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GROUND WATER QUALITY ASSESSMENT
SHERIDAN DAIRY LAGOON
ADNA, WASHINGTON

by
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Segment No.10-23-18GW
Water Body No.WA-23-1010GW

August 1992

ACKNOWLEDGEMENTS

I thank the many people who contributed to this project. Mr. Dan Watson volunteered to have Ecology conduct the study at his lagoon. Diane Harvester, former Ecology dairy waste inspector, found the site for monitoring and provided lagoon construction information. Bernie Strong and Pam Marti assisted with well installation and soil sampling. Cyronose Spicer, Ecology's Southwest Regional Office; Pam Marti and Betsy Dickes, Environmental Investigations; and Phil KauzLoric, Water Quality Program, provided peer review. Bill Yake, Section Supervisor, provided input on project design and peer review. Pam Covey, Craig Smith and Despina Strong, Manchester Laboratory, tracked sample flow and assured quality analytical results. Nancy Winters, Supervisor of the Water Quality Program Ground Water Unit, provided financial support. Bob Monn, formerly of the Water Quality Program, conceived the need for the project. Kelly Carruth typed the report.

ABSTRACT

Environmental Investigations Program of Ecology monitored ground water quality for one year at a seven-year-old dairy lagoon in Lewis County. Water Quality Program requested this study as part of a larger effort to define the impact of dairy lagoons on ground water quality at four locations in Washington State. The results of these studies will be used to augment existing dairy waste management programs.

Monitoring wells were installed and subsequently sampled quarterly. Analytes included chloride, total dissolved solids, total organic carbon, chemical oxygen demand, total phosphorus, ammonia-N, nitrate+nitrite-N, and total and fecal coliform bacteria. The target aquifer consisted of a thin, confined or semi-confined gravel layer at a depth of about 30 feet. Silt and clay deposits overlie the gravel layer and act to separate the lagoon from the aquifer. The lagoon does not appear to have affected ground water quality to date. Although nitrate+nitrite-N concentrations were elevated relative to upgradient conditions in two downgradient wells none of the other parameters tested, particularly chloride, were elevated.

INTRODUCTION

Problem Statement

Dairy lagoons temporarily store animal wastes and wastewater in winter when: 1) nutrient uptake by cover vegetation and crops is low and 2) the potential for surface runoff and ground water contamination from land application of wastes is high. In summer the lagoons store wastewater between spray applications. Dairy lagoons may leak if not properly sealed and may contaminate ground water. Reese and Loudon (1983) summarized past studies on dairy lagoon sealing. In general, these studies concluded that dairy lagoons are to some degree self-sealing and that leakage rates decrease substantially after lagoons are initially filled. Research into the causes and mechanisms related to self-sealing of dairy lagoons suggests that at least a partial seal, consisting of settled solids, a microbial layer or a combination of both, restricts leakage from lagoons. Also, leakage rates and the rates of sealing appear to be largely a function of soil texture and pore size, total solids concentration, and hydraulic head (Reese and Loudon, 1983). Although researchers agree that leakage rates decrease after lagoons first receive wastes, there is disagreement on the effectiveness of seals and whether the leakage rates pose a potential significant threat to ground water quality.

The Ground Water Quality Unit of the Ecology Water Quality Program requested that Toxics, Compliance, and Ground Water Investigations Section assess ground water quality near selected dairy lagoons in Washington. Four lagoons were selected: two in Whatcom County, one in Yakima County, and one in Lewis County. Monitoring at the lagoons was initiated sequentially with Sheridan Dairy Lagoon fourth in the series. This report presents and discusses the first year of results from Sheridan Dairy Lagoon. The results of the first three lagoons (Edaleen Dairy Lagoon, Whatcom County; Hornby Dairy Lagoon, Yakima County; and Whatcom Dairy Lagoon #2, Whatcom County) have been described previously by Erickson (1991, 1992a and 1992b).

Lagoon History and Construction

Sheridan Dairy Lagoon is located about five miles west of Chehalis, Washington, and about 1½ miles northwest of Adna, Washington. The single-stage lagoon was constructed in 1985 and was designed using Soil Conservation Service (SCS) Waste Storage Pond Guidelines (SCS, 1979). It is not known whether SCS inspected the lagoon during construction. The lagoon is unlined and was excavated about seven feet below ground surface with inside dimensions of about 100 by 255 feet. It has a capacity of about 1.1 million gallons. Solids are not separated from the manure prior to storage in the lagoon.

Geology, Hydrogeology and Soils

The lagoon is situated on the Chehalis River floodplain and is underlain by alluvial deposits consisting of mixtures of gravel, sand, silt and clay (Weigle and Foxworthy, 1962). Based on vicinity well logs, the thickness of alluvial deposits is highly variable and ranges from 30 to 190 feet. The alluvium is underlain by Tertiary sedimentary and igneous rocks. Based on the driller's log, the Sheridan Dairy water-supply well penetrated about 125 feet of unconsolidated deposits, primarily clay, that overlie sandstone. This well, with a total depth of 168 feet, taps the sandstone. The uppermost monitorable aquifer consists of a thin gravel layer at a depth of about 30 feet that appears to continuously underlie the site. Based on the well log for Sheridan Dairy water-supply well, the aquifer thickness is about 4 feet thick. All monitoring wells were installed in this layer. The alluvial deposits are a source of drinking water in the Adna area for some wells but many wells are drilled to bedrock. Wells completed in the alluvium generally have low to moderate yields. Regionally ground water flows north to south toward the Chehalis River. There are no water-supply wells located between the lagoon and the Chehalis River.

Soils developed at the site are designated as the Chehalis silty clay (Evans and Fibich, 1980). These soils consist of silty clay that overlies silt loam, silty clay loam and stratified fine sandy loam to silty clay loam. The soils have moderate permeability and are well drained.

METHODS

General

This section gives an overview of the approach used in this investigation. Specific methods are described in detail in subsequent sections.

A ground water monitoring network was installed around the lagoon to obtain ground water quality samples and to define directions and rates of ground water flow. Wells and the lagoon were sampled quarterly from June 1991 to April 1992. Samples were tested for ammonia-N, nitrate+nitrite-N, total phosphorus, total organic carbon (TOC), chemical oxygen demand (COD), total dissolved solids (TDS), chloride and total and fecal coliform bacteria. Total persulfate nitrogen (TPN), a measure of total inorganic and organic nitrogen, was tested during the June 1991 sampling round. TPN testing was stopped after the first round of sampling because TPN results at another lagoon study were consistently less than total inorganic nitrogen results (Erickson, 1991). Lagoon samples also were tested for total suspended solids.

The monitoring network consisted of four monitoring wells (Figure 1): one upgradient well (MW4), to define ambient ground water quality, and three downgradient wells (MW1, MW2 and MW3). Well water levels were measured each sampling event. The water level measurements were converted to elevations using mean sea level as a common datum. Differences in the water level elevations were used to determine ground water gradients and flow directions. Specific capacity data for nearby private wells were used to estimate hydraulic conductivity of the target aquifer. The hydraulic conductivity and ground water gradient data were combined to estimate ground water flow velocities. The study methods are described in detail below.

