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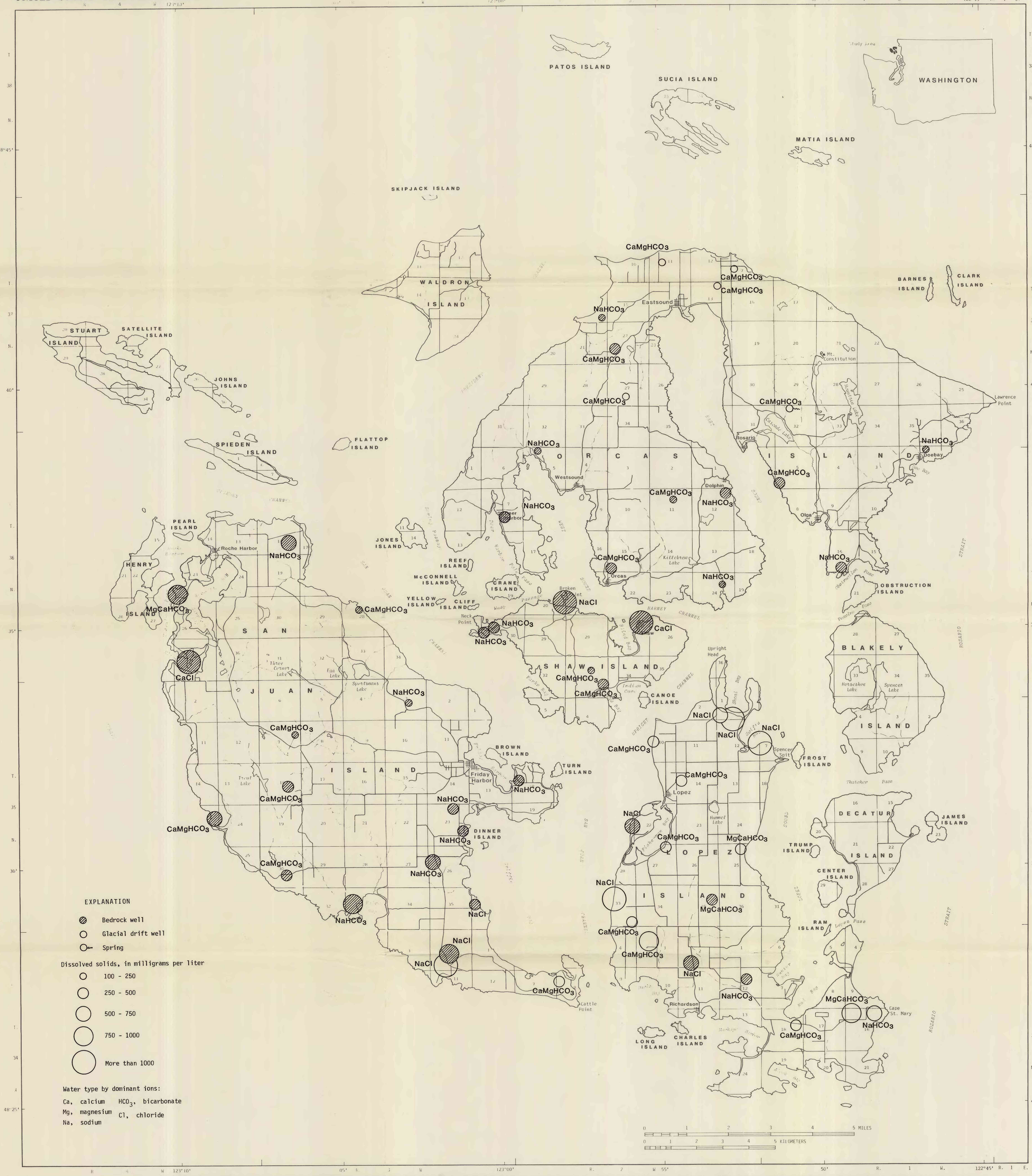

Base from U.S. Geological Survey
Orcas Island, Richardson 1:62:500, 1957,
Sucia Island, 1973, Stuart Island, 1953,
Waldron Island, 1954, Roche Harbor, 1954,
Friday Harbor, 1954, False Bay, 1:24,000,
1954.

OCCURRENCE, QUALITY, AND USE OF GROUND WATER IN ORCAS, SAN JUAN, LOPEZ, AND SHAW ISLANDS, SAN JUAN COUNTY, WASHINGTON

Geochemistry of Ground Water, June 1981

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INTRODUCTION

Man's development of San Juan County has depended partly on the use of hundreds of wells for water supplies. The suitability of a water supply for a particular use is often dependent on the quality of water. Therefore, a knowledge of existing ground-water quality is necessary for those who provide hydrologic information to city and county water managers.

