High Risk Areas

a. A history of chloride analyses showing concentrations ≥200 mg/l (existing systems); or

b. State certified lab tests from test well showing chloride concentrations ≥200 mg/l; or

c. Located within a ground water basin[4] with chloride concentrations ≥200 mg/l; or

d. Chloride concentration levels which are ≥100 mg/l but <200 mg/l, yet show evidence of increasing trend as indicated through yearly monitoring or an aquifer test.

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[2] Where a ground water basin has not been delineated, within a minimum 1/2-mile radius of a water well with a known chloride concentration ≥25 mg/l and <100 mg/l.

[3] Where a ground water basin has not been delineated, within a minimum 1/2-mile radius of a water well with a known chloride concentration ≥100 mg/l but <200 mg/l.

[4] Where a ground water basin has not been delineated, within a minimum 1/2-mile radius of a water well with a known chloride concentration ≥200 mg/l.

VII. Policy Coordination

Through this policy, Ecology shall strive for consistency with ongoing planning processes to be accomplished through participation in planning efforts, consultation, and review and comment on proposed policies and plans. Ecology actions shall be consistent with approved Ground Water Management Area and Growth Management Plans.

Ecology shall strive to coordinate its water right decisions with land use, water right and water system decisions with other governmental entities via memoranda of agreement, data collection, and information sharing. Under this provision, Ecology shall work in cooperation with the Washington Department of Health, affected Indian tribes, county health departments, county planning departments, and local building departments.

VIII. Education

Ecology shall educate the public about the causes and effects of seawater intrusion and inform the public about what steps can and are being taken. In addition, Ecology shall educate purveyors, potential water purveyors, well drillers, local governments, legislative committees, and citizens about the risk categories and requirements for each as established under this policy. Ecology will provide technical assistance and guidelines to local governments for review of single-domestic wells.

IX. Conservation

Since water conservation is recognized as one of the best defenses against seawater intrusion, Ecology shall require conservation plans and implementation measures for new or expanding developments within groundwater areas that are at risk. For instance, low-flow fixtures, lawn watering schedules, artificial recharge basins, and in-house use only restrictions are among the options to be considered. In addition, retrofitting existing facilities to offset new withdrawals or redesign of proposed system shall be considered as possible mitigation measures for new developments.

In order to improve our understanding of the human impact on the hydrologic cycle, to identify potentially wasteful practices, and to determine the effectiveness of conservation, metering shall be recommended for all wells within a seawater intrusion risk area.

Ecology shall provide technical assistance on water conservation to well owners and water users and work in cooperation with local government to develop innovative approaches for voluntary participation by the public. In order to curb wasteful practices, Ecology shall advise local government on water efficiency standards for building codes and encourage the use of progressive rate structures.

X. Water Right Administration - Policy Directive

The Department of Ecology shall seek to make informed decisions about seawater intrusion through its administration of the water right program. When hydrogeologic information is lacking, however, this policy defers to risk categories and requirements as specified under each. The unequivocal goals of this policy are to prevent seawater intrusion in areas where it has not occurred and to control seawater intrusion in areas where the problem already exists. Mitigation is appropriate provided that these goals are not compromised.

In areas where a seawater intrusion risk has been identified, data collection shall be required to determine the risk and to monitor changes in the hydrologic system. The onus shall be on the water right applicant or water right holder to provide this information. In recognition of the cumulative effects of groundwater withdrawals, Ecology shall evaluate water right applications from a hydrologic system perspective.

Ecology has a variety of options available to prevent and control seawater intrusion. Conservation plans and standards can be sanctioned. Innovative approaches such as requiring new applicants to retrofit existing facilities to offset the impact of additional withdrawals will also be considered.

Since our understanding of how to effectively control seawater intrusion is evolving, and given the variability of hydrogeologic conditions and the lack of groundwater information in many areas, this policy encourages the use of adaptive management techniques for controlling the problem in known seawater intrusion areas. Participants in adaptive management shall include, but not be limited to: Washington Department of Health, local health departments, Washington Department of Ecology (Water Resources and Water Quality Programs), Washington Department of Wildlife, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, environmental and citizen groups, consultants, water right holders, and purveyors.

For existing wells in areas where the risk of seawater intrusion has been identified, Ecology shall provide technical assistance, require monitoring, and review water plans as required by the Department of Health.

For new water right applications in low-risk areas, Ecology shall require stringent monitoring, operation, and design controls. In medium and high risk areas, new water right applications shall be denied unless the applicant can show that additional withdrawal of groundwater will not increase the risk of seawater intrusion.

Pursuant to the Growth Management Act, Ecology may also recommend to local government that building permits be withheld or denied in medium and high risk areas for any new or expanding developments which propose to increase ground water withdrawals above their existing water right unless the applicant can show that additional withdrawal of ground water will not increase the risk of seawater intrusion.

