A Department of Ecology Report

WASHINGTON STATE DEPARTMENT OF ECOLOGY

Evaluation of the Potential for Ground Water Contamination at Sunland Land Application Site

Summary

The potential effects of the Sunland land application facility on ground water quality were evaluated. The evaluation was based on the facility's records and a consultant's hydrogeologic report, as well as a site inspection and effluent sampling.

The potential for ground water contamination at the spray field is high for the following reasons:

- The spray field overlies a shallow water table aquifer
- The effluent application rate far exceeds recommended fertilization rates
- Sixty percent of the effluent is applied during the non-growing (dormant) season when plant uptake of nitrogen is low
- Nitrogen removal from the field does not occur, because the grass crop is mowed and left to decompose in the summer

As currently operated, I estimate that nitrate contributions from the land application site could elevate downgradient nitrate-N concentrations by 11 to 15 mg/L. Pulses of higher concentration may also occur due to application scheduling.

The existing ground water monitoring network is inadequate. The ground water flow direction cannot be determined with the current well network. The upgradient and downgradient monitoring wells are in different water-bearing zones and are therefore not comparable. Wells do not meet current construction standards. Existing ground water data are of limited value for three reasons:

1) Lack of an upgradient well
2) Poor well seals
3) Lack of quality assurance sampling

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Recommendations for the land application operation at Sunland are:

1. Complete the hydrogeologic characterization of the site. This includes:

   - Lateral and vertical extent of the uppermost aquifer
   - Flow direction of the uppermost aquifer
   - Hydraulic conductivity and estimated rates of ground water movement
   - Relationship between the uppermost aquifer and Cassalery Creek

2. Upgrade the ground water monitoring network based on the results of new characterization information. The upgraded network should be capable of defining the upgradient and downgradient quality of the uppermost aquifer. All wells must meet Minimum Standards for Construction and Maintenance of Wells (Chapter 173-160 WAC).

3. Prepare and implement an approved Sampling and Analysis Plan for the ground water monitoring network.

4. Redesign the nutrient and hydraulic loading rates for the spray field to correspond with recommended agronomic rates as specified in <u>Guidelines for Preparation of Engineering Reports for Industrial Wastewater Land Application Systems</u> (Ecology, 1993).

   The nutrient loading analysis should address: monthly crop uptake (lb/acre) of total nitrogen; total nitrogen applied (lb/acre); and total nitrogen stored in the soil and retained in the crop (lb/acre). Total nitrogen refers to total Kjeldahl N plus nitrate+nitrite-N.

   The hydraulic loading analysis should address: monthly water use and water balance showing precipitation (inches); evapotranspiration (inches); wastewater applied (inches); supplemental water, if any (inches); and total water applied (inches).

5. Develop an "Irrigation and Crop Management Plan" as described in <u>Guidelines for Preparation of Engineering Reports for Industrial Wastewater Land Application Systems</u> (Ecology, 1993). The plan should include management of the crop, i.e., removal of the harvested crop.

6. Develop a plan for storing effluent during the dormant season.

7. Modify the permit limits so that effluent land application rates correspond with agronomic rates. Effluent application rates should be measured in the field periodically, i.e., one day per week.

Introduction

The Sunland wastewater treatment plant (WTP) is located near Sequim, Washington in the northeast part of the Olympic Peninsula (Figure 1). The WTP serves a retirement community of 614 homes and condominiums and has operated under State Waste Discharge Permit No. STO6003 since 1979. Wastewater is treated in an aerated lagoon followed by a facultative lagoon. The effluent is then chlorinated and held in a polishing pond before being pumped to the spray field for final treatment and disposal. The permit does not contain any seasonal restrictions for land application.

The spray field is an 11-acre field of tall fescue mixed with other grasses (Perkins, 1995). The northwest corner of the field is bounded by Cassalery Creek as shown in Figure 2. Effluent is applied through a system of above-ground pipelines and movable lateral lines with sprinklers. The ground water monitoring network consists of five wells, two on site and three nearby.

The original plant design called for an upgrade when the flow exceeded 50,000 gallons/day (GPD) (ECNW, 1980). The flow has exceeded 50,000 GPD since August 1991. Some of the upgrade changes have recently been made (ECNW, 1994). The permit allows discharge of 130,000 GPD in the upgraded configuration. However, an additional 29 acres of spray field is required to accommodate the higher flow.

Ecology's Southwest Regional Office requested that Ecology's Environmental Investigations and Laboratory Services (EILS) conduct an assessment of the spray field. The objectives of the study were to:

- Evaluate the potential for ground water contamination
- Evaluate the adequacy of the monitoring well network
- Make recommendations for improving the ground water monitoring network and spray field management

Soils and Hydrogeology

Soils beneath the spray field consist primarily of moderately permeable Dungeness silt loam (SCS, 1987). The northeast one-fifth of the spray field is composed of Puget silt loam which is poorly drained and has moderately slow permeability. Both soil types are subject to occasional flooding.

