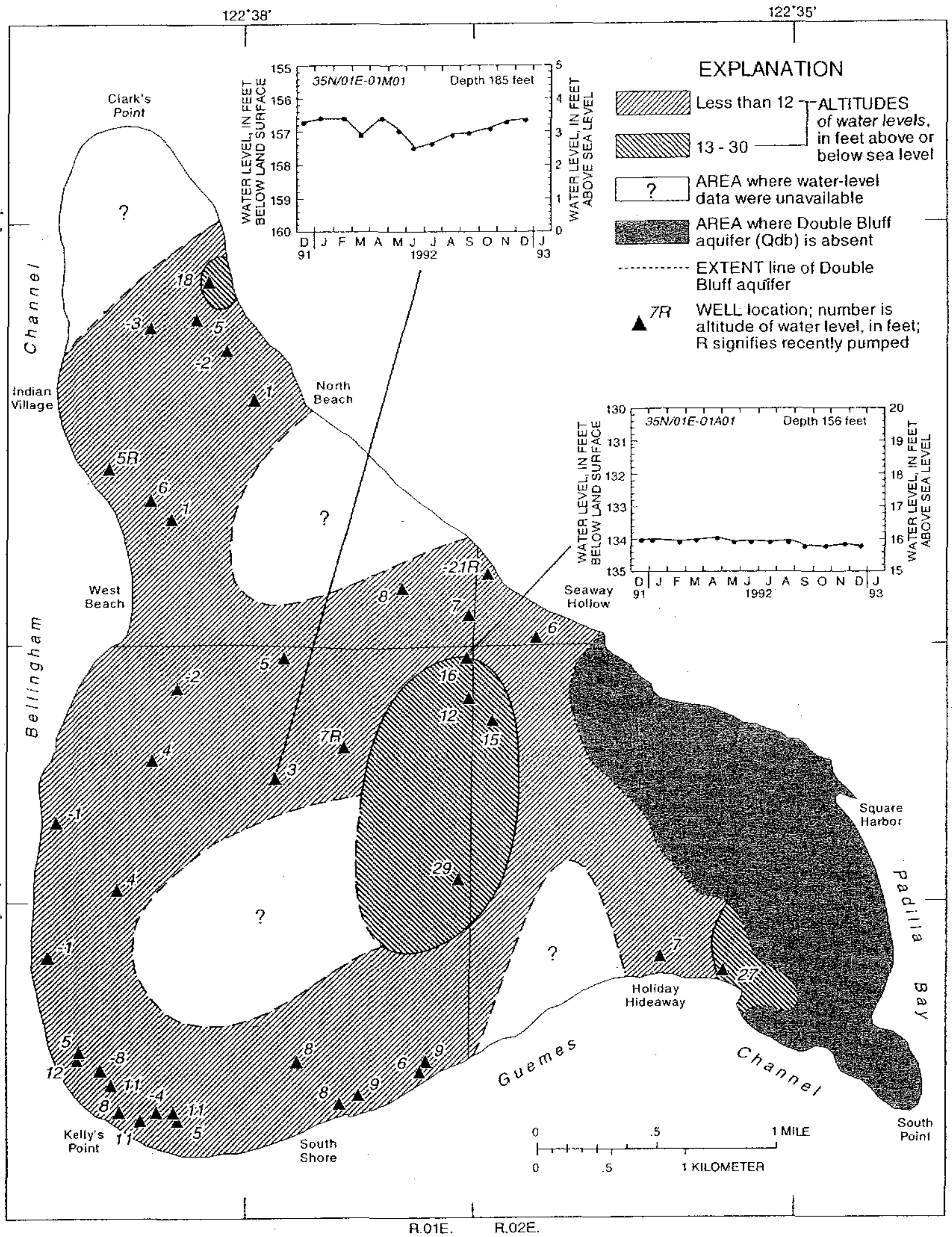


Figure 17.--Altitudes of water levels in wells completed in the Double Bluff aquifer (Qdb), and hydrographs of water levels in selected wells, October 1991.

0548

520-37

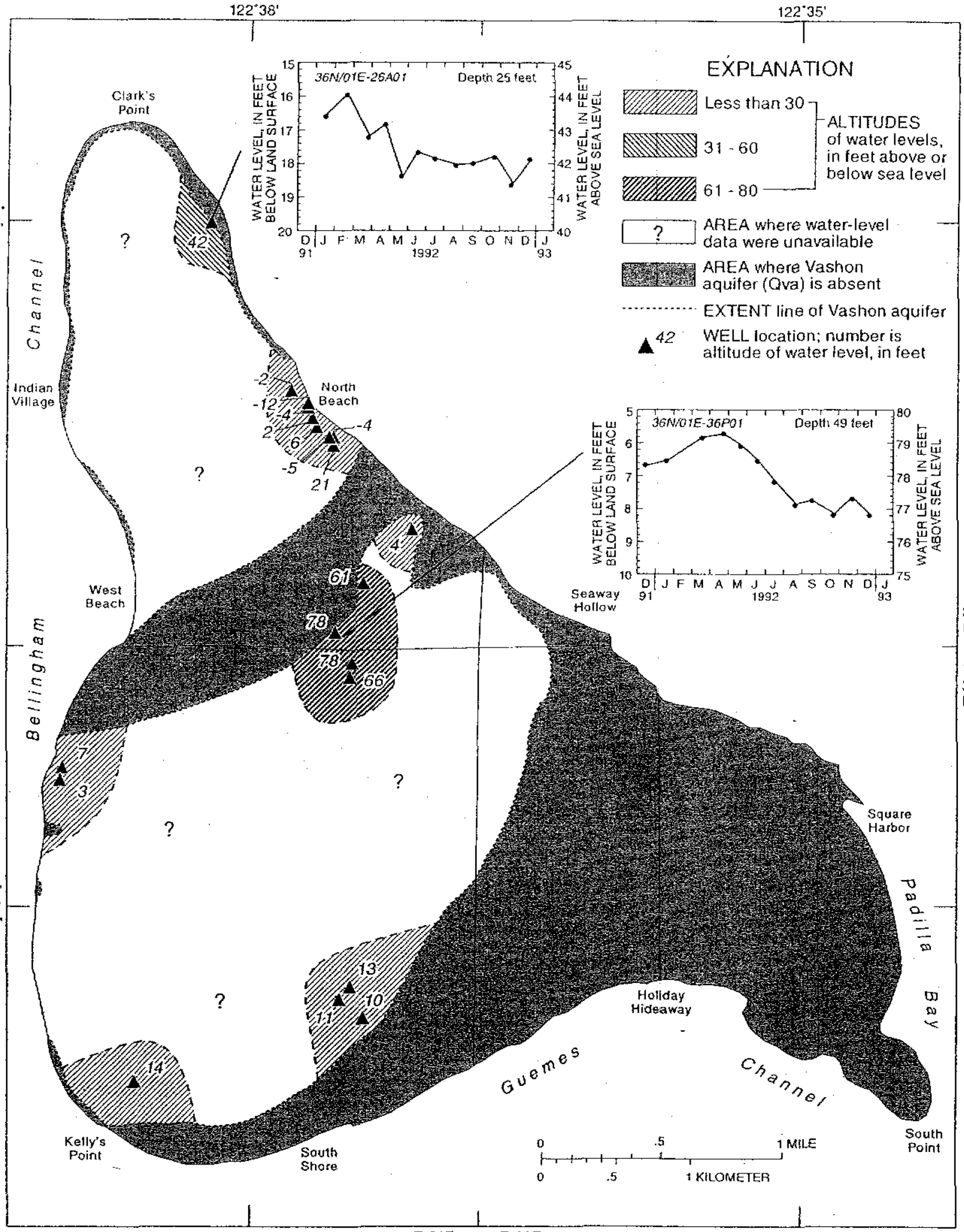


Figure 18.--Altitudes of water levels in wells completed in the Vashon aquifer (Qva), and hydrographs of water levels in selected wells, October 1991.

0549

520-38

little seasonal fluctuation, generally less than 1 foot, with slightly higher water levels occurring in late spring or early summer. Hydrographs for wells completed in the shallower Qva show seasonal fluctuations of 2 feet or more. Water levels generally were highest in late winter and early spring and lowest in summer and early fall. When graphs of precipitation data (fig. 13) are compared to hydrographs of wells in Qva, a lag of several months between periods of highest precipitation (November through January) and highest water levels (February through April) is apparent; this is likely due to impedance of recharge water by the overlying till and (or) glaciomarine drift.

Water-level fluctuations caused by marine tidal influences were recorded in two coastal wells, 35N/01E-2L01 and 36N/1E-36C04, in late December 1992 when the difference between high and low tides was at a maximum (approximately 10 feet). Ground-water levels were recorded every 5 minutes and the values were graphed and then compared with a graph of tide levels for the same period of time. Both wells are completed in Qva, are within approximately 400 feet of the shoreline, and have similar depths--64 feet for 2L01 and 54 feet for 36C04. However, the altitudes of the open intervals of the wells differ considerably, being 45 feet below sea level in 2L01 but only 9 feet below sea level in 36C04. As illustrated in figure 19, water levels in 2L01 closely follow the tidal curve, showing a large tidal influence. Well 2L01 had a maximum water-level fluctuation of approximately 7 feet while the maximum tidal fluctuation was nearly 10 feet. The water-level curve for 36C04, on the other hand, shows almost no response to the tidal influence; fluctuations in this well were less than half a foot.

The observed responses of ground-water levels to tidal fluctuations on Guemes Island result from a hydraulic connection between the aquifer(s) and the seawater of the Puget Sound and (or) from tidal loading on top of less-permeable units above the aquifer(s). Direct hydraulic connection between the aquifer and the sea causes water levels in coastal wells to rise and fall--as tides rise and fall--due to increasing or decreasing pressure on the saturated zone of the aquifer. If the aquifer is overlain by a less permeable unit, water-level changes can be caused by pressure loading transmitted through the material overlying the aquifer. Apparently, the hydraulic connection and (or) tidal loading is much greater for well 2L01 than it is for well 36C04.

SEAWATER INTRUSION

Wells in many coastal areas are in a delicate balance between rates of ground-water pumping that safely provide freshwater supplies and increased pumping rates that might result in the intrusion of seawater into near-shore aquifers. Generally, prevention or detection of seawater intrusion is desirable. Excessive salts in drinking water supplies produce unpalatable tastes and possible adverse physiological effects, are corrosive to plumbing, and may increase the cost of water treatment. Moreover, once seawater intrudes a coastal aquifer, control or reversal of the condition can be difficult and expensive. Because ground water moves slowly, remedial measures may require years or decades to take effect.

Freshwater-Seawater Relations

In order for seawater intrusion to occur, an unconfined or confined aquifer must be in hydraulic connection with the sea, and the hydraulic head of the fresh ground water must be less than that of the saline water. Around 1900, hydrologists working along coastal areas of Europe observed that saline water occurred beneath freshwater at a depth below sea level of about 40 times the height of the freshwater surface above sea level. The freshwater appeared to "float" on the seawater as a lens-shaped body. This relation, known as the Ghyben-Herzberg relation after the two scientists who first described it, occurs because the density of freshwater (1.000) is slightly less than the density of seawater (1.025).

The Ghyben-Herzberg relation states that in an homogeneous unconfined aquifer, for every 1 foot of altitude of the water table above sea level, fresh ground water will extend about 40 feet below sea level. For example, if the water table at a site is 3 feet above sea level, the freshwater-seawater interface is about 120 feet below sea level and the thickness of the freshwater zone is about 123 feet. The relation also indicates that if the water table is lowered 1 foot, the interface will rise 40 feet, thereby reducing the total thickness of the freshwater lens by 41 feet. This relation is of primary importance when considering the effects that long-term pumping or drought could have on a coastal aquifer by reducing the quantity of fresh ground water.

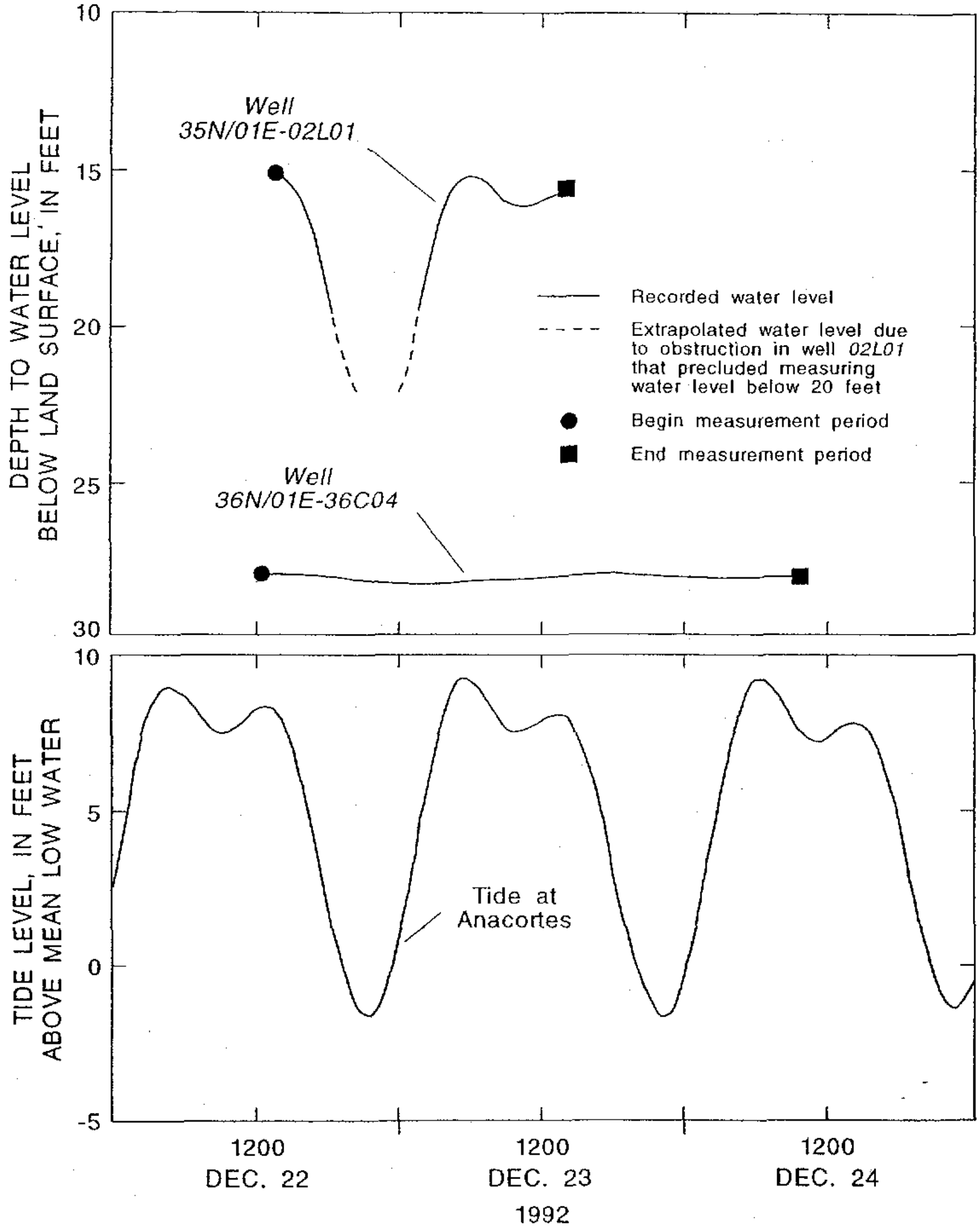


Figure 19.--Water levels in selected coastal wells on Guemes Island, and tidal fluctuations, December 22-24, 1992 (well locations shown on Plate 1).

0551

520-40

Sketches summarizing freshwater-seawater relations before and after seawater intrusion are shown in figure 20. In a confined aquifer under natural conditions, the altitude of the potentiometric surface in a coastal area is higher than sea level and decreases toward the shoreline (fig. 20a). Fresh ground water under these conditions moves downgradient toward the sea. When the potentiometric surface drops (such as from reduced rates of recharge or increased rates of pumping) and its gradient decreases (fig. 20b), the seaward flow of fresh ground water decreases and the interface moves landward and upward. Conversely, when the potentiometric surface rises, the interface moves seaward and downward.

Uncontaminated ground water in most coastal areas of Washington generally contains less than 10 mg/L of chloride, whereas seawater contains about 19,000 mg/L of chloride. For this study, chloride concentrations in excess of 100 mg/L were considered to represent seawater intrusion even though such high concentrations could actually be the result of contamination from surface sources, the presence of relict seawater, or sea spray.

Numerous wells on Guemes Island have been affected by seawater intrusion (Walters, 1971; Dion and Sumioka, 1984; D. P. Garland, Washington State Department of Ecology, written commun., 1992). The areal distribution of chloride concentrations in ground water on Guemes Island, based on field analyses of 83 samples collected during the inventory phase of this study, is shown in figure 21. Although field chloride analyses are not as precise or accurate as laboratory analyses, they give a good indication of where high chloride concentrations occur. The chloride concentrations varied from less than 20 mg/L to more than 200 mg/L. High chloride concentrations (greater than 100 mg/L) were found near West Beach, North Beach, and in the west-central part of the island. Chloride concentrations between 20 and 100 mg/L were detected near Kelly's Point, South Shore, and Holiday Hideaway.

From an islandwide perspective, significant seawater intrusion is unlikely at the present time given the small quantity of ground-water discharge that goes to pumping wells. However, the geographic distribution of the pumping wells is a critical factor in seawater intrusion. Excessive ground-water withdrawal in a near-shore area can cause large local movement of the freshwater-seawater interface especially if the aquifer is thin. The degree of seawater intrusion depends on the proximity of the well's opening to the freshwater-seawater interface, the rates of recharge and pumping, and the local permeability of the hydrogeologic unit.

Another important factor in seawater intrusion, and in the availability and storage of fresh ground water, is the thickness of the unconsolidated deposits that overlie low-permeability bedrock. The thickness of the unconsolidated deposits, or depth to bedrock, is largely unknown for most of Guemes Island. A thick assemblage of unconsolidated deposits would result in a relatively thick freshwater lens and a freshwater-seawater interface located seaward. A thin assemblage of unconsolidated deposits would result in a thinner freshwater lens and a freshwater-seawater interface located landward. In terms of seawater intrusion, a thick freshwater lens would be less likely to be affected than a thin lens, given the same near-shore pumping

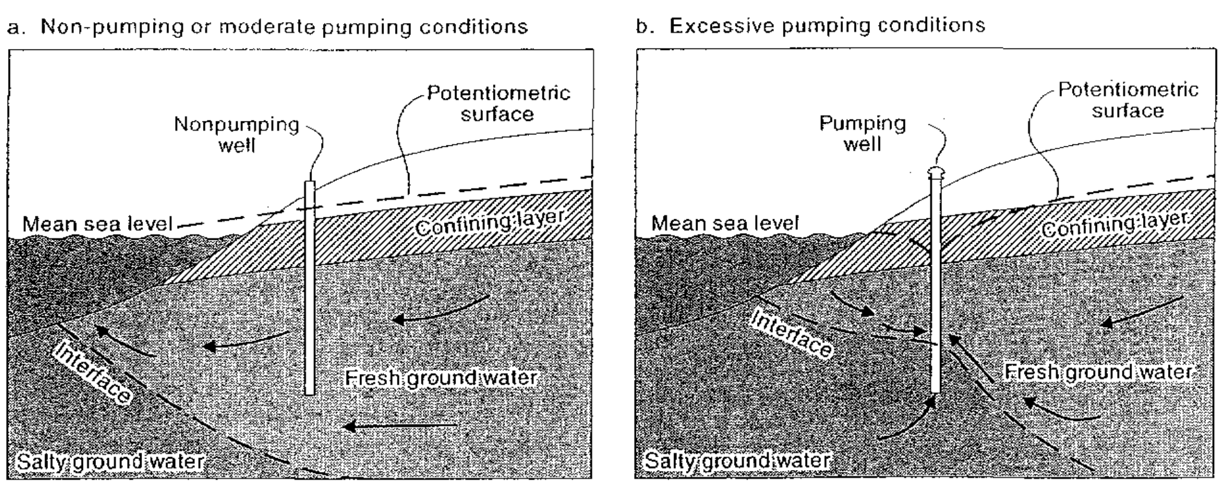


Figure 20.--Hypothetical hydrologic conditions (a) before and (b) after seawater intrusion (modified from Lum and Walters, 1976).

0552

520-41

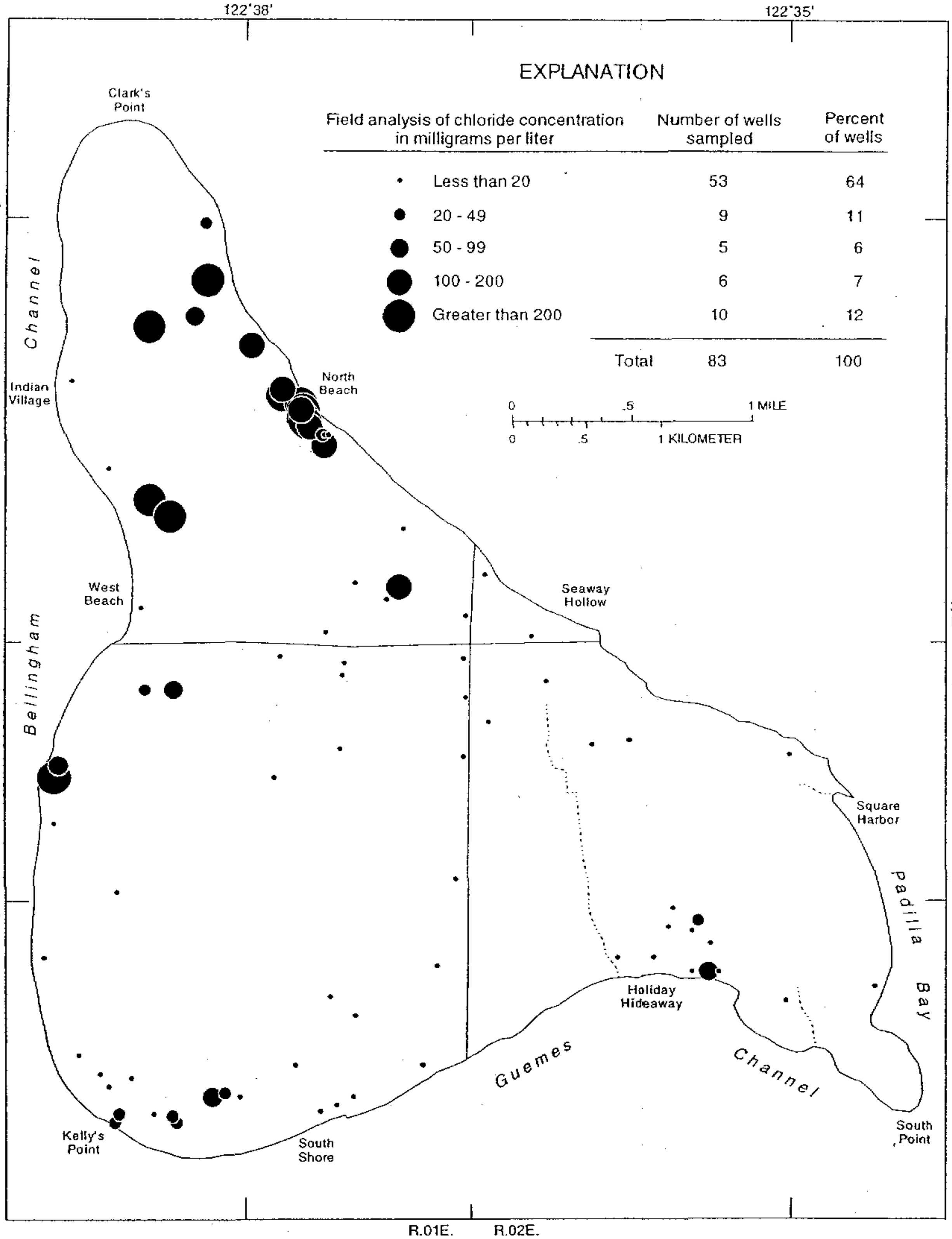


Figure 21.--Areal distribution of chloride concentrations, measured during the well and spring inventory, October 1991.

05

520-42

Sketches summarizing freshwater-seawater relations before and after seawater intrusion are shown in figure 20. In a confined aquifer under natural conditions, the altitude of the potentiometric surface in a coastal area is higher than sea level and decreases toward the shoreline (fig. 20a). Fresh ground water under these conditions moves downgradient toward the sea. When the potentiometric surface drops (such as from reduced rates of recharge or increased rates of pumping) and its gradient decreases (fig. 20b), the seaward flow of fresh ground water decreases and the interface moves landward and upward. Conversely, when the potentiometric surface rises, the interface moves seaward and downward.

Uncontaminated ground water in most coastal areas of Washington generally contains less than 10 mg/L of chloride, whereas seawater contains about 19,000 mg/L of chloride. For this study, chloride concentrations in excess of 100 mg/L were considered to represent seawater intrusion even though such high concentrations could actually be the result of contamination from surface sources, the presence of relict seawater, or sea spray.

Numerous wells on Guemes Island have been affected by seawater intrusion (Walters, 1971; Dion and Sumioka, 1984; D. P. Garland, Washington State Department of Ecology, written commun., 1992). The areal distribution of chloride concentrations in ground water on Guemes Island, based on field analyses of 83 samples collected during the inventory phase of this study, is shown in figure 21. Although field chloride analyses are not as precise or accurate as laboratory analyses, they give a good indication of where high chloride concentrations occur. The chloride concentrations varied from less than 20 mg/L to more than 200 mg/L. High chloride concentrations (greater than 100 mg/L) were found near West Beach, North Beach, and in the west-central part of the island. Chloride concentrations between 20 and 100 mg/L were detected near Kelly's Point, South Shore, and Holiday Hideaway.

From an islandwide perspective, significant seawater intrusion is unlikely at the present time given the small quantity of ground-water discharge that goes to pumping wells. However, the geographic distribution of the pumping wells is a critical factor in seawater intrusion. Excessive ground-water withdrawal in a near-shore area can cause large local movement of the freshwater-seawater interface especially if the aquifer is thin. The degree of seawater intrusion depends on the proximity of the well's opening to the freshwater-seawater interface, the rates of recharge and pumping, and the local permeability of the hydrogeologic unit.

Another important factor in seawater intrusion, and in the availability and storage of fresh ground water, is the thickness of the unconsolidated deposits that overlie low-permeability bedrock. The thickness of the unconsolidated deposits, or depth to bedrock, is largely unknown for most of Guemes Island. A thick assemblage of unconsolidated deposits would result in a relatively thick freshwater lens and a freshwater-seawater interface located seaward. A thin assemblage of unconsolidated deposits would result in a thinner freshwater lens and a freshwater-seawater interface located landward. In terms of seawater intrusion, a thick freshwater lens would be less likely to be affected than a thin lens, given the same near-shore pumping

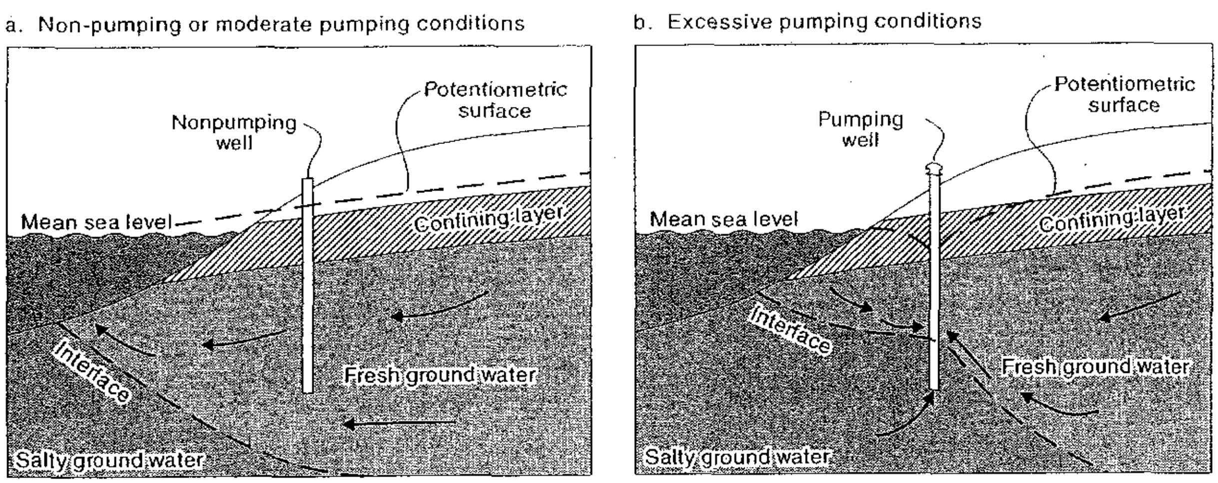


Figure 20.--Hypothetical hydrologic conditions (a) before and (b) after seawater intrusion (modified from Lum and Walters, 1976).

0554

520-43

conditions. Additionally, a thick freshwater lens would account for a greater availability of fresh ground water if the unconsolidated deposits are permeable.

Variability of Chloride Concentrations

Chloride concentrations in waters from coastal wells may vary in response to changes in the position of the freshwater-seawater interface. Factors affecting the position of the interface include the timing and quantities of pumping and recharge. Tides have a similar but much smaller effect on the position of the interface, by pushing it landward during high tide and seaward during low tide. Recent reconnaissance studies done on Lummi Island and Camano Island indicate that the differences in chloride concentrations at low and high tides are less significant than the overall increase in chloride due to the cumulative pumping duration (D. P. Garland, Washington State Department of Ecology, written commun., 1992 and 1993).

Seasonal variability of chloride concentration on Guemes Island was measured by sampling 12 coastal wells on a monthly basis from December 1991 through December 1992 (Appendix 5). Chloride concentrations varied seasonally in some wells but not in others (fig. 22). Wells yielding water with high chloride concentrations (above 100 mg/L) showed greater seasonal variability than those with low chloride concentrations. Most wells yielding water with concentrations less than 50 mg/L showed little or no seasonal variability. In general, the highest concentrations occurred from April through September, when water levels are typically declining. Similar seasonal chloride variability was observed in wells on Camano Island where chloride concentrations were highest in August and lowest from November through April (Garland and Safioles, 1988).

Chloride concentration and rate of pumping were measured by Ecology (D. P. Garland, Washington Department of Ecology, written commun., 1992) in a public-supply well (36N/01E-35G02) in West Beach, completed 20 feet below sea level, between April 1988 and October 1989. Chloride concentrations generally ranged from 400 to 600 mg/L and were highest during summer when pumping rates were highest.

QUALITY OF GROUND-WATER

In this section, the quality of the ground water on Guemes Island is described, on the basis of the results of chemical analyses of water samples collected in June 1992. Chemical concentrations and characteristics are discussed and related to hydrogeologic units, concentrations are compared with applicable U.S. Environmental Protection Agency (USEPA) drinking water standards, and causes of widespread or common water-quality problems are identified.

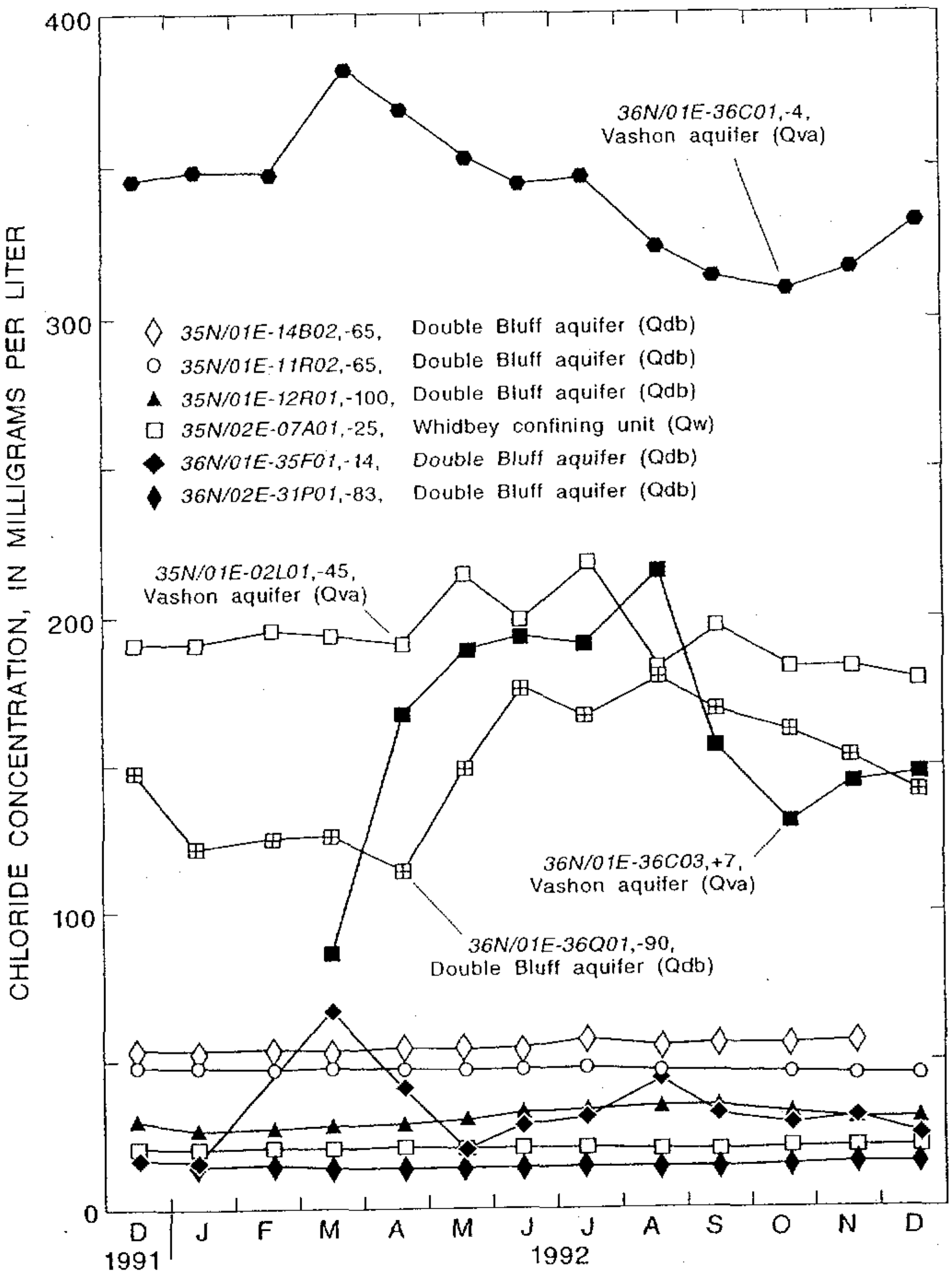
Ground-Water Chemistry

Most of the data that describe the general chemistry of the ground water are presented statistically in summary tables. Table 5 summarizes values of the common constituents determined; table 6 shows median concentration values for each of the common constituents, by hydrogeologic unit. Similar summary tables are presented for other constituents, as needed for the discussion. All supporting data are presented in Appendixes 6-8. Locations of the 24 wells from which samples were collected are shown on plate 1.

