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Effects of Land Application of Dairy Manure and Wastewater on Groundwater Quality

Pre- and Post-Animal Waste Holding Pond Monitoring

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Effects of Land Application of Dairy Manure and Wastewater on Groundwater Quality

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Pre- and Post-Animal Waste Holding Pond Monitoring

by
Denis R. Erickson[1] and Wym Matthews[2]

[1]Washington State Department of Ecology
Environmental Assessments Program
Olympia, Washington

[2]N3
Olympia, Washington

Conducted for the Department of Ecology
Water Quality Program

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Abstract

Groundwater beneath four land application fields of an operating dairy in Thurston County was monitored 16 months before and 44 months after an animal waste holding pond (AWHP) was constructed and used. Prior to the construction of the pond, manure and wastewater were applied to three of the fields year-round. Application methods and loading rates varied for three of the fields over the monitoring period and remained the same for the fourth field. Application methods consisted of tanker truck spreading, stationary and traveling guns, and soil injection.

The monitoring network, consisting of 13 monitoring wells, two water-supply wells, and three surface water stations, was sampled every two months for nitrate+nitrite-N, chloride, total dissolved solids, ammonia-N, total phosphorus, total organic carbon, and fecal coliform bacteria. At the onset of monitoring, groundwater quality beneath three of four fields showed substantial impairment. Groundwater quality beneath the fourth field was less affected. Fall soil nitrate concentrations were determined for some years, and annual nitrogen loading was estimated for each field using literature values. Trend analysis of the water quality results using the Seasonal Kendall test showed significant improvement at the 95% confidence level for portions of the aquifer underlying three of the application fields. Parameters showing improvement were nitrate+nitrite-N, chloride, and total dissolved solids. The AWHP contributed to improving groundwater quality, and potential mechanisms are identified. Other factors contributing to groundwater quality improvement are discussed in the report. Ammonia-N, fecal coliform bacteria, and total phosphorus concentrations in surface water downstream of the dairy showed significant decreases at the 95% confidence level.

Acknowledgements

Phil KauzLoric, Ecology Water Quality Program, requested this project as part of the fiscal year 1994 planning process.

The authors are grateful to the following for their assistance:

- Mr. and Mrs. Case Doelman volunteered to have the monitoring network installed and monitoring conducted on their dairy. Also, Mr. Case Doelman provided valuable information about past and current manure and wastewater management practices at the dairy.

- Phil KauzLoric, John Tooley, Dan Saul, Pam Marti, John Summers, Kirk Sinclair, Charles Pitz, Larry Goldstein, and Chris Evans assisted with sampling.

- Bernard Strong designed and built a sampling backpack that, in addition to carrying field instruments and the sampling pump, conveniently folded into a field table.

- Staff at Manchester Environmental Laboratory who conducted laboratory analyses included Kitty Bickle, Becky Bogaczyk, Sally Cull, Karin Feddersen, Nancy Jensen, Randy Knox, Debbie Lacroix, Michelle Lee, Casey Maggert, Meredith Jones, Greg Perez, Aileen Richmond, and Jim Ross. Will White transported samples to the laboratory.

- Pam Covey, Manchester Environmental Laboratory, maintained and tracked sample flow and reported analytical results.

- The Natural Resource Conservation Service surveyed well elevations.

- Dale Norton, Dave Garland, and Nora Jewett reviewed the report.

- Joan LeTourneau formatted and edited the report.

Introduction

Purpose

Land application of manure and wastewater, an integral part of operating dairies, can adversely affect groundwater quality. To reduce the potential effects of land application on groundwater quality, the Natural Resource Conservation Service developed land application Best Management Practices (BMPs) (SCS, 1993). One BMP used widely in Washington State is to apply dairy wastes at agronomic rates which requires winter storage of manure and wastewater in ponds. Animal Waste Holding Ponds (AWHP) hold manure and wastewater during the winter months so that it can be applied in the summer when vegetative uptake of nutrients is high and the potential for runoff is low.

The effect of this BMP on groundwater quality is not known. The operation of an AWHP requires that the ponds be empty by the fall to maximize winter storage. The warm soil temperatures and moisture additions existing in the fall create conditions favorable to rapid mineralization of organic nitrogen to nitrate. A concern is that the forage crop may have already produced the majority of its annual yield and that late summer/early fall applications of nutrients may exceed the uptake potential of the crop.

The objective of this study was to document groundwater quality before and after an AWHP was constructed at an operating dairy. A dairyman in Thurston County volunteered to participate in this study, and his dairy is herein referred to as the *Thurston County Dairy*. At the onset of the project, the dairy did not have an AWHP, and manure and wastewater were land-applied year-round. A groundwater monitoring network was established at the dairy in June 1995 and sampled every two months for five years. An AWHP was constructed and first used in September 1996. This report describes the monitoring results 16 months before and 44 months after construction of an AWHP.

Nitrate is the primary threat to groundwater quality at dairies. Nitrate is derived from the microbial degradation of ammonia and organic nitrogen in manure and wastewater generated at the dairy and applied to land as a source of nutrients for crops. The crops, in turn, are consumed by the dairy animals. If more nitrate is available than can be used by plants, the excess nitrate, which is highly soluble in water and readily moves through soil, may leach to groundwater. The drinking water standard and the groundwater criterion for nitrate is 10 mg/L in Washington State (Washington State Department of Health, 1994; Washington State Department of Ecology, 1990).

Previous Ecology studies have shown pollutant loading to Beaver Creek downstream of the dairy (Pickett, 1994 and Coots, 1994). Elevated parameters consisted of fecal coliform bacteria, total nitrogen and nitrate+nitrite-N. A secondary purpose of this assessment was to characterize the interaction of the groundwater beneath the dairy with the stream and determine if groundwater from beneath the dairy had a role in stream impairment.

Denis Erickson was the primary investigator for the project and conducted the hydrogeologic investigation and water quality sampling. Wym Matthews, formerly with the Thurston Conservation District, estimated nitrogen loading, determined soil nitrate concentrations, and described crop management and manure application practices.

Site Location and Setting

Thurston County Dairy is located in southwestern Thurston County, Washington about 15 miles south of Olympia (Figure 1). The dairy occupies about 400 acres. Beaver Creek, a perennial stream, divides the dairy into north (240 acres) and south (160 acres) portions. A groundwater monitoring network was established in the north portion of the dairy and is designated as the study area. A total of about 127 acres of study area was used for land application of manure.

For monitoring and discussion purposes, the dairy was subdivided into four land application fields: the Front Field, South Field, West Field, and North Field. The locations of the fields are shown in Figure 1 and the acreage for each field is listed as follows:

Front Field	19.3 acres
South Field	26.6 acres
West Field	39.2 acres
North Field	41.8 acres
Total=	126.9 acres

Beaver Creek bounds the study area on the east, south, and west. The topography is characterized by rolling upland surrounded by undulating to flat-lying floodplain lowlands. The upland occupies the northeastern portion of the study area. The study area relief is about 80 feet.

Thurston County Dairy has been an operating dairy for over 50 years. Mr. Case Doelman, the current owner, purchased the property in 1967 and has operated the dairy to the present. He believes that 20 to 40 years prior to 1967 previous owners operated the dairy with a herd size of 50 animals or less. From 1967 to 1995 herd sizes gradually increased from about 150 to 700 animals. Beginning in 1995, at the onset of this project, and through the monitoring period, the dairy maintained about 900 milking cows and 150 dry cows.

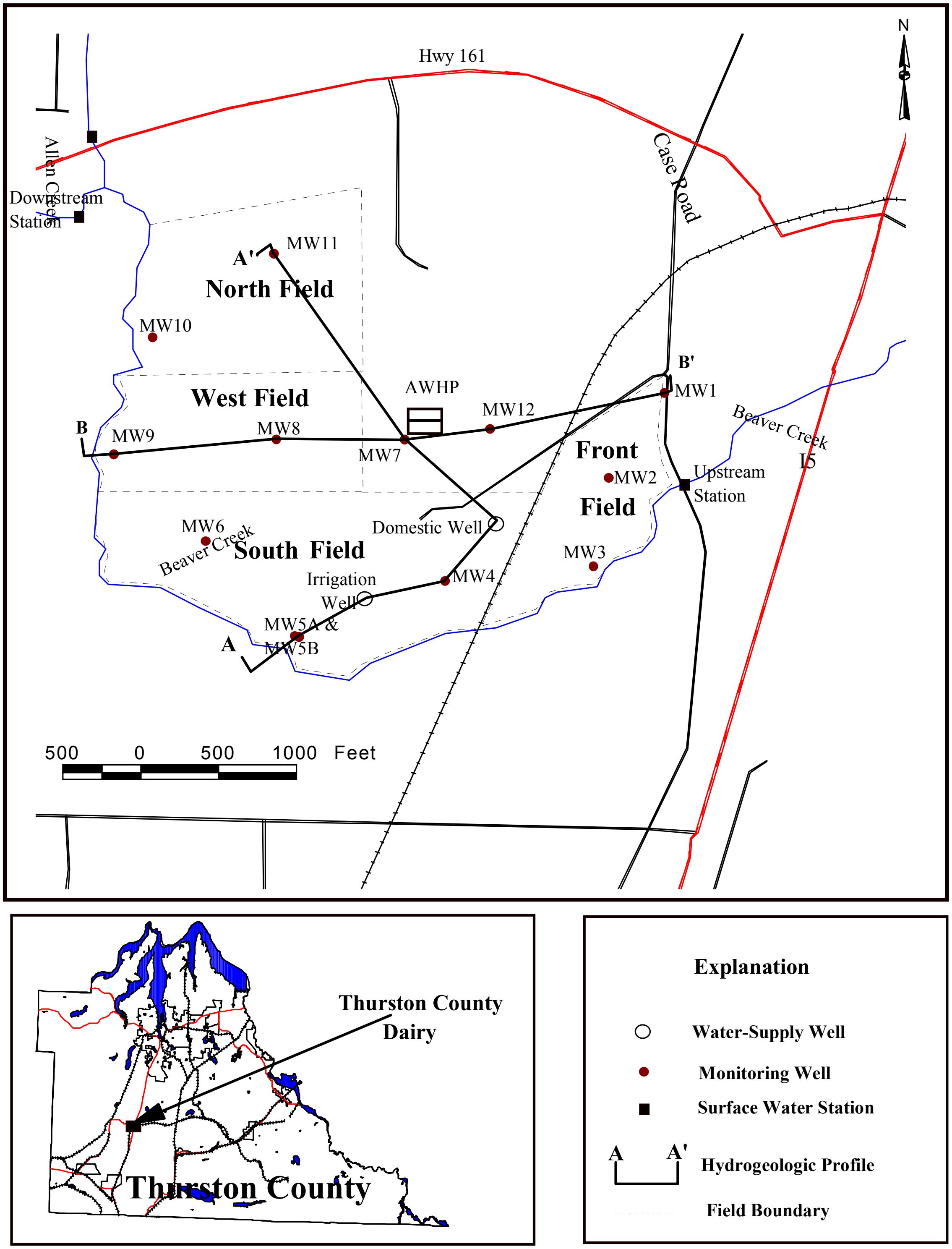

Figure 1. Thurston County Dairy Vicinity and Site Map.

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Methods

Monitoring Network

The monitoring network consisted of 13 monitoring wells, two existing onsite water supply wells, and three surface water monitoring stations. The locations are shown in Figure 1. Well locations were selected to 1) characterize the underlying site hydrostratigraphy, 2) define the rate and direction of groundwater flow, and 3) characterize groundwater quality upgradient of and under land application areas.

Monitoring wells were installed by a licensed well driller and constructed with 2-inch PVC, flush-threaded casing, and commercially fabricated 5-foot, 20-slot screens. Geologist's logs and as-built drawings for each well are shown in Appendix A, and well characteristics are summarized in Table A-1. Monitoring well depths ranged from 14 to 44 feet with an average open interval depth of 23 feet. Twelve monitoring wells were completed in the upper portion of the site's Principal Aquifer (See Site Hydrogeology in this report). One monitoring well, MW5B, was completed near the bottom of the Principal Aquifer to determine the vertical gradient near the stream.

Two onsite water-supply wells, a domestic well and an irrigation well, were included in the monitoring network. Ecology records for each well are shown in Appendix A. Both wells were open hole completions: the domestic well was 34.3 feet deep and the irrigation well was 31 feet deep. The irrigation well, which pumped nearly continuously year-round during the study, provides water for irrigation and process water for the dairy.

Grab samples were obtained from Beaver Creek at upstream and downstream stations during each sampling event. The surface water stations are shown in Figure 1. Allen Creek, which flows into Beaver Creek about 900 feet above the downstream station, was sampled by Ecology for nitrate+nitrite-N, ammonia-N, and fecal coliform bacteria as a part of the Chehalis River Best Management Practices assessment (Sargeant, 1996 and Sargeant, 1998). Most of these data were obtained in the winter associated with rain events. The Allen Creek station was added to the monitoring network for this study beginning December 1998.

The elevations of all wells and surface water stations were surveyed to a common datum using a surveyor's level and rod. The elevations of monitoring wells MW1 through MW11 and the surface water stations were surveyed by the Natural Resource Conservation Service survey team. The onsite water-supply wells and MW12 were surveyed by Ecology. Well elevations were recorded to 0.01 feet and accurate to 0.05 feet as determined by closure.

Hydrologic Testing

Short-term, constant-rate, aquifer tests were conducted at monitoring wells to estimate the hydraulic conductivity of the aquifer material. Aquifer tests consisted of measuring the water level response to pumping at low rates either using peristaltic, centrifugal, or submersible pumps.

Pumping was accurately determined and maintained until the well water level stabilized. Pumping rates ranged from 0.25 to 5.1 gallons per minute. Two to three aquifer tests were conducted at each well at different discharge rates. Drawdown was measured to 0.01 feet using an electric tape. Pumping duration ranged from 0.025 to 1.0 hour. Hydraulic conductivity was estimated from the test results using the method described by Bradbury and Rothschild (1985). This method is an iterative solution to the Theis equation with corrections for partial penetration and hydraulic efficiency. For calculations, the storage coefficient was assumed to be 0.25 and the hydraulic head loss was assumed to be negligible. The results from this testing should be considered approximate.

Sampling Procedures

The monitoring network was sampled every two months over the monitoring period. Standard sampling procedures for the monitoring wells, water-supply wells, and surface water were used and are described in detail in Appendix C. Monitoring wells with the exception of MW7 and MW8 were purged and sampled using a peristaltic pump with dedicated ½-inch polyethylene tubing. MW7 and MW8 were purged and sampled using a decontaminated 2-inch Teflon bailer or a dedicated submersible pump. Monitoring wells were purged a minimum of two well volumes and until pH, specific conductance, and temperature readings stabilized. Water-supply well samples were obtained from taps at the wellheads. Grab samples were obtained from surface water stations by filling the analyte bottles directly.

All well and surface water samples were tested for nitrate+nitrite-N, ammonia, total phosphorus, total persulfate nitrogen (TPN), total dissolved solids (TDS), total organic carbon (TOC), chloride, and fecal coliform bacteria. Sample bottles and preservatives used for each analyte are listed in Table C-1. Test methods and detection limits for the target analytes are listed in Table C-2. Organic nitrogen concentrations were calculated by subtracting ammonia-N and nitrate+nitrite-N concentrations from the TPN results. TPN was discontinued as a target analyte after December 1998, because the results from wells were inconsistent and to reduce analytical costs.

Manure and wastewater samples were obtained from the pumping pit or the waste storage pond after it was used (September 1996) and tested for the same target analytes listed above excluding TDS. Wastewater samples were tested for Total Kjeldahl Nitrogen (TKN).

Fall soil nitrate concentrations were determined for each agricultural field in 1993, 1996, 1998, and 1999. Composite samples were obtained from 0 to 1-foot depth and 1 to 2-foot depths for each field. A minimum of 20 to 25 soil cores were composited to provide a representative sample for each field. Samples were tested at the Thurston Conservation District Laboratory or at Agri-Check Laboratory. Soil nitrate concentrations (mg/kg) were converted to nitrogen loads (pounds N/acre), assuming a soil bulk density of 1.3 grams per cubic centimeter based on properties of typical soils in Thurston County.

Quality Assurance

Quality assurance results for field parameters and target analytes are described in Appendix D and summarized in this section. Based on RPDs (relative percent difference) of duplicate samples, the overall mean sampling and analytical precision for field parameters is within 5% excluding dissolved oxygen. RPDs for dissolved oxygen duplicates averaged 30%; however, concentrations for duplicates were less than 2 mg/L. Overall precision of dissolved oxygen measurements at higher concentrations was likely better than 30%, because RPDs typically decrease as concentrations increase.

For target analytes, quality assurance consisted of field duplicates and laboratory control samples including duplicate blanks, duplicate samples, spiked samples, and check (control) standards. Laboratory results were subject to an internal quality assurance review at Manchester Environmental Laboratory. Most of the target analyte results are considered acceptable for use without qualification. Exceptions are discussed in Appendix D and designated by qualifiers in Tables E-2 through E-11, Appendix E. Based on RPDs of field duplicates, the overall sampling and analytical precision for nitrate+nitrite-N, chloride, total dissolved solids, total organic carbon, and total persulfate nitrogen results are within 10%. The overall mean sampling and analytical precision is within 20% for ammonia-N and total phosphorus and within 28% for fecal coliform bacteria. The target for the overall sampling and analytical precision for field parameters and target analytes for this project was 15% (Erickson, 1995). This target was met for all parameters with the exception of ammonia-N, total phosphorus, fecal coliform bacteria, and dissolved oxygen.

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Hydrogeology

Regional Geology and Hydrogeology

The regional geology is a product of multiple glacial advances and retreats and subsequent re-working by fluvial processes. Deposits from two glacial episodes, the Vashon Stade of the Fraser glaciation and the Pre-Fraser glaciation, are exposed in the study area. In all, five unconsolidated depositional units are identified in the study area and include: modern alluvium, Vashon recessional outwash, Vashon till, Pre-Fraser Undifferentiated Drift, and Pre-Fraser outwash designated the Logan Hill formation (Wallace and Molenaar, 1961; Noble and Wallace, 1966; Walsh et al., 1987).

Alluvial deposits consist of unconsolidated mixtures of silt, sand, and gravel and occupy the floodplain of Beaver Creek. Recessional outwash deposits consist mostly of sand and gravel and underlie the broad lowland in the eastern, southern, and western portions of the study area. Vashon till and Pre-Fraser Undifferentiated Drift cap the upland area in the northeast portion of the dairy. Vashon till consists of a concrete-like mixture of silt, sand, and gravel with a thickness usually ranging from to 3 to 45 feet. Vashon till typically transmits water poorly but can transmit substantial quantities of water to underlying strata when large areas are considered.

The Pre-Fraser Undifferentiated Drift at the study area consists of mixtures of till and outwash. A thin wedge of Pre-Fraser outwash (Logan Hill Formation) crops out north of the upland and typically consists of rusty, cemented gravel. In Thurston County the Logan Hill Formation is not considered a significant aquifer (Noble and Wallace, 1966). Vashon till and the Logan Hill Formation dominate the geology across Beaver Creek south and west of the study area.

Site Hydrogeology

The site hydrogeology is known from the regional geologic and hydrogeologic literature, geologist's logs for the onsite monitoring wells, and onsite water-supply well logs. Four hydrogeologic units are identified beneath the site and are designated as follows: Till and Drift, Principal Aquifer, Aquitard, and Lower Aquifer.

The subsurface relationships of the units are shown in the south-north and west-east hydrogeologic profiles, Figure 2. The properties and occurrence of each unit are discussed below.

1. Till and Drift Unit

The Till and Drift Unit caps the upland in the northeast portion of the study area. The unit consists of silt, sandy silt, silty sand, and sand. The unit was observed at three wells: MW7, MW8, and MW12. The unit lies above the water table and is unsaturated. The thickness ranges from 5.5 to 20.5 feet. Because the unit consists of a substantial portion of fine-grained material,

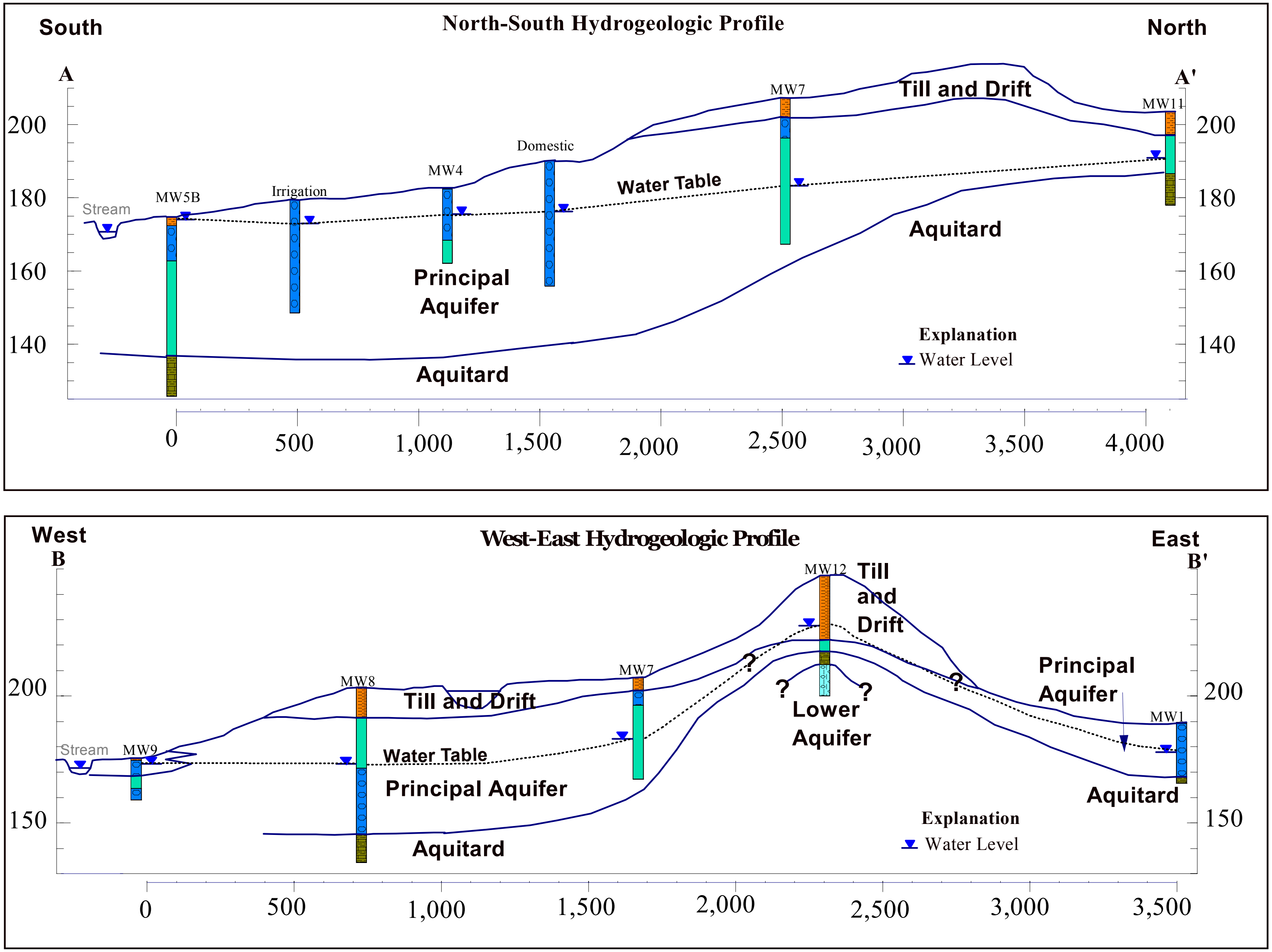

Figure 2. Generalized Hydrogeologic Profiles, Thurston County Dairy.

it probably has a moderate hydraulic conductivity that is lower than the hydraulic conductivity of the underlying aquifer. The Till and Drift Unit limits recharge to the underlying Principal Aquifer by resisting vertical downward flow of infiltrated precipitation.

2. Principal Aquifer

The Principal Aquifer, the uppermost aquifer beneath the study area, consists of saturated silty sand and gravel alluvial deposits as well as Vashon recessional outwash deposits. With the exception of MW 12, all monitoring wells and onsite water-supply wells are completed in the Principal Aquifer. The hydraulic relationship of the water-bearing zones at MW12 and the Principal Aquifer is not clearly defined, as shown in Figure 2. The aquifer ranges from five feet thick beneath the upland to about 35 feet thick near the stream.

Hydrographs for selected monitoring wells across the dairy are shown in Figure 3. The water table fluctuates about six to seven feet seasonally with water levels highest in December and lowest in August. Water level elevations for all water level measurements for the project are shown in Table B-2, Appendix B.

The groundwater flow patterns for the Principal Aquifer in summer and winter are shown in Figure 4. The figure was prepared using water level elevations in wells and surface water stations for August 11-12, 1997 and December 15-16, 1997. The spacing of the hydrographs in Figure 3 indicates that the water levels for these dates are representative of the summer and winter flow pattern. The pumping water level in the irrigation well was included in the analysis because the well pumped nearly continuously during the monitoring period. Water-table contours were determined using a kriging algorithm in Surfer® software package. Arrows on the figure show the approximate groundwater flow direction. In general, groundwater in the Principal Aquifer flows radially from the upland toward the stream. The pattern remains basically the same for winter and summer.

The hydraulic conductivity results for the Principal Aquifer derived from the hydrologic testing of the onsite monitoring wells are shown in Table B-1. Typical of alluvial and glacial outwash deposits, hydraulic conductivity showed substantial spatial variation ranging from 4 to 850 feet per day. The geometric mean, considered the best estimate of central tendency of hydraulic conductivity, for all wells was 51 feet/day.

The groundwater flow velocity of the Principal Aquifer can be estimated using Darcy's Law:

$v = [K_h (dh/dL)] / n_e$

Where,	v=	velocity (feet/day)
	K_h=	saturated horizontal hydraulic conductivity (feet/day)
	(dh/dL)=	hydraulic gradient
	n_e=	effective porosity

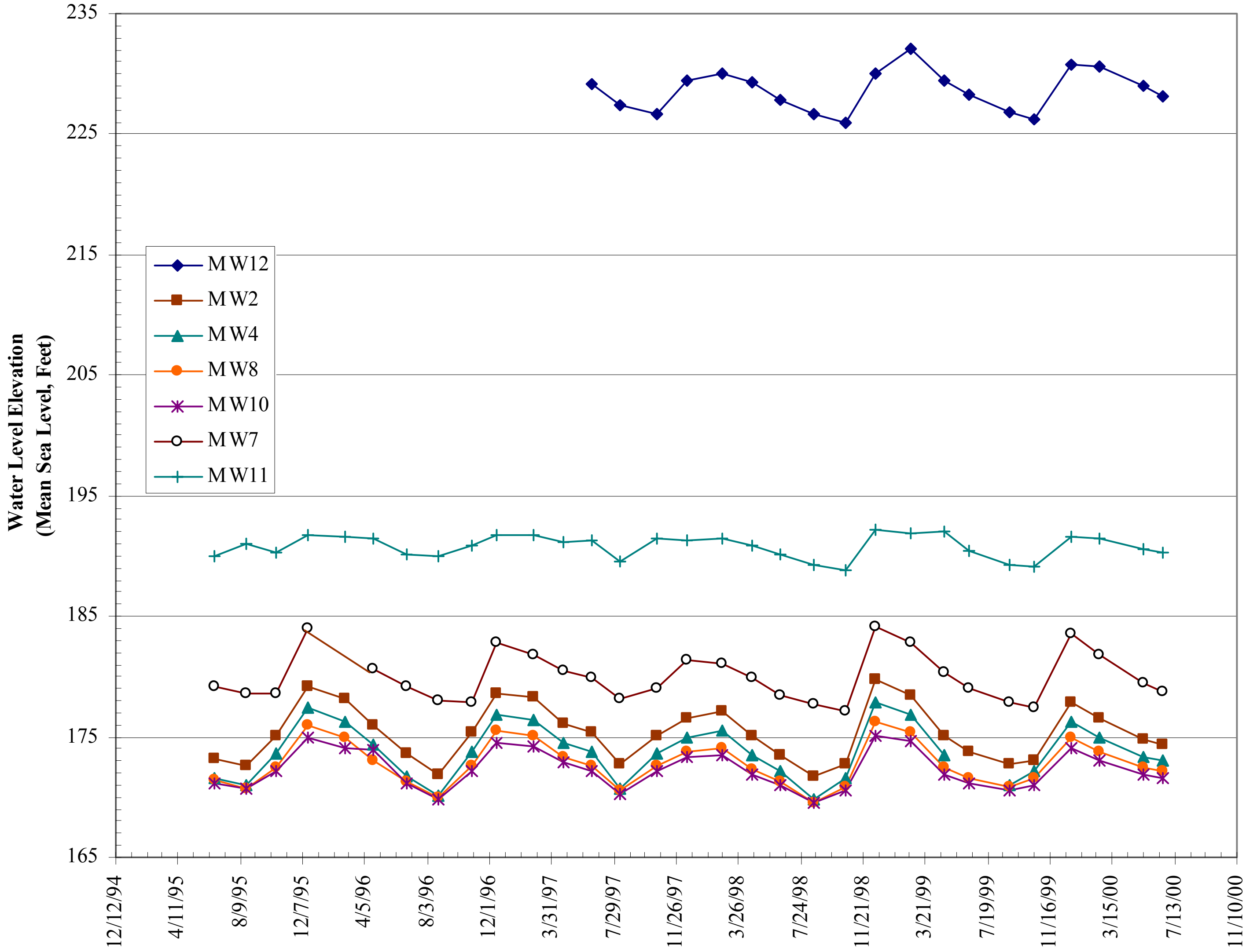

Figure 3. Well Hydrographs, Thurston County Dairy.

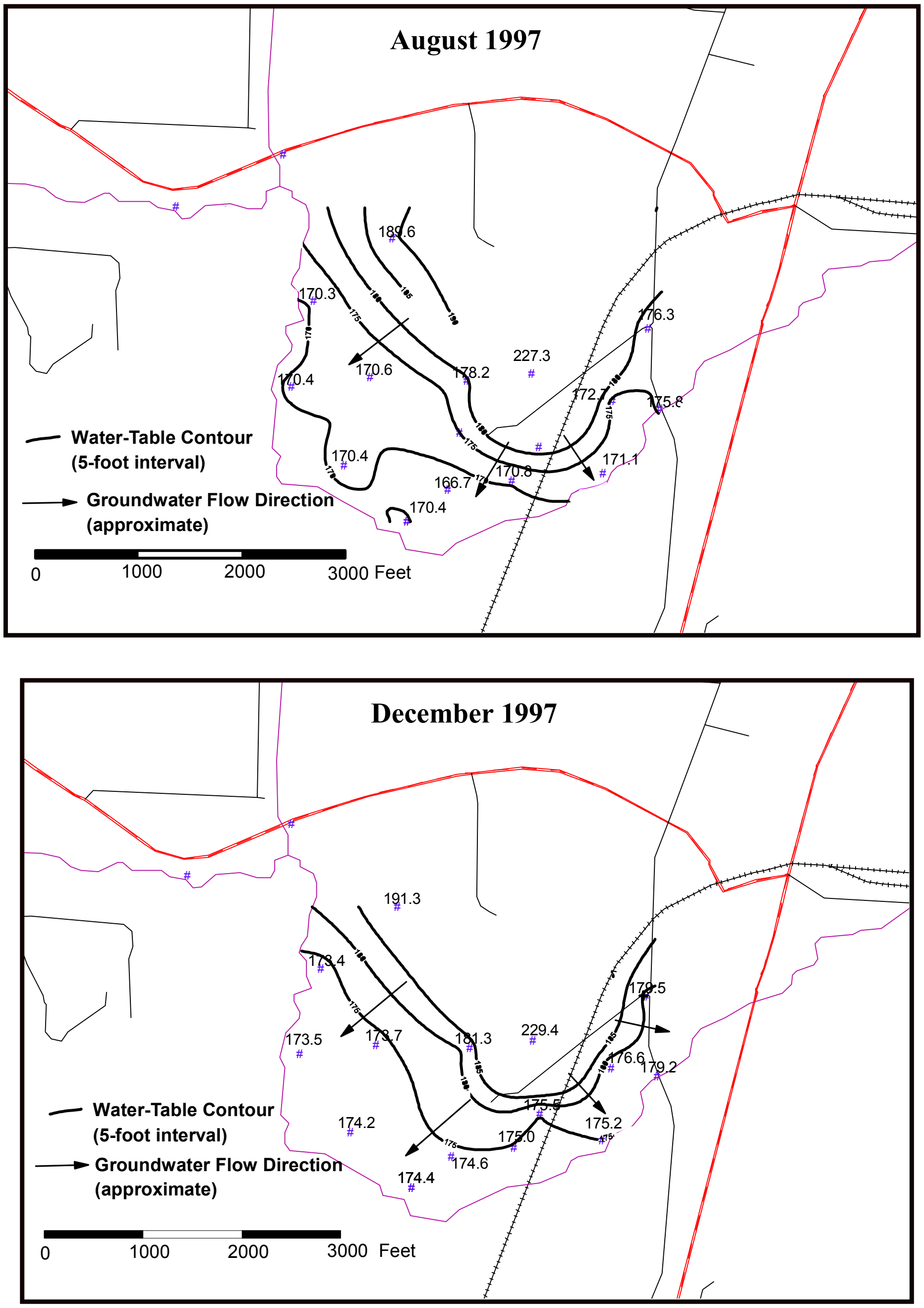

Figure 4. Water-Table Contour Map, Principal Aquifer, August and December 1997, Thurston County Dairy.

The input data and the resulting ranges of groundwater velocities for the Front Field, South Field, and West Field are listed in Table B-3, Appendix B and summarized below in Table 1. Estimated groundwater velocities in the Principal Aquifer ranged from 0.1 to 34 feet per day. The average groundwater flow velocity (K_h= 51 feet/day, dh/dL= 0.0073 and n_e=0.25) for the Principal Aquifer is about 1.5 feet/day.

Table 1. Summary of Estimated Groundwater Flow Velocities (feet/day) at Thurston County Dairy.

	Minimum	Maximum	Mean
Front Field	0.2	8	1
South Field	1	34	5
West Field	0.1	7	1
North Field	1	5	2

3. Aquitard

The Aquitard probably continuously underlies the study area. It consists of clayey silt with organics and was observed in five onsite borings: MW1, MW5B, MW8, MW11, and MW12. Only one boring, MW12, completely penetrated the entire thickness of the Aquitard. At this location the thickness was about five feet. The maximum observed thickness was 11 feet at MW5B. Because the Aquitard consists of the fine-grained particles, it transmits water poorly and acts as a partial hydraulic barrier between the Principal Aquifer and underlying Lower Aquifer. This unit was probably the source of the material used for the liner of the waste storage pond.

4. Lower Aquifer

The Lower Aquifer was observed in one onsite boring MW12. It consisted of greenish-gray silty sand. It is believed to represent the Pre-Fraser outwash deposits designated as the Logan Hill Formation. Regionally the Logan Hill Formation is not a productive aquifer. The unit probably underlies most of the study area but its actual extent is unknown.

Groundwater/Surface Water Interaction

The Principal Aquifer and Beaver Creek readily interact. In most of the study area the Principal Aquifer discharges to the stream. The average flux, q, (discharge per unit area, $q= K_h* (dh/dL)$) for the Principal Aquifer is estimated to be about 0.4 feet/day. Using an aquifer thickness of 30 feet and assuming that the entire aquifer discharges to the stream over a length of 6800 feet, the estimated contribution from groundwater to the stream is about 82,000 cubic feet per day which corresponds to about 0.9 cubic feet per second (cfs). In 1994 the late summer stream discharge rate at the upstream station ranged from 0.4 to 1.3 cfs, and winter discharge rates in 1994-1995 ranged from 5.6 to 113 cfs (Sargeant, 1996). Based on these results, the stream discharge in summer depends substantially on groundwater inputs while the relative contribution of groundwater to stream flow in the winter is much reduced.