XI. Water Right Administration - Policy Requirements

Based upon the risk categories defined in Section VI, this policy establishes the following requirements:

A. NEW WELLS - LOW RISK AREAS
1. Public Water Supply, Irrigation, and Industrial Wells
o monitor water use (via source meter)[5]
o chloride and conductivity test for each water well required at least once each year during August and analysis by a state certified laboratory - annual reporting to Washington Department of Health
o water conservation practices are required to be incorporated into the operation and maintenance agreement
o minimum aquifer test, as needed
2. Exempt Wells
o report to Ecology well location, status, type of use, and number of households served (at time of construction)
o water conservation fixtures and measures encouraged

B. NEW WELLS - MEDIUM RISK AREAS
1. Public Water Supply, Irrigation, and Industrial Wells
o a current hydrogeologic report, including a hydrogeologic evaluation of the potential for seawater intrusion, is required

[5] As specified in publication prepared by Washington Department of Ecology, Washington Department of Health, and Washington Water Utilities Council - *Interim Guidelines for Public Water Systems Regarding Water Use Reporting, Demand Forecasting Methodology, and Conservation Programs.*

o minimum 24-hour aquifer test
o sampling for chlorides and conductivity in April and August of each year and analysis by a state certified laboratory - annual reporting to Washington Department of Health
o water conservation practices are required to be incorporated into the operation and maintenance agreement
o source and individual meters required - annual reporting to Ecology of water use
o appropriate design modifications are likely to be required (e.g., raising pump intake or reducing pumping rate and increasing storage)
o phased development is likely to be required
o future degradation of water quality or elevation of chloride concentrations in water well may halt development at current levels, even if system is approved for additional connections
o mitigating measures are required and defined in approval
2. Exempt Wells
o report to Ecology well location, status, type of use, and number of households served (at time of construction)
o request local government to require installation of water conservation fixtures
o advise well owner of possible water use restrictions

C. NEW WELLS - HIGH RISK AREAS
1. Public Water Supply, Irrigation, and Industrial Wells
o a current hydrogeologic report, including a hydrogeologic evaluation of the potential for intrusion, shall be required
o aquifer test protocol
o sampling for chlorides and conductivity in April and August of each year and analysis by a state certified laboratory - annual reporting to Washington Department of Health
o water conservation practices are required to be incorporated into the operation and maintenance agreement
o source and individual meters required - annual reporting to Ecology of water use

o appropriate design modifications are likely to be required (e.g., raising pump intake or reducing pumping rate and increasing storage)

o phased development is likely to be required

o future degradation of water quality or increasing chloride concentrations in water well may halt development at current levels; water right permittee shall relinquish the option to perfect additional allocated quantities regardless of the state of construction

o retrofitting existing facilities to offset new withdrawals shall be considered

2. Exempt Wells

o report to Ecology well location, status, type of use, and number of households served (at time of construction)

o advise owner that water system is subject to water use restrictions including in-house use only

D. EXISTING WELLS - LOW RISK AREAS

1. Public Water Supply, Irrigation, and Industrial Wells

o monitor water use (via source meter) - annual reporting to Ecology of water use

o chloride and conductivity test for each water well required once each year during August - annual reporting to Washington Department of Health

2. Exempt Wells

o report to Ecology well location, status, type of use, and number of households served (at time of construction)

E. EXISTING WELLS - MEDIUM RISK AREAS

1. Public Water Supply, Irrigation, and Industrial Wells

o monitor water use (via source meter) - annual reporting to Ecology of water use

o sampling in April and August of each year and analysis for chlorides and conductivity by a state certified laboratory - annual reporting to Washington Department of Health

o recommend analysis of problem and investigation of solutions - Ecology is available for technical assistance

o institute rigorous water conservation measures
2. Exempt Wells
o report to Ecology well location, status, type of use, and number of households served (at time of construction)

F. EXISTING WELLS - HIGH RISK AREAS
1. Public Water Supply, Irrigation, and Industrial Wells
o monitor water use (via source meter)
o sampling for chlorides in April and August of each year and analysis for chlorides and conductivity by a state certified laboratory - annual reporting to Washington Department of Health
o annual reporting to Ecology of monthly source meter readings required
o require investigation and implementation of possible mitigation measures
o moratorium placed on new hook-ups for systems with chloride concentrations greater than 250 mg/l
o institute rigorous water conservation measures (e.g., in-house water use only)
o relinquishment of unused water right
2. Exempt Wells
o report to Ecology well location, status, type of use, and number of households served (at time of construction)
o advise well owner of possible water use restrictions