For many constituents, some concentrations may be reported as "less than" (<) a given value, where the value given is the detection limit of the analytical method. For example, the concentration of nitrate was often reported as <0.05 mg/L, where the detection limit is 0.05 mg/L. The correct interpretation of such a concentration is that the constituent was not detected at or above that particular concentration. The constituent may be present at a lower concentration, such as 0.01 mg/L, or it may not be present at all, but that is impossible to tell with the analytical method used.

<u>Specific Conductance, pH, Dissolved Oxygen, and Hardness</u>

Specific conductance is a measure of the water's ability to conduct an electric current and increases with the dissolved minerals content. The specific conductance values of the 24 samples, corrected for water temperature, ranged from 221 to 1,370 µS/cm (microsiemens per centimeter). The median specific conductance was 352 µS/cm (table 5).



EXPLANATION

36N/01E-36C01,-4, Vashon aquifer (Qva) — Local number, approximate altitude of top of open interval of well, in feet, hydrogeologic unit in which the well is open.

Figure 22.--Concentrations of chloride in water from selected wells on Guemes Island, December 1991 through December 1992.

0556

520-45

Table 5.--Summary of concentrations of common constituents, June 1992

[Concentrations in milligrams per liter unless otherwise noted. All are dissolved concentrations. Values are for samples from 24 wells unless noted; µS/cm, microsiemens per centimeter at 25 °Celsius; <, not detected at the given concentration; µg/L, micrograms per liter]

Constituent	Concentrations				
	Minimum	25th percentile	Median	75th percentile	Maximum
pH (standard units)	6.2	6.8	7.2	7.9	8.5
Dissolved oxygen[1]	.0	<.1	.7	2.4	9.2
Specific conductance (µS/cm, field)	221	266	352	586	1,370
Hardness (as $CaCO_3$)	63	91	120	170	270
Calcium	10	16	20	31	53
Magnesium	7.5	12	16	22	33
Sodium	10	13	19	72	200
Percent sodium[2]	9	18	26	53	85
Potassium	.5	1.8	3.2	5.2	11
Alkalinity (as $CaCO_3$)	48	68	128	172	286
Sulfate	<.1	10	22	36	82
Chloride	13	16	21	59	330
Fluoride	<.1	<.1	<.1	.1	.3
Silica	13	28	30	35	50
Dissolved solids[1]	141	178	236	357	760
Nitrate (as nitrogen)[1]	<.05	<.05	.08	1.3	6.8
Iron (µg/L)	10	19	160	1,170	7,100
Manganese (µg/L)	1	6	34	150	1,500

[1] Based on 23 samples.

[2] Sodium as a percentage of total cation milliequivalents.

The acidity or basicity of water is measured by pH, and is gauged on a scale from 0 to 14. A pH of 7.0 is neutral; lower values are acidic and higher values are basic. The pH values of the samples collected ranged from 6.2 to 8.5 and the median was 7.2. Wells completed in Qva generally yielded acidic waters, whereas wells completed in Qdb yielded basic waters. The median pH of waters ranged from 6.5 in Qva to 8.2 in Qw (table 6).

Dissolved-oxygen concentrations help determine the types of chemical reactions that can occur in water. Small dissolved-oxygen concentrations indicate that a chemically reducing reaction can occur, and large concentrations indicate that a chemically oxidizing reaction can occur. Dissolved-oxygen concentrations ranged from less than 0.1 to 9.2 mg/L, and the median concentration was 0.7 mg/L. As shown in table 6, median concentrations varied considerably by unit, being largest in Qva and smaller in Qsc, Qw, and Qdb. However, there was much variation within individual units.

Hardness is primarily caused by the presence of calcium and magnesium and is expressed as milligrams per liter of $CaCO_3$. The most familiar effects of hard water are poor production of lather from soap and formation of scale deposits on plumbing.

Most water samples were classified as moderately hard or hard, as defined by the following scheme (Hem, 1989):

0557

520-46

Table 6.--Median concentrations of common constituents by hydrogeologic unit, June 1992

[Hydrogeologic unit: Qsc, Surficial confining unit; Qva, Vashon aquifer; Qw, Whidbey confining unit; Qdb, Double Bluff aquifer; and Br, Bedrock. Concentrations in milligrams per liter (mg/L) unless otherwise noted. All are dissolved concentrations except pH, dissolved oxygen, and specific conductance; µS/cm, microsiemens per centimeter at 25° Celsius; <, not detected at the given concentration; µg/L, micrograms per liter]

	Hydrogeologic unit (Number of samples)				
	Qsc (1)	Qva (6)	Qw (2)	Qdb (13)	Br (2)
pH (standard units)	7.2	6.5	8.2	7.6	7.7
Dissolved oxygen	.4	2.4	<.1	.4	1.2
Specific conductance (µS/cm)	347	242	557	345	500
Hardness (as $CaCO_3$)	150	83	172	120	230
Calcium	38	18	33	19	42
Magnesium	13	10	21	18	30
Sodium	14	16	55	24	17
Percent sodium	17	29	38	27	14
Potassium	1.9	1.6	5.7	3.7	4.2
Alkalinity (as $CaCO_3$)	142	61	247	135	194
Sulfate	18	29	22	12	50
Chloride	13	18	24	27	20
Fluoride	<.1	<.1	.2	.1	<.1
Silica	13	30	29	32	30
Dissolved solids	199	165	341	[1]234	311
Nitrate (as nitrogen)	.55	1.0	<.05	[1]<.05	.06
Iron (µg/L)	33	19	971	500	157
Manganese (µg/L)	36	3	54	150	20
Arsenic (µg/L)	<1	<1	1	<1	<1

[1] Based on 12 samples.

Description	Hardness range (milligrams per liter of $CaCO_3$)	Number of samples	Percentage of samples
Soft	0-60	0	0
Moderately hard	61-120	13	54
Hard	121-180	6	25
Very hard	Greater than 180	5	21
		24	100

Dissolved Solids

The concentration of dissolved solids is the sum of the concentrations of all the minerals dissolved in the water. The major components of dissolved solids depend on many factors, but usually include calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, nitrate, and silica. Other constituents, such as carbonate and fluoride, or metals such as iron and manganese, are also components but rarely are found in large enough concentrations to make a significant difference in comparison with the major components.

0558

520-47

Dissolved-solids concentrations ranged from 141 to 760 mg/L, with a median concentration of 236 mg/L (table 5), and the concentrations tended to be larger in the deeper (older) units (table 6). Some of this variation is because of different geologic material in the units, but some is likely due to increased residence time of water in the deeper units. Water that has been in the ground for a longer time generally has had the opportunity to dissolve more minerals than water with a shorter residence time.

The areal distribution of dissolved-solids concentrations varied widely (fig. 23). A few wells near the shore had dissolved-solid contents greater than 400 mg/L, possibly because of seawater intrusion.

Major Ions

Most of the major components of dissolved solids are ions, meaning they have an electrical charge. Cations have a positive charge and include calcium, magnesium, sodium, potassium, and most metals. Anions have a negative charge and include bicarbonate, sulfate, chloride, nitrate, carbonate, and fluoride. Silica has no charge.

In Guemes Island ground water, the median concentration of dissolved calcium (table 5) was 20 mg/L, the largest of any of the cations. Magnesium and sodium had median concentrations of 16 and 19 mg/L, respectively, and account for most of the remaining cations. The median concentration of potassium was 3.2 mg/L.

The anion having the largest median concentration was bicarbonate, as indicated by the median alkalinity concentration of 128 mg/L (table 5). Alkalinity is attributed to the activities of bicarbonate, carbonate, and hydroxide, but the concentrations of each are dependent upon pH. At all pH values observed, bicarbonate is the major component of alkalinity. The largest alkalinity concentration observed in the study area was 286 mg/L, in a sample from well 35N/02E-07H04, which is completed in Qw. The median concentrations of sulfate, chloride, nitrate, and fluoride were small compared with alkalinity.

Chloride

Large chloride concentrations can indicate water-quality problems such as seawater intrusion, contamination from septic tank effluent, or the presence of connate water. Concentrations greater than about 250 mg/L commonly impart a salty taste. The distribution of chloride concentrations for June 1992 is shown in figure 24. Chloride concentrations in samples from wells in the central part of the island were generally less than 20 mg/L. Concentrations greater than 100 mg/L were found only in samples from wells in near-shore areas. Chloride concentrations islandwide ranged from 13 to 330 mg/L, with a median concentration of 21 mg/L (table 5). The range of median concentration by unit was small, from 13 mg/L in Qsc to 27 mg/L in Qdb (table 6). The chloride data from these 24 samples are consistent with the inventory data collected in October 1991. All of the chloride concentrations are above the background concentrations of 3 to 5 mg/L typically found in ground water in other parts of western Washington. A source of chloride other than seawater intrusion may be affecting ground water in Guemes Island wells not located in near-shore areas.

Chloride concentrations in water from some coastal wells in North Beach and West Beach exceeded 200 mg/L. Concentrations as large as 330 mg/L, in a sample from well 36N/01E-36C01, were found in these areas. Concentrations at Kelly's Point and along South Shore range from 17 to 100 mg/L.

Nitrate

Large concentrations of nitrate may indicate ground-water contamination from septic tanks, animal wastes, or fertilizer. Concentrations of nitrate greater than 10 mg/L may cause a sometimes fatal disease in infants. The actual analysis for nitrate includes both nitrite and nitrate; however, nitrite concentrations in ground water are usually much smaller than nitrate concentrations (National Research Council, 1978). The values determined, therefore, are considered to be mostly nitrate.

Concentrations ranged from less than 0.05 mg/L to 6.8 mg/L, but the median concentration was only 0.08 mg/L (table 5). Concentrations in most samples were 1.0 mg/L or less. Two areas appear to have nitrate concentrations generally exceeding 1.0 mg/L: near Indian Village and along North Beach (fig. 25); both areas are relatively densely populated. The values determined for the island are generally smaller than those reported for other parts of western Washington. Median nitrate concentrations have been reported as 0.16 mg/L in Clark County (Turney, 1990), 0.33 mg/L in Thurston County (Dion and others, 1994), and 0.10 mg/L or greater for much of the Puget Sound area (Turney, 1986).

The nitrate in the Guemes Island ground water probably originated from such local sources as septic tanks, lawn fertilizers, or domestic farm animals. Usually, shallow wells (less than 100 feet deep) are more susceptible to nitrate contamination than deeper wells. However, five of the seven wells where samples had nitrate

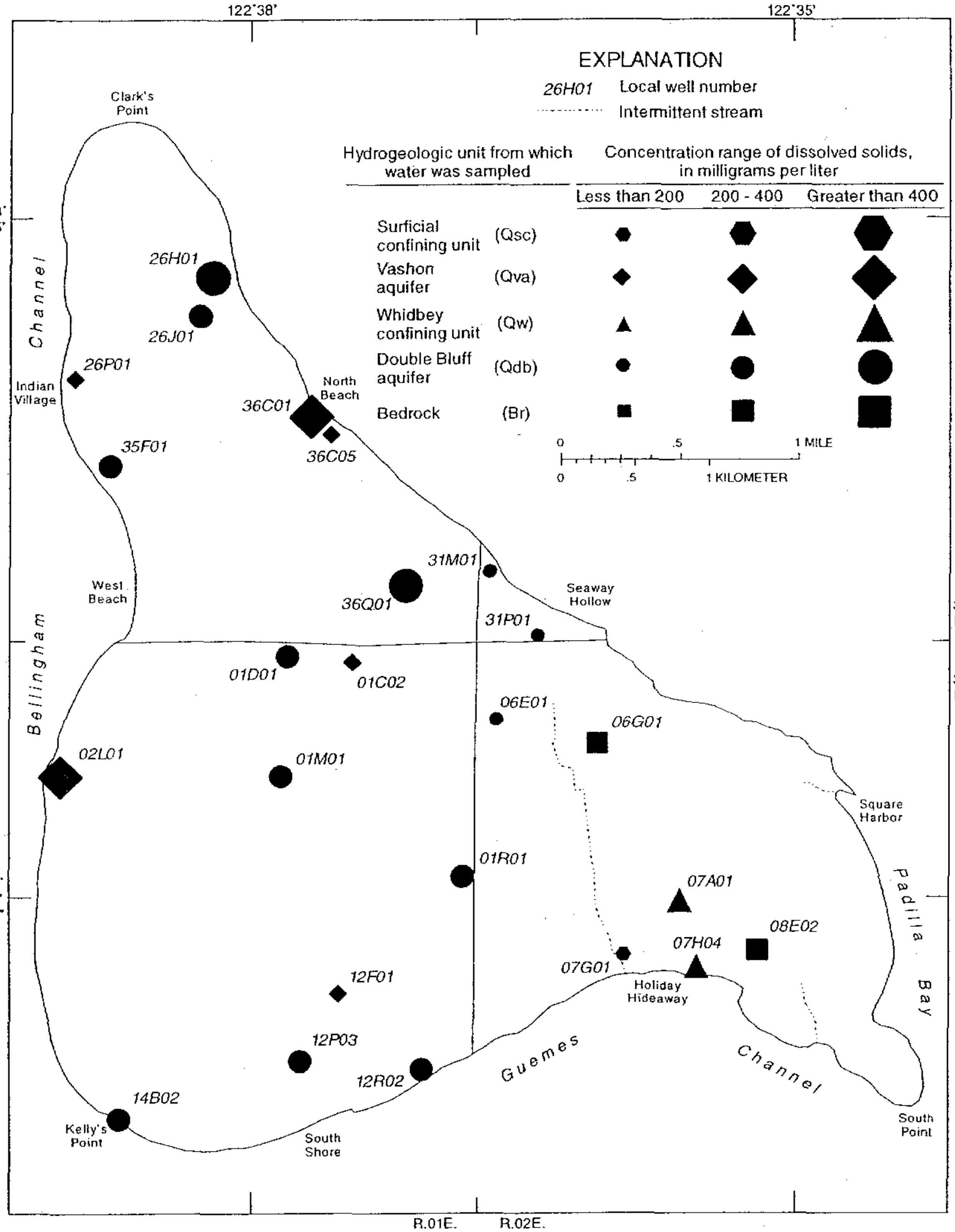


Figure 23.--Areal distribution of dissolved-solids concentrations, June 1992.

0560

520-49

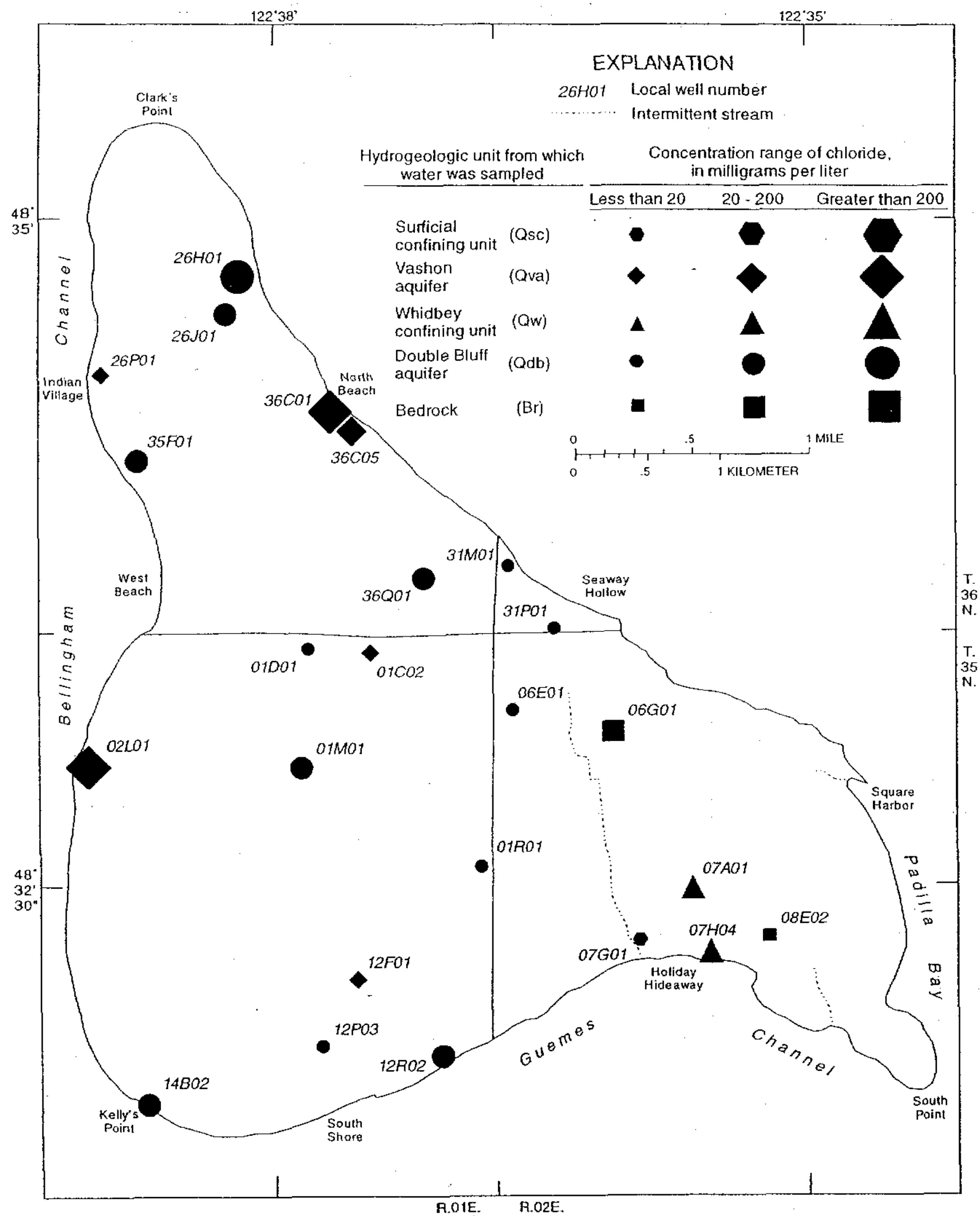


Figure 24.--Areal distribution of chloride concentrations, June 1992.

056

520-50

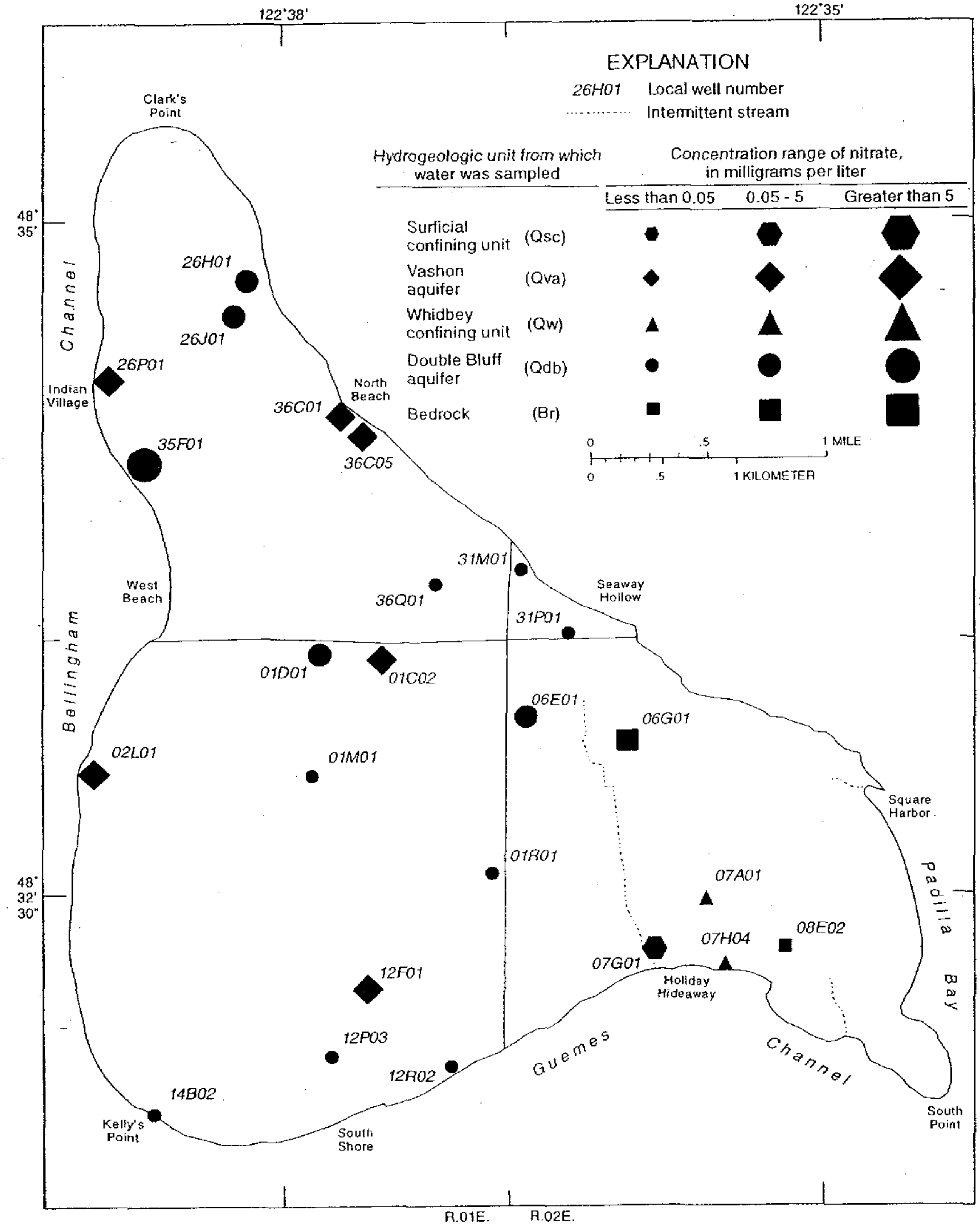


Figure 25.--Areal distribution of nitrate concentrations, June 1992.

0562

520-51

concentrations exceeding 1.0 mg/L were more than 100 feet deep. In fact, the maximum concentration of nitrate (6.8 mg/L) was detected in a sample from well 36N/01E-35F01, which is 182 feet deep. Nitrate concentrations in samples from several nearby deep wells, such as wells 36N/01E-26H01, 36N/01E-26J01, and 36N/01E-35F01 at Indian Village and North Beach, indicate areal rather than point-source contamination. Deeper wells may contain nitrate from local sources, but the cause of contamination is often poor well construction that allows seepage of contaminated surface water into the ground along the well casing. This may be the case at wells 35N/01E-12F01 and 35N/02E-06E01 in the central part of the island. Overall, there was no strong correlation of nitrate concentration with either hydrogeologic unit or well depth on the island.

Iron and Manganese

Concentrations of iron and manganese greater than 300 µg/L and 50 µg/L, respectively, commonly stain plumbing fixtures and give water a poor taste. Iron concentrations ranged from 10 to 7,100 µg/L, with a median concentration of 160 µg/L (table 5). Median concentrations were smaller in Qsc, Qva, and Br, and larger in Qw and Qdb (table 6). All but one of the samples with iron concentrations greater than 300 µg/L were from wells completed in Qdb, whereas most samples from Qva had concentrations much lower than 300 µg/L (fig. 26).

Manganese concentrations ranged from 1 µg/L to 1,500 µg/L, and the median concentration was 34 µg/L (table 5). Like iron, the median concentration for individual units was largest for samples from Qw and Qdb. Manganese concentrations followed the same general pattern as iron concentrations.

The variation and range of iron and manganese concentrations seen on the island are typical of western Washington ground waters (Van Denburgh and Santos, 1965; Turney, 1986, 1990; Dion and others, 1994), although the median values are somewhat larger. Ground-water samples from studies in Thurston, east King, and Whatcom Counties had median iron concentrations of 23, 24, and 38 µg/L, and median manganese concentrations of 5, 17, and 10 µg/L (Dion and others, 1994; Turney and others, 1995; and S. E. Cox, U.S. Geological Survey, written commun., 1993). Large iron and manganese concentrations are due typically to natural processes. These processes depend closely upon ambient geochemical conditions, in particular the concentration of dissolved oxygen. Water that is depleted of oxygen will dissolve iron from the surrounding minerals as the chemically reduced ferrous (Fe^{2+}) form of iron. Iron is highly soluble under these conditions and large concentrations can result. If the water is reoxygenated, the iron is oxidized to the ferric (Fe^{3+}) form, which is much less soluble than the ferrous form and will precipitate as an oxide or a carbonate, resulting in a smaller dissolved-iron concentration. Manganese undergoes a similar set of reactions. Because these reactions are oxygen-sensitive and the oxygen content of the ground water may vary considerably in a given area, dissolved iron and manganese concentrations also may vary greatly.

Trace Constituents

Concentrations of most trace constituents were small. For all except barium and zinc, the median concentrations were less than 1 µg/L (table 7). Arsenic was detected in 5 of 24 samples, with concentrations of 1 µg/L in 4 samples and a concentration of 14 µg/L in the fifth sample, from well 36N/01E-36Q01. The sample from well 36Q01 also had one of the largest concentrations of dissolved solids (574 mg/L) and chloride (180 mg/L) on the island. The U.S. Environmental Protection Agency (USEPA) currently has set the maximum contaminant level (MCL) for arsenic at 50 µg/L; however, that value is being reviewed and may be lowered to 3 µg/L or less.

The source of the arsenic in the ground water is probably natural. Arsenic is present to some degree in many igneous rocks, which are the source material for much of the unconsolidated deposits in the Puget Lowland. Furthermore, arsenic tends to concentrate in alumino-silicate minerals and igneous rocks that contain iron oxides (Welch and others, 1988), both of which are present in the study area. Elevated concentrations of arsenic have been documented in nearby areas of western Washington and are thought to be due to natural conditions. In particular, on the north end of nearby Lummi Island, concentrations commonly ranging from 30 to 50 µg/L but as large as 465 µg/L were reported in water from numerous wells (D. P. Garland, Washington Department of Ecology, written commun., 1993; V. A. Stern, Washington Department of Health, written commun., 1993).

Barium, which occurs naturally, was present in five samples, ranging in concentration from 15 to 63 µg/L (table 7); the median concentration was 48 µg/L. Zinc was also present in all samples, but the concentrations varied greatly, ranging from 6 to 540 µg/L. A major anthropogenic source of zinc is the pipe used in wells and in home plumbing systems. Concentrations of barium and zinc were well within applicable drinking water regulations in all cases.

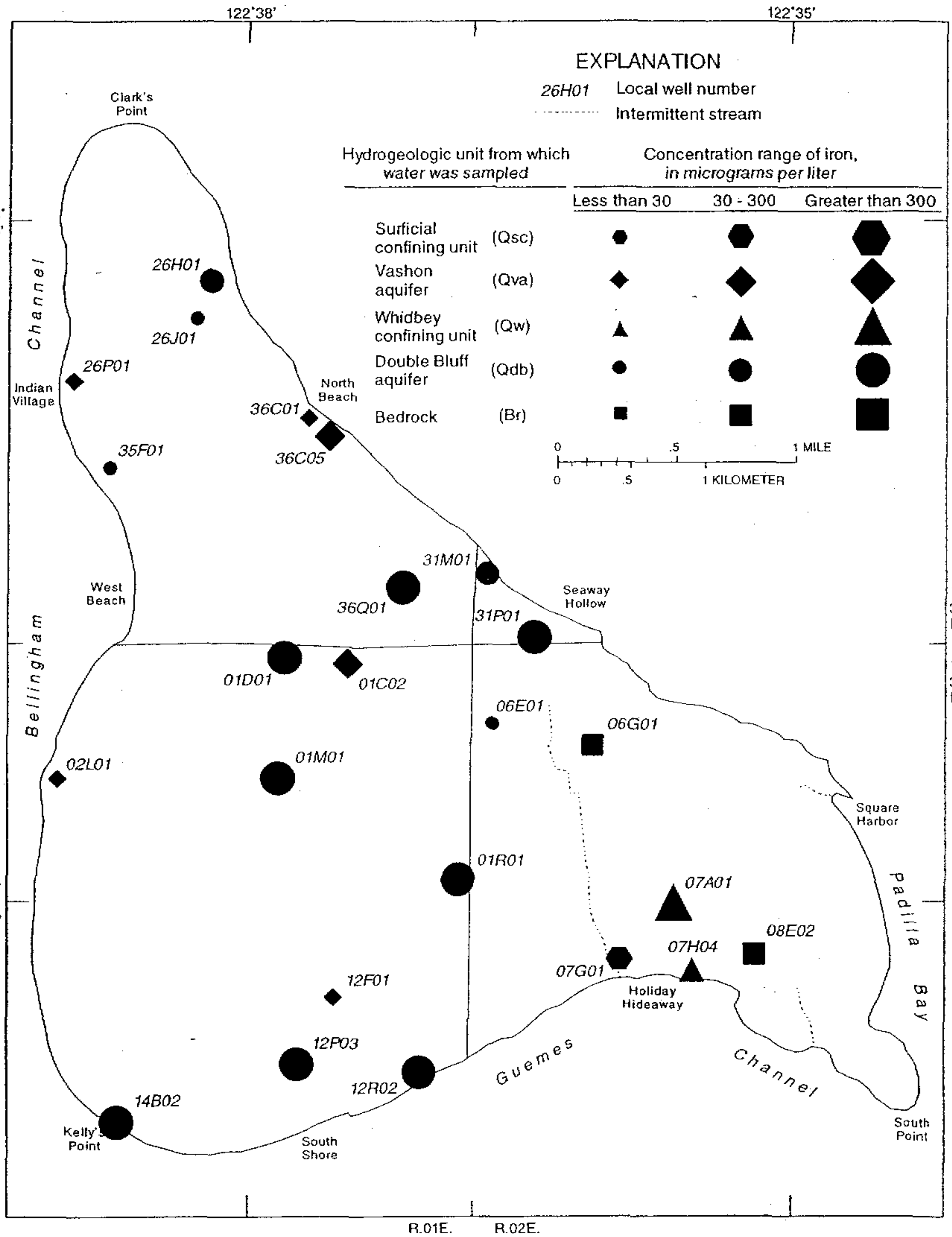


Figure 26.--Areal distribution of iron concentrations, June 1992.

056

520-53

Table 7.--Summary of concentrations of selected trace constituents, June 1992

[Concentrations in micrograms per liter unless otherwise noted. All are dissolved concentrations. <, not detected at the given concentration; pCi/L, picocuries per liter]

Constituent	Number of samples	Concentrations Minimum	Median	Maximum	Wells with trace constituent present Number	Percent
Arsenic	24	<1	<1	14	5	21
Barium	5	15	48	63	5	100
Cadmium	5	<1	<1	<1	0	0
Chromium	5	<1	<1	1	1	20
Copper	5	<1	<1	4	1	20
Lead	5	<1	<1	<1	0	0
Mercury	5	<.1	<.1	<.1	0	0
Selenium	5	<1	<1	2	1	20
Silver	5	<1	<1	<1	0	0
Zinc	5	6	200	540	5	100
Radon (pCi/L)	5	<80	120	390	3	60

Radon concentrations ranged from less than 80 pCi/L (picocuries per liter) to 390 pCi/L, with a median concentration of 120 pCi/L. The picocurie is a measure of radioactivity, not mass. Radon is a naturally occurring element and is part of the radioactive decay chain of uranium. The USEPA has proposed an MCL of 300 pCi/L. However, the radon concentrations observed on Guemes Island are considerably less than those found in ground water in Thurston and King Counties, where median radon concentrations were 410 and 250 pCi/L, respectively (Dion and others, 1994; Turney and others, 1995).

The remaining trace elements are rarely present, and when present are not significant chemically or in terms of health. Chromium was present in one sample, from well 35N/02E-08E02, but at a concentration of only 1 μg/L. Such levels likely reflect the natural occurrence of chromium in the mineral matrix. Copper and selenium were present only in the sample from well 36N/01E-26J01, at concentrations of 4 and 2 μg/L, respectively. The source for copper is likely plumbing systems because, like zinc, it is commonly used in pipe and fixtures. Selenium, on the other hand, is probably naturally occurring and may be associated with seawater intrusion or connate water; selenium at small concentrations is a natural component of seawater. Finally, cadmium, lead, mercury, and silver were not detected in any samples.

Volatile Organic Compounds

The individual volatile organic compounds analyzed for are shown in table 8. The presence of any of these volatile organic compounds is generally considered to represent some type of anthropogenic source. The wells sampled for volatile organic compounds were selected because they are located in populated areas. Trace concentrations of volatile organic compounds were detected in three of the samples collected from five wells (table 9).

Trichloromethane and 1,1,1-trichloroethane, both commonly used as solvents, were detected at 0.2 μg/L in water from wells 36N/01E-36C05 and 35N/O1E-02L01, respectively (table 9). Benzene, which is present in gasoline, was detected in water from well 36N/01E-26P01 at 0.2 μg/L. Possible sources of these volatile organic compounds include sampling and laboratory contaminants, accidental spills, improper disposal, and in the case of benzene, leaking fuel storage tanks. All samples containing a volatile organic compound were taken from shallow wells ranging in depth from 26 to 64 feet. The two samples that had no volatile organic compounds detected were both from relatively deep wells (90 and 114 feet). It is important to recognize, however, that the compounds detected were at low concentrations and that resampling would be needed in order to verify their presence or absence.