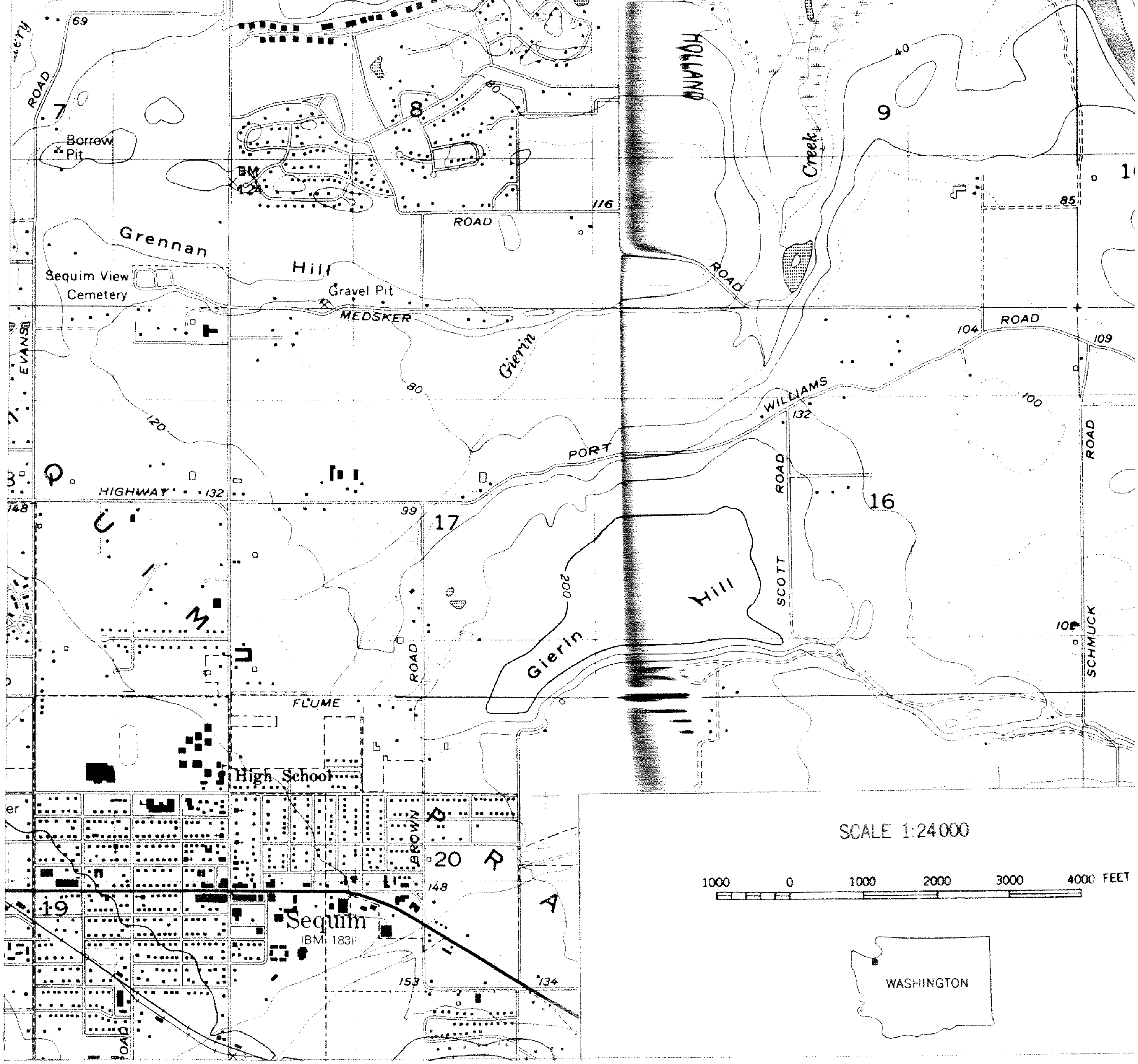

Figure 1. Map of the Sunland WTP, spray field, and vicinity.

