GROUND WATER MONITORING TECHNICAL COMPLETION REPORT

EVALUATION OF AGRICULTURAL BEST MANAGEMENT PRACTICES TO REDUCE NONPOINT SOURCE GROUND WATER NITRATE IN SOUTHERN MINIDOKA COUNTY, IDAHO

MINIDOKA/CASSIA GROUND WATER MONITORING PROJECT

by

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ABSTRACT

Nonpoint source nitrate contamination from traditional farming practices has lead to degradation of the ground water in agricultural areas of southern Minidoka County, Idaho. Agricultural practices in the southern Minidoka County area have been estimated to be responsible for 90 percent of the nitrate entering the ground water system and in many of these areas nitrate levels in domestic wells commonly exceed the United States Environmental Protection Agency (EPA) drinking water standard. Because ground water supplies the drinking water for the majority of residents in the area, leaching of nitrate to the ground water and the associated health risks have created great concern. High concentrations of nitrate plus nitrite in drinking water have been implicated with methemoglobinemia (blue baby syndrome) and non-Hodgekin's lymphoma.

In 1992, the EPA Section 319 National Monitoring Program (NMP) provided funding for the establishment of two demonstration fields within the Idaho Snake River Plain Water Quality Demonstration Project area in southern Minidoka County. A demonstration field was selected at each of two farms for a pilot ground water project primarily to monitor potential nonpoint source ground water nitrate contamination and to evaluate the effectiveness of two United States Department of Agriculture (USDA) recommended Best Management Practices (BMPs): (1) a nutrient management BMP through crop rotation and (2) a nutrient management BMP through reduced irrigation water application. An EPA suggested paired watershed approach was used to evaluate independently a different BMP at each demonstration field. For the paired watershed approach, each field was split into a control half and treatment half, and two periods of study were evaluated, a calibration period and treatment period.

The focus of this investigation was to evaluate BMP treatment period effects on ground water nitrate concentrations in shallow, perched aquifers underlying both demonstration fields, that are highly susceptible to agricultural nitrate contamination. Because agricultural nitrate is a potential nonpoint source of contamination, typical methods to evaluate point source contamination do not apply. For this reason, a geostatistical approach was developed to evaluate nitrate concentration distributions and BMP effectiveness. A monitoring network of lysimeters, ground water point samplers, and/or shallow wells based, in part, on a geostatistically-oriented design was installed at each demonstration field. Monthly nitrate data collected for these monitoring networks were evaluated using two different types of geostatistical approaches. A sequential Gaussian simulation (SGS) approach was used to evaluate ground water and soil water nitrate concentration distributions at the crop rotation BMP demonstration field (i.e., Forgeon Field). A trend surface analysis (TSA) approach was used to evaluate ground water and soil water nitrate concentration distributions at the irrigation BMP demonstration field (i.e., Moncur Field). Geostatistically derived spatial maps based on SGS and TSA results were compared using a spatial map subtraction technique to evaluate net nitrate changes at each demonstration field.

Results of these evaluations suggested that each BMP had a positive influence on the ground water quality in the shallow, unconfined aquifer beneath each demonstration field. At the Forgeon Field, hydrogeologic conditions were, in part, a controlling factor in observed BMP effects. The highest net changes were observed in ground water within sandy subsoils following heavy irrigation. Substantial differences in net nitrate changes in the ground water below the control and treatment halves of the sandy subsoils portion of the field indicated positive BMP effects. At the Moncur Field, hydrogeologic conditions were less of a factor. However, spatial maps of net ground water nitrate concentration changes over time indicated the occurrence of a reversal in the pattern of nitrate concentration changes evidently as a result of positive effects of the reduced water application rates of the irrigation BMP.

INTRODUCTION

The leaching of excess nitrogen fertilizer associated with current farming practices has led to ground water degradation in agricultural areas of the Eastern Snake River Plain (ESRP), Idaho. Past monitoring of shallow aquifers in agricultural areas of the ESRP showed that nitrate levels in some domestic wells exceeded the EPA drinking water standard of 10mg/l (Young et al., 1987a,b; Rupert, 1994; Osmond et al., 1995; Clark et al., 1998; Etcheverry, 1999). Studies also have indicated noticeable increases in nitrate levels within the more extensive, deep-seated Snake River Plain Aquifer (Mitchell, 1998). Because groundwater supplies the drinking water for 90 percent of the people in Minidoka County, Idaho, leaching of nitrate to the ground water and the associated health risks have created great concern. High concentrations of nitrate plus nitrite in drinking water have been implicated with methemoglobinemia (blue baby syndrome), which is characterized by a reduced ability of the blood to carry oxygen (Rupert, 1990). High concentrations of nitrate plus nitrite in drinking water also may be associated with a high incidence of non-Hodgekin's lymphoma (Rupert, 1990).

Scope

This investigation constitutes an investigation of potential nonpoint source ground water nitrate contamination and evaluation of the effectiveness of USDA prescribed BMP's at two demonstration test fields. The main focus of this investigation was to evaluate possible BMP effects on ground water nitrate concentrations in the shallow, unconfined aquifer underlying each demonstration test field. Physical and chemical data collected for the sites, geostatistical analysis techniques, prior on site investigations, well driller's reports, and other geologic and hydrogeologic studies provided the basis for this evaluation.

Description of Project Area

The demonstration fields (i.e., the Forgeon and Moncur Fields) are located in southern Minidoka County, Idaho, within the geographic province of the Eastern Snake River Plain (Figure 1). The ESRP is a volcanic trough consisting of Quaternary age basalt flows that are underlain by rhyolitic volcanic rocks. In the area of the demonstration fields, basalt flows are overlain by lacustrine strata believed to have been deposited by the prehistoric Raft Lake and Burley Lake; these lacustrine strata are overlain by alluvial deposits from the Snake River in some locations (Crosthwaite and Scott, 1956). Both fields are situated over shallow aquifers that extend from a depth of about 3 to 7 feet below land surface to 25 feet to 35 feet below land surface. Local ground water flow generally is northerly toward nearby irrigation drains at both demonstration fields. The deep-seated Snake River Plain Aquifer underlies this shallow aquifer at a depth of approximately 200 to 300 feet below the two demonstration fields.

The demonstration fields are situated in a rural area whose primary economic resource is irrigated agriculture. Major crops in the area include potatoes, alfalfa, beans, grain, sugar beets, corn, and irrigated pasture. Local irrigation systems vary from the historical practice of flood irrigation to more modern techniques of sprinkler irrigation. Sprinkler irrigation currently is in use at both demonstration fields. Approximate annual fertilizer applications of nitrogen within the Snake River Plain Water Quality Demonstration Project area typically range from 60 lb/acre to 300 lb/acre, depending on

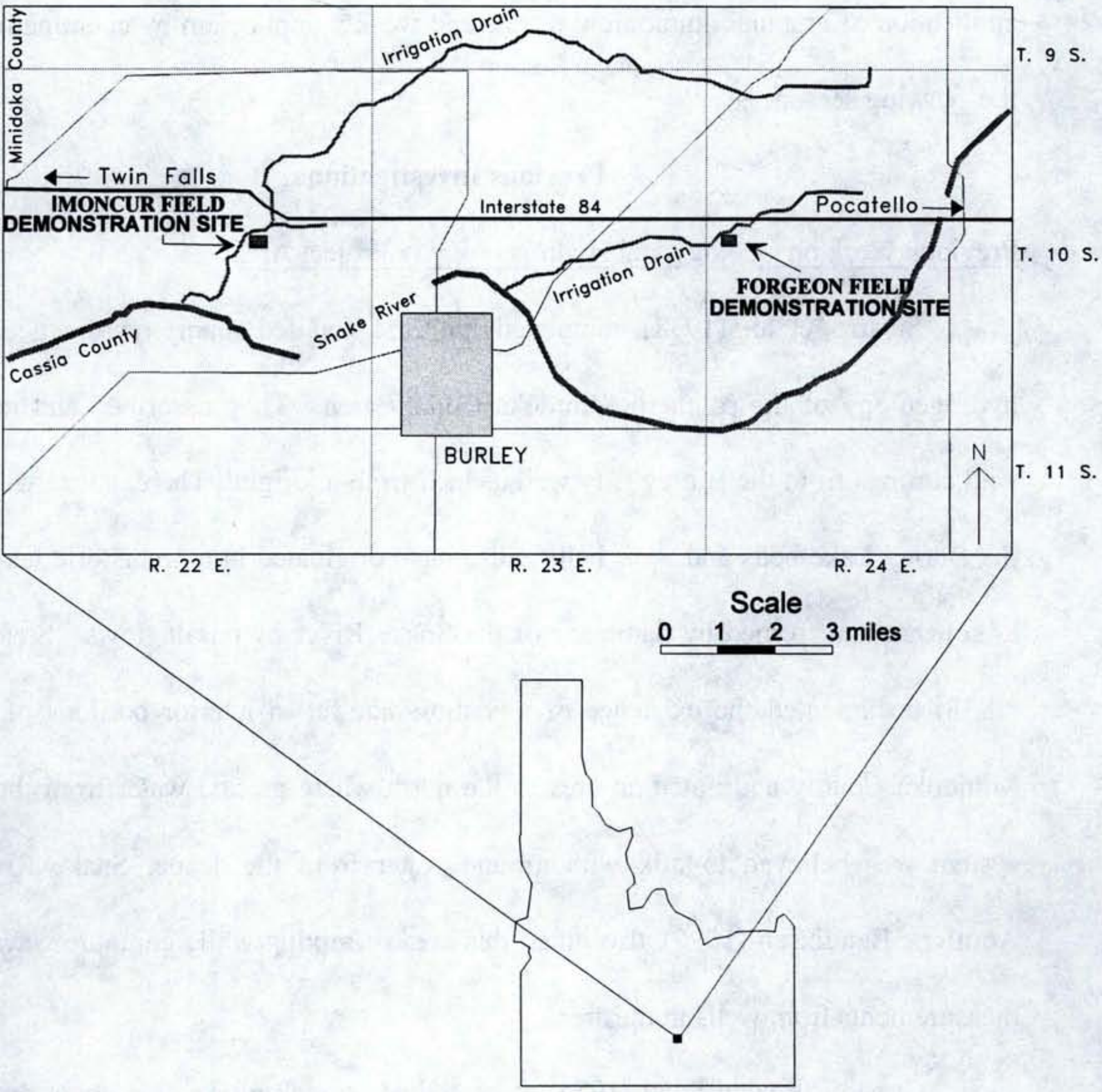


Figure 1. Index map showing location of nutrient BMP demonstration sites.

the crop (USDA, 1993). This nitrogen is applied chiefly by two methods, a fall application of granular ammonium nitrate and weekly application by chemigation during the growing season.