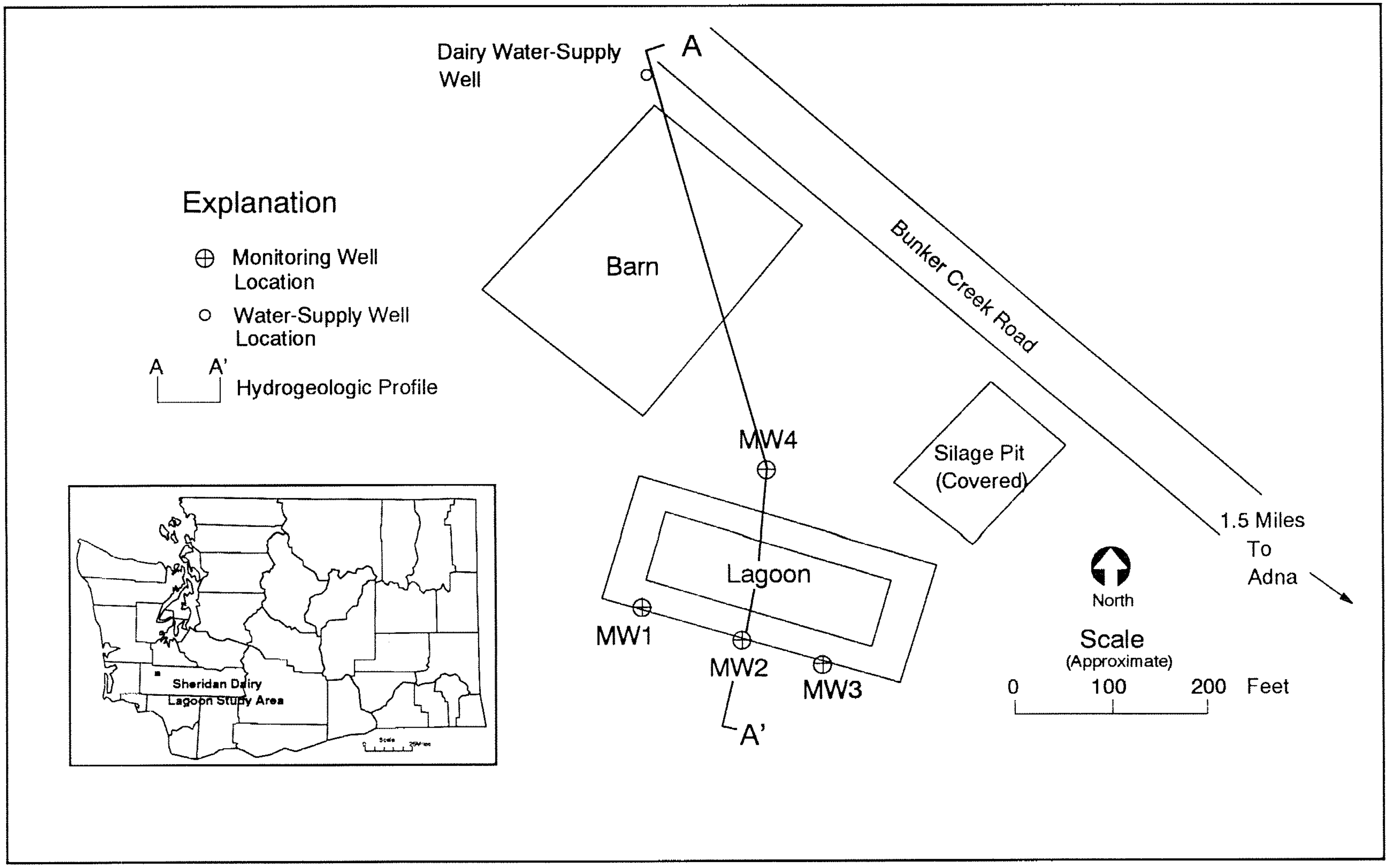

Figure 1. Sheridan Dairy Lagoon, Well Location Map

Well Installation and Water Levels

Monitoring wells were constructed with 1¼-inch diameter galvanized pipe and 2-foot-long, commercial, stainless steel wellpoints. Well screens and casing were steam cleaned before installation. Bentonite surface seals were installed at each well by auguring an oversized hole, about 6 inches in diameter and 3 feet deep. After the wellpoint was driven past the bottom of the oversized hole, hydrated bentonite was added to the annular space while the remaining casing was driven to the desired depth. During installation, wells were tested for yield at 3-foot intervals below a depth of 12 feet using a one-way foot valve attached to ¾-inch PVC. This testing was done to determine if monitorable quantities of water were present. The same tool was also used to develop the wells after they were installed at the desired depth. The depths of the wells ranged from 27.6 to 32.8 feet. As-built drawings for each well are shown in Appendix A.

Water levels were obtained using a commercial electric well probe. Relative elevations of measuring points for the monitoring wells were determined using a surveyor's level and rod. All elevations were measured relative to a concrete footing with an assumed elevation of 100 feet (mean sea level) using a USGS 7.5 minute topographic map. Relative elevations are considered to be accurate to 0.05 feet. Water level measurements are recorded to 0.01 feet and are considered accurate to 0.03 feet.

Hydraulic Conductivity Estimates

Hydraulic conductivity was estimated by using specific capacity data (the ratio of discharge rate and drawdown) and the method described by Bradbury and Rothschild (1985). This method is an iterative solution to the Theis equation with modifications for partial penetration and well loss. Results using this method are considered order of magnitude approximations. Specific capacity data was obtained from Ecology well records for wells within a one mile radius of the lagoon. The locations of wells on file were not field verified. On-site monitoring wells were not used to determine hydraulic conductivity because the exact screen length exposed to the gravel aquifer was not known.

Water Quality Sampling and Analysis

Wells were purged and sampled using a peristaltic pump attached to dedicated 3/8-inch ID polyethylene tubing. Flexible silastic tubing was used in the peristaltic pump head. Prior to sampling a minimum of three well volumes were purged. Also wells were purged until pH, temperature, and specific conductance measurements stabilized. Measurements were considered stable if the change between well volumes was less than 0.1 Standard Units for pH, 0.2°C for temperature, and 20 micromhos/cm for specific conductance. Grab samples from the lagoon were collected just below the wastewater surface. All samples were placed in coolers at 4°C and transported to the Ecology/EPA Region X Laboratory in Manchester, Washington. The parameters tested, test methods, and method detection limits are listed in Table 1.

Table 1. Sheridan Dairy Lagoon Parameters, Test Methods, and Detection Limits.

Parameter	Method of Analysis	Reference	Detection Limit
Water Level	Electric Well Probe	NA	0.01 feet
pH	Beckman pH Meter	NA	0.1 Std Units
Specific Conductance	YSI Conductance Meter	NA	10 umhos/cm
Temperature	Beckman Temperature Probe	NA	0.1°C
Ammonia-N	EPA Method 350.1	EPA (1983)	0.01 mg/L
Nitrate+Nitrite-N	EPA Method 353.2	EPA (1983)	0.01 mg/L
Total Persulfate Nitrogen	EPA Method 353.2	EPA (1983)	0.1 mg/L
Total Phosphorus	EPA Method 365.1	EPA (1983)	0.01 mg/L
Chloride	Std Methods No. 429	APHA (1985)	0.1 mg/L
Total Dissolved Solids	Std Methods No. 209B	APHA (1985)	10 mg/L
Total Suspended Solids	Std Methods No. 205C	APHA (1985)	10 mg/L
Chemical Oxygen Demand	Std Methods No. 508C	APHA (1985)	4 mg/L
Total Organic Carbon	Std Methods No. 505	APHA (1985)	1.0 mg/L
Total Coliform	Std Methods No. 909A	APHA (1985)	1 CFU/100 ml
Fecal Coliform	Std Methods No. 909C	APHA (1985)	1 CFU/100 ml

NA= Not Applicable

CFU= Colony Forming Unit

Quality Assurance

In addition to calibration standards, spikes, and laboratory duplicates, field quality assurance samples consisted of blind duplicates and TOC transport blanks. A blind duplicate was obtained for each parameter during each sampling event. Blind duplicate results and TOC transport blank results are shown in Table 2. Relative percent differences (RPDs) for blind duplicate results are calculated and shown in Table 2. RPDs are the ratio of the difference and the mean of duplicate results expressed as a percentage. They are used to estimate analytical precision. In general, the greater the RPD the lower or poorer the analytical precision.

Overall, the quality of the data is good. Most of the RPDs are less than 25% and frequently less than 5%. The September results showed high RPDs for total dissolved solids (58%), chemical oxygen demand (97%) and total phosphorus (105%). The RPD for TOC was 46% for the April sampling. The cause of the poor precision for these parameters for these sampling events is not known. In the results section of this report the analyte concentrations for field duplicates are reported as the mean of the duplicate results.

Other qualified data are discussed as follows. Lagoon sample results are estimated for many parameters because of interference due to high suspended solids in the samples. All TOC data are estimated for the September sampling because results from dual injections showed poor precision.

The concentrations for TOC transport blanks were less than the quantitation limit (1 mg/L) and no qualification of the data due to blank contamination is necessary.