Soils

The predominant soil beneath the manure and wastewater application areas consists of Everett very gravelly sandy loam (Pringle, 1990). This soil, which is very deep and excessively drained, developed on terraces and outwash deposits. It has rapid permeability (greater than 20 inches/hour), an effective rooting depth of 60 inches or more, and a low runoff potential. Along the stream the soil consists of Norma Silt Loam, a very deep, poorly drained soil that developed over alluvium. The Norma Silt Loam has a moderately rapid permeability (2.0 to 6.0 inches/hour) and high runoff potential. Cathcart gravelly loam covers the upland areas and has a moderate permeability (0.6 to 2.0 inches/hour) and a moderately low runoff potential.

Recharge

The amount of natural recharge to the Principal Aquifer beneath the dairy was estimated using a water balance approach described by Fenn (1975). With this method recharge is estimated on a monthly basis from precipitation totals by accounting for runoff, soil moisture change, and evapotranspiration. Potential evapotranspiration for these calculations was estimated using the methods described by Thornthwaite and Mather (1957) and Palmer and Havens (1958). Precipitation and temperature data measured at the Olympia Airport station, located six miles northeast of the dairy, were assumed to represent conditions at the dairy. Runoff was assumed to be 10% of the precipitation, and the average site soil was assumed to a have a field capacity of 50 millimeters/meter. The results are summarized in Table 2.

Table 2. Estimated Recharge for Thurston County Dairy 1995 through June 2000.
(Units in inches unless shown otherwise; years are calendar years.)

	1995	1996	1997	1998	1999	2000[1]	Normal
Precipitation	54.9	59.3	64.8	58.0	66.9	28.9	50.6
Runoff	5.5	5.9	6.5	5.8	6.7	2.9	5.1
Potential Evapotranspiration	23.3	22.1	22.7	22.8	22.1	9.2	22.1
Actual Evaporation	16.5	15.8	20.8	12.9	14.4	9.2	16.8
Recharge	32.9	37.5	38.1	39.3	45.8	17.3	28.7
Recharge Flux (feet/day)	0.0075	0.0086	0.0087	0.0090	0.0104	0.0079	0.0066
% Recharge/Precipitation	60	63	59	68	68	60	57

[1]January through June 2000
Water Balance Method from Fenn et al. (1975) using evapotranspiration estimates as described in Thornthwaite and Mather (1957).

Based on these results, between 60 and 68% of the precipitation at the dairy percolated to groundwater over the study period. The normal annual precipitation at the Olympia Airport station is 50.6 inches. For all five years of the monitoring period, the annual precipitation was substantially higher than normal, ranging from 4 to 14 inches above the annual average. Under normal precipitation and temperature conditions using the methods described above, about 57% of the precipitation would recharge groundwater. The higher than normal precipitation resulted in more runoff and increased recharge to groundwater than are typical at the dairy.

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Manure and Wastewater Management

General

In 1995, at the onset of monitoring, the dairy maintained about 900 milking cows and 150 dry cows. Manure and wastewater were applied to fields year-round, and manure storage capacity was small consisting of a below-ground, concrete-lined manure pit. About 20% of the manure generated at the dairy was trucked offsite in the summer, and 60-80% was trucked offsite in the winter. The dairy produces an estimated 235,000 gross pounds of nitrogen per year (SCS, 1992). In the fall of 1995, construction began on a two-cell Animal Waste Holding Pond (AWHP) system and was completed fall 1996. The AWHP system had a manure capacity of 6.9 million gallons and a total gross volume of 7.6 million gallons. The total manure, wash water and contaminated rain water collected by the manure system equaled 15.0 million gallons each year (NRCS, 1998). The number of animals remained essentially constant and the quantity of nutrients generated at the dairy remained essentially the same for pre- and post-AWHP conditions.

The AWHP had little effect on applications to the Front Field but significantly affected the volume, nutrient content, and timing of manure applications to the South, West, and North Fields.

During pre-AWHP conditions an estimated 5.7 million gallons of manure and wastewater were applied annually to the South, West, and North Fields. For post-AWHP conditions 6.8 million gallons of manure and wastewater are estimated to have been applied to the three fields. The increased volume was due to captured precipitation by the AWHP which was estimated to be about 1.1 million gallons when corrected for evapotranspiration losses (37%).

Nutrient content of the manure and wastewater was affected by the AWHP in two ways. First, precipitation that fell on the ponds' surfaces was captured by the AWHP and substantially diluted the nutrient content. Secondly, when manure was applied daily (during pre-AWHP conditions), storage losses of ammonia nitrogen were minimal. After the storage system was constructed, manure was stored from one to six months before application to the fields. Ammonia nitrogen losses due to manure storage are estimated to have increased from 5% for pre-pond conditions to 25% for post-pond conditions (SCS, 1992).

Timing of manure applications to the South, West, and North Fields changed substantially with the use of the AWHP. For pre-AWHP conditions, manure was applied year-round. For post-AWHP conditions, manure was not applied during the non-growing season (November to February). The AWHP was emptied in the fall to maximize pond storage, and manure was stored during the non-growing season. As a result, for post-AWHP conditions, larger amounts of manure and wastewater were applied to the fields over a shorter time in the late fall months.

Field Management Methods and Nitrogen Loading

Manure application methods and nitrogen loading for each of the fields are summarized in Table 3 and discussed below.

Table 3. Manure Application Methods and Estimated Annual Nitrogen Loading for Individual Fields.

Field ID	Area (acres)	Year	Application Method	Volume of Manure Applied (million gal.)	Net Nitrogen Loading (lbs/ac)	Residual Nitrogen Loading (lbs/ac)
Front	19.3	1995-1999	Tanker Truck	0.62	354	83
South and West	65.8	1995	Stationary Gun	3.9	682	541
		1996	Traveling Gun	2.6	454	314
		1997	Traveling Gun	5.4	678	537
		1998	Traveling Gun	4.6	632	441
		1999	Traveling Gun and Injector	4.6	632	492
North	41.8	1995	Stationary Gun	1.8	505	365
		1996	Traveling Gun	1.2	337	196
		1997	Traveling Gun	2.6	507	367
		1998	Traveling Gun	2.2	435	294
		1999	Traveling Gun	2.2	435	294
Total	126.9					

Front Field

For the Front Field, manure loading and timing of manure applications remained the same throughout the study. Manure was applied by a tanker truck which provided nearly 100% coverage and a uniform spread pattern across the field. Manure was applied several times each year. The first manure application occurred in late February or early March and subsequent applications after each harvest of grass silage. Four to five silage harvests were performed each year. The forage yield stayed relatively constant during the trial, averaging 6 tons of dry matter per acre per year.

The volume of manure applied to the Front Field is estimated to be 0.62 million gallons per year based on the number of tanker truck loads used to haul manure. Assuming a nitrogen content of 14 pounds N per 1000 gallons and a 30% application loss of ammonia-N, the net nitrogen loading is estimated to be 354 pounds N/acre. Assuming nitrification from soil provides 125 pounds-N per acre and crop harvesting removes 396 pounds-N per acre annually, the residual nitrogen loading to the Front Field is estimated to be about 83 pounds-N/acre.

South, West, and North Fields

For the South, West, and North Fields manure application methods changed during the monitoring period. Initially manure was applied using a stationary big gun. During post-AWHP conditions, manure was applied to the South and West Fields using a traveling big gun in 1996 through 1998 and a combination of a traveling big gun and traveling injector system in 1999. Manure was applied to the North Field in 1996 through 1999 using a traveling big gun. The change in manure application from the stationary big gun to the traveling big gun resulted in a more uniform manure applications to the fields.

The injector system on the West and South Fields provided additionally more uniform applications and allowed manure to be applied to the edge of the fields. Big gun manure application systems do not have the ability to accurately apply manure to the field edges because of the potential for overspray. However, the change in manure application equipment from a traveling big gun to the injector decreased application ammonia-N losses.

Ammonia-N losses to the atmosphere when manure was applied by spraying range from 20-40% (SCS, 1992) whereas for soil injection ammonia-N losses are estimated to be about 5%. In addition to changes in application equipment, the practice of grazing dry cows during the winter months was discontinued during the post-AWHP period. This change probably reduced nutrient loading slightly. The grass crop on the South, West, and North Fields was removed by grazing.

The South Field, particularly the eastern portion, was used extensively for winter pre-AWHP manure applications. The irregular shape of the South Field made it difficult to operate manure application machinery and to cover the entire field with manure. As a result the eastern portion of the South Field received less manure after the ponds were used, but there is no basis to quantify the difference in loading.

The West Field is closest to the lagoon and has an efficient shape for manure application equipment operation. As a result, the amount of manure applied to the West Field probably increased for the post-AWHP period. The West Field was the only field on the dairy that was reseeded during the study. The field was disked in the fall 1998 and reseeded to renew the forage stand and increase productivity. The soil disturbance during reseeding aerated the soil and mixed manure organic material throughout the depth the soil was worked. The net result is that a large amount of newly mineralized nitrogen may have migrated into the soil profile beyond the shallow root system of the new crop.

The North Field was not used intensively for winter pre-AWHP manure applications because of the rolling topography and distance from the old manure system pumps. After construction of the AWHP, this field was much closer to the manure storage. As a result, manure application may have increased for the North Field for post-AWHP conditions, but there is no basis to quantify the change.

Annual manure applications and nitrogen loading to the South, West, and North Fields were calculated using a mass balance spreadsheet that accounts for changes in storage, ammonia-N losses during storage and application, dilution from precipitation, and nitrogen removal due to cropping and grazing. Values were calculated on a monthly basis and summed to determine annual quantities. Initially, the volume of manure and wastewater applied to each of the fields was estimated for post-BMP conditions based on the total amount of manure available for onsite application, the area of the field, and the observed relative use of the fields for land application. The estimated post-BMP application volumes for each field are listed as follows:

- South Field 1.7 million gallons
- West Field 2.9 million gallons
- North Field 2.2 million gallons

For pre-BMP conditions these volumes were reduced based on the volume of precipitation captured by ponds corrected for potential evapotranspiration losses (37%). The spreadsheets are shown in Tables F-1 and F-2 in Appendix F. The assumptions for the calculations which are derived from SCS (1992) are listed as follows:

- Nitrogen content of unstored manure = 14 pounds/1000gallons
- Nitrogen content of stored manure = 10 pounds/1000 gallons (Due to storage losses of ammonia-N and dilution from precipitation on ponds.)
- Spray and tanker truck ammonia-N application losses = 30 %
- Injection ammonia-N application losses = 5%
- 50% of the manure applied to the West and South Fields was injected in 1998 and 1999
- Mineralization of nitrogen from soil = 125 pounds N/acre/year
- Nitrogen removal due to grazing = (2/3)x396 pounds N/acre

Based on this method and assumptions, the estimated residual nitrogen loading (nitrogen application exceeding uptake and removal) for the South and West Fields ranged from 314 to 541 pounds N/acre with a mean of 465. The residual nitrogen loading to the North Field is estimated to range from 196 to 367 pounds N/acre with a mean of 303 pounds N/acre.

Soil Nitrate Concentrations

Fall soil nitrate concentrations are used to estimate the relative risk of nitrate leaching to groundwater for the following winter and are used to adjust subsequent nitrogen management practices. Fall soil nitrate concentrations for the upper two feet of each field are listed in Table 4.

A relative scale for nitrate leaching from Sullivan (1994) is shown below Table 4. Soil nitrate concentrations ranged from 52 to 270 pounds N/acre over the study period. Levels in the Front Field were high at the onset of the study and decreased to medium levels at the end of the study. Generally, fall nitrate concentrations in the other three fields increased over the study period and were at very high levels.

Table 4. Fall Soil Nitrate Levels and Relative Leaching Risks.
(Units= pounds N/acre in the top two feet.)

	Front Field	South Field	West Field	North Field
1993	101	112	105	63
1996	96	128	202	136
1998	91	175	87.5	108.5
1999	52.5	303	269.5	203

Soil Nitrate Relative Risk Scale

Soil Nitrate Concentration (pounds N/acre)	Relative Risk
0 to 40	Low
40 to 80	Medium
80 to 160	High
>160	Very High

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Water Quality Results

Field Parameters

Field parameters results (specific conductance, temperature, pH, and dissolved oxygen) for all sampling events are listed in Table E-1, Appendix E and are summarized in Table 5. Specific conductance for groundwater ranged from 65 to greater than 1000 micromhos/cm with a mean of 320 micromhos/cm. Specific conductance of the stream was typically much lower than groundwater, ranging from 44 to 167 micromhos/cm with a mean of 90 micromhos/cm. Groundwater temperatures ranged from 7.9 to 15.2°C with a mean of 11.2°C. Stream temperatures ranged from 4.3 to 20.6 °C with a mean of 11.9°C. The pH of groundwater ranged from 4.2 to 7.1 Standard Units with a mean of 5.8. Dissolved oxygen for groundwater typically was lower than surface water, ranging from 0.0 to 8.7 mg/L with a mean of 3.2 mg/L. Surface water dissolved oxygen ranged from 5.1 to 12.2 mg/L with a mean of 7.5 mg/L.

Target Analytes

Results for all target analytes are listed in Tables E-2 through E-11, Appendix E and are summarized in Table E-12. Results for nitrate+nitrite-N, chloride, total dissolved solids, and total phosphorus for wells are summarized in Table 6. Nitrate+nitrite-N concentrations in groundwater were highly variable, ranging from less than the detection limit (0.01mg/L) to 141 mg/L. The overall mean nitrate+nitrite-N concentration for all groundwater samples was 14.4 mg/L. Chloride concentrations ranged from 2 to 140 mg/L with a mean of 21.4 mg/L. Total dissolved solids concentrations ranged from 36 to 1240 mg/L with a mean of 210 mg/L. Total phosphorus concentrations in groundwater ranged from less than the detection limit (0.01 mg/L) to 0.68 mg/L with a mean value of 0.06 mg/L. Fecal coliform bacteria (Table E-9) were detected infrequently in groundwater samples. Most detections occurred in the months immediately following well installation which suggests their occurrence was the result of surface contamination during well installation.

The water quality results for surface water stations are listed in Table E-10, Appendix E, and are summarized in Table 7. Concentrations for most target analytes including nitrate+nitrite-N, TDS, organic-N, total ammonia-N, TOC, and fecal coliform bacteria were higher at the downstream station than the upstream station. Chloride was an exception. Upstream chloride concentrations were typically higher than the downstream station, especially in summer and fall. Because chloride is stable in water and does not degrade, a dilution mechanism is required to account for the concentration decrease.

Effluent results are listed in Table E-11, Appendix E. The nitrogen content (Total Kjeldahl Nitrogen, TKN)) of wastewater samples ranged from 415 and 3085 mg/L and averaged 1157 mg/L. Most of the nitrogen in wastewater occurred as ammonia-N (58%) and organic nitrogen (42%). Chloride concentrations ranged from 143 to 791 mg/L and averaged 351 mg/L. TOC and total phosphorus averaged 3955 mg/L and 137 mg/L, respectively. Fecal coliform bacteria concentrations averaged 230,000 CFUs/100mL.

Table 5. Summary of Field Parameter Results.

	Specific Conductance (micromhos/cm)			Temperature (°C)			pH (Std. Units)			Dissolved Oxygen (mg/L)		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Front Field												
MW1	115	404	189	7.9	12.6	10.4	5.49	6.48	6.10	0.8	1.7	1.2
MW2	65	168	101	8.8	12.2	10.5	4.99	6.23	5.83	1.4	6.8	3.2
MW3	155	220	190	8.8	14.0	10.9	5.66	6.71	6.20	0.2	2.2	1.2
South Field												
Domestic	86	158	118	9.2	14.0	10.8	4.88	6.48	5.80	3.9	5.8	4.5
Irrigation	112	218	163	10.1	14.8	11.7	5.20	6.63	5.87	3.0	7.0	5.1
MW4	181	840	354	8.7	13.0	10.8	4.84	6.04	5.51	6.1	8.6	6.9
MW5A	295	550	405	9.1	14.7	11.8	5.00	6.46	5.68	0.6	1.4	1.0
MW5B	198	335	251	9.7	13.2	11.5	5.51	7.14	6.31	0.0	1.4	0.7
MW6	190	455	321	9.6	13.1	11.4	5.48	6.78	5.96	0.8	1.4	1.2
West Field												
MW12	122	178	371	10.0	13.7	11.4	5.34	6.55	5.76	3.2	5.6	4.3
MW7	218	620	346	9.0	15.2	11.1	4.20	6.30	5.17	1.1	1.9	1.6
MW8	345	725	532	9.8	13.7	11.6	4.32	6.42	5.70	1.6	4.9	3.5
MW9	239	620	378	8.5	13.9	11.0	4.85	6.55	5.59	2.0	4.2	3.3
North Field												
MW10	420	920	652	9.0	13.4	11.4	4.68	6.17	5.47	1.8	5.5	4.1
MW11	250	>1000	426	8.3	13.5	11.0	4.41	6.16	5.41	4.4	8.7	6.5
Groundwater	65	>1000	320	7.9	15.2	11.2	4.20	7.14	5.76	0.0	8.7	3.2
Surface Water												
Upstream	44	167	95	4.3	19.1	11.6	5.30	8.78	6.73	6.1	12.2	7.7
Allen Creek	60	91	79	5.0	18.3	12.1	5.05	7.19	6.33	5.1	11.3	7.5
Downstream	52	151	96	4.6	20.6	11.9	5.20	8.51	6.55	5.7	11.6	7.3
Overall	44	167	90	4.3	20.6	11.9	5.05	8.78	6.53	5.1	12.2	7.5

Table 6. Summary of Selected Target Analyte Results for Wells.
(Units =mg/L.)

	Nitrate+Nitrite-N			Chloride			Total Dissolved Solids			Total Phosphorus		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Front Field												
MW1	0.01U	17.2	1.10	2.02	11.3	4.1	74	295	135	0.04	0.68	0.20
MW2	0.15	8.7	2.1	2.18	9.62	3.99	36	133	74	0.01U	0.09	0.03
MW3	0.01U	0.18	0.02	10.8	17.7	13.8	122	159	142	0.01U	0.27	0.11
South Field												
Shallow												
MW12	0.01U	6.9	4.9	7.38	10.2	8.36	112	164	129	0.02	0.10	0.06
MW4	3.1	82	22.6	3.97	49.2	17.3	81	520	238	0.01U	0.10	0.02
MW5A	11.2	31.2	21.3	15.5	70.3	31.9	217	366	280	0.01U	0.11	0.03
MW6	5.28	26.1	14.2	11,8	51.4	26.6	154	321	227	0.01U	0.18	0.05
Deep												
Domestic	2.08	6.43	3.58	3.25	11.7	5.76	45	224	88	0.01U	0.43	0.05
Irrigation	1.94	13.1	6.71	3.85	21.8	8.87	73	168	115	0.01U	0.38	0.04
MW5B	0.01U	4.14	1.49	5.79	36.8	20.5	140	226	169	0.01U	0.16	0.04
West Field												
MW12	0.01U	6.9	4.9	7.38	10.2	8.36	112	164	129	0.02	0.10	0.06
MW7	2.92	32.0	14.5	13.9	88.2	35.9	106	401	224	0.01U	0.09	0.03
MW8	17.6	72.0	31.1	24.1	67.4	40.4	73	524	360	0.01U	0.22	0.08
MW9	13.2	52.0	25.4	6.48	39.4	21.6	152	450	268	0.01U	0.11	0.03
North Field												
MW11	4.79	141	27.9	11.2	140	41.9	168	1240	316	0.01U	0.08	0.02
MW10	20.8	80.0	47.3	29.6	106	53.3	276	707	465	0.01U	0.15	0.03
Overall	0.01U	141	14.3	2.02	140	21.4	36	1240	210	0.01U	0.68	0.06

U= Analyte not detected above listed value.

Table 7. Summary of Surface Water Quality Results.
(Units in mg/L unless shown otherwise.)

Parameter		Upstream Station		Downstream Station		Allen Creek	
Nitrate+Nitrite-N							
	Minimum=	0.10		0.37		0.08	
	Maximum=	0.73		2.50		0.38	
	Mean=	0.24		1.04		0.26	
Chloride							
	Minimum=	1.6		1.2		3.0	
	Maximum=	27.2		11.5		4.4	
	Mean=	9.5		5.9		3.5	
Total Dissolved Solids							
	Minimum=	44		44		65	
	Maximum=	124		110		87	
	Mean=	75		79		76	
Total Phosphorus							
	Minimum=	0.01		0.01	U	0.04	
	Maximum=	0.45		0.35		0.08	
	Mean=	0.07		0.10		0.06	
Total Persulfate Nitrogen							
	Minimum=	0.35		0.78		0.46	
	Maximum=	0.98		3.85		0.85	
	Mean=	0.51		1.54		0.64	
Ammonia-N							
	Minimum=	0.01	U	0.01	U	0.01	U
	Maximum=	0.1		0.6		0.06	
	Mean=	NA		*0.08		0.03	
Total Organic Nitrogen							
	Minimum=	0.10		0.02		0.28	
	Maximum=	0.61		1.29		0.45	
	Mean=	0.26		0.42		0.36	
Fecal Coliform Bacteria	(CFU/100mL)						
	Minimum=	4		12		2	
	Maximum=	350		32000		180	
	Geometric Mean=	36		165		33	
Total Organic Carbon							
	Minimum=	1.5		3.1		3.4	
	Maximum=	9.2		10.5		9.5	
	Mean=	4.4		5.4		5.2	

U= Analyte was not detected at or above the reported result.
*Mean calculated by setting non-detect results to 0.005mg/L.
CFU= Colony forming unit.

Discussion

Water Quality

The water quality results for each field are discussed below.

Front Field

Time-series plots of nitrate+nitrite-N, chloride, TDS, and total phosphorus results for the Front Field are shown in Figure 5. Of the three monitoring wells in the Front Field, MW2 is most representative of groundwater quality beneath the field. MW1 was intended to represent ambient conditions and was likely affected by the abandoned gravel pit north of the well. MW3 was probably affected by the creek, especially during times of high stream flow.

Of the four fields, groundwater quality beneath the Front Field was least affected by agricultural activities at the onset of monitoring. Manure management practices were unchanged over the monitoring period. Residual nitrogen loading averaged about 83 pounds N/acre. Fall soil nitrate concentrations ranged from 52 to 101 pounds N/acre.

Nitrate+nitrite-N concentrations, although variable from one sampling event to another, showed a cyclic seasonal pattern over the monitoring period with no apparent trend. Nitrate+nitrite-N concentrations peaked consistently each year in the winter at about 7 to 8 mg/L. By spring concentrations typically decreased to less than 1 mg/L and remained at this level until the following winter. Chloride and TDS concentrations showed a similar pattern. Total phosphorus concentrations showed no consistent seasonal variation and typically were low, averaging 0.03 mg/L.

South Field - Shallow Wells

The shallow monitoring network in the South Field consisted of three monitoring wells: MW4, MW5A, and MW6. MW12 located north of the field represents ambient water quality. MW4 and MW6 represent the quality of shallow groundwater beneath the South Field. MW5A represents the quality of shallow groundwater flowing from the dairy to Beaver Creek. Time-series plots for nitrate+nitrite-N, chloride, TDS, and total phosphorus results are shown in Figure 6.

Nitrate+nitrite-N concentrations varied widely. At MW4 sharp winter peaks occurred each year with a maximum concentration of over 80 mg/L. MW6 and MW5A showed broader, more subdued high levels in the winter. No trend is apparent in MW4 and MW5A but concentrations at MW6 appear to have declined. Chloride concentrations decreased since monitoring began. Initial chloride concentrations ranged between 30 and 70 mg/L and decreased to between 10 to 30 mg/L at the end of the monitoring period. Chloride and TDS concentrations at MW4 showed substantial peaks after soil injection of manure and wastewater in the winter of 1999.

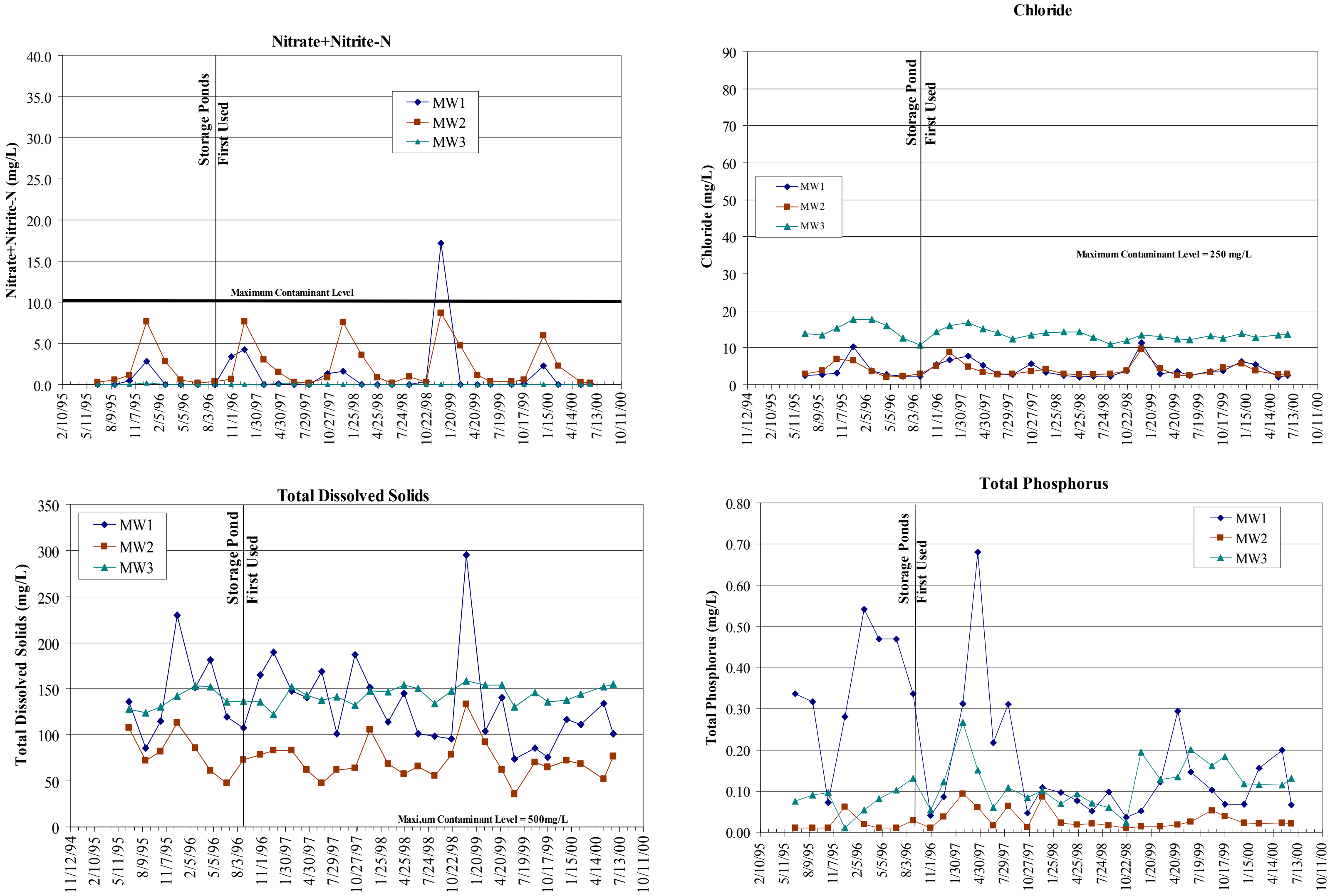


Figure 5. Front Field Water Quality Results.

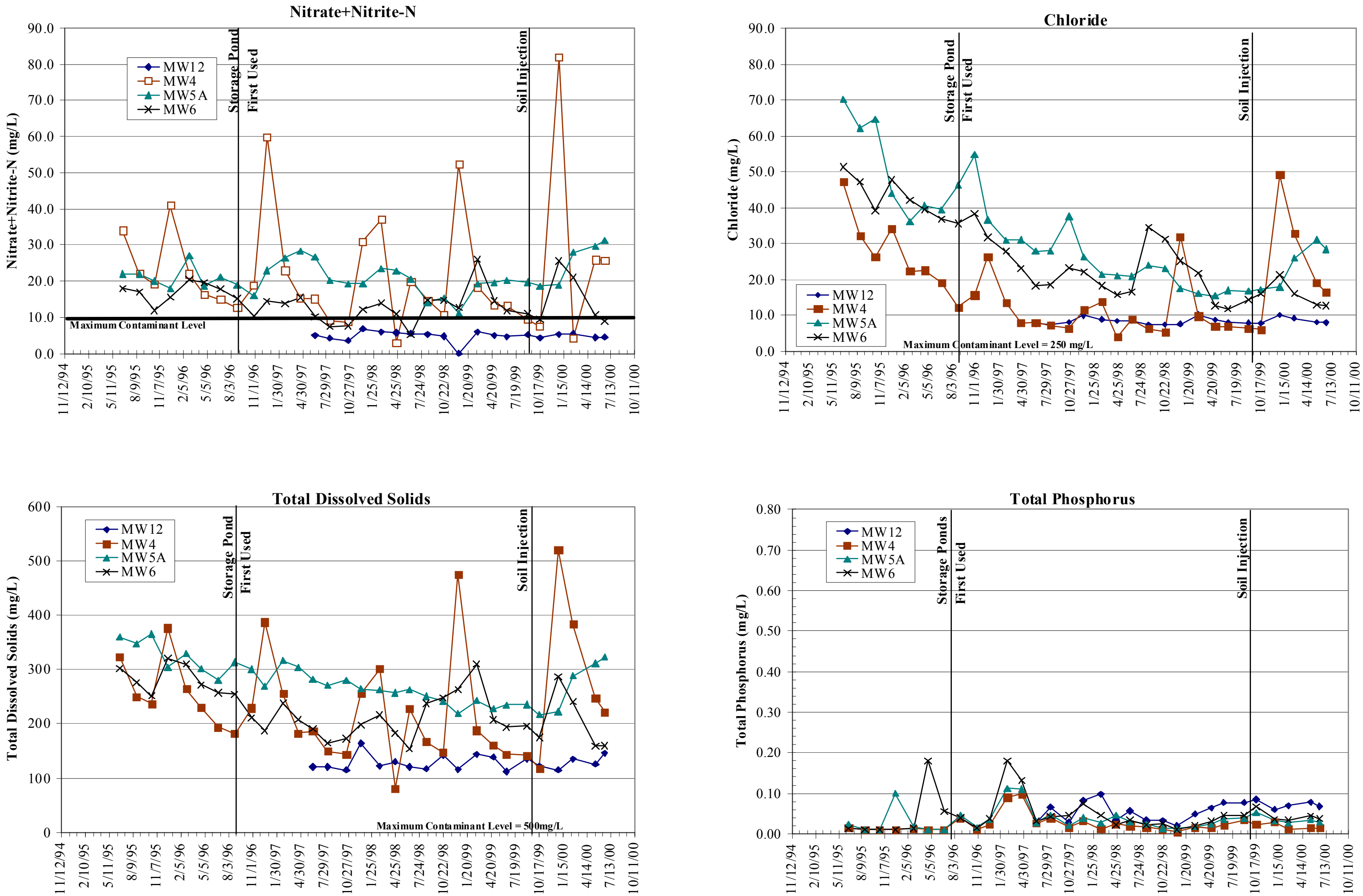


Figure 6. South Field, Shallow Wells, Water Quality Results.

TDS concentrations ranged from 220 to 350 mg/L at the beginning of monitoring and ranged from 180 to 270 mg/L at the end of the monitoring period. Chloride and TDS concentrations decreased both before and after the waste storage pond was constructed. Total phosphorus and TOC concentrations, although variable, show no apparent trend.

South Field - Deep Wells

The deep monitoring network in the South Field consisted of three wells: MW5B, the domestic water-supply well, and the irrigation well. Time-series plots of nitrate+nitrite-N, chloride, and TDS results are shown in Figure 7. Most of the total phosphorus results were non-detections and are not included in the figure.

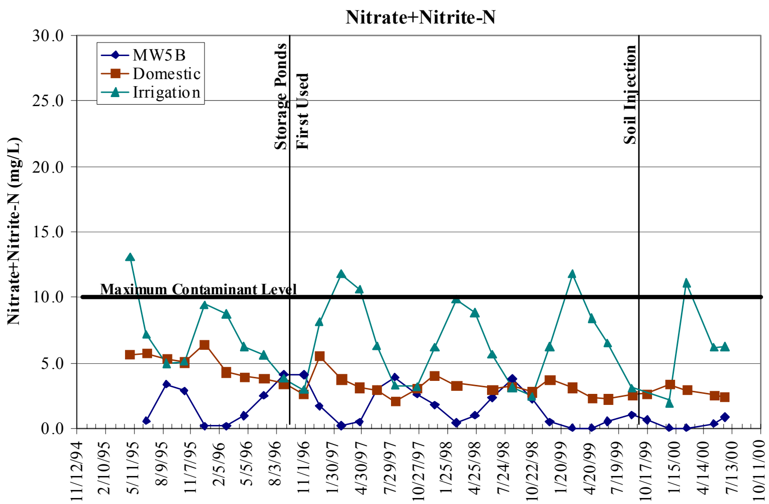
Nitrate+nitrite-N concentrations in the irrigation well varied seasonally with highs in February and lows in August. Concentrations, however, show no apparent trend. In the domestic well nitrate+nitrite-N concentrations appear to have declined both before and after the AWHP was constructed. Nitrate+nitrite-N concentrations in MW5B varied seasonally with highs in the summer and lows in the winter, the opposite pattern seen at the irrigation well. Nitrate+nitrite-N concentrations at MW5B appear to have declined over the last two years of the monitoring period. Chloride and TDS concentrations in all three wells declined over the monitoring period, before and after the AWHP was constructed.

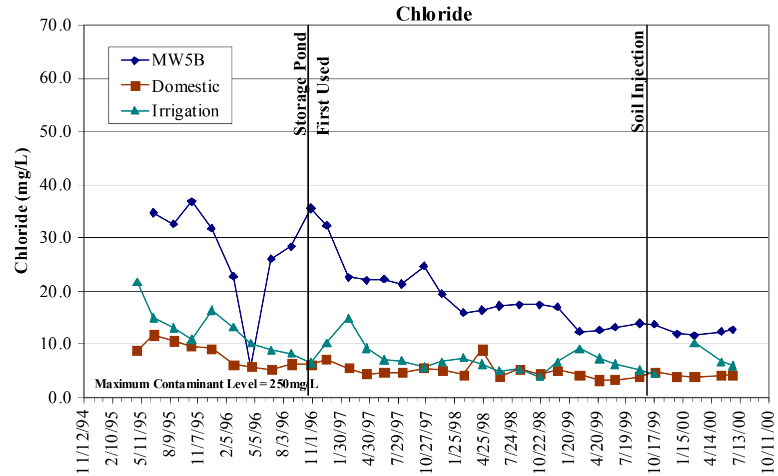
West Field

The monitoring network in the West Field consisted of three monitoring wells: MW7, MW8, and MW9. MW7 is downgradient of the AWHP. MW8 represents water quality beneath the West Field. MW9 represents the quality of groundwater flowing from beneath the West Field to the wetland and Beaver Creek. MW12 represents ambient water quality.

Time-series plots of results for nitrate+nitrite-N, chloride, TDS, and total phosphorus are shown in Figure 8. Nitrate+nitrite-N, chloride, and TDS concentrations beneath the West Field were elevated relative to ambient levels. Nitrate+nitrite-N concentrations show substantial variation and no apparent trend. Chloride concentrations at MW8 and MW9 declined initially but stabilized over the last two years of monitoring. Total phosphorus levels declined in MW8 but remained essentially the same in MW7 and MW9. Over the last two years of monitoring, ambient levels of total phosphorus (MW12) have been higher than West Field wells for most sampling events.