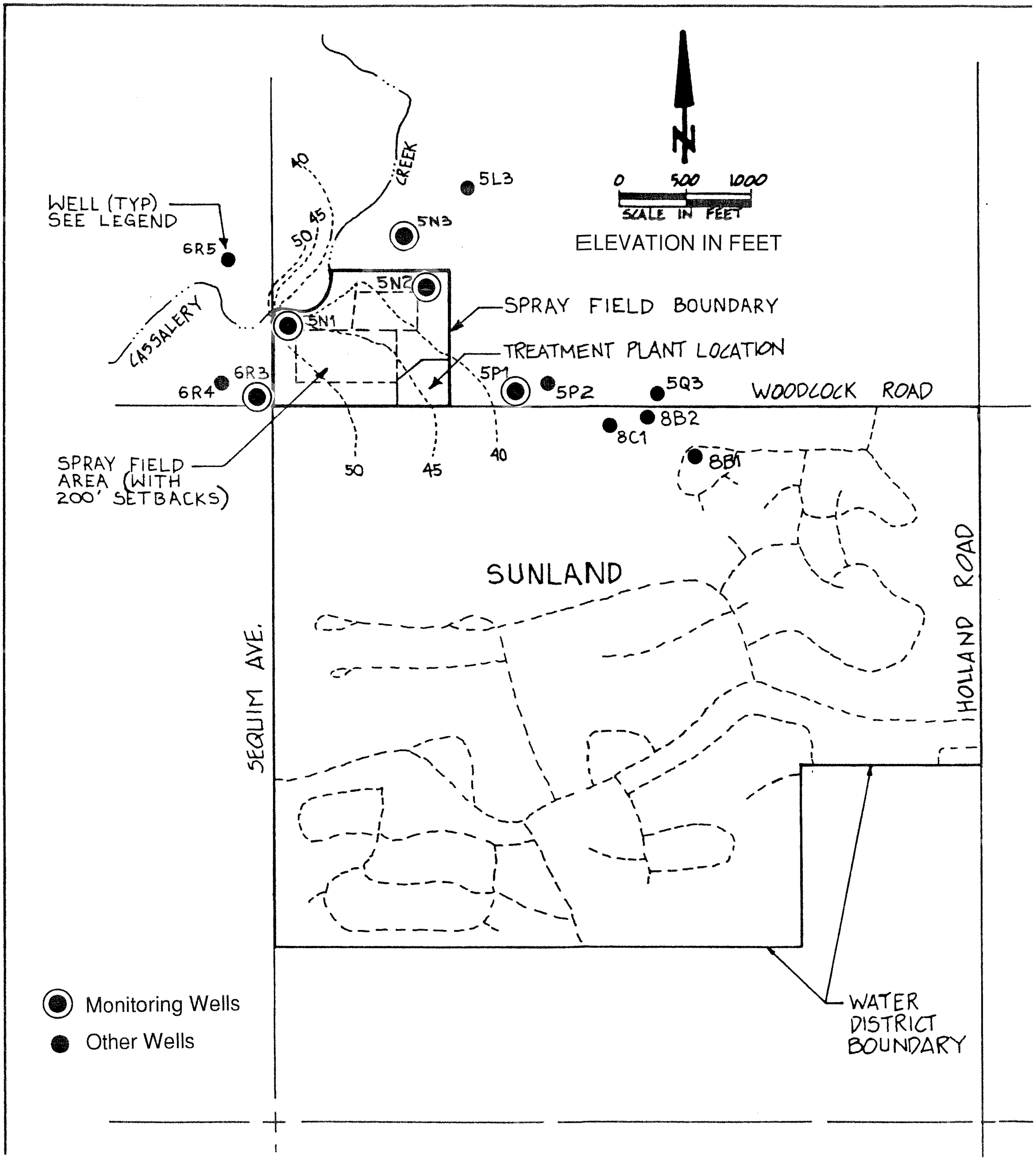

Figure 2. Map of the study area (from ECNW, 1994 and Sunland Water District).

Rongey Associates (1993) identified three hydrogeologic units in the Sunland area:

- Dungeness River channel and floodplain deposits
- The Potholes outwash deposits
- Glacial and interglacial fluvial deposits

The Dungeness River channel and floodplain deposits immediately underlie the spray field site. The uppermost aquifer beneath the spray field occurs in these deposits. These deposits consist of multiple layers of fine-grained silt and clay, interbedded with sand and gravel layers mixed with clay.

The Potholes outwash crops out in the low hills south of the Cassalery Creek floodplain and northwest of the spray field. These deposits consist of sand and gravel, but do not lie beneath the spray field.

The glacial and interglacial deposits are composed of clay and gravelly clay with thin, interbedded gravel water-bearing zones (Rongey Associates, 1993). These deposits underlie both the Potholes and Dungeness deposits, including the spray field area. The deep water-bearing zones in this unit are confined or semi-confined.

Drillers' logs from wells in the Dungeness River deposits near the Sunland WTP indicate the presence of three water-bearing zones: a water table aquifer at 14 to 18 feet depth (Unit A) and two confined or semi-confined water-bearing zones -- one at 30 to 50 feet (Unit B) and one at 100 to 125 feet depths (Unit C).

Two monitoring wells, 5N1 and 5N2, are completed in the water-table aquifer (Unit A). Two other wells, 5P1 and 5N3, may also be in this unit, but drillers' logs are not available for verification. The direction of ground water flow is probably toward Cassalery Creek to the north/northwest, but cannot be defined with the existing information.

The degree of hydraulic connection between the Potholes outwash deposits and the Dungeness River channel and floodplain deposits is not clear. Rongey Associates (1993) believe that little continuity exists between the two deposits. However, additional data are needed to verify this conclusion.

Methods

Representatives of the Southwest Regional Office, Cyronose Spicer, Kathy Cupps, Dick Schroeder, and I visited the Sunland WTP and spray field on July 12, 1994. We toured the WTP, collected two effluent samples, and inspected on-site monitoring well 5N2.

One effluent sample was collected near the bank edge of the polishing pond The other sample was taken from a hose connected to the discharge line from the polishing pond to the spray field. The hose was allowed to run for five minutes before samples were collected. Standard collection, preservation, and transport procedures were used (Glenn, 1994). Effluent samples were analyzed for:

Ammonia-N
Nitrate+Nitrite-N
Total Kjeldahl N (TKN)
Specific Conductance
Chloride
Total Dissolved Solids
pH

Analytical methods are listed in Appendix A. All samples, with the exception of TKN, were tested at the Ecology/EPA Manchester Laboratory. TKN samples were tested by a contract laboratory.

Laboratory quality assurance and quality control samples consisted of procedural blanks, check standards, and replicates (Ecology, 1994). All data are acceptable for use.

Field quality assurance consisted of a transport blank for nitrogen analyses (Appendix B). TKN was detected in the transport blank but did not require qualification of the results.

Results and Discussion

Potential for Ground Water Contamination

The potential for ground water contamination beneath the spray field is high for the following reasons:

- Shallow depth to water
- Spray field operation (crop not removed, sprinkler rotation, winter application)
- Excessive effluent application rate

These issues are discussed below. In addition, the effect of the spray field operation on nitrate concentration in downgradient ground water is estimated.

Shallow Depth to Water

The water table aquifer underlying the site is 14-18 feet deep. Figure 3 shows the water levels in the on-site monitoring wells, 5N1 and 5N2, for the period 1989-1994. The highest water levels occur during the period from November through February, when precipitation is highest and evapotranspiration is lowest. Effluent application varies little seasonally and probably contributes to the higher winter water table.

Spray Field Operation

Effluent is applied to the spray field on a different schedule than specified in the engineering design. The design specifies that effluent be applied every seven days to 1.7 acre areas (eight hours/day). The practice, however, is to apply effluent to a one-acre area for three consecutive days (four hours/day), returning to the same spot approximately every 30 days year-round (Thomsen, 1995). This schedule does not take full advantage of water and nitrogen uptake by the crop and probably leads to substantial leaching of effluent below the root zone, especially during the winter.