RESULTS

Site Hydrogeology

The relationship of the lagoon and the site hydrogeology is shown in Figure 2. The target aquifer is a thin unconsolidated gravel layer at a depth of about 30 feet. The layer was logged as four feet thick where the dairy water-supply well was drilled. Silt and clay deposits with low permeability overlie the gravel layer. These deposits act as a confining or semi-confining unit that reduces the hydraulic connection between the lagoon and the aquifer. Water levels in the monitoring wells (Table B-1 in Appendix B) ranged from about five to eleven feet deep during the course of the study. Hydrographs showing the relative water level elevations in the wells and lagoon are plotted in Figure 3. Water elevations in monitoring wells fluctuated three to four feet over the study period. The fluid elevation in the lagoon was higher than downgradient well water levels between July and March. Thus, there is a potential for vertical downward flow from the lagoon to ground water about nine months of the year. Differences in water levels between wells are used to show the ground water flow direction. Water-table contour maps based on water level data from all four sampling events are shown in Figures 4 through 7. Ground water moves perpendicular to the contours from high to low elevations. Based on these

Table 2. Sheridan Dairy Lagoon, Quality Assurance Results.
(Units= mg/L unless shown otherwise.)

Well ID	Date	Total Dissolved Solids	Chemical Oxygen Demand	Total Organic Carbon	Ammonia as N	Nitrate+ Nitrite as N	Total Persulfate Nitrogen	Total Phosphorus	Chloride	Total Coliform (CFU/100 ml)	Fecal Coliform (CFU/100 ml)	TOC Transport Blanks
MW3	06/18/91	334	10 U	1 U	0.031	3.6	3.6	0.13	22.2	3 U	3 U	1 U
Duplicate		333	10 U	1 U	0.033	3.6	3.6	0.13	21.7	3 UX	1 U	
	RPD(%)=	0.3	--	--	6.2	0.0	0.0	0.0	2.3	--	--	
MW3	09/16/91	380	3.1	1.8 J	0.04 U	2.4	NT	0.45	29	1 U	1 U	0.8
Duplicate		210	8.9	2.0 J	0.04 U	2.4	NT	0.14	29	1 U	1 U	
	RPD(%)=	58	97	11	--	0.0	--	105	0.0	--	--	
MW2	01/07/92	492	6.0	2.5	0.077	2.93	NT	0.131	45.0	1 U	1 U	1 U
Duplicate		512	7.5	2.5	0.072	2.93	NT	0.129	44.8	1 U	1 U	
	RPD(%)=	4.0	22	0.0	6.7	0.0	--	1.5	0.4	--	--	
MW3	04/14/92	308	4.8	2.4	0.01 U	4.64	NT	0.118	18.4	1 U	1 U	1 U
Duplicate		306	4.7	1.5	0.01 U	4.75	NT	0.123	19.0	1 U	1 U	
	RPD(%)=	0.7	2.1	46	--	2.3	--	4.1	3.2	--	--	

U= Analyte not detected above reported concentration.

J= Estimated value.

NT= Not tested.

RPD= Relative Percent Difference (ratio of the difference and mean of duplicate results expressed as a percentage).

CFU= Colony forming unit.

Note: Outlined RPD values represent duplicate results with poor precision. See quality assurance discussion in text of report.