0365

520-54

Table 8.--Volatile organic compounds analyzed, June 1992

[Volatile organic compounds listed below are those analyzed for in samples from five wells. Except for those noted on table 8, none was present at the detection limit of 0.2 micrograms per liter]

Constituents	
Chloromethane	2,2-dichloropropane
Dichloromethane	1,2,3-trichloropropane
Trichloromethane	1,2-dibromo,3-chloropropane
Tetrachloromethane	Propenol
Bromomethane	1,1-dichloropropene
Bromochloromethane	Cis-1,3-dichloropropene
Dibromomethane	Trans-1,3-dichloropropene
Tribromomethane	Hexachlorobutadiene
Bromodichloromethane	2-chloroethylvinylether
Dibromochloromethane	Tert-butylmethylether
Trichlorofluoromethane	Benzene
Dichlorodifluoromethane	Chlorobenzene
Chloroethane	1,2-dichlorobenzene
1,1-dichloroethane	1,3-dichlorobenzene
1,2-dichloroethane	1,4-dichlorobenzene
1,1,1-trichloroethane	1,2,3-trichlorobenzene
1,1,2-trichloroethane	1,2,4-trichlorobenzene
1,1,1,2-tetrachloroethane	Bromobenzene
1,1,2,2-tetrachloroethane	Toluene
1,2-dibromoethane	o-chlorotoluene
Trichlorotrifluoroethane	p-chlorotoluene
Chloroethene	Dimethylbenzene
1,1-dichloroethene	Ethylbenzene
Cis-1,2-dichloroethene	Ethenylbenzene
Trans-1,2-dichloroethene	1,2,4-trimethylbenzene
Trichloroethene	1,3,5-trimethylbenzene
Tetrachloroethene	N-propylbenzene
Cyanoethene	Isopropylbenzene
1,2-dichloropropane	N-butylbenzene
1,3-dichloropropane	Sec-butylbenzene
	Tert-butylbenzene
	1,methyl-4-propylbenzene
	Naphthalene

0566

520-55

Table 9.--Concentrations of volatile organic compounds in wells where they were detected
[Hydrogeologic unit: Qva, Vashon aquifer]

Local well number	Depth of well (feet)	Hydrogeo-logic unit	Constituent	Concentration (micrograms per liter)
35N/01E-02L01	64	Qva	1,1,1-trichloroethane	0.2
36N/01E-26P01	26	Qva	Benzene	.2
36N/01E-36C05	41.5	Qva	Trichloromethane	.2

Septage-Related Compounds

Methylene blue active substances (MBAS) and boron are present in household waste water as detergent residues, and have been identified in septage-contaminated ground water (LeBlanc, 1984). Boron is also present in seawater and rocks, however, and its presence does not necessarily indicate septage contamination. The presence of MBAS or boron in ground water, if found in conjunction with nitrate, may indicate contamination from septic systems. Concentrations of MBAS and boron were determined for samples from 12 wells, mostly situated in the more populated areas of the island, and are included in Appendix 8.

MBAS was detected at small concentrations (0.02 and 0.03 mg/L) in water from two wells: 36N/01E-26P01 and 36N/01E-36C05. Nitrate was present in the same samples at the relatively high concentrations of 4.80 and 1.90 mg/L, respectively.

Boron concentrations ranged from 20 to 420 µg/L, with a median concentration of 50 µg/L. Boron concentrations measured during this study correlated poorly with MBAS and nitrate concentrations. In fact, small concentrations of boron (20 µg/L) were measured in samples from wells with detectable concentrations of MBAS (36N/01E-26P01 and 36N/01E-36C05). Samples with the three largest boron concentrations (420, 120, and 110 µg/L) were from wells 35N/02E-07H04, 36N/01E-26H01, and 36N/01E-36C01, respectively, which had MBAS concentrations below the 0.02 µg/L detection limit. Nitrate, however, although undetected in the sample from well 35N/02E-07H04, was detected in the other samples at 3.40 and 0.75 mg/L, respectively.

Bacteria

Fecal-streptococci bacteria were detected in water from 1 of the 24 wells sampled; fecal-coliform bacteria were not detected in any of the sampled wells. Both types of bacteria are indicators; that is, they are not pathogenic themselves, but can occur in conjunction with pathogenic bacteria. The only sample with bacteria present was from a 35-feet deep dug well (35N/02E-07G01).

Water Types

Another way to describe the composition of water is to determine the water types (or dominant ions) from the analytical results. First, concentrations of the major ions are converted from milligrams, which are based on mass, to milliequivalents, which are based on the number of molecules and electrical charge. A milliequivalent is the amount of a compound, in this case one of the ions, that either furnishes or reacts with a given amount of H^+ or OH^-. When expressed as milliequivalents, all cations or anions are equivalent for the purpose of balancing equations; a milliequivalent of sulfate will balance a milliequivalent of calcium. The milliequivalents of all the cations and anions are each summed to obtain a cation sum and anion sum, in milliequivalents. Because the water is electrically neutral, the cation and anion sums should be close in value. The contribution of each ion to the appropriate sum is then calculated as a percentage. The cation(s) and anion(s) that are the largest contributors to their respective sums define the water types.

To make the determination of water types easier, the percentages of cations and anions for a given sample, as milliequivalents, are plotted on a trilinear, or Piper, diagram, as shown in figure 27. The water type is then determined from the area of the diagram in which the sample is plotted. One plot defines the dominant cation, the other the dominant anion. Combined water types, where more than one cation or anion dominate, are possible and are actually common. An inspection of the explanation diagram in figure 27 shows that to be defined as a dominant ion, an ion must account for 50 percent or more of the cation or anion sum, and the analysis will be plotted near one of the corners. On the other hand, an ion that accounts for less than 20 percent of the sum will not be included in the water type. An exception to the latter case occurs when two ions, such as chloride and nitrate, are included on a single axis of the plot. If both together contribute 20 percent, then the sample will plot as though chloride is a dominant anion, even though chloride and nitrate contributions individually may be less than 20 percent. For this study, the actual percentages were used to determine the water type, and if both were less than 20 percent neither was considered dominant. Also, for combined water types, the ions were listed in order of dominance. For example, a calcium-magnesium bicarbonate type has more calcium than magnesium, and a magnesium-calcium bicarbonate type has more magnesium than calcium, but both plot in the same section of the diagram. It also should be noted that the diagram, which is based on percentages, does not show actual concentrations or milliequivalents.

All 24 samples were plotted on a single trilinear diagram (fig. 27) with a different symbol representing each hydrogeologic unit. Samples with magnesium and calcium as the dominant cations and bicarbonate as the dominant anion were fairly common throughout the study area. Such water types are common in aquifers made up of the glacial and interglacial deposits of western Washington (Van Denburgh and Santos, 1965; Turney, 1986; Dion and others, 1994). High percentages of sodium, chloride, and sulfate may indicate varying degrees of seawater intrusion, or possibly the presence of incompletely flushed connate water. Five samples, from wells 35N/01E-02L01, 36N/01E-26H01, 36N/01E-26J01, 36N/01E-36C01, and 36N/01E-36Q01, had sodium chloride water types, a possible indication of seawater intrusion.

Drinking Water Regulations

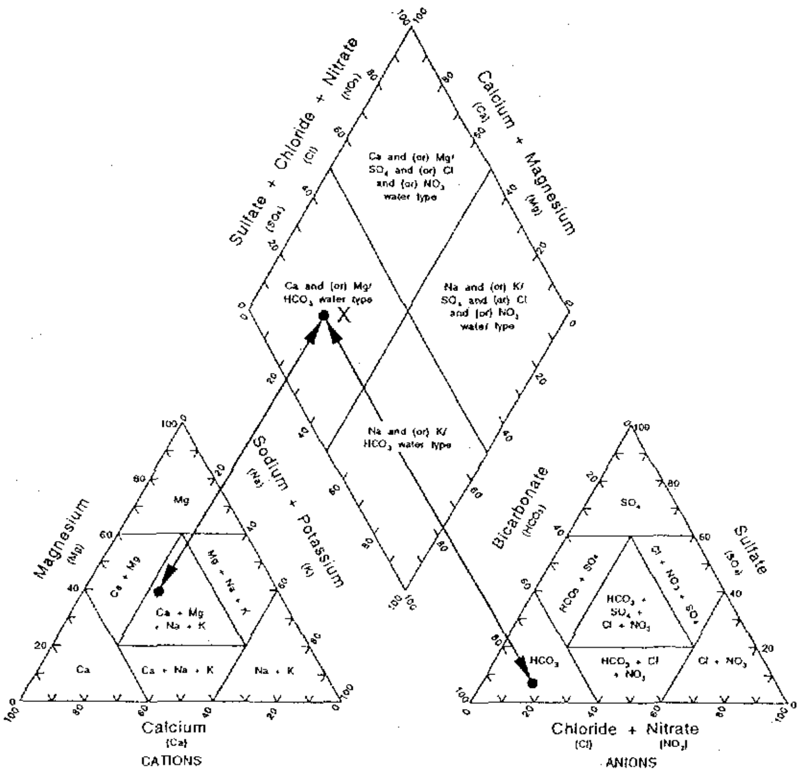
The USEPA establishes maximum concentrations of constituents allowed in public drinking water. Primary drinking water regulations concern constituents that affect human health. The maximum concentration allowed for each constituent is referred to by USEPA as the maximum contaminant level, or MCL (U.S. Environmental Protection Agency, 1988a, 1988b, 1989, 1991), and is legally enforceable by the USEPA or State regulatory agencies. Secondary drinking water regulations (U.S. Environmental Protection Agency, 1988c, 1991) pertain to the esthetic quality of water and are guidelines only. A secondary maximum contaminant level, or SMCL, is not enforceable by a Federal agency. Both sets of regulations legally apply only to public supplies, but also can be used to help assess the quality of water from private systems.

The drinking water regulations for all constituents analyzed in this study are shown in table 10. Because the standards are subject to revision, this report will use the MCL or SMCL in effect at the time the samples were collected. Along with each MCL or SMCL, the number of wells from which samples did not meet the standard is also shown in table 10.

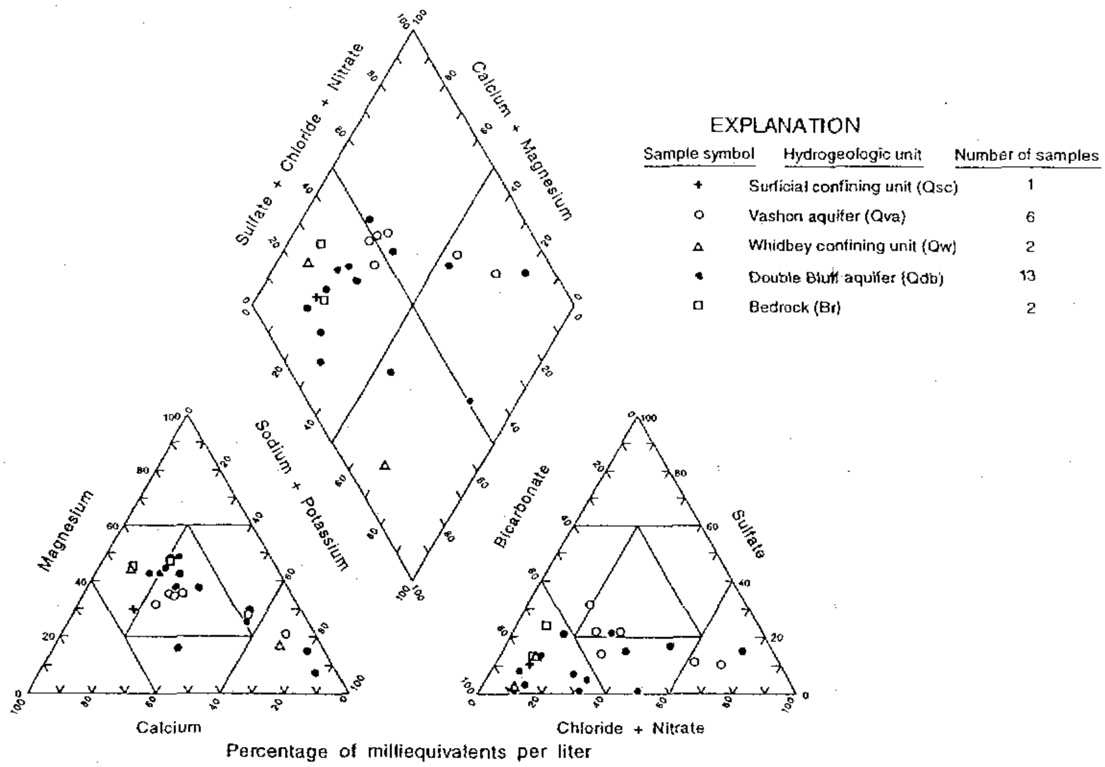
None of the primary MCLs was exceeded during this study. However, if the USEPA lowers the MCL for arsenic to 3 µg/L or less, as proposed, the sample from one well (36N/01E-36Q01) would exceed it. The current arsenic MCL of 50 µg/L is based on the concentration at which chronic arsenic poisoning can occur if continually ingested. The USEPA is considering lowering the current MCL because it does not take into account the carcinogenic effects of arsenic. Total-coliform bacteria were not analyzed for, but fecal-coliform bacteria, which are a subgroup of total coliform, were not detected in any of the samples.

Of 24 wells sampled, samples from 11, or 46 percent, did not meet the manganese SMCL of 50 µg/L. However, as described elsewhere, these large manganese concentrations occur naturally and are common in the ground waters of Puget Lowland. The SMCL for manganese is based on the level at which staining of laundry and plumbing fixtures may occur; the stain is usually black or purple. In addition, the taste of the water may be affected at concentrations greater than 50 µg/L. Extremely large concentrations of manganese may cause human health problems, but no such instances have ever been reported in the United States (U.S. Environmental Protection Agency, 1986).

Concentrations of iron in samples from nine wells (38 percent) did not meet the SMCL for iron of 300 µg/L. As with manganese, these large concentrations are likely due to natural causes. Iron concentrations exceeding the SMCL may cause an objectionable taste and may stain plumbing fixtures a characteristic red or brown color.



Example of a trilinear diagram, showing water types represented in each area. Numbers are percentages. Example "X" is a magnesium-calcium-sodium/bicarbonate water type



Chemical character of ground water on Guemes Island based on percentage of major ions.

Figure 27.--Trilinear diagrams showing the chemical character of ground water from 24 wells on Guemes Island, June 1992.

0569

5 20-58

Table 10.--Drinking water regulations and the number of samples not meeting them
[mg/L, milligrams per liter; µg/L, micrograms per liter; cols. per 100 mL, colonies per 100 milliliters]

Constituent	Maximum contaminant level (MCL) or secondary MCL (SMCL)	Number of wells with samples not meeting MCL or SMCL	Percentage of wells not meeting MCL	Total number of wells sampled
	Primary drinking water regulations			
Inorganic				
Fluoride	4 mg/L	0	0	24
Nitrate (as nitrogen)	10 mg/L	0	0	23
Arsenic	50 µg/L	0	0	24
Barium	2,000 µg/L	0	0	5
Cadmium	5 µg/L	0	0	5
Chromium	100 µg/L	0	0	5
Lead	50 µg/L	0	0	5
Mercury	2 µg/L	0	0	5
Selenium	50 µg/L	0	0	5
Silver	50 µg/L	0	0	5
Organic				
Trihalomethanes[1]	100 µg/L	0	0	5
Tetrachloromethane	5 µg/L	0	0	5
1,2-dichloroethane	5 µg/L	0	0	5
1,1,1-trichloroethane	200 µg/L	0	0	5
1,2-dibromoethane	.05 µg/L	0	0	5
Chloroethene	2 µg/L	0	0	5
1,1-dichloroethene	7 µg/L	0	0	5
Cis-1,2-dichloroethene	70 µg/L	0	0	5
Trans-1,2-dichloroethene	100 µg/L	0	0	5
Trichloroethene	5 µg/L	0	0	5
Tetrachloroethene	5 µg/L	0	0	5
1,2-dichloropropane	5 µg/L	0	0	5
Benzene	5 µg/L	0	0	5
Chlorobenzene	100 µg/L	0	0	5
1,2-dichlorobenzene	600 µg/L	0	0	5
1,3-dichlorobenzene	600 µg/L	0	0	5
1,4-dichlorobenzene	75 µg/L	0	0	5
Toluene	1,000 µg/L	0	0	5
Xylene	10,000 µg/L	0	0	5
Ethylbenzene	700 µg/L	0	0	5
Ethenylbenzene	100 µg/L	0	0	5
Microbiological				
Total coliform	0 cols. per 100 mL	0	0	24

0570

520-59

Table 10.--Drinking water regulations and the number of samples not meeting them--Continued

Constituent	Maximum contaminant level (MCL) or secondary MCL (SMCL)	Number of wells with samples not meeting MCL or SMCL	Percentage of wells not meeting MCL	Total number of wells sampled
	Secondary drinking water regulations			
Inorganic				
pH	6.5-8.5 units	1	4	24
Sulfate	250 mg/L	0	0	24
Chloride	250 mg/L	2	8	24
Fluoride	2 mg/L	0	0	24
Dissolved solids	500 mg/L	4	17	24
Iron	300 μg/L	9	38	24
Manganese	50 μg/L	11	46	24
Copper	1,000 μg/L	0	0	24
Silver	100 μg/L	0	0	5
Zinc	5,000 μg/L	0	0	5
Organic				
MBAS (methylene blue active substances)	.5 mg/L	0	0	12

[1] Includes trichloromethane, tribromomethane, bromodichloromethane, and dibromochloromethane.

Only 1 of the 24 samples had a pH value (6.2) outside the acceptable range of 6.5 to 8.5. The pH range used in the SMCL is based largely on the acceptable range for marine aquatic life, which is not readily applicable to ground-water systems. Water with a pH range from 5 to 9 is usually considered acceptable for domestic uses (U.S. Environmental Protection Agency, 1986). Water with small pH values may be corrosive to pipes and plumbing and can increase copper, lead, zinc, and cadmium concentrations. Water with large pH values may adversely affect the chlorination process and may cause carbonate deposits to form in pipes.

Samples from two wells (8 percent) had chloride concentrations above the SMCL of 250 mg/L: concentrations in wells 36N/01E-26H01 and 36N/01E-36C01 were 310 and 330 mg/L, respectively. The SMCL for chloride is the level at which a salty taste is discernible by most people.

Samples from four wells (17 percent) had dissolved-solids concentrations greater than the SMCL of 500 mg/L; the concentrations ranged from 543 to 760 mg/L. The SMCL for dissolved solids is based largely on taste, although other undesirable properties such as corrosiveness or hardness may be associated with large dissolved-solids concentrations.

The USEPA is in the process of establishing an MCL for radon of 300 pCi/L. Only one sample did not meet this proposed MCL.

For more information on drinking water regulations, the reader is referred to documents of the U.S. Environmental Protection Agency (1976, 1986, 1988a, 1988b, 1988c, 1989, 1991).

FUTURE MONITORING AND ADDITIONAL STUDIES

Long-term ground-water level and ground-water quality data for Guemes Island are generally sparse. Such data could be useful in detecting and characterizing natural or anthropogenic changes in the ground-water system. Measuring water levels in several wells monthly or bimonthly, with a representative number of wells in the major aquifers, Qva and Qdb, would allow the delineation of temporal trends. Declining water levels might indicate that the ground-water resource was being pumped faster than it was being recharged from rainfall.

A minimum level of water-quality monitoring would involve collecting samples periodically from selected wells for the analysis of chloride, nitrate, and bacteria. At the time of collection, perhaps quarterly, pH, specific conductance, dissolved-oxygen concentration, and temperature also could be measured in the field. Samples could be collected and analyzed for concentrations of common ions and trace elements at times of highest and lowest water levels. The resulting data could be compared to that collected during this and previous studies in order to identify cyclic or long-term changes in water chemistry. Degradation of ground-water quality might indicate inappropriate land-use practices or, in the case of seawater intrusion, overpumping of the ground-water resource. Long-term monitoring of chloride concentration and water levels in coastal wells finished below sea level would detect seawater intrusion.

Any monitoring efforts would need to be reviewed at least annually to ensure that the objectives of the data collection were being met. Modifications could be made as necessary, but should be kept to a minimum because the success of any monitoring program depends largely on its continuity.

The depth to bedrock on most of the island is mostly unknown, and therefore the total thickness of the potential water-bearing sediments above the bedrock is also unknown. Geophysical surveys and (or) drilling could help determine the geometry of the top of the underlying bedrock and of the island's most extensive and heavily used aquifer (Qdb).

The water-level maps constructed for this report could be refined with additional data, thereby allowing a better evaluation of ground-water flow directions. In the case of Qdb, which has a relatively flat potentiometric surface, more data points (water levels) and (or) more-accurate water-level altitudes would be useful in generating a water-level contour map of the unit. Refinement of water-level altitudes would involve determining the altitudes of the inventoried well heads more accurately than was done for this study. Additional data points could be gathered by locating and measuring water levels in new or previously uninventoried wells, preferably in areas where well coverage was limited at the time of this study.

The effects of additional ground-water development on the island's ground-water system cannot be accurately quantified at present. A mathematical ground-water model of the island is a tool that could help determine the effects of increased ground-water withdrawals.

SUMMARY AND CONCLUSIONS

The ground-water resource of Guemes Island provides all of the freshwater used by 535 year-round residents and an additional 1,605 seasonal residents. Population growth on the island is increasing the demand for ground water. Three water-use categories were recognized on the island: livestock (2 percent), public supply (28 percent), and domestic self-supplied (70 percent).

Guemes Island is composed of a sequence of unconsolidated glacial and interglacial deposits overlying consolidated bedrock. The unconsolidated deposits are lithologically variable and often are not present islandwide. Bedrock is exposed on the eastern end of the island; depth to bedrock on the remainder of the island is not known everywhere, but in places it may be greater than 300 feet. Six hydrogeologic units were identified on Guemes Island:

(1) Beach aquifer (Qb);

(2) Surficial confining unit (Qsc);

(3) Vashon aquifer (Qva);

(4) Whidbey confining unit (Qw);

(5) Double Bluff aquifer (Qdb); and

(6) Bedrock unit (Br).

The Double Bluff aquifer is the most laterally extensive hydrogeologic unit and is the unit from which most water is obtained. This unit generally occurs at or below sea level and the total thickness of the aquifer is unknown. The Vashon aquifer does not occur islandwide, ranges in thickness from zero to 100 feet, and is saturated only in places. The Beach aquifer occurs only in near-shore areas where beach deposits have accumulated to thicknesses of 10 to 20 feet.

Three less-permeable units, the Bedrock unit, the Whidbey confining unit, and the Surficial confining unit, occur on Guemes Island. The Bedrock unit is exposed in the southeastern part of the island and underlies the unconsolidated deposits throughout the rest of the island. Few wells are completed in the Bedrock unit, and those that are tend to have low yields of water. The Whidbey confining unit is generally fine-grained but has coarse-grained lenses that supply small yields of water to numerous wells. This unit is generally less than 120 feet thick and is found at depth over much of the island. The Surficial confining unit, which is composed of till and (or) glaciomarine drift, occurs on the surface of most of the island. The unit is commonly 20 feet thick where till alone occurs, but may be 200 or more feet thick where glaciomarine drift occurs. Few inventoried wells are completed in Qsc.

Hydraulic conductivity values of the hydrogeolgic units were estimated using specific-capacity data. Median values of hydraulic conductivity for the Double Bluff aquifer, the Vashon aquifer, the Whidbey confining unit, and the Surficial confining unit are 68, 43, 1.6, and 23, respectively. Data were unavailable for the Beach aquifer and the Bedrock unit.

An approximate water budget of the island indicates that of the 21-29 inches of precipitation falling on the island in a typical year, 0-4 inches runs off, 12-22 inches evapotranspires, and 2-10 inches recharges the ground-water system. Only 0.1-0.3 inch of the recharge is withdrawn (discharges) from wells. Discharge to springs and the sea was not quantified.

Although current (1992) withdrawals from wells may appear to be of little significance, the locations and density of pumping wells are critical factors affecting the ground-water system, especially in an island setting. Overpumping in near-shore areas could move the freshwater-seawater interface landward, thereby increasing the likelihood of seawater intrusion. Additionally, it is unknown how much of the recharge actually moves downward to the principal aquifer on the island, the Double Bluff aquifer. A significant part of this recharge water may be intercepted by pumping wells completed in overlying units, or part of the recharge water may leave the ground-water system at natural discharge points.

A water-level map for the Double Bluff aquifer illustrates that the unit has a fairly flat potentiometric surface, with hydraulic head varying less than 30 feet across the island. Water levels in wells completed in this aquifer generally had less than 0.5 foot of seasonal fluctuation. A water-level map for the Vashon aquifer shows that head ranges from 0 to 80 feet across the island. Water levels in wells completed in this unit generally showed slightly more than 2 feet of seasonal fluctuation. However, water-level fluctuations up to 7 feet were observed in coastal wells in response to tidal influences.

The chemical quality of ground water on the island is generally suitable for domestic use. Dissolved-solids concentrations ranged from 141 to 760 mg/L, with a median concentration of 236 mg/L. Dissolved-solids concentrations tended to be larger in the deeper units, and most water was moderately hard. Typically, magnesium, calcium, and bicarbonate were the dominant ions. Chloride concentrations ranged from 13 to 330 mg/L, with a median concentration of 21 mg/L. Nitrate concentrations were generally small, ranging from less than 0.05 to 6.8 mg/L, with a median concentration of 0.08 mg/L.

Iron and manganese concentrations varied greatly and in some cases were large. Iron concentrations ranged from 10 to 7,100 μg/L, with a median concentration of 160 μg/L. The largest concentrations of iron were found in the Double Bluff aquifer. Manganese concentrations ranged from 1 to 1,500 μg/L, with a median concentration of 34 μg/L. The largest concentrations of manganese were found in the Whidbey confining unit.

Arsenic was detected in 5 of 24 samples, at concentrations ranging from 1 to 14 μg/L. The arsenic probably occurs naturally and is present in ground water in other areas of western Washington. Radon concentrations ranged from less than 80 to 390 pCi/L, with a median concentration of 120 pCi/L.

Trace concentrations of volatile organic compounds were detected in three water samples. All of the samples with a volatile organic compound (VOC) present were collected from shallow wells. Possible sources of the VOCs (trichloromethane, 1,1,1-trichloroethane, and benzene) include sampling and laboratory contamination, accidental spills, improper disposal of fuels or solvents, or leaking storage tanks.

Concentrations of selected constituents were compared with maximum contaminant levels (MCLs) for applicable USEPA drinking water regulations. No primary MCLs were exceeded during this study. The *secondary maximum contaminant* level (SMCL) of 500 mg/L for dissolved solids was exceeded in four samples. Two of the four samples also had chloride concentrations larger than the chloride SMCL of 250 mg/L, suggesting seawater intrusion conditions. More samples did not meet the SMCL for manganese than for any other constituent; 11 samples exceeded the limit of 50 µg/L. Similarly, nine samples did not meet the SMCL of 300 µg/L for iron. Only one sample, with a pH of 6.2, exceeded the lower limit of the SMCL for pH. All other applicable drinking water regulations were met, including those for trace elements and organic compounds. However, one sample out of the five that were analyzed for radon would not meet the proposed radon MCL of 300 pCi/L.

Chloride concentrations in West Beach, North Beach, and Indian Village were generally above 100 mg/L, perhaps indicating the early stages of seawater intrusion. Chloride concentrations greater than 20 mg/L, but less than 100 mg/L, were found in water samples collected near Kelly's Point and along South Shore.

Chloride concentrations were determined monthly in water samples collected from 12 coastal wells. Water from wells with chloride concentrations generally in excess of 100 mg/L showed the greatest seasonal variation, with larger values occurring from April through September and smaller values occurring from October through March. Seasonal variations in chloride concentration are likely caused by shifting of the freshwater-seawater interface. This shifting most likely is due to seasonal changes in pumpage and in recharge to the ground-water system.

SELECTED REFERENCES

Anderson, H.W., Jr., 1968, Ground-water resources of Island County, Washington: Washington Department of Water Resources Water-Supply Bulletin 25, part II, 317 p.

Bauer, H.H., and Vaccaro, J.J., 1987, Documentation of a deep percolation model for estimating ground-water recharge: U.S. Geological Survey Open-File Report 86-536, 180 p.

Bear, Jacob, 1979, Hydraulics of ground water: New York, NY, McGraw-Hill, 569 p.

Blunt, D.J.; Easterbrook, D.J., and Rutter N.W., 1987, Chronology of Pleistocene sediments in the Puget Lowland, Washington, *in* Selected Papers on the Geology of Washington: Washington Division of Geology and Earth Resources Bulletin 77, p. 321-353

Brandon, M.T., 1989, Geology of the San Juan-Cascade Nappes, northwestern Cascade Range and San Juan Islands, *in* Geologic Guidebook for Washington and Adjacent Areas: Washington Division of Geology and Earth Resources information Circular 86, p. 137-151.

Brandon, M.T., Cowan, D.S., and Vance, J.A., 1988, The Late Cretaceous San Juan thrust system, San Juan Islands, Washington: Geological Society of America Special Paper 221, 81 p.

Bredehoeft, J.D., Papadopulos, S.S., and Cooper, H.H., Jr., 1982, Groundwater: The water-budget myth, *in* Studies in Geophysics, Scientific Basis of Water-Resource Management: National Academy Press, p. 51-57.

Carnahan, B., Luther, H.A., and Wilkes, J.O., 1969, Applied numerical methods: New York, John Wiley and Sons, Inc., 604 p.

Cline, D.R., Jones, M.A., Dion, N.P., Whiteman, K.J., and Sapik, D.B., 1982, Preliminary survey of ground-water resources for Island County, Washington: U.S. Geological Survey Open-File Report 82-561, 46 p.

Crandell, D.R., Mullineaux, D.R., and Waldron, H.H., 1965, Age and origin of the Puget Sound trough in western Washington: U.S. Geological Survey Professional Paper 525-B, p. B132 to B136.

Dion, N.P., and Sumioka, S.S., 1984, Seawater intrusion into coastal aquifers in Washington, 1978: Washington Department of Ecology Water-Supply Bulletin 56, 13 p., 14 pls.

0574

520-63

Dion, N.P., Olsen, T.D., and Payne, K.L., 1988, Preliminary evaluation of the ground-water resources of Bainbridge Island, Kitsap County, Washington: U.S. Geological Survey Water-Resources Investigations Report 87-2437, 82 p.

Dion, N.P., Turney, G.L., and Jones, M.A., 1994, Geohydrology and quality of ground water in Thurston County: U.S. Geological Survey Water-Resources Investigations Report 92-4109, 188 p., 6 pls.

Domack, E.W., 1983, Facies of late Pleistocene glacial-marine sediments on Whidbey Island, Washington: An isostatic glacial-marine sequence, *in* Molnia, B.F., ed., Glacial-marine sedimentation: New York, Plenum Press, p. 535-570.

Dunne, T., and Leopold, L.B., 1978, Water in environmental planning: New York, NY, W.H. Freeman and Company, 818 p.

Easterbrook, D.J., 1963, Late Pleistocene glacial events and relative sea-level changes in the northern Puget Lowland, Washington: Geological Society of America Bulletin, v. 74, no. 12, p. 1,465-1,484.

_____1966, Radiocarbon chronology of late Pleistocene deposits in northwest Washington: Science, v. 152, no. 3723, p. 764-767.

_____1968, Pleistocene stratigraphy of Island County, Washington: Washington Department of Water Resources Water-Supply Bulletin 25, part 1, 34 p.

_____1969, Pleistocene chronology of the Puget Lowland and San Juan Islands, Washington: Geological Society of America Bulletin, v. 80, no. 11, p. 2,273-2,286.

Easterbrook, D.J., Crandall, D.R., and Leopold, E.B., 1967, Pre-Olympia stratigraphy and chronology in the Central Puget Lowland, Washington: Geological Society of America Bulletin, v. 78, p. 13-20.

Ferris, J.G., Knowles, D.B., Brown, R.H., and Stallman, R.W., 1962, Theory of aquifer tests: U.S. Geological Survey Water-Supply Paper 1536-E, 174 p.

Fishman, M.J., and Friedman, L.C., eds., 1985, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 5, chap. A1, Open-File Report 85-495, 709 p.

Freeze, R.A., and Cherry, J.A., 1979, Groundwater: Englewood Cliffs, N.J., Prentice Hall, 604 p.

Friedman, L.C., and Erdmann, D.E., 1982, Quality assurance practices for the chemical and biological analyses of water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 5, chap. A6, 181 p.

Garland, D.P. and Safioles, S., 1988, Seasonal variation in chloride in ground water at southern Camano Island, Island County, Washington, 1985-1987: Washington State Department of Ecology Report no. 87-15, Redmond, Washington, 35 p.

Greeson, P.E., Ehlke, T.A., Irwin, G.A., Lium, B.W., and Slack, K.V., 1977, Methods for collection and analysis of aquatic biological and microbiological samples: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 5, chap. A4, 332 p.

Grisak, G.E., and Cherry, J.A., 1975, Hydrogeologic characteristics and response of fractured till and clay confining a shallow aquifer: Canadian Geotechnical Journal, v. 12, p. 23-43.

Hall, J.B., and Othburg, K.L., 1974, Thickness of unconsolidated sediments, Puget Lowland, Washington: Washington Department of Natural Resources Geologic Map GM-12, scale 1:250,000, 3 p., 1 pl.

Hansen, B.S., and Easterbrook, D.J., 1974, Stratigraphy and palynology of late Quaternary sediments in the Puget Lowland, Washington: Geological Society of America Bulletin, v. 85, p. 587-602.