Previous Investigations

Previous Work on Geology and Hydrogeology in Project Area

Stearns et al. (1938) completed the first detailed report on the geology and hydrogeology of the southern Minidoka County area. They described and interpreted well cuttings from the Burley City well as lacustrine in origin. The deposits were named the Burley Lake beds and were believed to have originated in a prehistoric lake (Burley Lake) that had formed by damming of the Snake River by basalt flows. Stearns et al. (1938) documented the existence of a shallow aquifer in interior portions of southern Minidoka County and noted an area to the north where ground water from the shallow system was believed to mix with ground water from the deeper Snake River Plain Aquifer. Bendixsen (1996) also noted this area of mixing while contouring water level measurements from wells in the area.

Crosthwaite and Scott (1956) presented additional information about the geology and hydrogeology of the area. A geologic map of southern Minidoka County presented in their report was used to delineate the areal extent of the older alluvium, providing an estimate of the boundary locations for the shallow, unconfined, ground water system in southern Minidoka County. In addition, they noted intercalated basalt flows, which separated the Burley Lake beds from a deeper sequence of lacustrine deposits. They postulated that the location and lithology of these beds were similar to that of the prehistoric Raft Lake beds to the east. Stearns et al. (1938) also suggested these deposits might correspond to the Raft Lake beds. Structural contour mapping by Whitehead (1992) indicated sedimentary deposits might be as thick as 1000 feet in the southern Minidoka County area. O'Conner (1993) mapped younger alluvial deposits in the same general area as Bonneville Flood deposits.

A report by Graham (1979) on the impacts of disposal wells in southern Minidoka County indicated that ground water flow in the shallow aquifer system was to the north and that recharge to the system was primarily from irrigation and possibly seepage from the Snake River. Stearns et al. (1938) and Bendixsen (1996) also cited evidence that ground water flow in the shallow system was to the north.

Hansen (1975) mapped the distribution of soil associations for all of southern Minidoka County. Hansen's soil map indicated that deep loams and sandy to clayey loams underlie the Moncur and Forgeon Fields, respectively. Soils and subsoils in the Moncur and Forgeon Fields were found to match Hansen's classification; however, some variations were found in the subsoil distributions in the Forgeon Field.

Whitehead (1992) produced a geologic map and several structural contour maps of the Snake River Plain that included southern Minidoka County. A structural contour map of Snake River Group basalts by Whitehead (1992) suggested basalts underlying southern Minidoka County may be as thick as 1000 feet. He also reported that these basalts are highly transmissive, but in areas where the Snake River Plain basalts interfinger with marginal lake sediments, transmissivity values are variable. Whitehead (1992) suggested that transmissivity values for the regional system underlying southern

Minidoka County might be greater than 1,200,000 ft^2 per day. Garbedian (1987) suggested based on digital flow modeling that the transmissivity of the deeper regional system in Minidoka County is about 790,000 ft^2 per day.

Previous Work on Nitrate Contamination in the Project Area

Stearns et al. (1938) were likely the first to document nitrate concentrations within the deep regional ground water system underlying Minidoka County. They reported ground water nitrate concentrations of 1.9 mg/L from a deep well sampled in the southern Minidoka County area. Crosthwaite and Scott, (1956) also presented early water quality information from southern Minidoka County, but made no mention of ground water nitrate concentrations in the current project area. Graham et al. (1977) reported maximum nitrate values of 3.2 mg/L and 2.5 mg/L in deep and shallow zones, respectively.

Ground water nitrate concentrations exceeding the EPA drinking water standard weren't reported until the 1980's and 1990's. Young, et al. (1987a,b), Rupert (1994) Osmond, et al. (1995) and Clark, et al., (1998) documented that ground water nitrate concentrations in portions of the shallow aquifer system in southern Minidoka County exceeded the 10mg/L EPA drinking water standard. Clark, et al. (1998) also described an increasing trend in ground water nitrate concentrations in the shallow ground water system from 1985 to 1995.

Rupert (1990) identified nitrogen sources and estimated nitrogen input and output for the Upper Snake River Basin. He estimated that 93 percent of nitrogen input in the Upper Snake River Basin comes from cattle manure, fertilizer, and legume crops. He suggested that no naturally occurring sources of nitrate are present in the basin and that domestic septic systems account for less than 1 percent of total nitrogen input.

Mitchell (1998) showed that an increasing trend in nitrate concentrations existed in the deep regional system in southern Minidoka County. Neely and Crockett (1999) also noted a general increase in nitrate concentrations in the deep system for the period from 1991 to 1998 based on samples collected as part of Statewide Ambient Ground Water Quality Monitoring Program. According to Etcheverry (1999), tests performed by the Idaho Division of Environmental Quality indicated that nitrate levels rose significantly in the Minidoka-Cassia County area by 1999.

Methods

Paired Watershed Approach

A paired watershed approach was used to evaluate a different BMP at each demonstration field, independently. Each field was divided into a control half and a treatment half. The BMP implemented for the Forgeon Field (NW1/4, SE1/4, Section 7, T10S, R24E) consisted of nutrient management through crop rotation. The BMP implemented for the Moncur Field (NW1/4, SW1/4, Section 11, T10S, R22E) consisted of nutrient management through reduced irrigation water application (i.e., increased nutrient residence time in soil). Two periods of study were necessary for the paired watershed approach: 1) a calibration period to establish baseline conditions and 2) a treatment period to evaluate results of BMP implementation (Claussen, et al. 1993).

Implementation of the treatment phase for the BMPs effectively began with the beginning of the 1997 growing season for the demonstration fields.

In the Forgeon Field, the control half of the field implemented a traditional alfalfa-beans crop rotation and the treatment half initiated a USDA recommended alfalfa-grain crop rotation. The treatment crop rotation was selected by the Natural Resources Conservation Service (NRCS) of the USDA. The rationale for the treatment rotation was that grain would better utilize nitrogen released by killed alfalfa plants compared to beans, which are a nitrogen-fixing crop. The only sources of nitrogen were residual soil water nitrate and nitrogen released by the alfalfa killed in October 1996. No fertilizer was applied during the BMP implementation.

In the Moncur Field, the control half of the field maintained a traditional 24-hour irrigation set rotation while the treatment half of the field implemented a 12-hour irrigation set rotation. The irrigation rotations were selected by the NRCS. The rationale for this BMP was that the 12-hour irrigation set would flush less nitrate to the ground water and still maintain typical crop yield. Granular nitrogen fertilizer was applied uniformly across the entire test site prior to the 1997 planting of potatoes. Only the application of irrigation water was varied between control and treatment halves of the test site during implementation of the BMP.

Geologic and Hydrogeologic Investigations

Interpretation of the local geology and hydrogeology was based on the evaluation of well driller's reports filed at the Idaho Department of Water Resources. Geologic cross sections of the subsurface geology in the vicinity of both demonstration fields were constructed. In addition, literature, and previous studies conducted in southern Minidoka County were used to aid hydrogeologic characterization and interpretations.

Monitoring Network Designs, Nitrate Sampling, and Field Measurements

Initiation of monitoring began in the spring of 1992 with the installation of 12 ground water monitoring wells at each demonstration field to establish baseline, ground water nitrate concentrations. These wells were installed to a depth of 11 ft and extended about 4 to 6 ft below the seasonal water table. Samples were taken from each well with a hand vacuum pump following the purging of about 4 gallons of ground water by a portable centrifugal pump (Appendix A). Sampling was completed on a monthly basis and continued throughout the periods of study for each field.

At the Forgeon Field, thirty-five dedicated, lysimeters were installed to a depth of about 3 feet in 1994 to 1995 and sampled during growing season months through the period of study (1994 to 1998) to gain a better understanding of soil water nitrate concentration distributions. At the Moncur Field, 15 vacuum and 10 pressure/vacuum lysimeters were installed at a depth of 1.6 feet and sampled during the 1995, 1996, and 1997 growing seasons. Soil water nitrate samples for both fields were collected with a hand vacuum pump. Approximately 80 millibars of vacuum pressure were applied to each lysimeter through a length of 0.25 inch outside diameter, flexible, polyethylene tubing attached to the lysimeter. Vacuum was maintained on the lysimeters for a 24-hour period to allow drawing of water from the soil for sampling.

At the Forgeon Field, a groundwater point sampler was installed below each lysimeter location in 1995 (total of 35) to allow geostatistical evaluation of ground water nitrate concentration distributions at the water table. Ground water point samplers were installed to a depth of about 1 foot below the seasonal low water table through 2 inch diameter augered boreholes. The point samplers consisted of common aquarium airstones composed of porous, compressed sand. A length of 0.25 in. outside diameter, flexible, polyethylene tubing was attached to each airstone and run to the land surface for sample collection. Ground water samples were collected from each point sampler with a hand vacuum pump following the purging of approximately 0.5 gallons of ground water. The predominantly clay rich soils and subsoils, and deep tillage practices by the farmer, excluded installation of ground water point samplers in the Moncur Field.

All ground water and soil water samples were collected in 125 ml polyethylene bottles, acidified with sulfuric acid ($pH<2$) and frozen until shipment to the University of Idaho Analytical Laboratory for nitrate analysis. Monthly nitrate plus nitrite concentrations with a laboratory detection limit of 0.1 mg/L were determined for each ground water and soil water sample taken over the period of this study.

Various field measurements were made monthly to aid in the analysis of site conditions and evaluation of BMP effectiveness. Water table elevations were measured in each monitoring well to an accuracy of 0.01 feet by steel measuring tape (Appendix B). Precipitation and irrigation amounts were measured by a digital recording rain gauge located at each interior monitoring well for the treatment phase growing season at each demonstration field. In addition, ground water samples were collected for measurement of the field parameters pH, dissolved oxygen (DO), total dissolved solids (TDS), conductivity and temperature. Sample pH was measured using an Oakton™ Digital pH meter. DO, TDS, and conductivity, were measured with a portable Corning™ Checkmate Modular Testing System.

Geostatistical Analysis

Lysimeter and ground water point sampler locations were selected for a geostatistical type analysis. Each location was evaluated for measured geological heterogeneity, needed separation distances between sampling points, and adequate perimeter control. In part, the sampling network was designed in an unbiased attempt to provide sampling locations representative of heterogeneities at each test site. Heterogeneities were evaluated based on grain size analyses performed for both test sites prior to installation of lysimeters. Final selection of sampling locations also was made to partially accommodate established geostatistical protocol. Locations then were surveyed in by transit and mapped accordingly.

Variogram modeling of nitrate concentrations was conducted for both demonstration fields to determine if ground water nitrate data and soil water nitrate data were correlated spatially. Initial variogram analyses of pre-BMP data indicated that ground water nitrate data as well as soil water nitrate data for the Forgeon Field were well correlated spatially. This spatial correlation also was apparent in subsequent variogram modeling of ground water nitrate data for the BMP treatment period at the site. An attempt was made to use a moving-windows technique (Miller, 1996c) to model variograms for the limited ground water nitrate and soil water nitrate data collected at the

Moncur Field. However, the quality of the moving-window variograms were not adequate to justify a variogram based geostatistical analysis.