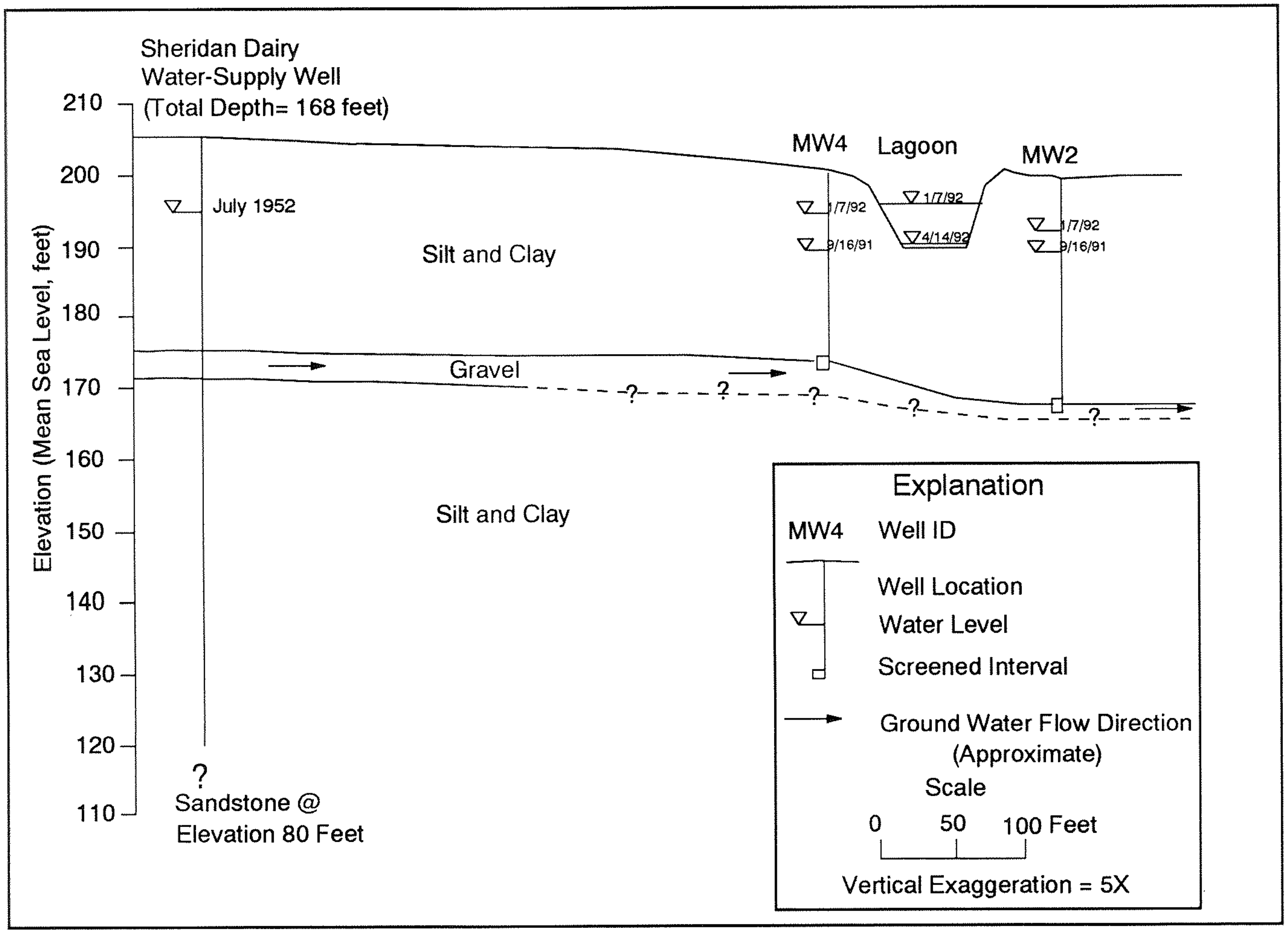

Figure 2. Sheridan Dairy, Hydrogeologic Profile

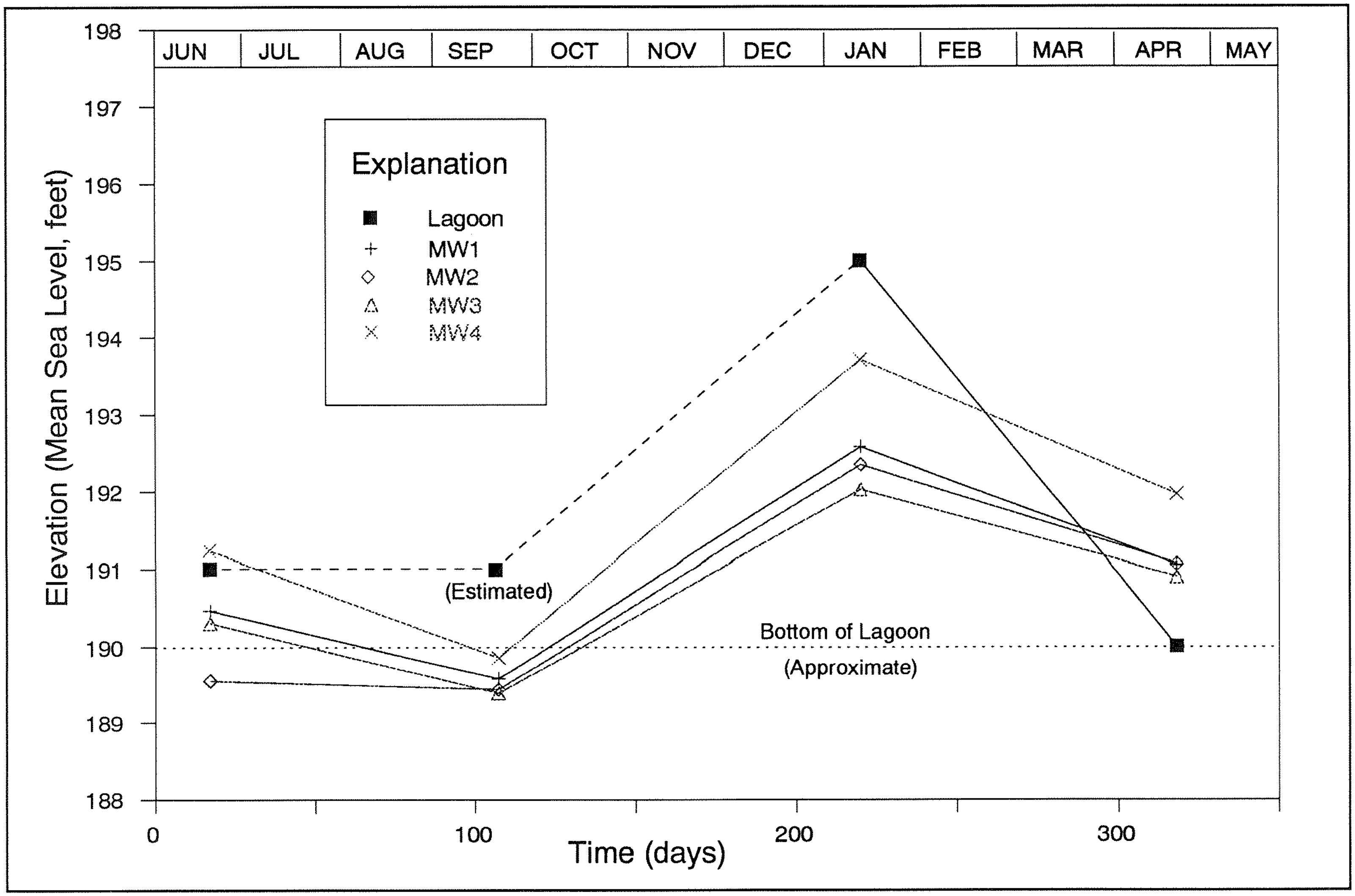

Figure 3. Hydrographs for Wells and Lagoon, June 1991 through April 1992 Sheridan Dairy Lagoon.

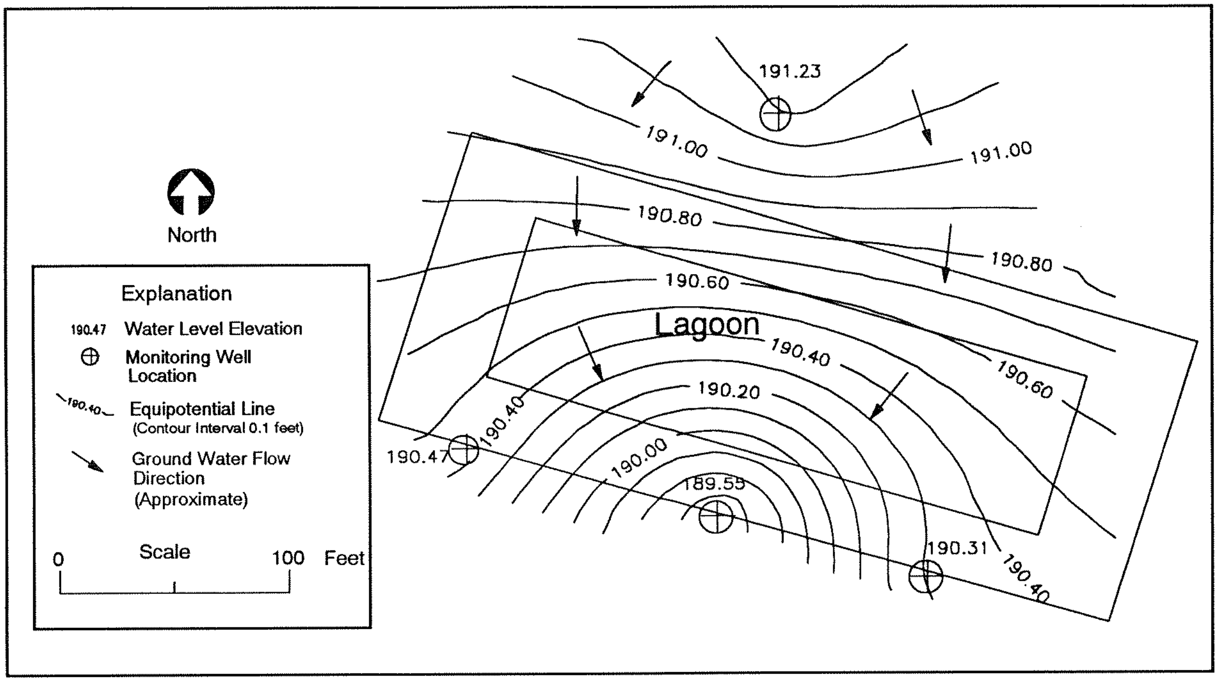

Figure 4. Sheridan Dairy Lagoon, Potentiometric Map, June 1991.

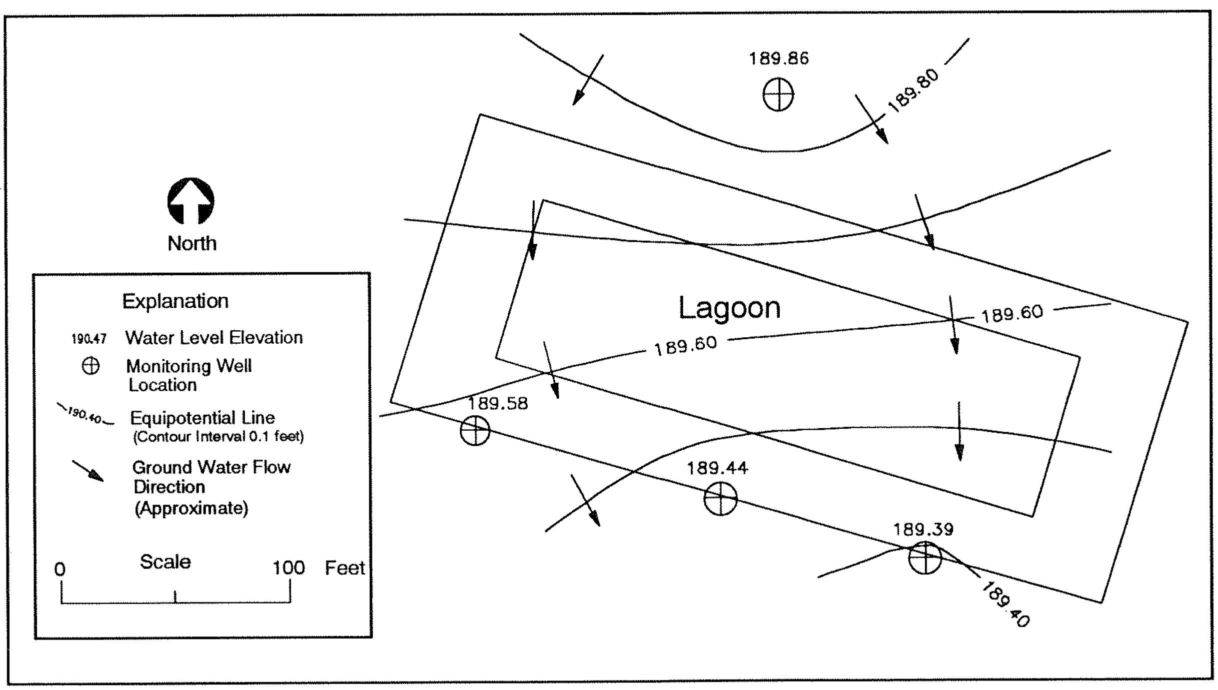

Figure 5. Sheridan Dairy Lagoon, Potentiometric Map, September 1991.