Specific information needed to aid in effective management includes: (1) determination of the inorganic chemical character of water from major aquifers, (2) delineation of areas where degradation is occurring and where it may occur in the future, and (3) definition of the chemical characteristics of geologic materials that may influence ground-water chemistry.

In June 1981, water-chemistry analyses were made of samples taken from 56 wells and one spring. In addition, 16 of the 56 wells were selected for analyses of minor inorganic elements. A summary of the results of the water-quality analyses is given in table 1.

GENERAL WATER QUALITY

In general, the ground water in the San Juan Islands is high in dissolved solids and is classified as "hard," in that the median hardness value was 170 milligrams per liter (mg/L) expressed as calcium carbonate. The following is a descriptive hardness scale (McNeely and others, 1979, p. 18):

Range in hardness as $CaCO_3$ (mg/L)	Degree of hardness
0-60	Soft
60-120	Moderately hard
120-180	Hard
More than 180	Very hard

Shown on the accompanying map are water types distinguished by dominant cations and anions, and the dissolved-solids concentrations in water from the 56 wells and one spring sampled. The major ionic composition shows wide areal variation. Bedrock wells contain water in which sodium bicarbonate usually predominate, whereas in glacial-drift wells both sodium bicarbonate and calcium-magnesium bicarbonate water occurs. Fifty-four percent of the wells producing water classified as "very hard" are dominated by calcium-magnesium bicarbonate ions, whereas 100 percent of the wells having water classified as "soft" are dominated by sodium-bicarbonate ions. Nine of the 10 wells having water dominated by sodium chloride are located near the coast and are likely to be contaminated by seawater (see sheet 7). High sodium chloride water may also be indicative of (1) salt trapped in rock formations from ancient seawater, (2) leaching of waste water into aquifers, or (3) waste water directly entering wells. The data in table 1 show that, although the sodium and chloride concentrations have a wide range of values, the ranges of calcium, magnesium, bicarbonate, and sulfate values are much smaller. An expanded discussion of chloride concentrations in ground water is presented on sheets 7 and 8.

The diversity in chemical composition is due to such controls as chemical characteristics of the recharge water, the pattern of ground-water movement, and the type, texture, and solubility of the minerals in the soils and aquifers. These controls are complex and difficult to evaluate; some of the variation in the chemical composition of the water, however, can be explained by separating the water-quality data according to aquifer source, thereby allowing differences in chemistry to be better related to differences in the texture and mineral content of the aquifer. As shown in table 2, the median and mean values for most major and minor components are higher in glacial drift than in bedrock. Three constituents—magnesium, potassium, and silica—are shown to be significantly higher statistically (at the 95-percent level of confidence) in glacial drift.

TABLE 1.--Summary of chemical analyses of water from 59 observation wells

[All constituents in dissolved phase; major and secondary constituents expressed as milligrams per liter and minor constituents expressed as micrograms per liter except as otherwise shown]

Constituent or property	Number of analyses	Median	Mean	Range: Minimum value	Range: Maximum value
Properties and major constituents					
Alkalinity, total as $CaCO_3$	56	210	224	47	570
Calcium	57	50	54	.9	350
Chloride	57	46	162	7	2,700
Dissolved solids	57	404	557	123	4,200
Hardness, as $CaCO_3$	57	170	257	3	1,700
Magnesium	57	16	29	0	210
pH, in units	57	7.6	7.7	6.3	9.6
Potassium	57	2.5	4.5	.2	33
Silica	57	20	21	9	41
Sodium	56	68	105	5	870
Sulfate	56	32	42	1	140
Specific conductance, in micromhos/centimeter, 25°C	56	670	1,000	205	8,400
Secondary constituents					
Fluoride	57	0.1	0.2	0	2.9
Iron	57	.04	.56	.01	21
Manganese	57	.02	.08	0	.9
Nitrate	57	.05	.41	0	3.1
Minor constituents					
Aluminum	16	0	3	0	20
Arsenic	16	1	4	0	22
Barium	16	200	170	70	300
Cadmium	16	1	1	0	1
Chromium	16	0	4	0	10
Copper	16	8	140	0	1,000
Lead	16	0	2	0	21
Mercury	16	0	0	0	.3
Selenium	16	0	0	0	1
Silver	16	0	0	0	0
Zinc	16	160	330	20	1,600

Of the dissolved chemical constituents usually found at detectable concentrations, only iron and manganese had higher mean and median concentrations in bedrock than in glacial drift. Iron is derived naturally from the weathering of rocks and minerals. Manganese is similar to iron in its chemical behavior and is frequently found in association with iron. Low oxygen concentrations produce an environment favorable for the dissolution of iron and manganese. In fact, 14 of the 17 wells that smelled of hydrogen sulfide, an indication of low or zero oxygen conditions, were bedrock wells.