The results at MW7, downgradient of the AWHP, show distinctive trends. Nitrate+nitrite-N, chloride, and TDS concentrations declined initially, even before the AWHP was constructed, but increased over the last two years of monitoring. The increase may be the result of leakage from the AWHP. However, MW7 is also located along an access route which is subject to ponding of manure and wastewater.





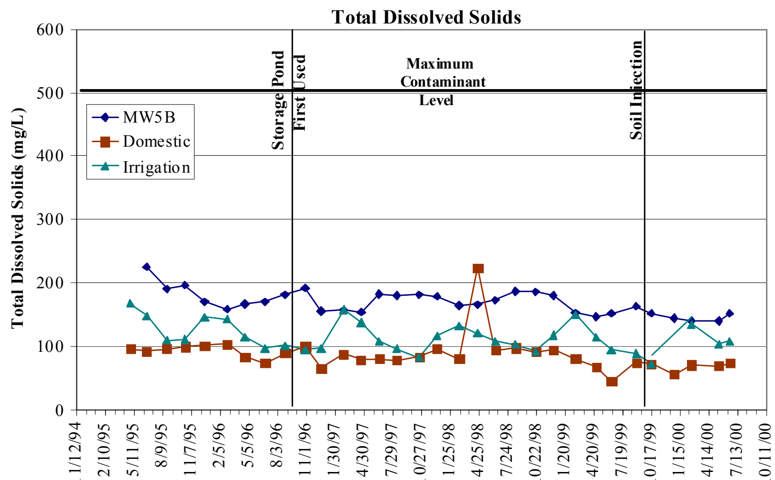


Figure 7. South Field, Deep Wells, Water Quality Results.

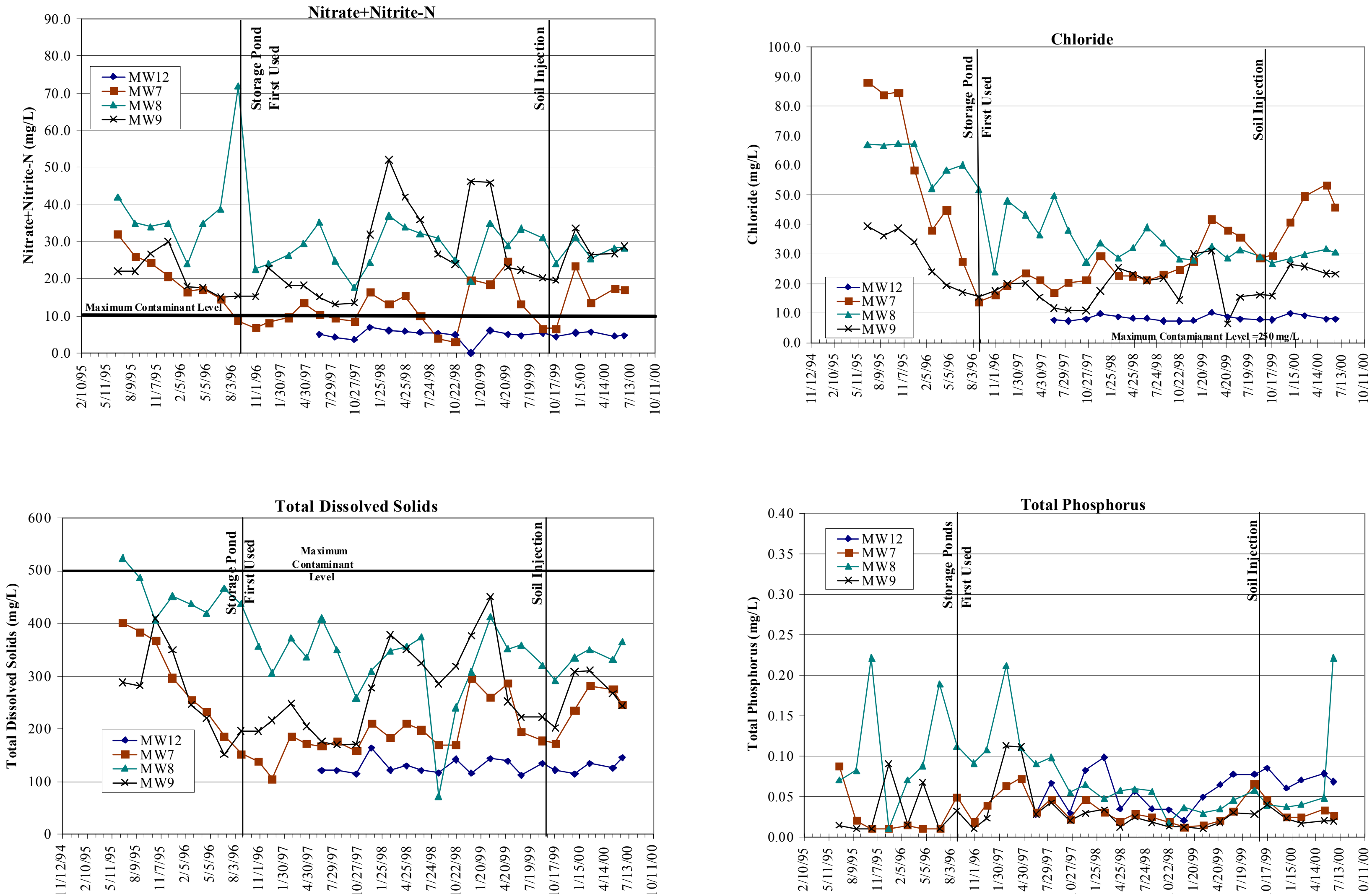


Figure 8. West Field Water Quality Results.

North Field

The monitoring network at the North Field consisted of two wells: MW10 and MW11. MW10 represents quality of groundwater flowing from beneath the North Field and entering the wetland and Beaver Creek. MW11 is representative of the water quality beneath North Field. The aquifer at MW11 is only about 13-feet deep and four-feet thick. As a result the water quality observed at MW11 is very sensitive to surface activities.

Time-series plots for nitrate+nitrite-N, chloride, TDS, and total phosphorus results for North Field wells are shown in Figure 9. At MW10, chloride and TDS concentrations clearly declined over the monitoring period. Nitrate+nitrite-N concentrations at MW10 show substantial variation with no apparent trend. At MW11 nitrate+nitrite-N, chloride, and TDS concentrations declined initially but, despite large concentration spikes in the winter, the overall concentrations appear to have stabilized over the last three years.

Surface Water

Time-series plots for nitrate+nitrite-N, chloride, ammonia-N and fecal coliform bacteria (log transformed) for surface water stations are shown in Figure 10. Pre-AWHP nitrate+nitrite-N, ammonia-N, and fecal coliform bacteria concentrations were higher in the downstream station than the upstream station. Nitrate+nitrite-N and fecal coliform results obtained for the Chehalis River Best Management Practices assessment are included in the figures (Sargeant, 1996; Sargeant,1998) Nitrate+nitrite-N concentrations exhibit a cyclic seasonal pattern with highs in the late summer.

Ammonia-N and fecal coliform bacteria concentrations decreased at the downstream station after the pond was constructed. Chloride results reveal a different pattern compared to other parameters; upstream chloride concentrations typically were higher than the downstream station, especially in summer and fall. Because chloride is stable in water and does not readily degrade, a dilution process is required to account for the concentration decrease.

Nitrogen loading to Beaver Creek via the groundwater pathway is estimated using the mean nitrate+nitrite-N concentrations for wells MW5A, MW9, and MW10 (31.3 mg/L). Assuming these wells are representative of the water quality of the upper 15 feet of the aquifer and using a groundwater flux rate of 0.4 feet/day along a 6800 foot-long reach, the nitrogen loading from the dairy is about 80 pounds N/day.

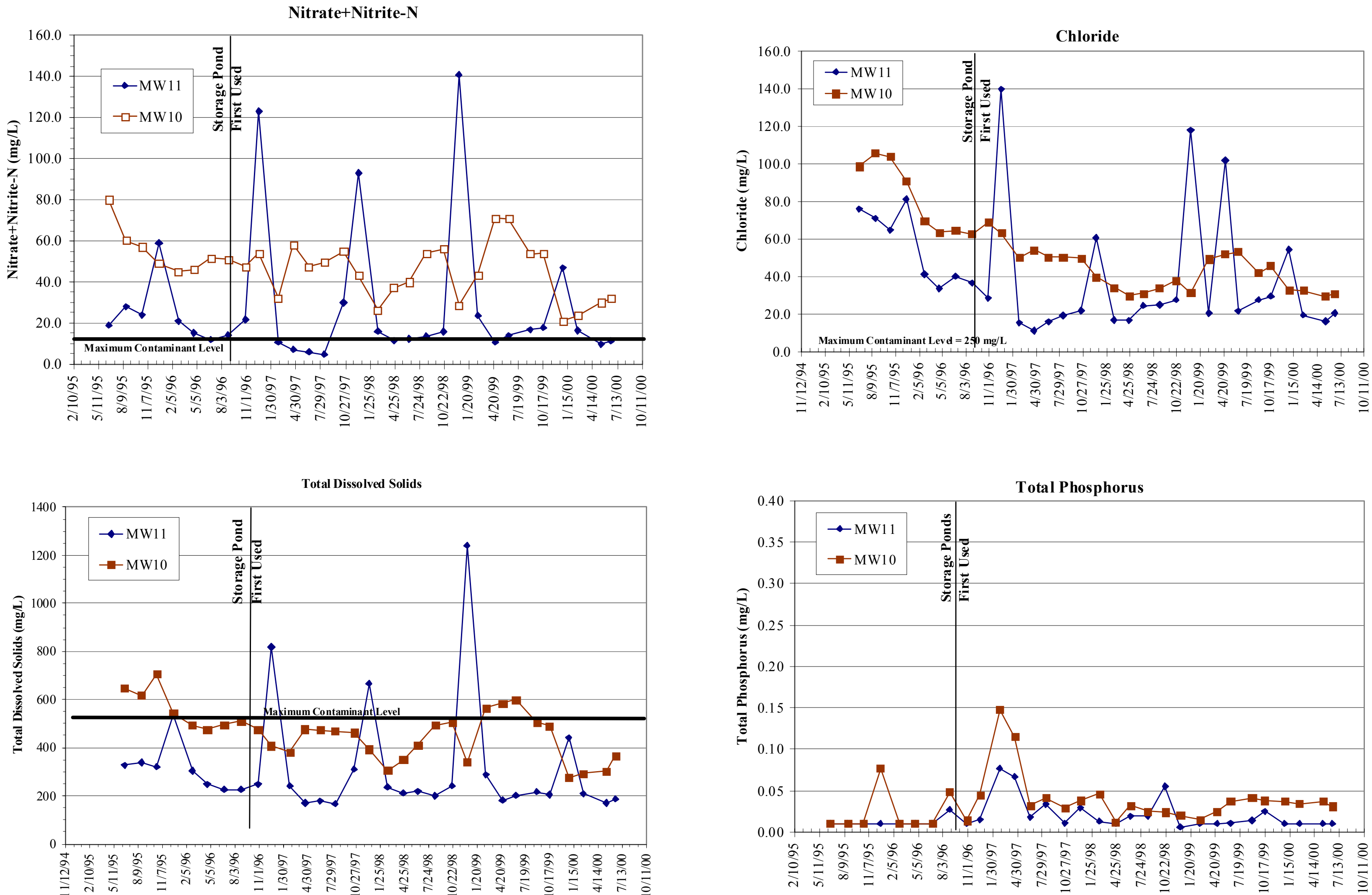


Figure 9. North Field Water Quality Results.

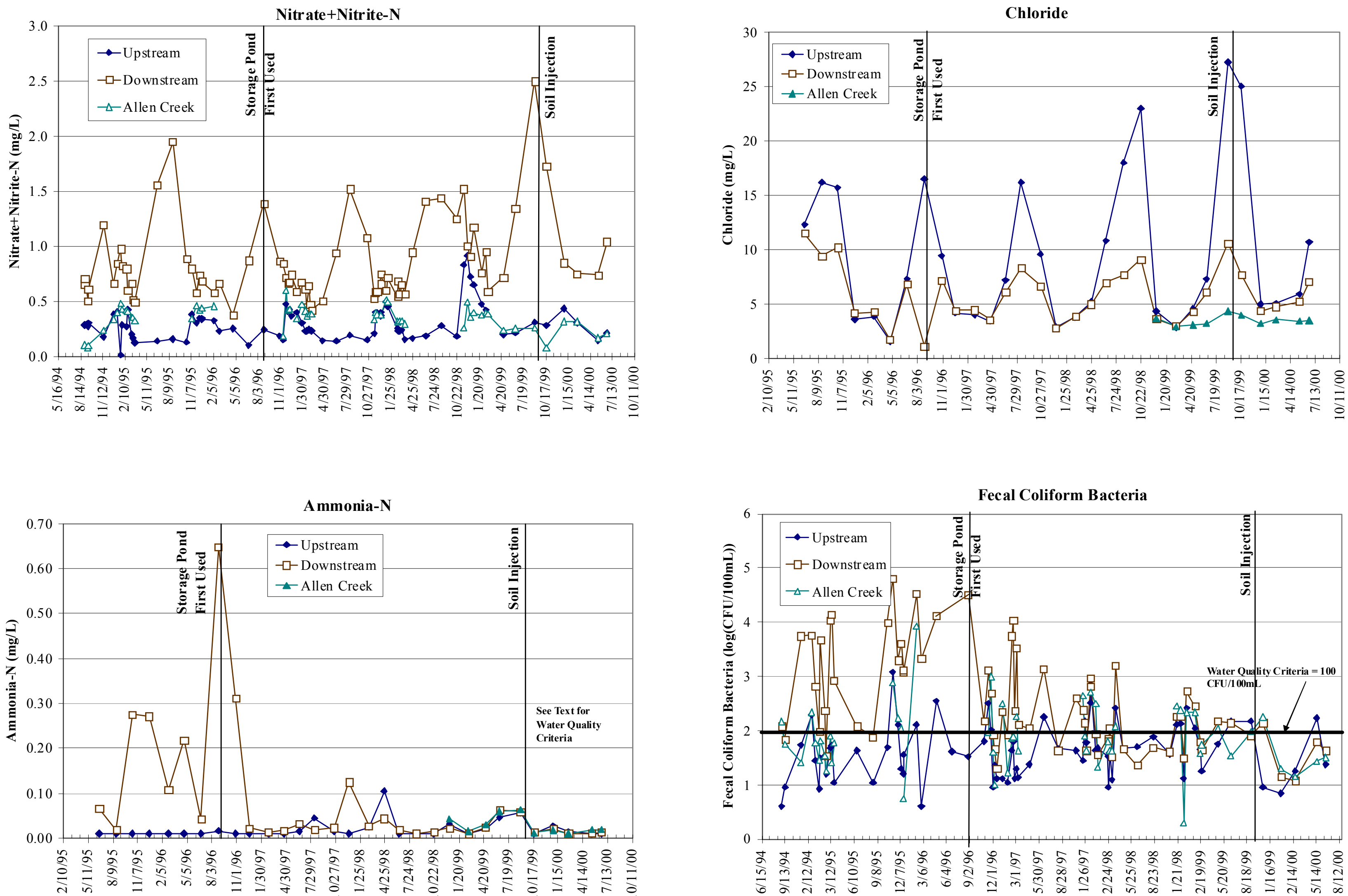


Figure 10. Surface Water Quality Results.

Trend Analysis of Water Quality Results

Seasonal Kendall Test

The Seasonal Kendall test was used to identify water quality trends and determine their statistical significance. The Seasonal Kendall test is appropriate for data with seasonal cycles and can be used even though there are missing, tied, or non-detect values (Gilbert, 1987). Also, the data do not need to be normally distributed for valid results. For the Seasonal Kendall test, the null hypothesis assumes that no trend is present. The null hypothesis is rejected for a downward trend (one-tailed test) if the test statistic is negative and the absolute value of the calculated test statistic is greater than the theoretical critical value (two-tailed test). The null hypothesis is rejected for an upward trend if the test statistic is positive and the absolute value of the calculated test statistic is greater than the theoretical critical value. Calculations were performed using the WQSTAT II software package (Colorado State University, 1989.)

Groundwater Trends

The Seasonal Kendall test statistics and trend slopes for nitrate+nitrite-N, chloride, TDS, TOC, and total phosphorus in wells are listed in Table 8. The table includes only wells in land application fields and does not include ambient wells (MW1 and MW12) or wells affected by interaction with surface water (MW3). In the table, shaded cells designate occurrences of statistically significant *decreasing* trends at a 95% confidence level. A decreasing trend represents decreased concentrations and improved groundwater quality. Outlined values designate occurrences of statistically significant *increasing* trends at a 95% confidence level. An increasing trend represents increased concentrations and degraded groundwater quality.

Table 8 shows that the occurrence of statistically significant trends in groundwater quality varied spatially and by target analyte. The Front Field (MW2) showed no statistically significant trends for any of the target analytes. The South Field showed the most improvement in groundwater quality. Chloride and TDS concentrations for most wells in the South Field showed statistically significant decreasing trends. And nitrate+nitrite-N concentrations declined significantly in two deep South Field wells (MW5B and the domestic well). In addition nitrate+nitrite-N, chloride, and TDS concentrations showed statistically significant improvement in the central portion of the West Field (MW8) and the western portion of the North Field (MW10).

Surface Water Trends

The Seasonal Kendall results for target analytes at the upstream and downstream stations are listed in Table 9. The downstream station showed statistically significant decreasing trends for ammonia-N, fecal coliform bacteria (log transformed), total phosphorus, TOC, and organic-N. The upstream station showed statistically significant decreasing trends for TOC and organic-N. Nitrate+nitrite-N increased significantly at the upstream station but showed no significant change at the downstream station. The decreasing trends observed at the downstream station for ammonia-N, fecal coliform bacteria, and total phosphorus are likely due to the use of the AWHP at the dairy. The cause for the decreasing trends for TOC and organic-N at the upstream station is unknown.

Table 8. Seasonal Kendall Test Results for Groundwater Data, June 1995 through June 2000.

	Nitrate+Nitrite-N		Chloride		Total Dissolved Solids		Total Organic Carbon		Total Phosphorus	
Well ID	Test Statistic	Slope (Units/yr)	Test Statistic	Slope (Units/yr)	Test Statistic	Slope (Units/yr)	Test Statistic	Slope (Units/yr)	Test Statistic	Slope (Units/yr)
Front Field										
MW2	-0.589	-0.009	0.000	-0.030	-1.402	-3.500	NA	NA	+1.096	+0.002
South Field										
Shallow										
MW4	-1.571	-1.233	**-2.357**	**-3.190**	-1.571	-13.333	-0.100	0.000	+0.603	+0.001
MW5A	-1.179	-0.325	**-4.321**	**-8.750**	**-4.125**	**-25.200**	NA	NA	+1.086	+0.002
MW6	-1.571	-1.000	**-4.911**	**-6.625**	**-2.073**	**-19.333**	NA	NA	+1.571	+0.005
Deep										
MW5B	**-2.161**	**-0.214**	**-5.107**	**-4.500**	**-3.257**	**-6.333**	NA	NA	+2.270	+0.006
Domestic	**-4.164**	**-0.507**	**-4.658**	**-0.843**	**-3.166**	**-5.500**	NA	NA	+0.955	+0.002
Irrigation	-1.480	-0.233	**-4.321**	**-1.602**	**-2.613**	**-6.000**	NA	NA	+1.480	+0.004
West Field										
MW7	-0.589	-0.520	+0.786	+2.900	+0.786	+6.000	+3.174	+0.357	+0.992	+0.002
MW8	**-1.964**	**-2.000**	**-4.518**	**-7.600**	**-3.143**	**-29.250**	-0.101	0.000	**-2.161**	**-0.014**
MW9	+1.768	+1.533	-0.393	-1.333	+0.982	+10.667	+0.793	+0.165	+0.397	+0.001
North Field										
MW10	**-2.357**	**-2.767**	**-4.441**	**-14.000**	**-2.554**	**-35.667**	+0.992	+0.060	+0.897	+0.004
MW11	-0.116	0.000	-1.571	-5.425	**-2.750**	**-16.000**	+0.793	+0.050	+0.315	0.000

NA= A majority of results are non-detect values and trend analysis was not conducted.
Shaded cell denotes a statistically significant concentration *decrease* at the 95% Confidence Level.
Outlined cell denotes a statistically significant concentration *increase* at the 95% Confidence Level.

Table 9. Seasonal Kendall Test Results for Beaver Creek Data.

Analyte	Upstream Station		Downstream Station	
	Test Statistic	Slope (Units/year)	Test Statistic	Slope (Units/year)
Nitrate+Nitrite-N	+3.204	+0.022	+1.431	+0.042
Chloride	+1.542	+0.300	-0.204	-0.020
Total Dissolved Solids	+1.350	+2.333	+0.308	+0.333
Ammonia-N	NA	NA	**-3.720**	**-0.013**
Fecal Coliform Bacteria (Log Transformed)	0.000	0.000	**-2.946**	**-0.403**
Total Phosphorus	-0.818	-0.004	**-3.067**	**-0.022**
Total Organic Carbon	**-2.364**	**-0.450**	**-2.686**	**-0.475**
Organic-N	**-2.658**	**-0.032**	**-2.249**	**-0.060**

Shaded cell with black lettering denotes a statistically significant *decrease* at the 95% Confidence Level.
Shaded cell with white lettering denotes a statistically significant *increase* at the 95% Confidence Level.

Mechanisms for Groundwater Quality Improvement

Overall, groundwater quality beneath the South, West, and North Fields and surface water quality improved over the monitoring period. The mechanisms by which storage ponds protect surface water quality are straightforward. Ponds allow for storage of manure and wastewater during winter months so that they can be land-applied during the growing season when the potential for contaminants to be transported by runoff is low and nutrient uptake is high. The mechanisms by which storage ponds protect groundwater quality are more subtle especially when addressing conservative contaminants such as chloride. Five potential mechanisms by which ponds may help to improve groundwater quality are listed as follows:

1. For nitrogen species, losses of ammonia-N due to volatilization during storage
2. Dilution of contaminants with direct precipitation to the ponds
3. Reduced applications to land during initial filling of the AWHP
4. More uniform applications to fields because of central location of the AWHP
5. More uniform applications to land because of better field accessibility during the growing season

Not all groundwater quality improvements observed over the monitoring period were related to the AWHP. For example, chloride and TDS concentrations in a number of wells (MW4, MW5A, MW6, irrigation well, MW7, MW8, MW9, MW10, and MW11) decreased before the ponds were used. Other factors that may have contributed to improved groundwater quality are listed as follows:

- Raised awareness due to monitoring presence
- Higher loading rates prior to the study than estimated
- Elimination of grazing dry cows during the winter months

Nitrogen Loading and Nitrate+Nitrite-N in Groundwater

Table F-3, Appendix F, shows fall soil nitrate concentrations, nitrogen loading estimates, and mean nitrate+nitrite-N concentrations for each field. Mean nitrate+nitrite-N concentrations are calculated separately for the growing season (March through October) and non-growing season (November through March). The results are plotted in Figure 11.

Two general trends in Figure 11 are apparent: 1) the higher nitrate+nitrite-N concentrations in groundwater are associated with higher nitrogen loading rates and fall soil nitrate concentrations and 2) non-growing season nitrate+nitrite-N concentrations were generally greater than growing season concentrations.

For the Front Field where residual nitrogen loading is estimated to be about 80 pounds N/acre/year and fall soil nitrate concentrations ranged from 52 to 101 pounds N/acre/year, non-growing season nitrate+nitrite-N concentrations ranged from 4.1 to 6.7 mg/L. For the South, West, and North Fields where residual nitrogen loading ranged from 196 to 541 pounds and fall soil nitrate concentrations ranged from 62 to 303 pounds N/acre, non-growing nitrate+nitrite-N concentrations in groundwater ranged from 23 to 30 mg/L, 23 to 37 mg/L, and 27 to 59 mg/L, respectively. Groundwater beneath the North Field was more sensitive to comparable nitrogen loading than the other fields due to the shallow and thin aquifer at the MW11 location.

While nitrogen loading estimates and soil nitrate concentrations correspond to elevated nitrate+nitrite-N concentrations, in general, changes in nitrogen loading for specific years did not necessarily correspond to changes in nitrate+nitrite-N levels in groundwater. For example, the fall soil nitrate concentration for the West Field in 1999 increased from 88 to 270 pounds N/acre, but the non-growing nitrate+nitrite-N concentration decreased from 37 mg/L in 1998 to 29 mg/L in 1999.

In August 1999, a traveling soil injector was used to apply manure and wastewater to the South and West Fields. A concern exists that soil injection may result in increased nitrate leaching to groundwater because of decreased ammonia volatilization losses and the placement of potential contaminants at depth in the soil. One well, MW4 (Figure 6), showed higher peaks than previous years for nitrate+nitrite-N and chloride concentrations in the winter following the soil injection application. The mean nitrate+nitrite-N concentrations shown in Figure 11 show a

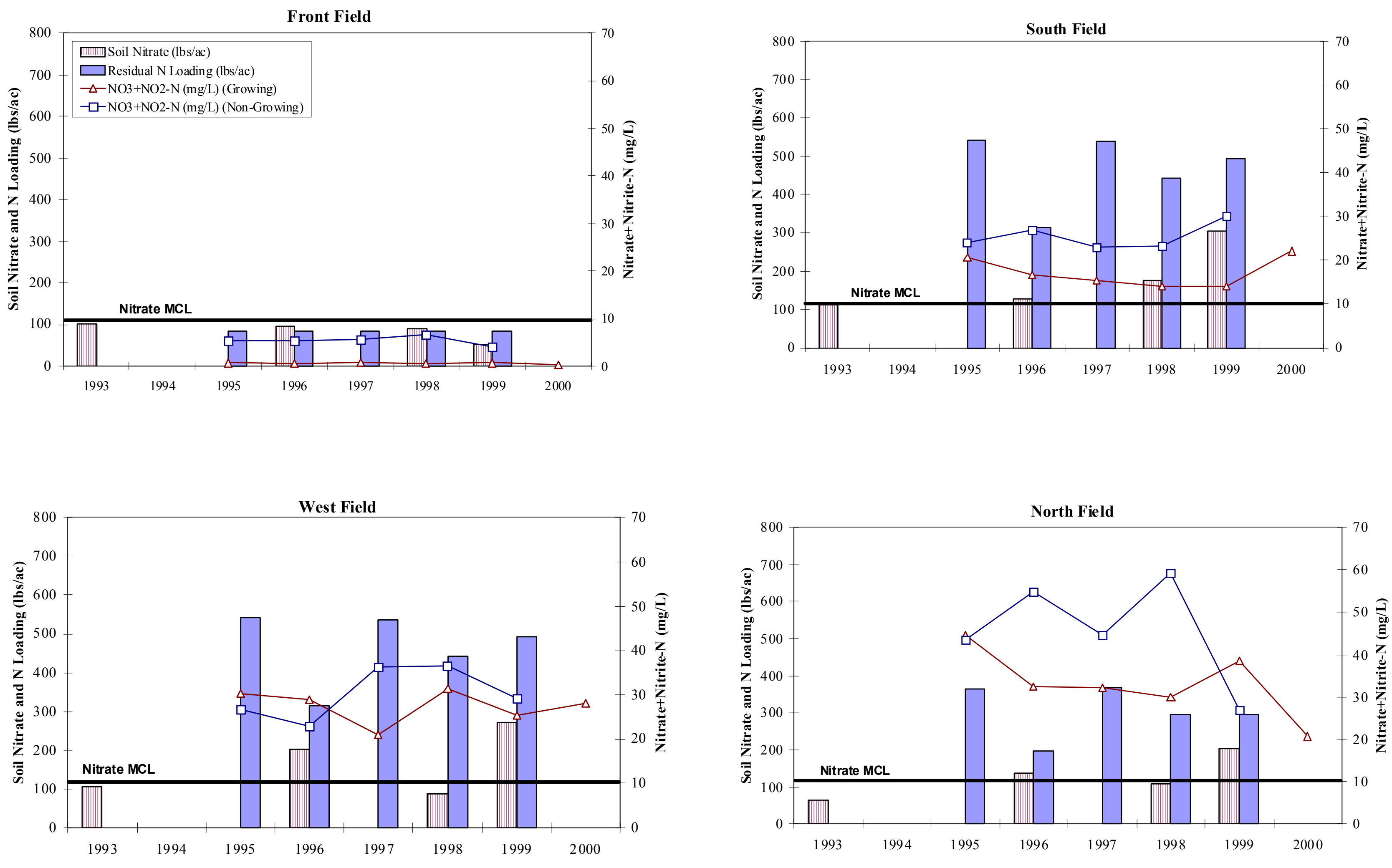


Figure 11. Soil Nitrate Concentrations, Estimated Residual Nitrogen Loading, and Growing and Non-Growing Season Nitrate+Nitrite-N Concentrations.

mixed response to soil injection. For the South Field shallow wells, the non-growing season nitrate+nitrite-N concentrations increased 6.6 mg/L in 1999. For the West Field, both the growing and non-growing season nitrate+nitrite-N levels declined in 1999.

Water Quality Standards

Groundwater criteria, drinking water standards, and surface water quality standards for the parameters tested are listed in Table 10 and discussed below in relation to observed concentrations.

Table 10. Maximum Contaminant Levels, Groundwater Quality Criteria, and Surface Water Quality Standards for Tested Parameters.

Parameter	Groundwater Quality Criteria[2]	Drinking Water Standard: Primary Maximum Contaminant Levels[1]	Drinking Water Standard: Secondary Maximum Contaminant Levels[1]	Surface Water Quality Standards for Class A Streams[3]
pH (Standard Units)	6.6-8.5	None	None	6.5-8.5
Temperature (°C)	None	None	None	Less than 18.0
Specific Conductance (µmhos/cm)	None	None	700	None
Dissolved Oxygen (mg/L)	None	None	None	Greater than 8.0
Nitrate+Nitrite-N (mg/L)	10	10	None	None
Ammonia-N (mg/L)	None	None	None	Temperature and pH Dependent (See Text)
Chloride (mg/L)	250	None	250	230 (Chronic)
Total Dissolved Solids (mg/L)	500	None	500	None
Total Phosphorus	None	None	None	None
Total Organic Carbon	None	None	None	None
Fecal Coliform Bacteria	1CFU/100mL[4]	1CFU/100mL[4]	None	100 CFU/100mL

[1]Washington State Department of Health, 1994.
Primary Maximum Contaminant Levels are based on adverse health effects.
Secondary Maximum Contaminant Levels are based on esthetics such as taste, odor, or staining.

[2]Washington Sate Department of Ecology, 1990.

[3]Washington State Department of Ecology, 1997.

[4]Total Coliform Bacteria.
CFU = Colony Forming Units.

Groundwater

The primary parameter of concern in groundwater is nitrate. The groundwater quality criterion and maximum contaminant level (MCL) for drinking water for nitrate is 10 mg/L (Washington State Department of Ecology, 1990; Washington State Department of Health, 1994). Annual mean nitrate +nitrite-N concentrations beneath each field for both the growing season (April through October) and non-growing season (November through March) are shown in Figure 11. Mean nitrate+nitrite-N concentrations beneath the Front Field remained below 10 mg/L during the monitoring period. Mean nitrate +nitrite-N concentrations beneath the South, West, and North Fields exceeded 10 mg/L at the onset of the monitoring and, even though concentrations decreased under portions of some fields, mean concentrations continued to exceed 10 mg/L at the end of the monitoring period.

The groundwater criterion and secondary drinking water standard for total dissolved solids (TDS) is 500 mg/L. Most of the TDS excursions above 500 mg/L occurred beneath the North Field. TDS exceeded 500 mg/L at MW10 for six months at the onset of monitoring and during most of 1999. At MW11 a spike above 500mg/L was observed every winter of the monitoring period except 2000. TDS concentrations exceeded 500 mg/L on two other occasions: at MW 4 (South Field) in December 1999, at MW8 (West Field) at the onset of monitoring.

The groundwater criterion and secondary drinking water standard for chloride is 250 mg/L. No measured chloride concentrations in groundwater exceeded 250 mg/L over the monitoring period. The highest chloride concentration in groundwater, 140 mg/L, was measured at MW11 (North Field) December 1996. The mean chloride concentration in the effluent was 351 mg/L.

The groundwater criterion and primary drinking water standard for total coliform bacteria is one colony forming unit (CFU) per 100mL. Fecal coliform bacteria, the target analyte for this study, are a subset of total coliform bacteria. Fecal coliform bacteria were detected infrequently in groundwater samples. Most detections occurred in the months immediately following well installation which suggests their occurrence was the result of surface contamination during well installation. One occurrence of 200CFU/100mL in the domestic well was likely due to contamination during sampling.

Surface Water

The surface water criterion for fecal coliform bacteria is 100 CFU/100mL. Pre-AWHP concentrations at the downstream station (Figure 10) consistently exceeded the criteria. After the AWHP was used, fecal coliform bacteria concentrations at the downstream station gradually decreased until, during the last year of monitoring, they were below the criterion.

To meet Class A standards the dissolved oxygen concentrations must exceed 8.0 mg/L. Dissolved oxygen was measured during five sampling events from October 1999 through June 2000. Concentrations were less than 8.0 mg/L for four of the five sampling events at both the upstream and downstream stations.

Ammonia-N criteria are dependent upon the temperature and pH of the surface water body (Washington State Department of Ecology, 1997). Ammonia-N was detected infrequently at the upstream station at concentrations that ranged from 0.01 to 0.10 mg/L (Table E-10). Ammonia-N concentrations at the downstream station ranged from 0.01 to 0.65 mg/L. The average pH at the downstream station was about 6.5 standard units and temperatures over the monitoring period ranged from 4.6 to 20.6 C.

A spreadsheet pwsspread.xls (http://www.ecy.wa.gov/programs/eap/pwsspread/pwspread.xls) at Ecology's web page was used to calculate the chronic toxicity criteria for total ammonia-N for this range of conditions. The calculated criteria ranged from 1.4 to 2.3 mg/L. Observed concentrations were well below criteria levels.

The temperature criterion for a Class A stream is 18.0°C. Temperatures at the upstream and downstream stations were usually less than 18°C. The criterion was exceeded at the upstream station in August 1995 (19.1°C) and August 1997 (18.8°C) and at the downstream station in August 1997 (20.6°C).

The chronic toxicity criterion for chloride in surface water is 230 mg/L. The maximum chloride concentrations measured at the upstream and downstream stations were 27.2 and 11.5 mg/L, respectively.

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Conclusions

1. At the onset of monitoring in 1995, Thurston County Dairy land applied about 6.3 million gallons of manure and wastewater year-round to four onsite fields designated the Front, South, West, and North Fields. An Animal Waste Holding Pond (AWHP) system with a storage capacity of seven million gallons was constructed and first used in September 1996. After the AWHP system was constructed, manure and wastewater were applied to onsite dairy fields during the growing season between April and October.

2. Initially, groundwater quality beneath the South, West, and North Fields showed substantial impairment. Elevated analytes included nitrate+nitrite-N, chloride, and total dissolved solids. Initial nitrate+nitrite-N concentrations exceeded the 10 mg/L groundwater quality criterion for nitrate-N in much of the aquifer beneath the dairy. Groundwater quality beneath the Front Field was less affected.

3. The dairy is underlain by an unconfined, shallow, sand and gravel aquifer that ranges in thickness from 3 to 30 feet. For this report the aquifer is designated the Principal Aquifer. The depth to water ranges from less than a foot to about 35 feet. Groundwater velocities in the Principal Aquifer range from about 0.1 to 34 feet per day with and mean of 1.5 feet/day. The Principal Aquifer discharges to Beaver Creek. The contribution from the Principal Aquifer underlying the dairy to Beaver Creek is estimated to be about 0.9 cubic feet per second. It is estimated that about 80 pounds of nitrogen discharges daily from the aquifer to Beaver Creek.