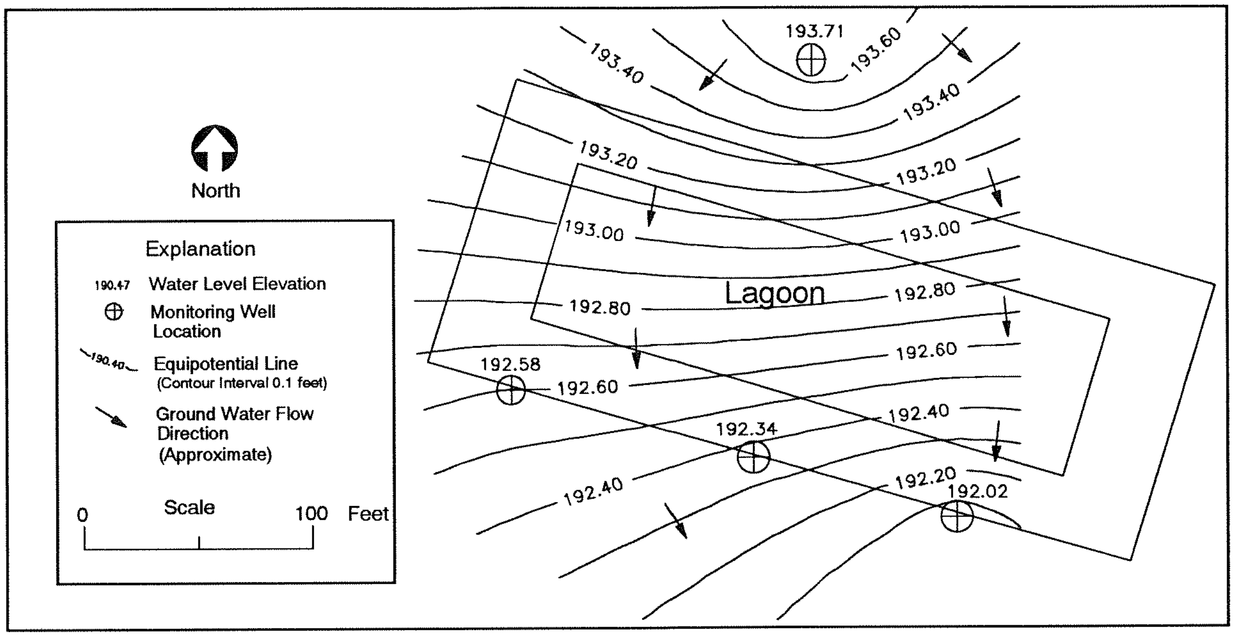

Figure 6. Sheridan Dairy Lagoon, Potentiometric Map, January 1992.

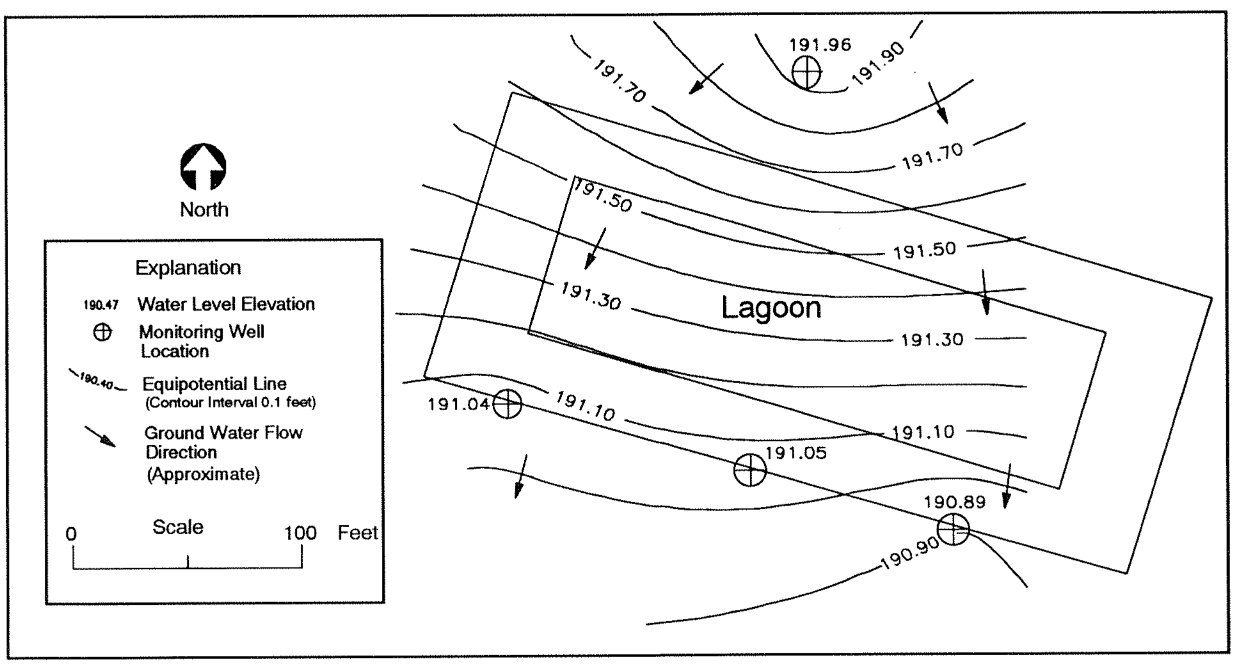

Figure 7. Sheridan Dairy Lagoon, Potentiometric Map, April 1992.

figures ground water flowed south during the study period. The hydraulic gradients ranged from 0.0026 (September) to 0.0084 (January).

Hydraulic Conductivity

Hydraulic conductivity of the target aquifer was estimated using specific capacity and well construction data from Ecology well records. Based on the records four wells within a one mile radius of the lagoon were screened in the alluvial gravel and had specific capacity test results. For these estimates the storage coefficient was assumed to range between 0.001 and 0.0001 because the aquifer is confined or semi-confined. No corrections were made for well loss. The input data and results are listed in Table B-2 in Appendix B. Based on this method, hydraulic conductivities of the alluvial gravel ranged from about 34 to 156 feet per day with arithmetic and geometric means of 81 and 69 feet per day, respectively. Because hydraulic conductivity is considered to be log-normally distributed (Freeze, 1986) the geometric mean is a better indicator of central tendency than the arithmetic mean.

Ground Water Velocities

Ground water velocities can be estimated using Darcy's Law:

$$v=\frac{K_h \times \frac{dh}{dL}}{n_e}$$

where,

v= estimated average linear velocity
dh/dL= hydraulic gradient
K_h= saturated hydraulic conductivity
n_e= effective porosity

Because the aquifer consisted of unconsolidated gravel, the effective porosity was assumed to range from 0.10 to 0.35. This variability combined with the range of hydraulic conductivity and hydraulic gradient, results in a range in flow velocity of 0.3 to 13 feet per day. The results are shown in Table 3. The mean linear velocity (using a hydraulic conductivity of 69 feet per day, and effective porosity of 0.25 and a hydraulic gradient of 0.0055 (feet/feet)) is 1.5 feet per day.

Table 3. Estimated Ground Water Velocities.

	Minimum	Maximum	Mean
Hydraulic Conductivity (feet/day)	34	156	69 (Geometric)
Effective Porosity	0.10	0.35	0.25
Hydraulic Gradient (feet/feet)	0.0026	0.0084	0.0055
Ground Water Velocity (feet/day)	0.3	13	1.5

Water Quality

Field parameter results for pH, temperature and specific conductance are shown in Table 4. The pH of ground water ranged 6.6 to 7.3 and was highest in the upgradient well (MW4). Temperature ranged from 11.1 to 15.3°C and was consistently high in fall and low in the winter. Specific conductance ranged from 360 to 910 micromhos/cm and was typically higher in the upgradient well (MW4).