Specific conductance, determined for samples from 279 wells, is a useful measure of the degree of mineralization of water or the amount of dissolved ions. The waters with least mineral content occur on Orcas Island, where specific-conductance values from the September sampling ranged from 215 to 630 micromhos per centimeter (µmho/cm), and most of the wells are drilled in bedrock. Elsewhere in the county, specific-conductance values vary widely from well to well, even some that are proximate. Excluding wells having water dominated by sodium and chloride, specific-conductance values during the September sampling ranged from 215 to 3,000 µmho/cm.

TABLE 2.--Median, mean and ranges of chemical constituents and properties in water in observation wells grouped according to rock type

[All constituents in dissolved phase; major and secondary constituents expressed as milligrams per liter and minor constituents expressed as micrograms per liter except as otherwise shown]

Constituent or property	Bedrock: Number	Bedrock: Median	Bedrock: Mean	Bedrock: Range	Glacial drift: Number	Glacial drift: Median	Glacial drift: Mean	Glacial drift: Range
Properties and major constituents								
Alkalinity, total as $CaCO_3$	36	210	212	47-570	19	230	256	73-500
Calcium	37	38	53	0.9-350	19	59	60	24-110
Chloride	37	36	162	7-2,700	19	46	172	10-790
Dissolved solids	37	392	545	155-4,200	19	484	602	134-1,700
Hardness, as $CaCO_3$	37	160	223	3-1,700	19	300	332	85-730
Magnesium	37	9.6	22	0-210	19	33	*44	6.1-130
pH, in units	37	7.8	7.8	6.3-9.6	19	7.5	7.5	7.0-7.9
Potassium	37	1.4	2.8	0.4-22	19	6	*8.0	0.7-33
Silica	37	18	19	9-36	19	27	*26.6	14-41
Sodium[1]	36	86	116	11-870	19	37	90	8.4-380
Sulfate	36	38	43	1-140	19	28	42	7.4-140
Specific conductance, in micromhos/centimeter, 25°C	36	650	985	255-8,400	19	815	1,077	205-3,000
Secondary constituents								
Fluoride	37	0.1	0.2	0-2.9	19	0.1	0.1	0.1-0.2
Iron	37	.04	.82	0.01-21	19	.03	.10	0.01-0.95
Manganese	37	.02	.10	0.002-0.91	19	.01	.04	0.001-0.16
Nitrate	37	.03	.33	0.0-3.1	19	*.631	.59	0-1.5
Minor constituents								
Aluminum	11	0	5	0-20	5	0	0	0-0
Arsenic	11	1	3	0-22	5	3	4.8	0-16
Barium	11	200	179	70-300	5	100	134	80-300
Cadmium	11	1	1	1-1	5	1	.8	0-1
Chromium	11	0	5	0-10	5	0	2	0-10
Copper	11	3	89	0-700	5	17	243	1-1,000
Lead	11	0	.7	0-4	5	0	4.4	0-21
Mercury	11	0	.03	0-0.3	5	0	0	0-0.1
Selenium	11	0	.09	0-1	5	0	.4	0-1
Silver	11	0	0	0-0	5	0	0	0-0
Zinc	11	160	386	20-1,600	5	160	204	30-550

Asterisk (*) indicates mean constituent concentrations that are significantly higher at the 95-percent confidence level in glacial drift than in bedrock.

[1] Sodium concentrations are significantly higher at 95-percent level of confidence in bedrock if nine ground-water sites dominated by sodium and chloride are eliminated from data set.

SUITABILITY OF GROUND WATER FOR DRINKING

The primary objectives of water-quality management are the protection and enhancement of beneficial water uses. Standards have been established for many beneficial uses of water, but because drinking-water standards are generally restrictive, they will be used in this study for comparative purposes only. A comparison of the observed chemical characteristics to drinking-water standards is especially pertinent because the principal use of ground water in San Juan County is for public and domestic supplies (sheet 10). Other uses include irrigation, stock watering, and industrial and commercial supplies.

Standards adopted by the Washington State Board of Health (1978, p. 29, 35) for public water supplies are shown in table 3. Standards for physical properties and inorganic constituents are divided into primary and secondary categories. The primary chemicals relate to human health, and the secondary chemicals relate to odor, appearance, and other esthetic qualities.