Heath, R.C., 1983, Basic ground-water hydrology: U.S. Geological Survey Water-Supply Paper 2220, 84 p.

0575

520-64

Hem, J.D., 1989, Study and interpretation of the chemical characteristics of natural water (3rd ed.): U.S. Geological Survey Water-Supply Paper 2254, 263 p.

Jones, M.A., 1985, Occurrence of ground water and potential for seawater intrusion, Island County, Washington: U.S. Geological Survey Water-Resources Investigations Report 85-4046, 6 pls.

_____1992, Ground-water availability from a dune-sand aquifer near Coos Bay and North Bend, Oregon: U.S. Geological Survey Open-File Report 90-563, 76 p.

Kruckeberg, A.R., 1991, The natural history of Puget Sound country: Seattle, Washington, University of Washington Press, 468 p.

LeBlanc, D.R., 1984, Sewage plume in a sand and gravel aquifer, Cape Cod, Massachusetts: U.S. Geological Survey Water-Supply Paper 2218, 28 p.

Lum, W.E., II, and Walters, K.L., 1976, Reconnaissance of ground-water resources of the Squaxin Island Indian Reservation, Washington: U.S. Geological Survey Open-file Report 76-382, 49 p.

McLellan, R.D., 1927, The geology of the San Juan Islands: University of Washington Publications in Geology, v. 2, 185 p.

National Oceanic and Atmospheric Administration, 1992, Climatological Data Annual Summary, Washington, v. 96, no. 13, 35 p.

National Research Council, 1978, Nitrates: An environmental assessment: Washington, D.C., National Academy of Sciences, 723 p.

Oldow, J.S., Bally, A.W., Ave Lallemant, H.G., and Leeman, W.P., 1989, Phanerozoic evolution of the North American Cordillera: United States and Canada, *in* Bally, A.W., and Palmer, A.R., eds., The geology of North America: An overview: Boulder, Colorado, Geological Society of America, The Geology of North America, v. A., p. 139-232.

Russell, R.H., ed., 1975, Geology and water resources of the San Juan Islands, San Juan County, Washington: Washington Department of Ecology Office of Technical Services, Water-Supply Bulletin, no. 46, 171 p., 3 pls.

Sapik, D.B., Bortleson, G.C., Drost, B.W., Jones, M.A., and Prych, E.A., 1988, Ground-water resources and simulation of flow in aquifers containing freshwater and seawater, Island County, Washington: U.S. Geological Survey Water-Resources Investigations Report 87-4182, 4 pls.

Simmons, D.L., 1986, Geohydrology and ground-water quality on Shelter Island, Suffolk County, New York, 1983-1984: U.S. Geological Survey Water-Resources Investigations Report 85-4165, 39 p.

Todd, D.K., 1980, Groundwater hydrology, 2nd ed.: New York, NY, John Wiley, 535 p.

Turney, G.L., 1986, Quality of ground water in the Puget Sound region, Washington, 1981: U.S. Geological Survey Water-Resources Investigations Report 84-4258, 169 p.

_____1990, Quality of ground water in Clark County, Washington, 1988: U.S. Geological Survey Water-Resources Investigations Report 90-4149, 97 p.

Turney, G.L., Kahle, S.C., and Dion, N.P., 1995, Geohydrology and ground-water quality of east King County, Washington: U.S. Geological Survey Water-Resources Investigations Report 94-4082, in press.

U.S. Department of Agriculture, 1965, Mean annual precipitation, State of Washington: Portland, Oregon, U.S. Soil Conservation Service Map M-4430.

U.S. Department of Agriculture Soil Conservation Service, 1989, Soil survey of Skagit County area, Washington: U.S. Government Printing Office, 372 p.

U.S. Environmental Protection Agency, 1976, National interim primary drinking water regulations: U.S. Government Printing Office, 159 p.

_____1986, Quality criteria for water, 1986: U.S. Environmental Protection Agency Publications EPA 440/5-86-001, no pagination.

_____1988a, Maximum contaminant levels (subpart B of part 141, National interim primary drinking water regulations): U.S. Code of Federal Regulations, Title 40, Parts 100 to 149, revised as of July 1, 1988, p. 530-533.

_____1988b, National revised primary drinking water regulations: Maximum contaminant levels (subpart G of part 141, National interim primary drinking water regulations): U.S. Code of Federal Regulations, Title 40, Parts 100 to 149, revised as of July 1, 1988, p. 586-587.

_____1988c, Secondary maximum contaminant levels (section 143.3 of part 143, National secondary drinking water regulations): U.S. Code of Federal Regulations, Title 40, Parts 100 to 149, revised as of July 1, 1988, p. 608.

_____1989, Final rule, National primary drinking water regulations; Giardialamblia, viruses, Legionella, and total coliforms (subparts F and G of part 141): U.S. Federal Register, v. 54, no. 124, June 29, 1989, p. 27,486-27,568.

_____1991, Drinking water regulations and health advisories, April 1991: U.S. Environmental Protection Agency Office of Water, unpaginated.

Van Denburgh, A.S., 1965, Chemical distinction between ground water of four sedimentary units on the Kitsap Peninsula and adjacent islands, Washington: U.S. Geological Survey Professional Paper 525-d, p. D219.

Van Denburgh, A.S., and Santos, J.F., 1965, Ground water in Washington--Its chemical and physical quality: Washington Division of Water Resources Water-Supply Bulletin 24, 93 p.

Walters, K.L., 1971, Reconnaissance of sea-water intrusion along coastal Washington, 1966-68: Washington Department of Ecology Water-Supply Bulletin No. 32, 208 p.

Washington Department of Ecology, 1978, Coastal zone atlas of Washington, Volume 2: Washington State Department of Ecology, DOE 77-21-2, 40 p.

Welch, A.H., Lico, M.S., and Hughs, J.L., 1988, Arsenic in ground water of the western United States: Ground Water, v. 26, no. 3, p. 333-347.

Wershaw, R.L., Fishman, M.J., Grabbe, R.R., and Lowe, L.E., eds., 1987, Methods for the determination of organic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 5, chap. A3, 80 p.

Whiteman, K.J., Molenaar, Dee, Bortleson, G.C., and Jacoby, J.M., 1983, Occurrence, quality, and use of ground water in Orcas, San Juan, Lopez, and Shaw Islands, San Juan County, Washington: U.S. Geological Survey Water-Resources Investigations Report 83-4019, scale 1:62,500, 12 sheets.

Willis, Baily, 1898, Drift phenomena of Puget Sound: Bulletin of the Geological Society of America, v. 9, p. 111-162, pls. 6-10.

Winter, T.C., 1975, Delineation of buried glacial-drift-aquifers: U.S. Geological Survey Journal of Research, v. 3, no. 2, Mar-Apr., p. 137-148.

_____1981, Uncertainties in estimating the water balance of lakes: U.S. Geological Survey Water Resources Bulletin, v. 17, no. 1, p. 82-115.

Wood, W.W., 1981, Guidelines for collection and field analysis of ground-water samples for selected unstable constituents: U.S. Geological Survey Techniques of Water-Resources Investigations Book 1, chap. D2, 24 p.

520-66

0578

520-67

Appendix 1.--Physical and hydrologic data for the inventoried wells

[Hydrogeologic unit: Qb, Beach aquifer; Qsc, Surficial confining unit; Qva, Vashon aquifer; Qw, Whidbey confining unit; Qdb, Double Bluff aquifer; and Br, Bedrock. Use of water: H, domestic; I, irrigation; P, public supply; and U, unused. Water level code indicates status of well at time of visit; R, recently pumped. Remarks: L, driller's (lithologic) log available; C, project observation well for chloride concentration; and W, project observation well for water level. --, not determined]

Local well number	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Hydro-geo-logic unit	Altitude of land surface (feet)	Depth of well (feet)	Surface casing dia-meter (in.)	Well yield (gallons per minute)	Draw-down (feet)	Use of water	Water level below land surface (feet)	Date water level measured	Estimated horizontal hydraulic conductivity (feet per day)	Remarks
35N/01E-01A01	48°33'24"	122°36'48"	Qdb	150	156	6	20	10	H	134.25	10-12-91	110	L,W
35N/01E-01A02	48°33'15"	122°36'47"	Qdb	145	185	6	--	--	H	133.31	10-30-91	--	--
35N/01E-01C01	48°33'20"	122°37'28"	Qva	145	92	6	6	4	H	78.80	10-17-91	42	L
35N/01E-01C02	48°33'23"	122°37'27"	Qva	130	70	6	20	0	H	51.92	10-11-91	--	L
35N/01E-01D01	48°33'24"	122°37'48"	Qdb	70	90	6	30	13	H	65.30	10-29-91	140	L
35N/01E-01F01	48°33'04"	122°37'28"	Qdb	165	180	6	--	--	H	157.86 R	10-18-91	--	--
35N/01E-01H01	48°33'02"	122°36'47"	Qdb	140	166	6	--	--	H	--	--	--	--
35N/01E-01M01	48°32'57"	122°37'50"	Qdb	160	185	6	12	12	H	157.04	10-10-91	--	L,W
35N/01E-01R01	48°32'35"	122°36'50"	Qdb	120	228	6	12	66	H	90.85	10-18-91	7.4	L,W
35N/01E-02A01	48°33'17"	122°38'23"	Qdb	50	83	6	15	0	P	51.63	10-11-91	--	L
35N/01E-02B01	48°33'17"	122°38'33"	Qb	20	25	36	--	--	P	13.62	10-16-91	--	--
35N/01E-02G01	48°33'01"	122°38'31"	Qdb	122	158	6	--	--	--	117.68	10-17-91	--	L
35N/01E-02L01	48°32'57"	122°39'02"	Qva	19	64	6	--	--	P	15.65	10-10-91	--	--,C,W
35N/01E-02L02	48°33'00"	122°39'01"	Qva	16	43	6	--	--	P	8.96	10-10-91	--	--
35N/01E-02L03	48°32'59"	122°38'59"	Qdb	30	107	6	--	--	H	--	--	--	L
35N/01E-02P01	48°32'47"	122°39'02"	Qdb	85	130	6	--	--	H	85.71	10-12-91	--	L
35N/01E-11B01	48°32'32"	122°38'42"	Qdb	105	135	6	--	--	H	100.53	10-10-91	--	L
35N/01E-11E01	48°32'17"	122°39'05"	Qdb	65	120	6	--	--	P	65.47	10-16-91	--	--
35N/01E-11L01	48°31'56"	122°38'54"	Qdb	150	200	6	--	--	H	145.20	10-11-91	--	L
35N/01E-11P01	48°31'52"	122°38'47"	Qdb	100	128	6	--	--	H	107.58	10-29-91	--	L

520-68

Appendix 1.--Physical and hydrologic data for the inventoried wells--continued

Local well number	Latitude (degrees)	Longitude (degrees)	Hydro-geo-logic unit	Altitude of land surface (feet)	Depth of well (feet)	Surface casing dia-meter (in.)	Well yield (gallons per minute)	Draw-down (feet)	Use of water	Water level below land surface (feet)	Date water level measured	Estimated horizontal hydraulic conductivity (feet per day)	Remarks
35N/01E-11P02	48°31'49"	122°38'44"	Qdb	72	112	6	45	10	H	61.03	10-10-91	--	L
35N/01E-11P03	48°31'54"	122°38'52"	Qdb	135	158	6	15	0	H	--	--	--	L
35N/01E-11P04	48°31'54"	122°38'55"	Qdb	145	177	6	15	4	H	132.76	10-10-91	180	L
35N/01E-11Q01	48°31'51"	122°38'37"	Qva	80	106	6	20	20	I	66.44	10-16-91	28	L
35N/01E-11Q02	48°31'43"	122°38'41"	Qdb	30	97	6	20	15	H	21.86	12-16-91	60	L,W
35N/01E-11Q03	48°31'43"	122°38'29"	Qdb	40	62	6	20	3	H	43.57	10-10-91	350	L
35N/01E-11R01	48°31'43"	122°38'23"	Qdb	50	60	6	--	--	H	39.30	10-17-91	--	L
35N/01E-11R02	48°31'47"	122°38'10"	Qw	90	114	6	--	--	H	79.62	10-10-91	--	L,C,W
35N/01E-11R03	48°31'48"	122°38'06"	Qw	110	132	6	--	--	H	95.21	10-11-91	--	L
35N/01E-12F01	48°32'09"	122°37'31"	Qva	110	114	6	--	--	H	99.15	10-17-91	--	L
35N/01E-12F02	48°32'12"	122°37'27"	Qva	110	120	6	--	--	H	97.23	10-30-91	--	L
35N/01E-12H02	48°32'16"	122°36'56"	Qdb	79	220	6	4	80	H	--	--	--	L
35N/01E-12K01	48°32'05"	122°37'23"	Qva	95	155	6	10	2	H	84.75	10-17-91	--	L
35N/01E-12L02	48°32'07"	122°37'26"	Qw	110	122	6	--	--	U	97.79	10-17-91	--	L,W
35N/01E-12N01	48°31'47"	122°38'01"	Qw	100	140	6	--	--	H	82.15	10-17-91	--	L
35N/01E-12P02	48°31'44"	122°37'34"	Qsc	30	80	6	--	--	H	--	--	--	--
35N/01E-12P03	48°31'54"	122°37'43"	Qdb	80	260	6	6	70	H	72.36	10-30-91	1.3	L,W
35N/01E-12P04	48°31'45"	122°37'29"	Qdb	25	164	6	45	45	H	16.62	10-17-91	51	L
35N/01E-12Q01	48°31'47"	122°37'23"	Qdb	37	171	6	--	--	H	27.70	10-17-91	--	L
35N/01E-12Q02	48°31'48"	122°37'25"	Qsc	40	65	6	8	23	H	30.67	10-17-91	16	L

520-69

0580

Appendix 1.--Physical and hydrologic data for the inventoried wells--continued

Local well number	Latitude (degrees)	Longitude (degrees)	Hydro-geo-logic unit	Altitude of land surface (feet)	Depth of well (feet)	Surface casing dia-meter (in.)	Well yield (gallons per minute)	Draw-down (feet)	Use of water	Water level below land surface (feet)	Date water level measured	Estimated horizontal hydraulic conductivity (feet per day)	Remarks
35N/01E-12R01	48°31'54"	122°37'01"	Qdb	65	170	6	7.5	52	H	56.52	10-10-91	6.4	L,C
35N/01E-12R02	48°31'52"	122°37'03"	Qdb	61	158	6	--	--	H	54.80	10-29-91	--	L,W
35N/01E-13C01	48°31'41"	122°37'37"	Qdb	15	165	6	18	105	H	--	--	7.8	L
35N/01E-14A01	48°31'41"	122°38'22"	Qdb	40	65	6	--	--	H	34.97	10-17-91	--	--
35N/01E-14B01	48°31'41"	122°38'40"	Qdb	25	81	6	10	40	H	--	--	12	L
35N/01E-14B02	48°31'41"	122°38'42"	Qdb	20	90	6	15	12	H	--	--	56	L,C
35N/01E-14B03	48°31'41"	122°38'34"	Qdb	30	58	6	20	18	U	18.60	10-18-91	52	L
35N/01E-14B04	48°31'39"	122°38'33"	Qdb	20	63	6	20	22	H	--	--	46	L
35N/02E-05F01	48°33'03"	122°35'00"	Qsc	200	11.5	36	--	--	H	9.28	10-11-91	--	L
35N/02E-06C01	48°33'18"	122°36'12"	Br	90	80	--	--	--	-	--	--	--	L
35N/02E-06C02	48°33'19"	122°36'20"	Qdb	75	98	6	--	--	H	--	--	--	L
35N/02E-06E01	48°33'10"	122°36'39"	Qdb	161	175	6	--	--	H	146.03	10-10-91	--	--
35N/02E-06G01	48°33'05"	122°36'05"	Br	100	165	6	--	--	H	17.30	10-10-91	--	L,W
35N/02E-06G02	48°33'06"	122°35'52"	Br	210	264	6	--	--	H	43.03	10-10-91	--	L
35N/02E-07A01	48°32'29"	122°35'38"	Qw	75	110	6	--	--	H	62.61	10-10-91	--	L,C,W
35N/02E-07A02	48°32'24"	122°35'32"	Qw	85	118	6	--	--	P	--	--	--	L
35N/02E-07A03	48°32'25"	122°35'40"	Qw	65	123	6	--	--	H	52.86	10-09-91	--	L
35N/02E-07A04	48°32'26"	122°35'30"	Qw	90	109	6	--	--	H	76.83	10-09-91	--	L
35N/02E-07A05	48°32'21"	122°35'26"	Qw	130	116	6	2.5	0	H	109.32	10-10-91	--	L
35N/02E-07G01	48°32'18"	122°35'56"	Qsc	45	35	42	--	--	H	1.13	12-17-91	--	--

520-70

Appendix 1.--Physical and hydrologic data for the inventoried wells--continued

Local well number	Latitude (degrees)	Longitude (degrees)	Hydro-geo-logic unit	Altitude of land surface (feet)	Depth of well (feet)	Surface casing dia-meter (in.)	Well yield (gallons per minute)	Draw-down (feet)	Use of water	Water level below land surface (feet)	Date water level measured	Estimated horizontal hydraulic conductivity (feet per day)	Remarks
35N/02E-07H01	48°32'18"	122°35'44"	Qdb	45	72	36	40	52	H	38.45	10-09-91	80	L,C,W
35N/02E-07H02	48°32'15"	122°35'35"	Qw	45	104	6	--	--	H	38.72	10-11-91	--	L
35N/02E-07H03	48°32'15"	122°35'27"	Qw	50	81	6	--	--	H	42.16	10-11-91	--	L
35N/02E-07H04	48°32'15"	122°35'32"	Qw	50	158	6	--	--	H	--	--	--	--
35N/02E-08E01	48°32'15"	122°35'23"	Qdb	40	154	6	8	70	H	13.26	10-16-91	5.0	L
35N/02E-08E02	48°32'19"	122°35'12"	Br	80	189	6	--	--	H	--	--	--	L
35N/02E-08E03	48°32'19"	122°35'20"	Qw	75	206	6	11	164	-	14.95	10-11-91	1.6	L
35N/02E-08F01	48°32'09"	122°35'00"	Qw	58	140	8	--	--	P	--	--	--	--
35N/02E-08F02	48°32'09"	122°35'01"	Qw	57	120	6	--	--	P	27.21	10-14-91	--	L
35N/02E-08G01	48°32'12"	122°34'32"	Br	190	403	6	--	--	H	53.16	10-29-91	--	L,W
36N/01E-25N01	48°34'33"	122°37'58"	Qdb	120	125	6	--	--	H	--	--	--	--
36N/01E-25N02	48°34'23"	122°37'48"	Qva	55	69	6	--	--	H	57.43	10-29-91	900	L
36N/01E-25N03	48°34'21"	122°37'47"	Qva	60	77	6	10	2	H	--	--	170	L
36N/01E-25N04	48°34'22"	122°37'48"	Qva	60	72	6	10	3	H	--	--	110	L
36N/01E-25N05	48°34'21"	122°37'44"	Qdb	30	175	6	10	0	H	--	--	--	L
36N/01E-25N06	48°34'21"	122°37'58"	Qdb	150	167	6	5	2.3	H	149.31	10-16-91	130	L,W
36N/01E-26A01	48°34'59"	122°38'14"	Qva	60	25	36	--	--	P	17.98	10-17-91	--	--,C-W
36N/01E-26H01	48°34'47"	122°38'13"	Qdb	130	134	6	15	10	H	111.56	10-12-91	75	L
36N/01E-26J01	48°34'39"	122°38'17"	Qdb	163	180	6	10	1	H	158.28	10-09-91	610	L
36N/01E-26K01	48°34'37"	122°38'32"	Qdb	155	184	6	20	1	H	158.45	10-09-91	1,200	L

520-71

0582

Appendix 1.--Physical and hydrologic data for the inventoried wells--continued

Local well number	Latitude (degrees)	Longitude (degrees)	Hydro-geo-logic unit	Altitude of land surface (feet)	Depth of well (feet)	Surface casing dia-meter (in.)	Well yield (gallons per minute)	Draw-down (feet)	Use of water	Water level below land surface (feet)	Date water level measured	Estimated horizontal hydraulic conductivity (feet per day)	Remarks
36N/01E-26K02	48°34'40"	122°38'39"	Qdb	135	180	--	--	--	-	--	--	--	L
36N/01E-26K03	48°34'41"	122°38'37"	Qw	135	105	6	--	--	H	90.63	10-16-91	--	L
36N/01E-26P01	48°34'25"	122°38'58"	Qva	75	26	48	--	--	H	--	--	--	--
36N/01E-26P02	48°34'30"	122°38'57"	Qva	38	23	6	10	14	H	--	--	44	L
36N/01E-26R01	48°34'32"	122°38'07"	Qdb	165	194	6	10	4	U	166.70	10-16-91	130	L
36N/01E-35C01	48°34'17"	122°38'52"	Qdb	100	140	6	--	--	-	--	--	--	--
36N/01E-35F01	48°34'06"	122°38'46"	Qdb	158	182	6	20	2	P	152.92 R	10-29-91	260	L,C,W
36N/01E-35G01	48°33'59"	122°38'32"	Qdb	150	168	6	--	--	P	143.94	10-08-91	--	L
36N/01E-35G02	48°33'55"	122°38'25"	Qdb	130	160	6	--	--	P	129.43	10-08-91	--	L
36N/01E-35Q01	48°33'36"	122°38'34"	Qb	15	10	48	--	--	H	1.22	10-09-91	--	--
36N/01E-35Q01S	48°33'35"	122°38'34"	Qva	30	--	--	--	--	-	--	--	--	--
36N/01E-36C01	48°34'17"	122°37'41"	Qva	45	54	6	--	--	H	43.16	10-09-91	--	L,C
36N/01E-36C02	48°34'15"	122°37'39"	Qva	48	70	48	--	--	P	41.70	10-10-91	--	--
36N/01E-36C03	48°34'11"	122°37'34"	Qva	35	28	8	--	--	P	14.19	10-09-91	--	--,C,W
36N/01E-36C04	48°34'13"	122°37'35"	Qva	25	43	6	10	9	H	30.05	10-11-91	29	L
36N/01E-36C05	48°34'13"	122°37'34"	Qva	25	41.5	6	7	9	H	28.84	10-11-91	21	L
36N/01E-36C06	48°34'13"	122°37'33"	Qva	20	37	6	10	4	H	--	--	150	L
36N/01E-36C07	48°34'19"	122°37'41"	Qva	20	55	--	--	--	H	--	--	--	--
36N/01E-36C08	48°34'16"	122°37'40"	Qva	40	54	8	2	1	H	--	--	--	--
36N/01E-36C09	48°34'20"	122°37'42"	Qva	30	58	6	--	--	H	41.64	10-16-91	--	--

530-72

05

Appendix 1.--Physical and hydrologic data for the inventoried wells--continued

Local well number	Latitude (degrees)	Longitude (degrees)	Hydro-geo-logic unit	Altitude of land surface (feet)	Depth of well (feet)	Surface casing dia-meter (in.)	Well yield (gallons per minute)	Draw-down (feet)	Use of water	Water level below land surface (feet)	Date water level measured	Estimated horizontal hydraulic conductivity (feet per day)	Remarks
36N/01E-36C10	48°34'19"	122°37'42"	Qva	25	--	--	--	--	H	29.42	10-17-91	--	--
36N/01E-36G01	48°33'53"	122°37'10"	Qva	50	71	6	--	--	-	--	--	--	L
36N/01E-36G02	48°33'53"	122°37'08"	Qva	50	71	6	--	--	H	46.12	10-09-91	--	L
36N/01E-36K01	48°33'41"	122°37'24"	Qva	70	12	45	--	--	H	8.64	10-17-91	--	--
36N/01E-36P01	48°33'30"	122°37'33"	Qva	85	49	6	8	35	H	7.47	10-17-91	9.5	L,W
36N/01E-36P02	48°33'35"	122°37'28"	Qsc	90	36	6	5	6	-	15.92	10-18-91	30	L
36N/01E-36Q01	48°33'40"	122°37'09"	Qdb	110	205	6	--	--	H	102.03	10-17-91	--	L,C,W
36N/01E-36Q02	48°33'37"	122°37'13"	Qw	114	69	6	--	--	H	49.43	10-17-91	--	L
36N/01E-36R01	48°33'34"	122°36'47"	Qdb	130	144	6	--	--	H	123.08	10-12-91	--	L
36N/02E-31M01	48°33'43"	122°36'41"	Qdb	90	144	6	--	--	H	111.11 R	10-17-91	--	L
36N/02E-31M02	48°33'44"	122°36'43"	Qdb	90	104	6	--	--	U	--	--	--	L
36N/02E-31P01	48°33'29"	122°36'25"	Qdb	85	168	6	--	--	P	79.20	10-29-91	--	--,C,W

0584

520-73

Appendix 2.--Drillers' lithologic logs of wells used in the construction of hydrogeologic sections

Local well number	Driller's description of materials	Thickness (feet)	Depth of bottom (feet)	Driller's name	Year drilled
35N/01E-01A01	Topsoil	6	6	Brown	1976
	Sandy loam	3	9		
	Tan clay	25	34		
	Coarse sand	44	78		
	Gravel	14	92		
	Coarse sand and fine gravel	41	133		
	Large rocks and gravel	4	137		
	Coarse sand	9	146		
	Fine gravel	7	153		
	Coarse gravel and fine sand; water bearing strata 153-156 feet	10	163		
35N/01E-01C02	Topsoil	1	1	Hayes	1990
	Boulder	1	2		
	Brown clay and gravel	18	20		
	Brown sand and gravel	35	55		
	Brown sand, gravel, and water	19	74		
	Gray clay	9	83		
	Brown peat	1	84		
	Brown clay	1	85		
	Gray clay	17	102		
35N/01E-01D01	Dirty sand and gravel	6	6	Dahlman	1990
	Brown clay	12	18		
	Blue clay	67	85		
	Water and gravel	5	90		
35N/01E-01M01	Dirty sand and gravel	8	8	Dahlman	1986
	Brown clay	7	15		
	Blue clay	35	50		
	Sand and gravel	53	103		
	Brown clay	15	118		
	Blue clay	60	178		
	Water and gravel	7	185		
35N/01E-01R01	Gravelly hard clay	31	31	Whidbey	1980
	Hardpan	9	40		
	Soupy sand	18	58		
	Clay	59	117		
	Gravelly hard clay	104	221		
	Water and sand	7	228		

05

520-74

Appendix 2.--Drillers' lithologic logs of wells used in the construction of hydrogeologic sections--Continued

Local well number	Driller's description of materials	Thickness (feet)	Depth of bottom (feet)	Driller's name	Year drilled
35N/01E-02A01	Topsoil	2	2	Hayes	1988
	Brown sand	2	4		
	Tan clay	14	18		
	Gray clay and gravel	12	30		
	Tan clay	5	35		
	Tan clay, sand, and gravel	4	39		
	Gray dirty sand	2	41		
	Hard gray layered clay	28	69		
	Gray clay, wood, and silt	2	71		
	Gray silt, sand, clay, and seepage	4	75		
	Gray clay	1	76		
	Semi-consolidated gravel, sand, and water	5	81		
	Coarse gravel, sand, and water	2	83		
35N/01E-02G01	Topsoil	2	2	Hayes	1988
	Tan clay and gravel	15	17		
	Brown sand and gravel	38	55		
	Tan clay and gravel	2	57		
	Brown sand and gravel	13	70		
	Dirty gray fine sand and seepage	3	73		
	Hard peat	3	76		
	Gray clay and wood	7	83		
	Gray clay and silt	12	95		
	Tan clay, wood, and silt	22	117		
	Gray clay	16	113		
	Brown silt and sand and seepage	20	153		
	Gray clay	2	155		
	Consolidated brown gravel and water	2	157		
	Brown gravel and water	1	158		
35N/01E-02L03	Dirty sand and gravel	50	50	Dahlman	1989
	Brown clay	15	65		
	Blue clay	37	102		
	Gravel and water	5	107		
35N/01E-11B01	Brown clay	32	32	Dahlman	1988
	Blue clay and gravel	18	50		
	Brown clay and gravel	10	60		
	Sand and gravel	10	70		
	Brown clay	10	80		
	Blue clay	48	128		
	Water and gravel	7	135		

Appendix 2.--Drillers' lithologic logs of wells used in the construction of hydrogeologic sections--Continued

Local well number	Driller's description of materials	Thickness (feet)	Depth of bottom (feet)	Driller's name	Year drilled
35N/01E-11P04	Topsoil	1	1	Hayes	1989
	Tan gravel, sand, and clay	15	16		
	Brown sand	14	30		
	Brown sand and gravel	65	95		
	Dark layered gray and brown clay and wood	19	114		
	Layered gray and brown clay	6	120		
	Dirty brown sand	15	135		
	Brown sand	25	160		
	Brown sand and water	19	179		
35N/01E-12H02	Topsoil	5	5	Dahlman	1983
	Brown clay	17	22		
	Blue clay	197	219		
	Water, sand, and clay	1	220		
35N/01E-12R01	Brown clay	10	10		
	Blue clay	140	150		
	Silt, sand, and water	5	155		
	Clay	3	158		
	Silt, sand, and water	12	170		
35N/01E-12R02	Topsoil	2	2	Dahlman	1990
	Brown clay	53	55		
	Blue clay	95	150		
	Fine sand and water	8	158		
35N/02E-05F01	Brown loam	1	1	Skagit	1990
	Sand and gravel	7.5	8.5		
	Sand, gravel, and water	3	11.5		
35N/02E-06C01	Topsoil	2	2	Hayes	1991
	Brown clay and gravel	8	10		
	Green basalt	70	80		
35N/02E-06C02	Brown sand and gravel	17	17	Hayes	1991
	Brown clay and gravel	16	33		
	Brown gravel and sand	42	75		
	Brown gravel and water	16	91		
	Gray gravel, sand, and water	8	99		
35N/02E-06G01	Brown clay	18	18	Dahlman	1981
	Rock	106	124		
	Soft shale with clay	2	126		
	Rock, water at 150 feet	39	165		

520-76

Local well number	Driller's description of materials	Thickness (feet)	Depth of bottom (feet)	Driller's name	Year drilled
35N/02E-06G02	Dirty sand and gravel	20	20	Dahlman	1985
	Green granite; water at 183 feet	244	264		
35N/02E-07A02	Topsoil	3	3	Dahlman	1982
	Brown clay	27	30		
	Blue clay	60	90		
	Brown sand	20	110		
	Gray sand and water	8	118		
	Blue clay	22	140		
35N/02E-07A03	Topsoil	2	2	Dahlman	1978
	Clay and stone	78	80		
	Clay and sand	25	105		
	Water and gray sand	18	123		
35N/02E-07A05	Topsoil	1	1	Hayes	1990
	Tan sandy clay	14	15		
	Tan silty clay and gravel	9	24		
	Tan silty clay	30	54		
	Gray clay	13	67		
	Brown clay and scattered gravel	7	74		
	Gray clay	39	113		
	Gray fine sand and water	4	117		
	Gray clay and fine sand	1	118		
35N/02E-08E02	Topsoil	2	2	Olympic	1979
	Gravelly clay	18	20		
	Blue clay	5	25		
	Brown cemented sand and gravel	5	30		
	Gray cemented sand and gravel	23	53		
	Gray clay	88	141		
	Sand and clay	19	160		
	Gray hardpan	26	186		
	Shattered rock	3	189		
35N/02E-08E03	Topsoil	1	1	Hayes	1990
	Brown gravel, sand, and clay	11	12		
	Gray clay and gravel	46	58		
	Gray gravel, sand, and clay and seepage	3	61		
	Gray clay	5	66		
	Gray clay and gravel	4	70		
	Gray clay	29	99		
	Gray clay and little gravel	11	110		
	Gray clay	20	130		
	Gray clay and gravel	1	131		

0588

520-77

Local well number	Driller's description of materials	Thickness (feet)	Depth of bottom (feet)	Driller's name	Year drilled
35N/02E-08E03--cont	Gray clay	53	184		
	Gray clay and little gravel	16	200		
	Gray silty sand and water	5	205		
	Layered gray clay and water	12	217		
35N/02E-08G01	Brown clay and rock	12	12	Dahlman	1988
	Hard greenish rock	396	408		
36N/01E-26H01	Gravel	6	6	Whidbey	1976
	Hardpan	19	25		
	Gravel	44	69		
	Sandy clay	23	92		
	Hardpan	15	107		
	Sand	3	110		
	Dry gravel	6	116		
	Water and gravel	18	134		
36N/01E-26R01	Gravel	6	6	Whidbey	1976
	Gravelly clay	16	22		
	Gravel and sand	43	65		
	Gravel	33	98		
	Sand	26	124		
	Gravelly hardpan	16	140		
	Sand and clay	14	154		
	Clay	13	167		
	Hardpan	9	176		
	Gravel, hard	5	181		
	Gravel and water	13	194		
36N/01E-35G02	Topsoil	5	5	Dahlman	1985
	Brown clay	20	25		
	Blue clay	10	35		
	Brown sandy clay	15	50		
	Brown clay and gravel	35	85		
	Brown sand and clay	26	111		
	Blue clay	37	148		
	Water, sand, and gravel	12	160		
36N/01E-36R01	Dirty sand and gravel	10	10	Dahlman	1983
	Blue clay	12	22		
	Brown clay and gravel	21	43		
	Sand	12	55		
	Blue clay	20	75		
	Brown clay	59	134		
	Sand	3	137		
	Gravel and water	7	144		

520-78

Appendix 2.--Drillers' lithologic logs of wells used in the construction of hydrogeologic sections--Continued

Local well number	Driller's description of materials	Thickness (feet)	Depth of bottom (feet)	Driller's name	Year drilled
36N/02E-31M01	Sand	3	3	Kounkel	1973
	Gravel	12	15		
	Sand	7	22		
	Gravel	13	35		
	Yellow clay	15	50		
	Clayey sand	45	95		
	Blue clay	30	125		
	Gravel	10	135		
	Sand, gravel, and water	13	148		

Appendix 3.--Monthly precipitation totals

[Anacortes values were obtained from the National Oceanographic and Atmospheric Administration (1992); all units are inches]

Date	Guemes Island Station[1] 1	2	3	4	5	6	Anacortes
October 1991	0.98	0.84	0.90	1.05	0.90	1.11	0.84
November 1991	5.37	4.82	5.23	5.01	5.39	5.48	4.94
December 1991	1.99	1.79	2.26	1.96	1.98	2.40	2.25
January 1992	4.46	3.88	4.53	3.84	4.49	5.08	5.14
February 1992	2.28	2.04	2.41	2.25	2.12	2.40	2.47
March 1992	.72	.69	.83	.72	.80	.86	.94
April 1992	3.07	3.09	3.16	3.14	3.04	3.68	3.03
May 1992	.50	.47	.47	.45	.49	.56	.45
June 1992	1.88	1.87	2.10	2.11	2.00	2.31	2.02
July 1992	1.80	1.66	1.81	1.72	1.64	2.28	1.62
August 1992	.98	.84	.88	.90	.96	.98	.71
September 1992	3.42	3.41	3.60	3.46	3.09	3.77	2.99
October 1992	1.68	1.28	1.46	1.48	1.55	1.65	1.56
November 1992	5.40	4.90	5.68	5.50	5.52	5.75	6.31
December 1992	3.16	2.34	2.82	2.70	2.88	2.56	2.93

[1] See figure 14 for location of stations.