Ground water and soil water nitrate evaluations for the Forgeon Field were completed using a sequential Gaussian simulation approach because an adequate number of data points were available for analysis and strong spatial correlation existed between the data. A trend surface analysis approach was used at the Moncur Field to evaluate ground water and soil water nitrate concentrations. Geostatistical spatial maps were completed for all applicable treatment phase months for both demonstration fields based on geostatistically derived estimations. Month-to-month estimates of net ground water nitrate changes were derived by a substraction technique using these geostatistically derived spatial maps.

GEOLOGY AND HYDROGEOLOGY

Regional Geologic Overview

The locations of the BMP demonstration fields place them within the southernmost extent of the Eastern Snake River Plain (ESRP) geographic province. The Snake River Plain is physiographically continuous, but is separated into western and eastern portions based on the geology and tectonic origin (Othberg, 1994). The ESRP is approximately 55 to 65 miles wide and about 280 miles long. It is a volcanic trough covered by undissected basalt, lava flows that are underlain by rhyolitic volcanic rocks. The rhyolitic volcanic rocks that underlie the ESRP are thought by many to be the products of a hot spot, located in the mantle beneath a part of the North American plate that has been drifting southwestward (Malde, 1991). Maximum thickness of these rhyolites may be greater than 2 miles as suggested by an exploratory well at the Idaho National Environmental Engineering laboratory and seismic evidence (Malde, 1991). The basalt flows that overlie most of the ESRP are thought to be a result of volcanic eruptions beginning soon after passage of the hot spot (about 9 ma.) and continuing into the Holocene (Malde, 1991). Basalts attain a maximum thickness of 5000 feet in the central part of the ESRP and thin out towards the margins of the plain (Whitehead, 1992). These basalts, which are associated in places with marginal alluvium and lacustrine deposits, terminate at the flanks of mountain ranges to the north and south. Basalts of the ESRP are assigned both to the upper Idaho Group and Snake River Group geologic formations (Whitehead, 1992).

Mountain ranges to the north and south of the ESRP are comprised of thrusted and folded Paleozoic and Mesozoic sedimentary rocks. Orientation and position of mountain ranges of Paleozoic and Mesozoic sedimentary rocks to the north and south of the ESRP suggest they were once continuous across what is now the ESRP. A 10,365 foot drill hole east of Arco bottomed in rhyolitic volcanic rocks (Whitehead, 1992). The Albion Mountain Range, which is believed to be a metamorphic core complex of Precambrian age, is present approximately 10 miles southeast of the Forgeon Field.

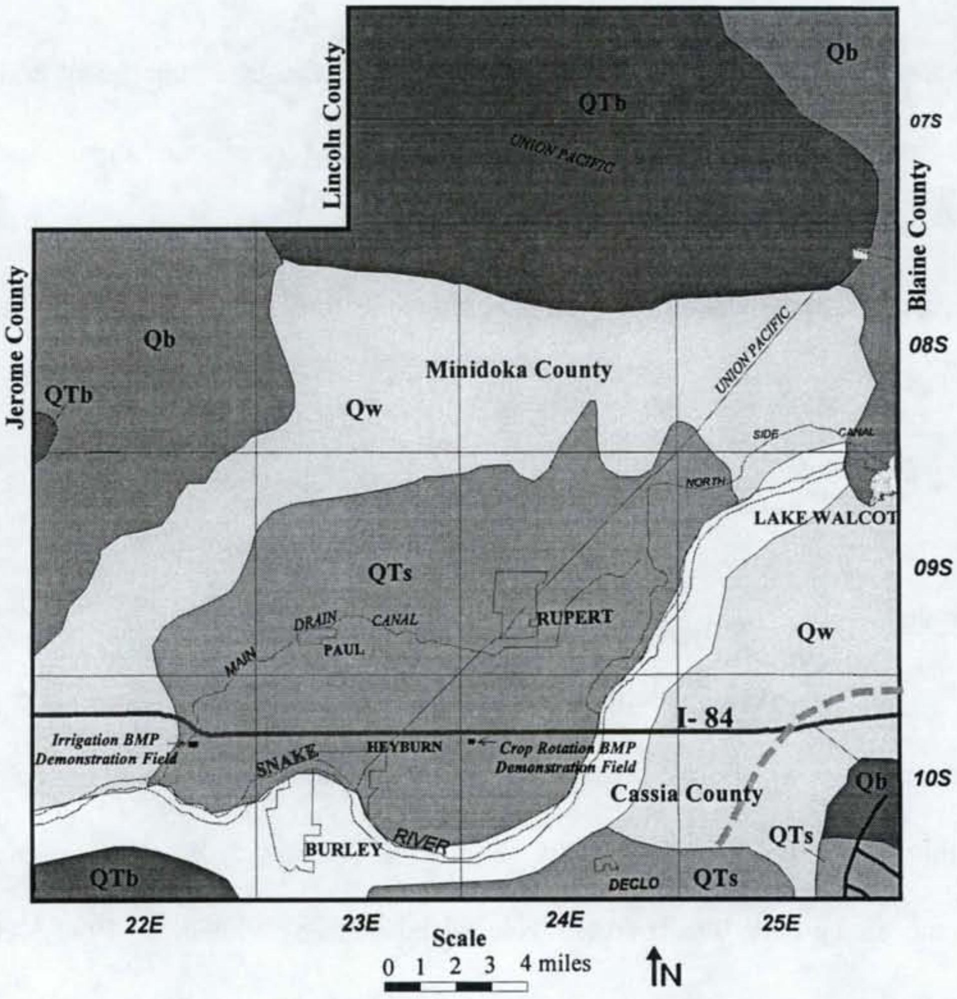
The basalt flows of the ESRP abut and overlap sedimentary deposits of the Western Snake River Plain (WSRP) to the west and rhyolitic ash-flow tuffs to the east. Lacustrine deposits of the WSRP are believed to have been deposited as a result of prehistoric Lake Idaho during the Pliocene. Rhyolitic ash-flow tuffs are believed to be a result of relatively recent volcanic activity associated with the Yellowstone Park region.

Much of the Eastern Snake River Plain region is located within the Basin and Range extensional province. However, the lack of developed fault block topography, and low seismicity of the ESRP suggest the plain does not respond to the regional extensional stress field in the same manner as the rest of Basin and Range Province (Parsons, et al., 1998). Several mechanisms have been proposed to explain development of the Eastern Snake River Plain. These mechanisms fall into four general categories (Parsons et al., 1998): (1) The ESRP is too weak to fail by faulting because of thermal input from the Yellowstone hotspot. (2) The ESRP is too strong to fail by faulting because the midcrust is relatively strong basalt. (3) The ESRP and transition zone were weakened while the hotspot passed beneath it causing fast extension, and then subsequent cooling after the hotspot passed prevented failure. (4) The ESRP and transitional zone extend by variable amounts of dike intrusion, limiting or preventing the formation of normal faults. Regardless of which mechanism is responsible for lack of Basin and Range Province style faulting, it is clearly evident that faulting within upper geologic units of ESRP is nearly absent.

Local Geology

Basalts

Basaltic rocks underlie the entire area of southern Minidoka County (Crosthwaite and Scott, 1956). Basalt flows also crop out as surface units or appear below soil cover within southern Minidoka County (Figure 2). Depths to basalt in southern Minidoka County range from 0 to 1000 feet below land surface (Whitehead, 1992). Although older basalt flows are mapped as possibly Upper Idaho Group Rocks, distinction between Upper Idaho Group Basalts and Snake River Group Basalts can be nearly impossible to determine (Whitehead, 1992). Kuntz and others (1983) have reclassified some older units in the Minidoka County area as Snake River Group rocks. The total thickness of deep basalt units underlying southern Minidoka County is not known. The only known faults in the area are present within basalt flows in northern Cassia County, outside the approximate boundary of the ESRP (Figure 2).



EXPLANATION

Generalized Description of Map Units		
Alluvium	Qa	Chiefly flood-plain deposits. Clay, sand, gravel, and boulders.
Windblown deposits	Qw	Chiefly windblown deposits, includes some lake deposits.
Younger basalt	Qb	Chiefly basalt of the Snake River Plain Group. Includes beds of basalt cinders, rubbly basalt, and interflow sedimentary rocks.
Older Alluvium	QTs	Assigned to upper part of Idaho Group. Subaerial and lake deposits of clay, silt, sand, and gravel. Contains beds of ash and intercalated basalt.
Basalt	QTb	Tentatively assigned to upper Idaho Group. Included as part of the Snake River Plain Aquifer.

Map Symbols	
─	Contact
━	Fault
- - -	Approimate boundary of Snake River Plain.

Figure 2. Generalized geologic map of southern Minidoka County (modified from Whitehead, 1992; and Crosthwaite and Scott, 1956).

Older Alluvium- Lake Beds

Deposits of Older alluvium cover a large portion of the interior of southern Minidoka County including the locations of both BMP demonstration fields (Figure 2). The primary source of these deposits appears to have been marginal lakes of the ESRP. Two of these lakes are inferred to have once covered southern Minidoka County due to damming of the Snake River by basalt flows. An older sequence of lacustrine deposits is observed in several deep wells in southern Minidoka County from about 225 feet below land surface to a maximum depth of 575 feet. This deep sequence of lacustrine deposits is considered to be a westward extension of the prehistoric Raft Lake beds based on stratigraphic position and lithologic similarities (Stearns et al., 1938; Crosthwaite and Scott, 1956). The maximum thickness of sedimentary deposits within southern Minidoka County is 1000 feet (Whitehead, 1992).

A younger sequence of sedimentary deposits was found in well cuttings from the Burley City well and other local wells from about 15 feet to 150 feet below land surface. This sequence is interpreted to have been deposited by prehistoric Burley Lake (Stearns et al., 1938). The areal extent of Burley Lake deposits covers much of interior southern Minidoka County including the locations of BMP demonstration fields (Figure 3). The lake beds, which are known only from drill holes in the Rupert-Paul-Burley area, consist of unconsolidated to well-compacted, clay, silt, sand, and fine gravel (Crosthwaite and Scott, 1956). Intercalated basalt flows occur from 150 to 225 feet below land surface and separate the Burley Lake beds from the older Raft Lake bed deposits (Crosthwaite and Scott, 1956). Drill holes in the area also indicate the presence of intercalated basalt flows above 150 feet.