Results of water chemistry and bacteriological analyses are shown in Tables 5 and 6, respectively. The lagoon wastewater concentrations for total dissolved solids (TDS, 5800 to 9180 mg/L), chemical oxygen demand (COD, 2100 to 10785 mg/L), total organic carbon (TOC, 724 to 1900 mg/L), ammonia-N (230 to 594 mg/L), total phosphorus (125 to 150 mg/L), chloride (158 to 463 mg/L), total coliform bacteria (150,000 to 800,000 CFU/100mL) and fecal coliform bacteria (120,000 to 520,000 CFU/100mL) were substantially higher than concentrations in ground water upgradient of the lagoon (MW4). Therefore these parameters are potential indicators of leakage from the lagoon.

The quality of the target aquifer upgradient of the lagoon is poor. Concentrations for COD, TDS, ammonia-N, and chloride appear to be higher than would be expected for a shallow alluvial aquifer. The cause of the degradation is not known but is probably related to upgradient land uses.

In general, the concentrations of most parameters in downgradient wells are not elevated relative to upgradient conditions. In fact concentrations for TDS, COD, TOC, and ammonia-N are higher in the upgradient monitoring well. Nitrate+nitrite-N is an exception. Nitrate+nitrite-N was not detected in the upgradient well but was present in MW2 and MW3 at concentrations ranging from 1.6 to 2.9 mg/L and 2.4 to 4.7 mg/L, respectively. Total coliform bacteria were detected in only one sample (June 1991) and that was in the upgradient well. Fecal coliform bacteria were not detected in any of the samples.

Table 4. Sheridan Dairy Lagoon Field Parameter Results.

Site Name	Date	pH (Std Units)	Temperature (°C)	Specific Conductance (micromhos/cm)
Lagoon	09/16/91	NT	22	7000
Lagoon	01/07/92	7.4	NT	NT
MW1	06/18/91	7.3	12.5	400
MW1	09/16/91	NT	13.8	535
MW1	01/07/92	7.0	11.1	500
MW1	04/14/92	7.0	11.7	403
MW2	06/18/91	6.6	14.1	550
MW2	09/16/91	NT	15.5	720
MW2	01/07/92	6.6	11.3	660
MW2	04/14/92	6.6	12.6	505
MW3	06/18/91	6.9	13.9	382
MW3	09/16/91	NT	13.8	595
MW3	01/07/92	6.7	11.4	490
MW3	04/14/92	6.7	12.5	360
MW4	06/18/91	6.6	13.9	710
MW4	09/16/91	NT	15.3	720
MW4	01/07/92	6.5	11.5	910
MW4	04/14/92	6.6	12.6	700

NT= Not tested.

Table 5. Sheridan Dairy Lagoon, Water Quality Results June 1991 through April 1992.

Site Name	Date	Total Dissolved Solids	Chemical Oxygen Demand	Total Organic Carbon	Ammonia as N	Nitrate+ Nitrite as N	Total Inorganic Nitrogen	Total Persulfate Nitrogen	Total Phosphorus	Chloride	Total Solids
Lagoon	06/18/91		2100	724	230	0.07	230	130 J	140	158	4620[1]
Lagoon	09/16/91	5800	10785	1900 J	360	0.23	360	NT	150 J	380	NT[2]
Lagoon	01/07/92	9180 J	7300	1990	594 J	0.07 J	594	NT	125 J	463	8820
MW4 Upgradient	06/18/91	557	11	5.5	0.67	0.01 U	0.67	0.4 J	0.47	44	
MW4	09/16/91	590	40	5.8 J	0.50	0.02 U	0.50	NT	0.27	38	
MW4	01/07/92	643	23	6.1	0.71	0.01 U	0.71	NT	0.09	40	
MW4	04/14/92	571	18	6.4	0.73	0.01 U	0.73	NT	0.10	38	
MW1 Downgradient	06/18/91	458	10 U	1.4	0.08	0.01 U	0.08	0.1 U	0.19	29	
MW1	09/16/91	340	3.1	2.4 J	0.04 U	0.02 U	NA	NT	0.18	25	
MW1	01/07/92	364	5.0	1.1	0.07	0.01 U	0.07	NT	0.12	24	
MW1	04/14/92	342	2.3	1.4	0.07	0.01 U	0.07	NT	0.18	27	
MW2 Downgradient	06/18/91	463	11	2.5	0.13	1.6	1.7	1.8	0.54	45	
MW2	09/16/91	450	8.4	3.8 J	0.04 U	2.7	2.7	NT	0.17	39	
MW2	01/07/92	502	6.8	2.5	0.07	2.9	3.0	NT	0.13	45	
MW2	04/14/92	417	9.3	2.6	0.01 U	2.7	2.7	NT	0.10	42	
MW3 Downgradient	06/18/91	334	10 U	1.0 U	0.03	3.6	3.6	3.6	0.13	22	
MW3	09/16/91	295	6	1.9 J	0.04 U	2.4	2.4	NT	0.30	29	
MW3	01/07/92	344	5.5	1.3	0.02	3.1	3.1	NT	0.14	24	
MW3	04/14/92	307	4.8	2.0	0.01 U	4.7	4.7	NT	0.12	19	

[1]Total suspended solids = 880 mg/l

[2]Total suspended solids= 5400 mg/L

J= Estimated value.

U= Analyte not detected above reported limit.

NA= Not applicable.

Table 6. Sheridan Dairy Lagoon Bacteriologic Results.
(Units= Colony Forming Units (CFUs)/100 ml)

Site Name	Date	Total Coliform		Fecal Coliform	
Lagoon	06/18/91	430000	X	360000	
Lagoon	09/16/91	150000		120000	
Lagoon	01/07/92	800000		520000	
MW4 Upgradient	06/18/91	1		1	U
MW4	09/16/91	1	UX	1	U
MW4	01/07/92	1	U	1	U
MW4	04/14/92	1	U	1	U
MW1 Downgradient	06/18/91	1	U	1	U
MW1	09/16/91	1	U	1	U
MW1	01/07/92	1	U	1	U
MW1	04/14/92	1	U	1	U
MW2 Downgradient	06/18/91	1	UX	1	U
MW2	09/16/91	1	U	1	U
MW2	01/07/92	1	U	1	U
MW2	04/14/92	1	U	1	U
MW3 Downgradient	06/18/91	1	UX	1	U
MW3	09/16/91	1	U	1	U
MW3	01/07/92	1	U	1	U
MW3	04/14/92	1	U	1	U

X= Many Background Organisms.

U= Analyte Not Detected Above Reported Limit.

DISCUSSION

Effects on Ground Water Quality

Based on the results of one year of monitoring there is no consistent evidence to indicate that leakage from the lagoon is affecting ground water quality. Concentrations for most parameters were higher in the upgradient well than the downgradient wells. One parameter, nitrate+nitrite-N, was elevated in two downgradient wells relative to upgradient concentrations. Nitrate+nitrite-N was not detected in the upgradient well but was present in MW2 and MW3 at concentrations ranging from 1.6 to 2.9 mg/L and 2.4 to 4.7 mg/L, respectively. However, because no other parameters tested were elevated relative to background it is unlikely that leakage from the lagoon is the cause of the elevated nitrate+nitrite-N.

In particular, the lack of chloride in the downgradient wells supports this idea. Chloride was shown to be a good indicator of ground water contamination from lagoon leakage at previously studied lagoons (Erickson,1991 and 1992b). Also, it is a good tracer in ground water because it is soluble in water, does not adsorb readily to soil, and does not degrade (Davis and DeWiest, 1966; Freeze and Cherry, 1979). Chloride was present in the wastewater at concentrations ranging from 158 mg/L to 463 mg/L. Upgradient of the lagoon, chloride concentrations (MW4) ranged from 38 to 44 mg/L. Chloride concentrations in downgradient wells (MW1 though MW3) ranged from 22 to 45 mg/L. Moreover, chloride concentrations in two of the monitoring wells (MW1 and MW3) were substantially lower than upgradient concentrations.