4. Manure application and crop management of the Front Field appears to represent agronomic conditions. Over the monitoring period, about 0.62 million gallons of manure were applied annually to the Front Field (19.3 acres) with a tanker truck. Applications occurred only during the growing season, March through October, and the grass crop was harvested prior to applications. Residual nitrogen applied to the Front Field was estimated at 83 pounds N/acre, and fall soil nitrate concentrations declined from 101 pounds N/acre in 1993 to 53 pounds N/acre in 1999. Concentrations of target analytes in groundwater beneath the Front Field remained essentially the same over the monitoring period. Nitrate+nitrite-N concentrations in groundwater beneath the Front Field averaged between 4.1 to 6.7 mg/L during the non-growing season and were less than 0.7 mg/L during the growing season.

5. The AWHP system affected the volume, nutrient content, and timing of manure and wastewater applications to the South, West, and North Fields (107.6 acres). The pre-AWHP application volume to the three fields was about 5.7 million gallons, which increased to about 6.8 million gallons for post-AWHP conditions. The nitrogen content of manure and wastewater decreased because of volatilization losses of ammonia-N during storage and dilution by precipitation on the AWHP. Timing of applications changed from year-round to only during the growing season (April through October) with most of the manure and wastewater applied in August and September.

6. Application methods changed over the study period for the South, West, and North Fields, which affected the nitrogen loading. Initially manure and wastewater were applied by stationary gun. In 1996, 1997, and 1998 a traveling gun was used for applications. In 1999 about half of the manure and wastewater applied to the South and West Fields was applied with a traveling injector in the late fall.

7. Timing and quantity of manure and wastewater applications exceed recommended rates. Annual residual nitrogen loading to the South, West, and North Fields was estimated to range from 196 to 541 pounds N/acre, with a mean of 465 pounds N/acre for the South and West Fields and a mean of 303 pounds N/acre for the North Field. Fall soil nitrate concentrations ranged from 63 to 303 pounds N/acre, with a mean of 158 pounds N/acre. Soil nitrate concentrations above 80 pounds N/acre are considered to be high and represent a threat of nitrate leaching to groundwater.

8. Trend analysis using the Seasonal Kendall test shows that groundwater quality improved beneath substantial portions of the South, West, and North Fields over the monitoring period. Chloride and TDS concentrations for most wells in the South Field showed statistically significant decreasing trends at the 95% confidence level. Nitrate+nitrite-N concentrations declined significantly in two deep South Field wells (MW5B and the domestic well). In addition, nitrate+nitrite-N, chloride, and TDS concentrations showed statistically significant improvement in the central portion of the West Field (MW8) and the western portion of the North Field (MW10).

9. The improvement to groundwater quality is partially attributed to the use of the AWHP. Potential mechanisms by which the AWHP may have helped to protect groundwater quality are listed as follows:
   - For nitrogen species, losses of ammonia-N due to volatilization during storage
   - Dilution of nutrient and contaminants with direct precipitation to the ponds
   - More uniform applications to land because of better field accessibility during the growing season

10. The groundwater quality criterion and maximum contaminant level (MCL) for drinking water for nitrate is 10 mg/L. Mean nitrate+nitrite-N concentrations beneath the Front Field remained below 10 mg/L during the monitoring period. Mean annual nitrate +nitrite-N concentrations beneath the South, West, and North Fields exceeded 10 mg/L at the onset of the monitoring and, even though concentrations decreased under portions of some fields, mean concentrations continued to exceed 10 mg/L at the end of the monitoring period.

11. At many wells chloride and TDS concentrations declined prior to use of the waste storage pond. Factors that may have contributed to improved groundwater quality, other than the AWHP, are listed as follows:
    - Greater than normal precipitation over the monitoring period
    - High loading rates prior to the initiation of the study
    - Raised awareness due to monitoring presence

12. Ammonia-N, fecal coliform bacteria, and total phosphorus concentrations in Beaver Creek downstream of the dairy decreased significantly at the 95% confidence level. The improvement is likely a result of the use of the AWHP. Pre-AWHP fecal coliform bacteria concentrations at the downstream station consistently exceeded the surface water criteria (100 CFU/mL). After the AWHP was used, concentrations at the downstream station gradually decreased until, during the last year of monitoring, they were below the criterion.

13. Soil injection of manure and wastewater in August 1999 resulted in a mixed response of mean nitrate+nitrite-N concentrations in groundwater beneath the South and West Fields. Some concentrations increased, some decreased, and some remained the same. The data do not support the rejection of the soil injection method compared to other application methods.

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Recommendations

1. Manure and wastewater applications to the South, West, and North Fields have resulted in elevated nitrate, chloride, and TDS concentrations in groundwater. Nitrate concentrations continue to be higher than groundwater quality standards. The construction and operation of the AWHP has resulted in improvement of groundwater quality beneath portions of the fields. Continued use of the AWHP will likely translate to more improvement to groundwater quality. Additional farming practices that the Thurston County Dairy should initiate to reduce contaminant loading to groundwater are listed as follows:

   - Nearly 500 additional offsite acres have been identified for application of manure and wastewater. Use of this acreage for land application of manure and wastewater generated at the dairy could substantially reduce loading to onsite fields.

   - Over the years of dairy operation, organic matter has accumulated in the soil of the South, West, and North Fields. This material will provide an ongoing source of nitrogen as decay and mineralization occurs. The availability of this nitrogen should be considered in the crop management of these fields.

   - Grazing/harvesting management of the South, West, and North Fields should be reviewed to maximize dry matter removal.

   - Pumping from the AWHP should begin earlier in the growing season rather than waiting until August, so that applications will coincide with vegetative uptake rates.

   - The ration balance (animal diet) should be evaluated with a nutritionist, and the nutrient content of the manure should be considered in adjusting the balance.

2. Additional groundwater monitoring studies should be conducted at operating dairies in various hydrogeologic and climatologic settings to further define the relationship of nitrogen loading and nitrate concentrations in groundwater. Information from these studies would be used to determine acceptable nitrogen loading rates that protect groundwater quality.

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Appendices

A. Geologist’s Logs and As-Built Drawings

B. Hydrologic Test Results

C. Sampling Procedures

D. Quality Assurance Results

E. Water Quality Results

F. Loading Estimates

Appendix A

Geologist's Logs and As-Built Drawings

Table A-1. Characteristics of Sampling Stations.

Table A-1. Characteristics of Sampling Stations, Pre- and Post-BMP Groundwater Monitoring Project.

Site Name	Measuring Pt. Altitude (MSL, Feet)	State Plane Coordinate X	State Plane Coordinate Y	Diameter (Inches)	Depth to Top of Screen (Feet)	Depth to Bottom of Screen (Feet)	Drilled Depth (Feet)	Date Drilled	Status
MW1	192.48	1383730	578511	2	17.2	22.2	24.0	6/13/95	Inactive
MW2	189.44	1383390	577790	2	16.9	21.9	23.7	6/13/95	Decommissioned
MW3	180.46	1383290	577070	2	11.7	16.7	18.5	6/12/95	Decommissioned
MW4	185.95	1382410	577000	2	15.4	20.4	20.7	6/12/95	Decommissioned
MW5A	177.44	1381390	576590	2	9.7	14.7	15.0	6/9/95	Decommissioned
MW5B	177.57	1381390	576590	2	32.6	37.6	49.0	6/9/95	Decommissioned
MW6	180.82	1380780	577150	2	12.3	17.3	17.6	6/8/95	Decommissioned
MW7	209.56	1381970	578000	2	33.7	38.7	40.0	6/6/95	Inactive
MW8	205.78	1381030	578030	2	38.9	43.9	69.0	6/8/95	Decommissioned
MW9	178.05	1380270	577930	2	9.2	14.2	16.5	6/7/95	Inactive
MW10	177.21	1380480	578790	2	9.1	14.1	16.5	6/8/95	Inactive
MW11	206.50	1381250	579410	2	12.4	17.4	25.5	6/8/95	Inactive
MW12	249.82	1382600	578070	2	26.1	31.1	46.5	5/12/97	Inactive
Domestic Well	191.22	1382670	577330	6	34.3	34.3	34.3	Unknown	Water Supply
Irrigation Well	180.65	1381790	576900	12	31	31	31.0	Unknown	Irrigation
Upstream Gage	187.26	1383850	577710	NA	NA	NA	NA	NA	NA
Downstream Gage	172.14	1379150	579730	NA	NA	NA	NA	NA	NA
Allen Creek Mouth	175	1380050	580300	NA	NA	NA	NA	NA	NA

Appendix B

Hydrologic Test Results

Table B-1. Hydrologic Tests - Input Data and Results.

Well ID	Pump*	Diameter (In)	Static Water Level (Ft)	Test Water Level (Ft)	Test Length (Hr)	Pumping Rate (GPM)	Aquifer Thickness (Ft)	Open Interval (Ft)	Storage Coeff.	Well Loss Coeff.	T (gpd/ft)	Kh (ft/d)	Geometric Mean Kh (ft/d)
MW1	C	2	15.74	19.2	0.025	4.2	8.6	4.3	0.25	1	1652	26	
MW1	C	2	15.74	17.06	1.00	2.0	8.6	4.3	0.25	1	2794	43	
MW1	P	2	16.21	16.35	0.2	0.28	8.0	5	0.25	1	2687	45	37
MW2	C	2	16.65	17.94	0.1167	0.8	10.4	5	0.25	1	982	13	
MW2	C	2	16.65	20.66	0.1167	1.2	10.4	5	0.25	1	447	5.8	
MW2	P	2	16.7	17.0	0.236	0.29	10.0	5	0.25	1	1594	21	12
MW3	C	2	9.42	9.75	0.1	3.3	11.8	5	0.25	1	21737	246	
MW3	C	2	9.42	9.75	0.0333	3.3	11.8	5	0.25	1	20405	231	
MW3	C	2	9.39	9.99	0.5167	5.1	11.8	5	0.25	1	19994	227	
MW3	P	2	9.37	9.4	0.16	0.3	12.0	5	0.25	1	22688	253	236
MW4	P	2	15.2	15.23	0.245	0.26	9.0	5	0.25	1	15027	223	223
MW5A	S	2	7.12	8.2	0.3333	2.8	33.0	5	0.25	1	16117	65	
MW5A	P	2	7.04	7.135	0.29	0.275	33.0	5	0.25	1	17985	73	69
MW5B	S	2	7.29	7.94	0.5	2.8	33.0	5	0.25	1	27239	110	
MW5B	P	2	7.19	7.3	0.26	0.32	33.0	5	0.25	1	18039	73	90
MW6	S	2	10.46	10.55	0.1667	2.7	30.0	5	0.25	1	175138	780	
MW6	P	2	10.38	10.39	0.21	0.31	30.0	5	0.25	1	181861	810	795
MW7	S	2	30.83	37.13	0.5	1.2	20.0	5	0.25	1	658	4.4	
MW7	S	2	30.83	36.45	0.1667	1.2	20.0	5	0.25	1	713	4.8	5
MW8	S	2	36.26	37.36	0.333	1.6	24.0	5	0.25	1	6409	36	36
MW9	S	2	7.75	8.11	0.5	3.0	30.0	5	0.25	1	48458	216	
MW9	P	2	7.61	7.67	0.18	0.25	30.0	5	0.25	1	23391	104	150
MW10	S	2	7.04	9.53	0.5	2.7	30.0	5	0.25	1	6046	27	
MW10	P	2	6.95	7.22	0.167	0.29	30.0	5	0.25	1	5850	26	26
MW11	P	2	16.9	17.09	0.19	0.25	2.8	2.8	0.25	1	1104	53	53
MW12	S	2	22.49	30.85	0.35	1.0	2.0	2	0.25	1	71	5.0	
MW12	P	2	22.49	23.87	0.225	0.24	9.0	4	0.25	1	279	4.0	4
*C=Centrifugal Pump											Geometric Mean=		51
P=Peristaltic Pump												Minimum=	4
S=ES-60 Submersible Pump												Maximum=	795

Table B-2. Water-Level Elevations for Pre- and Post- BMP Groundwater Monitoring Project.

	Front Field			West Field				North Field	
Date	MW1	MW2	MW3	MW12	MW7	MW8	MW9	MW11	MW10
6/19/95	176.92	173.20	171.81		179.20	171.41	171.39	190.02	171.19
8/21/95	176.09	172.57	171.36		178.62	170.76	170.79	190.97	170.73
10/17/95	177.99	175.10	173.94		178.58	172.46	172.34	190.27	172.18
12/18/95	181.67	179.19	177.65		183.94	175.95	175.09	191.69	174.99
2/26/96	180.99	178.12	176.53			174.88	174.23	191.54	174.02
4/22/96	179.38	175.97	174.60		180.58	173.08	174.33	191.41	173.86
6/24/96	177.4	173.67	172.16		179.19	171.35	171.22	190.15	171.09
8/26/96	175.72	171.84	170.42		177.94	169.94	170.02	190.01	169.86
10/28/96	178.61	175.44	174.09		177.85	172.53	172.38	190.86	172.11
12/16/96	181.12	178.63	177.04		182.84	175.46	174.55	191.75	174.50
2/24/97	181.06	178.28	176.70		181.84	175.08	174.22	191.73	174.19
4/21/97	179.89	176.17	174.77		180.54	173.37	173.01	191.11	172.86
6/16/97	178.83	175.34	173.91	229.21	179.84	172.60	172.29	191.32	172.12
8/11/97	176.27	172.74	171.09	227.33	178.20	170.57	170.44	189.60	170.26
10/20/97	177.99	175.15	173.92	226.63	179.08	172.55	172.27	191.42	172.09
12/15/97	179.46	176.55	175.18	229.44	181.30	173.71	173.52	191.33	173.37
2/22/98	180.35	177.18	175.70	230.06	181.01	174.10	173.62	191.45	173.45
4/21/98	178.46	175.08	173.70	229.26	179.89	172.33	172.02	190.87	171.91
6/15/98	176.71	173.48	172.33	227.85	178.40	171.30	171.20	190.08	170.92
8/17/98	172.2	171.74	170.12	226.69	177.66	169.60	169.62	189.28	169.50
10/19/98	175.71	172.70	171.65	225.88	177.06	170.80	170.70	188.87	170.52
12/14/98	182.07	179.73	178.16	230.06	184.16	176.29	175.29	192.17	175.15
2/22/99	181.25	178.51	177.04	232.03	182.78	175.31	174.89	191.87	174.70
4/26/99	178.52	175.03	173.67	229.48	180.33	172.40	172.08	192.00	171.94
6/14/99	177.01	173.75	172.59	228.32	179.06	171.62	171.47	190.50	171.17
8/31/99	175.62	172.75	171.28	226.86	177.82	170.84	170.81	189.21	170.57
10/17/99	175.69	173.11	172.15	226.16	177.44	171.52	171.45	189.08	171.05
12/27/99	180.42	177.85	176.42	230.73	183.52	174.99	174.05	191.66	174.12
2/20/00	179.57	176.59	175.20	230.65	181.83	173.74	173.16	191.51	173.07
5/15/00	177.94	174.78	173.56	228.95	179.42	172.51	172.15	190.60	171.83
6/19/00	177.31	174.31	173.15	228.06	178.71	172.20	172.01	190.24 R	171.60

Table B-2. Water-Level Elevations

	South Field - Shallow				South Field - Deep		
Date	**MW12**	**MW4**	**MW5A**	**MW6**	**MW5B**	**Domestic**	**Irrigation**
4/28/95							173.20 P
6/19/95		171.55	171.36	171.39	171.45		
8/21/95		170.95	170.72	170.77	170.81		166.40 P
10/17/95		173.66	172.83	172.70	172.93	174.13	173.24 P
12/18/95		177.38	176.05	175.94	176.16	178.03	176.77 P
2/26/96		176.23	175.14	174.90	175.15	176.97	175.33 P
4/22/96		174.33	174.55	174.83	174.63	174.83 R	173.82 P
6/24/96		171.76	171.36	171.34	171.37	172.38	167.14 P
8/26/96		170.10	169.89	169.93	169.91		166.09 P
10/28/96		173.83	172.97	172.83	173.00		173.32 P
12/16/96		176.81	175.64	175.46	175.64		176.30 P
2/24/97		176.46	175.22	175.02	175.22	177.13 R	175.98 P
4/21/97		174.54	173.74	173.56	173.71	175.16 R	174.19 P
6/16/97	229.21	173.70	172.87	172.67	172.86		173.22 P
8/11/97	227.33	170.75	170.40	170.44	170.38		166.70 P
10/20/97	226.63	173.69	172.93	172.66	172.90	174.21	173.24 P
12/15/97	229.44	173.69	174.42	174.16	174.38	175.53	174.58 P
2/22/98	230.06	174.98	174.48	174.27	174.46	176.09	175.03 P
4/21/98	229.26	175.54	172.62	172.38	172.61	174.03	173.09 P
6/15/98	227.85	173.50	171.55	171.36	171.51	172.56	171.75 P
8/17/98	226.69	172.13	169.58	169.51	169.53	170.46	165.67 P
10/19/98	225.88	169.83	171.01	170.86	171.00		171.31 P
12/14/98	230.06	171.55	176.43	176.21	176.45		177.36 P
2/22/99	232.03	177.90	175.93	175.66	175.94		176.37 P
4/26/99	229.48	176.85	172.68	172.46	172.67		173.10 P
6/14/99	228.32	173.50	171.84	171.64	171.81		172.12 P
8/31/99	226.86	170.98	170.70	170.69	170.66		166.46 P
10/17/99	226.16	172.11	171.66	171.54	171.65		171.85 P
12/27/99	230.73	176.24	174.99	174.70	174.98		175.49
2/20/00	230.65	175.00	173.99	173.66	173.99		172.74 P
5/15/00	228.95	173.40	172.68	172.40	172.64		173.10 P
6/19/00	228.06	173.00	172.38	172.14	172.35		172.74 P

R= Water level recovering.

P= Well pumping.

Table B-3. Thurston County Dairy Estimated Groundwater Flow Velocities.				
	Front Field	**South Field**	**West Field**	**North Field**
Minimum Hydraulic Conductivity (feet/day), Kh	12	69	5	26
Maximum Hydraulic Conductivity (feet/day), Kh	236	795	150	53
Mean Hydraulic Conductivity (feet/day), Kh	55	177	28	33
August 1997 Hydraulic Gradient, dh/dL	0.005	0.0064	0.0097	0.0193
December 1997 Hydraulic Gradient, dh/dL	0.0067	0.0085	0.0077	0.0179
Effective Porosity, n_e	0.20-0.35	0.20-0.35	0.20-0.35	0.20-0.35
Minimum Groundwater Velocity (feet/day), v	0.2	1	0.1	1
Maximum Groundwater Velocity (feet/day), v	8	34	7	5
Mean Groundwater Velocity (feet/day), v	1	5	1	2

Appendix C

Sampling Procedures

Table C-1. Parameters, Bottle Types, Holding Times, and Preservation.

Table C-2. Parameters, Test Methods, and Practical Quantitation Limits.

Sampling Procedures

Groundwater samples were obtained bi-monthly (every two months) to estimate seasonal groundwater quality variability. Near-bank, grab samples from Beaver Creek were taken upstream and downstream of the dairy each sampling event. Bi-monthly grab samples were obtained near the mouth of Allen Creek where it discharges into Beaver Creek.

Water levels were measured in each well prior to sampling using a commercial electric probe. Measurements were recorded to 0.01 feet and are considered accurate to less than 0.03 feet. Well volumes were calculated using the height of water in the well casing above the bottom of the well. The water elevation for Beaver Creek was measured at two locations: Case Road bridge and Beaver Creek Ranch bridge.

All monitoring wells, with the exception of MW7 and MW8, were purged and sampled using dedicated polyethylene tubing and a peristaltic pump. MW7 and MW8 were purged and sampled using 1-liter decontaminated Teflon bailers. Bailers were decontaminated with hot tapwater and Liquinox® followed by tapwater and de-ionized water rinses. A minimum of two well volumes were purged from each well and specific conductance, pH, and temperature were measured for each well volume pumped. Purging was conducted at a rate of about one liter per minute until field parameters stabilized (changes of 10% or less between well volumes). Samples from the domestic well and irrigation wells were obtained with polyethylene tubing attached with a hose bib adapter to the faucets at the wellheads. Typically pumps in these wells were running nearly continuously and no pre-sampling purging was required. Samples were placed in pre-cleaned bottles obtained from Manchester Laboratory. Bottle materials and preservatives for the target analytes are listed in Table C-1.

All samples were placed in coolers with ice. Samples were transported by the sampling team to the Ecology Headquarters building in Lacey and placed in the Ecology walk-in cooler. The laboratory courier transported the samples to the Ecology/EPA Manchester Environmental Laboratory in Manchester, Washington.

Samples were tested at Manchester Laboratory for: nitrate+nitrite-N, ammonia, total phosphorus, total persulfate nitrogen (TPN), total dissolved solids (TDS), total organic carbon (TOC), chloride, and fecal coliform bacteria. Test methods and detection limits for the target analytes are listed in Table C-2.

Table C-1. Parameters, Bottle Types, Holding Times and Preservation for Pre- and Post-BMP Groundwater Monitoring Project.

Parameter	Bottle	Holding Time	Preservative
Total Dissolved Solids	1000 mL w/m polyethylene	7 Days	Cool to 4°C
Ammonia-N	125 mL clear wide mouth, polyethylene	28 Days	Sulfuric Acid to pH<2 Cool to 4°C
Nitrate+Nitrite-N	125 mL clear wide mouth, polyethylene	28 Days	Sulfuric Acid to pH<2 Cool to 4°C
Total Persulfate Nitrogen	125 mL clear wide mouth, polyethylene	28 Days	Sulfuric Acid to pH<2 Cool to 4°C
Total Phosphorus	125 mL clear wide mouth, polyethylene	28 Days	Sulfuric Acid to pH<2 Cool to 4°C
Chloride	1000 mL polyethylene	28 Days	Cool to 4°C
Total Organic Carbon	60 mL narrow mouth, polyethylene	28 Days	Sulfuric Acid to pH<2 Cool to 4°C
Fecal Coliform Bacteria	250 mL glass, autoclaved	30 Hours	Cool to 4°C

Manchester Environmental Laboratory, 1994.

Table C-2. Parameters, Test Methods, and Practical Quantitation Limits for Pre- and Post-BMP Groundwater Monitoring Project.

Parameter	Test Method EPA Methods/Standard Methods (US EPA, 1983/APHA, 1992)	Practical Quantitation Limit
pH (Field)	Orion Model 250A	0.1 Std Units
Temperature (Field)	Orion Model 250A	0.1°C
Specific Conductance (Field)	Beckman Meter	10 umhos/cm
Total Dissolved Solids	EPA 160.1/2540C	1 mg/L
Ammonia-N	EPA 350.1/4500 NH3 D	0.01 mg/L
Nitrate+Nitrite-N	EPA 353.2/4500 NO3 F	0.01 mg/L
Total Persulfate Nitrogen	EPA 353.2 (Modified)/4500	0.01 mg/L
Total Phosphorus	EPA 365.3/4500-P F	0.01 mg/L
Chloride	EPA 330.0/4110B	0.1 mg/L
Total Organic Carbon	EPA 415.1/5310B	0.1 mg/L
Fecal Coliform Bacteria	--------/MF 9222D	1 cfu/100mL

Appendix D

Quality Assurance Results

Field Parameters

Quality assurance samples for field parameters consisted of two duplicate samples for each sampling event. Duplicate samples consisted of two samples obtained from the same well at different times using the same sampling procedure. The duplicate results for field parameters are listed in Table D-1.

The relative percent difference (RPD), defined as the ratio of the difference and the mean of duplicate results expressed as a percentage, was calculated for each duplicate set and are shown in Table D-1. RPDs of field duplicate results provide an estimate of overall sampling and analytical precision. High RPDs indicate poor precision and low RPDs indicate good precision. However, as a general rule, RPDs become less representative of sampling and analytical precision as measured values approach the detection limit. The RPDs for specific conductance ranged from 0 to 23% with a mean of 4%. The RPDs for temperature ranged from 0 to 10% with a mean of 2%. The RPDs for pH ranged from 0 to 14% with a mean of 2%. The RPDs for dissolved oxygen ranged from 0 to 90% with a mean of 30%. The high RPDs for dissolved oxygen are likely the result of the low dissolved oxygen concentrations (less than 2 mg/L) in the duplicate samples.

Target Analytes

Laboratory

Precision and accuracy of laboratory results were estimated using laboratory quality control tests done on each set of 20 or fewer samples. Laboratory quality control tests consisted of duplicate blanks, duplicate samples, spiked samples, and control standards. Manchester Laboratory's quality control samples and procedures are discussed in *Quality Assurance Manual, Manchester Environmental Laboratory* (1988). Manchester Laboratory quality assurance reviews were completed for each sample set. All data are considered acceptable for use without qualification with the following exceptions:

- August 1995 TPN results for MW4, MW5A, and MW6 through MW11 are rejected because TPN concentrations were substantially less the NO3+NO2-N concentrations. The remainder of August 1995 TPN results were qualified due to matrix interference.
- December 1998 TPN results for MW1 trough MW4, MW7, irrigation well, and domestic well are qualified as estimates because analyses occurred one day over the holding time. Also the TPN result for MW5A was qualified due to poor matrix spike recovery.
- April 1996 TOC results are qualified because the 1ppm standard exceeded control limits.
- June 1997 nutrient results are qualified because of refrigeration failure at the laboratory.
- Over the study period occasional fecal coliform samples are qualified either because of spreader colonies or the number of colonies on a plate exceeded 150.
- Occasionally total phosphorus results were qualified due to matrix interference.

Field Duplicate Samples

Overall sampling and analytical precision was estimated using RPDs of field duplicate results as described above for field parameters. Field duplicate results and RPDs for target analytes are shown in Table D-2. The results are summarized in Table D-3.

Table D-3. Summary of RPDs for Target Analytes.

	Nitrate+ Nitrite-N	Chloride	Total Dissolved Solids	Ammonia-N	Total Phosph.	Total Organic Carbon	Fecal Coliform Bacteria	Total Persulfate N
Minimum=	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maximum=	62.2	7.5	53.9	74.3	129.7	81.5	100.0	31.4
N=	45	62	62	19	56	60	20	44
Mean=	7.9	1.7	4.0	18.9	16.4	8.6	28.0	6.5

RPD= Relative percent difference, the ratio of the difference and mean of duplicate results expressed as a percentage.

The overall mean precision for nitrate+nitrite-N, chloride, total dissolved solids, total organic carbon, and total persulfate nitrogen results is within 10%. The overall mean precision for ammonia-N and total phosphorus is within 20%. The overall mean precision of fecal coliform results is within 28%. The target for the overall sampling and analytical precision for field parameters and target analytes for this project was 15% (Erickson, 1995). This target was met for all parameters with the exception of ammonia-N (19%), total phosphorus (16%), fecal coliform bacteria (28%), and dissolved oxygen (30%).

Table D-1. Quality Assurance Results for Field Parameters.

Site ID	Date	Specific Conductance (umhos/cm)	Temperature (°C)	pH (SU's)	Dissolved Oxygen (mg/L)
BCMW1	6/19/95	150	9.9	6.4	
BCMW1	6/19/95	142	10.2	6.39	
RPD=		5.5	3.0	0.2	
BCMW5A	6/19/95	525	12.3	5.71	
BCMW5A	6/19/95	545	12.2	5.62	
RPD=		3.7	0.8	1.6	
BCMW1	8/21/95	140	11.8	5.93	
BCMW1	8/21/95	142	12.1	6.24	
RPD=		1.4	2.5	5.1	
BCMW5A	8/22/95	530	14	5.64	
BCMW5A	8/22/95	540	13.5	5.57	
RPD=		1.9	3.6	1.2	
BCMW1	10/17/95	172	12.5	5.96	
BCMW1	10/17/95	173	12.6	6.38	
RPD=		0.6	0.8	6.8	
BCMW5A	10/18/95	560	14.3	5.71	
BCMW5A	10/18/95	540	13.8	5.73	
RPD=		3.6	3.6	0.3	
BCMW1	12/18/95	310	11.8	5.91	
BCMW1	12/18/95	312	12.2	5.83	
RPD=		0.6	3.3	1.4	
BCMW5A	12/19/95	440	11.4	5.81	
BCMW5A	12/19/95	420	11.1	5.83	
RPD=		4.7	2.7	0.3	
BCMW1	2/26/96	201	8.7	6.3	
BCMW1	2/26/96	197	9.3	6.36	
RPD=		2.0	6.7	0.9	
BCMW5A	2/27/96	510	8.9	6.42	
BCMW5A	2/27/96	485	9.2	6.49	
RPD=		5.0	3.3	1.1	
BCMW1	4/22/96	260	8.2	6.37	
BCMW1	4/22/96	261	8.2	6.39	
RPD=		0.4	0.0	0.3	
BCMW6	4/24/96	355	10.6	5.69	
BCMW6	4/24/96	410	10.8	5.71	
RPD=		14.4	1.9	0.4	
BCMW1	6/24/96	191	10.1	6.52	
BCMW1	6/24/96	189	10.1	6.41	
RPD=		1.1	0.0	1.7	
BCMW5A	6/25/96	382	11.8	5.78	
BCMW5A	6/25/96	425	12	5.73	
RPD=		10.7	1.7	0.9	
BCMW1	8/26/96	158	11.9	6.26	
BCMW1	8/26/96	158	11.7	6.2	
RPD=		0.0	1.7	1.0	

Table D-1. Quality Assurance Results for Field Parameters.

		Specific Conductance	Temperature	pH	Dissolved Oxygen
BCMW5A	8/27/96	462	13.6	5.54	
BCMW5A	8/27/96	465	13.6	5.54	
RPD=		0.6	0.0	0.0	
BCMW1	10/28/96	272	12.2	6.36	
BCMW1	10/28/96	250	12.2	5.81	
RPD=		8.4	0.0	9.0	
BCMW5A	10/29/96	458	12.9	5.44	
BCMW5A	10/29/96	458	12.6	5.46	
RPD=		0.0	2.4	0.4	
BCMW1	12/16/96	288	11.2	5.98	
BCMW1	12/16/96	320	11.4	5.93	
RPD=		10.5	1.8	0.8	
BCMW5A	12/17/96	460	10.3		
BCMW5A	12/17/96	450	10.9		
RPD=		2.2	5.7		
BCMW1	2/24/97	190	7.6	6.04	
BCMW1	2/24/97	188	8.3	6.26	
RPD=		1.1	8.8	3.6	
BCMW5A	2/25/97	450	9.4	5.55	
BCMW5A	2/25/97	358	9.8	4.81	
RPD=		22.8	4.2	14.3	
BCMW1	4/21/97	185	7.9	5.88	
BCMW1	4/21/97	184	8.7	5.58	
RPD=		0.5	9.6	5.2	
BCMW5A	4/22/97	390	9.6		
BCMW5A	4/22/97	450	9.8		
RPD=		14.3	2.1		
BCMW1	6/16/97	240	10.2	5.97	
BCMW1	6/16/97	245	9.9	6.14	
RPD=		2.1	3.0	2.8	
BCMW5A	6/17/97	430	11.9	5.51	
BCMW5A	6/17/97	435	11.5	5.5	
RPD=		1.2	3.4	0.2	
BCMW1	8/11/97	140	12.2	6.28	
BCMW1	8/11/97	120	12	6.33	
RPD=		15.4	1.7	0.8	
BCMW5A	8/12/97	390	15	5.88	
BCMW5A	8/12/97	390	14.4	5.9	
RPD=		0.0	4.1	0.3	
BCMW1	10/20/97	265	12.3	6.22	
BCMW1	10/20/97	265	12.3	6.1	
RPD=		0.0	0.0	1.9	
BCMW5A	10/21/97	416	13.3	5.77	
BCMW5A	10/21/97	418	13.3	5.77	
RPD=		0.5	0.0	0.0	

Table D-1. Quality Assurance Results for Field Parameters.

		Specific Conductance	Temperature	pH	Dissolved Oxygen
BCMW1	12/15/97	191	12.2	6.37	
BCMW1	12/15/97	202	12	6.54	
RPD=		5.6	1.7	2.6	
BCMW6	12/16/97	270	11.6	6.84	
BCMW6	12/16/97	280	11.5	6.72	
RPD=		3.6	0.9	1.8	
BCMW1	2/22/98	172	7.8	6.38	
BCMW1	2/22/98	179	8	5.92	
RPD=		4.0	2.5	7.5	
BCMW5A	2/24/98	438	9.4	5.86	
BCMW5A	2/24/98	425	9.4	5.5	
RPD=		3.0	0.0	6.3	
BCMW1	4/21/98	210	10	6.37	
BCMW1	4/21/98	209	9.8	6.36	
RPD=		0.5	2.0	0.2	
BCMW5A	4/23/98	345	10.2	5.53	
BCMW5A	4/23/98	374	10.2	5.52	
RPD=		8.1	0.0	0.2	
BCMW1	6/15/98	140	9.7	6.32	
BCMW1	6/15/98	140	9.7	6.48	
RPD=		0.0	0.0	2.5	
BCMW5A	6/16/98	380	12.4	5.92	
BCMW5A	6/16/98	400	12.4	5.85	
RPD=		5.1	0.0	1.2	
BCMW1	8/17/98	180	11.7	6.47	
BCMW1	8/17/98	160	12.1	6.48	
RPD=		11.8	3.4	0.2	
BCMW5A	8/18/98	335	14	5.87	
BCMW5A	8/18/98	335	13.8	5.91	
RPD=		0.0	1.4	0.7	
BCMW1	10/19/98	127	12	5.9	
BCMW1	10/19/98	123	11.7	5.63	
RPD=		3.2	2.5	4.7	
BCMW5A	10/20/98	335	14.2	6.03	
BCMW5A	10/20/98	340	13.8	5.89	
RPD=		1.5	2.9	2.3	
BCMW1	12/14/98	410	11.8	6.03	
BCMW1	12/14/98	398	12.2	6.17	
RPD=		3.0	3.3	2.3	
BCMW5A	12/15/98	280	11.5	5.88	
BCMW5A	12/15/98	310	11.3	5.75	
RPD=		10.2	1.8	2.2	
BCMW1	2/22/99	122	8.9	6.37	
BCMW1	2/22/99	122	8.7	6.29	
RPD=		0.0	2.3	1.3	

Table D-1. Quality Assurance Results for Field Parameters.

		Specific Conductance	Temperature	pH	Dissolved Oxygen
BCMW5A	2/23/99	320	9.8	5.76	
BCMW5A	2/23/99	320	9.7	5.71	
RPD=		0.0	1.0	0.9	
BCMW1	4/26/99	180	8.5	6.25	
BCMW1	4/26/99	153	8.5	6.3	
RPD=		16.2	0.0	0.8	
BCMW5A	4/27/99	312	9.9	5.85	
BCMW5A	4/27/99	315	10	5.82	
RPD=		1.0	1.0	0.5	
BCMW1	6/14/99	125	9.6	6.2	
BCMW1	6/14/99	128	10.6	6.28	
RPD=		2.4	9.9	1.3	
BCMW5A	6/15/99	338	11.8		
BCMW5A	6/15/99	340	11.6		
RPD=		0.6	1.7		
BCMW1	8/31/99	116	11.1	5.98	0.42
BCMW1	8/31/99	116	11	6.04	1.1
RPD=		0.0	0.9	1.0	89.5
BCMW5A	9/1/99	319	14.6	6.1	0.98
BCMW5A	9/1/99	318	14.4	6.17	1.03
RPD=		0.3	1.4	1.1	5.0
BCMW1	10/17/99	107	11.8	5.87	1.8
BCMW1	10/17/99	123	12.1	5.59	0.92
RPD=		13.9	2.5	4.9	64.7
BCMW5A	10/19/99	323	13.3	5.4	1.19
BCMW5A	10/19/99	318	13.5	5.71	1.39
RPD=		1.6	1.5	5.6	15.5
BCMW1	12/27/99	178	10.9	5.74	1.08
BCMW1	12/27/99	180	10.4	5.59	1.04
RPD=		1.1	4.7	2.6	3.8
BCMW5A	12/28/99	312	10.8	5.26	1.48
BCMW5A	12/28/99	310	11.1	5.35	1.35
RPD=		0.6	2.7	1.7	9.2
BCMW1	2/20/00	148	7.9	5.55	1.37
BCMW1	2/20/00	149	8.4	5.67	0.88
RPD=		0.7	6.1	2.1	43.6
BCMW5A	2/21/00	422	9.7	5.54	
BCMW5A	2/21/00	421	9.7	4.98	
RPD=		0.2	0.0	10.6	
BCMW1	5/15/00	188	9	5.81	1.72
BCMW1	5/15/00	186	8.7	5.59	1.72
RPD=		1.1	3.4	3.9	0.0
BCMW5A	5/16/00	450	11.5	5.33	0.66
BCMW5A	5/16/00	460	11.3	5.22	0.62
RPD=		2.2	1.8	2.1	6.3

Table D-1. Quality Assurance Results for Field Parameters.