Appendix 4.--Monthly water-level measurements

Local well number	Date water level measured	Water level (feet below land surface)
35N/01E-01A01	12-17-91	134.01
	01-04-92	133.99
	02-19-92	134.05
	03-19-92	134.00
	04-21-92	133.95
	05-20-92	134.08
	06-16-92	134.05
	07-18-92	134.08
	08-20-92	134.04
	09-17-92	134.19
	10-21-92	134.23
	11-21-92	134.15
	12-21-92	134.22
35N/01E-01M01	12-16-91	156.72
	01-14-92	156.63
	02-19-92	156.62
	03-18-92	157.10
	04-21-92	156.59
	05-20-92	156.95
	06-16-92	157.50
	07-16-92	157.35
	08-20-92	157.08
	09-16-92	157.05
	10-21-92	156.89
	11-21-92	156.70
	12-21-92	156.64
35N/01E-01R01	12-17-91	90.15
	01-14-92	93.02
	02-19-92	89.62
	03-18-92	89.96
	04-21-92	89.82
	05-20-92	90.18
	06-16-92	90.30
	07-16-92	90.25
	08-20-92	90.36
	09-16-92	91.57
	10-21-92	90.15
	11-19-92	90.49
	12-21-92	90.03
35N/01E-02L01	12-16-91	15.73
	01-14-92	16.23
	02-19-92	16.52
	03-19-92	17.55
	04-21-92	19.17
	05-20-92	20.84
	06-16-92	21.50
	07-18-92	17.56
	08-20-92	17.36
	09-16-92	16.96

Appendix 4.--Monthly water-level measurements--Continued

Local well number	Date water level measured	Water level (feet below land surface)
	10-21-92	16.32
	11-20-92	15.41
	12-21-92	14.99
35N/01E-11Q02	12-16-91	21.86
	01-14-92	21.89
	02-19-92	21.57
	03-18-92	22.19
	04-21-92	21.85
	05-21-92	22.41
	06-16-92	22.34
	07-16-92	22.28
	08-20-92	22.31
	09-16-92	22.34
	10-21-92	22.25
	11-19-92	22.25
	12-21-92	21.96
35N/01E-11R02	12-16-91	79.41
	01-14-92	79.88
	02-19-92	79.82
	03-18-92	79.85
	04-21-92	79.77
	05-20-92	79.82
	06-16-92	79.85
	07-16-92	79.85
	08-20-92	79.90
	09-16-92	79.91
	10-21-92	79.98
	11-20-92	80.06
	12-21-92	80.08
35N/01E-12L02	12-16-91	97.58
	01-14-92	97.94
	02-19-92	97.70
	03-18-92	97.70
	04-21-92	97.28
	05-20-92	97.40
	06-16-92	97.48
	07-16-92	97.52
	08-20-92	97.60
	09-16-92	97.76
	10-22-92	97.90
	11-20-92	98.11
	12-22-92	98.04
35N/01E-12P03	12-16-91	71.40
	01-14-92	71.04
	02-20-92	70.72
	03-18-92	72.43
	04-23-92	70.99
	05-20-92	70.96
	06-16-92	71.31

520-80

Appendix 4.--Monthly water-level measurements--Continued

Local well number	Date water level measured	Water level (feet below land surface)
	07-16-92	71.16
	08-21-92	71.23
	09-16-92	72.08
	10-21-92	71.04
	11-21-92	73.99
	12-22-92	72.55
35N/01E-12R02	12-17-91	54.15
	01-14-92	55.02
	02-19-92	53.85
	03-18-92	54.55
	04-21-92	55.08
	06-15-92	55.46
	07-16-92	55.00
	08-20-92	54.90
	09-16-92	55.00
35N/02E-06G01	12-17-91	14.81
	01-14-92	13.36
	02-19-92	10.10
	03-18-92	9.45
	04-21-92	10.99
	05-20-92	13.77
	06-16-92	14.52
	07-16-92	15.03
	08-20-92	16.72
	09-17-92	16.15
	10-21-92	15.47
	11-21-92	13.60
	12-21-92	11.27
35N/02E-07A01	12-17-91	62.35
	01-14-92	62.64
	02-20-92	62.15
	03-18-92	62.50
	04-21-92	62.39
	05-20-92	62.65
	06-16-92	62.78
	07-16-92	62.80
	08-20-92	62.85
	09-17-92	63.10
	10-21-92	62.82
	11-21-92	63.08
	12-21-92	63.43
35N/02E-07H01	12-17-91	1.79
	01-14-92	1.40
	02-19-92	.75
	03-18-92	1.30
	04-21-92	1.18
	05-20-92	33.70
	06-16-92	37.61
	07-16-92	35.43

Appendix 4.--Monthly water-level measurements--Continued

Local well number	Date water level measured	Water level (feet below land surface)
	08-20-92	37.48
	09-16-92	37.70
	10-20-92	37.27
	11-23-92	10.37
	12-22-92	1.08
35N/02E-08G01	12-17-91	49.07
	01-14-92	49.76
	03-18-92	52.59
	04-27-92	30.87
	05-20-92	46.68
	06-16-92	59.54
	07-16-92	72.30
	08-20-92	54.08
	09-16-92	29.27
36N/01E-25N06	12-16-91	148.71
	01-14-92	150.49
	02-19-92	148.07
	03-18-92	148.83
	04-21-92	148.44
	05-22-92	148.86
	06-16-92	148.97
	07-16-92	148.87
	08-20-92	149.09
	09-16-92	149.20
	10-21-92	148.95
	11-20-92	148.92
	12-21-92	148.63
36N/01E-26A01	01-14-92	16.55
	02-19-92	15.91
	03-26-92	17.17
	04-21-92	16.84
	05-21-92	18.37
	06-16-92	17.67
	07-16-92	17.85
	08-20-92	18.02
	09-16-92	17.99
	10-22-92	17.75
	11-20-92	18.57
	12-21-92	17.86
36N/01E-35F01	12-17-91	151.76
	01-14-92	152.69
	03-18-92	152.80
	04-21-92	152.37
	05-22-92	153.34
	06-16-92	153.05
	07-16-92	153.05
	08-20-92	152.89
	09-16-92	152.69
	10-22-92	152.99

Appendix 4.--Monthly water-level measurements--Continued

Local well number	Date water level measured	Water level (feet below land surface)
	11-20-92	152.03
	12-22-92	152.38
36N/01E-36C03	03-18-92	14.15
	04-21-92	13.42
	05-22-92	13.86
	06-16-92	13.96
	07-16-92	13.87
	08-21-92	13.95
	09-16-92	14.10
	10-21-92	13.91
	11-20-92	13.88
	12-22-92	13.67
36N/01E-36P01	12-16-91	6.67
	01-19-92	6.53
	03-18-92	5.82
	04-21-92	5.71
	05-20-92	6.04
	06-16-92	6.50
	07-16-92	7.15
	08-20-92	7.85
	09-16-92	7.75
	10-22-92	8.15
	11-21-92	7.63
	12-21-92	8.19
36N/01E-36Q01	12-16-91	101.55
	01-14-92	101.38
	02-19-92	101.05
	03-18-92	101.42
	04-21-92	101.36
	05-20-92	101.80
	06-16-92	102.56
	07-16-92	101.88
	08-20-92	102.55
	09-16-92	101.90
	10-21-92	101.70
	11-19-92	101.60
	12-21-92	101.44
36N/02E-31P01	01-14-92	78.92
	02-19-92	78.79
	03-18-92	78.82
	04-21-92	78.70
	05-20-92	79.02
	06-16-92	79.00
	07-16-92	78.90
	08-20-92	78.81
	09-17-92	79.14
	10-21-92	79.06
	11-21-92	79.09
	12-22-92	79.00

0593

520-82

Appendix 5.--Monthly values of chloride concentration and specific conductance
[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius]

Local well number	Date	Chloride, dissolved (mg/L as CL)	Specific conductance (µS/cm)
35N/01E-02L01	12-16-91	191	865
	01-14-92	191	938
	02-19-92	196	959
	03-18-92	194	951
	04-21-92	191	941
	05-20-92	214	1,030
	06-16-92	199	972
	07-18-92	218	1,040
	08-20-92	183	917
	09-16-92	197	962
	10-21-92	183	930
	11-20-92	183	935
	12-21-92	179	912
35N/01E-11R02	12-16-91	48.4	441
	01-14-92	48.4	466
	02-19-92	47.5	466
	03-18-92	47.9	466
	04-21-92	47.5	466
	05-20-92	47.5	467
	06-16-92	47.5	467
	07-16-92	48.0	467
	08-20-92	47.0	467
	09-16-92	46.0	461
	10-21-92	46.0	463
	11-20-92	45.0	457
	12-21-92	45.0	456
35N/01E-12R01	12-16-91	30.3	377
	01-14-92	27.1	390
	02-19-92	28.0	394
	03-18-92	28.4	395
	04-21-92	29.1	397
	05-22-92	30.8	402
	06-16-92	33.0	409
	07-16-92	34.0	411
	08-20-92	35.0	418
	09-16-92	35.0	415
	10-21-92	33.0	408
	11-19-92	31.0	403
	12-21-92	31.0	402

0594

520·83

Appendix 5.--Monthly values of chloride concentration and specific conductance--Continued

Local well number	Date	Chloride, dissolved (mg/L as CL)	Specific conductance (µS/cm)
35N/01E-14B02	12-16-91	54.2	444
	01-14-92	53.8	476
	03-18-92	53.5	476
	03-18-92	30.5	302
	05-21-92	51.0	530
	06-16-92	44.3	541
	08-20-92	37.0	525
	09-16-92	31.0	488
	10-23-92	32.0	499
	11-21-92	44.0	602
	12-23-92	35.0	352
35N/02E-07A01	12-17-91	21.1	442
	01-14-92	20.7	497
	02-19-92	20.9	505
	03-18-92	20.6	494
	04-21-92	20.9	507
	05-20-92	20.6	504
	06-16-92	20.9	502
	07-16-92	21.0	495
	08-20-92	20	483
	09-17-92	20	451
	10-21-92	21	487
	11-21-92	21	497
	12-21-92	21	447
35N/02E-07H01	12-17-91	49.4	399
	01-14-92	46.3	398
	02-19-92	31.9	298
	03-18-92	30.5	302
	05-21-92	51	530
	06-16-92	44.3	541
	08-20-92	37	525
	09-16-92	31	488
	10-23-92	32	499
	11-21-92	44	602
	12-23-92	35	352

05

520·84

Appendix 5.--Monthly values of chloride concentration and specific conductance--Continued

Local well number	Date	Chloride, dissolved (mg/L as CL)	Specific conductance (µS/cm)
36N/01E-26A01	01-14-92	32.0	457
	02-19-92	32.2	241
	03-18-92	39.0	285
	04-21-92	35.1	276
	05-21-92	37.2	279
	06-16-92	36.5	276
	07-16-92	35.0	267
	08-20-92	64.0	388
	09-16-92	48.0	329
	10-22-92	34.0	271
	11-20-92	41.0	291
	12-21-92	39.0	288
36N/01E-35F01	12-17-91	16.8	277
	01-14-92	15.9	285
	03-18-92	67.0	468
	04-21-92	41.1	378
	05-20-92	19.9	304
	06-16-92	28.4	335
	07-16-92	31.0	347
	08-20-92	44.0	395
	09-16-92	32.0	352
	10-24-92	29.0	345
	11-21-92	31.0	352
	12-23-92	25.0	333
36N/01E-36C01	12-16-91	345	1,310
	01-14-92	348	1,450
	02-19-92	347	1,470
	03-26-92	381	1,570
	04-21-92	368	1,530
	05-22-92	352	1,490
	06-16-92	344	1,450
	07-16-92	346	1,460
	08-20-92	323	1,380
	09-16-92	313	1,350
	10-21-92	309	1,350
	11-20-92	316	1,380
	12-21-92	331	1,430

0596

520-85

Appendix 5.--Monthly values of chloride concentration and specific conductance--Continued

Local well number	Date	Chloride, dissolved (mg/L as CL)	Specific conductance (μS/cm)
36N/01E-36C03	03-18-92	86.9	530
	04-21-92	168	818
	05-22-92	189	891
	06-16-92	194	909
	07-16-92	191	892
	08-21-92	215	986
	09-16-92	157	769
	10-21-92	131	692
	11-20-92	144	735
	12-22-92	147	744
36N/01E-36Q01	12-16-91	148	865
	01-14-92	122	868
	02-19-92	125	864
	03-18-92	126	865
	04-21-92	114	845
	05-20-92	149	921
	06-16-92	176	1,020
	07-16-92	167	977
	08-20-92	169	1,030
	09-16-92	180	1,000
	10-21-92	162	963
	11-19-92	153	948
	12-21-92	141	917
36N/02E-31P01	01-14-92	15.6	260
	02-19-92	15.2	261
	03-18-92	14.9	261
	04-21-92	14.9	259
	05-20-92	14.5	257
	06-16-92	14.5	256
	07-16-92	14.0	253
	08-20-92	14.0	252
	09-17-92	14.0	254
	10-21-92	15.0	259
	11-21-92	16.0	261
	12-22-92	15.0	260

05

520-86

Appendix 6.--Values and concentrations of field measurements, common constituents, arsenic, and radon

[deg. C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; mg/L, micrograms per liter; <, not detected at the given concentration; cols. per 100 mL, colonies per 100 milliliters; pCi/L, picocuries per liter; --, not determined]

Local well number	Date	Time	Temperature water (deg. C)	Specific conductance (µS/cm)	Specific conductance lab (µS/cm)	pH, (standard units)	pH, lab (standard units)	Oxygen, dissolved (mg/L)	Hardness total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)
35N/01E-01C02	06-15-92	1525	12.5	234	231	6.6	6.8	1.3	78	16
35N/01E-01D01	06-17-92	1205	10.0	358	352	7.4	7.7	.2	140	24
35N/01E-01M01	06-16-92	1300	12.5	345	383	7.7	7.6	.2	160	30
35N/01E-01R01	06-16-92	1705	10.5	334	347	8.1	7.8	<.1	120	25
35N/01E-02L01	06-16-92	1530	10.5	749	972	7.2	7.4	.9	200	31
35N/01E-12F01	06-16-92	1705	12.5	221	219	6.2	6.5	2.5	78	18
35N/01E-12P03	06-17-92	0830	12.0	336	329	7.9	7.9	.4	150	29
35N/01E-12R02	06-15-92	0920	11.0	511	488	8.2	8.2	.5	110	19
35N/01E-14B02	06-16-92	1200	11.0	481	485	7.1	7.1	<.1	180	34
35N/02E-06E01	06-17-92	0940	11.5	248	244	6.3	7.1	8.7	89	16
35N/02E-06G01	06-16-92	1135	15.0	555	549	7.2	7.5	2.3	270	53
35N/02E-07A01	06-15-92	1205	11.0	518	505	7.9	7.8	<.1	250	51
35N/02E-07G01	06-17-92	1040	14.0	347	341	7.2	7.4	.4	150	38
35N/02E-07H04	06-15-92	1405	11.5	597	593	8.5	8.5	<.1	94	16
35N/02E-08E02	06-16-92	1530	11.5	446	467	8.2	8.1	.1	190	31
36N/01E-26H01	06-16-92	0920	12.5	1330	1280	6.7	6.9	1.7	100	10
36N/01E-26J01	06-15-92	1655	10.5	707	679	7.2	7.4	9.2	140	20
36N/01E-26P01	06-15-92	1400	10.5	250	255	6.2	6.5	3.2	88	17
36N/01E-35F01	06-15-92	1230	10.0	318	335	6.9	7.0	8.9	100	17
36N/01E-36C01	06-15-92	1530	11.5	1370	1430	6.9	7.0	2.3	190	22
36N/01E-36C05	06-15-92	1700	11.0	222	225	6.4	6.6	5.3	74	15
36N/01E-36Q01	06-16-92	1000	11.5	970	1010	7.9	7.6	.1	63	13
36N/02E-31M01	06-16-92	1040	14.0	302	298	7.6	7.7	2.2	120	19
36N/02E-31P01	06-15-92	1000	10.5	254	254	7.6	7.6	<.1	99	15

520.87

Appendix 6.--Values and concentrations of field measurements, common constituents, arsenic, and radon--Continued

Local well number	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium, percent	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity lab (mg/L as $CaCO_3$)	Alkalinity field (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)
35N/01E-01C02	9.2	12	25	0.6	1.7	55	--	35	14	0.1
35N/01E-01D01	19	21	24	.8	4.2	159	--	12	13	.3
35N/01E-01M01	20	17	19	.6	3.4	135	134	11	39	.1
35N/01E-01R01	15	25	30	1	3.7	165	--	.3	15	<.1
35N/01E-02L01	30	110	54	3	5.5	122	--	50	210	<.1
35N/01E-12F01	8.1	11	23	.5	1.5	53	--	22	16	<.1
35N/01E-12P03	18	13	16	.5	3.0	147	--	4.2	17	<.1
35N/01E-12R02	15	61	53	3	5.2	174	174	.1	57	.1
35N/01E-14B02	22	30	27	1	3.8	148	162	10	60	.1
35N/02E-06E01	12	10	19	.5	1.8	57	--	24	19	<.1
35N/02E-06G01	33	14	10	.4	1.6	197	--	68	21	<.1
35N/02E-07A01	30	12	9	.3	2.0	208	208	36	24	<.1
35N/02E-07G01	13	14	17	.5	1.9	142	--	18	13	<.1
35N/02E-07H04	13	99	67	4	9.4	286	--	7.1	24	.2
35N/02E-08E02	28	20	18	.6	6.9	191	--	32	19	<.1
36N/01E-26H01	19	190	78	8	11	51	--	82	310	.2
36N/01E-26J01	22	76	53	3	5.3	104	--	52	120	.1
36N/01E-26P01	11	18	31	.8	.50	67	--	17	16	<.1
36N/01E-35F01	14	24	34	1	2.2	72	--	21	27	<.1
36N/01E-36C01	32	200	69	6	8.8	115	--	67	330	<.1
36N/01E-36C05	8.8	13	27	.7	1.2	48	--	23	21	<.1
36N/01E-36Q01	7.5	180	85	10	4.3	247	247	<.1	180	.2
36N/02E-31M01	18	13	18	.5	3.1	116	--	19	15	<.1
36N/02E-31P01	15	13	22	.6	2.2	79	83	25	16	<.1

0

520-88

Appendix 6.--Values and concentrations of field measurements, common constituents, arsenic, and radon--Continued

Local well number	Silica, dis-solved (mg/L as SiO_2)	Solids, sum of consti-tuents, dis-solved (mg/L)	Nitro-gen, NO_2+ NO_3, dis-solved (mg/L as N)	Iron, dis-solved (µg/L as Fe)	Manga-nese, dis-solved (µg/L as Mn)	Arsenic, dis-solved (µg/L as As)	Coli-form, fecal (cols. per 100 mL)	Strep-tococci, fecal (cols. per 100 mL)	Radon 222 total (pci/L)
35N/01E-01C02	31	156	0.75	270	79	<1	<1	<1	--
35N/01E-01D01	44	234	--	770	890	<1	<1	<1	--
35N/01E-01M01	34	237	<.05	1,300	190	<1	<1	<1	--
35N/01E-01R01	39	223	<.05	480	190	<1	<1	<1	120
35N/01E-02L01	30	543	.75	10	3	1	<1	<1	--
35N/01E-12F01	27	141	1.3	18	12	<1	<1	<1	--
35N/01E-12P03	50	223	<.05	500	150	<1	<1	<1	--
35N/01E-12R02	23	286	<.05	1,300	150	<1	<1	<1	--
35N/01E-14B02	43	310	<.05	7,100	1,500	<1	<1	<1	<80
35N/02E-06E01	29	159	2.9	12	31	<1	<1	<1	--
35N/02E-06G01	29	338	.08	54	21	<1	<1	<1	170
35N/02E-07A01	36	318	<.05	1,900	96	1	<1	<1	--
35N/02E-07G01	13	199	.55	33	36	<1	<1	2	--
35N/02E-07H04	23	364	<.05	42	13	<1	<1	<1	--
35N/02E-08E02	32	284	<.05	260	19	<1	<1	<1	<80
36N/01E-26H01	25	693	3.4	140	26	<1	<1	<1	390
36N/01E-26J01	30	394	1.2	16	2	<1	<1	<1	--
36N/01E-26P01	34	175	4.8	20	2	<1	<1	<1	--
36N/01E-35F01	31	209	6.8	14	1	<1	<1	<1	--
36N/01E-36C01	28	760	.75	18	2	<1	<1	<1	--
36N/01E-36C05	30	149	1.9	39	4	<1	<1	<1	--
36N/01E-36Q01	41	574	<.05	1,400	280	14	<1	<1	--
36N/02E-31M01	32	189	<.05	180	120	1	<1	<1	--
36N/02E-31P01	29	167	<.05	1,900	150	1	<1	<1	--

0600

520-89

Appendix 7.--Concentrations of trace metals
[µg/L, micrograms per liter]

Local well number	Date	Time	Arsenic, dis-solved (µg/L as As)	Barium, dis-solved (µg/L as Ba)	Cadmium, dis-solved (µg/L (as Cd)	Chrom-mium, dis-solved (µg/L as Cr)
35N/01E-01M01	06-16-92	1300	<1	48	<1	<1
35N/01E-14B02	06-16-92	1200	<1	63	<1	<1
35N/02E-08E02	06-16-92	1530	<1	25	<1	1
36N/01E-26J01	06-15-92	1655	<1	15	<1	<1
36N/01E-36Q01	06-16-92	1000	14	50	<1	<1

Local well number	Copper, dis-solved (µg/L as Cu)	Lead, dis-solved (µg/L as Pb)	Mercury, dis-solved (µg/L as Hg)	Sele-nium, dis-solved (µg/L as Se)	Silver, dis-solved (µg/L as Ag)	Zinc, dis-solved (µg/L as Zn)
35N/01E-01M01	<1	<1	<0.1	<1	<1	7
35N/01E-14B02	<1	<1	<.1	<1	<1	220
35N/02E-08E02	<1	<1	<.1	<1	<1	6
36N/01E-26J01	4	<1	<.1	2	<1	540
36N/01E-36Q01	<1	<1	<.1	<1	<1	200

520-90

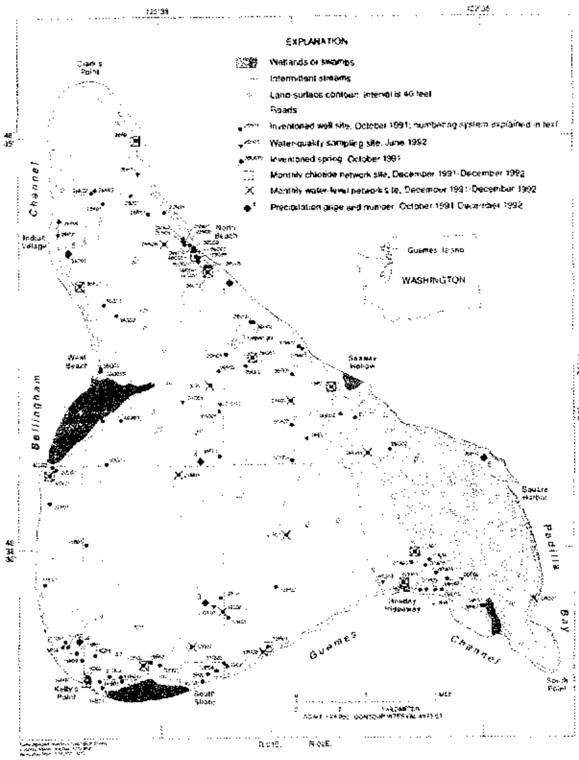
Appendix 8.--Concentrations of septage-related constituents
[mg/L, milligrams per liter; µg/L, micrograms per liter]

Local well number	Date	Time	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)	Boron, dissolved (µg/L as B)	Methylene blue active substance (mg/L)
35N/01E-01M01	06-16-92	1300	<0.05	30	<0.02
35N/01E-02L01	06-16-92	1530	.75	60	<.02
35N/01E-12F01	06-16-92	1705	1.30	20	<.02
35N/01E-14B02	06-16-92	1200	<.05	50	<.02
35N/02E-07H04	06-15-92	1405	<.05	420	<.02
35N/02E-08E02	06-16-92	1530	<.05	100	<.02
36N/01E-26H01	06-16-92	0920	3.40	120	<.02
36N/01E-26J01	06-15-92	1655	1.20	50	<.02
36N/01E-26P01	06-15-92	1400	4.80	20	.02
36N/01E-36C01	06-15-92	1530	.75	110	<.02
36N/01E-36C05	06-15-92	1700	1.90	20	.03
36N/02E-31P01	06-15-92	1000	<.05	20	<.02

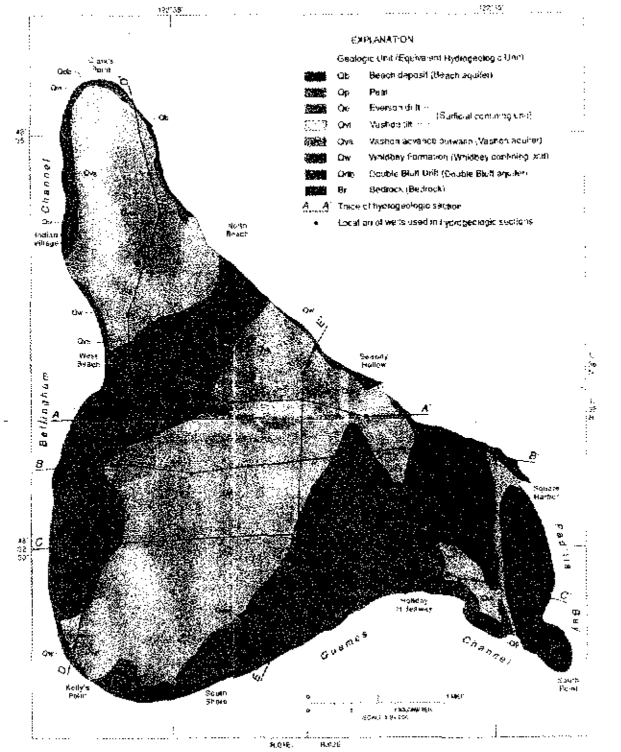
06^2

520-92

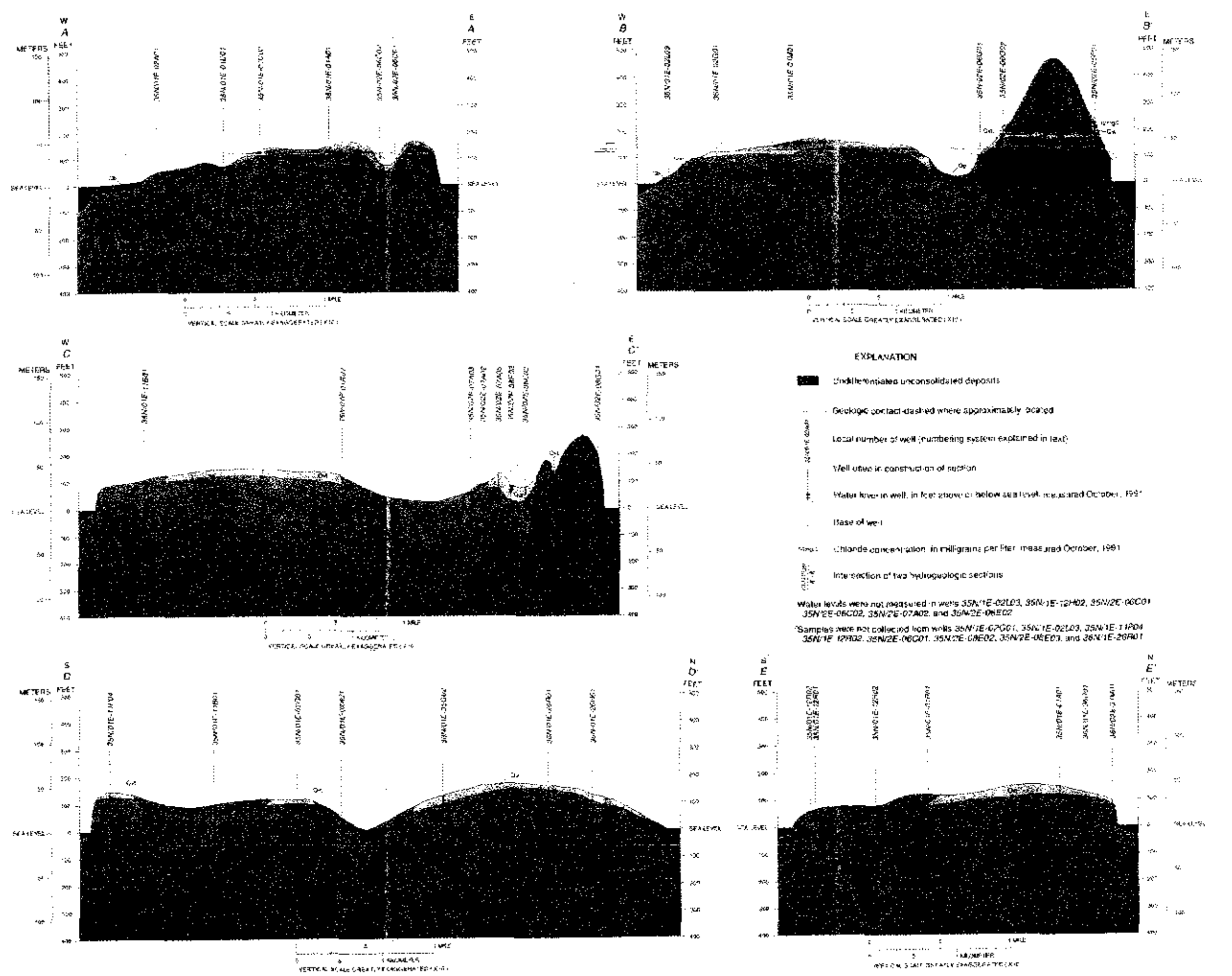
☆ U.S. GOVERNMENT PRINTING OFFICE: 1995 - 692-435 / 22003 REGION NO. 10



(a) Location of inventoried wells used to collect geologic and hydrologic data



(b) Surficial geology with location of hydrogeologic sections



(c) Hydrogeologic sections A-A' through E-E'

MAPS SHOWING THE LOCATIONS OF INVENTORIED WELLS AND SURFICIAL GEOLOGY, AND HYDROGEOLOGIC SECTIONS ON GUEMES ISLAND, SKAGIT COUNTY, WASHINGTON

By
S.C. Kahle and T.D. Olsen
1995

POTLATCH BEACH
HYDROGEOLOGIC STUDY

Project No. 94001

April 28, 1994

PREPARED FOR
POTLATCH BEACH WATER ASSOCIATION

HWA
HONG WEST
& ASSOCIATES, INC.

0604

5221

HONG WEST
& ASSOCIATES, INC.

Geotechnical Engineering
Hydrogeology
Geoenvironmental Services
Testing & Inspection

April 28, 1994

Potlatch Beach Water Association
c/o Dix Baker
430A West Shore Road
Guemes Island, Washington 98221

Subject: Potlatch Beach Hydrogeologic Study

Dear Mr. Baker:

Please find attached, our hydrogeologic report evaluating seawater intrusion contamination of the Potlatch Beach Water Association's wells. Unfortunately, our analysis indicates that seawater intrusion will preclude or limit additional ground water development in the north end of Guemes Island and only through significant reductions in water usage and pumping can you halt or reverse the increases in chloride concentrations in your existing wells. If you have any questions or comments about the report, please contact us. We enjoyed working with you and appreciate the opportunity to be of service on this project.

Sincerely,

Hong West & Associates, Inc.

Larry West

Robert E. Long Jr.
Hydrogeologist

Larry West
Hydrogeologist

0605

522-2

19730-64th Ave. W.
Lynnwood, WA 98036-5904
Tel. 206-774-0106
Fax. 206-775-7506

POTLATCH BEACH
HYDROGEOLOGIC STUDY

TABLE OF CONTENTS

INTRODUCTION

At the request of the Potlatch Beach Water Association (the Association), Hong West & Associates, Inc. (HWA) conducted a preliminary hydrogeologic study of sea water intrusion on Guemes Island, Skagit County, Washington. The Association is under an Ecology water rights order of compliance to submit regular results of chloride concentration testing, record of flow rate, and water levels for the Association's wells. We characterized site hydrogeology using existing information supplemented with data collected by the Potlatch Beach Water Association.