In addition, the grass crop is not harvested. The grass is mowed but is then left on the ground to decompose. This allows the nitrogen to be recycled again into plant material or leached below the root zone. The net effect, however, is that all the nitrogen taken up in plant tissue eventually becomes available to leach into the ground water. In addition, cattle were grazed on the spray field until the fall of 1991, adding still more nitrogen to the system.

Excessive Effluent Application Rate

A monthly water balance for the spray field was used to estimate the nitrogen application rate. The water balance for water year 1994 is shown in Table 1. The total water applied for the year was 77 inches over 11 acres based on an irrigation efficiency of 90%. Assuming an effluent total N concentration of 24-37 mg/L, as found in the four samples collected in 1994 and shown in Appendix C, the annual nitrogen loading rate to the spray field was 400-600 lb/acre.

The water balance in Table 1 indicates that about 75 inches/acre of water were available for percolation below the root zone taking consumptive use into account. Sixty percent of the estimated deep percolation occurred during the six-month dormant season, October through March.

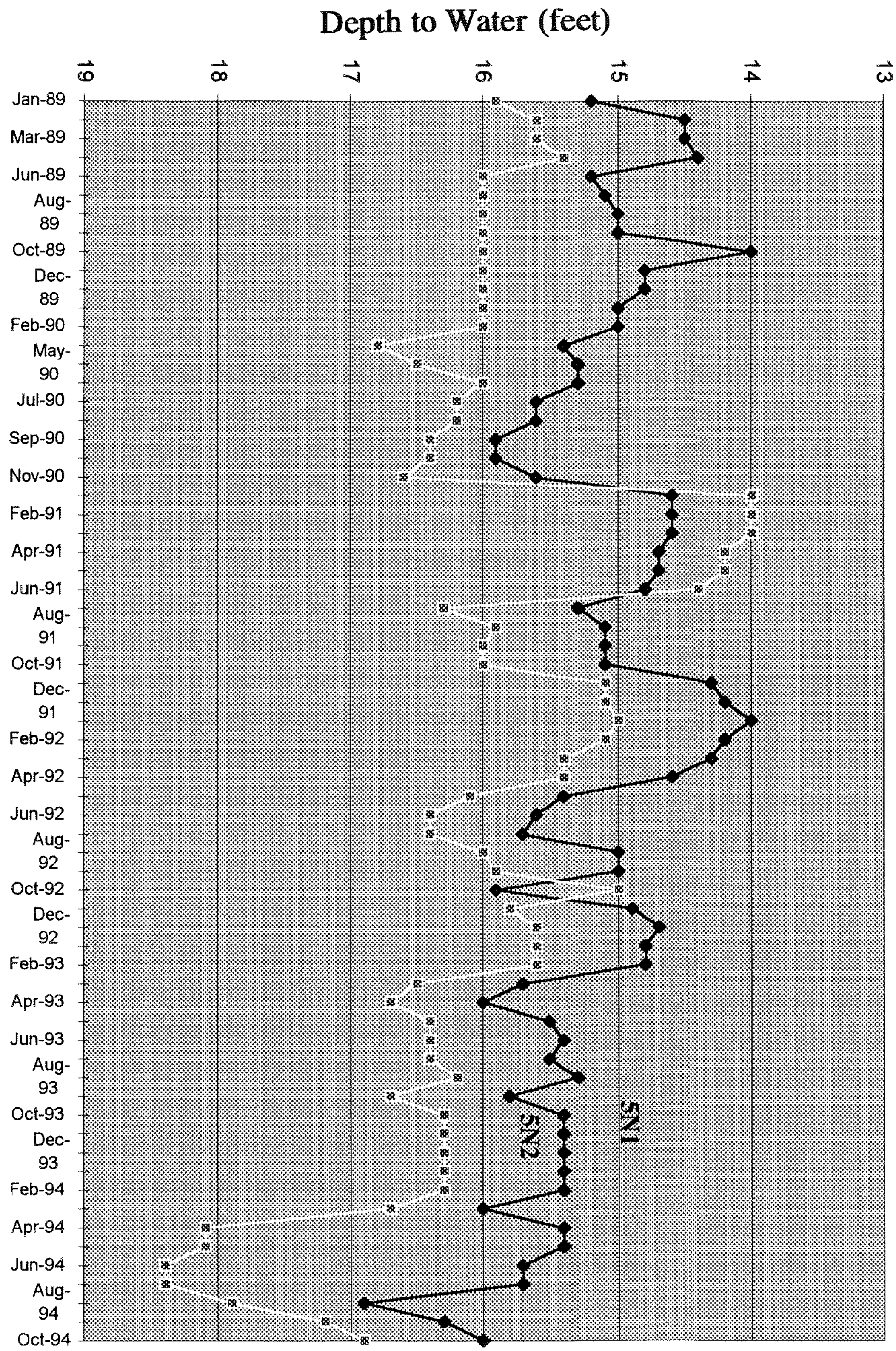

Figure 3. Water level measurements for the on-site monitoring wells from January 1989 to October 1994.

Table 1. Water balance for Sunland land application site. Application rates are taken from Discharge Monitoring Reports for October 1993-September 1994.