			Specific Conductance	Temperature	pH	Dissolved Oxygen
BCMW1		6/19/00	128	9.1	5.56	1.22
BCMW1		6/19/00	128	9.6	5.41	0.92
RPD=			0.0	5.3	2.7	28.0
BCMW5A		6/20/00	430	12.1	5.7	0.73
BCMW5A		6/20/00	432	12.2	5.91	0.39
RPD=			0.5	0.8	3.6	60.7
	N=		62	62	59	11
	Minimum=		0.0	0.0	0.0	0.0
	Maximum=		22.8	9.9	14.3	89.5
	Mean=		3.8	2.4	2.4	29.7

RPD= Relative percent difference, the ratio of the difference and the mean of duplicate results expressed as a percentage.

Table D-2. Field Quality Assurance Results for Target Analytes.

Site ID	Date	NO2/NO3	Cl	TDS	NH3-N	T.Phos.	TOC	FC	TPN
BCMW1	6/19/95	0.01 U	2.49	99	0.01 U	0.332	9.2	2	0.565
BCMW1	6/19/95	0.01 U	2.49	172	0.01 U	0.341	9.3	2	0.602
RPD=		NA	0.0	53.9	NA	2.7	1.1	0.0	6.3
BCMW5A	6/19/95	19	71.2	351	0.011	0.03	3	30	19.4
BCMW5A	6/19/95	25	69.4	368	0.01 U	0.017	2.8	33	22.6
RPD=		27.3	2.6	4.7	NA	55.3	6.9	9.5	15.2
BCMW1	8/21/95	0.01 U	2.65	96	0.01 U	0.305	4	1 U	0.28
BCMW1	8/21/95	0.01 U	2.64	76	0.01 U	0.329	4	1 U	0.277
RPD=		NA	0.4	23.3	NA	7.6	0.0	NA	1.1
BCMW5A	8/22/95	21	62	351	0.01 U	0.01 U	2	11	4.635 J
BCMW5A	8/22/95	23	62.4	344	0.01 U	0.01 U	2.2	11	4.801 J
RPD=		9.1	0.6	2.0	NA	NA	9.5	0.0	3.5
BCMW1	10/17/95	0.444	3.13	116	0.01 U	0.074	5.2	1 U	0.853
BCMW1	10/17/95	0.475	3.13	114	0.01 U	0.071	5.1	1	0.821
RPD=		6.7	0.0	1.7	NA	4.1	1.9	NA	3.8
BCMW5A	10/18/95	21.3	64.2	374	0.01 U	0.01 U	2.2	69	22.6
BCMW5A	10/18/95	18.9	65.3	357	0.01 U	0.01 U	2.3	57 X	20.3
RPD=		11.9	1.7	4.7	NA	NA	4.4	19.0	10.7
BCMW1	12/18/95	2.8	10.3	229	0.011	0.01 U	17.2	1	4.43
BCMW1	12/18/95	2.82	10.2	231	0.024	0.563	17.2	2	4.45
RPD=		0.7	1.0	0.9	74.3	NA	0.0	66.7	0.5
BCMW5A	12/19/95	12.4	43.7	306	0.01 U	0.1	1.5	1 U	28.3
BCMW5A	12/19/95	23.6	44.1	303	0.01 U	0.01 U	1.6	1 U	26
RPD=		62.2	0.9	1.0	NA	NA	6.5	NA	8.5
BCMW1	2/26/96	0.081	3.84	152	0.03	0.558	16.5	2	1.18
BCMW1	2/26/96	0.01 U	3.82	150	0.028	0.526	16.7	1	1.01
RPD=		NA	0.5	1.3	6.9	5.9	1.2	66.7	15.5
BCMW5A	2/27/96	27	35.7	336	0.01 U	0.013	1.8	1 U	28
BCMW5A	2/27/96	27	36.6	323	0.01 U	0.021	1.8	1 U	37
RPD=		0.0	2.5	3.9	NA	47.1	0.0	NA	27.7
BCMW1	4/22/96	0.01 U	2.83	180	0.044	0.478	17.9	1	1.02
BCMW1	4/22/96	0.01 U	2.81	182	0.077	0.46	17.5	3	1.04
RPD=		NA	0.7	1.1	54.5	3.8	2.3	100.0	1.9
BCMW6	4/24/96	16.9	38.3	274	0.01 U	0.01 U	1 UJ	1 U	17
BCMW6	4/24/96	22.3	40.6	269	0.01 U	0.347 J	1 UJ	1 U	16.8
RPD=		27.6	5.8	1.8	NA	NA	NA	NA	1.2
BCMW1	6/24/96	0.01 U	2.25	119	0.071	0.484	9.2	1 U	1.06
BCMW1	6/24/96	0.01 U	2.24	119	0.095	0.454	9.3	1 U	1.04
RPD=		NA	0.4	0.0	28.9	6.4	1.1	NA	1.9
BCMW5A	6/25/96	22.5	38.7	283	0.01 U	0.01 U	1.1	1 U	20.4
BCMW5A	6/25/96	19.8	40.3	278	0.01 U	0.01 U	1.3	1 U	28
RPD=		12.8	4.1	1.8	NA	NA	16.7	NA	31.4
BCMW1	8/26/96	0.01	2.4	107	0.042	0.336	3.1 J	1 U	0.456
BCMW1	8/26/96	0.01 U	2.32	109	0.042	0.336	3.3 J	1 U	0.396
RPD=		NA	3.4	1.9	0.0	0.0	6.2	NA	14.1
BCMW5A	8/27/96	19.4	45	316	0.01 U	0.045	2 J	110	17.9
BCMW5A	8/27/96	18.6	47.4	311	0.01 U	0.047	2 J	68	19.2
RPD=		4.2	5.2	1.6	NA	4.3	0.0	47.2	7.0

Table D-2. Field Quality Assurance Results for Target Analytes.

Site ID	Date	NO2/NO3	Cl	TDS	NH3-N	T.Phos.	TOC	FC	TPN
BCMW1	10/28/96	3.7	5.5	162	0.01 U	0.04	5.5	1	4.5
BCMW1	10/28/96	3.17	5.54	168	0.01 U	0.043	5.9	1	4.68
RPD=		15.4	0.7	3.6	NA	7.2	7.0	0.0	3.9
BCMW5A	10/29/96	15.4	55	301	0.01 U	0.014	3.1	130	15.2
BCMW5A	10/29/96	16.6	54.6	300	0.01 U	0.017	2.8	130	15.1
RPD=		7.5	0.7	0.3	NA	19.4	10.2	0.0	0.7
BCMW1	12/16/96	4.24	6.76	192	0.017	0.085	22.3	1	5.06
BCMW1	12/16/96	4.22	6.65	188	0.016	0.088	19.8	1 U	5.07
RPD=		0.5	1.6	2.1	6.1	3.5	11.9	NA	0.2
BCMW5A	12/17/96	22	36.9	262	0.01 U	0.04	1.2	1	24.5
BCMW5A	12/17/96	24	36.3	276	0.01 U	0.032	1.2	1	23.5
RPD=		8.7	1.6	5.2	NA	22.2	0.0	0.0	4.2
BCMW1	2/24/97	0.023	7.89	151	0.016	0.366	15	1 U	1.27
BCMW1	2/24/97	0.01 U	7.84	145	0.017	0.258	16	1	1.21
RPD=		NA	0.6	4.1	6.1	34.6	6.1	0.0	4.8
BCMW5A	2/25/97	26.6	30.7	311	0.01 U	0.077	1.5	1 U	30.7
BCMW5A	2/25/97	26.3	31.2	322	0.01 U	0.147	2	1 U	29
RPD=		1.1	1.6	3.5	NA	62.5	28.6	NA	5.7
BCMW1	4/21/97	0.064	5.3	138	0.046	0.617 J	16.1	22	1.49
BCMW1	4/21/97	0.066	5.26	143	0.047	0.727	16	26	1.56
RPD=		3.1	0.8	3.6	2.2	16.4	0.6	16.7	4.6
BCMW5A	4/22/97	28.4	31.4	306	0.01 U	0.141	2	1 U	27.5
BCMW5A	4/22/97	28.4	30.7	302	0.01 U	0.08	1.9	1 U	26.4
RPD=		0.0	2.3	1.3	NA	55.2	5.1	NA	4.1
BCMW1	6/16/97	0.01 UJ	2.97	167	0.08 J	0.255 J	11.1	1 U	0.855 J
BCMW1	6/16/97	0.01 UJ	2.98	171	0.085 J	0.179 J	9.1	1 U	1 J
RPD=		NA	0.3	2.4	6.1	35.0	19.8	NA	15.6
BCMW5A	6/17/97	28 J	27.3	280	0.01 UJ	0.025 J	2.2	1	23.8 J
BCMW5A	6/17/97	25.3 J	28.6	283	0.01 UJ	0.031 J	2.6	3	24.2 J
RPD=		10.1	4.8	1.1	NA	21.4	16.7	100.0	1.7
BCMW1	8/11/97	0.01 U	2.68	100	0.089	0.312	6	1 U	0.404
BCMW1	8/11/97	0.01 U	2.68	103	0.08	0.311	6.2	1 U	0.402
RPD=		NA	0.0	3.0	10.7	0.3	3.3	NA	0.5
BCMW5A	8/12/97	19.7	28.7	271	0.01 U	0.048	2.8	1 U	20.3
BCMW5A	8/12/97	20.8	27.3	271	0.01 U	0.045	2.2	1 U	19.3
RPD=		5.4	5.0	0.0	NA	6.5	24.0	NA	5.1
BCMW1	10/20/97	1.28	5.48	186	0.01 U	0.046	11.1	2	2.03
BCMW1	10/20/97	1.27	5.68	187	0.01 U	0.047	9.6	1	2.06
RPD=		0.8	3.6	0.5	NA	2.2	14.5	66.7	1.5
BCMW5A	10/21/97	19.8	37.3	276	0.01 U	0.022	3.1	3	18.9
BCMW5A	10/21/97	18.8	38	285	0.01 U	0.019	3.5	3	19
RPD=		5.2	1.9	3.2	NA	14.6	12.1	0.0	0.5
BCMW1	12/15/97	1.59	3.46	150	0.01 U	0.08	9.6	1 U	2.43
BCMW1	12/15/97	1.63	3.45	153	0.01 U	0.136	9.5	1 U	2.37
RPD=		2.5	0.3	2.0	NA	51.9	1.0	NA	2.5
BCMW6	12/16/97	12.3	22.3	200	0.01 U	0.074	1 U	3 J	11.9
BCMW6	12/16/97	12	21.8	197	0.01 U	0.074	1 U	3 J	13.1
RPD=		2.5	2.3	1.5	NA	0.0	NA	0.0	9.6

Table D-2. Field Quality Assurance Results for Target Analytes.

Site ID	Date	NO2/NO3	Cl	TDS	NH3-N	T.Phos.	TOC	FC	TPN
BCMW1	2/22/98	0.04	2.59	115	0.008	0.103	10	1 U	0.59
BCMW1	2/22/98	0.046	2.61	113	0.015	0.089	9.4	1 U	0.729
RPD=		14.0	0.8	1.8	60.9	14.6	6.2	NA	21.1
BCMW5A	2/24/98	23 J	21.7	258	0.01 U	0.025	1.8	1 U	20.1 J
BCMW5A	2/24/98	24.1 J	21.1	267	0.01 U	0.028	1.7	1 U	20.5 J
RPD=		4.7	2.8	3.4	NA	11.3	5.7	NA	2.0
BCMW1	4/21/98	0.01 U	2.04	147	0.01 U	0.079	9.9	1 U	0.831
BCMW1	4/21/98	0.01 U	1.99	142	0.01 U	0.076	11.6	1 U	0.725
RPD=		NA	2.5	3.5	NA	3.9	15.8	NA	13.6
BCMW5A	4/23/98	23.2	20.9	255	0.01 U	0.016	2.2	1 U	23.1
BCMW5A	4/23/98	22.6	21.2	259	0.01 U	0.075	2.6	1 U	23
RPD=		2.6	1.4	1.6	NA	129.7	16.7	NA	0.4
BCMW1	6/15/98	0.01 U	2.35	102	0.022	0.054	4.85	1 U	0.339
BCMW1	6/15/98	0.01 U	2.31	101	0.018	0.049	4.6	1 U	0.341
RPD=		NA	1.7	1.0	20.0	9.7	5.3	NA	0.6
BCMW5A	6/16/98	19.7	21.3	262	0.01 U	0.032	2.4	1 U	19.3
BCMW5A	6/16/98	21.5	20.4	264	0.01 U	0.027	1.8	1 U	19.7
RPD=		8.7	4.3	0.8	NA	16.9	28.6	NA	2.1
BCMW1	8/17/98	0.01 U	2.32	96	0.021	0.104	4.8	1 U	0.312
BCMW1	8/17/98	0.01 U	2.31	100	0.012	0.093	4.6	1 U	0.326
RPD=		NA	0.4	4.1	54.5	11.2	4.3	NA	4.4
BCMW5A	8/18/98	14.2	24.1	251	0.01 U	0.021	2.1	1 U	13.6
BCMW5A	8/18/98	14.3	23.7	250	0.01 U	0.027	2.2	1 U	14.1
RPD=		0.7	1.7	0.4	NA	25.0	4.7	NA	3.6
BCMW1	10/19/98	0.328	3.79	95	0.01 U	0.025 J	2.7	1 U	0.517
BCMW1	10/19/98	0.348	3.8	97	0.01 U	0.036	2.7	1 U	0.602
RPD=		5.9	0.3	2.1	NA	36.1	0.0	NA	15.2
BCMW5A	10/20/98	15.6	22.7	239	0.01 U	0.01 UJ	1.9	1 U	15.2
BCMW5A	10/20/98	15.3	23.4	244	0.01 U	0.014	2.2	1 U	14.9
RPD=		1.9	3.0	2.1	NA	33.3	14.6	NA	2.0
BCMW1	12/14/98	16	11.3	307	0.023	0.05	12	1 U	22.8 J
BCMW1	12/14/98	18.3	11.3	283	0.021	0.054	13.9	1 U	21.3 J
RPD=		13.4	0.0	8.1	9.1	7.7	14.7	NA	6.8
BCMW5A	12/15/98	12	17.4	221	0.01 U	0.014	2.2	1 U	16.6
BCMW5A	12/15/98	10.4	17.6	216	0.01 U	0.011	2.4	1 U	16.6 J
RPD=		14.3	1.1	2.3	NA	24.0	8.7	NA	0.0
BCMW1	2/22/99	0.036	3.04	103	0.01 U	0.124	8.2	3	
BCMW1	2/22/99	0.042	3.04	104	0.019 J	0.122	8.5	3	
RPD=		15.4	0.0	1.0	NA	1.6	3.6	0.0	
BCMW5A	2/23/99	19	15.5	246	0.01 U	0.022	3.8	1 U	
BCMW5A	2/23/99	19.6	16.7	240	0.01 U	0.014	1.6	1 U	
RPD=		3.1	7.5	2.5	NA	44.4	81.5	NA	
BCMW1	4/26/99	0.01 U	3.49	142	0.033	0.293	11.9	1	
BCMW1	4/26/99	0.01 U	3.6	139	0.034	0.296	11.9	1 U	
RPD=		NA	3.1	2.1	3.0	1.0	0.0	NA	
BCMW5A	4/27/99	19.6	15.3	231	0.01 U	0.025	1	1 U	
BCMW5A	4/27/99	19.7	15.6	225	0.01 U	0.023	1.3	1 U	
RPD=		0.5	1.9	2.6	NA	8.3	26.1	NA	

Table D-2. Field Quality Assurance Results for Target Analytes.

Site ID	Date	NO2/NO3	Cl	TDS	NH3-N	T.Phos.	TOC	FC	TPN
BCMW1	6/14/99	0.01 U	2.44	73	0.022	0.146	5.8	1 U	
BCMW1	6/14/99	0.01 U	2.42	75	0.02	0.148	5.8	1 U	
RPD=		NA	0.8	2.7	9.5	1.4	0.0	NA	
BCMW5A	6/15/99	20	16.9	238	0.033	0.036	1.3	1 U	
BCMW5A	6/15/99	20.7	16.9	231	0.032	0.036	1.4	1 U	
RPD=		3.4	0.0	3.0	3.1	0.0	7.4	NA	
BCMW1	8/31/99	0.01 U	3.64	88	0.04	0.102	2.4	1 U	
BCMW1	8/31/99	0.017	3.68	84	0.04	0.102	2.4	1 U	
RPD=		NA	1.1	4.7	0.0	0.0	0.0	NA	
BCMW5A	9/1/99	19.3	16.9	229	0.031	0.037	1.4	1 U	
BCMW5A	9/1/99	20.2	16.6	242	0.032	0.039	1.3	1 U	
RPD=		4.6	1.8	5.5	3.2	5.3	7.4	NA	
BCMW1	10/17/99	0.094	3.72	80	0.01 U	0.07	2.2	1 U	
BCMW1	10/17/99	0.097	3.75	72	0.01 U	0.067	2.3	1 U	
RPD=		3.1	0.8	10.5	NA	4.4	4.4	NA	
BCMW5A	10/19/99	18.5	17.1	212	0.01 U	0.052	1.4	1	
BCMW5A	10/19/99	18.8	17.2	221	0.01 U	0.054	1.5	1	
RPD=		1.6	0.6	4.2	NA	3.8	6.9	0.0	
BCMW1	12/27/99	2.31	6.28	117	0.01 U	0.069	8.8	1 U	
BCMW1	12/27/99	2.27	6.41	117	0.01 U	0.066	8.8	1 U	
RPD=		1.7	2.0	0.0	NA	4.4	0.0	NA	
BCMW5A	12/28/99	19	17.9	228	0.01 U	0.035	1.2	1 U	
BCMW5A	12/28/99	18.9	18	217	0.01 U	0.031	1.5	1 U	
RPD=		0.5	0.6	4.9	NA	12.1	22.2	NA	
BCMW1	2/20/00	0.01 U	5.5	112	0.01 U	0.154	10.1		
BCMW1	2/20/00	0.01 U	5.48	111	0.01 U	0.158	9.9		
RPD=		NA	0.4	0.9	NA	2.6	1.5		
BCMW5A	2/21/00	30.6	25.6	271	0.01 U	0.026	1.4	1 U	
BCMW5A	2/21/00	25.3	26.2	305	0.01 U	0.027	1.4	1 U	
RPD=		19.0	2.3	11.8	NA	3.8	0.0	NA	
BCMW1	5/15/00	0.01 U	2.19	130	0.01 U	0.199	9.6	1 U	
BCMW1	5/15/00	0.01 U	2.16	138	0.01 U	0.198	9.8	1 U	
RPD=		NA	1.4	6.0	NA	0.5	2.1	NA	
BCMW5A	5/16/00	30.1	31.2	306	0.01 U	0.035	1.7	2	
BCMW5A	5/16/00	29.4	30.8	317	0.01 U	0.033	1.7	1	
RPD=		2.4	1.3	3.5	NA	5.9	0.0	66.7	
BCMW1	6/19/00	0.061	2.5	102 J	0.01 U	0.068	5.4	1 U	
BCMW1	6/19/00	0.059	2.46	101 J	0.01 U	0.066	5.5	1 U	
RPD=		3.3	1.6	1.0	NA	3.0	1.8	NA	
BCMW5A	6/20/00	30.3	28.3	314	0.01 U	0.029	1.7	1 U	
BCMW5A	6/20/00	32.1	28.5	332	0.01 U	0.028	1.8	2	
RPD=		5.8	0.7	5.6	NA	3.5	5.7	NA	
Minimum=		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maximum=		62.2	7.5	53.9	74.3	129.7	81.5	100.0	31.4
N=		45	62	62	19	56	60	20	44
Mean=		7.9	1.7	4.0	18.9	16.4	8.6	28.0	6.5

RPD= Relative percent difference, the ratio of the difference and mean of duplicate results expressed as a percentage.

Appendix E

Water Quality Results

Table E-1. Thurston County Dairy Field Parameter Results.

ID	Sample Date	pH (SU)	Specific Conduct. (umhos/cm)	Temp (°C)	Dissolved Oxygen (mg/L)	ID	Sample Date	pH (SU)	Specific Conduct. (umhos/cm)	Temp (°C)	Dissolved Oxygen (mg/L)
MW1	6/19/95	6.40	146	10.1		**MW2**	6/19/95	6.23	88	9.3	
	8/21/95	6.09	141	12.0			8/21/95	5.84	104	11.6	
	10/17/95	6.17	173	12.6			10/17/95	5.77	125	12.0	
	12/18/95	5.87	311	12.0			12/18/95	5.72	152	11.9	
	2/26/96	6.33	199	9.0			2/26/96	5.95	125	9.7	
	4/22/96	6.38	261	8.2			4/22/96	6.20	85	9.0	
	6/24/96	6.47	190	10.1			6/24/96	6.23	82	10.0	
	8/26/96	6.23	158	11.8			8/26/96	5.87	93	11.0	
	10/28/96	6.09	261	12.2			10/28/96	6.18	115	11.9	
	12/16/96	5.96	304	11.3			12/16/96	5.84	168	10.8	
	2/24/97	6.15	189	8.0			2/24/97	5.72	109	8.8	
	4/21/97	5.73	185	8.3			4/21/97	4.99	86	8.8	
	6/16/97	6.06	243	10.1			6/16/97	5.68	73	9.8	
	8/11/97	6.31	130	12.1			8/11/97	5.99	80	11.8	
	10/20/97	6.16	265	12.3			10/20/97	6.09	101	11.9	
	12/15/97	6.46	197	12.1			12/15/97	6.06	132	12.1	
	2/22/98	6.15	176	7.9			2/22/98	5.66	115	9.3	
	4/21/98	6.37	210	9.9			4/21/98	6.06	79	10.9	
	6/15/98	6.40	140	9.7			6/15/98	6.11	71	9.8	
	8/17/98	6.48	170	11.9			8/17/98	6.10	95	11.1	
	10/19/98	5.77	125	11.9			10/19/98	5.58	95	11.6	
	12/14/98	6.10	404	12.0			12/14/98	5.84	158	12.2	
	2/22/99	6.33	122	8.8			2/22/99	6.18	118	9.8	
	4/26/99	6.28	167	8.5			4/26/99	5.97	70	9.3	
	6/14/99	6.24	127	10.1			6/14/99	6.00	65	10.7	
	8/31/99	6.01	116	11.1	0.76		8/31/99	5.63	85	10.7	1.55
	10/17/99	5.73	115	12.0	1.36		10/17/99	5.53	99	11.7	1.39
	12/27/99	5.67	179	10.7	1.06		12/27/99	5.32	121	10.1	4.81
	2/20/00	5.61	149	8.2	1.13		2/20/00	5.44	92	9.8	6.75
	5/15/00	5.70	187	8.9	1.72		5/15/00	5.64	72	9.8	3.16
	6/19/00	5.49	128	9.4	1.07		6/19/00	5.28	70	9.6	1.55
Minimum=		5.49	115	7.9	0.76			4.99	65	8.8	1.39
Maximum=		6.48	404	12.6	1.72			6.23	168	12.2	6.75
Mean=		6.10	189	10.4	1.18			5.83	101	10.5	3.20
Median=		6.15	176	10.1	1.10			5.84	95	10.7	2.36

	Sample Date	pH (SU)	Specific Conduct. (umhos/cm)	Temp (°C)	Dissolved Oxygen (mg/L)		Sample Date	pH (SU)	Specific Conduct. (umhos/cm)	Temp (°C)	Dissolved Oxygen (mg/L)
MW3	6/19/95	6.34	188	10.7		**MW4**	6/19/95	5.56	525	10.5	
	8/21/95	6.23	161	13.0			8/21/95	5.54	385	12.3	
	10/17/95	6.42	172	12.5			10/17/95	5.71	335	12.4	
	12/18/95	6.23	190	11.2			12/18/95	5.54	530	11.2	
	2/26/96	6.22	213	9.7			2/26/96	5.95	398	9.5	
	4/22/96	6.35	203	10.0			4/22/96	5.95	360	9.6	
	6/24/96	6.18	198	11.4			6/24/96	5.44	338	10.5	
	8/26/96	6.22	164	11.7			8/26/96	5.55	280	11.7	

Table E-1. Thurston County Dairy Field Parameter Results.

MW3	10/28/96	6.71	183	11.7		**MW4**	10/28/96	6.00	312	11.3	
	12/16/96	5.92	210	9.5			12/16/96	5.67	600	10.5	
	2/24/97	6.19	188	9.1			2/24/97	5.34	351	9.9	
	4/21/97	5.72	192	9.8			4/21/97	4.87	270	9.3	
	6/16/97	5.92	192	10.9			6/16/97	5.09	275	11.5	
	8/11/97	6.4	155	14.0			8/11/97	5.68	218	13.0	
	10/20/97	6.44	175	12.0			10/20/97	5.72	208	11.6	
	12/15/97	6.67	183	10.9			12/15/97	6.02	250	11.1	
	2/22/98	5.98	220	8.8			2/22/98	5.07	463	8.7	
	4/21/98	6.39	215	10.8			4/21/98	5.54	325	10.4	
	6/15/98	6.3	200	10.7			6/15/98	6.04	310	10.9	
	8/17/98	6.59	200	12.7			8/17/98	5.79	270	12.8	
	10/19/98	6.32	170	11.8			10/19/98	5.67	198	12.1	
	12/14/98	6.38	190	11.3			12/14/98	5.38	670	11.3	
	2/22/99	6.43	195	9.6			2/22/99	5.31	210	9.0	
	4/26/99	6.3	192	9.8			4/26/99	5.57	221	8.9	
	6/14/99	6.26	194	12.1			6/14/99	5.61	222	10.9	
	8/31/99	6.04	185	11.6	0.79		8/31/99	5.34	192	10.9	
	10/17/99	5.8	180	11.7	1.61		10/17/99	5.40	181	11.8	6.10
	12/27/99	5.81	195	9.6	1.45		12/27/99	4.84	840	10.1	6.28
	2/20/00	5.66	200	9.5	1.01		2/20/00	5.18	570	9.9	6.88
	5/15/00	6.08	199	10.4	2.18		5/15/00	5.22	352	10.4	8.62
	6/19/00	5.79	185	10.5	0.24		6/19/00	5.22	313	10.6	6.50
Minimum=		5.66	155	8.8	0.24			4.84	181	8.7	6.10
Maximum=		6.71	220	14.0	2.18			6.04	840	13.0	8.62
Mean=		6.20	190	10.9	1.21			5.51	354	10.8	6.88
Median=		6.23	192	10.9	1.23			5.54	313	10.9	6.50
	Sample Date	**pH (SU)**	**Specific Conduct. (umhos/cm)**	**Temp (°C)**	**Dissolved Oxygen (mg/L)**		**Sample Date**	**pH (SU)**	**Specific Conduct. (umhos/cm)**	**Temp (°C)**	**Dissolved Oxygen (mg/L)**
MW5A	6/19/95	5.67	535	12.3		**MW5B**	6/19/95	6.35	270	11.5	
	8/22/95	5.61	535	13.8			8/22/95	6.05	292	12.0	
	10/18/95	5.72	550	14.1			10/18/95	6.45	335	12.2	
	12/19/95	5.82	430	11.3			12/19/95	6.26	250	10.8	
	2/27/96	6.46	498	9.1			2/27/96	7.14	240	9.7	
	4/24/96	6.05	465	10.3			4/24/96	6.64	258	11.9	
	6/25/96	5.76	404	11.9			6/25/96	6.31	279	11.8	
	8/27/96	5.54	464	13.6			8/27/96	6.12	303	11.8	
	10/29/96	5.45	458	12.8			10/29/96	5.98	310	11.0	
	12/17/96	5.00	455	10.6			12/17/96	6.61	290	10.6	
	2/25/97	5.18	404	9.6			2/25/97	6.26	233	10.9	
	4/22/97		420	9.7			4/22/97		240	11.5	
	6/17/97	5.51	433	11.7			6/17/97	6.02	265	11.6	
	8/12/97	5.89	390	14.7			8/12/97	6.45	270	13.2	
	10/21/97	5.77	417	13.3			10/21/97	6.51	266	10.9	
	12/16/97		320	11.6			12/16/97	6.98	225	11.0	
	2/24/98	5.68	432	9.4			2/24/98	6.10	275	10.2	
	4/23/98	5.53	360	10.2			4/23/98	6.17	228	11.3	
	6/16/98	5.89	390	12.4			6/16/98	6.31	268	12.5	

Table E-1. Thurston County Dairy Field Parameter Results.

MW5A	8/18/98	5.89	335	13.9		**MW5B**	8/18/98	6.39	270	12.0	
	10/20/98	5.96	338	14.0			10/20/98	6.48	268	11.7	
	12/15/98	5.82	295	11.4			12/15/98	6.35	239	10.7	
	2/23/99	5.74	320	9.8			2/23/99	6.03	210	10.8	
	4/27/99	5.84	314	10.0			4/27/99	6.38	207	11.3	
	6/15/99		339	11.7			6/15/99		225	12.1	
	9/1/99	6.14	319	14.5	1.01		9/1/99	6.91	230	12.9	0.45
	10/19/99	5.56	321	13.4	1.29		10/19/99	5.87	226	11.6	0.96
	12/28/99	5.31	311	11.0	1.42		12/28/99	5.74	206	10.8	1.35
	2/21/00	5.26	422	9.7			2/21/00	6.08	198	11.0	
	5/16/00	5.28	455	11.4	0.64		5/16/00	5.51	208	12.3	0.47
	6/20/00	5.81	431	12.2	0.56		6/20/00	6.48	204	12.3	0.00
Minimum=		5.00	295	9.1	0.56			5.51	198	9.7	0.00
Maximum=		6.46	550	14.7	1.42			7.14	335	13.2	1.35
Mean=		5.68	405	11.8	0.98			6.31	251	11.5	0.65
Median=		5.73	417	11.7	1.01			6.31	250	11.5	0.47
	Sample Date	**pH (SU)**	**Specific Conduct. (umhos/cm)**	**Temp (°C)**	**Dissolved Oxygen (mg/L)**		**Sample Date**	**pH (SU)**	**Specific Conduct. (umhos/cm)**	**Temp (°C)**	**Dissolved Oxygen (mg/L)**
MW6	6/19/95	5.88	455	10.9		**MW7**	6/19/95	5.19	620	10.4	
	8/22/95	5.78	415	12.6			8/21/95	5.09	600	11.8	
	10/18/95	6.17	370	12.4			10/17/95	5.22	590	10.2	
	12/19/95	5.92	400	11.5			12/18/95	5.14	460	9.8	
	2/27/96	6.61	430	9.6			2/26/96	5.86	391	9.4	
	4/24/96	5.70	383	10.7			4/22/96	6.29	375	9.8	
	6/25/96	5.76	338	11.4			6/24/96	5.17	305	10.8	
	8/26/96	5.70	395	12.0			8/27/96	5.29	236	9.7	
	10/29/96	5.72	338	11.3			10/28/96	5.20	218	9.5	
	12/17/96	6.24	315	11.3			12/16/96	6.30	235	9.0	
	2/25/97	5.83	318	10.4			2/24/97	4.96	251	10.4	
	4/22/97		322	10.9			4/21/97	4.88	260	10.9	
	6/17/97	5.75	260	11.0			6/16/97	4.77	245	11.3	
	8/12/97	6.24	232	12.6			8/11/97	5.44	255	12.1	
	10/21/97	6.06	245	11.6			10/20/97	5.42	245	10.4	
	12/16/97	6.78	275	11.6			12/15/97	5.74	270	10.3	
	2/24/98	5.77	340	9.9			2/22/98	4.20	320	10.1	
	4/23/98	5.72	190	10.9			4/22/98	5.23	315	11.9	
	6/16/98	6.31	220	12.1			6/15/98	5.27	290	11.2	
	8/18/98	5.97	345	12.4			8/17/98	5.41	295	11.8	
	10/20/98	6.17	340	12.9			10/19/98	5.40	253	12.1	
	12/15/98	6.08	357	11.6			12/14/98	5.16	405	11.2	
	2/23/99	5.82	420	9.9			2/22/99	4.50	410	11.5	
	4/27/99	5.97	295	9.7			4/26/99	5.10	392	13.4	
	6/15/99		268	11.2			6/14/99	5.05	330	15.2	
	9/1/99	6.29	268	13.1	1.08		9/1/99	5.62	265	11.9	
	10/19/99	5.83	253	12.3	1.40		10/18/99	5.00	273	11.6	1.89
	12/28/99	5.61	387	11.2	1.18		12/27/99	4.47	395	10.9	1.11
	2/21/00	5.51	319	10.3			2/20/00	4.54	420	11.6	1.74
	5/16/00	5.48	241	11.8	1.27		5/15/00	4.78	440	12.0	1.87

Table E-1. Thurston County Dairy Field Parameter Results.