Older Alluvium-River and Terrace Deposits

The Burley Lake beds are mantled with 0 to greater than 40 feet of silt, sand, and gravel that make-up the Rupert Terrace (Crosthwaite and Scott, 1956). The deposits are primarily silt and sand, but gravel occurs at some places, especially near the lower part of the formation (Crosthwaite and Scott, 1956). The extent of sediments which make-up the Rupert Terrace have been mapped to include both demonstration fields, but detailed information is limited as to their source of deposition. In part, more recent investigations in the area indicate that at least a portion of sediments of the Rupert Terrace were deposited as a result of the Bonneville Flood about 14,500 years ago (Figure 4). Erosional features in basalt along the western boundary of southern Minidoka County indicate maximum flood stage was at an elevation of 4,250 to 4,260 feet (O'Connor, 1993). These elevations are well above the land surface elevations of both demonstration fields. The extremely low gradient of the flood in the area is reflected by the deposits which are restricted to cobble bars near the present day course of the Snake River and sand and silt farther away from the main channel (O'Conner, 1993).

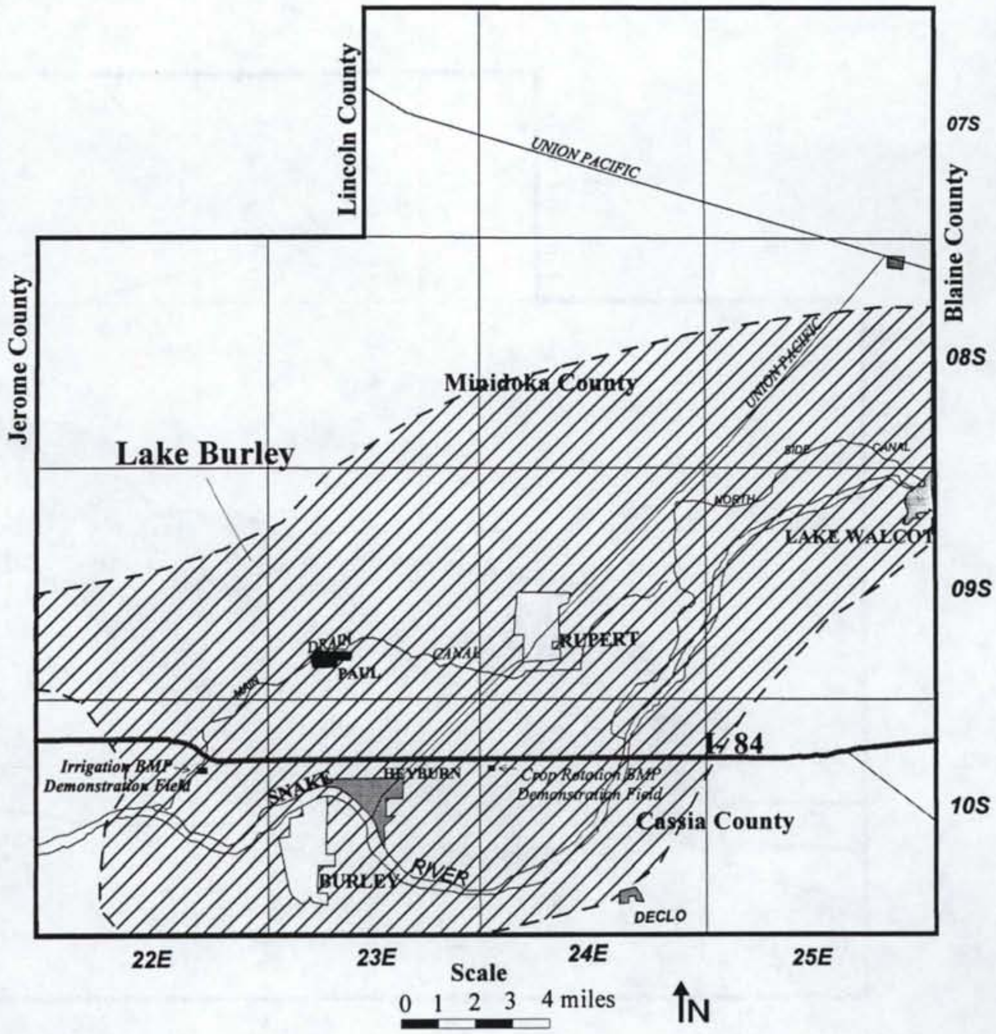


Figure 3. Map showing approximate extent of Burley Lake in southern Minidoka County (after Malde, 1991).

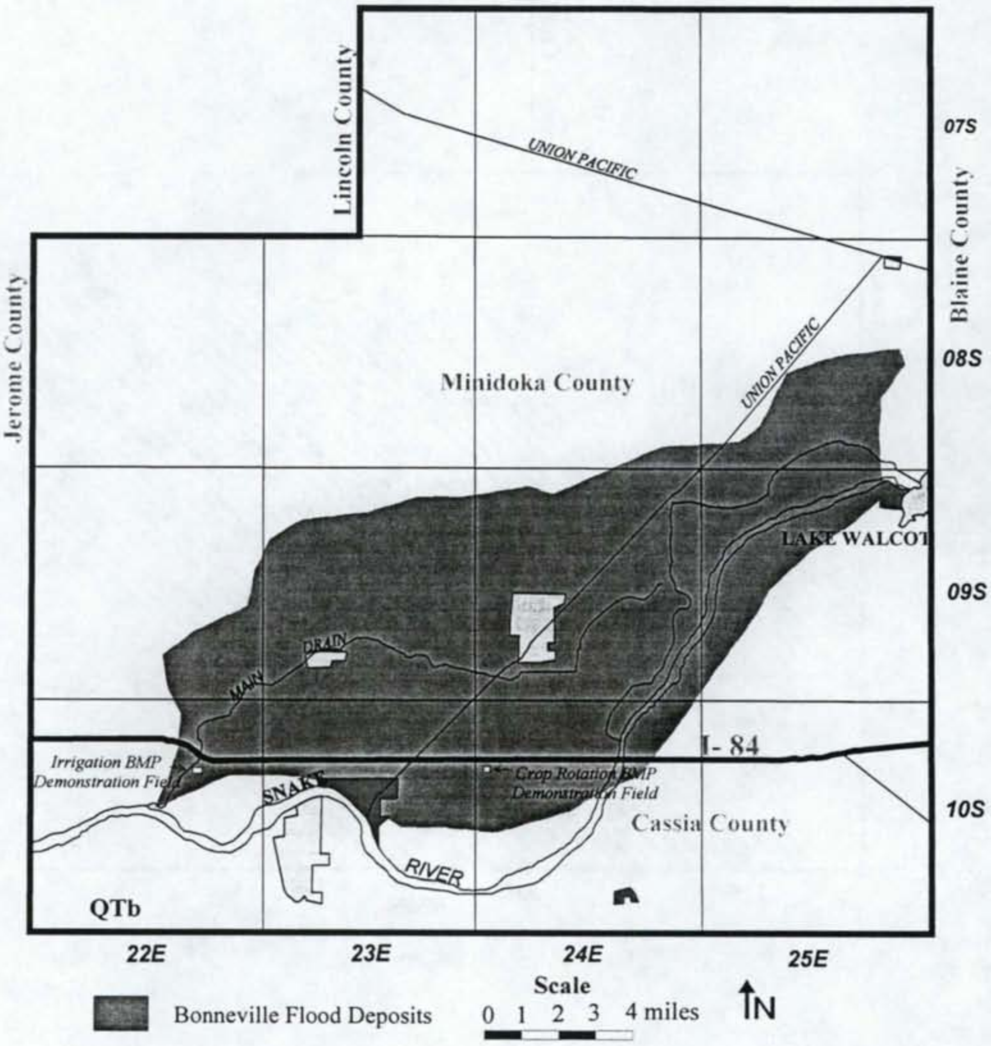


Figure 4. Map showing approximate extent of Bonneville Flood deposits in southern Minidoka County (modified from O'Connor 1993).

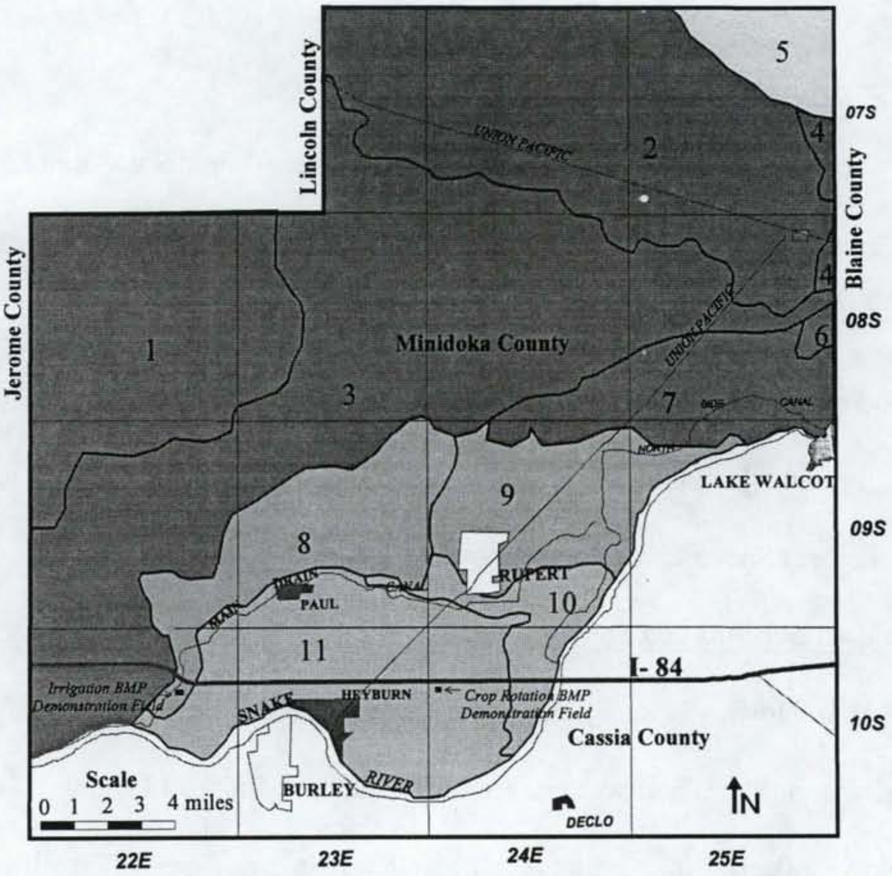
Younger Alluvium

Younger alluvial deposits mapped in southern Minidoka County are confined to areas near the present channel of the Snake River. Deposits consist of units up to 40 feet thick; they are composed primarily of reworked older alluvium composed of clay, silt, sand and clean, water-worn gravels which are locally fossilferous (Crosthwaite and Scott, 1956). Previous mapping in the area suggests that both demonstration fields lie outside areas of recent Snake River flood deposits.