	Precipitation (Inches)* (a)	Effluent Applied (Inches/acre)** (b)	Total of Precipitation + Effluent, (a)+(b) (Inches/Acre) (c)	Potential ET (Inches)* (d)	Consumptive Use= (d) x 0.76^ (Inches) (e)	Total Water Percolated (c)-(e) (Inches/Acre) (f)	Fraction of Total Percolated = Effluent (b)/(c) (g)	Percolating Water from Effluent, (f)x(g) (Inches/Acre) (h)
Jan	2.2	6.0	8.2	0.4	0.30	7.9	0.73	5.8
Feb	1.8	5.2	7.0	0.6	0.46	6.5	0.74	4.9
Mar	1.2	5.9	7.1	1.1	0.84	6.2	0.83	5.2
Apr	0.9	6.0	6.9	1.9	1.44	5.5	0.87	4.8
May	1.0	6.6	7.6	2.8	2.13	5.5	0.87	4.8
June	1.2	6.5	7.7	3.6	2.74	5.0	0.84	4.2
July	0.6	7.5	8.1	4.1	3.12	5.0	0.93	4.6
Aug	0.6	7.9	8.5	3.8	2.89	5.6	0.93	5.3
Sept	1.0	6.5	7.5	2.8	2.13	5.4	0.87	4.7
Oct	1.5	6.3	7.8	1.7	1.29	6.5	0.81	5.2
Nov	2.3	6.0	8.3	0.9	0.68	7.6	0.72	5.5
Dec	2.8	6.3	9.1	0.6	0.46	8.7	0.69	6.0
Total	17	77	94	24	18.5	75		61

* from Washington Climate Data for Clallam, Grays Harbor, Jefferson, Pacific, and Wahkiakum counties, Washington State Cooperative Extension Service, WSU.

** Volume land-applied divided by 11 acres and assuming 90% irrigation efficiency.

^ Average pan factor for pasture/turf in Sequim, Washington from SCS, 1990. Washington State Irrigation Guide.

The estimated annual mass of total N percolating below the root zone during the 1994 water year, based on the estimated amount of percolating effluent water (Table 1) and the concentration of total N in the percolate (Appendix C), was about 280 lb/acre. Sixty-two percent of the estimated nitrogen leaching to ground water occurred during the dormant season. I estimated nitrogen losses as follows, assuming that volatilization and denitrification are the only mechanisms for loss, because the crop is not removed:

- 30% of effluent nitrate+nitrite-N and ammonia-N are lost during the growing season (EPA, 1981)
- 10% of effluent nitrate+nitrite-N and ammonia-N are lost during the dormant season
- 30% of organic nitrogen is available for plant uptake or percolation during the entire year (Sullivan, 1995)

Based on these assumptions, the total N concentration in the mixed percolate of effluent and precipitation-related water was 18 to 22 mg/L depending on the season (Appendix C). If the grass crop had been harvested and removed from the field, the concentration of total N in the percolate would have been substantially lower (EPA, 1981).

Estimated Effect on Ground Water

The nitrogen loading estimated above is substantial. I estimated the effects of this loading on the ground water quality downgradient of the spray field using a Darcy strip mass-balance method (Darr, 1994). Assumptions for this calculation are:

- Hydraulic conductivity is 10^{-1} to 10^{-3} cm/sec
- Hydraulic gradient is 0.001 based on water level differences between monitoring wells 5N1 and 5N2
- The cross-sectional distance perpendicular to the direction of ground water flow at the site is 1,200 feet
- Percolate nitrate-N is 15-18 mg/L (see Appendix D)
- Mixing occurs in the top 10 feet of the aquifer

See Appendix E for further details of the method. The estimated nitrate-N concentration downgradient of the spray field would increase by 11 to 15 mg/L. However, the 30-day rotation schedule may lead to localized pulses of higher nitrate concentrations.

Adequacy of the Ground Water Monitoring Network

The ground water monitoring network must be capable of defining ground water flow direction and ground water quality upgradient and downgradient of the uppermost aquifer. The network consists of five wells: two on-site monitoring wells, 5N1 and 5N2, and three private wells, 6R3, 5N3, and 5P1. The well locations are shown in Figure 2. Well construction information is summarized in Table 2.

Four wells, 5N1, 5N2, 5N3, and 5P1, are completed in Hydrogeologic Unit A and one well, 6R3, is completed in Hydrogeologic Unit B. There is no upgradient well completed in Unit A. This monitoring network cannot adequately determine flow direction or ground water quality in Unit A. In addition, water quality data collected from wells 5N3 and 5P1 are not reliable, because well construction information is not available.

Water quality data from most of the monitoring wells are also questionable, because the wells do not meet current construction standards (Chapter 173-162 WAC). Well screens consist of perforations sawed in "plastic" pipe for wells 5N1 and 5N2 and sawed perforations in steel well casing for well 6R3.

The open intervals in wells 5N1 and 5N2 (19-22 feet and 17-20 feet, respectively) appear to be close to the bottom of the 18-foot deep bentonite and puddling clay seal. In fact, the open interval in 5N2 may be partially obstructed by the seal. Typically a two- to three-foot separation between the bottom of the seal and open interval is desired. A gravel pack was not used but would have helped prevent sealing of the perforations. Both wells produce ample water for sampling (Thomsen, 1995), despite the potential seal problem.

Data from the designated upgradient well, 6R3, is considered suspect because of its proximity to a septic system (Rongey Associates, 1993). The upgradient well also appears to be completed in Unit B rather than the target aquifer, Unit A.

Review of Existing Monitoring Data

The existing ground water data have limited usefulness for several reasons. First, there is no upgradient well in Unit A to compare with downgradient water quality. Second, well seals for the spray field wells, 5N1 and 5N2, may not be adequate to prevent surface contaminants from migrating along the well casing. Third, lack of field and laboratory quality assurance samples makes it impossible to estimate sampling and analytical precision and accuracy.