The source of the elevated nitrate+nitrite-N concentrations in wells MW2 and MW3 is unknown. One possible source is the silage pit located northeast of the lagoon (See Figure 1). The pit appears to be generally upgradient of wells MW2 and MW3 and it is excavated a few feet below the ground surface. However, silt and clay deposits, similar to the deposits that underlie the lagoon, probably underlie the silage pit. Therefore, travel times for contaminants from the silage pit to the aquifer would be expected to be very long. To identify the source of nitrate+nitrite-N additional monitoring wells would be needed upgradient of the lagoon. These additional wells would be used to better define the ground water flow pattern and the distribution of nitrate+nitrite-N concentrations.

Comparison to Standards

Drinking water standards (Maximum Contaminant Levels, MCLs) for public systems and ground water quality standards (Chapter 173-200 WAC) are shown in Table 7 for the parameters tested. Only two parameters, nitrate-N (10 mg/L) and total coliform bacteria (one Colony Forming Unit(CFU)/100mL) have primary MCLs. Primary MCLs are maximum allowable concentrations for public water-supply systems based on potential health effects (Department of Health, 1989). None of the nitrate+nitrite-N concentrations exceeded 10 mg/L. The maximum observed nirate+nitrite-N concentration in downgradient wells was 4.7 mg/L. However,

Table 7. Sheridan Dairy Lagoon, Drinking Water Standards and Ground Water Quality Standards (mg/L unless shown otherwise).

Parameter	Primary Maximum Contaminant Level(MCL)[1]	Secondary Maximum Contaminant Level(MCL)[2]	Ground Water Quality Standards[3]
Chloride	None	250	250
Total Dissolved Solids	None	500	500
Total Organic Carbon	None	None	None
Chemical Oxygen Demand	None	None	None
Ammonia-N	None	None	None
Nitrate-N	10	None	10
Total Phosphorus	None	None	None
Specific Conductance (micromhos/cm @ 25°C)	None	700	None
Total Coliform Bacteria (Colony Forming Units(CFUs)/100mL)	1	None	1
Fecal Coliform Bacteria (CFUs/100mL)	None	None	None

None= No standard has been established.

[1] Department of Health (1989). Primary MCLs are maximum allowable contaminant concentrations for public water supply systems based on potential adverse health effects.

[2]Department of Health (1989). Secondary MCLs are maximum allowable contaminant concentrations for public water supply systems based on aesthetics such as taste, odor, or staining.

[3] Chapter 173-200 WAC, Water Quality Standards for Ground Waters of the State of Washington.

Note: Water Quality Standards for Ground Water have narrative antidegradation standards to protect existing ground water quality and beneficial uses.

nitrogen is present in the wastewater, primarily as ammonia-N, at concentrations ranging from 230 to 594 mg/L. If leakage did occur over the long term the potential exists for nitrate-N concentrations to exceed 10 mg/L.

Total coliform bacteria were detected in the upgradient monitoring well during the June sampling event at a concentration of 1 CFU/100 mL. Total coliform bacteria were not detected in any of the downgradient monitoring wells.

Secondary MCLs have been established for public drinking water systems for three of the parameters tested: specific conductance (700 micromhos/cm), TDS (500 mg/L), and chloride (250 mg/L). Secondary MCLs are based on aesthetics such as taste, odor or discoloration. Specific conductance and TDS measurements consistently exceeded secondary MCLs in the upgradient well and on one occasion each in MW2. The exceedances do not appear to be related to leakage from the lagoon.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions from the first year of monitoring at Sheridan Dairy Lagoon are discussed below.

1. Ground water immediately downgradient of the lagoon shows no consistent effects of leakage from the lagoon. Nitrate+nitrite-N concentrations were elevated relative to upgradient conditions in two downgradient monitoring wells. However, the elevated concentrations are probably not related to leakage from the lagoon because none of the other parameters, in particular chloride, are elevated.

2. The target aquifer consists of a thin gravel layer at a depth of about 30 feet. The aquifer is confined or semi-confined and is separated from the lagoon by about 24 feet of alluvial silt and clay. Ground water in the target aquifer flows southward. If the aquifer is continuous it probably discharges to the Chehalis River about 1500 feet south of the lagoon. The ground water flow velocity is estimated to range from 0.3 to 13 feet per day.

3. The rate of vertical downward movement from the lagoon to the aquifer is probably very slow. A slow travel rate is expected because of the low hydraulic conductivity of the separating silt and clay layer and because vertical downward hydraulic potential exists only about nine months of the year.

4. The quality of the target aquifer upgradient of the lagoon is poor. Total dissolved solids, chemical oxygen demand, ammonia-N, and chloride concentrations appear to be higher than would be expected for ground water in shallow alluvial sediments. The cause of this degradation is not known but is probably related to upgradient land uses.

5. Concentrations in downgradient monitoring wells did not exceed the Primary Maximum Contaminant Levels (MCLs) for nitrate-N (10 mg/L) or total coliform bacteria (1 CFU/100 mL). The Secondary MCLs for total dissolved solids (500 mg/L) and specific

conductance (700 micromhos/cm) were exceeded consistently in the upgradient well and on one occasion each in one downgradient well (MW2). The exceedances are probably not related to leakage from the lagoon.

Recommendations based on the first year of monitoring are described below.

1. Monitoring at the lagoon should be discontinued because the rate of movement from the lagoon to the aquifer is probably very slow and no water quality affects are likely to occur for a number of years, if at all.

2. The Soil Conservation Service (SCS) should conduct a review of the lagoon construction to determine if it meets current standards and guidelines.

3. On-site monitoring wells should be properly decommissioned in accordance with Chapter 173-160 WAC, Minimum Standards for the Construction and Maintenance of Wells.

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APPENDIX A

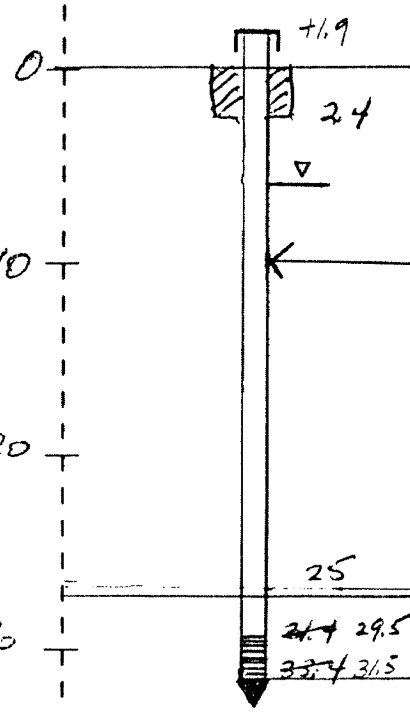
Drill Logs and Well As-Built Drawings

RESOURCE PROTECTION WELL REPORT

START CARD NO. 078213

PROJECT NAME: Watson Lagoon
WELL IDENTIFICATION NO. MW-1
DRILLING METHOD: Driven
DRILLER: Denis Erickson
FIRM: Wash. St. Dept of Ecology
SIGNATURE: Denis R. Erickson
CONSULTING FIRM: None
REPRESENTATIVE: None

COUNTY: Lewis
LOCATION: SW ¼ NE ¼ Sec 5 Twn 13 R 3W
STREET ADDRESS OF WELL: 451 Bunker Hill Road Adna, WA
WATER LEVEL ELEVATION: ~~196~~ 194
GROUND SURFACE ELEVATION: ~~205~~ 202
INSTALLED: 3/5/91
DEVELOPED: 3/5/91



AS-BUILT	WELL DATA	FORMATION DESCRIPTION
+1.9	Locked 1¼" Cap +1.9	
0		Ground Surface
2.4	Bentonite Pellet Seal, 6-inch dia. borehole	Topsoil Brown organic silt and Gray clayey SILT, damp to wet
10	1¼" Galvanized Casing	
25		
~~24.4~~ 29.5 ~~33.4~~ 31.5	2-foot Stainless Steel Screen 60 gze	Sand + Gravel
		Total Depth ~~33.4~~ 31.5