SCOPE OF WORK

Work for this project (outlined in our proposal dated September 21, 1993) consisted of two Tasks, as follows:

TASK 1 Collect and Review Hydrogeologic Information
TASK 2 Evaluate Site Aquifer and Prepare Hydrogeologic Report

The objectives of this investigation include characterizing hydrogeologic conditions of the production aquifer in the vicinity of the Association's wells and assessing the potential for additional or future seawater intrusion of the aquifer. This information will provide a basis for evaluating options to reduce chloride concentrations in the Association's wells and/or whether or not the Association should construct additional wells.

SOURCES OF INFORMATION & ANALYSES

The evaluations, conclusions and recommendations included in this report are based on existing published information, and a brief site reconnaissance. In addition, we have reviewed Ecology water well reports (refer to Appendix A) and data collected by the USGS as part of their current seawater intrusion study of Guemes Island. The USGS study has not been completed and our conclusions are not based on the data interpretations or conclusions reached by the USGS. However, a review of the USGS data has provided insight to the hydrogeologic character of north Guemes Island.

During our site reconnaissance, we visited Potlatch Beach Water Association on March 12, 1994 to conduct general surface geologic reconnaissance of the area, inspect the pump house operations, and collect available groundwater information collected by Potlatch Beach Water Association representatives. We received chemical data, a record of water levels, pumping rates from Potlatch Wells #1 and #2, and measured the water levels on this date. In addition, with the permission of Mr. Tim Fanton, we received one set of chemistry data and measured the water level in the T. Fanton Well. We performed a comparative analysis of the data provided by the Association. These analyses are illustrated in graphical form (refer to Appendix A) and include:

0607

522-4

- Average Water Use in gallons per day (gpd) over time, compared to the Chloride Concentration in parts per million (ppm) for Potlatch Wells #1 and #2 (Graph 1 and Graph 2 respectively).
- Average Water Use in gallons per day (gpd) over time, compared to the Water Level in Feet (below ground surface) for Potlatch Wells #1 and #2 (Graph 3 and Graph 4 respectively).
- A comparison of Average Water Use in gallons per day (gpd) over time between Potlatch Well #1 and Potlatch Well #2 (Graph 5).

The extreme peaks for water use in Well #2 near the beginning of December 1993 and the negative values for Well #1 resulted from a faulty valving and metering mechanism.

PROJECT LOCATION AND DESCRIPTION

Figure 1, Vicinity Map And Cross-Section Locations, illustrates Potlatch Beach Water Association well positions at the north west side of Guemes Island. The site is located in the Southwest 1/4 of the Northeast 1/4 of Section 35, Township 35 North, Range 1 East of the Willamette Meridian, as shown on the USGS Cypress Island, Washington 7.5 minute topographic quadrangle. Access to the site is gained by ferry from Anacortes, Washington. The elevations in the area of the site range between approximately sea level and elevation 160 feet.

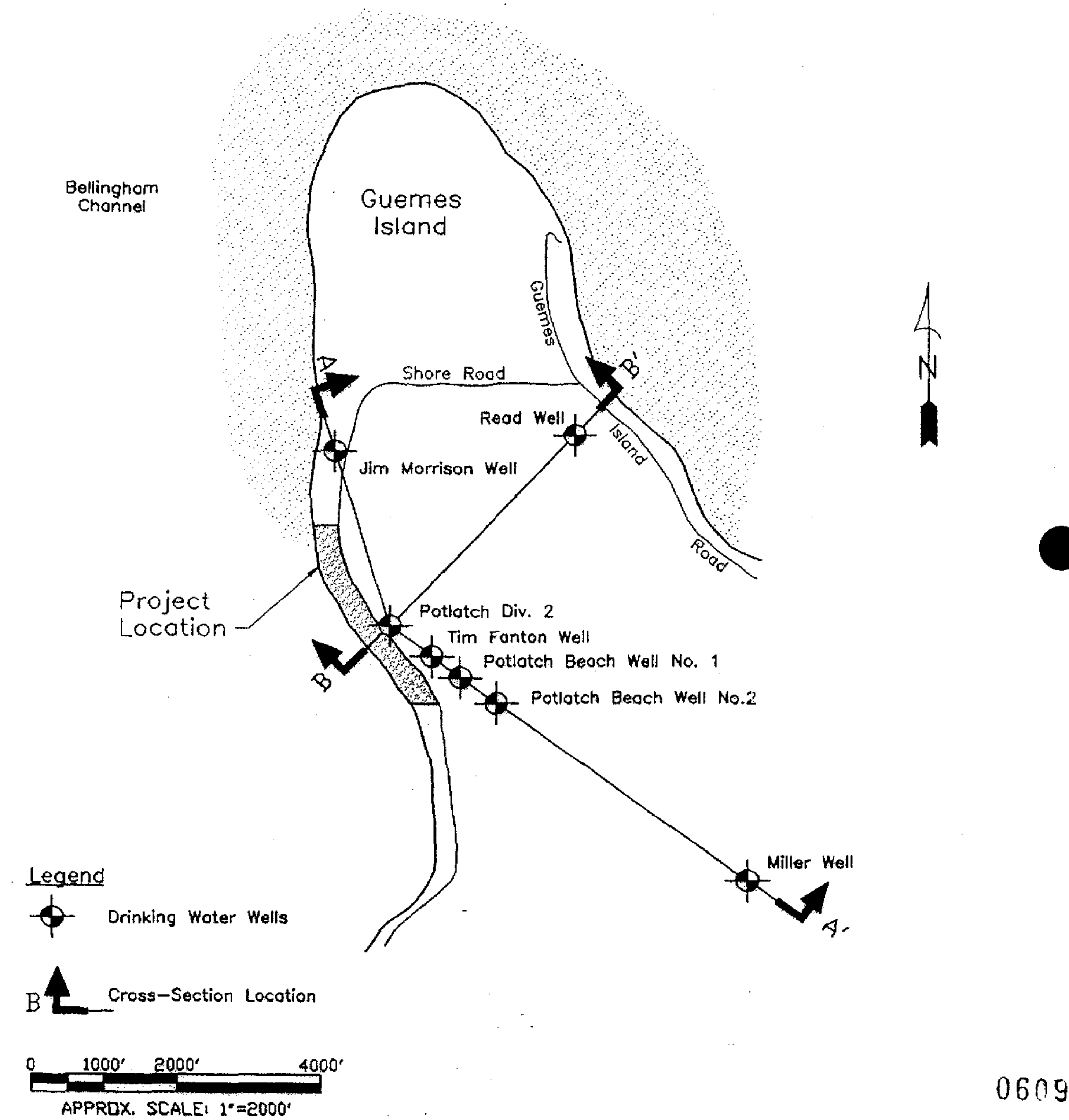
HYDROGEOLOGY

Guemes Island is located due north of the City of Anacortes, Washington, at the mouth of Padilla Bay. Guemes Island is about 4 miles long and 3.4 miles in width at its widest point. In the area of the Potlatch Beach Water Association Wells #1 and #2 the width tapers to approximately 0.85 miles. Topography of the island is characterized by glacially deposited rolling uplands in the north reaching 180 feet above sea level. In the south, bedrock outcrops form steep hills reaching 688 feet above sea level, wide shallow bays form a shoreline with steep slopes and cliffs composed of compact glacial deposits.

The geology of Guemes Island is dominated by a complex sequence of glacial and interglacial sediments deposited during the Quaternary Period (about 1.6 million to 10,000 years before present). At least 4 major glacial advances and retreats are believed to have occurred. The most recent, termed the Vashon stade of the Fraser Glaciation, occurred between 10,000 and 20,000 years before present. This most recent glacial advance left well exposed deposits of two units that mantle most of Guemes Island surface; the *Vashon Till* and the *Vashon Advance Outwash.* Older deposits that may be present and are buried beneath the Vashon deposits include (from youngest to oldest): the *Possession Drift* (glacial), the *Whidbey Formation* (interglacial), and the *Double Bluff Drift* (glacial). Refer to Figure 2, Generalized Stratigraphic Section, for a schematic of typical vertical sequence of geologic units on Guemes Island.

0608

522-5



0609

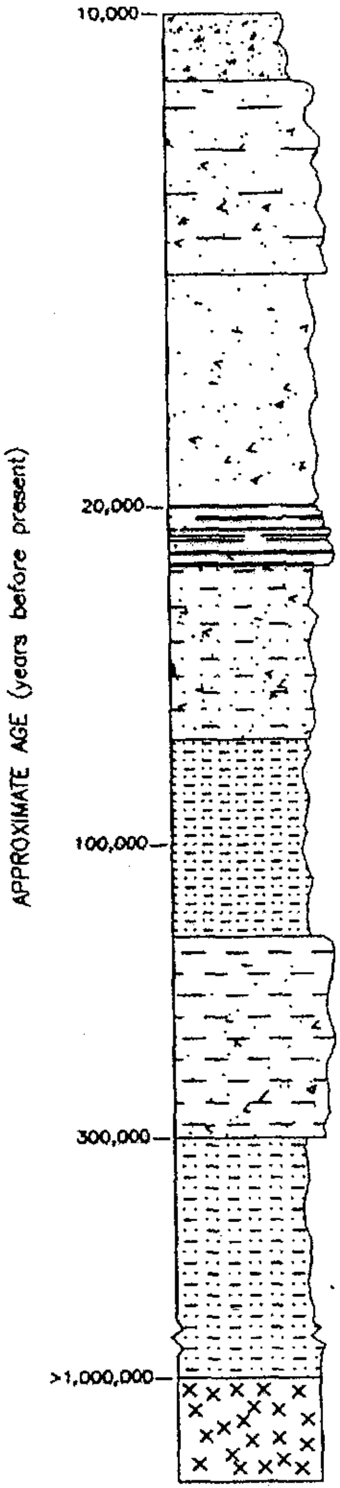
HWA
HONGWEST
& ASSOCIATES, INC.

POTLATCH BEACH
HYDROGEOLOGIC STUDY

VICINITY MAP 522-6
AND CROSS–SECTION LOCATIONS

PROJECT NO.: 94001 FIGURE: 1

C:\PROJECTS\94001\A–001.DWG



APPROXIMATE THICKNESS	MAP UNIT	UNIT NAME
0–15'	Qvr	Vashon Recessional Outwash
0–50'	Qvt	Vashon Till
0–200'	Qva	Vashon Advance Outwash
0–100'	Qtb	Transitional Beds
0–100'	Qpd	Possession Drift
0–50'	Qw	Whidbey Formation
0–50'	Qdb	Double Bluff Drift
?		Older, pre–Double Bluff sediment
? >650' below sea level		Bedrock – Tertiary Age

0610

DRAWING NOT TO SCALE

NOTE: Thickness and distribution of units vary – not all units are present at all locations. See Report Text for Unit Descriptions.

HONG WEST & ASSOCIATES, INC.

POTLATCH BEACH HYDROGEOLOGIC STUDY

GENERALIZED 522-7
STRATIGRAPHIC SECTION
GUEMES ISLAND AREA

PROJECT NO.: 94001 FIGURE: 2

C:\PROJECTS\94001\A-002.DWG

GEOLOGIC UNITS

Geologic conditions directly influence the occurrence and flow of ground water. Exposures of glacial deposits along the extensive sea cliffs and bluffs of Guemes Island, together with well logs, have provided an opportunity for geologic mapping and interpretation of the island's complex sediments. The following geologic unit descriptions are based largely on USGS water supply studies completed in Island County where similar geologic conditions prevail, and on recorded drilling logs from numerous locations on Guemes Island. They are presented in order from youngest to oldest:

Vashon Till - Symbol Qvt

Much of the Puget Lowland is covered by this very dense material formed at the base of the moving glacier. The till is comprised of an unsorted, nonstratified mixture of clay, silt, sand and gravel, with cobbles and boulders. Till often mimics pre-existing topography and is found to have great variability in thickness and location. In the northern area of Guemes Island, the till covers most of the upland areas, and varies in thickness from about 10 to 35 feet. Refer to Figures 3 and 4, Cross Sections. Where present, till overlies either advance outwash, or when the outwash is not present, older sediments such as the Whidbey Formation (USGS, 1982).

Vashon Advance Outwash - Symbol Qva

Meltwater streams emanating from the advancing glacial front produced extensive outwash deposits composed primarily of sand and gravel that filled existing topographic depressions which were subsequently overridden by glacial ice. Typically found beneath till, advance outwash sediments consist of gray silty fine sands to sandy gravels which typically become coarser upwards and are well sorted. They exhibit subhorizontal and cross bedded stratification. Over-consolidation (as evidenced by high density), produced by the weight of the glacier ice, is common. The lower part of the unit may transition into or include the upper part of the Whidbey Formation.

Transitional Beds - Symbol Qtb

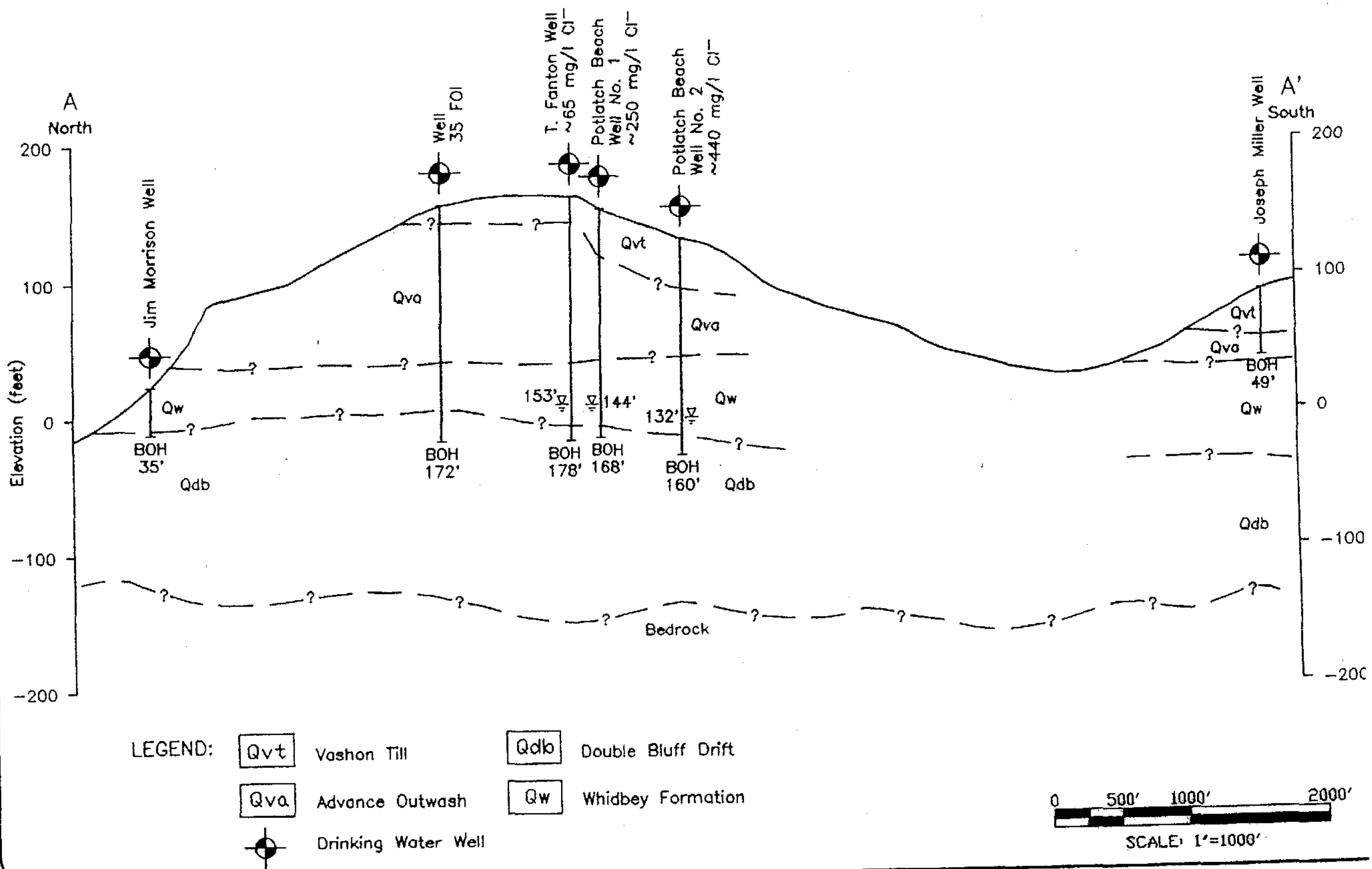
These fine grained interglacial deposits generally separate the Vashon glacial materials from older glacial deposits. Deposited during the Discovery interglacial period, the Transitional Beds typically consist of gray silts and very fine sands. Beneath north Guemes Island and the Potlatch area, the Transitional Beds appear to be absent along with the underlying Possession Drift.

Possession Drift - Symbol Qpd

0611

After the Vashon glacial deposits, the next-oldest glacial unit is termed the Possession Drift, an undivided mixture of till, glaciomarine sediments and outwash. The unit is discontinuous due to partial removal by subsequent glacial and nonglacial erosion. Based on existing data, it appears that the Possession Drift is not present beneath the Potlatch Beach project site.

522-8



522-9

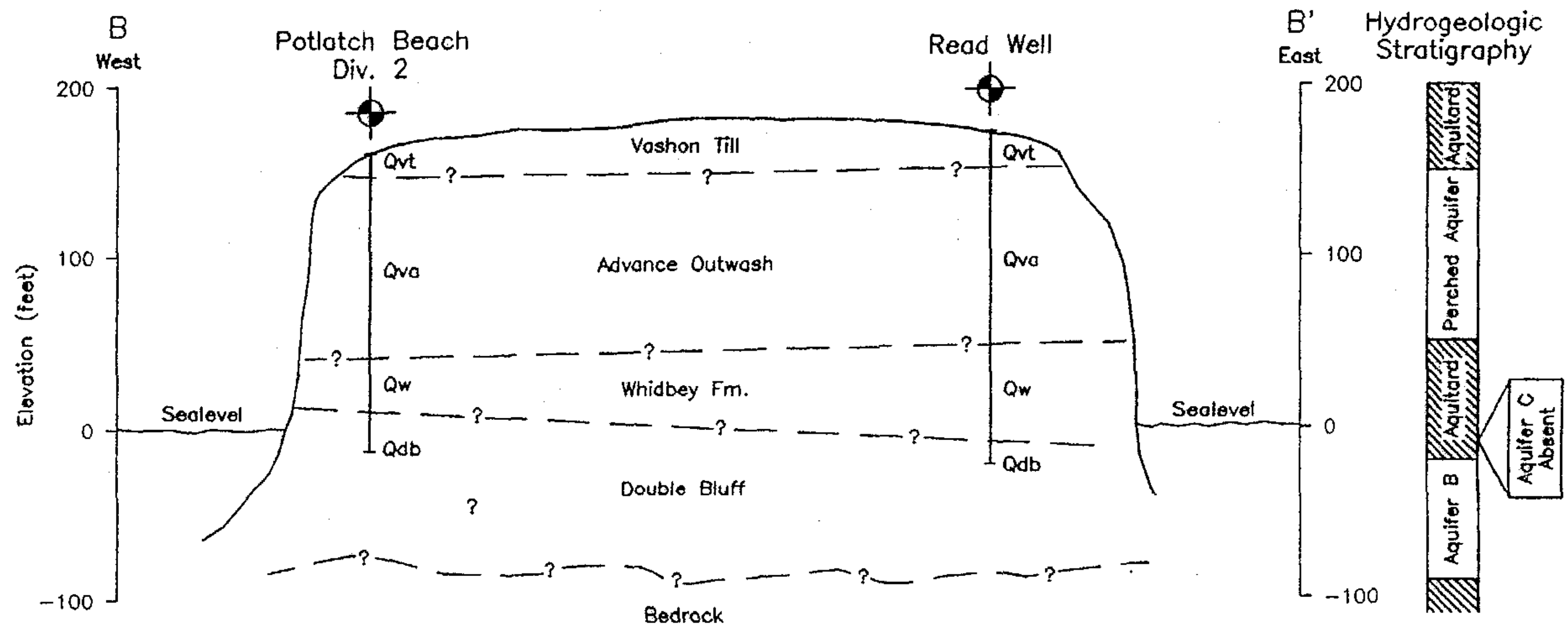
HONGWEST & ASSOCIATES, INC.

0612

POTLATCH BEACH
SEAWATER INTRUSION STUDY

GENERALIZED NORTH-SOUTH
CROSS-SECTION

PROJECT NO.: 94001 FIGURE: 3



LEGEND:

Qvt	Vashon Till	Qdb	Double Bluff Drift
Qva	Advance Outwash	Qw	Whidbey Formation
(well symbol)	Drinking Water Well		

0 500' 1000' 2000'

SCALE: 1"=1000'

HONGWEST & ASSOCIATES, INC.

0613

522-10

POTLATCH BEACH
SEAWATER INTRUSION STUDY

GENERALIZED WEST-EAST CROSS-SECTION AND HYDROSTRATIGRAPHY

PROJECT NO.: 94001 FIGURE: 4

Whidbey Formation - Symbol Qw

The Whidbey Formation represents the first significant interglacial deposit exposed beneath the Vashon (and where present, Possession) glacial units. It consists of medium to fine sand, fine sand and silt, with minor gravel. Peat beds and organic rich fine grained layers are an identifying feature. Thickness ranges from about 150 to 200 feet.

Double Bluff Drift - Symbol Qdb

This unit, the oldest glacial deposit recognized in the project area, resembles the Possession Drift, except for its lowermost stratigraphic position and distinctive wood-bearing lower silt/sand unit. Thickness ranges between about 20 and 70 feet. This unit appears to occur at about 10 to 20 feet below sea level (approximately 150-170 feet below the project site). The drift contains sand and gravel layers which yield water to the Potlatch Beach Water Association Wells #1 and #2, as well as others in the area.

Bedrock

Bedrock outcrops occur in the southern part of the island and likely form the base of the Double Bluff Drift. However, none of the wells in the northern part of the Island have penetrated the bedrock.

GROUND WATER OCCURRENCE

All of the above-described Pleistocene sediments are capable of storing and transmitting ground water to some degree. On Guemes Island, ground water is typically withdrawn from the coarser glacial sand and gravel deposits. For the purpose of this investigation we will adopt the established nomenclature from previous studies in nearby Island County (West et.al 1989; Anderson 1968) that have identified and named the vertical succession of potential water producing units, referred to as *aquifers*. Finer-grained deposits, including glacial till, and interglacial silt and clay, which tend to inhibit lateral and vertical ground water flow are referred to as *aquitards*. A discontinuous vertical sequence of aquifers has been identified (M.A. Jones, USGS, 1985). Refer to Table 1 for a listing of the aquifers and aquitards in the Guemes Island vicinity.

The Vashon Advance Outwash aquifer appears locally unproductive. Only a few wells in the northern part of the island produce from the Advance Outwash and they typically exhibit low yields (5 to 10 gallons per minute). This aquifer also experiences significant water level declines during drought periods.

Water well reports for the Potlatch area indicate the presence of only one significant aquifer, the Double Bluff Drift. Both the Association's supply wells produce from this aquifer which occurs beneath the site, at a depth of about 150 to 180 feet, approximately 20 to 30 feet below sea level. The available data indicate a confined aquifer with a potentiometric head (water level in the wells) above the top of the aquifer and above the base of the overlying Whidby Formation aquitard which serves as the confining unit. 0614

522-11

TABLE 1
HYDROSTRATIGRAPHY

Hydrogeologic Unit	Geologic Unit	Present/Absent at Site
Aquifer	Vashon Recessional Outwash	Absent, typically a seasonally perched aquifer where present.
Aquitard	Vashon Till	Present
Aquifer	Vashon Advance Outwash	Present, but locally not productive
Aquitard	Transitional Beds	Absent
Aquifer	Possession Drift	Absent
Aquitard	Whidbey Formation	Present
Aquifer	Double Bluff Drift	Present
Aquitard ?	Bedrock	Present, depth unknown.

522-12

AQUIFER RECHARGE AND DISCHARGE

Recharge to the aquifers of Guemes Island is exclusively from infiltration of precipitation. Although total annual precipitation is slightly greater than 25 inches, the low permeability of the Vashon Till mantling most of the north end of Guemes Island and steep slopes favor rapid runoff of rainfall. Consequently, only a small fraction of the total precipitation infiltrates to the underlying aquifers. Where the till thins or is absent, to the north of Potlatch Beach Wells #1 and #2 (Figure 3), rates of recharge may increase by several orders of magnitude providing ready recharge for the Vashon Advance Outwash aquifer. The fine grained, low permeability Whidbey Formation aquitard further reduces the recharge of infiltration of precipitation to the underlying Double Bluff Drift aquifer.

Natural discharge of ground water occurs as springs and seeps from the Advance Outwash aquifer along the bluffs and directly to Puget Sound from the deeper Double Bluff Drift aquifer. In addition, ground water discharges to wells. Over the period of data collection, September 1993 to March 1994, Potlatch Beach Wells #1 and #2 discharged an approximate average of 56 gallons per day (gpd) and 138 gallons per day (gpd), respectively. Refer to Data Graphs in Appendix A.

GROUND WATER FLOW

Ground water flow is governed by the differences in elevation or hydraulic pressure between the recharge and discharge areas and the permeability of the aquifer material. Insufficient data exist to adequately characterize ground water flow rate and direction beneath the Potlatch area. The Double Bluff Drift aquifer appears confined and in all cases ground water would flow from an area of high pressure to low pressure. The available information indicate the aquifer receives recharge from the upland areas, it follows that the general ground water flow direction would be from the uplands, toward the surrounding sea water. However, when discharge from wells within the aquifer exceeds the recharge rate and/or pumping levels in wells drop below sea level, the direction of ground water flow may reverse. A reversal of ground water flow direction in the Double Bluff Drift aquifer appears likely considering the high chloride concentrations recorded in Potlatch Beach Wells #1 and #2.

GROUND WATER QUALITY

The data graphs presented in Appendix A show the range of chloride concentrations in Well #1 from a low of 210 mg/l in early 1993 to a high of 355.4 mg/l in August 1993. Chloride concentrations for Well #2 range from 429 mg/l to 540 mg/l. The average chloride concentration for Potlatch Beach Wells #1 and #2 are approximately 268 mg/L and 504 mg/L respectively. In both cases, chloride concentrations exceed State of Washington water quality standards. Both the Potlatch Beach Water supply wells are completed in the Double Bluff Drift aquifer and are screened below sea level. Wells within this aquifer throughout the north end of the Island are known to be susceptible to sea water intrusion, a serious and nearly always irreversible water quality problem. Water quality data for wells north and east of the Potlatch area indicate ground water chloride concentrations greater than 250 mg/L are common.

0616

522-13

SEA WATER INTRUSION

Data graphs presented in Appendix A indicate chloride concentrations are increasing in Well #2 despite decreased pumping since the beginning of the year. Sea water intrusion into the coastal aquifers of Washington State is not uncommon and has been documented by Walters, 1971. On Guemes Island, sea water intrusion was identified by the Walters study in wells on the northeastern shore as early as 1966.

The general hydrogeologic conditions that cause sea water intrusion are fairly simple; the aquifer must be in hydraulic connection with the sea and the withdrawal, called *discharge*, of fresh water must be sufficient to lower water levels within the fresh water aquifer below that of sea level. This induces the sea water to enter the aquifer, and to encroach landward in the direction of the water withdraw. Refer to Figure 5. The interface between the encroaching sea water and the fresh water with in the aquifer is called *the zone of diffusion*.

The degree to which seawater enters the aquifer and the zone of diffusion advances landward depends on the balance between the net rate of water withdrawn (discharge) and the net rate at which fresh water naturally enters the aquifer, via infiltration from the surface (recharge). Typically, the wells closest to the saltwater experience the earliest and worst seawater intrusion. In the Potlatch system's case, Well #2 appears to experience the worst intrusion of the two, although Well #2 is further from the saltwater. This anomalous condition implies the presence of low-flow/no-flow zone or barrier near Well #2 which significantly reduces freshwater recharge to the aquifer on the landward side of the well inducing a greater rate of seawater intrusion. This situation is illustrated hypothetically as the *"barrier"* in Figure 5.

Based on the distribution of geologic units, the northern part of the island apparently experienced a period of significant erosion documented by the absence of the Possession Drift and the Transition Beds in the Potlatch area. During this erosional event, a deep channel may have been cut well into the Double Bluff Drift aquifer immediately south of the Potlatch wellfield. Silt and clay infilling of the channel would form an hydraulic barrier minimizing subsurface flow to the aquifer from the southern part of the island.

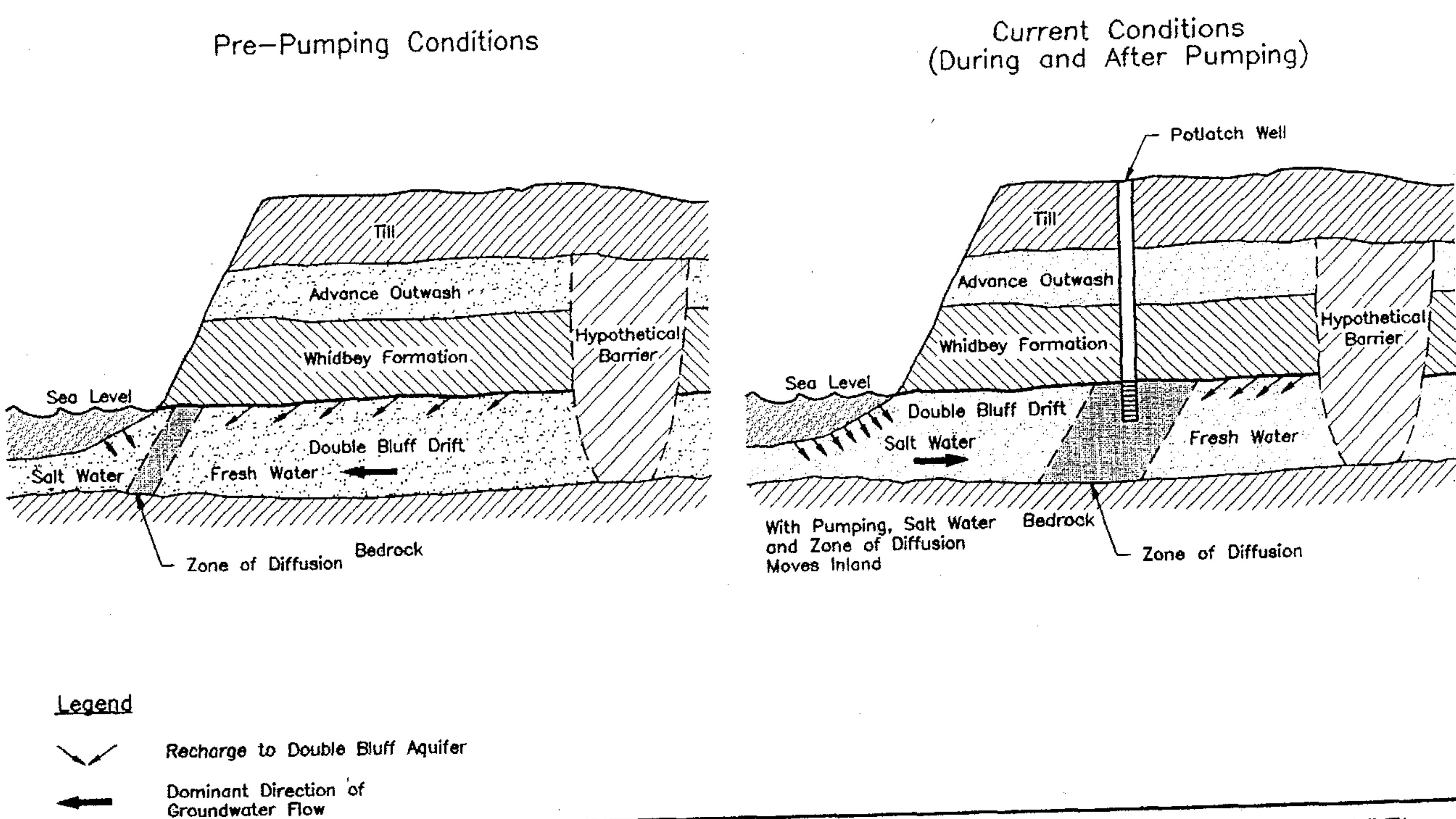
In effect, the aquifer the Potlatch wells produce from is like a pipe with an open end to the marine waters and a closed end to the fresh water. When the wells pump, the water they pull in is replaced by seawater.

CONCLUSIONS AND RECOMMENDATIONS

Over the period of this investigation the Association required nearly 200 gallons of water a day to sustain operations. This investigation was conducted over the low water use and high water recharge time of year, late fall to early spring. During the summer months we expect the addition of summer residents to significantly increase the Association's water consumption. Presently, plans exist for continued development of properties within the Association that will place additional demand on the Potlatch water system.

06

522-14



522-15

HWA HONGWEST & ASSOCIATES, INC.

0618

POTLATCH BEACH
SEAWATER INTRUSION STUDY

CONCEPTUAL MODEL
SEAWATER INTRUSION
NORTH GUEMES ISLAND

PROJECT NO.: 94001 FIGURE: 5

C:\PROJECTS\94001\B-005.DWG

Review of the site geology, hydrogeology, and ground water quality history provided to us by the Association lead us to the following conclusions:

- Ground water quality of Potlatch Beach Well #1 appears marginal with respect to chloride concentrations at the present rate of pumping.
- Ground water quality of Potlatch Beach Well #2 clearly exceeds the allowed chloride drinking water standard of 250 ppm at the present pumping rate.
- The low infiltration rate of surface waters through the Vashon Till that covers the majority of Guemes Island uplands impedes recharge to ground water resources.
- Recharge of the Double Bluff Drift aquifer appears greater north of the Potlatch Beach Wells. However it is not known if this area will support additional development of ground water resources.
- Undiscovered aquifers in older glacial materials may exist below the Double Bluff Drift. No evidence of wells or borings penetrating below the upper part of the Double Bluff Drift was found in the course of our investigation.
- Ground water resources are not well characterized within the Advance Outwash deposits but due to the lack of wells screened in this unit they appear relatively unproductive.
- The likely presence of a ground water flow barrier immediately south of the Potlatch wells implies that recharge to aquifers in the northern end off the island will be limited only to very limited infiltration of precipitation occurring on the northern end of the island.
- Eventually, at current rates of withdrawal, most of the wells on the north end of the island will likely experience significant seawater intrusion. Additional development will exacerbate this trend.
- Construction and pumping of new wells in the northern part of the island will likely produce low chloride water for only a short time before additional seawater intrusion begins to take place.