During the past five years, nitrate-N concentrations measured quarterly in monitoring well 5N2 have ranged from 0.4 to 12 mg/L (Figure 4). It is not clear whether the higher concentrations are due to land application of wastewater by the facility, cattle wastes, flooding, or poor well construction.

Table 2. Construction information for monitoring wells.

Well I.D.	Depth (feet)	Date Installed	Screened Interval (feet)	Aquifer Designation*	Casing Material	Type of Perforations	Surface Seal Present	Gravel Pack Present
5N1	22	1974	19–22	Unit A	PVC	Sawed, covered w/	0–18 feet	No
						wire mesh		No
5N2	20	1974	17–20	Unit A	PVC	Sawed, covered w/	0–18 feet	
						wire mesh		
6R3	49	1986	45–49	Unit B	Steel	Sawed, 1/4 in x 5 in	0–18 feet	No
5N3	25	nknown	NA	Unit A	Unknown	Unknown	Unknown	Unknown
5P1	25	nknown	NA	Unit A	Unknown	Unknown	Unknown	Unknown

* A,B, and C represent the upper three aquifer zones in the Dungeness channel and floodplain deposits, with A as the uppermost.

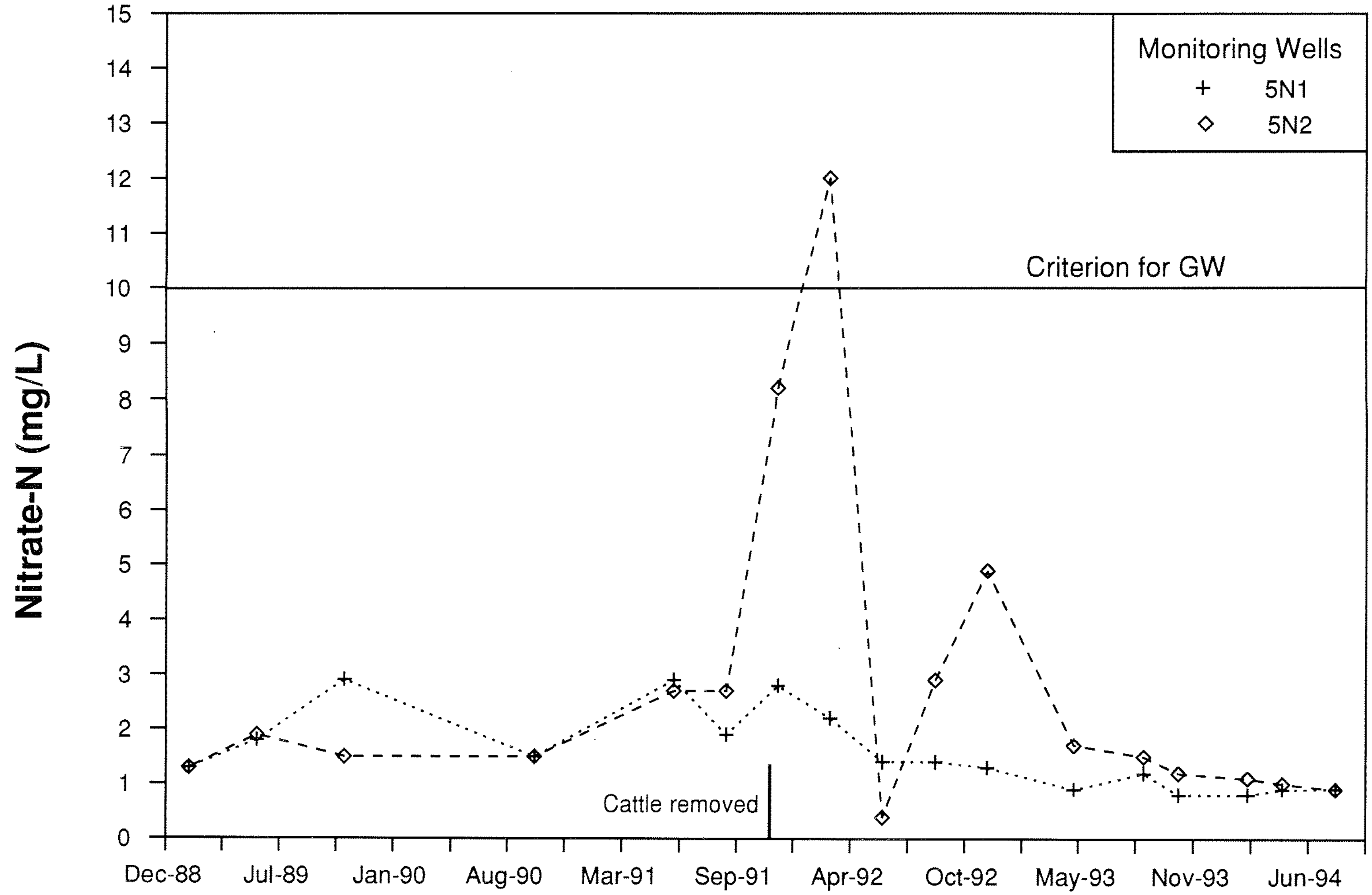

Figure 4. Nitrate results from monitoring wells 5N1 and 5N2 reported in DMR's.

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Appendix A. Analytical parameters, methods, and method detection limits.