MW6	6/20/00	6.03	215	11.9	0.82	**MW7**	6/19/00	4.67	372	11.8	1.27
Minimum=		5.48	190	9.6	0.82			4.20	218	9.0	1.11
Maximum=		6.78	455	13.1	1.40			6.30	620	15.2	1.89
Mean=		5.96	321	11.4	1.15			5.17	346	11.1	1.58
Median=		5.88	322	11.4	1.18			5.17	315	11.2	1.74

	Sample Date	pH (SU)	Specific Conduct. (umhos/cm)	Temp (°C)	Dissolved Oxygen (mg/L)		Sample Date	pH (SU)	Specific Conduct. (umhos/cm)	Temp (°C)	Dissolved Oxygen (mg/L)
MW8	6/19/95	5.76	725	11.8		**MW9**	6/19/95	5.88	430	11.2	
	8/21/95	5.91	690	12			8/22/95	5.66	392	12.7	
	10/17/95	5.95	700	11.5			10/18/95	5.76	485	12.4	
	12/18/95	5.67	650	10			12/19/95	5.65	460	10.7	
	2/26/96	6.30	640	11.5			2/27/96	5.84	372	8.8	
	4/22/96	5.88	600	11.2			4/24/96	5.74	312	10.1	
	6/24/96	5.67	650	12.9			6/25/96	5.71	292	11.5	
	8/27/96	5.62	610	11.4			8/26/96	5.57	283	13.5	
	10/28/96	5.84	520	11			10/29/96			12.7	
	12/16/96	6.17	525	10.5			12/17/96	5.00	360	9.0	
	2/24/97	5.47	510	12.6			2/25/97	4.96	342	9.1	
	4/21/97	5.52	500	11.7			4/22/97	4.97	298	9.6	
	6/16/97	5.45	590	11.6			6/17/97	5.30	262	10.7	
	8/11/97	5.86	475	13.7			8/12/97	5.95	245	13.5	
	10/20/97	5.97	369	11.3			10/21/97	5.69	239	11.8	
	12/15/97	6.42	360	10.2			12/16/97	6.02	320	10.9	
	2/22/98	5.27	550	9.8			2/22/98	5.72	620	8.5	
	4/22/98	5.72	520	12.2			4/22/98	5.59	455	11.5	
	6/15/98	6.06	540	11.4			6/15/98	5.75	425	11.0	
	8/17/98	5.96	555	12.3			8/17/98	5.80	418	13.9	
	10/19/98	5.90	445	11.9			10/20/98	5.54	317	12.5	
	12/15/98	5.81	345	10.2			12/15/98	5.69	545	10.5	
	2/22/99	4.32	570	11			2/23/99	5.67	575	9.3	
	4/26/99	5.96	502	11.1			4/27/99	5.72	340	9.4	
	6/14/99	5.68	520	13.3			6/15/99	6.55	320	10.8	
	9/1/99	6.30	480	13			9/1/99	6.18	295	13.2	
	10/18/99	5.48	425	12.2	3.57		10/18/99	5.45	298	13.1	3.93
	12/27/99	5.04	480	10.8	1.56		12/28/99	5.14	435	10.4	3.08
	2/20/00	5.13	475	11.4	3.38		2/21/00	4.85	437	8.9	
	5/15/00	5.27	498	12.5	3.96		5/16/00	5.13	395	10.4	2.00
	6/19/00	5.31	480	12.2	4.88		6/20/00	5.34	363	10.9	4.24
Minimum=		4.32	345	9.8	1.56			4.85	239	8.5	2.00
Maximum=		6.42	725	13.7	4.88			6.55	620	13.9	4.24
Mean=		5.70	532	11.6	3.47			5.59	378	11.0	3.31
Median=		5.76	520	11.5	3.57			5.68	362	10.9	3.51

	Sample Date	pH (SU)	Specific Conduct. (umhos/cm)	Temp (°C)	Dissolved Oxygen (mg/L)		Sample Date	pH (SU)	Specific Conduct. (umhos/cm)	Temp (°C)	Dissolved Oxygen (mg/L)
MW10	6/20/95	5.40	860	10.7		**MW11**	6/20/95	5.52	470	10.2	
	8/22/95	5.47	900	12.5			8/22/95	5.40	575	12.4	
	10/18/95	5.62	920	13.1			10/18/95	5.70	510	13.2	

Table E-1. Thurston County Dairy Field Parameter Results.

MW10	12/19/95	5.55	740	10.3		**MW11**	12/19/95	5.30	780	11.3	
	2/27/96	6.17	740	10			2/27/96	6.16	475	9.1	
	4/24/96	5.54	725	10.3			4/24/96	5.50	380	9.3	
	6/25/96	5.51	740	12			6/25/96	5.52	399	12.0	
	8/26/96	5.45	735	12.9			8/26/96	5.40	368	12.9	
	10/29/96	5.25	630	12.9			10/29/96	5.24	402	13.3	
	12/17/96		675	10.5			12/17/96		>1000	10.1	
	2/25/97	4.68	520	9.7			2/25/97	4.47	342	8.3	
	4/22/97	4.74	700	10.5			4/22/97	4.61	275	9.0	
	6/16/97	5.31	720	11.5			6/17/97	5.41	264	11.1	
	8/12/97	5.69	680	13.2			8/12/97	5.88	250	12.7	
	10/21/97	5.56	650	12.5			10/21/97	5.63	411	13.1	
	12/16/97	6.06	430	11.2			12/15/97	5.35	1000	11.9	
	2/22/98	5.50	485	9			2/22/98	5.80	385	8.3	
	4/22/98	5.61	500	11.8			4/22/98	5.70	314	10.8	
	6/15/98	5.79	550	11.3			6/15/98	5.80	335	11.0	
	8/17/98	5.75	700	13.2			8/17/98	5.73	350	13.5	
	10/20/98	5.58	690	12.8			10/20/98	5.33	314	12.3	
	12/15/98	5.65	500	10.6			12/15/98	5.11	1000	11.0	
	2/23/99	5.56	825	10.5			2/23/99	5.50	420	8.7	
	4/27/99	5.53	780	10.3			4/27/99	5.64	280	9.0	
	6/15/99		700	11.2			6/15/99		310	10.5	
	9/1/99	5.98	650	13.4	5.13		9/1/99	6.11	320	12.8	8.65
	10/18/99	5.31	735	12.9	5.54		10/18/99	5.48	330	12.5	7.88
	12/28/99	4.91	420	10.4	1.84		12/28/99	4.64	650	10.0	5.56
	2/21/00	4.88	425	9.7			2/21/00	4.41	318	8.9	
	5/16/00	5.06	450	10.5	3.31		5/16/00	5.17	268	10.1	4.36
	6/20/00	5.46	445	11	4.64		6/20/00	5.33	275	10.8	6.1
Minimum=		4.68	420	9.0	1.84			4.41	250	8.3	4.36
Maximum=		6.17	920	13.4	5.54			6.16	1000	13.5	8.65
Mean=		5.47	652	11.4	4.09			5.41	426	11.0	6.51
Median=		5.53	690	11.2	4.64			5.48	359	11.0	6.10
	Sample Date	**pH (SU)**	**Specific Conduct. (umhos/cm)**	**Temp (°C)**	**Dissolved Oxygen (mg/L)**						
MW12	6/16/97	5.68	159	10.9							
	8/11/97	6.18	122	13.7							
	10/20/97	6.32	152	11							
	12/15/97	6.41	172	10.7							
	2/22/98	6.20	178	10							
	4/21/98	6.24	165	12.2							
	6/15/98	6.55	167	11.7							
	8/17/98	6.42	170	12.1							
	10/19/98	6.10	150	11							
	12/14/98	6.28	127	11							
	2/22/99	6.22	162	10.6							
	4/26/99	6.13	158	11.4							
	6/14/99	6.07	155	13.1							
	8/31/99	5.74	155	11.4	5.09						

Table E-1. Thurston County Dairy Field Parameter Results.

MW12	10/17/99	5.87	157	12.1	5.03
	12/27/99	5.43	160	10.5	3.2
	2/20/00	5.50	168	10.8	4.29
	5/15/00	5.65	161	12.3	5.19
	6/19/00	5.34	150	12.1	5.6
Minimum=		5.34	122	10.0	3.20
Maximum=		6.55	178	13.7	5.60
Mean=		5.76	371	11.4	4.33
Median=		6.13	159	11.4	5.06

	Sample Date	**pH (SU)**	**Specific Conduct. (umhos/cm)**	**Temp (°C)**	**Dissolved Oxygen (mg/L)**		**Sample Date**	**pH (SU)**	**Specific Conduct. (umhos/cm)**	**Temp (°C)**	**Dissolved Oxygen (mg/L)**
Domestic	4/28/95	5.83	103	10.6		**Irrigation**	4/28/95	5.88	190	11.8	
	6/20/95	5.86	150	10.8			6/20/95	5.77	200	11.4	
	8/21/95	5.80	150	11.3			8/21/95	5.89	183	12.5	
	10/17/95	6.27	150	10.2			10/17/95	6.24	152	11.1	
	12/18/95	5.67	158	10.5			12/18/95	5.95	218	10.6	
	2/26/96	6.39	140	10.4			2/26/96	6.37	212	11.7	
	4/22/96	6.06	130	10.7			4/22/96	6.12	178	11.2	
	6/24/96	5.81	128	10.6			6/24/96	5.85	155	11.5	
	8/26/96	5.76	123	10.6			8/26/96	5.96	143	11.7	
	10/28/96	6.37	138	9.9			10/28/96	6.23	150	10.8	
	12/16/96	6.28	150	9.7			12/16/96	6.01	196	10.5	
	2/24/97	5.93	106	11.5			2/24/97	5.85	187	11.2	
	4/21/97	5.44	108	10.8			4/21/97	5.27	190	11.8	
	6/16/97	5.50	110	10.5			6/16/97	5.34	155	11.3	
	8/11/97	6.08	89	12.4			8/11/97	6.15	112	12.3	
	10/20/97	6.11	117	9.9			10/20/97	6.04	122	10.8	
	12/15/97	6.48	120	10			12/15/97	6.58	140	10.8	
	2/22/98	5.00	125	9.6			2/22/98	5.81	209	10.1	
	4/21/98	6.08	112	11.8			4/21/98	5.93	170	12.6	
	6/15/98	6.21	108	10.8			6/15/98	6.63	144	11.5	
	8/17/98	6.28	145	14			8/17/98	6.07	145	12.6	
	10/19/98	5.59	113	11.4			10/19/98	5.37	115	12	
	12/14/98	5.86	118	11.2			12/14/98	6.03	158	11.7	
	2/22/99	4.98	100	10.1			2/22/99	5.69	195	10.6	
	4/26/99	5.91	88	10.1			4/26/99	5.78	163	12	
	6/14/99	5.78	86	12.7			6/14/99	5.81	128	14.8	
	8/31/99	5.59	91	10.9			8/31/99	5.68	117	11.3	
	10/17/99	5.60	108	10.3	4.52		10/17/99	5.56	125	11.8	3.03
	12/27/99	4.88	97	9.2	3.9						
	2/20/00	5.38	111	10.7	3.9		2/20/00	5.60	208	12	3.47
	5/15/00	5.43	108	12.3	5.84		5/15/00	5.20	148	13.5	6.81
	6/19/00	5.35	98	10.6	4.13		6/19/00	5.20	142	12	6.96
Minimum=		4.88	86	9.2	3.90			5.20	112	10.1	3.03
Maximum=		6.48	158	14.0	5.84			6.63	218	14.8	6.96
Mean=		5.80	118	10.8	4.46			5.87	163	11.7	5.07
Median=		5.82	113	10.6	4.13			5.88	155	11.7	5.14

Table E-1. Thurston County Dairy Field Parameter Results.

	Sample Date	pH (SU)	Specific Conduct. (umhos/cm)	Temp (°C)	Dissolved Oxygen (mg/L)		Sample Date	pH (SU)	Specific Conduct. (umhos/cm)	Temp (°C)	Dissolved Oxygen (mg/L)
Upstream	6/20/95	6.64	105	13.7		**Down-**	6/20/95	6.65	125	14.8	
Station	8/22/95	6.47	141	19.1		**Stream**	8/22/95	6.42	142	17.2	
	10/18/95	6.74	140	10.6		**Station**	10/18/95	6.89	143	9.2	
	2/27/96	7.61	70	4.3			2/27/96	7.43	84	4.6	
	4/24/96	6.36	52	11.5			4/24/96	6.63	53	11.4	
	6/25/96	6.56	109	16.8			6/25/96	7.00	110	17.7	
	8/27/96	6.52	147	16.4			8/27/96	6.27	151	17	
	10/29/96	6.31	105	9.1			10/29/96	5.29	96	9.3	
	12/17/96	7.47	72	4.8			12/17/96	6.90	79	4.8	
	2/25/97	6.68	52	6.9			2/25/97	6.74	69	7.6	
	4/22/97		58	11.1			4/22/97		66	11.6	
	6/17/97	7.16	85	15.5			6/17/97	6.33	90	16.3	
	8/12/97	6.88	125	18.8			8/12/97	6.78	121	20.6	
	10/21/97	6.64	92	8.8			10/21/97	6.52	91	9	
	12/16/97	8.78	44	7.6			12/16/97	8.51	52	7.8	
	2/24/98	7.06	71	6.3			2/24/98	6.67	80	6.1	
	4/22/98	6.87	75	14.3			4/22/98	6.78	88	15.4	
	6/16/98	6.75	105	16.2			6/16/98	6.75	110	16.8	
	8/18/98	7.08	130	16.4			8/18/98	6.82	115	16.1	
	10/20/98	6.82	160	10.4			10/20/98	6.38	122	10.8	
	12/15/98	6.56	52	7.5			12/15/98	6.45	60	7.2	
	2/23/99	5.84	45	6.5			2/23/99	5.76	53	6.4	
	4/27/99	6.75	66	10.4			4/27/99	6.67	84	12	
	6/15/99		91	17.1			6/15/99		91	17.9	
	9/1/99	7.27	143	16			9/1/99	6.93	127	15.7	
	10/19/99	6.27	167	8.2	6.12		10/19/99	5.67	128	9.9	6.13
	12/28/99	5.30	73	5.4	6.70		12/28/99	5.20	75	5	6.95
	2/21/00	5.70	70	6.9	12.2		2/21/00	5.85	77	5	11.59
	5/16/00	6.38	94	15.3	6.20		5/16/00	6.19	92	16.7	5.99
	6/20/00	6.97	101	15.6	7.14		6/20/00	6.82	102	17.1	5.68
Minimum=		5.30	44	4.3	6.12	Minimum=		5.20	52	4.6	5.68
Maximum=		8.78	167	19.1	12.2	Maximum=		8.51	151	20.6	11.6
Mean=		6.73	95	11.6	7.67	Mean=		6.55	96	11.9	7.27
Median=		6.71	92	10.9	6.70	Median=		6.66	91	11.5	6.13

Table E-1. Thurston County Dairy Field Parameter Results.

	Sample Date	pH (SU)	Specific Conduct. (umhos/cm)	Temp (°C)	Dissolved Oxygen (mg/L)
Allen	12/15/98	6.83	60	7.7	
Creek	2/23/99	5.70	60	6.6	
	4/27/99	6.68	79	12.7	
	6/15/99		85	18.3	
	9/1/99	7.19	90	16.6	
	10/19/99	6.18	91	10.3	6.57
	12/28/99	5.05	74	5.0	
	2/21/00	6.26	77	8.3	11.3
	5/16/00	6.27	87	17.8	7.04
	6/20/00	6.83	87	18.0	5.13
Minimum=		5.05	60	5.0	5.13
Maximum=		7.19	91	18.3	11.3
Mean=		6.33	79	12.1	7.50
Median=		6.27	82	11.5	6.81

Table E-2. Thurston County Dairy Nitrate+Nitrite-N Results (mg/L).

Sample	Front Field			West Field				North Field	
Date	MW1	MW2	MW3	MW12	MW7	MW8	MW9	MW11	MW10
28-Apr-95									
19-Jun-95	0.01 U	0.27	0.01		32.0	42.0	22.0	19.0	80.0
21-Aug-95	0.01 U	0.58	0.01		26.1	35.0	22.0	28.0	60.0
17-Oct-95	0.46	1.10	0.01 U		24.4	34.1	26.7	23.8	57.0
18-Dec-95	2.81	7.63	0.18		20.7	35.0	30.0	59.0	49.0
26-Feb-96	0.04	2.83	0.01 U		16.5	24.0	18.0	21.0	45.0
22-Apr-96	0.01 U	0.55	0.03		17.1	35.0	17.5	15.1	45.9
24-Jun-96	0.01 U	0.18	0.01 U		14.6	38.8	15.0	11.8	51.6
26-Aug-96	0.01	0.35	0.03		8.61	72	15.4	14.2	50.9
28-Oct-96	3.44	0.62	0.01 U		6.81	22.6	15.2	21.6	47.4
16-Dec-96	4.23	7.68	0.01 U		8.18	24	22.8	123	54
24-Feb-97	0.01	3.01	0.02		9.51	26.35	18.3	10.6	32
21-Apr-97	0.07	1.48	0.07		13.4	29.5	18.2	7.06	58.1 J
16-Jun-97	0.01 U J	0.31 J	0.07 J	5.03 J	10.4 J	35.2 J	15.1 J	5.85 J	47.4 J
11-Aug-97	0.01 U	0.15	0.02	4.26	9.34	24.9	13.2	4.79	49.6
20-Oct-97	1.28	0.82	0.01	3.59	8.48	17.6	13.5	30.0	55.0
15-Dec-97	1.61	7.58	0.01 U	6.91	16.35	24.3	31.9	93.0	43.0
22-Feb-98	0.04	3.60	0.01 U	6.03	13.2	37.0 J	52.0 J	16.0 J	26.2
21-Apr-98	0.01 U	0.87	0.01 U	5.8	15.4	33.9	42	11.4	37.2
15-Jun-98	0.01 U	0.17	0.01 U	5.55	9.88	32.1	35.8	12.2	39.9
17-Aug-98	0.01 U	0.93	0.01 U	5.34	3.9	30.8	26.6	13.5	53.9
19-Oct-98	0.34	0.30	0.01 U	4.85	2.92	25.0	23.9	15.8	56.0
14-Dec-98	17.15	8.69	0.01 U	0.01 U	19.7	19.2	46.2	141	28.6
22-Feb-99	0.04	4.69	0.03	5.99	18.5	35.0	45.9	23.7	43.4
26-Apr-99	0.01 U	1.12	0.01 U	4.96	24.6	29.0	23.0	10.6	71.0
14-Jun-99	0.01 U	0.40	0.04	4.7	13.1	33.5	22.3	13.9	70.7
31-Aug-99	0.01	0.42	0.01 U	5.25	6.54	31.1	20.2	16.7	53.6
17-Oct-99	0.10	0.60	0.01 U	4.4	6.52	24.1	19.6	17.7	54.0
27-Dec-99	2.29	5.95	0.01 U	5.38	23.4	31.1	33.6	46.8	20.8
20-Feb-00	0.01 U	2.28	0.01 U	5.61	13.6	25.5	26.4	16.4	23.7
15-May-00	0.01 U	0.26	0.01 U	4.51	17.3	28.3	26.8	9.72	29.9
19-Jun-00	0.06	0.15	0.02	4.63	17.0	28.3	28.7	11.2	31.9
Minimum=	0.01 U	0.15	0.01 U	0.01 U	2.92	17.6	13.2	4.79	20.8
Maximum=	17.2	8.69	0.18	6.91	32.0	72.0	52.0	141	80.0
Mean=	1.10	2.11	0.02	4.88	14.5	31.1	25.4	27.9	47.3
Median=	0.01 U	0.82	0.01 U	5.03	13.6	30.8	22.8	16.0	49.0

U= Analyte was not detected at or above the reported result.

J= The analyte was positively identified. The reported result is an estimate.

UJ= The analyte was not detected at or above the reported estimated result.

Non-detect values set to 0.005 mg/L for mean determination.

Table E-2. Thurston County Dairy Nitrate+Nitrite-N Results (mg/L)

Sample	South Field - Shallow				South Field - Deep		
Date	MW12	MW4	MW5A	MW6	MW5B	Domestic	Irrigation
28-Apr-95						5.64	13.1
19-Jun-95		34.0	22.0	18.0	0.56	5.76	7.2
21-Aug-95		22.1	22.0	17.0	3.36	5.3	4.96
17-Oct-95		19.2	20.1	11.9	2.86	5.05	5.1
18-Dec-95		41	18	15.7	0.18	6.43	9.45
26-Feb-96		22	27	20.5	0.16	4.3	8.75
22-Apr-96		16.4	18.8	19.6	0.97	3.96	6.27
24-Jun-96		14.9	21.2	17.9	2.51	3.78	5.59
26-Aug-96		12.7	19	15.2	4.14	3.42	3.8
28-Oct-96		18.8	16	10.4	4.09	2.6	2.93
16-Dec-96		60	23	14.5	1.68	5.51	8.12
24-Feb-97		23	26.5	13.8	0.21	3.76	11.8
21-Apr-97		15.3	28.4	15.5	0.49	3.11	10.6
16-Jun-97	5.03 J	15.2 J	26.7 J	10.2 J	2.99 J	2.96 J	6.3 J
11-Aug-97	4.26	9.17	20.3	7.55	3.9	2.08	3.27
20-Oct-97	3.59	8.75	19.3	7.74	2.61	3.06	3.21
15-Dec-97	6.91	31	19.3	12.15	1.8	4.05	6.18
22-Feb-98	6.03	37.1	23.6 J	14	0.43	3.27	9.84
21-Apr-98	5.8	3.08	22.9	11	1.00	25 R	8.83
15-Jun-98	5.55	20	20.6	5.28	2.33	2.98	5.64
17-Aug-98	5.34	14.8	14.3	14.8	3.75	3.2	3.12
19-Oct-98	4.85	10.7	15.5	14.8	2.2	2.8	2.43
14-Dec-98	0.01 U	52.3	11.2	12.7	0.48	3.74	6.27
22-Feb-99	5.99	18.3	19.3	26.1	0.01	3.12	11.8
26-Apr-99	4.96	13.4	19.7	14.6	0.03	2.32	8.41
14-Jun-99	4.7	13.2	20.4	11.8	0.51	2.26	6.55
31-Aug-99	5.25	9.39	19.8	11.0	1.01	2.55	3.1
17-Oct-99	4.4	7.5	18.7	9.46	0.65	2.64	
27-Dec-99	5.38	81.9	19.0	25.6	0.01 U	3.38	1.94
20-Feb-00	5.61	4.44	28.0	21.0	0.01 U	2.95	11.1
15-May-00	4.51	25.9	29.8	10.7	0.35	2.53	6.17
19-Jun-00	4.63	25.8	31.2	8.97	0.86	2.39	6.25
Minimum=	0.01 U	3.08	11.2	5.28	0.01 U	2.08	1.94
Maximum=	6.91	81.9	31.2	26.1	4.14	6.4	13.1
Mean=	4.88	22.6	21.3	14.2	1.49	3.58	6.71
Median=	5.03	18.3	20.3	14.0	0.97	3.20	6.27

U= Analyte was not detected at or above the reported result.
J= The analyte was positively identified. The reported result is an estimate.
UJ= The analyte was not detected at or above the reported estimated result.
R= Result rejected. Result disagrees with prior and subsequent data.
Non-detect values set to 0.005 mg/L for mean determination.

Table E-3. Thurston County Dairy Chloride Results (mg/L).

Sample	Front Field			West Field				North Field	
Date	MW1	MW2	MW3	MW12	MW7	MW8	MW9	MW11	MW10
28-Apr-95									
19-Jun-95	2.49	3.02	13.8		88.2	67.1	39.4	76.1	98.8
21-Aug-95	2.65	3.73	13.4		83.9	66.7	36.2	71.0	106
17-Oct-95	3.13	6.91	15.4		84.7	67.4	38.7	64.8	104
18-Dec-95	10.3	6.44	17.7		58.5	67.4	34.1	81.4	91.0
26-Feb-96	3.83	3.67	17.7		38.2	52.3	24.1	41.2	69.7
22-Apr-96	2.82	2.18	15.9		44.9	58.4	19.4	33.7	63.6
24-Jun-96	2.25	2.38	12.6		27.5	60.1	17.0	40.2	64.5
26-Aug-96	2.36	2.85	10.8		13.9	51.8	15.4	36.7	62.6
28-Oct-96	5.52	5.11	14.2		16	24.1	17.6	28.4	69.0
16-Dec-96	6.71	8.76	16.0		19.4	48.0	19.9	140	63.4
24-Feb-97	7.87	4.79	16.7		23.5	43.4	20.2	15.4	50.1
21-Apr-97	5.28	3.26	15.2		21.2	36.6	15.4	11.2	54.1
16-Jun-97	2.98	2.64	14.0	7.63	17.1	49.7	11.7	16	50.5
11-Aug-97	2.68	2.87	12.4	7.38	20.3	38.0	11.0	19.4	50.5
20-Oct-97	5.58	3.52	13.5	8.01	21.2	27.3	10.9	21.8	49.9
15-Dec-97	3.46	4.27	14.1	9.91	29.6	33.7	17.6	60.6	39.8
22-Feb-98	2.60	2.84	14.3	8.87	22.8	28.7	25.3	16.8	34.2
21-Apr-98	2.02	2.66	14.2	8.36	22.6	32.2	23.3	16.7	29.8
15-Jun-98	2.33	2.74	12.9	8.34	21.2	39.1	21.1	24.5	31.0
17-Aug-98	2.32	2.99	11.0	7.39	23.2	33.7	21.8	24.9	33.8
19-Oct-98	3.80	3.71	12.0	7.45	24.9	28.4	14.4	27.6	37.8
14-Dec-98	11.3	9.62	13.4	7.56	27.5	27.9	30.1	118	31.3
22-Feb-99	3.04	4.47	13.0	10.2	41.8	32.6	31.1	20.6	49.3
26-Apr-99	3.55	2.52	12.3	8.83	38.2	28.6	6.48	102	52.0
14-Jun-99	2.43	2.55	12.2	8.01	35.8	31.5	15.4	21.6	53.3
31-Aug-99	3.66	3.44	13.2	7.89	28.6	29.2	16.2	27.8	42.1
17-Oct-99	3.74	4.66	12.5	7.81	29.6	26.9	15.9	29.5	45.8
27-Dec-99	6.35	5.61	13.9	10.0	40.8	28.4	26.4	54.4	32.8
20-Feb-00	5.49	3.83	12.7	9.22	49.6	29.9	25.8	19.5	32.5
15-May-00	2.18	2.69	13.5	8.04	53.4	31.7	23.4	16.1	29.6
19-Jun-00	2.48	2.87	13.6	7.98	46.0	30.6	23.3	20.6	31.0
Minimum=	2.02	2.18	10.8	7.38	13.9	24.1	6.48	11.2	29.6
Maximum=	11.3	9.62	17.7	10.20	88.2	67.4	39.4	140	106
Mean=	4.10	3.99	13.8	8.36	35.9	40.4	21.6	41.9	53.3
Median=	3.13	3.44	13.5	8.01	28.6	33.7	20.2	27.8	50.1

U= Analyte was not detected at or above the reported result.
J= The analyte was positively identified. The reported result is an estimate.
UJ= The analyte was not detected at or above the reported estimated result.

Table E-3. Thurston County Dairy Chloride Results (mg/L)

Sample Date	South Field - Shallow				South Field - Deep		
	MW12	MW4	MW5A	MW6	MW5B	Domestic	Irrigation
28-Apr-95						8.8	21.8
19-Jun-95		47.3	70.3	51.4	34.7	11.7	15.0
21-Aug-95		32.2	62.2	47.3	32.6	10.6	13.1
17-Oct-95		26.2	64.8	39.3	36.8	9.65	10.9
18-Dec-95		34.2	43.9	47.8	31.8	9.17	16.4
26-Feb-96		22.3	36.2	42.1	22.8	6.16	13.2
22-Apr-96		22.5	40.6	39.5	5.79	5.78	10.2
24-Jun-96		19.1	39.5	36.9	26.1	5.30	8.9
26-Aug-96		12.3	46.2	35.6	28.3	6.25	8.22
28-Oct-96		15.6	54.8	38.4	35.5	6.21	6.51
16-Dec-96		26.4	36.6	31.7	32.3	7.16	10.3
24-Feb-97		13.5	31.0	27.9	22.6	5.48	14.9
21-Apr-97		7.82	31.1	23.1	22.0	4.38	9.29
16-Jun-97	7.63	7.99	27.9	18.3	22.2	4.69	7.06
11-Aug-97	7.38	7.14	28.0	18.5	21.3	4.66	6.84
20-Oct-97	8.01	6.32	37.7	23.3	24.7	5.48	5.76
15-Dec-97	9.91	11.4	26.4	22.1	19.5	5.11	6.71
22-Feb-98	8.87	13.8	21.4	18.3	15.9	4.27	7.39
21-Apr-98	8.36	3.97	21.1	15.8	16.4	8.99	6.24
15-Jun-98	8.34	8.78	20.9	16.5	17.2	3.88	5.02
17-Aug-98	7.39	6.26	23.9	34.5	17.4	5.33	5.31
19-Oct-98	7.45	5.41	23.1	31.3	17.4	4.46	3.85
14-Dec-98	7.56	31.9	17.5	25.2	17	5.11	6.68
22-Feb-99	10.2	9.7	16.1	21.8	12.4	4.22	9.22
26-Apr-99	8.83	6.79	15.5	12.7	12.6	3.25	7.34
14-Jun-99	8.01	6.93	16.9	11.8	13.2	3.29	6.24
31-Aug-99	7.89	6.34	16.8	14.3	13.9	3.94	5.18
17-Oct-99	7.81	6.03	17.2	16.1	13.7	4.77	4.49
27-Dec-99	10.0	49.2	18.0	21.3	11.9	4.02	
20-Feb-00	9.22	32.8	25.9	16.1	11.6	3.93	10.3
15-May-00	8.04	19	31.0	12.9	12.4	4.1	6.67
19-Jun-00	7.98	16.3	28.4	12.7	12.7	4.22	5.98
Minimum=	7.38	3.97	15.5	11.8	5.79	3.25	3.85
Maximum=	10.2	49.2	70.3	51.4	36.8	11.7	21.8
Mean=	8.36	17.3	31.9	26.6	20.5	5.76	8.87
Median=	8.01	13.5	28.0	23.1	17.4	5.11	7.34

U= Analyte was not detected at or above the reported result.

J= The analyte was positively identified. The reported result is an estimate.

UJ= The analyte was not detected at or above the reported estimated result.

Table E-4. Thurston County Dairy Total Dissolved Solids Results (mg/L).

Sample	Front Field			West Field				North Field	
Date	MW1	MW2	MW3	MW12	MW7	MW8	MW9	MW11	MW10
28-Apr-95									
19-Jun-95	136	108	128		401	524	288	328	646
21-Aug-95	86	72	124		384	486	282	339	616
17-Oct-95	115	82	130		367	407	409	320	707
18-Dec-95	230	113	142		297	452	349	538	543
26-Feb-96	151	86	153		256	437	246	304	494
22-Apr-96	181	61	152		233	420	220	248	476
24-Jun-96	119	47	136		186	466	152	226	495
26-Aug-96	108	73	137		153	437	196	226	510
28-Oct-96	165	78	136		138	357	196	249	475
16-Dec-96	190	83	122		106	306	216	819	408
24-Feb-97	148	83	152		186	372	248	241	382
21-Apr-97	141	62	143		172	336	205	171	477
16-Jun-97	169	47	138	121	167	409	177	179	474
11-Aug-97	102	62	141	121	177	350	170	168	468
20-Oct-97	187	64	132	115	159	259	171	310	462
15-Dec-97	152	106	148	164	211	310	278	667	393
22-Feb-98	114	68	147	122	183	348	378	237	305
21-Apr-98	145	57	154	130	210	356	351	211	350
15-Jun-98	102	66	150	121	198	374	325	218	412
17-Aug-98	98	56	134	117	170	73 J	285	201	493
19-Oct-98	96	78	148	142	170	241	319	242	505
14-Dec-98	295	133	159	116	296	308	377	1240	340
22-Feb-99	104	92	154	144	259	412	450	288	564
26-Apr-99	141	62	154	139	286	352	252	183	584
14-Jun-99	74	36	130	112	194	359	222	202	599
31-Aug-99	86	70	146	135	178	321	223	216	507
17-Oct-99	76	65	136	122	173	292	202	205	491
27-Dec-99	117	72	138	115	236	335	308	442	276
20-Feb-00	112	68	144	135	282	350	311	208	293
15-May-00	134	52	152	126	275	331	267	170	303
19-Jun-00	102 J	77 J	155	146	246	366	244	187	367
Minimum=	74	36	122	112	106	73	152	168	276
Maximum=	295	133	159	164	401	524	450	1240	707
Mean=	135	74	142	129	224	360	268	316	465
Median=	119	70	143	122	198	356	252	237	476

U= Analyte was not detected at or above the reported result.
J= The analyte was positively identified. The reported result is an estimate.
UJ= The analyte was not detected at or above the reported estimated result.

Table E-4. Thurston County Dairy Total Dissolved Solids Results (mg/L), Continued.

Sample	South Field - Shallow				South Field - Deep		
Date	MW12	MW4	MW5A	MW6	MW5B	Domestic	Irrigation
28-Apr-95						96	168
19-Jun-95		323	360	302	226	93	148
21-Aug-95		250	348	276	191	96	110
17-Oct-95		237	366	251	197	100	111
18-Dec-95		376	305	321	171	102	146
26-Feb-96		264	330	310	159	104	143
22-Apr-96		230	301	272	167	84	115
24-Jun-96		194	281	257	171	74	97
26-Aug-96		182	314	254	182	90	102
28-Oct-96		229	301	211	192	100	95
16-Dec-96		387	269	187	156	66	97
24-Feb-97		255	317	238	157	88	158
21-Apr-97		183	304	208	154	79	138
16-Jun-97	121	186	282	191	183	81	108
11-Aug-97	121	150	271	165	180	78	96
20-Oct-97	115	144	281	173	182	84	83
15-Dec-97	164	256	264	199	179	96	117
22-Feb-98	122	301	263	216	165	81	133
21-Apr-98	130	81	257	183	166	224	121
15-Jun-98	121	227	263	154	173	94	108
17-Aug-98	117	167	251	238	187	98	103
19-Oct-98	142	147	242	248	186	92	93
14-Dec-98	116	475	219	263	180	95	118
22-Feb-99	144	188	243	310	153	81	151
26-Apr-99	139	160	228	207	147	68	115
14-Jun-99	112	144	235	194	152	45	95
31-Aug-99	135	142	236	196	163	75	89
17-Oct-99	122	118	217	175	152	73	73
27-Dec-99	115	520	223	287	145	56	
20-Feb-00	135	383	288	241	140	71	135
15-May-00	126	247	312	159	140	70	104
19-Jun-00	146	222	323	160	152	74 J	108 J
Minimum=	112	81	217	154	140	45	73
Maximum=	164	520	366	321	226	224	168
Mean=	129	238	280	227	169	88	115
Median=	122	227	281	216	167	84	110

U= Analyte was not detected at or above the reported result.

J= The analyte was positively identified. The reported result is an estimate.

UJ= The analyte was not detected at or above the reported estimated result.

Table E-5. Thurston County Dairy Total Phosphorus Results (mg/L).

Sample	Front Field			West Field				North Field	
Date	MW1	MW2	MW3	MW12	MW7	MW8	MW9	MW11	MW10
19-Jun-95	0.34	0.01 U	0.08		0.09	0.07	0.01	0.01 U	0.01 U
21-Aug-95	0.32	0.01 U	0.09		0.02	0.08	0.01 U	0.01 U	0.01 U
17-Oct-95	0.07	0.01	0.10		0.01 U	0.22	0.01 U	0.01 U	0.01 U
18-Dec-95	0.28	0.06	0.01 U		0.01 U	0.01 U	0.09	0.01 U	0.08
26-Feb-96	0.54	0.02	0.06		0.01	0.07	0.02	0.01 U	0.01 U
22-Apr-96	0.47	0.01 U	0.08		0.01 UJ	0.09	0.07	0.01 UJ	0.01 U
24-Jun-96	0.47	0.01 U	0.10		0.01 U	0.19	0.01 U	0.01 U	0.01 U
26-Aug-96	0.34	0.03	0.13		0.05	0.11	0.03	0.03	0.05
28-Oct-96	0.04	0.01 U	0.06		0.02	0.09	0.01 U	0.01 U	0.01
16-Dec-96	0.09	0.04	0.12		0.04	0.11	0.02	0.02	0.05
24-Feb-97	0.31	0.09	0.27		0.06	0.21	0.11	0.08	0.15
21-Apr-97	0.70 J	0.06	0.15		0.07	0.11	0.11	0.07	0.12
16-Jun-97	0.22 J	0.02 J	0.06 J	0.03 J	0.03 J	0.09 J	0.03 J	0.02 J	0.03 J
11-Aug-97	0.31	0.06	0.11	0.07	0.05	0.10	0.04	0.03	0.04
20-Oct-97	0.05	0.01	0.08	0.03	0.02	0.06	0.02	0.01	0.03
15-Dec-97	0.11	0.09	0.10	0.08	0.05	0.06	0.03	0.03	0.04
22-Feb-98	0.10	0.02	0.07	0.10	0.03	0.05	0.03	0.01	0.05
21-Apr-98	0.08	0.02	0.09	0.03	0.02	0.06	0.01	0.01 U	0.01
15-Jun-98	0.05	0.02	0.07	0.06	0.03	0.06	0.02	0.02	0.03
17-Aug-98	0.10	0.02	0.06	0.03	0.02	0.06	0.02	0.02	0.03
19-Oct-98	0.03 J	0.01 U	0.02	0.03	0.02	0.02	0.01	0.06	0.02
14-Dec-98	0.05	0.01	0.20	0.02	0.01	0.04	0.01	0.01	0.02
22-Feb-99	0.12	0.01	0.13	0.05	0.01	0.03	0.01 U	0.01 U	0.02
26-Apr-99	0.29	0.02	0.13	0.06	0.02	0.03	0.02	0.01 U	0.03
14-Jun-99	0.15	0.03	0.20	0.08	0.03	0.05	0.03	0.01	0.04
31-Aug-99	0.10	0.05	0.16	0.08	0.07	0.06	0.03	0.01	0.04
17-Oct-99	0.07	0.04	0.18	0.09	0.05	0.04	0.04	0.03	0.04
27-Dec-99	0.07	0.02	0.12	0.06	0.02	0.04	0.02	0.01 U	0.04
20-Feb-00	0.16	0.02	0.12	0.07	0.02	0.04	0.02	0.01 U	0.03
15-May-00	0.20	0.02	0.12	0.08	0.03	0.05	0.02	0.01 U	0.04
19-Jun-00	0.07	0.02	0.13	0.07	0.03	0.22	0.02	0.01 U	0.03
Minimum=	0.03 J	0.01 U	0.01 U	0.02	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
Maximum=	0.70	0.09	0.27	0.10	0.09	0.22	0.11	0.08	0.15
Mean=	0.20	0.03	0.11	0.06	0.03	0.08	0.03	0.02	0.03
Median=	0.12	0.02	0.10	0.06	0.02	0.06	0.02	0.01	0.03

U= Analyte was not detected at or above the reported result.
J= The analyte was positively identified. The reported result is an estimate.
UJ= The analyte was not detected at or above the reported estimated result.
Non-detect values set to 0.005 mg/L for mean determination.