Unfortunately, the data do not indicate positive conditions for either increasing good quality ground water production in the Potlatch Beach area or for significantly reducing chloride concentrations in the existing wells over the near term. Below we present a few options for the Association to consider which might reduce the chloride problems over the longer term.

- Significantly reduce present water use by elimination of nonessential water consumption.
- Augment ground water supply with roof rain collectors and cisterns.
- Further reduction of the production rate in Potlatch Beach #1 might result in lowering chloride concentrations below the state standards.
- Significant pumping reductions in Well #2 are not likely to significantly reduce chloride concentration from present values over the short term. However, stopping or reducing production to only few gallons/day may help over the long term.
- Stretch daily pumping on both wells out over a longer period (i.e. cut rate of pumping by fifty percent but pump twice as long).
- Insufficient data exist for an accurate analysis of seawater intrusion parameters; therefor the association should continue collecting flow, water level and water quality data as they have since the begining of 1994.

0[illegible]9

522-16

One of the most significant constraints on the Association is the Department of Ecology's compliance order with the requirement to not promote further degradation of the ground water quality by inducing seawater intrusion and Skagit County Health Department's concern over the health implications of drinking high chloride water. Implementation of a chloride treatment system and construction of new wells may be the only way for the Association to meet these requirements.

Based on the available data, the most likely location to obtain acceptable quality ground water supplies which would not experience seawater intrusion problems in the *short term*, would be in the central part of the island about 2+ miles southeast of Potlatch Beach Well #2 and well beyond any barrier structure.

Several very low yield (20-30 gpd) wells drilled north east of the existing Potlatch wells might provide short term relief. However, with time, these wells would likely experience seawater intrusion also.

REFERENCES

Anderson, H., 1968. *Ground-Water Resources of Island County.* State of Washington Department of Water Resources Water Supply Bulletin 25, Part II.

Boatsman, C., 1991, *Identification of Geologically Susceptible Recharge Areas-Draft Copy,* Groundwater Management Programs in King County, 21p.

Culhane, T., 1993, *High Chloride Concentrations in Ground Water Withdrawn from above Sea Level Aquifers, Whidbey Island, Washington,* State of Washington, Department of Ecology, Water Resources Program Open File Technical Report, OFTR 93-07.

Dion, N.P. and S.S. Sumioka, 1984, *Seawater Intrusion into Coastal Aquifers in Washington,* State of Washington, Department of Ecology, Water Supply Bulletin 56.

Easterbrook, D., 1968. *Pleistocene Stratigraphy of Island County.* State of Washington Department of Water Resources Water Supply Bulletin 25, Part I.

Economic and Engineering Services, Inc., 1991, *Snohomish County Groundwater Characterization Study*; Report to Snohomish County Planning Department, Volumes I and II, July, 1991.

Sapik, D., Bortleson, G, Drost, B., Jones, M, and Pyrch, E., 1987. *Ground-Water Resources and Simulation of Flow in Aquifers Containing Freshwater and Seawater, Island County, Washington,* U.S. Geological Survey Water Resources Investigation Report 87-4182.

Stoffel, K., 1981. *Stratigraphy of Pre-Vashon Quaternary Sediments Applied to the Evaluation of a Proposed Major Tectonic Structure in Island County, Washington,* U.S. Geological Survey Open-File Report 81-292, 161 p.

U.S. Department of Agriculture, Soil Conservation Service, 1958. *Soil Survey Skagit County, Washington.*

U.S. Geological Survey, 1982. *Preliminary Geologic Map of Maxwelton Quadrangle, Island County, Washington.* USGS Open File Report 82-192.

U.S. Geological Survey, 1985, M.A. Jones, Author. *Occurrence of Ground Water and Potential for Seawater Intrusion, Island County, Washington.* USGS Water Resources Investigation Report 85-4046.

Walters, K.L., 1971, *Reconnaissance of Sea-water Intrusion along Coastal Washington,* 1966-68. Washington Department of Ecology Water Supply Bulletin 32.

0

522-18

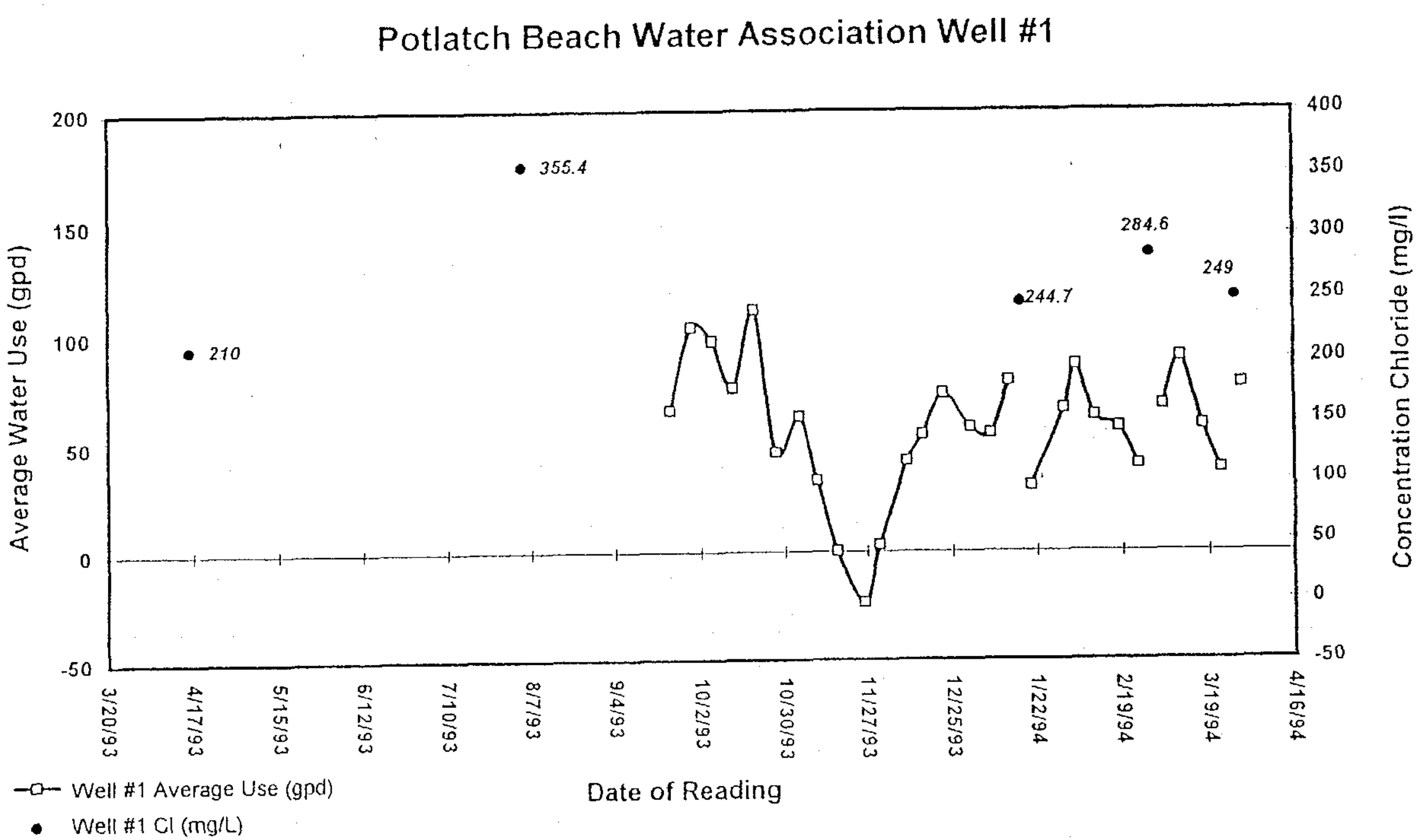
Washington State Department of Ecology, 1994, Water Well Report Files.

West, L., Dykes, D. and Joye Bonvouloir, 1989. *Evaluation of Pollution Potential and Monitoring Strategies for Eight Landfills in Island County, Washington*, in Engineering Geology in Washington, Washington Division of Geology and Earth Resources Bulletin 78.

0622

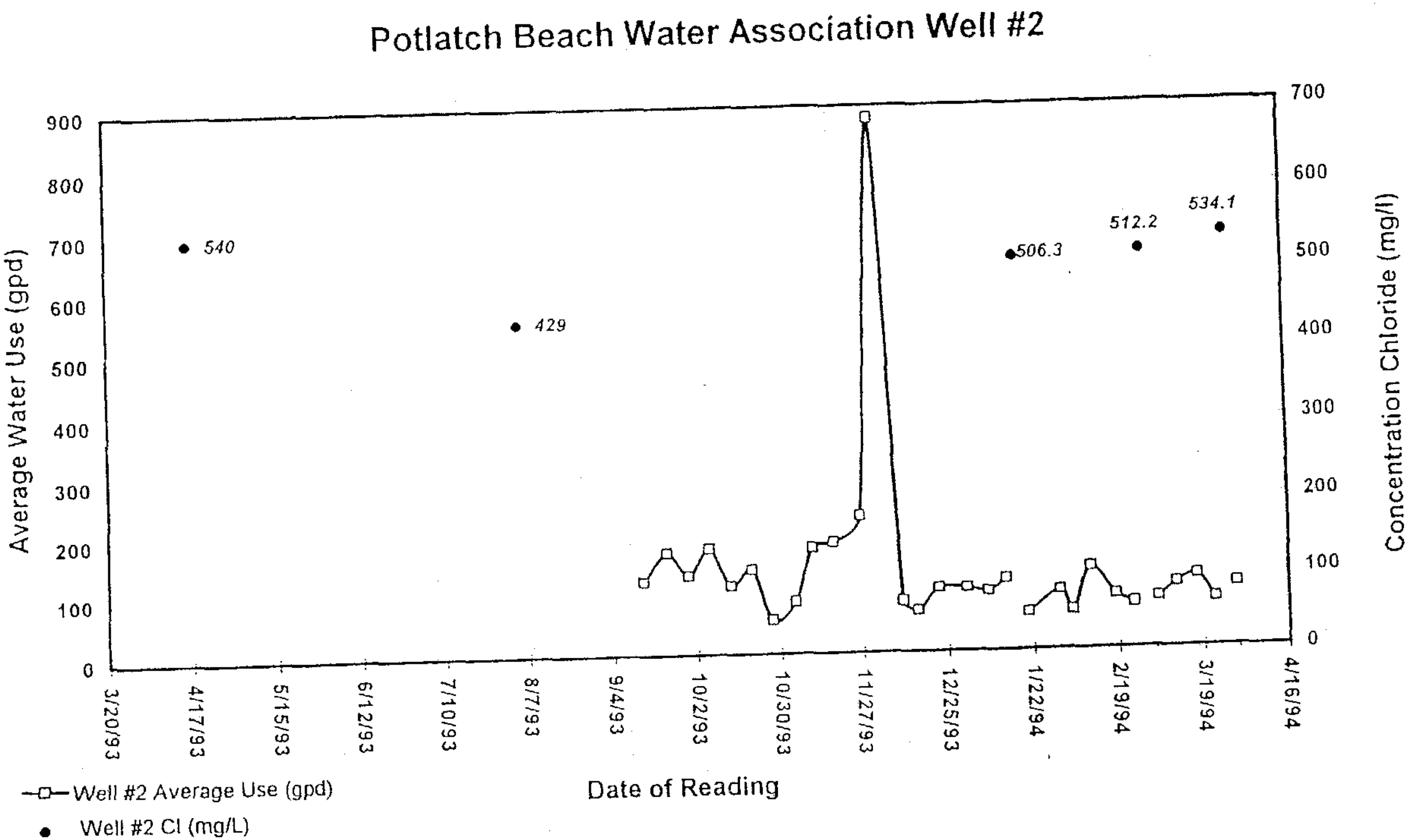
522-19

Graph 1



522-20

Graph 2

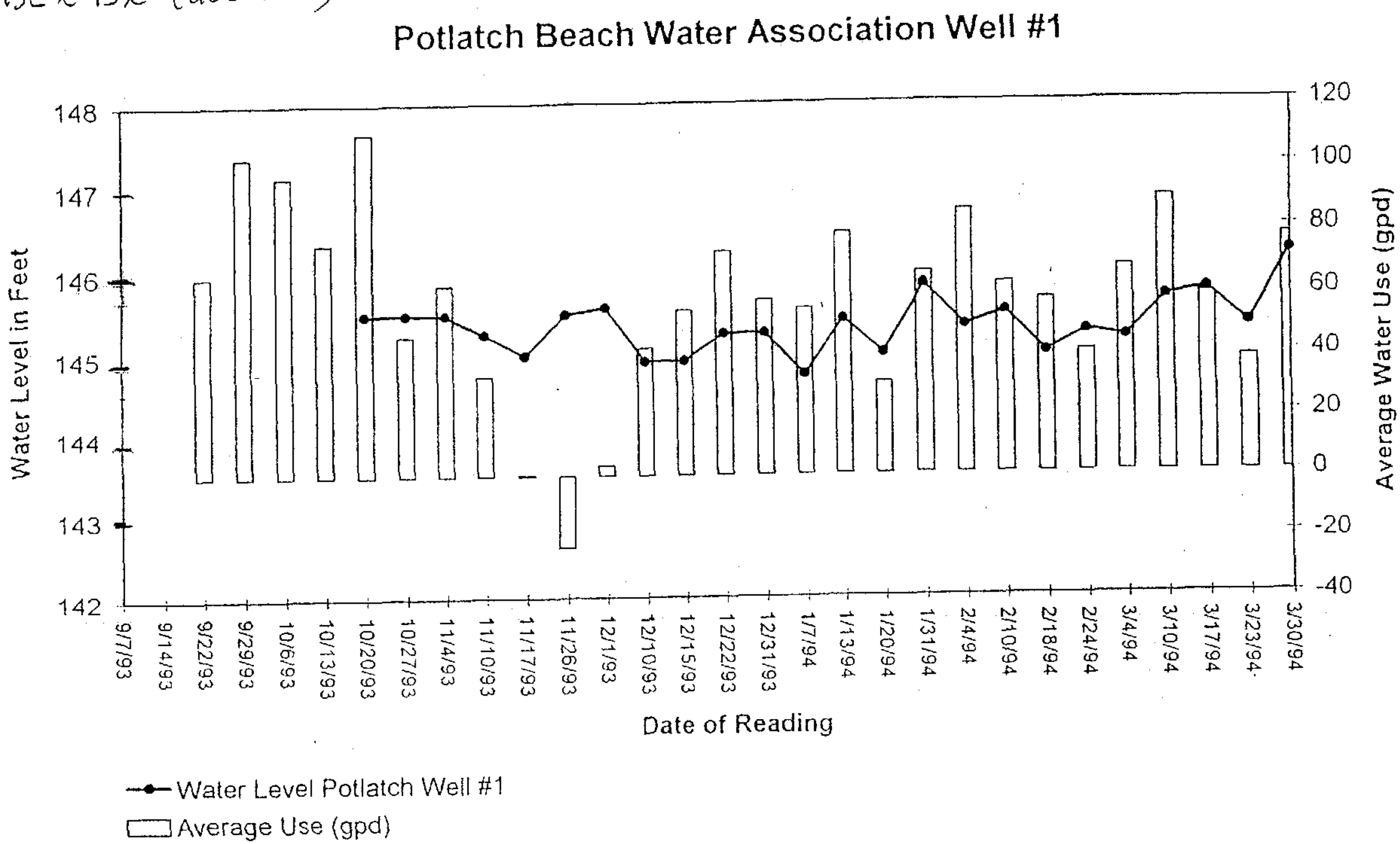


0624

522-21

Graph 3

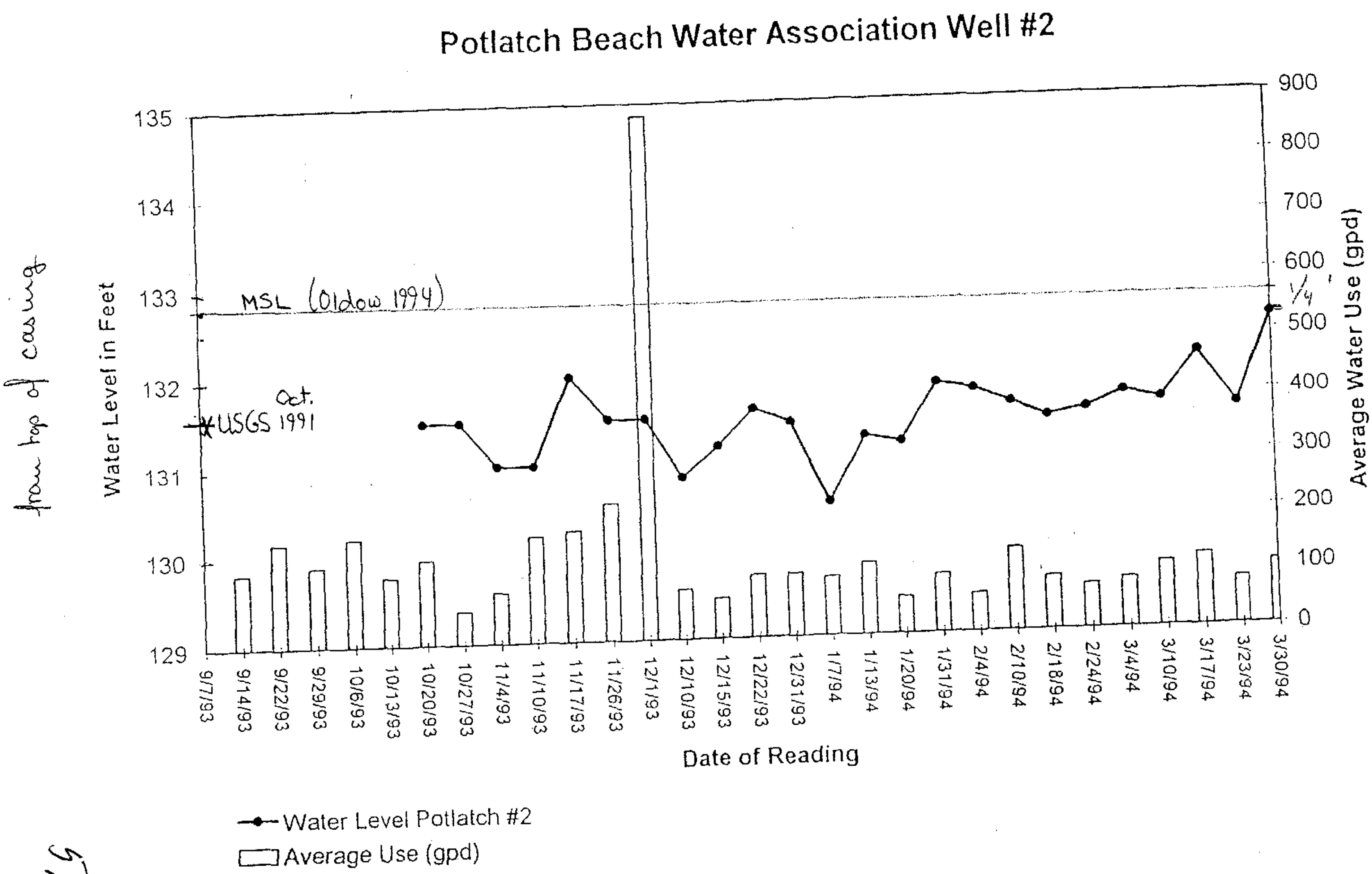
MSL ~ 152' (USGS, 1991)



USGS Oct '91 143.94' B.G.S.

522-22

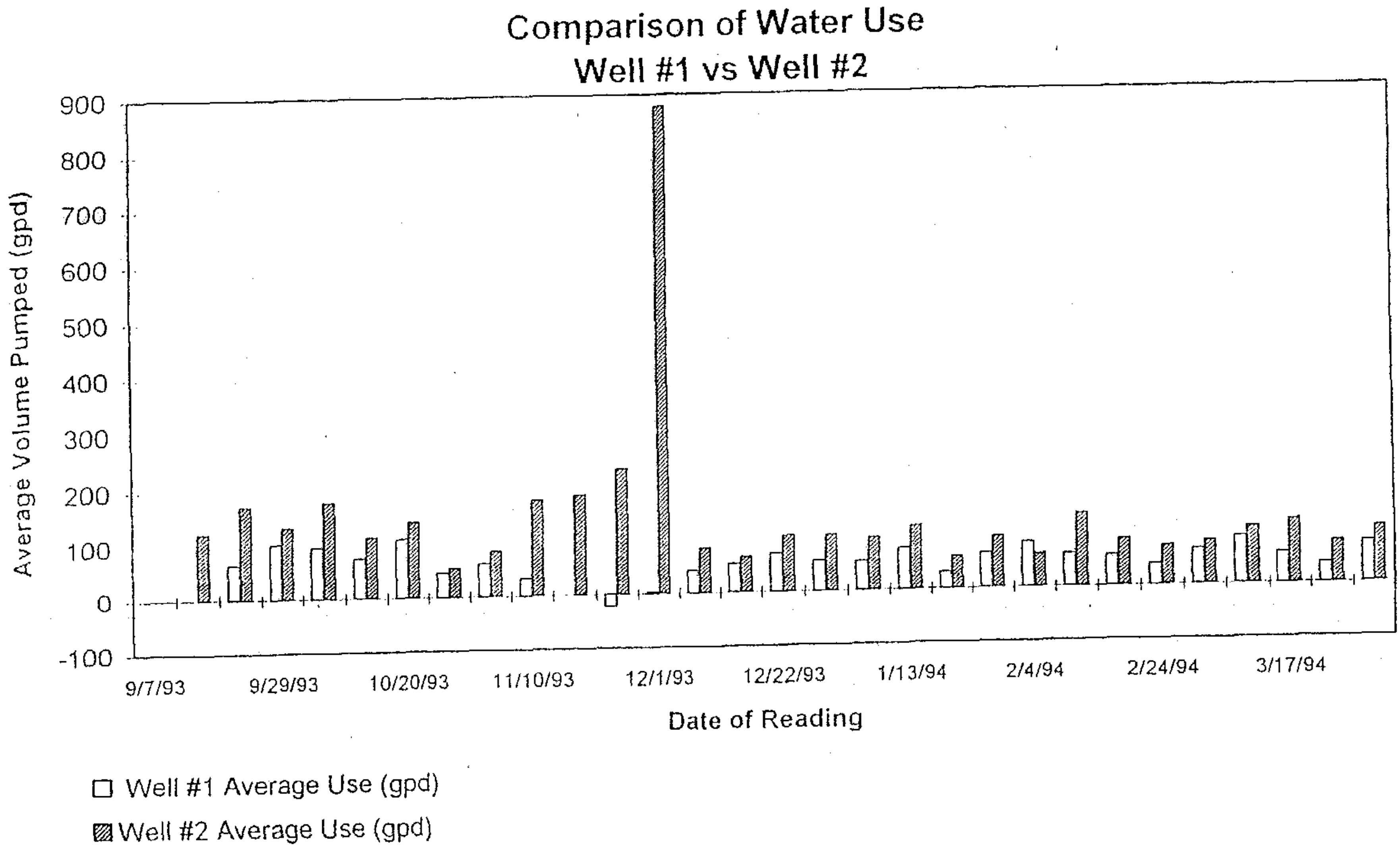
Graph 4



522-23

0620

Graph 5



522-24

GERALD STEEL, PE

ATTORNEY-AT-LAW
7303 YOUNG ROAD NW
OLYMPIA, WA 98502
Tel/fax (360) 867-1166

April 20, 2007

Corinne Story, Environmental Health Supervisor
Skagit County Health Department
700 South 2nd, Room 301
Mount Vernon, WA 98273

RE: Comments on Chapter 12.48 SCC Revisions

Dear Ms. Story:

I submit these comments on behalf of myself and Friends of Guemes Island. I have two comments. First, the Maximum Contaminant Levels (MCLs) reported in revised Table 1 in proposed SCC 12.48.110 do not agree with and do not implement the MCLs defined in WAC 246-290-310 and elsewhere in WAC and C.F.R.

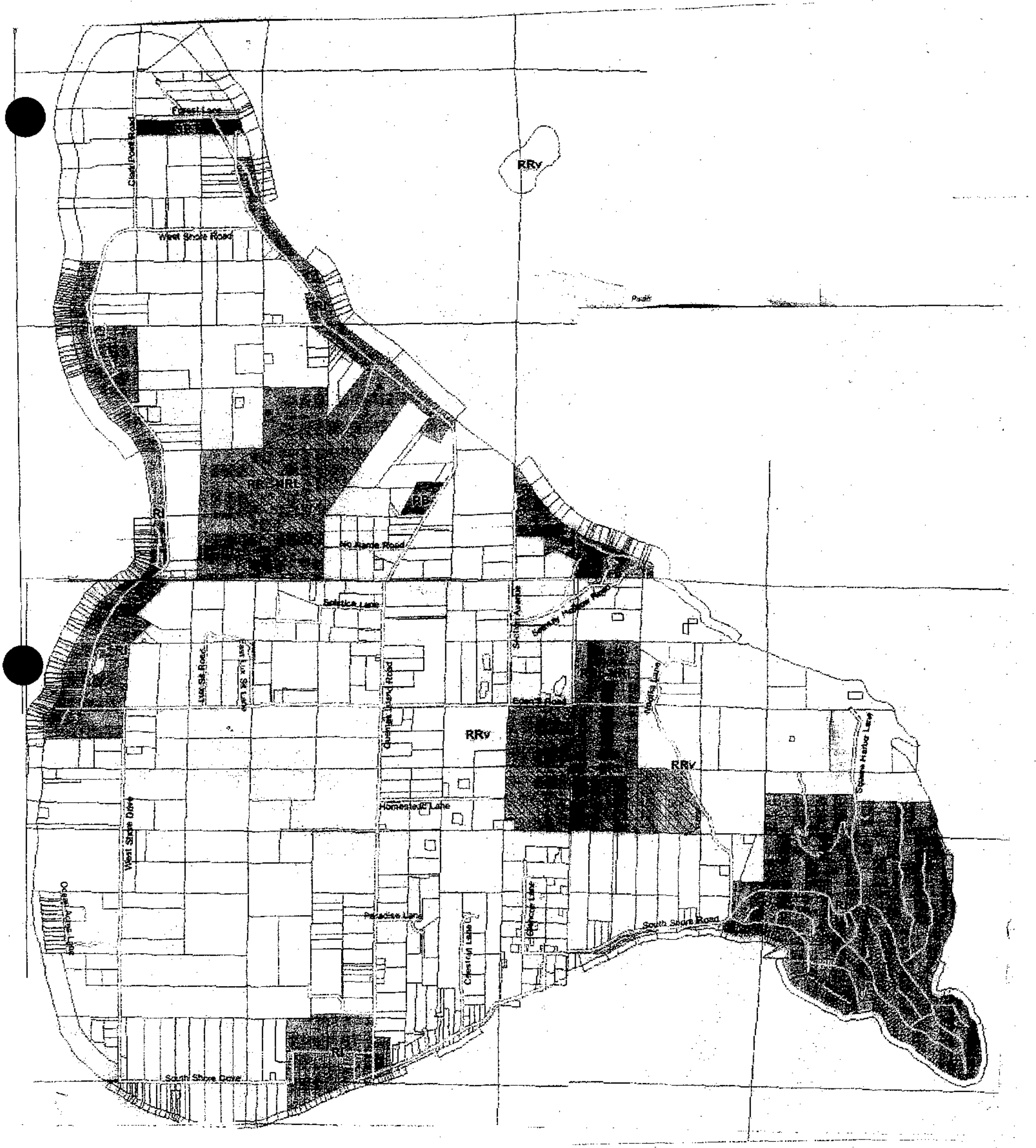
Second, SCC 14.24.350(2) requires conformance with the "Seawater Intrusion Policy" in effect under SCC 12.48. I do not find such a policy in your draft. I have reviewed Resolution #15570 adopting an interim seawater intrusion policy. This interim policy is unacceptable for areas with a sole source aquifer such as Guemes Island. The problem on Guemes Island is that evidence suggests that the existing aquifers may not even be able to sustain in the long term the current level of pumping on the island which is almost solely for domestic use. HongWest & Associates, Inc., Potlatch Beach Hydrogeologic Study (1994) at 7-8 ("Based on the available data, the most likely location to obtain acceptable quality ground water supplies which would not experience seawater intrusion problems **in the short term**, would be in the central part of the island.") *(emphasis supplied)*.

Currently, every new well that is allowed on Guemes will likely speed up the failure by seawater intrusion of other existing wells. In the interim on Guemes, I suggest that there be a moratorium on new freshwater wells unless the owner of the new well contracts with other existing well owners to reduce others' water consumption so that there is no net increase in pumping on the whole island. Meanwhile, there should be commissioned a study to determine and monitor a safe pumping level for the whole island that can be sustained in the long term and actions should then be taken to ensure that this safe pumping level will not be exceeded with full development of the island.

Respectfully,

Gerald Steel, PE

531 0628



GUEMES ISLAND - 2007 CP Book 21 775-M

threshold presently set forth in the Plan. Policy language has also been added that would commit the County to consider permitting certain mining activities through an administrative approval process.

63. In addition to the refinements described in finding 62, a significant undertaking of the Update included the reevaluation of the existing Mineral Resource Overlay for accuracy, omissions, and errors. To accomplish this, the County engaged a geotechnical firm to apply the designation criteria and the most recent geological data to review the extent of the current MRO, confirm known resources, identify previously omitted mineral resource-rich geologic formations, and map those areas of potential significance. Further review and field verification by the County geologist, mineral industry experts, and staff led to the final draft MRO that is recommended by the Planning Commission.

64. The Planning Commission finds that limiting the mineral resource lands overlay to designated resource areas only, leaves substantial areas containing significant mineral resources within the rural portion of the County without meaningful regulatory protections. Many of these rural areas contain mineral resources that may be more easily extracted than those present within resource-designated areas, and closer to the markets and populations to be served by the resource. The Planning Commission specifically finds that this potential inequity warrants further scrutiny by the County in the future, and that the County should contemplate providing protections for mineral resource extraction activities wherever they are located, provided that the impacts of such activities can be effectively mitigated.

(This recommendation was made by a 8-1 vote)

65. The County's mineral resource overlay designation encompasses areas containing a diversity of various mineral resources, including various hard rock resources (e.g., olivine and limestone) as well as a wide range of different types and qualities of sands and gravels with different properties and applications in construction. The Planning Commission finds that given the multiplicity of varying mineral resource types and qualities, that identification and designation of a 20-year supply of mineral resources is largely impractical, and that flexibility must be retained within the County's regulations to extract the resources needed by the market wherever they may be located within resource areas of the County.

Environment (Chapter 5)

66. The Planning Commission finds that the Update changes to the Environment Element are largely minor and non-substantive in nature at this time. However, the Planning Commission acknowledges the requirements under RCW 36.70A.130 and 36.70A.172 to classify, designate and regulate to protect critical areas using the "best available science," and notes that a comprehensive review and revision to the critical areas chapter of the Skagit County Code is in progress.

67. The Planning Commission received considerable public comment pertaining to the data sources used in classifying and designating floodplain areas within the County, as well as the potential impact of climate change on the potential extent of flood hazard areas. In this regard, the Planning Commission specifically finds that both the current Comprehensive Plan policies

2005 GROWTH MANAGEMENT UPDATE

Adopting Ordinance

Attachment C

Countywide Planning Policy Amendments

September 10, 2007

1. Urban Growth

Encourage urban development in urban areas where adequate public facilities and services exist or can be provided in an efficient manner.

1.1 Urban growth shall be allowed only within cities and towns, their designated UGAs and within any non-municipal urban growth areas already characterized by urban growth, identified in the County Comprehensive Plan with a Capital Facilities Plan meeting urban standards. Population and commercial/industrial land allocations for each UGA shall be consistent with those allocations shown in the following table:

Urban Growth Areas	Residential Population (20~~15~~25)	Commercial/Industrial Land Allocations (New)
Anacortes	18,300	558
Bayview Ridge[1]	~~3,420~~5,600	750
Burlington	~~7,065~~12,000	242
Concrete	~~1,561~~1,350	28
Hamilton	~~315~~450	60
La Conner	~~930~~950	2
Lyman	~~370~~550	0
Mount Vernon	~~41,725~~47,900	~~869~~959
Sedro-Woolley	~~12,030~~15,000	~~243~~278
Swinomish	~~2,720~~3,650	0
~~Reserve~~[2]	~~909~~	~~0~~
~~Non-Urban Growth Areas~~		
~~Other Unincorporated County~~	~~48,355~~	~~584~~[3]
Urban Growth Area Total[3] ~~County~~	~~137,700~~105,750	~~3,336~~2,877

[1] The residential population has been placed in a reserve category until the completion of the Bayview Ridge subarea plan. At that time, it will either be accommodated in the proposed Bayview Ridge UGA, reallocated to other UGAs, or a combination thereof. The Port of Skagit County has 258 acres of the designated commercial / industrial properties. A sub-area plan and implementing regulations are proposed to be adopted for the Bayview Ridge UGA ~~by June 1, 2001~~; the urban standards set forth in this plan/regulations for roads, sewer, and stormwater shall meet or

Policies 1.2 – 1.8 **[No change]**

exceed those in effect in the City of Burlington on April 1, 1999. Police and Fire services shall, at a minimum, meet the requirements of CPP 1.7.