In 29 of the 56 ground-water samples taken in June 1981, concentrations of one or more constituents exceeded secondary standards—in most cases dissolved solids and manganese, followed by chloride and iron. High concentrations of these constituents, with the possible exception of chloride, are most probably due to natural conditions. In order to meet secondary standards, treatment of water may be necessary. Twenty-three of the well-water samples in which one or more standards were exceeded are privately owned and are used for domestic supply. Standards were also exceeded in water in four public supply wells and in one well serving a recreational facility.

High concentrations of dissolved solids limit the water as a desirable drinking source. Some of the ground water sampled contained more than 1,000 mg/L of total dissolved solids and was thus considered slightly saline. Industrial water users generally require that concentrations be less than 1,000 mg/L (McNeely and others, 1979). Limits for the maximum concentration of chloride have been set largely by taste preferences; large amounts of chloride can also increase a water's corrosiveness. High iron concentrations are objectionable for drinking water because of taste, discoloring of washed clothes and plumbing fixtures, and the scaling of pipes. The presence of substantial amounts of manganese is objectionable because of its staining effects.

In only one well-water sample was the primary standard for fluoride exceeded; this may be an anomaly. The mean and median concentrations of nitrate were low, 0.41 and 0.05 mg/L, respectively, and none of the nitrate concentrations (as N) determined in this study exceeded the 10-mg/L primary standard. Concentrations of trace elements were low and did not exceed primary standards. Silver and aluminum were not detected in any of the samples; all other trace elements were detected in one or more wells. The median concentrations of six trace elements—aluminum, chromium, lead, mercury, selenium, and silver—were zero (table 1). Some of the wells had water containing quantities of copper and zinc, believed to be caused by contamination from within the distribution system.

TABLE 3.--Maximum contaminant levels for drinking water supplies

[From Washington State Board of Health, 1978, p. 29, 35]

Primary inorganic constituents (in micrograms per liter unless shown otherwise)		Secondary inorganic constituents and physical properties (in milligrams per liter unless shown otherwise)	
Arsenic	50	Color (cobalt-platinum units)	15
Barium	1,000	Iron	.3
Cadmium	10	Manganese	.05
Chromium	50	Total dissolved solids	500
Fluoride (mg/L)	2.0	Chloride	250
Lead	50	Sulfate	250
Mercury	2	Copper (µg/L)	1,000
Nitrate (mg/L)	10	Zinc (µg/L)	5,000
Selenium	10		
Silver	50		

TABLE 4.--Exceedence of Washington State Board of Health standards in ground-water samples from observation wells, June 1981

[DS, dissolved solids; Mn, manganese; Fe, iron; Cl, chloride; Fl, fluoride.
[a] Wells where chloride concentration exceeds standard, but water is not a sodium chloride type.]

Island and well No.	Well use	Constituents exceeding standards	Remarks
Lopez:			
34/1-16B1	Domestic	DS, Mn	Water reported very hard.
-16D1	do--	DS	Water reported to have odor.
-18H1	do--	Mn, Fe	Sulfide odor.
34/2-2P7	do--	DS	--
-3F7	do--	DS	--
35/1-7M1	do--	DS, Mn, Cl	Chloride concentrations increased from May to September 1981 by 500 mg/L.
35/2-1N1	Public supply	DS, Mn, Cl	Well was plugged at 81 ft due to presence of seawater.
-1P2	Domestic	DS	--
-21H1	do--	DS	--
-33G1	do--	DS, Cl	Chloride concentration increased from May to September 1981 by 100 mg/L.
-35H1	do--	Mn	--
San Juan:			
34/3-2P2[a]	Recreational	DS, Cl, Mn	Owner reports salty taste.
-2P4	Domestic	DS, Cl, Mn	Well bottom above sea level.
35/3-18K1	do--	Mn	--
-23J1	do--	Mn	Sulfide odor.
-26E1	do--	DS	--
-33E1	Public supply	DS, Mn	--
35/4-23H1	Domestic	DS, Mn	Chloride concentration increased steadily from spring to fall 1981.
36/3-18K2	do--	DS, Mn	Sulfide odor.
-28F1	do--	Fe	--
36/4-23N1	Public supply	DS, Fe, Mn	--
-35L3	Domestic	DS, Cl, Fe, Mn	--
Shaw:			
36/2-20J1[a]	Domestic	DS, Cl, Fe, Mn	--
-27B1	Commercial	DS, Cl, Mn	Chloride concentration increased from May to September 1981 by 1,000 mg/L.
-33J1	Domestic	Mn	--
Orcas:			
36/1-5N1	Domestic	Fe	--
36/2-11G1	do--	Mn, Fe	--
-12A1	do--	Fl	--
37/2-22L1	do--	Fe, Mn	--