Table E-5. Thurston County Dairy Total Phosphorus Results (mg/L)

Sample Date	South Field - Shallow				South Field - Deep		
	MW12	MW4	MW5A	MW6	MW5B	Domestic	Irrigation
28-Apr-95						0.01 U	0.01 U
19-Jun-95		0.02	0.02	0.01	0.06	0.01 U	0.01 U
21-Aug-95		0.01 U	0.01 U	0.01 U	0.03	0.01 U	0.01 U
17-Oct-95		0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01
18-Dec-95		0.01 U	0.10	0.01 U	0.01 U	0.01 U	0.01 U
26-Feb-96		0.01	0.02	0.01	0.01	0.01	0.01 U
22-Apr-96		0.01 U	0.01 U	0.18 J	0.03	0.29 J	0.01 U
24-Jun-96		0.01 U	0.01 U	0.06	0.02	0.01 U	0.02
26-Aug-96		0.04	0.05	0.04	0.03	0.03	0.04
28-Oct-96		0.01 U	0.02	0.02	0.01 U	0.01 U	0.01
16-Dec-96		0.02	0.04	0.04	0.03	0.03	0.04
24-Feb-97		0.09	0.11	0.18	0.16	0.11	0.38
21-Apr-97		0.10	0.11	0.13	0.11	0.08	0.11
16-Jun-97	0.03 J	0.03 J	0.03 J	0.03 J	0.04 J	0.04 J	0.03 J
11-Aug-97	0.07	0.04	0.05	0.04	0.06	0.04	0.04
20-Oct-97	0.03	0.02	0.02	0.05	0.04	0.43	0.02
15-Dec-97	0.08	0.03	0.04	0.07	0.03	0.05	0.05
22-Feb-98	0.10	0.01	0.03	0.05	0.04	0.05	0.03
21-Apr-98	0.03	0.02	0.05	0.02	0.04	0.01 U	0.02
15-Jun-98	0.06	0.02	0.03	0.04	0.05	0.03	0.03
17-Aug-98	0.03	0.02	0.02	0.02	0.03	0.02	0.02
19-Oct-98	0.03	0.01 U	0.01	0.03	0.03	0.01	0.01 U
14-Dec-98	0.02	0.00	0.01	0.01	0.01	0.01	0.02
22-Feb-99	0.05	0.02	0.02	0.02	0.02	0.01	0.01
26-Apr-99	0.06	0.01	0.02	0.03	0.04	0.02	0.02
14-Jun-99	0.08	0.02	0.04	0.05	0.06	0.02	0.03
31-Aug-99	0.08	0.03	0.04	0.05	0.10	0.03	0.03
17-Oct-99	0.09	0.02	0.05	0.07	0.09	0.02	0.03
27-Dec-99	0.06	0.03	0.03	0.04	0.04	0.02	
20-Feb-00	0.07	0.01	0.03	0.03	0.04	0.02	0.02
15-May-00	0.08	0.02	0.03	0.04	0.06	0.02	0.03
19-Jun-00	0.07	0.02	0.03	0.04	0.06	0.02	0.03
Minimum=	0.02	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
Maximum=	0.10	0.10	0.11	0.18	0.16	0.43	0.38
Mean=	0.06	0.02	0.03	0.05	0.04	0.05	0.04
Median=	0.06	0.02	0.03	0.04	0.04	0.02	0.02

U= Analyte was not detected at or above the reported result.
J= The analyte was positively identified. The reported result is an estimate.
UJ= The analyte was not detected at or above the reported estimated result.
Non-detect values set to 0.005 mg/L for mean determination.

Table E-6. Thurston County Dairy Total Organic Carbon Results (mg/L).

Sample	Front Field			West Field				North Field	
Date	MW1	MW2	MW3	MW12	MW7	MW8	MW9	MW11	MW10
28-Apr-95									
19-Jun-95	9.3	1.2	3.0		2.0	4.5	2.0	2.5	1.4
21-Aug-95	4.0	1.0 U	3.1		1.1	2.0	1.0	2.5	2.0
17-Oct-95	5.2	1.2	3.2		1.3	1.3	1.8	1.8	1.1
18-Dec-95	17.2	1.0 U	2.4		1.3	1.0 U	3.0	2.4	1.3
26-Feb-96	16.6	1.1	2.6		1.5	2.6	2.2	3.4	1.4
22-Apr-96	17.7	1.1 J	2.3 J		1.2 J	1.0 UJ	1.2 J	2.5 J	1.1 J
24-Jun-96	9.3	1.0 U	1.9		1.0 U	1.0 U	1.0 U	1.6	1.0 U
26-Aug-96	3.2 J	1.0 UJ	1.8 J		1.0 UJ	1.0 UJ	1.0 UJ	1.8 J	1.0 UJ
28-Oct-96	5.7	1.2	3.2		1.4	1.0 U	1.0	1.9	1.1
16-Dec-96	21.1	1.7	2.8		1.0 U	1.0 U	1.6	2.1	1.4
24-Feb-97	15.5	1.0 U	2.4		1.2 U	1.3	2.1	3.2	1.3
21-Apr-97	16.1	1.5	2.7		1.1	1.4	1.8	3.2	1.4
16-Jun-97	10.1	1.0 U	2.6	1.2	2.1	2.1	1.7	3.0	2.3
11-Aug-97	6.1	1.0 U	3.1	1.0 U	1.0	1.4	1.6	2.8	1.4
20-Oct-97	10.4	2.0	3.9	1.6	1.6	2.3	2.2	3.1 J	2.3
15-Dec-97	9.6	1.0 U	2.3	1.0 U	1.2	1.0 U	1.2	2.5	1.0 U
22-Feb-98	9.7	1.0 U	2.3	1.0 U	1.4	1.2	1.5	3.2	1.1
21-Apr-98	10.8	1.4	2.7	1.0	2.2	1.6	2.1	3.9	1.9
15-Jun-98	4.7	1.0 U	2.3	1.0 U	1.8	1.0 U	1.3	2.4	2.2
17-Aug-98	4.7	1.2	3.6	1.1	2.5	1.6	1.9	2.9	1.9
19-Oct-98	2.7	1.1	3.3	1.0 U	2.4	1.4	1.5	2.7	1.8
14-Dec-98	13.0	1.7	2.9	1.1	2.4	1.7	1.9	3.2	1.9
22-Feb-99	8.4	1.3	2.4	1.0 U	2.7	2.4	2.8	3.7	5.6
26-Apr-99	11.9	1.0 U	2.5	1.0 U	2.1	3.4	2.2	3.2	1.2
14-Jun-99	5.8	1.0 U	2.3	1.0 U	2.2	1.0 U	1.6	2.6	1.3
31-Aug-99	2.4	1.0 U	2.5	1.0 U	2.5	1.2	1.2	1.9	1.5
17-Oct-99	2.3	1.0 U	3.1	1.0 U	2.4	1.0	1.5	1.8	1.5
27-Dec-99	8.8	1.0 U	1.9	1.0 U	1.9	1.2	2.1	2.0	1.4
20-Feb-00	10.0	1.0 U	2.3	1.0 U	2.5	1.2	2.0	2.9	1.5
15-May-00	9.7	1.0 U	2.3	1.0 U	2.7	1.2	1.7	2.9	1.3
19-Jun-00	5.5	1.0 U	2.6	1.0 U	2.9	1.8	2.0	2.8	1.7
Minimum=	2.3	1.0 U	1.8	1.0 U	1.0 U	1.0 U	1.0 U	1.6	1.0 U
Maximum=	21.1	2.0	3.9	1.6	2.9	4.5	3.0	3.9	5.6
Mean=	9.3	NA	2.7	NA	*1.7	*1.4	*1.7	2.7	*1.6
Median=	9.3	1.0 U	2.6	1.0	1.8	1.3	1.7	2.7	1.4

U= Analyte was not detected at or above the reported result.

J= The analyte was positively identified. The reported result is an estimate.

UJ= The analyte was not detected at or above the reported estimated result.

* Mean calculated by setting non-detect values to 0.5 mg/L.

Table E-6. Thurston County Dairy Total Organic Carbon (mg/L), Continued.

Sample	South Field - Shallow				South Field - Deep		
Date	MW12	MW4	MW5A	MW6	MW5B	Domestic	Irrigation
28-Apr-95						1.0 U	1.0 U
19-Jun-95		1.6	2.9	1.6	2.0	1.0 U	1.0 U
21-Aug-95		1.0 U	2.1	1.5	1.1	1.0 U	1.0 U
17-Oct-95		1.3	2.3	1.0 U	1.0 U	1.0 U	1.0 U
18-Dec-95		1.6	1.6	1.1	1.0 U	1.0 U	1.0 U
26-Feb-96		2.5	1.8	1.4	1.2	1.0 U	1.0 U
22-Apr-96		1.9 J	2.2	1.0 UJ	1.0 U	1.0 UJ	1.0 UJ
24-Jun-96		1.2	1.2	3.3	1.0 U	1.0 U	1.0 U
26-Aug-96		1.0 UJ	2.0 J	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ
28-Oct-96		1.2	3.0	1.0 U	1.0 U	1.0 U	1.0 U
16-Dec-96		2.5	1.2	1.0 U	1.0 U	1.0 U	1.0
24-Feb-97		1.8	1.8	1.0 U	1.0 U	1.0 U	1.1
21-Apr-97		2.0	2.0	1.0 U	1.0 U	1.1	1.3
16-Jun-97	1.2	3.5	2.4	1.4	1.4	1.1	1.0 U
11-Aug-97	1.0 U	1.7	2.5	1.0 U	1.1	1.0 U	1.0 U
20-Oct-97	1.6	2.0	3.3	2.0	1.5	1.1	1.2
15-Dec-97	1.0 U	1.2	1.9	1.0 U	1.0 U	1.0 U	1.0 U
22-Feb-98	1.0 U	1.4	1.8	1.0 U	1.0 U	1.0 U	1.0 U
21-Apr-98	1.0	1.0	2.4	1.1	1.4	2.1	1.1
15-Jun-98	1.0 U	1.3	2.1	1.0 U	1.4	1.0 U	1.0 U
17-Aug-98	1.1	1.8	2.2	1.7	1.2	1.3	1.0 U
19-Oct-98	1.0 U	1.5	2.1	1.3	1.2	1.0 U	1.0 U
14-Dec-98	1.1	2.5	2.3	1.2	1.7	1.5	1.3
22-Feb-99	1.0 U	2.0	2.7	1.5	1.1	1.0 U	1.0 U
26-Apr-99	1.0 U	1.6	1.2	1.3	1.0 U	1.0 U	1.0 U
14-Jun-99	1.0 U	1.4	1.4	1.0 U	1.0 U	1.0 U	1.0 U
31-Aug-99	1.0 U	1.2	1.4	1.1	1.0 U	1.0 U	1.0 U
17-Oct-99	1.0 U	1.1	1.5	1.0 U	1.1	1.0 U	1.0 U
27-Dec-99	1.0 U	1.6	1.4	1.0 U	1.0 U	1.0 U	
20-Feb-00	1.0 U	1.4	1.4	1.0 U	1.0 U	1.0 U	1.0 U
15-May-00	1.0 U	1.3	1.7	1.0 U	1.0 U	1.0 U	1.0 U
19-Jun-00	1.0 U	1.5	1.8	1.0	1.2	1.0 U	1.0 U
Minimum=	1.0 U	1.0 U	1.2	1.0 U	1.0 U	1.0 U	1.0 U
Maximum=	1.6	3.5	3.3	3.3	2.0	2.1	1.3
Mean=	NA	*1.6	2.0	NA	NA	NA	NA
Median=	1.0 U	1.5	2.0	1.0 U	1.0 U	1.0 U	1.0 U

U= Analyte was not detected at or above the reported result.
J= The analyte was positively identified. The reported result is an estimate.
UJ= The analyte was not detected at of above the reported estimated result.
* Mean calculated by setting non-detect values to 0.5 mg/L.

Table E-7. Thurston County Dairy Ammonia-N Results (mg/L).

Sample Date	Front Field			West Field				North Field	
	MW1	MW2	MW3	MW12	MW7	MW8	MW9	MW11	MW10
19-Jun-95	0.01 U	0.01 U	0.07		0.01 U	0.19	0.01 U	0.01 U	0.01 U
21-Aug-95	0.01 U	0.01 U	0.12		0.01 U	0.572	0.01 U	0.01 U	0.01 U
17-Oct-95	0.01 U	0.01 U	0.13		0.01 U	0.423	0.01 U	0.01 U	0.01 U
18-Dec-95	0.02	0.01 U	0.13		0.01 U	0.202	0.01 U	0.01 U	0.01 U
26-Feb-96	0.03	0.01 U	0.10		0.01 U	0.095	0.01 U	0.01 U	0.01 U
22-Apr-96	0.06	0.01 U	0.13		0.01 U	0.115	0.01 U	0.01 U	0.01 U
24-Jun-96	0.08	0.01 U	0.12		0.011	0.124	0.01 U	0.01 U	0.01 U
26-Aug-96	0.04	0.01 U	0.10		0.015	0.069	0.01 U	0.01 U	0.01 U
28-Oct-96	0.01 U	0.01 U	0.11		0.01 U	0.041	0.01 U	0.01 U	0.01 U
16-Dec-96	0.02	0.01 U	0.10		0.01 U	0.046	0.01 U	0.01 U	0.01 U
24-Feb-97	0.02	0.01 U	0.09		0.01 U	0.042	0.01 U	0.01 U	0.01 U
21-Apr-97	0.05	0.01 U	0.09		0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
16-Jun-97	0.08 J	0.01 UJ	0.09 J	0.03 J	0.01 UJ	0.012 J	0.01 UJ	0.01 UJ	0.01 UJ
11-Aug-97	0.08	0.01 U	0.12	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
20-Oct-97	0.01 U	0.01 U	0.11	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
15-Dec-97	0.01 U	0.01 U	0.09	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
22-Feb-98	0.01	0.01 U	0.11	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
21-Apr-98	0.01 U	0.01 U	0.09	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.069
15-Jun-98	0.02	0.01 U	0.10	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
17-Aug-98	0.02	0.01 U	0.10	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
19-Oct-98	0.01 U	0.01 U	0.09	0.01 U	0.01 U	0.01 U	0.01 U	0.03	0.01 U
14-Dec-98	0.02	0.01 U	0.12	0.01 U	0.01 U	0.011	0.01 U	0.01 U	0.01 U
22-Feb-99	0.01 J	0.01 U	0.06	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
26-Apr-99	0.03	0.01 U	0.09	0.01 U	0.01 U	0.018	0.01 U	0.01 U	0.01 U
14-Jun-99	0.02	0.01 U	0.11	0.01 U	0.025	0.04	0.036	0.03	0.036
31-Aug-99	0.04	0.04	0.13	0.03	0.033	0.037	0.032	0.03	0.03
17-Oct-99	0.01 U	0.01 U	0.09	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
27-Dec-99	0.01 U	0.01 U	0.08	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
20-Feb-00	0.01 U	0.01 U	0.06	0.01 U	0.012	0.01 U	0.01 U	0.01 U	0.01 U
15-May-00	0.01 U	0.01 U	0.07	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
19-Jun-00	0.01 U	0.01 U	0.09	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
Minimum=	0.01 U	0.01 U	0.06	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
Maximum=	0.08	0.04	0.13	0.03	0.03	0.57	0.04	0.03	0.07
Mean=	NA	NA	0.10	NA	NA	NA	NA	NA	NA
Median=	0.02	0.01 U	0.10	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U

U= Analyte was not detected at or above the reported result.

J= The analyte was positively identified. The reported result is an estimate.

UJ= The analyte was not detected at or above the reported estimated result.

Table E-7. Thurston County Dairy Ammonia-N Results (mg/L), Continued.

Sample	South Field - Shallow				South Field - Deep		
Date	MW12	MW4	MW5A	MW6	MW5B	Domestic	Irrigation
28-Apr-95						0.01 U	0.01 U
19-Jun-95		0.028	0.011	0.01 U	0.02	0.01 U	0.01 U
21-Aug-95		0.052	0.01 U	0.01 U	0.05	0.01 U	0.01 U
17-Oct-95		0.024	0.01 U	0.01 U	0.02	0.01 U	0.01 U
18-Dec-95		0.069	0.01 U	0.01 U	0.02	0.01 U	0.01 U
26-Feb-96		0.01 U	0.01 U	0.01 U	0.02	0.01 U	0.01 U
22-Apr-96		0.01 U	0.01 U	0.01 U	0.03	0.01 U	0.01 U
24-Jun-96		0.01 U	0.01 U	0.01 U	0.02	0.01 U	0.01 U
26-Aug-96		0.01 U	0.01 U	0.01 U	0.02	0.01	0.01 U
28-Oct-96		0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
16-Dec-96		0.01 U	0.01 U	0.01 U	0.02	0.01 U	0.01 U
24-Feb-97		0.01 U	0.01 U	0.01 U	0.02	0.01 U	0.01 U
21-Apr-97		0.01 U	0.01 U	0.01 U	0.01	0.01 U	0.01 U
16-Jun-97				UJ	0.02 J	0.01 UJ	0.01 UJ
	0.03 J	0.01 UJ	0.01 UJ	0.01			
11-Aug-97	0.01 U	0.01 U	0.01 U	0.01 U	0.03	0.01 U	0.01 U
20-Oct-97	0.01 U	0.01 U	0.01 U	0.01 U	0.02	0.01 U	0.01 U
15-Dec-97	0.01 U	0.01 U	0.01 U	0.01 U	0.03	0.01 U	0.01 U
22-Feb-98	0.01 U	0.01 U	0.01 U	0.01 U	0.03	0.02	0.01 U
21-Apr-98	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
15-Jun-98	0.01 U	0.01 U	0.01 U	0.01 U	0.02	0.01 U	0.01 U
17-Aug-98	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
19-Oct-98	0.01 U	0.01 U	0.01 U	0.01 U	0.02	0.01 U	0.01 U
14-Dec-98	0.01 U	0.01 U	0.01 U	0.011	0.07	0.01 U	0.01 U
22-Feb-99	0.01 U	0.01 U	0.01 U	0.01 U	0.03	0.01 U	0.01 U
26-Apr-99	0.01 U	0.01 U	0.01 U	0.01 U	0.04	0.01 U	0.01 U
14-Jun-99	0.01 U	0.01 U	0.033	0.036	0.07	0.01 U	0.01 U
31-Aug-99	0.03	0.034	0.032	0.033	0.06	0.03	0.03
17-Oct-99	0.01 U	0.01 U	0.01 U	0.01 U	0.02	0.01 U	0.01 U
27-Dec-99	0.01 U	0.01 U	0.01 U	0.01 U	0.02	0.01 U	
20-Feb-00	0.01 U	0.01 U	0.01 U	0.01 U	0.01	0.01 U	0.01 U
15-May-00	0.01 U	0.01 U	0.01 U	0.01 U	0.02	0.01 U	0.01 U
19-Jun-00	0.01 U	0.01 U	0.01 U	0.01 U	0.02	0.01 U	0.01 U
Minimum=	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
Maximum=	0.03	0.07	0.03	0.04	0.07	0.03	0.03
Mean=	NA	NA	NA	NA	*0.03	NA	NA
Median=	0.01 U	0.01 U	0.01 U	0.01 U	0.02	0.01 U	0.01 U

U= Analyte was not detected at or above the reported result.

J= The analyte was positively identified. The reported result is an estimate.

UJ= The analyte was not detected at or above the reported estimated result.

* Mean calculated using 0.005 mg/L for non-detect values.

Table E-8. Thurston County Dairy Total Persulfate Nitrogen Results (mg/L), April 1995 through December 1998.

Sample	Front Field			West Field				North Field	
Date	MW1	MW2	MW3	MW12	MW7	MW8	MW9	MW11	MW10
28-Apr-95									
19-Jun-95	0.58	0.33	0.24		29.5	42.1	21.3	17.5	54.2
21-Aug-95	0.28	0.59	0.23		5.36 J	6.71 J	4.55 J	5.56 J	5.99 J
17-Oct-95	0.84	1.08	0.28		26.0	35.9	27.6	24.9	55.3
18-Dec-95	4.44	8.24	0.20		27.8	44.0	38.0	60.0	55.0
26-Feb-96	1.10	2.87	0.23		20.0	36.0	21.0	24.0	45.0
22-Apr-96	1.03	0.57	0.27		17.6	38.0	17.2	15.2	47.1
24-Jun-96	1.05	0.22	0.14		14.7	39.8	15.3	12.5	56.5
26-Aug-96	0.43	0.32	0.23		8.39	29.0	14.9	13.9	49.1
28-Oct-96	4.59	0.65	0.23		7.35	24.9	16.2	20.7	48.3
16-Dec-96	5.07	7.83	0.21		8.15	25.2	22.0	113	46.0
24-Feb-97	1.24	3.20	0.22		11.1	30.1	21.4	11.7	31.0
21-Apr-97	1.53	1.42	0.32		11.4	37.8	16.5	6.70	48.7 J
16-Jun-97	0.93 J	0.32 J	0.32 J	4.88 J	10.2 J	31.9 J	13.9 J	5.57 J	53.1 J
11-Aug-97	0.40	0.15	0.21	4.12	9.36	24.7	13.1	4.86	50.2
20-Oct-97	2.05	0.84	0.25	3.66	8.26	18.3	13.0	29.2	53.0
15-Dec-97	2.40	7.46	0.20	7.27	16.6	24.1	33.4	87.9	42.1
22-Feb-98	0.66	4.06	0.18	6.12	11.9	31.9 J	44.0 J	12.0 J	27.2
21-Apr-98	0.78	0.88	0.22	5.86	15.3	33.2	42.0	10.9	33.0
15-Jun-98	0.34	0.17	0.22	5.30	8.97	30.5	32.4	11.9	37.5
17-Aug-98	0.32	0.96	0.23	5.24	4.04	30.1	25.5	12.9	48.2
19-Oct-98	0.56	0.30	0.23	4.62	2.96	24.4	23.2	15.4	55.0
14-Dec-98	22.1 J	10.7 J	0.24 J	0.01 UJ	28.5 J	24.0	46.7	160	31.1
Minimum=	0.28	0.15	0.14	0.01 UJ	2.96	6.71	4.55	4.86	5.99
Maximum=	22.1	10.7	0.32	7.3	29.5	44.0	46.7	160.0	56.5
Mean=	2.39	2.42	0.23	4.71	13.8	30.1	23.8	30.7	44.2
Median=	0.98	0.86	0.23	5.06	11.3	30.3	21.4	14.6	48.3

U= Analyte was not detected at or above the reported result.
J= The analyte was positively identified. The reported result is an estimate.
UJ= The analyte was not detected at of above the reported estimated result.

Table E-8. Thurston County Dairy Total Persulfate N Results (mg/L)

Sample	South Field - Shallow				South Field - Deep		
Date	MW12	MW4	MW5A	MW6	MW5B	Domestic	Irrigation
28-Apr-95						5.52	11.9
19-Jun-95		32.1	21.0	17.2	0.96	5.86	7.16
21-Aug-95		4.20 J	4.72 J	3.00 J	3.78 J	0.88 J	5.32 J
17-Oct-95		19.7	21.5	15.1	3.13	5.04	4.99
18-Dec-95		47.0	27.2	19.4	0.10	7.24	10.8
26-Feb-96		22.0	32.5	23.5	0.11	4.27	8.52
22-Apr-96		16.8	26.4	16.9	1.11	4.06	6.42
24-Jun-96		15.8	24.2	20.9	3.60	3.83	4.77
26-Aug-96		12.9	18.6	15.5	4.18	3.39	3.45
28-Oct-96		20.0	15.2	10.9	3.91	2.92	3.68
16-Dec-96		55.0	24.0	14.4	1.85	5.68	8.27
24-Feb-97		24.0	29.9	16.1	0.31	3.96	11.4
21-Apr-97		13.8	27.0	14.3	0.56	3.02	21.8
16-Jun-97	4.88 J	14.2 J	24.0 J	9.73 J	2.79 J	2.75 J	5.97 J
11-Aug-97	4.12	9.17	19.8	7.34	3.82	2.17	3.29
20-Oct-97	3.66	8.71	19.0	7.56	2.45	3.08	3.11
15-Dec-97	7.27	30.6	19.2	12.5	1.95	4.27	5.97
22-Feb-98	6.12	37.7	20.3 J	12.7	0.49	3.49	10.1
21-Apr-98	5.86	3.25	23.1	10.5	1.14	48.0 R	8.73
15-Jun-98	5.30	20.2	19.5	5.49	2.12	3.01	5.33
17-Aug-98	5.24	14.8	13.9	15.0	3.64	3.18	3.10
19-Oct-98	4.62	10.1	15.1	14.4	2.23	2.70	2.35
14-Dec-98	0.01 UJ	59.8 J	16.6 J	22.4	0.88	4.11 J	7.42 J
Minimum=	0.01 UJ	3.25	4.72	3.00	0.10	0.88	2.35
Maximum=	7.27	59.8	32.5	23.5	4.18	7.2	21.8
Mean=	4.71	22.4	21.0	13.9	2.05	3.84	7.12
Median=	5.06	18.3	20.7	14.4	2.04	3.66	5.97

U= Analyte was not detected at or above the reported result.

J= The analyte was positively identified. The reported result is an estimate.

UJ= The analyte was not detected at of above the reported estimated result.

Table E-9. Thurston County Dairy Fecal Coliform Bacteria Results (CFU/100mL).

Sample Date	Front Field			West Field				North Field	
	MW1	MW2	MW3	MW12	MW7	MW8	MW9	MW11	MW10
19-Jun-95	2	1 U	2		8	67	1 U	2	1 U
21-Aug-95	1 U	1 U	1 U		1 U	22	1 U	1 U	1 U
17-Oct-95	1	1 U	1 U		1 U	3	1 U	1 U	3
18-Dec-95	1.5*	1 U	1 U		1 U	1 U	1	1	1 U
26-Feb-96	1.5*	1 U	1 U		1 U	1 U	1 U	1 U	1 U
22-Apr-96	2	1 U	1 U		1 U	7	1 U	1 U	1 U
24-Jun-96	1 U	1 U	1 U		1 U	1 U	1 U	1 U	1 U
26-Aug-96	1 U	1 U	1 U		1 U	1 U	1 U	1 U	1 U
28-Oct-96	1	1 U	1 U		1 U	3	6	1 U	1 U
16-Dec-96	1	1 U	1 U		1 U	1	1 U	1 U	1 U
24-Feb-97	1	1 U	1 U		1 U	1 U	1 U	1 U	1 U
21-Apr-97	24	1 U	1 U		1 U	1 U	1 U	1 U	1 U
16-Jun-97	1 U	1	1 U	1 U	1 U	6	1 U	1 U	1 U
11-Aug-97	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
20-Oct-97	1.5*	1 U	1 U	1 U	1 U	2	1 U	1 U	1 U
15-Dec-97	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
22-Feb-98	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
21-Apr-98	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
15-Jun-98	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
17-Aug-98	1 U	1 U	1	1 U	1 U	1 U	1 U	1 U	1 U
19-Oct-98	1 U	1 U	1 U	1 U	1 U	1 U	1 U	3 U	1 U
14-Dec-98	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
22-Feb-99	3	1 U	1 U	1 U	1 U	1	1 U	1 U	1 U
26-Apr-99	1	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
14-Jun-99	1 U	1 U	1 U	1 U	1 U	1 U	1	1 U	1 U
31-Aug-99	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
17-Oct-99	1 U	1 U	1 U	1 U	7	1 U	1 U	1 U	1 U
27-Dec-99	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
21-Feb-00							1 U	1 U	1 U
15-May-00	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
19-Jun-00	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Minimum=	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Maximum=	24	1	2	1 U	8	67	6	2	3
Mean=	NA	NA	NA	NA	NA	NA	NA	NA	NA
Median=	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U

U= Analyte was not detected at or above the reported result.
J= The analyte was positively identified. The reported result is an estimate.
UJ= The analyte was not detected at of above the reported estimated result.
* Result based on field duplicate samples.

Table E-9. Thurston County Dairy Fecal Coliform Bacteria Results (CFU/100mL)

Sample	South Field - Shallow				South Field - Deep		
Date	MW12	MW4	MW5A	MW6	MW5B	Domestic	Irrigation
19-Jun-95		1 U	32	40	160	1 U	1 U
21-Aug-95		1 U	11	61	12	1	1 U
17-Oct-95		1 U	63	4 X	1 U	1 U	2
18-Dec-95		1 U	1 U	1 U	1 U	1 U	1 U
26-Feb-96		1 U	1 U	1 U	1 U	1 U	1 U
22-Apr-96		1 U	1 U	1 U		1 U	1
24-Jun-96		1 U	1 U		1 U	1 U	1 U
26-Aug-96		1 U	89	14	1 U	1 U	1 U
28-Oct-96		1 U	130	260 J	1 U	1 U	1 U
16-Dec-96		1 U	1	1 U	1 U	1 U	1 U
24-Feb-97		1 U	1 U	1 U	1 U	1 U	1 U
21-Apr-97		1 U	1 U	1 U	1 U	1 U	1 U
16-Jun-97	1 U	1 U	2	1 U	1 U	1 U	1
11-Aug-97	1 U	1 U	1 U	1 U	1 U	220 J	1 U
20-Oct-97	1 U	1 U	3	1 U	1 U	1 U	1 U
15-Dec-97	1 U	1 U	1 U	3 J	1 U	3 U	1 U
22-Feb-98	1 U	1 U	1 U	1 U	1 U	1 U	1 U
21-Apr-98	1 U	1 U	1 U	1 U	1 U	1 U	1 U
15-Jun-98	1 U	1 U	1 U	1 U	1 U	1 U	1 U
17-Aug-98	1 U	1 U	1 U	6	1 U	1 U	1 U
19-Oct-98	1 U	1 U	1 U	1 U	1 U	1 U	1 U
14-Dec-98	1 U	1 U	1 U	1 U	1 U	1 U	1 U
22-Feb-99	1 U	1 U	1 U	1 U	1 U	1 U	1 U
26-Apr-99	1 U	1 U	1 U	1 U	1 U	1 U	1 U
14-Jun-99	1 U	1 U	1 U	1 U	1 U	1 U	1 U
31-Aug-99	1 U	1 U	1 U	1 U	1 U	1 U	1 U
17-Oct-99	1 U	1 U	1	1 U	1 U	1 U	1
27-Dec-99	1 U	1 U	1 U	1 U	1 U	1 U	
21-Feb-00			1 U	1 U	1 U		
15-May-00	1 U	1 U	2	1 U	1 U	1 U	1 U
19-Jun-00	1 U	1 U	1	1 U	1 U	1 U	1 U
Minimum=	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Maximum=	1 U	1 U	130	260	160	220	2
Mean=	NA	NA	NA	NA	NA	NA	NA
Median=	1 U	1 U	1 U	1 U	1 U	1 U	1 U

U= Analyte was not detected at or above the reported result.
J= The analyte was positively identified. The reported result is an estimate.
UJ= The analyte was not detected at of above the reported estimated result.
X=High background count.

Table E-10. Thurston County Dairy, Surface Water Quality Results.

Sample Date	Nitrate+Nitrite-N Up-stream Station	Nitrate+Nitrite-N Down-stream Station	Nitrate+Nitrite-N Allen Creek	Chloride Up-stream Station	Chloride Down-stream Station	Chloride Allen Creek	Total Dissolved Solids Up-stream Station	Total Dissolved Solids Down-stream Station	Total Dissolved Solids Allen Creek
6/20/95	0.14	1.56		12.3	11.5		82	92	
8/22/95	0.16	1.95		16.2	9.5		96	99	
10/18/95	0.13	0.88		15.7	10.2		96	101	
12/19/95	0.35	0.68		3.6	4.2		65	71	
2/27/96	0.23	0.67		3.9	4.3		73	78	
4/24/96	0.25	0.37		1.6	1.8		44	54	
6/25/96	0.10	0.87		7.3	6.8		65	74	
8/27/96	0.24	1.39		16.5	1.2		102	110	
10/29/96	0.18	0.86		9.4	7.2		82	90	
12/17/96	0.37	0.74		4.2	4.4		45	44	
2/25/97	0.24	0.64		4.1	4.5		57	63	
4/22/97	0.14	0.50		3.4	3.6		44	58	
6/17/97	0.14 J	0.94 J		7.2	6.1		76	85	
8/12/97	0.19	1.52		16.2	8.3		96	95	
10/21/97	0.15	1.08		9.6	6.7		81	82	
12/16/97	0.40	0.66		2.9	2.8		50	58	
2/24/98	0.23	0.69		3.8	3.9		53	62	
4/22/98	0.17	0.94		5.2	5.0		68	75	
6/16/98	0.19	1.41		10.8	7.0		90	93	
8/18/98	0.28	1.44		18.0	7.7		103	87	
10/20/98	0.18	1.25		23.0	9.1		124	104	
12/15/98	0.73	0.91	0.36	4.4	3.7	3.7	58	69	75
2/23/99		0.59	0.38	2.9	3.0	3.0	48	56	65
4/27/99	0.20	0.72	0.23	4.6	4.4	3.1	56	70	72
6/15/99	0.22	1.34	0.25	7.3	6.1	3.2	76	87	85
9/1/99	0.31	2.50	0.26	27.2	10.6	4.4	107	100	79
10/19/99	0.28	1.73	0.08	25.0	7.7	4.0	108	86	67
12/28/99	0.43	0.85	0.32	5.0	4.4	3.2	71	77	76
2/21/00	0.31	0.75	0.32	5.1	4.8	3.6	61	67	80
5/16/00	0.15	0.74	0.17	5.9	5.3	3.4	66	74	77
6/20/00	0.21	1.04	0.21	10.7	7.1	3.5	93 J	93 J	87 J
Minimum=	0.10	0.37	0.08	1.6	1.2	3.0	44	44	65
Maximum=	0.73	2.50	0.38	27.2	11.5	4.4	124	110	87
Mean=	0.24	1.04	0.26	9.5	5.9	3.5	75	79	76
Median=	0.21	0.88	0.25	7.2	5.3	3.5	73	78	77

J= Analyte was positively identified. The reported result is an estimate.