~~[2] The former Big Lake Urban Growth Area has been redesignated as a Rural Village. The urban residential population allocated to Big Lake (2,400) from the previous CPP 1.1 has been placed in a reserve category, from which 1,491 has been allocated to Sedro-Woolley's, Concrete's, and La Conner's Urban Growth Area as indicated on this revised table. The remaining balance of urban residential population (909) will be reallocated to the urban growth areas in 2002 as a part of the Comprehensive Plan updates required in RCW 36.70A.130.~~

[2] The projected 2025 population for the remainder of Skagit County, outside of Urban Growth Areas, is 43,330. Adding that to the Urban Growth Area total cited above results in a total County population of 149,080. The Growth Management Act does not require a commercial/industrial land allocation for the rural area.

~~[3] This 584 acres will consist of rural commercial and industrial development permitted by the Growth Management Act (specifically including RCW 36.70A.070(5)(d) and related provisions) and the 1997 ESB 6094 amendments thereto. This development will not constitute development that is urban in scale or character or that requires the extension of urban services outside of urban growth areas, except where necessary to address an existing public health, safety or environmental problem. Permitted development shall be of a scale and nature consistent and compatible with rural character and rural services, and may include commercial services to serve the rural population, natural resource-related industries, small scale businesses and cottage industries that provide job opportunities for rural residents, and recreation, tourism and resort development that relies on the natural environment unique to the rural area. Furthermore, priority consideration will be given to siting of new rural commercial and industrial uses in areas of existing development, including existing Rural Villages and existing Rural Centers, followed by already developed sites in the rural area, and only lastly to wholly undeveloped sites in the rural area.~~

2. Reduce Sprawl

Reduce the inappropriate conversion of undeveloped land into sprawling, low-density development.

2.1 Contiguous and orderly development and provision of urban services to such development within urban growth boundaries shall be required.

2.2 Development within the urban growth area shall be coordinated and phased through inter-agency agreements.

2.3 Rural development shall be allowed in areas outside of the urban growth boundaries having limited resource production values (e.g. agriculture, timber, mineral) and having access to public services. Rural development shall have access through suitable county roads, have limited impact on agricultural, timber, mineral lands, critical areas, shorelands, historic landscapes or cultural resources and must address their drainage and ground water impacts.

2.4 Rural commercial and industrial development shall be consistent with that permitted by the Growth Management Act, specifically including RCW 36.70A.070(5)(d) and related provisions and the 1997 ESB 6094 amendments thereto. This development shall not be urban in scale or character or require the extension of urban services outside of urban growth areas, except where necessary to address an existing public health, safety or environmental problem.

2.5 Rural commercial and industrial development shall be of a scale and nature consistent and compatible with rural character and rural services, or as otherwise allowed under RCW 36.70A.070(5)(d), and may include commercial services to serve the rural population, natural resource-related industries, small scale businesses and cottage industries that provide job opportunities for rural residents, and recreation, tourism and resort development that relies on the natural environment unique to the rural area.

2.6 Priority consideration will be given to siting of new rural commercial and industrial uses in areas of existing development, including existing Rural Villages and existing Rural Centers, followed by already developed sites in the rural area, and only lastly to wholly undeveloped sites in the rural area.

2.47 Master planned sites designated for industrial and large-scale commercial uses shall be clustered, landscaped, and buffered to alleviate adverse impacts to surrounding areas.

2.~~5~~8 Commercial areas should be aggregated in cluster form, be pedestrian oriented, provide adequate parking and be designed to accommodate public transit. Strip commercial development shall be prohibited.

2.~~6~~9 Urban commercial and urban industrial development, except development directly dependent on local agriculture, forestry, mining, aquatic and resource operations, and major industrial development which meets the criteria contained in RCW 36.70A.365, should be restricted to urban or urban growth areas where adequate transportation networks and appropriate utility services are available.

The process to consider siting of specific major industrial developments outside of urban growth areas shall follow the process included in the Memorandum of Understanding between the County and the cities for adoption of Countywide Planning Policies. Major industrial developments shall mean a master planned location for specific manufacturing, industrial, or commercial business that:

1. Requires a parcel of land so large that no suitable parcels are available within an urban growth area; or

2. Is a natural resource-based industry requiring a location near agricultural land, forest land, or mineral resource land upon which it is dependent. The major industrial development shall not be for the purpose of retail commercial development or multi-tenant office park.

A major industrial development may be approved outside an urban growth area if the following criteria are met:

1. New infrastructure is provided for and/or applicable impact fees are paid;

2. Transit-oriented site planning and traffic demand management programs are implemented;

3. Buffers are provided between the major industrial development and adjacent non-urban areas;

4. Environmental protection including air and water quality has been addressed and provided for;

5. Development regulations are established to ensure that urban growth will not occur in adjacent non-urban areas;

6. Provision is made to mitigate adverse impacts on designated agricultural lands, forest lands, and mineral resource lands;

7. The plan for the major industrial development is consistent with the County's development regulations established for the protection of critical areas; and

8. An inventory of developable land has been conducted and the County has determined and entered findings that land suitable to site the major industrial development is unavailable within the urban growth area. Priority shall be given to applications for sites that are adjacent to or in close proximity to the urban growth areas.

Final approval of an application for a major industrial development shall be considered an adopted amendment to the Comprehensive Plan adopted pursuant to RCW 36.70A.070 designating the major industrial development site on the land use map as an urban growth area. Final approval of the application shall not be considered an amendment to the Comprehensive Plan for the purposes of RCW 36.70A.130(2) and may be considered at any time.

2.~~7~~10 Establishment or expansion of local improvement districts and special purpose taxing districts, except flood control, diking districts and other districts formed for the purpose of protecting water quality, in designated commercial forest resource lands shall be discouraged.

Chapter 9: Utilities Element (and Profile) The policies in this chapter discuss the following: natural gas, telecommunications, electricity, solid waste, sewer, public water, water quality, drainage, flooding and storm runoff.

Chapter 10: Capital Facilities and Essential Public Facilities Element (and Profile) The focus of this chapter is the planning and provision of needed public facilities for the County's unincorporated and countywide populations. This chapter includes the specific goals, objectives and policies which address capital costs, financing, levels of service methods and consequences, statutory requirements, and specific related goals, objectives and policies. The element also includes goals and policies for the establishment of regional, or difficult-to-site facilities referred to under state law as essential public facilities.

Chapter 11: Economic Development Element (and Profile) This chapter details policies relating to economic needs such as: creating and maintaining diverse employment opportunities, protecting natural resource utilization, increasing non-resource industry diversity, promoting a range of commercial retail and service businesses, increasing tourism, conserving natural resources and open spaces and fostering a healthy public-private cooperative partnership in support of diverse business operations and investment.

Chapter 12: Plan Implementation and Monitoring This element describes the concepts involved in putting a plan into action, how this Plan is updated and amended, and how the Plan is monitored and evaluated. This chapter also addresses how the Plan and its development regulations will be applied at the community level, through the community planning process.

Appendices

Appendix A contains definitions and a list of acronyms used within this document.

Appendix B contains a chronological list of the Comprehensive Plan process from 1965 to the initial adoption of this Comprehensive Plan in 1997.

Appendix C identifies and describes related plans, studies and regulations.

Appendix D contains a list of ordinances adopting or amending this Plan.

Technical Appendices (under separate cover)

The following documents are included in the Plan, as they are used in the development and implementation of the Plan's policies:

- *Comprehensive Economic Development Strategy (CEDS)*, Skagit Council of Governments, 2003
- *Skagit County Housing Needs Assessment*, March 1993
- *Skagit County Coordinated Water System Plan - Regional Supplement*, 2000
- *Skagit County Urban Growth Areas Analysis Update: Population, Employment, & UGA Land Allocations by Jurisdiction*, March 1997
- *The Capital Facilities Plan (CFP) 2003-2008 - Goals and Policies, Capital Improvements, and Implementation Programs*
- *Skagit County Transportation Systems Plan*, August 2003
- *Memorandum of Agreement Regarding Utilization of Skagit River Basin Water Resources for Instream and Out of Stream Purposes*, December 1996
- *Skagit County Comprehensive Solid Waste Management Plan Update and Environmental Impact Statement*, December, 2005
- *Skagit County Draft GMA Puget Power Electrical Facility Plan and map updates*, November 1992
- *Skagit County Countywide Policies*, amended in 1996, 2000 and 2007
- *Population & Employment Forecasting & Allocation 2025*, December, 2003

Comprehensive Plan/Zoning Map and Supplemental Maps (under separate cover)

The Skagit County Comprehensive Plan/Zoning Map depicts general land-uses, such as Urban Growth Areas, Rural lands, and Natural Resource Lands, among others. These land uses are guided by and designated county-wide based on the policies and criteria set forth in the Comprehensive Plan. The Map also establishes zoning boundaries that are part and parcel of the Skagit County Code. Within each designated land use are one or more zoning districts, within which specific Skagit County land-use regulations apply. Such regulations are consistent with and carry out the policies of the Comprehensive Plan. Also shown on the map are federally designated lands such as national parks and wilderness areas.

In recent years, Skagit County has maintained a variety of maps on the County's website at www.skagitcounty.net. Online mapping technology allows for greater public access,

8A-3.4 Encourage public transportation services to serve cities, towns, and Rural Villages, and to link with systems in adjoining counties, when financially feasible and supported by the public.

8A-3.5 Encourage private transit providers to continue to provide services that public transit cannot, including services to the County and State ferry system, and local and regional airports.

PASSENGER RAIL

GOAL A4 PASSENGER RAIL TRANSPORTATION

Support passenger rail service to and through Skagit County as an important element of a balanced transportation system.

Policies

8A-4.1 Encourage rail agencies to implement a public education program on railroad safety.

8A-4.2 Work with the Washington State Department of Transportation, local jurisdictions other agencies, and the public to make safety and other improvements to the rail corridors to allow for increased speeds.

8A-4.3 Work with the Washington State Department of Transportation, local jurisdictions, other agencies and the public to determine the location of potential rail crossing closures.

8A-4.4 Road improvement decisions shall be consistent with any plans for rail crossings closures and with other aspects of rail service.

8A-4.5 Plan for commuter rail service to Skagit County at such time it is determined to be economically and socially acceptable.

FERRY SERVICE

GOAL A5 FERRY SERVICE

Work to maintain county and state ferry services as an *important element of the transportation network.*

Policies

8A-5.1 Encourage the provision of adequate street, highway, and road facilities to accommodate traffic to the ferry terminals in Anacortes.

8A-5.2 Work with the City of Anacortes, property owners, and residents on Guemes Island to develop and maintain adequate parking areas.

8A-5.3 To meet future increases in demand, increase service capacity of the Guemes Island Ferry by: (a) encouraging car-pooling and walk-on passengers; (b) increasing the frequency of ferry runs based on demand; (c) considering additional ferry capacity if the aforementioned procedures fail to accommodate demand; and (d) adding additional runs outside the current schedule.

8A-5.4 In making all decisions related to the Guemes Island Ferry, balance the needs of the Island residents, the non-resident property owners, and the County citizenry as a whole. Decisions that would have significant service or financial impacts should be made after providing ample opportunities for public review and comment.

8A-5.5 Continue to provide safe and adequate ferry service between Anacortes and Guemes Island, and a fare structure designed to recover as much operating cost as Washington State Ferries does from the users.

8A-5.6 Support the State's continued provision of ferry service to and from Anacortes- San Juan Islands-Vancouver Island, B.C.

Non-Motorized Transportation

Goal A6 Network

Provide a safe and efficient network of trails and bikeways, including both on- and off-road facilities that link populated areas of the County with important travel destinations.

Achieve high standards in meeting the needs of non-motorized users, through appropriate planning, design, construction and maintenance of user-friendly facilities.

ECONOMIC DEVELOPMENT PROFILE

INTRODUCTION

This profile includes a summary of analysis and strategies that support the goals and policies in the Economic Development Element. The source of this information is the *Skagit County Comprehensive Economic Development Strategy*, maintained by the Skagit Council of Governments. This profile, together with the economic development chapter containing goals and policies, fulfills the County's obligations under the GMA to include an economic development element in the Comprehensive Plan.

BACKGROUND SUMMARY

DEMOGRAPHIC PROFILE

As of 2005, Skagit County's population was estimated at 110,900 by the state Office of Financial Management (OFM). This represents an average annual increase of 1.5% since the 2000 Census, significantly slower than the 2.6% average annual population growth rate the county realized during the 1990s. The county's largest cities are Mount Vernon (over 26,200 residents in 2000), Anacortes (14,600), Sedro-Woolley (8,700) and Burlington (6,800). Growth projections for 2025 allocate the highest growth rates to Mount Vernon and Sedro-Woolley, and the significantly smaller East County towns of Concrete and Hamilton. Table 1 below shows average annual growth rate.

Table 1 Skagit County Population Trends (1980-2000)

Jurisdiction	1980	1990	2000	Average Annual Growth Rate 1980-1990	1990-2000
Cities & Towns					
Anacortes	9,013	11,451	14,557	2.4%	2.4%
Burlington	3,894	4,349	6,757	1.1%	4.5%
Concrete	592	735	790	2.2%	0.7%
Hamilton	283	228	309	-2.1%	3.1%
La Conner	660	686	761	0.4%	1.0%
Lyman	285	275	409	-0.4%	4.0%
Mount Vernon	13,009	17,647	26,232	3.1%	4.0%
Sedro-Woolley	6,110	6,333	8,658	0.4%	3.2%
Unincorporated Area	30,292	37,841	44,506	2.3%	1.6%

Skagit County	64,138	79,545	102,979	2.2%	2.6%
State of Washington	4,132,156	4,866,663	5,894,121	1.6%	1.9%

Source: Skagit County OEDP 2000, U.S. Census Bureau.

Average annual population growth is generally expected to slow for all jurisdictions after 2000. Annual projected growth rates from 2000 - 2025 range from around 1.0% (Anacortes, La Conner, and unincorporated regions of the County) to 2.1% for Mount Vernon and 3.1% for the County's unincorporated urban growth areas (UGAs). The County average annual growth rate is projected to be 1.5% through 2025. Table 2 below shows populations projections through 2025 for Skagit County.

Table 2 Skagit County Population Projections (2025)

Jurisdiction	2000 Population	Location	Adopted 2025 Allocation	Increase by 2025 Number	Increase by 2025 Percent
Cities					
Anacortes	14,647		18,300	3,653	25%
Burlington	8,728	I-5 Corridor	12,000	3,272	37%
Concrete	960		1,350	390	41%
Hamilton	309		450	141	46%
La Conner	761		950	189	25%
Lyman	409		550	141	34%
Mount Vernon	28,332	I-5 Corridor	47,900	19,568	69%
Sedro-Woolley	10,358	I-5 Corridor	15,000	4,642	45%
Subtotal Cities & UGAs	64,504		96,500	31,996	50%
UGAs					
Swinomish	2,664		3,650	986	37%
Bayview	1,700	I-5 Corridor	5,600	3,900	229%
Subtotal UGAs	4,364		9,250	4,886	112%
Total Urban	68,868		105,750	36,882	54%
Total Rural	34,110		43,330	9,220	27%
Total Skagit County	102,978		149,080	46,102	45%

Source: Growth Management Act Steering Committee, March 2003.

The county's housing costs have responded to its rapid 1990s growth rate, with median home values rising 88% in that decade (compared with 70% for the state as a whole). Rents have also increased dramatically, more than double the rate of any other I-5 corridor county. This is in part due to the county's low rental costs in 1990. More information on housing costs is located in the Housing Profile.

Incomes have also risen rapidly in comparison. In 2002, county median household income averaged $42,400. This was 93% of the statewide median income, up from 91% in 1990. The largest household income gains were seen in Burlington, La Conner and Sedro-Woolley. Poverty declined in almost all Skagit County jurisdictions during the 1990s, with the exception

Traffic Demand Models (Traffic Models)

Software systems that use land use information to simulate the traffic patterns of an area. These models can convert future land use growth projections into future traffic volumes.

Transfer of Development Rights (TDR)

The transfer of the right to develop or build, expressed in dwelling units per acre, either on land within one zoning district under contiguous ownership, or from land in one zoning district to land in another district where such density/development is permitted.

Transit

A general term applied to passenger rail and bus service available for the use by the public and generally operated on fixed routes with fixed schedules.

Transitional Housing

Per the definition of Transitional Housing from the Federal McKinney Act, transitional housing is made available for up to 24 months to people who are homeless or are leaving emergency shelters.

Transportation Demand Management (TDM)

Methods or strategies aimed at changing travel behavior by reducing the demand for single occupancy vehicle travel rather than by expanding transportation facilities to meet travel demand. The strategies can include such things as expanding transit of ride-sharing options, changing parking policies, promoting work hour changes, and providing for telecommuting.

Transportation Improvement Program (TIP)

A plan or schedule showing specific expenditures for transportation capital projects over a specific time period, often for six years.

Transportation Facilities

Includes capital facilities related to air, water or land transportation.

Transportation Level of Service Standards

A measure that describes the operational condition of the travel stream and acceptable adequacy requirements. Such standards may be expressed in terms such as speed and travel time, freedom to maneuver, traffic interruptions, comfort, convenience, geographic accessibility, and safety.

BEFORE THE WESTERN WASHINGTON
GROWTH MANAGEMENT HEARINGS BOARD

FRIENDS OF GUEMES ISLAND, Petitioner, v. SKAGIT COUNTY, Respondent.	NO. 07-2-0023 PETITIONER'S OPPOSITION TO DISMISSAL OF PREHEARING ORDER ISSUE 11

Friends of Guemes Island ("FGI") responds to Skagit County's Motion to Dismiss Challenge to Resolution No. R20060184. The County's Motion should be denied.

FACTS

As the County states, Resolution No. R20060184 was adopted on May 30, 2006 as a permanent ordinance (as opposed to an interim ordinance under RCW 36.70A.390). There was no publication of the adoption of the Resolution pursuant to RCW 36.70A.290(2)(b). The Resolution (Exhibit 506)[1] makes significant changes to the method of operation of the

[1] Exhibits 500 to 531 are all relevant to the adoption of the Resolution and to the issues raised in this case. These exhibits are listed in the Petitioners' additions dated 12/27/07.

GERALD STEEL, PE
ATTORNEY-AT-LAW
7303 YOUNG ROAD NW
OLYMPIA, WA 98502
Tel/fax (360) 867-1166

Guemes Island Ferry. First, it expands the Ferry's transportation service from Anacortes to unincorporated Guemes Island. Second, it decreases the frequency of Guemes Ferry runs based on demand.

It expands the Ferry's transportation service to unincorporated Guemes Island by significantly expanding the schedule day for Ferry service on weeknights, Monday through Thursday. Historically, since ferry service was established in the early 1900's, the last scheduled run of the day on Monday through Thursday was at 6:00 PM. The number (or frequency) of runs at 6:00 PM was based on demand.

> Although the County does not have a Ferry System level of service in place, it does have a practice in effect: all vehicles in line at Anacortes at 6:00 p.m. are provided with passage to the island.

Addendum to Environmental Checklist, Exhibit 513 at 10.

The Resolution expands the Ferry's transportation service by extending the schedule day, Monday through Thursday, by adding scheduled commuter-hour ferry service after 6:00 p.m. The weeknight expansion of service adds five scheduled runs after 6:00 p.m. that include runs at 6:30 p.m., 7:00 p.m., 8:30 p.m., 9:00 p.m. and 10:00 p.m. Compare the schedule established by Attachment A of the Resolution (Exhibit 506) with the schedule in effect immediately prior to adoption of the Resolution (Exhibit 508). The record shows that the weeknight schedule day ended at 6:00 p.m. back in 1977. 1997 DEIS (changing the ferry size to the current ferry) Table F, Exhibit 504.

The Resolution also terminated the practice of increasing the frequency (or number) of ferry runs at 6:00 p.m. based on demand. Attachment B of the Resolution (Exhibit 506).

GERALD STEEL, PE
ATTORNEY-AT-LAW
7303 YOUNG ROAD NW
OLYMPIA, WA 98502
Tel/fax (360) 867-1166

ANALYSIS

The expansion of weeknight ferry service will have profound impacts on Guemes Island. Because of the historic lack of weeknight commuter-hour ferry service, the growth rate on the island has been much lower than the average growth rate in Skagit County. For example, Exhibit 509 at 10 reports that there were 592 houses on Guemes Island registered in the 2000 Census and that 35 additional permits were issued by May, 2007. This corresponds to a total growth rate over that period of (35)/(592) = 0.059 or 5.9%. Proposed Exhibit 798 (attached to Skagit County's Motion to Supplement the Record dated January 3, 2008) shows a countywide population of 102,979 in year 2000 and 113,100 in year 2006 for an overall countywide increase over that period of 10,121. This corresponds to a total growth rate over that period of (10,121)/(102,979) = 0.098 or 9.8%. Thus the overall growth rate in Skagit County has been double the growth rate on Guemes Island.

The demographics on Guemes Island reflect the prior lack of weeknight commuter-hour ferry service. Approximately 50% of the houses on Guemes Island are listed as vacant in the 2000 Census because they are only used seasonally. Exhibit 509 at 19. With 50% of the households collecting social security, the average occupancy per dwelling unit is only 1.96 persons, substantially lower than the 2.6 persons per household Countywide. Id. Only 23 households on the Island have children. Id.

With historic ferry service ending at 6 p.m. on weekdays, families with children with weeknight activities were discouraged from living on the island and families supported by persons who worked where they could not return to the island each weeknight by 6 p.m. were discouraged from living on the island. There is a unique rural character that has developed

GERALD STEEL, PE
ATTORNEY-AT-LAW
7303 YOUNG ROAD NW
OLYMPIA, WA 98502
Tel/fax (360) 867-1166

on the island where people are generally not dependent on being off the island on weeknights after 6 p.m. Because this lifestyle is not satisfactory to everyone, it has limited the growth rate of new homes on the island to half of that experienced Countywide.

With the expanded weeknight ferry service, access to the island for families and commuters is substantially improved and it should be expected that the demographics will change to be more similar to Countywide averages. Today the population on Guemes Island is 563 people. Exhibit 509 at 11. If the increased access to the island caused the existing vacant houses to become occupied and if the persons per household increased to the Countywide average, the population would increase to 1,630 people just considering the new occupants of the existing houses alone. Id.

The rate of development of the existing vacant lots should also increase. Without any further subdivision, approximately 962 homes could be built on existing parcels. Id. at 10. Under the current zoning approximately 52 additional parcels and homes on those parcels would be allowed. Id. If all of the potential homes were occupied on the island at the Countywide rate of persons per household, the population would increase to 4,272 people. Id. at 10-11.

Exhibit 509 establishes the likelihood that increased access to the island will result in increased growth rate and population on the island. While Exhibit 509 identifies several concerns regarding increased growth caused by expanded weeknight ferry service, the most important problem will be loss of potable water supply to the existing residents and to the new residents. Id. at 12-14. The County has not even started a long-term watershed resource planning study for Guemes Island as is provided for in RCW 90.82. Id. at 13-14.

GERALD STEEL, PE
ATTORNEY-AT-LAW
7303 YOUNG ROAD NW
OLYMPIA, WA 98502
Tel/fax (360) 867-1166

> The water supply on Guemes is tenuous with the current population and increased population drawing water from the aquifer system is likely to create a crisis situation.

Id. at 12-15. The looming water crisis is a subject of concern that is relevant to Issues 4 to 12 the December 18, 2007 Prehearing Order. To delve into this issue properly will require consideration of virtually all of Exhibits 500 to 531 in Petitioners' additions dated 12/27/08.

Focusing on Prehearing Order Issue 11 sought to be dismissed by the County in its Motion, Petitioner's first argument is that this issue is complex and it will require more than a limited review of the record. In choosing not to review previous dispositive motions, this Board has stated that it would:

> reach our decision on a dispositive motion by reviewing an inter-related combination of criteria as to the size of the limited record in conjunction with time availability, the nature of the motion, the complexity of the issue including whether it is one of first impression, and the reasonableness of the claims

ICCGMC v. Island County, WWGMHB No. 98-2-0023c (Order on Dispositive Motions, March 2, 1999) at 4. This Board should refuse to decide this Dispositive Motion because the issue is complex and requires review of an extensive record. Id.

FGI agrees with the County that the Resolution did not adopt an amendment to the Comprehensive Plan. See Motion at 1. It is a question of law, and not a fact as the County asserts in its Motion at 1, as to whether the Resolution is a development regulation. Whether the Resolution is or is not a development regulation, it certainly authorized an activity that was inconsistent with duties established in the Comprehensive Plan. This Board has quoted with favor the Central Board's decision in COPAC-Preston Mill v. King County, CPSGMHB Case No. 96-3-0013c (Final Decision and Order, August 21, 1996) at 10 that states: "when

GERALD STEEL, PE
ATTORNEY-AT-LAW
7303 YOUNG ROAD NW
OLYMPIA, WA 98502
Tel/fax (360) 867-1166

a local government includes a self-imposed duty in its plan . . . the consistency requirements of RCW 36.70A.070 and .120 oblige it to meet this duty." Wiesen v. Whatcom County, WWGMHB No. 06-2-0008 (Order Granting Motion to Dismiss, July 18, 2006) at 10; See Id. at 11-12.

In Wiesen, the duty was a deadline. Id at 10-12. In the instant case, there are several duties. To fully discuss these duties and the way that the Resolution violates these duties is a complex issue that requires review of all of the duties imposed by the 2000 Comprehensive Plan (Exhibit 364 (Ordinance No. 17938) Case Nos. 00-2-0046c through 00-2-0050c) that was in effect when the Resolution was adopted, requires review of background documents that give the history regarding ferry scheduling before the Resolution was adopted, requires review of the demographics of Guemes before the Resolution was adopted, requires review of the several surveys taken before the Resolution was adopted that the show lack of public support for expanding the weeknight ferry hours, and requires this Board to become familiar with the water supply issues that impact the Island. It is inappropriate to address all of these issues in a Dispositive Motion.

The relevant self-imposed duties of the County will be more fully addressed in the briefing for the hearing on the merits. In this Response, Petitioner will introduce some of these relevant duties. The County adopted the Resolution when the July 24, 2000 Comprehensive Plan was in effect. The first duty to be discussed is in Policy 9A-8.2 of that Plan. See Attachment E at 9-9, Exhibit 364 (Ordinance No. 17938) Case Nos. 00-2-0046c through 00-2-0050c (attached hereto).

Policy 9A-8.2 states:

GERALD STEEL, PE
ATTORNEY-AT-LAW
7303 YOUNG ROAD NW
OLYMPIA, WA 98502
Tel/fax (360) 867-1166

> To meet future increases in demand, increase service capacity of the Guemes Island Ferry by: (a) encouraging car-pooling and walk-on passengers; (b) increasing the frequency of ferry runs based on demand; (c) considering additional ferry capacity if the aforementioned procedures fail to accommodate demand.

Id.

This Comprehensive Plan policy establishes a duty for the County to use three specific options to meet future increases in demand for the Guemes Ferry. The first two options are (a) to encourage car-pooling and walk-on passengers and (b) to increase the frequency of ferry runs during the schedule day. If these procedures fail to accommodate the demand, the third option was to consider adding ferry capacity.

However, there is no record of a County program to encourage car-pooling and walk-on passengers. The Resolution does not mention such a program. The County had a duty to conduct such a program if it found a need to meet increases in demand for the Ferry. Instead of increasing the frequency of on-demand ferry runs as required by Policy 9A-8.2, the County acted to decrease and eliminate the on-demand runs at 6 p.m. This is contrary to the duty imposed in Policy 9A-8.2. The County had a duty under Policy 9A-8.2 to seek to accommodate demand by a program to encourage walk-on passengers and car-pooling and by increasing "on-demand" runs before it took any other action to accommodate demand. If these actions failed to accommodate the demand, the County had the duty to next consider adding ferry capacity. The Resolution does not mention consideration of adding ferry capacity. The activity imposed by the Resolution was inconsistent with the duty imposed by Policy 9A-8.2 and therefore the activity and Resolution are in violation of RCW 36.70A.070(preamble) and 36.70A.120. See Wiesen at 10-12.

GERALD STEEL, PE
ATTORNEY-AT-LAW
7303 YOUNG ROAD NW
OLYMPIA, WA 98502
Tel/fax (360) 867-1166

The second duty to be discussed is established by 2000 Comprehensive Plan Policy 9A-6.1. See Attachment E at 9-6 to 9-7, Exhibit 364 (Ordinance No. 17938) Case Nos. 00-2-0046c through 00-2-0050c (attached hereto). Policy 9A-6.1 states:

> Skagit County supports expansion of public transportation service into the unincorporated areas only with public support.

The Resolution (Exhibit 506) does not document any public support. The record presented to the BOCC at the time of the adoption of the Resolution showed overwhelmingly that the proposal to extend weekday ferry service from 6 p.m. to 10 p.m. did not have public support. Exhibit 505 shows the results of the official February, 2006, Ferry Committee survey which asked the question: "Should ferry service, Monday through Thursday, be extended from 6 pm to 10pm?" The response with 289 votes against and 94 votes in favor showed that more than 75 percent of the public opposed this expansion of public transportation service.

Petitioner's letter to the BOCC on May 23, 2006, prior to adoption of the Resolution, explained to the BOCC that a super majority of respondents to the 2006 Ferry Survey opposed the weeknight hour extension, and it informed the BOCC that there was a conflict with County duties found in Policies 9A-6.1 and 9A-8.2. Exhibit 502.

Another relevant self-imposed duty is provided in Objective 3 of the Rural Element of the 2000 Comprehensive Plan. See Attachment E at 6-8, Exhibit 364 (Ordinance No. 17938) Case Nos. 00-2-0046c through 00-2-0050c (attached hereto). Said Objective 3 provides:

> Assure that the provision of public facilities, services, roads and utilities are consistent with rural character and lifestyles.

As Petitioner's have described earlier in this Response, the Guemes residents have a unique

GERALD STEEL, PE
ATTORNEY-AT-LAW
7303 YOUNG ROAD NW
OLYMPIA, WA 98502
Tel/fax (360) 867-1166

rural character and lifestyle with unusual demographics where people are generally not dependent on being off the island on weeknights after 6 p.m. Supra, this brief at 3-4. This has led to a tightly knit and caring community where neighbors help neighbors and crime is almost non-existent. The provision of weeknight ferry service is not consistent with the rural character and lifestyle on the island which the residents desire to preserve. On-going weeknight ferry service will lead to a water crisis that is definitely inconsistent with rural character and lifestyles.

Because the County includes self-imposed duties in its Comprehensive Plan, it violated the consistency requirements of RCW 36.70A.070 and .120 when it adopted the Resolution and the adoption of this Resolution fails to comply with the GMA.

The County cites to RCW 36.70A.280(1) for the jurisdiction of this Board. Motion at 2. This statute authorizes this Board to hear a petition that alleges "that a . . . county. . planning under this chapter is not in compliance with the requirements of this chapter." One of the requirements of the GMA is that the County shall perform its activities (such as the operation of the Guemes Island Ferry) in compliance with its Comprehensive Plan. RCW 36.70A.120. The County is obligated to perform its activities in accord with the duties in its Comprehensive Plan.

The County also cites to RCW 36.70A.280(1) which provides a filing time requirement for certain challenges. Motion at 2. This statute is irrelevant to Petitioner's challenge to the Resolution because 1) the Resolution either is or is not a development regulation and 2) if it is not a development regulation, the 60 day-after-publication requirement of RCW 36.70A.290(2) does not apply and 3) if it is a development regulation,

GERALD STEEL, PE
ATTORNEY-AT-LAW
7303 YOUNG ROAD NW
OLYMPIA, WA 98502
Tel/fax (360) 867-1166

the 60 day-after-publication requirement is met because the County did not publish. Supra, this brief at 1.

The County argues that the schedule change under Resolution No. R20060184 was a proprietary, and not legislative, act. Motion at 2. RCW 36.70A.120 establishes that the activities of the County must conform to the duties in its Comprehensive Plan. Whether proprietary or legislative, if the activities are the County's activities, they must comply with duties in the Comprehensive Plan. The County recognizes that it is responsible for capital facilities and service levels for the Guemes Ferry. See 2007 Comprehensive Plan (provided by County), Chapter 10 at 1 (Ordinance No. O20070009, Book 21 Exhibit 775) ("Skagit County is responsible for capital facilities and service levels related to: . . . County roads/ferry"

Just as the County would be responsible under RCW 36.70A.070(3) for complying with water capital facilities and service requirements in the Comprehensive Plan if it operated a County public water system, it is also responsible for complying with RCW 36.70A.070(6) for its public transportation systems that it operates. It matters not that the County systems might be proprietary.

The County argues that the Resolution is not a development regulation citing to RCW 36.70A.030(7) which states that development regulation means the controls placed on land use activities. Motion at 3. Neither the GMA nor the Comprehensive Plan defines "land use activities." In this case one can rely on the common meaning of the terms. Ferry loading and unloading operations at the ferry terminals qualifies as a land use activity. Establishing a schedule qualifies as establishing controls over this land use activity. Therefore Petitioner

GERALD STEEL, PE
ATTORNEY-AT-LAW
7303 YOUNG ROAD NW
OLYMPIA, WA 98502
Tel/fax (360) 867-1166

concludes that the Resolution is a development regulation. However, this is not a material issue in the instant case as discussed previously. Supra, this brief at 9-10.

Because Petitioner has a valid claim that the County's activities authorized by the Resolution are not consistent with the duties in its Comprehensive Plan, this Board should find that Petitioner has the right to bring a challenge to the Resolution under RCW 36.70A.280(1) and this Board should dismiss the County's Motion. Alternatively, this Board should find that the matter is complex and not appropriate for a limited record and this Board should deny the Motion and delay its decision until after the hearing on the merits. See ICCGMC at 3.

As Petitioner's Attorney previously informed the Board, he will not be available for a hearing on any motion before February 5, 2008 and he understood that the parties agreed, as indicated in the Prehearing Order schedule, that there would be no separate hearing for motions.

Dated this 17th day of January, 2008.

Respectfully submitted,

By: [signature]
Gerald Steel, PE, WSBA #31084
Attorney for Friends of Guemes Island

FGIIa17.08

GERALD STEEL, PE
ATTORNEY-AT-LAW
7303 YOUNG ROAD NW
OLYMPIA, WA 98502
Tel/fax (360) 867-1166

0654