Windblown Deposits and Soils

Windblown silt, sandy clay, and very fine sand mantle most of the volcanic rocks primarily in northern and western areas of southern Minidoka County. The thickness of windblown material may be as much as 50 feet in some areas (Crosthwaite and Scott, 1956). Level to strongly sloping, well-drained silt loam soils formed in these areas (Hansen, 1975).

Soils within southern Minidoka County have been grouped into five general series based on landscape (Figure 5). These series are (1) level to strongly sloping, well-drained silt loams on basalt plains, (2) very gently sloping to strongly sloping, well-drained silt loams on basalt plains, (3) level to strongly sloping, well-drained sands and fine sandy loams on basalt plains, (4) level to sloping, well-drained sands to silty clay loams on low alluvial terraces, and (5) level and nearly level, somewhat poorly drained loamy sands to clay loams on low alluvial terraces (Hansen, 1975).



SOIL ASSOCIATIONS †

LEVEL TO STRONGLY SLOPING, WELL-DRAINED SILT LOAMS ON BASALT PLAINS

1	Portneuf-Portino-Trevino association: Level to strongly sloping, very deep to shallow soils.
2	Minidoka-Portneuf association: Level to sloping soils that are moderately deep to indurated hardpan and soils that are deep and very deep.
3	Portneuf association: Level to sloping, deep and very deep soils.
4	Portino-Portneuf association: Level to sloping, moderately deep to very deep soils.

VERY GENTLY SLOPING TO STRONGLY SLOPING, WELL-DRAINED SILT LOAMS ON BASALT PLAINS

5	Trevino-Portino association: Dominantly shallow and moderately deep soils interspersed with rock outcrops.

† The terms for texture used in the descriptive heading of the assocation apply to the surface layer of the major soils.

LEVEL TO STRONGLY SLOPING, WELL-DRAINED SANDS AND FINE SANDY LOAMS ON BASALT PLAINS

6	Somsen-Vining association: Moderately deep fine sandy loams interspersed with rock outcrops.
7	Vining-Escalante-Quincy association: Moderately deep to very deep sandy loams and sands.

LEVEL TO SLOPING, WELL-DRAINED SANDS AND SILTY CLAY LOAMS ON LOW ALLUVIAL TERRACES

8	Paulville-Delco association: Deep and very deep loams.
9	Tindahay-Quincy association: Deep and very deep sandy loams and sands.

LEVEL AND NEARLY LEVEL, SOMEWHAT POORLY DRAINED LOAMY SANDS TO CLAY LOAMS ON LOW ALLUVIAL TERRACES

10	Schodsan-Arloval-Maxey association: Very deep sandy loams to loamy sands.
11	Wodskow-Decker-Abo association: Very deep sandy loams to clay loams.

Figure 5. Generalized soils map of southern Minidoka County (modified from Hansen, 1975).

Series 4 and series 5 are present at the Moncur Field and the Forgeon Field, respectively (Figure 5).

The five series described above were subdivided into specific soil phases, which were classified based on nation-wide uniform procedures (Hansen, 1975). Two distinct soil associations have been mapped at the Moncur and Forgeon Fields: (1) the Paul-Delco association (deep and very deep loams) and (2) the Wodskow-Decker-Abo association (very deep sandy loams to clay loams), respectively. The associations have been further subdivided into more specific soil descriptions at various localities.

According to Hansen (1975), soils and subsoils in the area of the Moncur Field are a Paulville loam of which the upper 42 to 47 inches is a silty loam or loam that overlies a fine sand that extends to 60 inches below the surface. In the area of the Forgeon Field, soils are classified as a Wodskow sandy loam which is primarily a varied color, sandy loam that extends to a typical depth of 55 inches below the surface.

Forgeon Field

Geologic Cross Sections

Two geologic cross sections were constructed to gain a better qualitative understanding of the subsurface geology at the Forgeon Field. This was accomplished through a search of well driller's reports filed at the Idaho Department of Water Resources and subsequent construction of stratigraphic columns based on lithologic descriptions of drill holes in the vicinity of the Forgeon Field. The stratigraphic columns completed from lithologic descriptions in the driller's reports were used to correlate north-south and west-east, geologic cross sections.

Search of well driller's reports for use in development of the cross sections was initiated using the following criteria: (1) if possible, the geologic cross sections would include lithologic well driller's information from the section of the demonstration field (Section 7, T10S, R24E) and adjacent sections (2) if possible, wells used would be no greater than 0.5 miles apart, and (3) priority would be given to the location of the deepest wells with the most detailed lithologic descriptions.

Based on the aforementioned criteria, 16 well logs were located and their positions plotted to an accuracy of a quarter-quarter section (approximately +/- 1000 feet) on a 7.5 minute topographic base map of the area to develop the cross section lines. All well data were entered into the program WELL LOG (Baker, 1994) and well locations were digitized. Both north-south and west-east cross sections containing the stratigraphic columns then were generated, with the program WELL LOG. Units were correlated manually based on the following characteristics: lithologic elevation, lithologic type, water bearing zones, water levels, and predominant lithologic type (e.g., more sand than clay or more clay than sand).

Although some discrepancies were noted between the two geologic cross sections, some general features below the two demonstration fields were observable (Figure 6). Both cross sections indicated that a 25 to 50 foot thick clay layer is present directly beneath the fields. The cross sections further suggested that a coarser grained deposit, (sand on the north-south cross section, and gravel on the west-east cross section) approximately 50 feet thick underlies the shallow clay layer. Below this coarser grained

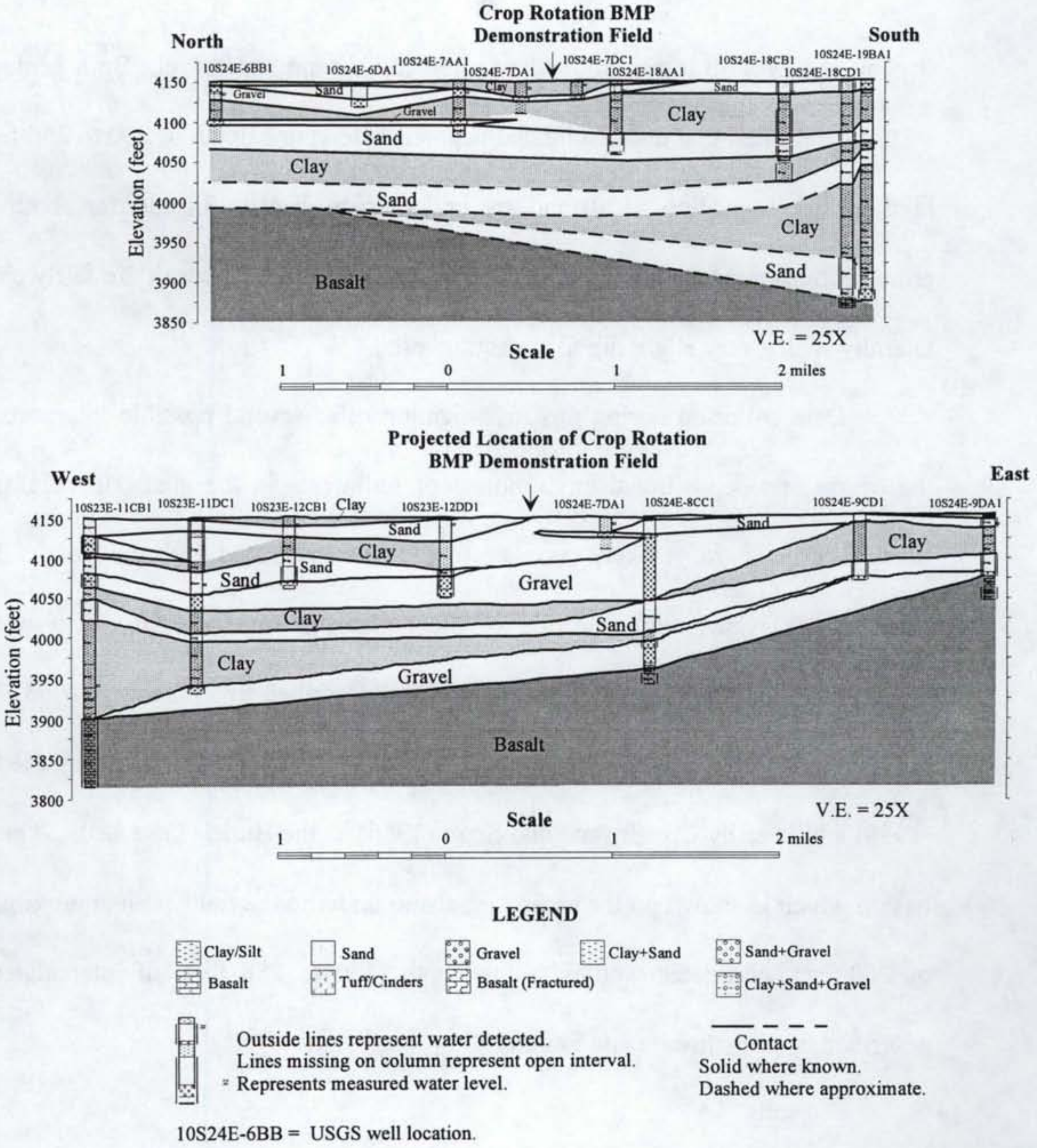


Figure 6. North-south and west-east geologic cross sections based on well driller's reports in the vicinity of the Forgeon Field.

deposit is clay with lesser amounts of interbedded sand and gravel. Both geologic cross sections indicated that unconsolidated deposits extend to a depth of 200 to 250 feet below land surface (elevation 4150) and are underlain by basalt. In addition, both geologic cross sections suggested that the unconsolidated deposits and basalt are fairly continuous laterally with a very slight dip to the southwest.

Data collected during this investigation offer several possible interpretations for the origin and depositional environment of sediments in the area. In part, the upper subsurface layers most likely correlate to deposits associated with the Bonneville Flood about 14,500 years ago. Location of the demonstration sites puts them well within maximum flood stage of the Bonneville Flood described by O'Conner (1993). Deeper, predominantly clay deposits show similar depth and thickness described by Stearns et al. (1938) and later by Crosthwaite and Scott (1956) as the Burley Lake beds. The depth to basalt, which is shown on the cross sections to underlie the field at an approximate depth of 200 feet, correlates well with the depth (150 to 250 feet) to intercalated basalts described by Crosthwaite and Scott (1956).