Table E-10. Thurston County Dairy, Surface Water Quality Results.

Sample Date	Total Persulfate Nitrogen			Ammonia-N			Total Organic Nitrogen		
	Up-stream Station	Down-stream Station	Allen Creek	Up-stream Station	Down-stream Station	Allen Creek	Up-stream Station	Down-stream Station	Allen Creek
6/20/95	0.51	2.14		0.01 U	0.07		0.37	0.51	
8/22/95	0.37	2.36 J		0.01 U	0.02		0.22	0.39	
10/18/95	0.44	2.00		0.01 U	0.28		0.31	0.84	
12/19/95	0.58	1.15		0.01 U	0.27		0.24	0.20	
2/27/96	0.46	1.25		0.01 U	0.11		0.23	0.48	
4/24/96	0.61	1.30		0.01 U	0.22		0.35	0.71	
6/25/96	0.57	1.45		0.01 U	0.04		0.47	0.54	
8/27/96	0.45	3.17		0.02	0.65		0.19	1.13	
10/29/96	0.60	1.83		0.01 U	0.31		0.41	0.66	
12/17/96	0.62	1.15		0.01 U	0.02		0.26	0.39	
2/25/97	0.47	0.97		0.01 U	0.01		0.22	0.32	
4/22/97	0.43	0.84		0.01 U	0.02		0.29	0.32	
6/17/97	0.44 J	1.41 J		0.02 J	0.03 J		0.29	0.44	
8/12/97	0.39	1.56		0.05	0.02		0.15	0.02	
10/21/97	0.51	1.56		0.02	0.02		0.35	0.46	
12/16/97	0.76	1.41		0.01 U	0.13		0.36	0.63	
2/24/98	0.35	0.78		0.02	0.03		0.10	0.06	
4/22/98	0.41	1.25		0.11	0.04		0.14	0.26	
6/16/98	0.43	1.47		0.01 U	0.02		0.25	0.04	
8/18/98	0.51	1.74		0.01 U	0.01 U		0.24	0.30	
10/20/98	0.42	1.48		0.01 U	0.01		0.23	0.22	
12/15/98	0.98	1.33	0.85	0.03	0.02	0.04	0.22	0.40	0.45
2/23/99	0.61 J	0.87	0.79	0.01 U	0.01 U	0.02	0.61	0.29	0.39
4/27/99	0.40	1.01	0.69	0.02	0.02	0.03	0.18	0.27	0.43
6/15/99	0.50	1.82	0.60	0.05	0.06	0.06	0.23	0.42	0.28
9/1/99	0.54	3.85	0.65	0.06	0.06	0.06	0.17	1.29	0.33
10/19/99	0.45	2.08	0.46	0.01 U	0.01	0.01	0.16	0.34	0.37
12/28/99	0.63	1.12	0.67	0.03	0.02	0.02	0.17	0.25	0.33
2/21/00	0.54	1.12	0.66	0.01	0.01 U	0.01 U	0.22	0.37	0.35
5/16/00	0.43	1.09	0.54	0.01 U	0.01	0.02	0.28	0.34	0.36
6/20/00	0.43	1.33	0.50	0.01 U	0.01	0.02	0.22	0.28	0.28
Minimum=	0.35	0.78	0.46	0.01 U	0.01 U	0.01 U	0.10	0.02	0.28
Maximum=	0.98	3.85	0.85	0.1	0.6	0.06	0.61	1.29	0.45
Mean=	0.51	1.54	0.64	NA	*0.08	0.03	0.26	0.42	0.36
Median=	0.47	1.41	0.66	0.01 U	0.02	0.02	0.23	0.37	0.35

J= Analyte was positively identified. The reported result is an estimate.

U= Analyte was not detected at or above the reported result.

*Mean calculated by setting non-detect results to 0.005mg/L.

Table E-10. Thurston County Dairy, Surface Water Quality Results.

Sample Date	Fecal Coliform Bacteria: Up-stream Station	Fecal Coliform Bacteria: Down-stream Station	Fecal Coliform Bacteria: Allen Creek	Total Organic Carbon: Up-stream Station	Total Organic Carbon: Down-stream Station	Total Organic Carbon: Allen Creek	Total Phosphorus: Up-stream Station	Total Phosphorus: Down-stream Station	Total Phosphorus: Allen Creek
6/20/95	43	120		5.4	6.2		0.03	0.15	
8/22/95	11	77		3.3	4.7		0.03	0.08	
10/18/95	49	9900 J		6.5	10.5		0.03	0.29	
12/19/95	16	1200		6.1	7.2		0.04	0.01 U	
2/27/96	4	2100		4.2	5.2		0.25	0.13	
4/24/96	350	13000		7.0	8.5		0.35 J	0.22	
6/25/96	41			3.6	3.5		0.03	0.07	
8/27/96	33	32000 J		1.5 UJ	6.3		0.06	0.34	
10/29/96	64	150		9.2	9.7		0.03	0.20	
12/17/96	13	20		5.3	6.0		0.04	0.07	
2/25/97	13	230		4.0	4.4		0.08	0.12	
4/22/97	24	110		6.0	6.5		0.09	0.09	
6/17/97	180	1400		4.7	5.4		0.06 J	0.13 J	
8/12/97	47	43		3.6	4.4		0.09	0.08	
10/21/97	43	400		5.8	6.7		0.03	0.09	
12/16/97	330	930 J		3.9	5.2		0.04	0.35	
2/24/98	9	66		3.9	4.4		0.04	0.06	
4/22/98	47	46		4.0	4.5		0.03	0.06	
6/16/98	51	23		5.5	3.8		0.05	0.06	
8/18/98	76	49		2.9	4.0		0.05	0.04	
10/20/98	37	41		3.9	3.6		0.01	0.02	
12/15/98	13	31	2	6.8	8.9	9.5	0.01	0.04	0.04
2/23/99	18	44	55	4.4	5.4	6.3	0.01	0.03	0.05
4/27/99	57	150	110	3.0	3.4	4.0	0.03	0.05	0.07
6/15/99	150	140	34	3.6	4.3	4.4	0.45	0.07	0.08
9/1/99	150	80	96	2.1	3.1	3.4	0.05	0.08	0.08
10/19/99	9	140	180	2.1	3.6	3.7	0.05	0.07	0.07
12/28/99	7	14	20	3.8	4.9	6.1	0.03	0.04	0.05
2/21/00	18	12	14	3.0	3.6	4.6	0.03	0.04	0.06
5/16/00	170	61	27	3.9	4.2	5.0	0.04	0.05	0.08
6/20/00	24	43	32	4.3	4.6	4.9	0.04	0.06	0.08
Minimum=	4	12	2	1.5	3.1	3.4	0.01	0.01 U	0.04
Maximum=	350	32000	180	9.2	10.5	9.5	0.45	0.35	0.08
Mean=	68	2087	57	4.4	5.4	5.2	0.07	0.10	0.06
Median=	41	95	33	4.0	4.7	4.8	0.04	0.07	0.07

J= Analyte was positively identified. The reported result is an estimate.
UJ= Analyte was not detected at or above the estimated reported result.

Table E-11. Thurston County Dairy Effluent Water Quality. (Units in mg/L unless shown otherwise.)

Sample Date	NH3-N	Nitrate+ Nitrite-N	Total Kjeldahl Nitrogen	Total Organic Nitrogen	Chloride	TOC	Total Phosph.	Fecal Coliform Bacteria (CFU/100mL)
6/20/95	330	2.69			266	2960 J		81,000,000 S
8/22/95	664	6.41			439	6880 J		170,000,000 S
10/18/95	188	4.41			143	1650	106	47,000,000
12/19/95	217	7.02			292	1280	19	28,000,000
2/27/96	185	5.86	599	414	173		1 J	16,000,000
4/24/96	841	3.46	1495	654	177	5110 J	399	120,000,000
6/25/96	826	3.89	964 J	138 J	311	4170	378	145,000,000
8/27/96	530	3.12	992	462	248	2540	190	140,000,000
10/29/96	934	2.00	1120	186	239	5390	175	36,000,000
12/17/96	730 R	4.48	541 R	-189 R	232	4850	133	43,000,000
2/25/97	1051	5.95	3085	2034	393	11800		160,000,000
4/22/97	577	1.40	1145	568	181	5300	36 J	300,000
6/17/97	523 J	1.57 J	744 J	221 J	183	3515	95 J	14,000 J
8/12/97	315	1.40	415	100	208	1960	72	230,000
10/21/97	339	0.22	504	165	160	1540	52	2,500
12/16/97	452	0.01	556	104	184	1380	82	200,000 J
2/24/98	407 J	0.97	540	133 J	225	1760	64	110,000 J
4/22/98	810	0.01 U	912	102	362	2920	140	190,000
6/16/98	700	0.01 U	1380	680	464	6070		260,000
8/18/98	840	0.01 UJ	1335	495	434	3200	115	1,050,000
10/20/98	450	2.46	1850	1400	791	7000 J		240,000
12/15/98	460	1.76	1135	675	395	7000	152	190,000
2/23/99	780	0.08	986	206	459	16.3	185	140,000
4/27/99	564	0.09	1660	1096	462	2100	2060	160,000
6/15/99	846	0.03	1925	1079	459	8600	387	27,000
9/1/99	1400	0.01 U	23000 R	21600 R	390		1240 J	3,800
10/19/99	820	0.15	2310	1490	658	10400	669	6,400
12/28/99	560	1.18	807	247	453	688 J	93	130,000
2/21/00	337	0.21	1230	893	538	3575	149	110,000
5/16/00	651	0.03	922	271	482	510	100	3,100
6/20/00	667	0.01 U	939	272	476	543	160	7,300 J
Minimum=	185	0.01	415	100	143	16.3	1.04	2,500
Maximum=	1400	7.02	3085	2034	791	11800	2060	170,000,000 S
Mean=	609	1.96	1182	563	351	3955	279	32,000,000
Median=	571	1.40	992	414	362	3200	137	230,000

U= Analyte was not detected at or above the reported result.
J= The analyte was positively identified. The reported result is an estimate.
UJ= The analyte was not detected at or above the reported estimated result.
S= Spreader present, may have reduced count.

Table E-12. Summary of Target Analyte Results.

	Nitrate+Nitrite-N			Chloride			Total Dissolved Solids			Total Phosphorus		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Front Field												
MW1	0.01U	17.2	1.10	2.02	11.3	4.1	74	295	135	0.04	0.68	0.20
MW2	0.15	8.7	2.1	2.18	9.62	3.99	36	133	74	0.01U	0.09	0.03
MW3	0.01U	0.18	0.02	10.8	17.7	13.8	122	159	142	0.01U	0.27	0.11
South Field - Shallow												
MW12	0.01U	6.9	4.9	7.38	10.2	8.36	112	164	129	0.02	0.10	0.06
MW4	3.1	82	22.6	3.97	49.2	17.3	81	520	238	0.01U	0.10	0.02
MW5A	11.2	31.2	21.3	15.5	70.3	31.9	217	366	280	0.01U	0.11	0.03
MW6	5.28	26.1	14.2	11,8	51.4	26.6	154	321	227	0.01U	0.18	0.05
South Field - Deep												
Domestic	2.08	6.43	3.58	3.25	11.7	5.76	45	224	88	0.01U	0.43	0.05
Irrigation	1.94	13.1	6.71	3.85	21.8	8.87	73	168	115	0.01U	0.38	0.04
MW5B	0.01U	4.14	1.49	5.79	36.8	20.5	140	226	169	0.01U	0.16	0.04
West Field												
MW12	0.01U	6.9	4.9	7.38	10.2	8.36	112	164	129	0.02	0.10	0.06
MW7	2.92	32.0	14.5	13.9	88.2	35.9	106	401	224	0.01U	0.09	0.03
MW8	17.6	72.0	31.1	24.1	67.4	40.4	73	524	360	0.01U	0.22	0.08
MW9	13.2	52.0	25.4	6.48	39.4	21.6	152	450	268	0.01U	0.11	0.03
North Field												
MW11	4.79	141	27.9	11.2	140	41.9	168	1240	316	0.01U	0.08	0.02
MW10	20.8	80.0	47.3	29.6	106	53.3	276	707	465	0.01U	0.15	0.03
Groundwater	0.01U	141	14.3	2.02	140	21.4	36	1240	210	0.01U	0.68	0.06
Surface Water												
Upstream	0.10	0.73	0.24	1.6	27.2	9.5	44	124	75	0.01	0.45	0.07
Downstream	0.37	2.5	1.04	1.2	11.5	5.9	44	110	79	0.01U	0.35	0.10
Allen Creek	0.08	0.38	0.26	3.0	4.4	3.5	65	87	76	0.04	0.08	0.06
Effluent	0.01U	7.02	1.96	143	791	351	NT	NT	NT	1.04	399	134

U= Analyte not detected above listed value.
NT= Not tested.

Table E-12. Summary of Target Analyte Results.

	Total Organic Carbon			Ammonia-N			Total Persulfate Nitrogen			Organic Nitrogen		
	Min	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
Front Field												
MW1	2.3	21.1	9.3	0.01U	0.08	NA	0.28	22.1	2.4	NC	NC	NC
MW2	1.0U	2.0	NA	0.01U	0.04	NA	0.15	10.7	2.4	NC	NC	NC
MW3	1.8	3.9	2.7	0.06	0.13	0.10	0.14	0.32	0.23	NC	NC	NC
South Field - Shallow												
MW12	1.0U	1.6	NA	0.01U	0.03	NA	0.01UJ	7.3	4.71	NC	NC	NC
MW4	1.0U	3.5	1.6	0.01U	0.07	NA	3.25	59.8	22.4	NC	NC	NC
MW5A	1.2	3.3	2.0	0.01U	0.03	NA	4.72	32.5	21.0	NC	NC	NC
MW6	1.0U	3.3	NA	0.01U	0.04	NA	3.00	23.5	13.9	NC	NC	NC
South Field - Deep												
Domestic	1.0U	2.1	NA	0.01U	0.03	NA	0.88	7.2	5.76	NC	NC	NC
Irrigation	1.0U	1.3	NA	0.01U	0.03	NA	2.35	21.8	7.12	NC	NC	NC
MW5B	1.0U	2.0	NA	0.01U	0.07	0.03	0.10	4.18	2.05	NC	NC	NC
West Field												
MW12	1.0U	1.6	NA	0.01U	0.03	NA	0.01UJ	7.3	4.71	NC	NC	NC
MW7	1.0U	2.9	1.7	0.01U	0.03	NA	2.96	29.5	13.8	NC	NC	NC
MW8	1.0U	4.5	1.4	0.01U	0.57	NA	6.71	44.0	30.1	NC	NC	NC
MW9	1.0U	3.0	1.7	0.01U	0.04	NA	4.55	46.7	23.8	NC	NC	NC
North Field												
MW11	1.6	3.9	2.7	0.01U	0.03	NA	4.86	160	30.7	NC	NC	NC
MW10	1.0U	5.6	1.6	0.01U	0.07	NA	5.99	56.5	44.2	NC	NC	NC
Groundwater	1.0U	21.1	2.7	0.01U	0.57	NA	0.01UJ	160	14.3	NC	NC	NC
Surface Water												
Upstream	1.5	9.2	4.4	0.01U	0.10	NA	0.35	0.98	0.51	0.10	0.61	0.26
Downstream	3.1	10.5	5.4	0.01U	0.65	0.08	0.78	3.85	1.54	0.02	1.29	0.42
Allen Creek	3.4	9.5	5.2	0.01U	0.06	0.03	0.46	0.85	0.64	0.28	0.45	0.36
Effluent	16	11,800	3,955	185	1400	613	415*	3085*	1182*	100	2,034	563

U= Analyte not detected above listed value.

UJ= Analyte not detected above listed estimated value.

NA= Mean not calculated because analyte not detected in a majority of samples.

* Sample tested for Total Kjeldahl Nitrogen

Effluent Organic Nitrogen= TKN - Ammonia-N

Water Organic Nitrogen= TPN-[(Ammonia-N) - (Nitrate+nitrite-N)]

Note: Organic N concentrations less than 0 ppm are rejected (R).

NC= Value not calculated because of inconsistent TPN results likely due to matrix interference.

Table E-12. Summary of Target Analyte Results.

	Fecal Coliform Bacteria		
	Min	**Max**	**GeoMean**
Front Field			
MW1	1U	24	NA
MW2	1U	1	NA
MW3	1U	2	NA
South Field - Shallow			
MW12	1U	1U	NA
MW4	1U	1U	NA
MW5A	1U	130	NA
MW6	1U	260	NA
South Field - Deep			
Domestic	1U	220	NA
Irrigation	1U	2	NA
MW5B	1U	160	NA
West Field			
MW12	1U	1U	NA
MW7	1U	8	NA
MW8	1U	67	NA
MW9	1U	6	NA
North Field			
MW11	1U	2	NA
MW10	1U	3	NA
Groundwater	1U	260	NA
Surface Water			
Upstream	4	350	68
Downstream	12	32,000	2087
Allen Creek	2	180	57
Effluent	2,500	170,000,000S	32,000,000

U= Analyte not detected above listed value.
NA= Mean not calculated because analyte not detected in a majority of samples.

Appendix F

Loading Estimates

Table F-1. Estimated Monthly Manure and Nitrogen Loading to South and West Fields.

1995	Manure Generated for Onsite Application (Gallons|)	Storage (Gallons|)	Gross Nitrogen Loading (lbs)	Ammonia-N Application Losses (lbs)	Net Nitrogen Loading (lbs)	Net Nitrogen Loading (lbs/ac)
Jan	3.23E+05	0.00E+00	4.52E+03	7.87E+02	3.74E+03	57
Feb	3.23E+05	0.00E+00	4.52E+03	7.87E+02	3.74E+03	57
Mar	3.23E+05	0.00E+00	4.52E+03	7.87E+02	3.74E+03	57
Apr	3.23E+05	0.00E+00	4.52E+03	7.87E+02	3.74E+03	57
May	3.23E+05	0.00E+00	4.52E+03	7.87E+02	3.74E+03	57
Jun	3.23E+05	0.00E+00	4.52E+03	7.87E+02	3.74E+03	57
Jul	3.23E+05	0.00E+00	4.52E+03	7.87E+02	3.74E+03	57
Aug	3.23E+05	0.00E+00	4.52E+03	7.87E+02	3.74E+03	57
Sep	3.23E+05	0.00E+00	4.52E+03	7.87E+02	3.74E+03	57
Oct	3.23E+05	0.00E+00	4.52E+03	7.87E+02	3.74E+03	57
Nov	3.23E+05	0.00E+00	4.52E+03	7.87E+02	3.74E+03	57
Dec	3.23E+05	0.00E+00	4.52E+03	7.87E+02	3.74E+03	57
Total=	3.88E+06		Volume Applied (gallons)=		3.88E+06	682

1996	Manure Generated for Onsite Application (Gallons|)	Storage (Gallons|)	Gross Nitrogen Loading (lbs)	Ammonia-N Application Losses (lbs)	Net Nitrogen Loading (lbs)	Net Nitrogen Loading (lbs/ac)
Jan	3.23E+05	0.00E+00	4.52E+03	7.87E+02	3.74E+03	57
Feb	3.23E+05	0.00E+00	4.52E+03	7.87E+02	3.74E+03	57
Mar	3.23E+05	0.00E+00	4.52E+03	7.87E+02	3.74E+03	57
Apr	3.23E+05	0.00E+00	4.52E+03	7.87E+02	3.74E+03	57
May	3.23E+05	0.00E+00	4.52E+03	7.87E+02	3.74E+03	57
Jun	3.23E+05	0.00E+00	4.52E+03	7.87E+02	3.74E+03	57
Jul	3.23E+05	0.00E+00	4.52E+03	7.87E+02	3.74E+03	57
Aug	3.23E+05	0.00E+00	4.52E+03	7.87E+02	3.74E+03	57
Sep	3.86E+05	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0
Oct	3.86E+05	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0
Nov	3.86E+05	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0
Dec	3.86E+05	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0
Total=	4.13E+06		Volume Applied (gallons)=		2.59E+06	454

1997	Manure Generated for Onsite Application (Gallons|)	Pond Storage (Gallons|)	Gross Nitrogen Loading (lbs)	Ammonia-N Application Losses (lbs)	Net Nitrogen Loading (lbs)	Net Nitrogen Loading (lbs/ac)
Jan	3.86E+05	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0
Feb	3.86E+05	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0
Mar	3.86E+05	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0
Apr	3.86E+05	0.00E+00	7.71E+03	1.34E+03	6.37E+03	97
May	3.86E+05	0.00E+00	7.71E+03	1.34E+03	6.37E+03	97
Jun	3.86E+05	0.00E+00	7.71E+03	1.34E+03	6.37E+03	97
Jul	3.86E+05	0.00E+00	7.71E+03	1.34E+03	6.37E+03	97
Aug	3.86E+05	0.00E+00	7.71E+03	1.34E+03	6.37E+03	97
Sep	3.86E+05	0.00E+00	7.71E+03	1.34E+03	6.37E+03	97
Oct	3.86E+05	0.00E+00	7.71E+03	1.34E+03	6.37E+03	97
Nov	3.86E+05	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0
Dec	3.86E+05	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0
Total=	4.63E+06		Volume Applied (gallons)=		5.40E+06	678

1998	Manure Generated for Onsite Application (Gallons|)	Pond Storage (Gallons|)	Gross Nitrogen Loading (lbs)	Ammonia-N Application Losses (lbs)	Net Nitrogen Loading (lbs)	Net Nitrogen Loading (lbs/ac)
Jan	3.86E+05	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0
Feb	3.86E+05	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0
Mar	3.86E+05	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0
Apr	3.86E+05	0.00E+00	6.61E+03	1.15E+03	5.46E+03	83
May	3.86E+05	0.00E+00	6.61E+03	1.15E+03	5.46E+03	83
Jun	3.86E+05	0.00E+00	6.61E+03	1.15E+03	5.46E+03	83
Jul	3.86E+05	0.00E+00	6.61E+03	1.15E+03	5.46E+03	83
Aug	3.86E+05	0.00E+00	6.61E+03	1.15E+03	5.46E+03	83
Sep	3.86E+05	0.00E+00	6.61E+03	1.15E+03	5.46E+03	83
Oct	3.86E+05	0.00E+00	6.61E+03	1.15E+03	5.46E+03	83
Nov	3.86E+05	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0
Dec	3.86E+05	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0
Total=	4.63E+06		Volume Applied (gallons)=		4.63E+06	581

1999	Manure Generated for Onsite Application (Gallons|)	Pond Storage (Gallons|)	Gross Nitrogen Loading (lbs)	Ammonia-N Application Losses (lbs)	Net Nitrogen Loading (lbs)	Net Nitrogen Loading (lbs/ac)
Jan	3.86E+05	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0
Feb	3.86E+05	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0
Mar	3.86E+05	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0
Apr	3.86E+05	0.00E+00	3.86E+03	6.71E+02	3.19E+03	48
May	3.86E+05	0.00E+00	3.86E+03	6.71E+02	3.19E+03	48
Jun	3.86E+05	0.00E+00	3.86E+03	6.71E+02	3.19E+03	48
Jul	3.86E+05	0.00E+00	3.86E+03	6.71E+02	3.19E+03	48
Aug	3.86E+05	0.00E+00	3.86E+03	6.71E+02	3.19E+03	48
Sep	3.86E+05	0.00E+00	2.31E+04	6.71E+02	2.25E+04	341
Oct	3.86E+05	0.00E+00	3.86E+03	6.71E+02	3.19E+03	48
Nov	3.86E+05	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0
Dec	3.86E+05	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0
Total=	4.63E+06		Volume Applied (gallons)=		4.63E+06	632

2000	Manure Generated for Onsite Application (Gallons|)	Pond Storage (Gallons|)	Gross Nitrogen Loading (lbs)	Ammonia-N Application Losses (lbs)	Net Nitrogen Loading (lbs)	Net Nitrogen Loading (lbs/ac)
Jan	3.86E+05	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0
Feb	3.86E+05	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0
Mar	3.86E+05	3.86E+05	0.00E+00	0.00E+00	0.00E+00	0
Apr	3.86E+05	0.00E+00	3.86E+03	6.71E+02	3.19E+03	48
May	3.86E+05	0.00E+00	3.86E+03	6.71E+02	3.19E+03	48
Jun	3.86E+05	0.00E+00	3.86E+03	6.71E+02	3.19E+03	48
Total=	2.31E+06		Volume Applied (gallons)=		1.16E+06	145

Assumptions:

N content of unstored manure= 14lbs/1000gal

Gross N from stored manure= 10lbs/1000 gal

Spray and Tanker Truck Ammonia-N Application Losses = 30 %

Injection N Application Losses= 5%

50% of the manure was injected in 1998 and 1999.

Mineralization of N from Soil=125Lbs N/ac/yr N removal due to grazing = (2/3)X 396 lbs/ac

Table F-2. Estimated Monthly Manure and Nitrogen Loading to the North Field.

1995	Manure Generated for Onsite Application (Gallons|)	Storage (Gallons|)	Gross Nitrogen Loading (lbs)	Ammonia-N Application Losses (lbs)	Net Nitrogen Loading (lbs)	Net Nitrogen Loading (lbs/ac)
Jan	1.52E+05	0.00E+00	2.13E+03	3.70E+02	1.76E+03	42
Feb	1.52E+05	0.00E+00	2.13E+03	3.70E+02	1.76E+03	42
Mar	1.52E+05	0.00E+00	2.13E+03	3.70E+02	1.76E+03	42
Apr	1.52E+05	0.00E+00	2.13E+03	3.70E+02	1.76E+03	42
May	1.52E+05	0.00E+00	2.13E+03	3.70E+02	1.76E+03	42
Jun	1.52E+05	0.00E+00	2.13E+03	3.70E+02	1.76E+03	42
Jul	1.52E+05	0.00E+00	2.13E+03	3.70E+02	1.76E+03	42
Aug	1.52E+05	0.00E+00	2.13E+03	3.70E+02	1.76E+03	42
Sep	1.52E+05	0.00E+00	2.13E+03	3.70E+02	1.76E+03	42
Oct	1.52E+05	0.00E+00	2.13E+03	3.70E+02	1.76E+03	42
Nov	1.52E+05	0.00E+00	2.13E+03	3.70E+02	1.76E+03	42
Dec	1.52E+05	0.00E+00	2.13E+03	3.70E+02	1.76E+03	42
Total =	1.82E+06		Volume Applied(gallons)=		1.82E+06	505

1996	Manure Generated for Onsite Application (Gallons|)	Storage (Gallons|)	Gross Nitrogen Loading (lbs)	Ammonia-N Application Losses (lbs)	Net Nitrogen Loading (lbs)	Net Nitrogen Loading (lbs/ac)
Jan	1.52E+05	0.00E+00	2.13E+03	3.70E+02	1.76E+03	42
Feb	1.52E+05	0.00E+00	2.13E+03	3.70E+02	1.76E+03	42
Mar	1.52E+05	0.00E+00	2.13E+03	3.70E+02	1.76E+03	42
Apr	1.52E+05	0.00E+00	2.13E+03	3.70E+02	1.76E+03	42
May	1.52E+05	0.00E+00	2.13E+03	3.70E+02	1.76E+03	42
Jun	1.52E+05	0.00E+00	2.13E+03	3.70E+02	1.76E+03	42
Jul	1.52E+05	0.00E+00	2.13E+03	3.70E+02	1.76E+03	42
Aug	1.52E+05	0.00E+00	2.13E+03	3.70E+02	1.76E+03	42
Sep	1.83E+05	1.83E+05	0.00E+00	0.00E+00	0.00E+00	0
Oct	1.83E+05	1.83E+05	0.00E+00	0.00E+00	0.00E+00	0
Nov	1.83E+05	1.83E+05	0.00E+00	0.00E+00	0.00E+00	0
Dec	1.83E+05	1.83E+05	0.00E+00	0.00E+00	0.00E+00	0
Total =	1.95E+06		Volume Applied(gallons)=		1.22E+06	337

1997	Manure Generated for Onsite Application (Gallons|)	Pond Storage (Gallons|)	Gross Nitrogen Loading (lbs)	Ammonia-N Application Losses (lbs)	Net Nitrogen Loading (lbs)	Net Nitrogen Loading (lbs/ac)
Jan	1.83E+05	1.83E+05	0.00E+00	0.00E+00	0.00E+00	0
Feb	1.83E+05	1.83E+05	0.00E+00	0.00E+00	0.00E+00	0
Mar	1.83E+05	1.83E+05	0.00E+00	0.00E+00	0.00E+00	0
Apr	1.83E+05	0.00E+00	3.67E+03	6.38E+02	3.03E+03	72
May	1.83E+05	0.00E+00	3.67E+03	6.38E+02	3.03E+03	72
Jun	1.83E+05	0.00E+00	3.67E+03	6.38E+02	3.03E+03	72
Jul	1.83E+05	0.00E+00	3.67E+03	6.38E+02	3.03E+03	72
Aug	1.83E+05	0.00E+00	3.67E+03	6.38E+02	3.03E+03	72
Sep	1.83E+05	0.00E+00	3.67E+03	6.38E+02	3.03E+03	72
Oct	1.83E+05	0.00E+00	3.67E+03	6.38E+02	3.03E+03	72
Nov	1.83E+05	1.83E+05	0.00E+00	0.00E+00	0.00E+00	0
Dec	1.83E+05	1.83E+05	0.00E+00	0.00E+00	0.00E+00	0
Total =	2.20E+06		Volume Applied(gallons)=		2.57E+06	507

1998	Manure Generated for Onsite Application (Gallons|)	Pond Storage (Gallons|)	Gross Nitrogen Loading (lbs)	Ammonia-N Application Losses (lbs)	Net Nitrogen Loading (lbs)	Net Nitrogen Loading (lbs/ac)
Jan	1.83E+05	1.83E+05	0.00E+00	0.00E+00	0.00E+00	0
Feb	1.83E+05	1.83E+05	0.00E+00	0.00E+00	0.00E+00	0
Mar	1.83E+05	1.83E+05	0.00E+00	0.00E+00	0.00E+00	0
Apr	1.83E+05	0.00E+00	3.14E+03	5.47E+02	2.60E+03	62
May	1.83E+05	0.00E+00	3.14E+03	5.47E+02	2.60E+03	62
Jun	1.83E+05	0.00E+00	3.14E+03	5.47E+02	2.60E+03	62
Jul	1.83E+05	0.00E+00	3.14E+03	5.47E+02	2.60E+03	62
Aug	1.83E+05	0.00E+00	3.14E+03	5.47E+02	2.60E+03	62
Sep	1.83E+05	0.00E+00	3.14E+03	5.47E+02	2.60E+03	62
Oct	1.83E+05	0.00E+00	3.14E+03	5.47E+02	2.60E+03	62
Nov	1.83E+05	1.83E+05	0.00E+00	0.00E+00	0.00E+00	0
Dec	1.83E+05	1.83E+05	0.00E+00	0.00E+00	0.00E+00	0
Total =	2.20E+06		Volume Applied(gallons)=		2.20E+06	435

1999	Manure Generated for Onsite Application (Gallons|)	Pond Storage (Gallons|)	Gross Nitrogen Loading (lbs)	Ammonia-N Application Losses (lbs)	Net Nitrogen Loading (lbs)	Net Nitrogen Loading (lbs/ac)
Jan	1.83E+05	1.83E+05	0.00E+00	0.00E+00	0.00E+00	0
Feb	1.83E+05	1.83E+05	0.00E+00	0.00E+00	0.00E+00	0
Mar	1.83E+05	1.83E+05	0.00E+00	0.00E+00	0.00E+00	0
Apr	1.83E+05	0.00E+00	3.14E+03	5.47E+02	2.60E+03	62
May	1.83E+05	0.00E+00	3.14E+03	5.47E+02	2.60E+03	62
Jun	1.83E+05	0.00E+00	3.14E+03	5.47E+02	2.60E+03	62
Jul	1.83E+05	0.00E+00	3.14E+03	5.47E+02	2.60E+03	62
Aug	1.83E+05	0.00E+00	3.14E+03	5.47E+02	2.60E+03	62
Sep	1.83E+05	0.00E+00	3.14E+03	5.47E+02	2.60E+03	62
Oct	1.83E+05	0.00E+00	3.14E+03	5.47E+02	2.60E+03	62
Nov	1.83E+05	1.83E+05	0.00E+00	0.00E+00	0.00E+00	0
Dec	1.83E+05	1.83E+05	0.00E+00	0.00E+00	0.00E+00	0
Total =	2.20E+06		Volume Applied(gallons)=		2.20E+06	435

2000	Manure Generated for Onsite Application (Gallons|)	Pond Storage (Gallons|)	Gross Nitrogen Loading (lbs)	Ammonia-N Application Losses (lbs)	Net Nitrogen Loading (lbs)	Net Nitrogen Loading (lbs/ac)
Jan	1.83E+05	1.83E+05	0.00E+00	0.00E+00	0.00E+00	0
Feb	1.83E+05	1.83E+05	0.00E+00	0.00E+00	0.00E+00	0
Mar	1.83E+05	1.83E+05	0.00E+00	0.00E+00	0.00E+00	0
Apr	1.83E+05	0.00E+00	3.14E+03	5.47E+02	2.60E+03	62
May	1.83E+05	0.00E+00	3.14E+03	5.47E+02	2.60E+03	62
Jun	1.83E+05	0.00E+00	3.14E+03	5.47E+02	2.60E+03	62
Total=	9.43E+05		Volume Applied(gallons)=		5.50E+05	186

Assumptions:
N content of unstored manure= 14lbs/1000gal
Gross N from stored manure= 10lbs/1000 gal

Table F-3. Summary of Nitrogen Loading, Soil Nitrate Concentrations, and Mean Nitrate+ Nitrite-N Concentrations in Groundwater.

Field	Year	Residual Nitrogen (lbs/ac)	Fall Soil Nitrate (lbs/ac)	Mean Nitrate+Nitrite-N Growing Season (mg/L	Mean Nitrate+Nitrite-N Non-Growing Season (mg/L)
Front Field	1993		101		
	1994				
	1995	83		0.65	5.23
	1996	83	96	0.43	5.35
	1997	83		0.69	5.59
	1998	83	91	0.57	6.69
	1999	83	52	0.64	4.12
	2000			0.21	
	Year	**Residual Nitrogen (lbs/ac)**	**Fall Soil Nitrate (lbs/ac)**	**Mean Nitrate+Nitrite-N Growing Season (mg/L**	**Mean Nitrate+Nitrite-N Non-Growing Season (mg/L)**
South Field	1993		112		
	1994				
	1995	541		16.74	24.03
	1996	314	128	15.33	26.79
	1997	537		13.97	22.85
	1998	441	175	14.06	23.32
	1999	492	303	22.05	29.97
	2000			22.05	
	Year	**Residual Nitrogen (lbs/ac)**	**Fall Soil Nitrate (lbs/ac)**	**Mean Nitrate+Nitrite-N Growing Season (mg/L**	**Mean Nitrate+Nitrite-N Non-Growing Season (mg/L)**
West Field	1993		105		
	1994				
	1995	541		30.30	26.75
	1996	314	202	28.94	22.86
	1997	537		20.90	36.30
	1998	441	88	31.26	36.58
	1999	492	270	25.35	29.15
	2000			28.03	
	Year	**Residual Nitrogen (lbs/ac)**	**Fall Soil Nitrate (lbs/ac)**	**Mean Nitrate+Nitrite-N Growing Season (mg/L**	**Mean Nitrate+Nitrite-N Non-Growing Season (mg/L)**
North Field	1993		63		
	1994				
	1995	365		44.63	43.50
	1996	196	136	32.31	54.90
	1997	367		32.23	44.55
	1998	294	108	29.99	59.18
	1999	294	203	38.53	26.93
	2000			20.68	

Growing Season= April through October
Non-Growing Season= November through March