Parameter	Method of Analysis	Reference	Method Detection Limit
pH	Beckman pH meter	NA	0.1 Std Unit
Specific Conductance	Std Method #2510	APHA (1989)	10 umhos/cm
Total Dissolved Solids	Std Method #209B	APHA (1989)	10 mg/L
Ammonia-N	EPA #350.1	EPA (1983)	0.01 mg/L
Nitrate+ Nitrite-N	EPA # 353.2	EPA (1983)	0.01 mg/L
Kjeldahl-N	Std Methods #4500-N org	APHA (1989)	
Chloride	Std Methods #4110B	APHA (1989)	0.1 mg/L

EPA, 1983. Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020. Revised March 1983.

American Public Health Association, 1989. Methods for the Examination of Water and Wastewater, 17th Edition.

Appendix B. Results of transport blanks in mg/L.

Parmeter	Concentration
Ammonia-N	<0.01
Nitrate+nitite-N	<0.01
Total Kjeldahl N	0.22 J

J= Estimated value

Appendix C. Results of July 12, 1994, effluent samples collected by Ecology in mg/L and Sunland DMR data.

Parameter	Ecology Results #1	Ecology Results #2	Sunland Results	
Date	07/12/94	07/12/94	05/24/94	08/31/94
pH	7.8	7.8		
Specific conductance	807	800	870	720
Total Dissolved Solids	430	423		
Ammonia-N	15.0	14.2	25	20
Nitrate+Nitrite-N	6.16	2.87	1.5	11
Total Kjeldahl N	24	22	35	13
Total N	30	25	37	24
Chloride	67.2	66.2		

Appendix D. Calculated values for percolating total N.

Table D.1. Calculated values for percolating effluent organic N, inorganic N, mixing with precipitation.

Parameter	Ecology Results #1	#2	Sunland Results		Mean
Date	07/12/94	07/12/94	05/24/94	08/31/94	
Organic N*	9	8	10	NA	
Percolating Organic N (30% of Organic N)	2.7	2.3	3.0		2.7
Summer Inorganic N Percolating**	15	12	19		15
Summer Total N Percolating***	18	14	22		18
Winter Inorganic N Percolating^	19	15	24		19
Winter Total N Percolating***	22	18	27		22

* Organic N = (Total Kjeldahl N) - (Ammonia-N).

** Because the crop was not removed, Summer Inorganic N Percolating = 70% of (Ammonia-N + Nitrate+Nitrite-N).

*** Total N Percolating= (Percolating Organic N) + (Mean Percolating Inorganic N).

^ Winter Inorganic N Percolating = 90% of (Ammonia-N + Nitrate+nitrite-N).

Table D.2. Estimates of total N concentrations in percolate before mixing with ground water.

Month	Percolating Water from Effluent (Inches/Acre) (a)	Percolating Water from Effluent (L/Acre) (b)	Percolating Effluent N Concentration N Conc (mg/L)** (c)	Mass of N Percolating (b)x(c), (kg/acre) (d)	Total Water Percolated (Inches/Acre)* (e)	Total Water Percolated (L/Acre) (f)	N Concentration in Mixed Percolate (d)/(f), (mg/L) (g)
Jan	5.8	6.0E+05	22	13	7.9	8.1E+05	16.1
Feb	4.9	5.0E+05	22	11	6.5	6.7E+05	16.3
Mar	5.2	5.3E+05	22	12	6.2	6.4E+05	18.3
Apr	4.8	4.9E+05	18	9	5.5	5.6E+05	15.7
May	4.8	4.9E+05	18	9	5.5	5.6E+05	15.6
June	4.2	4.3E+05	18	8	5.0	5.1E+05	15.2
July	4.6	4.8E+05	18	9	5.0	5.1E+05	16.7
Aug	5.3	5.4E+05	18	10	5.6	5.8E+05	16.7
Sept	4.7	4.8E+05	18	9	5.4	5.6E+05	15.6
Oct	5.2	5.4E+05	22	12	6.5	6.7E+05	17.8
Nov	5.5	5.6E+05	22	12	7.6	7.8E+05	15.9
Dec	6.0	6.2E+05	22	14	8.7	8.9E+05	15.3
Total	61			126	75		
Mean							16.3

* from Table 1.

** from Appendix D.1.

Appendix E. Estimating downgradient nitrate-N concentrations

I used a mass balance mixing model to estimate the concentration of nitrate-N downgradient of the spray field (Darr, 1994). I assumed that the mass of nitrate moving below the water table mixes with the mass of nitrate in the top ten feet of the aquifer upgradient of the spray field to yield a total mass of nitrate moving downgradient. The following equation summarizes the method:

$$(Q_{PERC} \times C_{PERC}) + (Q_{UP} \times C_{UP}) = Q_{DN} \times C_{DN}$$

where:

Q_{PERC} = Flow of water below the root zone (75 inches on 11 acres = 8,204 cubic feet/day)

C_{PERC} = 15-18 mg/L

Q_{UP} = Horizontal flow of water in the top 10 feet of the aquifer past a cross-section of the field perpendicular to the direction of flow, or Q =(Hydraulic conductivity) x (Gradient) x (Area of the cross-section).

For a 1,200 foot by 10 foot strip with a hydraulic conductivity of 10^{-1} to 10^{-3} cm/second, and gradient of 0.001, the estimate for Q_{UP} is 34-3,400 cubic feet/day.

C_{UP} = 1.0 mg/L

$Q_{DN} = Q_{UP} + Q_{PERC}$

$C_{DN} = (Q_{PERC}\, C_{PERC} + Q_{UP}\, C_{UP})/Q_{DN}$

Table E.1. shows the monthly estimates for the variables above. The resulting mean concentration downgradient, C_{DN}, is 12-16 mg/L.

Table E.1. Estimates for downgradient nitrogen concentration where hydraulic conductivity of the aquifer, K, = 10exp−1 to 10exp−3 and the gradient, i, based on the difference in water level in monitoring wells 5N1 and 5N2 over the period of record is 0.001.