SCALE: 1" = 10 feet PAGE 1 OF 1

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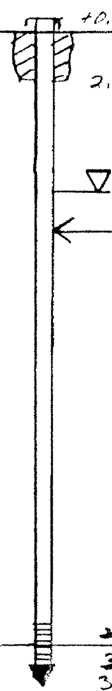
RESOURCE PROTECTION WELL REPORT

START CARD NO. 078213

PROJECT NAME: Watson Lagoon
WELL IDENTIFICATION NO. MW-2
DRILLING METHOD: Driven
DRILLER: Denis Erickson
FIRM: Wash. St. Dept of Ecology
SIGNATURE: Denis R. Erickson
CONSULTING FIRM: NONE
REPRESENTATIVE: NONE

COUNTY: Lewis
LOCATION SW 1/4 NE 1/4 Sec 5 Twn 13 R 3W
STREET ADDRESS OF WELL: 451 Bunker Hill Rd
WATER LEVEL ELEVATION: 194
GROUND SURFACE ELEVATION: 202
INSTALLED: 5/28/91
DEVELOPED: 5/28/91

Depth	AS-BUILT	WELL DATA	FORMATION DESCRIPTION
0	+0.55	Locking Cap	Ground Surface
	2.4	Bentonite Pellet Seal 6-inch dia. borehole	Top soil, Brown
			Brown organic SILT and Brown to gray clayey SILT, damp to wet
10		1¼" Galvanized Casing	
20			
30	~~31.4~~ 30.8	Stainless Steel Well Screen 60 slot	
	~~32.4~~ 32.8		GRAVEL Total Depth ~~32.4~~ 32.8 (Refusal)
40			



SCALE: 1" = 10 feet

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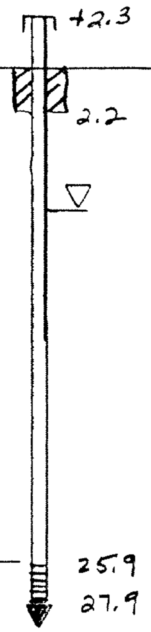
RESOURCE PROTECTION WELL REPORT

START CARD NO. 078213

PROJECT NAME: Watson Lagoon
WELL IDENTIFICATION NO. MW-3
DRILLING METHOD: Driven
DRILLER: Denis Erickson
FIRM: Wash St. Dept. of Ecology
SIGNATURE: Denis R. Erickson
CONSULTING FIRM: NONE
REPRESENTATIVE: NONE

COUNTY: Lewis
LOCATION: SW 1/4 NE 1/4 Sec 5 Twn 13 R 3W
STREET ADDRESS OF WELL: 451 Bunker Hill Rd
WATER LEVEL ELEVATION: 194
GROUND SURFACE ELEVATION: 202
INSTALLED: 5/28/91
DEVELOPED: 5/28/91

Depth	AS-BUILT	WELL DATA	FORMATION DESCRIPTION
	+2.3	Locking Cap	
0	2.2	Bentonite Pellet Seal (Hydrated)	Brown Topsoil Brown organic SILT and Gray clayey SILT, damp to wet
10		1 1/4" Galvanized Steel Casing	
20			
	25.9 27.9	Stainless Steel Well Screen 60 gauze	Sand & Gravel Total Depth 27.9 feet
30			



SCALE: 1" = 10 feet

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RESOURCE PROTECTION WELL REPORT

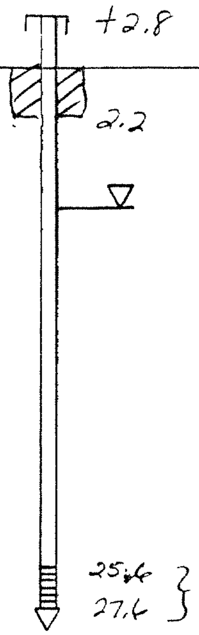
START CARD NO. 078213

PROJECT NAME: Watson Lagoon
WELL IDENTIFICATION NO. MW-4
DRILLING METHOD: Driven
DRILLER: Denis Erickson
FIRM: Washington State Dept of Ecology
SIGNATURE: Denis R. Erickson
CONSULTING FIRM: NONE
REPRESENTATIVE: NONE

COUNTY: Lewis
LOCATION SW ¼ NE ¼ Sec 5 Twn 13 R 3W
STREET ADDRESS OF WELL: 451 Bunker Creek Road

WATER LEVEL ELEVATION: 195
GROUND SURFACE ELEVATION: 205
INSTALLED: 5/29/91
DEVELOPED: 5/29/91

Depth	AS-BUILT	WELL DATA	FORMATION DESCRIPTION
	+2.8	Locking Cap	
0			Ground Surface
			Brown topsoil
	2.2	Bentonite Pellet Seal (Hydrated)	Brown organic SILT and Gray clayey SILT, damp to wet
10		1¼" Galvanized Steel casing	
20			
	25.6 } 27.6	Stainless Steel Screen 60 size	GRAVEL
30			Total Depth 27.6



SCALE: 1" = 10 feet   PAGE 1 OF 1

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APPENDIX B

Table B-1. Water Level Data

Table B-2. Specific Capacity Data

Table B-1. Sheridan Dairy Lagoon, Water Level Data.

Site Name	Date	Top of Casing (MSL, feet)	State Plane Coordinates X	Y	Depth to Water (LSD, feet)	Depth to Water (TOC,feet)	Water Elevation (MSL, feet)
Lagoon	06/18/91	199	0	0	8	NA	191
Lagoon	01/07/92	199	0	0	4	NA	195
Lagoon	04/14/92	199	0	0	9	NA	190
MW1	06/18/91	199.82	1351384	487814	7.5	9.35	190.47
MW1	09/16/91	199.82	1351384	487814	8.3	10.24	189.58
MW1	01/07/92	199.82	1351384	487814	5.3	7.24	192.58
MW1	04/14/92	199.82	1351384	487814	6.9	8.78	191.04
MW2	06/18/91	199.4	1351487	487784	9.3	9.85	189.55
MW2	09/16/91	199.4	1351487	487784	9.4	9.96	189.44
MW2	01/07/92	199.4	1351487	487784	6.5	7.06	192.34
MW2	04/14/92	199.4	1351487	487784	7.8	8.35	191.05
MW3	06/18/91	201.07	1351574	487758	8.5	10.76	190.31
MW3	09/16/91	201.07	1351574	487758	9.4	11.68	189.39
MW3	01/07/92	201.07	1351574	487758	6.8	9.05	192.02
MW3	04/14/92	201.07	1351574	487758	7.9	10.18	190.89
MW4	06/18/91	203.12	1351518	487962	9.1	11.89	191.23
MW4	09/16/91	203.12	1351518	487962	10.5	13.26	189.86
MW4	01/07/92	203.12	1351518	487962	6.6	9.41	193.71
MW4	04/14/92	203.12	1351518	487962	8.4	11.16	191.96

LSD= Land Surface Datum.
TOC= Top of Casing.
MSL= Mean Sea Level.

Table B–2. Specific Capacity Data and Estimated Hydraulic Conductivities, Sheridan Dairy Lagoon

Well ID	Diameter (inches)	Static Water Level (feet)	Test Water Level (feet)	Test Duration (hours)	Discharge Rate (GPM)	Aquifer Thickness (feet)	Open Interval (feet)	Storage Coefficient	Well Loss	Estimated Hydraulic Conductivity (feet/day)
4R01	6	37	49	2	8	3	3	0.001	1.0	44
13C01	6	11.5	26.25	8	50	32	19	0.001	1.0	34
13D01	6	20	26	1	11	7	0.5	0.001	1.0	146
31N01	6	12	32	1	22	7	0.5	0.001	1.0	86
4R01	6	37	49	2	8	3	3	0.0001	1.0	52
13C01	6	11.5	26.25	8	50	32	19	0.0001	1.0	38
13D01	6	20	26	1	11	7	0.5	0.0001	1.0	156
31N01	6	12	32	1	22	7	0.5	0.0001	1.0	92
								Arithmetic Mean=		81
								Geometric Mean=		69