Subsoils

A detailed study of subsoil deposits down to the water table in the Forgeon Field was completed based on soil samples collected during excavation of the monitoring well and point sampler boreholes. In general, the soils and subsoils were similar to those described by Hansen (1975). However, some variations in subsoil distributions were

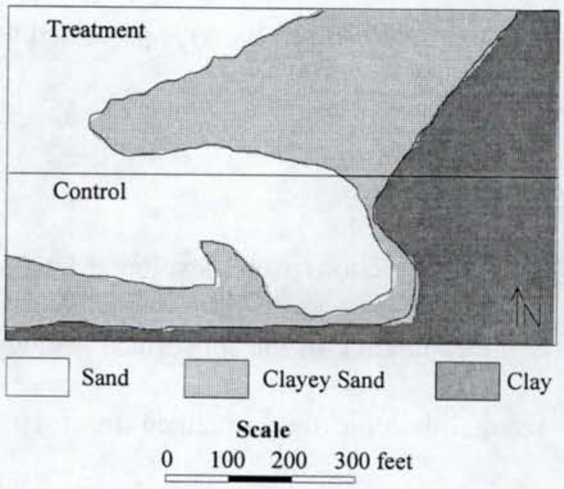


Figure 7. Map showing distribution of subsoils at the Forgeon Field.

noted as a gradational change from more sandy subsoils in western areas of the field to more clay rich subsoils to the east. A map based on variations in subsoil distributions as determined from borehole logs (Appendix A) is presented in Figure 7.

Moncur Field.

Geologic Cross Sections

Two geologic cross sections were developed for the Moncur Field to get a more detailed qualitative understanding of the subsurface geology. The geologic cross sections were completed using lithologic data obtained from 10 well driller's reports for the section containing the field (Section 11, T10S, R22E) and adjacent sections. Construction of the north-south and west-east geologic cross sections followed the same methods and criteria as the geologic cross sections completed for the Forgeon Field.

Some discrepancies were noted between the two cross sections; however, some general features below the Moncur Field were observable (Figure 8). Both cross sections indicated a clay zone extended from land surface (elevation approximately 4150 feet) to a depth of about 25 feet below land surface. Both cross sections further indicated that the clay zone is underlain by two distinct, shallow intercalated basalt flows. The basalt flows are separated by a 10 to 20 foot thick clay layer. Below the lower intercalated basalts, clay is the most abundant lithology with lesser amounts of interbedded sand and gravel. Both geologic cross sections suggested unconsolidated deposits and basalt to be somewhat laterally continuous with a very slight southeasterly dip.

The origin and depositional environment for the sediments beneath the Moncur Field were similar to those at the Forgeon Field. The upper most subsurface layers are

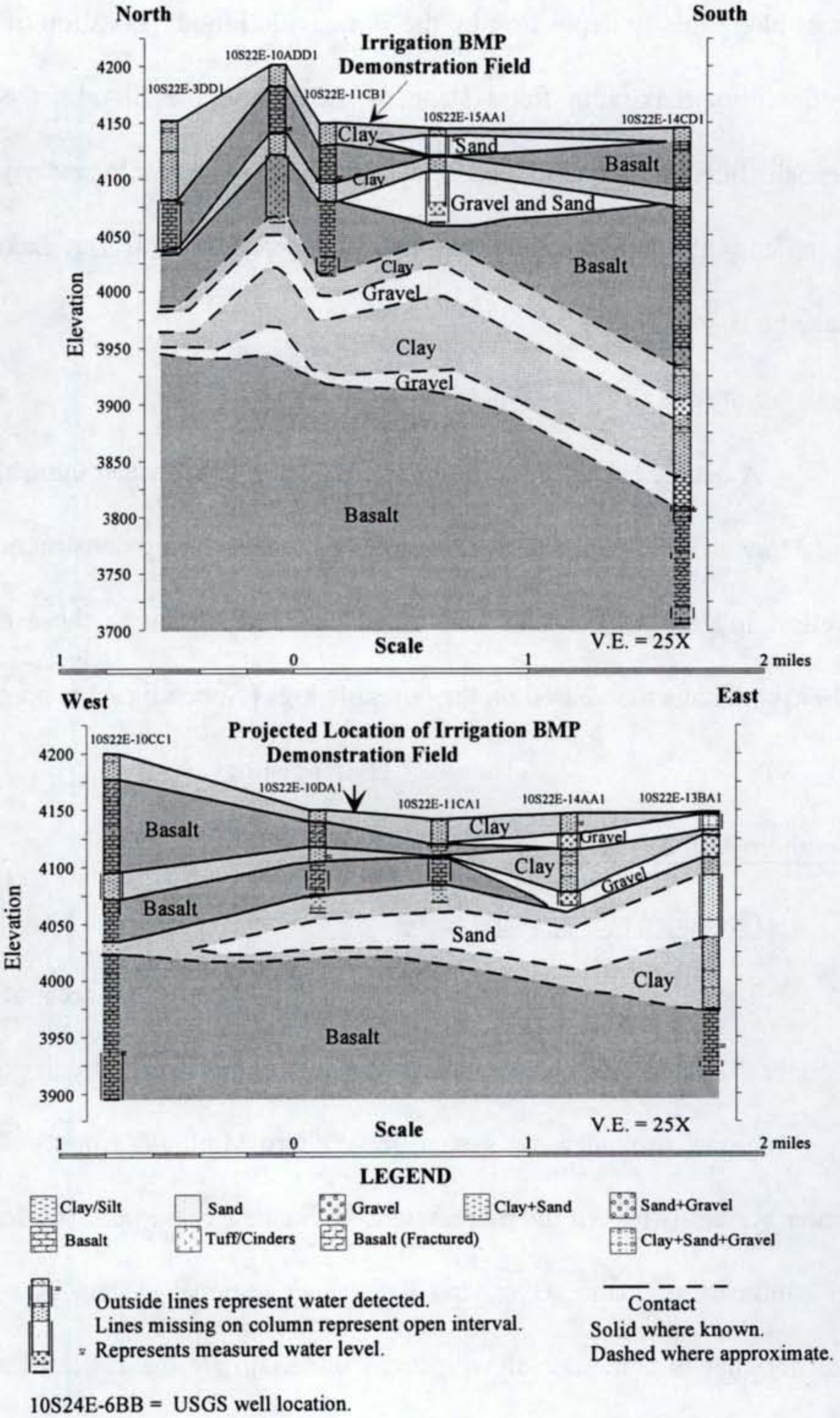


Figure 8. North-south and west-east geologic cross sections based on well driller's reports in the vicinity of the Moncur Field.

most likely due to deposition by the Bonneville Flood. Location of the Moncur Field is well within maximum flood stage of the Bonneville Flood. Deeper, abundant clay deposits likely correlate to the Burley Lake beds. The basalts underlying the field, likely correlate with the intercalated basalts which separate the Burley Lake beds from the Raft Lake beds.

Subsoils

A detailed study of subsoil deposits down to the water table also was completed at the Moncur Field based on soil samples collected during construction of the monitoring wells. In general, the soils and subsoils where similar to those described by Hansen (1975). A soils map based on the borehole logs (Appendix A) is presented in Figure 9.

Hydrogeology

Southern Minidoka County

Ground Water Systems

Two distinct ground water flow systems exist in area of southern Minidoka County. Basalts and deeper lake sediments comprise the hydrogeologic media of the deep regional ground water system in southern Minidoka County. The regional ground water system is part of the more extensive Snake River Plain Aquifer, which covers most of southeastern Idaho. Overlying the deeper regional system is a shallow, unconfined aquifer that is coincidental with areas underlain by the Burley Lake beds, Bonneville Flood deposits, and other alluvial deposits. According to Garbedian (1986), as much as 60 percent of the recharge to the entire Snake River Plain Aquifer may originate as

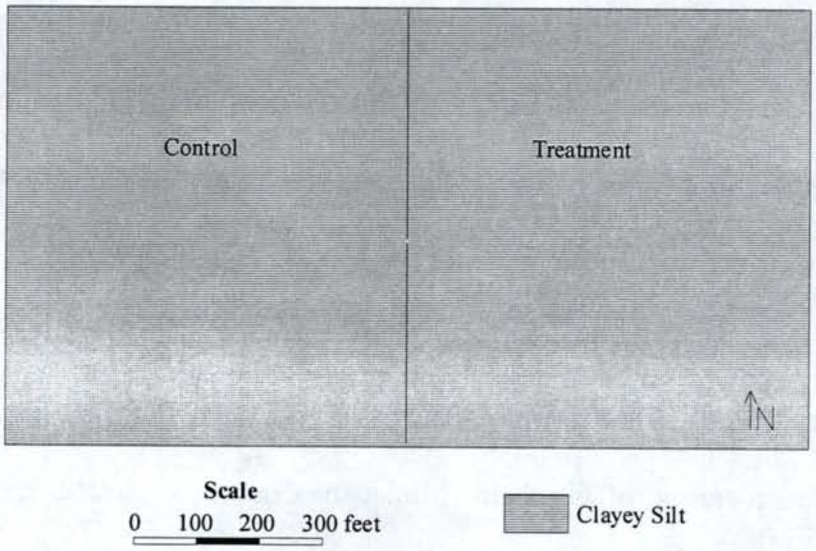


Figure 9. Map showing distribution of subsoils in the Moncur Field.

irrigation water. Recharge to the shallow system originates primarily from irrigation waters; however, seepage from the Snake River is probably another source (Graham, 1979). Discharge from the shallow system occurs to local drainage ditches and possibly to the regional aquifer to the north.

As a whole, the regional system behaves as an unconfined aquifer, but clay layers and dense, unfractured basalts are locally confining (Johnson, et al., 1993). Contour mapping in the area indicates that the general flow directions in the regional system are towards the west and southwest (Figure 10). Based on Figure 10, the typical gradient of the regional system below the shallow system is about 0.004. Average flow velocity may be as high as 20 feet per day. The basalts are highly transmissive. Aquifer test results in northern areas of southern Minidoka County suggested transmissivity values of approximately 1,200,000 ft^2 per day and a storativity of about 0.014 (Whitehead, 1992). Digital modeling of a zone including all of southern Minidoka County suggested a transmissivity value of 790,000 ft^2 per day (Garbedian, 1986). Typical depths to the deep regional system underlying southern Minidoka County vary from 150 feet to greater than 300 feet (Crosthwaite and Scott, 1956). Graham (1979) reported depths to water ranging from 140 feet to greater than 200 feet for the regional system.