Month	Upgradient flow, K=10exp−3, Qup (ft3/day) (a)	Upgradient N Concentration (mg/L) (b)	Total Water Percolated (Inches/Acre)* (c)	Total Water Percolated, Qperc (ft3/day)** (d)	N Concentration in Mixed Percolate, Cperc (mg/L)*** (e)	Downgradient Flow, Qdn= (a)+(d) (ft3/day) (f)	Downgradient N Concentration, Cdn= (e)/(f), (mg/L) (g)
Jan	34	1	7.9	1.1E+04	16.1	1.1E+04	16.1
Feb	34	1	6.5	8.6E+03	16.3	8.7E+03	16.3
Mar	34	1	6.2	8.2E+03	18.3	8.3E+03	18.2
Apr	34	1	5.5	7.3E+03	15.7	7.3E+03	15.6
May	34	1	5.5	7.3E+03	15.6	7.3E+03	15.6
June	34	1	5.0	6.6E+03	15.2	6.7E+03	15.1
July	34	1	5.0	6.6E+03	16.7	6.7E+03	16.6
Aug	34	1	5.6	7.4E+03	16.7	7.5E+03	16.7
Sept	34	1	5.4	7.2E+03	15.6	7.2E+03	15.5
Oct	34	1	6.5	8.6E+03	17.8	8.7E+03	17.7
Nov	34	1	7.6	1.0E+04	15.9	1.0E+04	15.8
Dec	34	1	8.7	1.2E+04	15.3	1.2E+04	15.2
Mean							16.2

* Total Water Percolated (Inches/Acre) from Table 1.

** (d) = (c)/(12 inches/foot) x (11 acres) x (43,500 cubic feet/acre−foot)/(days/month).

*** from Appendix D.

Table E.1. (cont.)

Month	Upgradient flow, K=10exp-2, Qup (ft3/day) (a)	Upgradient N Concentration (mg/L) (b)	Total Water Percolated (Inches/Acre)* (c)	Total Water Percolated, Qperc (ft3/day)** (d)	N Concentration in Mixed Percolate, Cperc (mg/L)*** (e)	Downgradient Flow, Qdn= (a)+(d) (ft3/day) (f)	Downgradient N Concentration, Cdn= (e)/(f), (mg/L) (g)
Jan	340	1	9.0E+06	1.1E+04	16.1	1.1E+04	15.7
Feb	340	1	7.4E+06	9.3E+03	16.3	9.6E+03	15.8
Mar	340	1	7.0E+06	8.0E+03	18.3	8.3E+03	17.6
Apr	340	1	6.2E+06	7.3E+03	15.7	7.6E+03	15.0
May	340	1	6.2E+06	7.1E+03	15.6	7.4E+03	15.0
June	340	1	5.6E+06	6.6E+03	15.2	7.0E+03	14.5
July	340	1	5.6E+06	6.4E+03	16.7	6.8E+03	15.9
Aug	340	1	6.4E+06	7.3E+03	16.7	7.6E+03	16.0
Sept	340	1	6.1E+06	7.2E+03	15.6	7.5E+03	15.0
Oct	340	1	7.3E+06	8.3E+03	17.8	8.7E+03	17.1
Nov	340	1	8.6E+06	1.0E+04	15.9	1.0E+04	15.4
Dec	340	1	9.8E+06	1.1E+04	15.3	1.2E+04	14.8
Mean							15.6

* Total Water Percolated (Inches/Acre) from Table 1.

** (d) = (c)/(12 inches/foot) x (11 acres) x (43,500 cubic feet/acre-foot)/(days/month).

*** from Appendix D.

Table E.1. (cont.)

Month	Upgradient flow, K=10exp-1, Qup (ft3/day) (a)	Upgradient N Concentration (mg/L) (b)	Total Water Percolated (Inches/Acre)* (c)	Total Water Percolated, Qperc (ft3/day)** (d)	N Concentration in Mixed Percolate, Cperc (mg/L)*** (e)	Downgradient Flow, Qdn= (a)+(d) (ft3/day) (f)	Downgradient N Concentration, Cdn= (e)/(f), (mg/L) (g)
Jan	3,396	1	9.0E+06	1.1E+04	16.1	1.4E+04	12.4
Feb	3,396	1	7.4E+06	9.3E+03	16.3	1.3E+04	12.2
Mar	3,396	1	7.0E+06	8.0E+03	18.3	1.1E+04	13.1
Apr	3,396	1	6.2E+06	7.3E+03	15.7	1.1E+04	11.0
May	3,396	1	6.2E+06	7.1E+03	15.6	1.0E+04	10.9
June	3,396	1	5.6E+06	6.6E+03	15.2	1.0E+04	10.4
July	3,396	1	5.6E+06	6.4E+03	16.7	9.8E+03	11.3
Aug	3,396	1	6.4E+06	7.3E+03	16.7	1.1E+04	11.7
Sept	3,396	1	6.1E+06	7.2E+03	15.6	1.1E+04	10.9
Oct	3,396	1	7.3E+06	8.3E+03	17.8	1.2E+04	12.9
Nov	3,396	1	8.6E+06	1.0E+04	15.9	1.3E+04	12.1
Dec	3,396	1	9.8E+06	1.1E+04	15.3	1.5E+04	11.9
Mean							11.7

* Total Water Percolated (Inches/Acre) from Table 1.

** (d) = (c)/(12 inches/foot) x (11 acres) x (43,500 cubic feet/acre-foot)/(days/month).

*** from Appendix D.