Contour mapping suggests that a ground water ridge may delineate an area along the northern portion of the shallow, unconfined aquifer where waters percolate down and mix with the deeper regional system (Bendixsen, 1999) (Figure 10). Stearns (1938) also described this area to the north and west as a steep ground water cascade where water seeping away from the shallow perched zone descends to the main water table. Depths

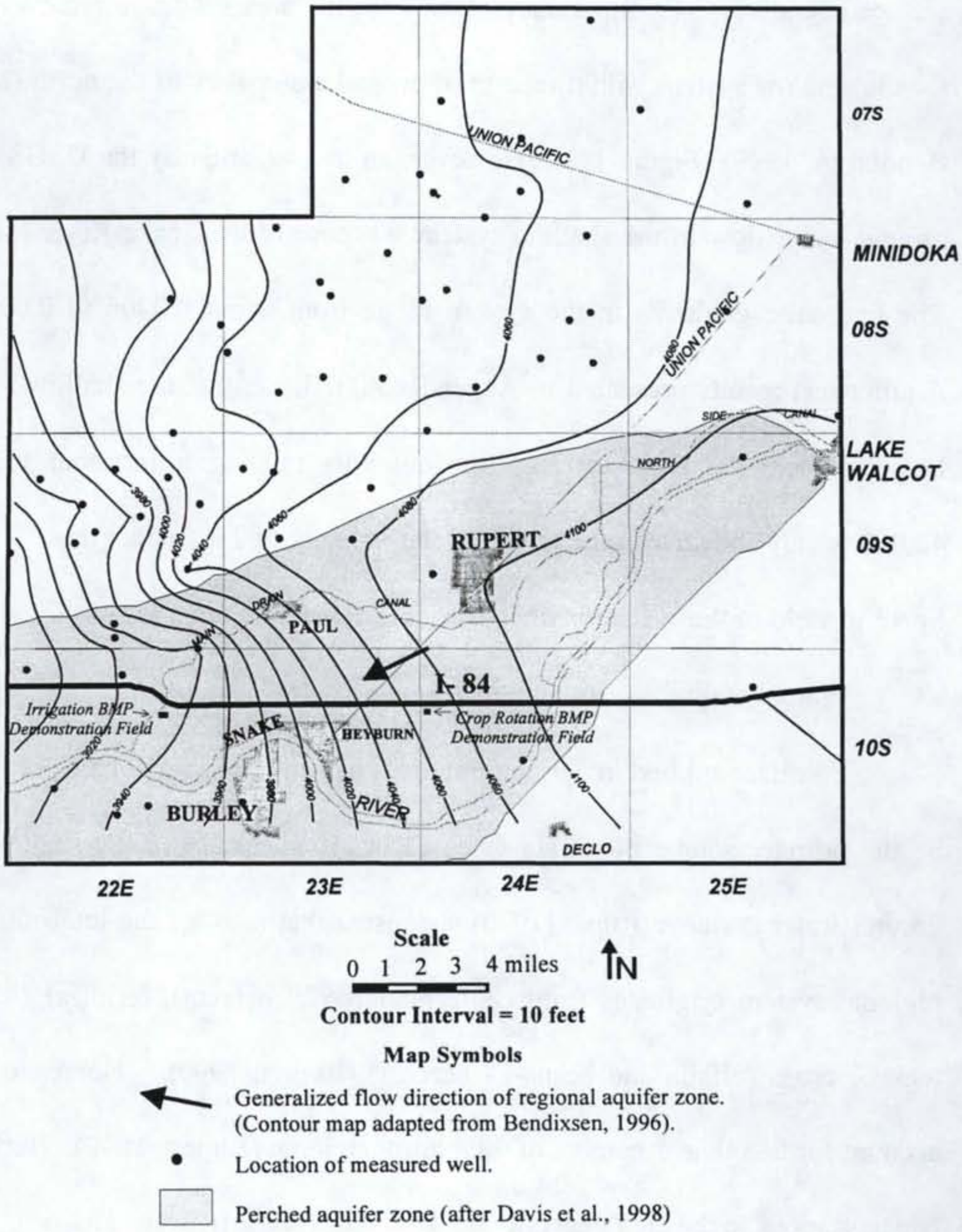


Figure 10. Contour map of the regional ground water system underlying southern Minidoka County. Map shows generalized direction of groundwater flow and extent of perched aquifer system.

to water within the shallow alluvial aquifer range from 5 feet to about 100 feet below land surface (Bendixsen, 1999). Data collected for the area suggest a relatively low gradient for the shallow system with direction of ground water flow to the north (Mitchell, 1998; Bendixsen, 1999) (Figure 11). However, an investigation by the USGS suggested that ground water flow in the shallow system was toward the Snake River (Mitchell, 1998). The hydraulic gradients in the system range from about 0.0006 to 0.002 (Figure 11). Aquifer test results presented in Appendix A, indicate that the shallow system near the Forgeon Field has relatively low transmissivity ranging from about 11,000 ft^2/day to 42,000 ft^2/day and an average ground water velocity of 2.9 feet per day.

Specific yield of the system is likely variable depending upon location.

Water Quality

Fertilizer applied in agricultural areas of southern Minidoka County is believed to be the primary source of nitrate detected in ground water in the shallow and regional ground water systems. Rupert(1990) suggested that most of the total nitrate load to the regional system originates from cattle manure (29 percent), fertilizer (45 percent), and legume crops (alfalfa and beans-19 percent) (Rupert, 1990). Domestic septic systems account for less than 1 percent of total nitrogen input (Rupert, 1990). Background nitrate concentrations in the area generally are less than 1mg/L (Rupert, 1990).

Measurable and increasing levels of nitrate contamination in both the regional and shallow aquifer systems are well documented in the southern Minidoka County area. This has created great concern because ground water supplies 90 percent of the drinking water

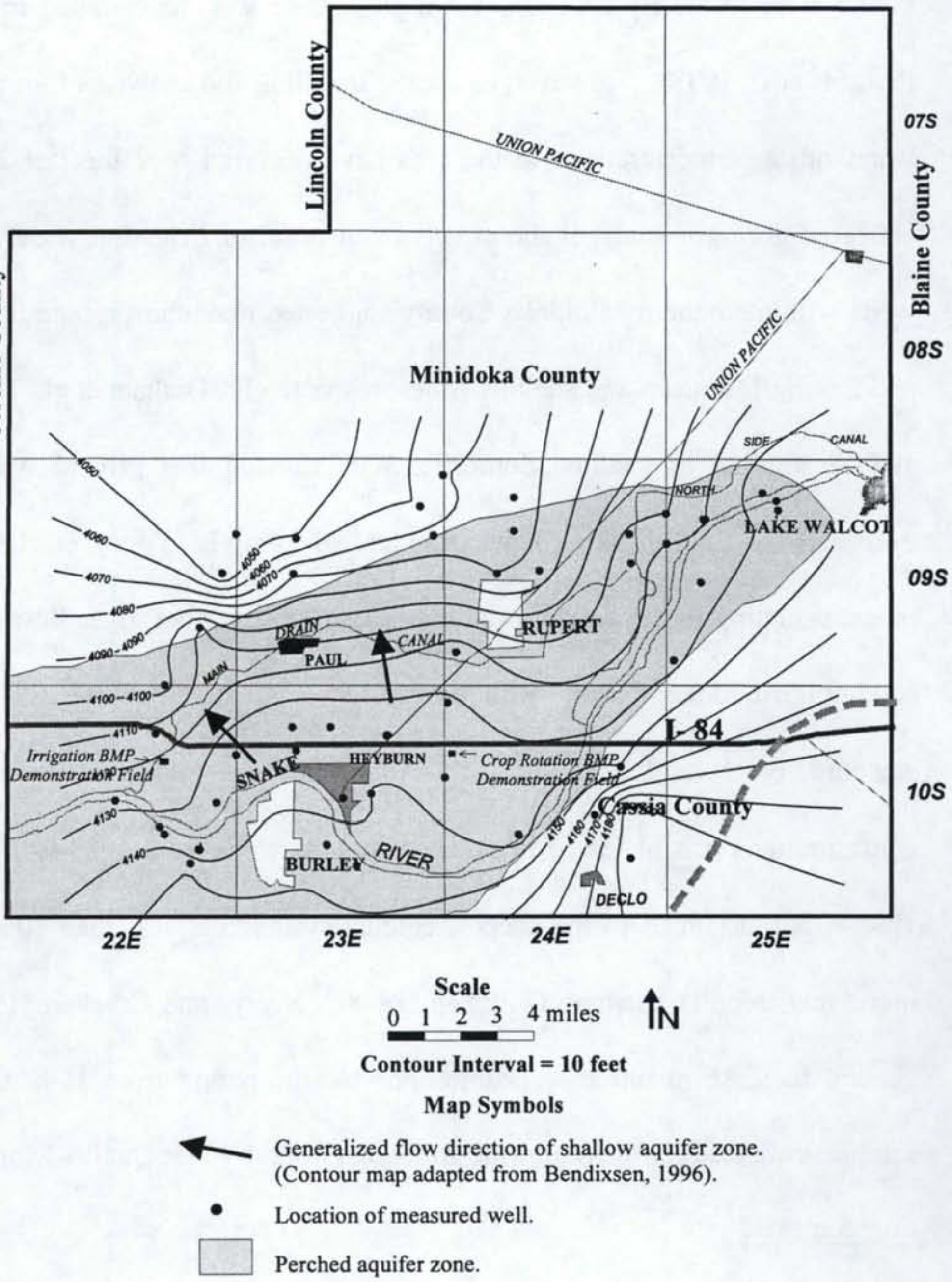


Figure 11. Contour map of the shallow ground water system underlying interior portions of southern Minidoka County. Map shows generalized direction of ground water flow and extent of perched aquifer zone.

in the area. As early as 1938, 1.9 mg/L nitrate was documented in the deep system (Stearns et al, 1938). However, extensive sampling and analysis of ground water nitrate concentrations in the area have occurred over the last 2 decades. Data collected during a study of the effects of disposal of irrigation wastewater in injection wells within southern Minidoka County suggested maximum nitrate levels of 3.2 mg/L and 2.5 mg/L in deep and shallow zones, respectively (Graham et al., 1977). As early as 1987, sampling of shallow domestic wells showed that ground water nitrate levels exceeded the EPA drinking water standard of 10mg/L (Young et al., 1987a,b). More recent sampling in the area showed increases in the number of shallow domestic wells in southern Minidoka County with nitrate levels greater then the EPA drinking water standard of 10mg/L (Figure 12). An increasing trend in ground water nitrate concentrations was observed in selected shallow wells from 1985 to 1995 (Clark, et al., 1998). Nitrate levels in the deeper regional system are less than 10mg/L; however an increasing trend is apparent (Mitchell, 1998). Neely and Crockett (1999) also noted a general increase in nitrate concentrations for the period from 1991 to 1998 based on samples collected for the Statewide Ambient Ground Water Quality Monitoring Program.

Forgeon Field

Ground Water System

The water table in the shallow, unconfined ground water system in the Forgeon Field ranges from about 3 to 7 feet below land surface. Well driller's reports and the geologic cross sections constructed in the vicinity of the Forgeon Field (Figure 6) suggest that the

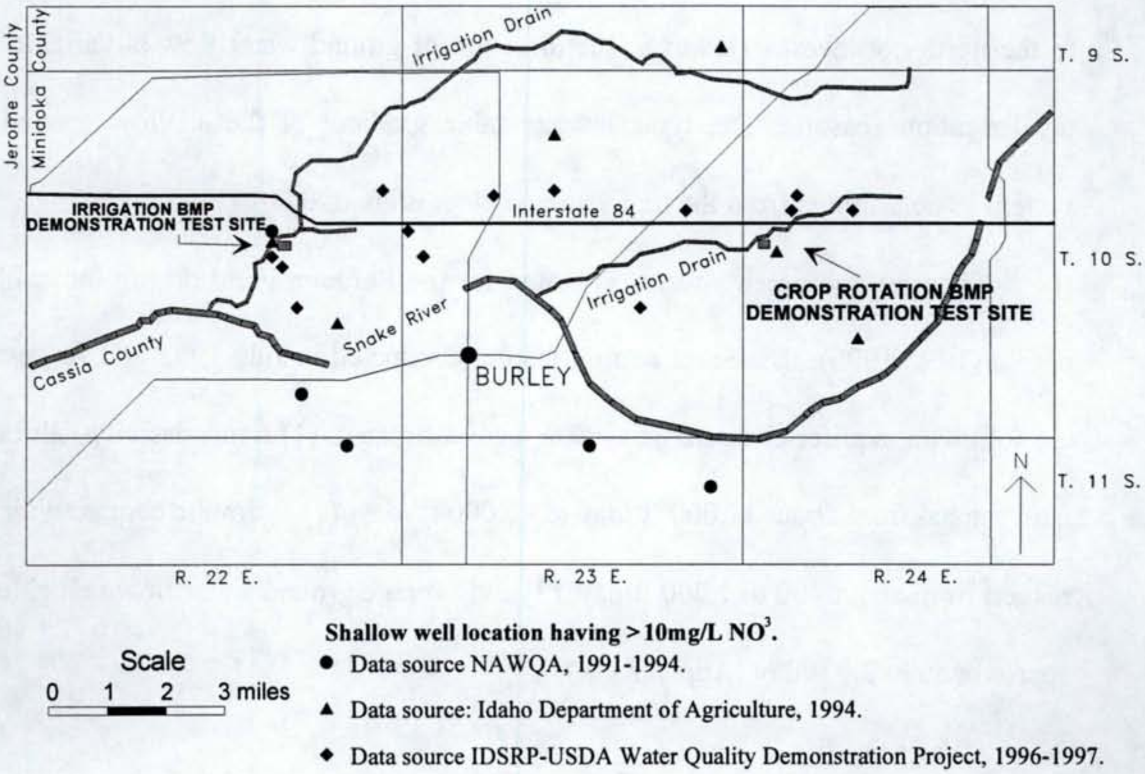


Figure 12. Map showing shallow well locations with ground water nitrate concentrations greater than 10 mg/L during the 1990 decade.

shallow aquifer extends to depth of about 25 to 35 feet below land surface. Well driller's reports and the geologic cross sections further suggest that the deeper regional ground water system is present about 200 feet below the Forgeon Field. Water level measurements int the Forgeon Field indicate that shallow ground water flow is generally to the north-northwest. However, the direction of ground water flow is variable during the irrigation season. The typical water table gradient of the shallow ground water system as determined from the trend surface plots is about 0.001 (Figure 13).

Aquifer coefficients were estimated for the Forgeon Field during the calibration period (1992-1996). Based on aquifer testing conducted in July 1992 and August 1992, the following aquifer characteristics data were estimated: (1) transmissivity values in the field ranged from about 11,000 ft^2/day to 42,000 ft^2/day, (2) hydraulic conductivity values ranged from about 400 to 1,700 ft/day, (3) and average ground water flow velocities were approximately 2.9 ft/day (Appendix A).

Water Quality

Sampling of 12 monitoring wells was initiated at the Forgeon Field in 1992 as part of calibration period evaluation of baseline ground water nitrate concentrations. Ground water nitrate sampling of monitoring wells continued throughout the calibration period (1992-1996) and the treatment phase period (1997-1998). Time series results of average nitrate concentrations computed for the eight interior monitoring wells for the control and treatment halves of the field are presented in Figure 14.

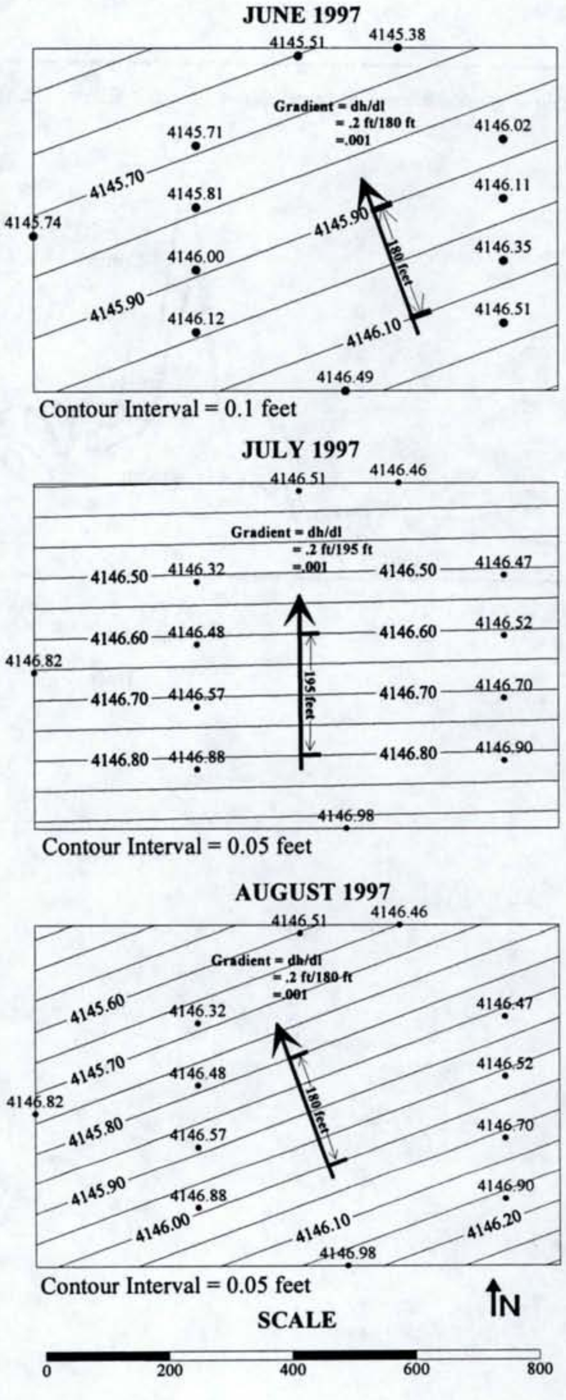


Figure 13. Trend surface contour maps of the water table in the Forgeon Field during the irrigated growing season months of 1997. Plots show generalized direction of ground water flow and gradient calculations.

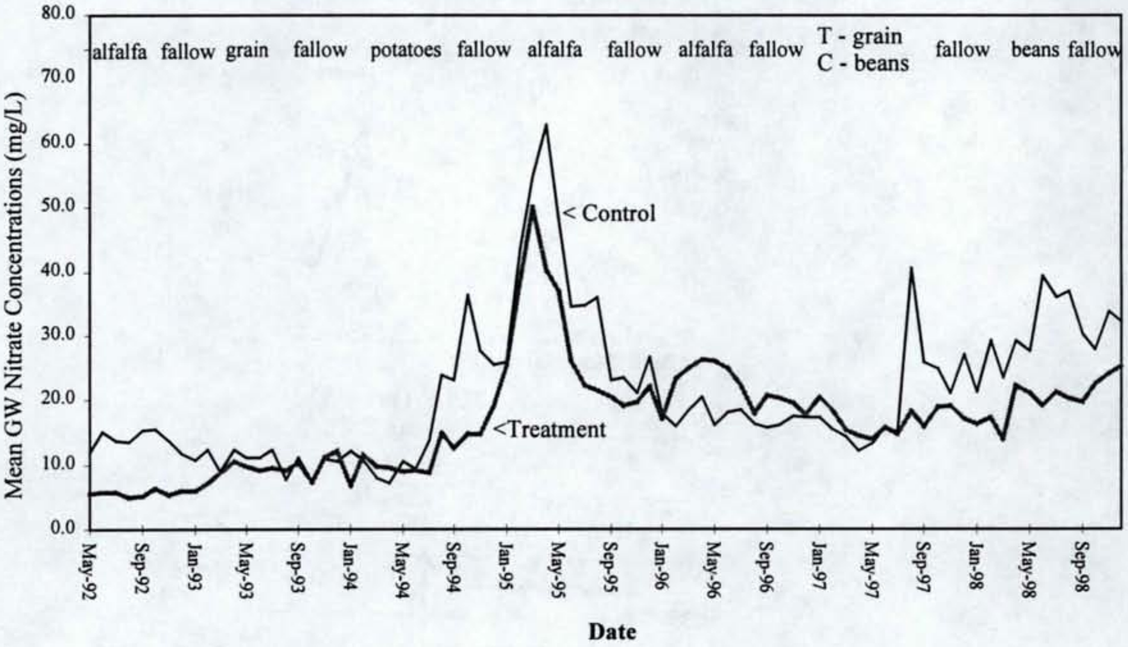


Figure 14. Time series plot of average month-to-month ground water nitrate concentrations for control and treatment halves of the Forgeon Field for the entire sampling period at the field.

Typical, averaged monthly ground water nitrate concentrations in the Forgeon Field fluctuated in the neighborhood of 10 mg/L from 1992 to 1994 under crops of alfalfa and grain. Following the planting of potatoes in spring 1994 and the addition of approximately 380 lbs/acre of ammonium nitrate fertilizer, ground water nitrate concentrations increased dramatically until May, 1995 (average concentration of about 65 mg/L). After peaking in May 1995, ground water nitrate concentrations decreased rapidly through January 1996 to an average concentration of about 18mg/L under a crop of alfalfa. A slight but steady decline in average concentrations was observed through May, 1997 to an average concentration of about 14mg/L. Thereafter, a trend towards higher ground water nitrate levels was observed during the treatment phase period for the field due to release of nitrogen from the decaying alfalfa.

Moncur Field

Ground Water System

The water table in the shallow, unconfined aquifer at the Moncur Field ranges from about 3 to 7 feet below land surface. Well driller's reports, and the geologic cross sections constructed for the vicinity of the field (Figure 6) suggest that the shallow aquifer extends to a depth of about 25 feet below land surface. Well driller's reports and geologic cross sections further suggest the deeper regional ground water system exists about 225 to 300 feet below the land surface at the Moncur Field.. Trend surface analysis of shallow water table measurements indicate that ground water flow is generally to the northwest (Figure 15) at a gradient between about .0007 and .001.

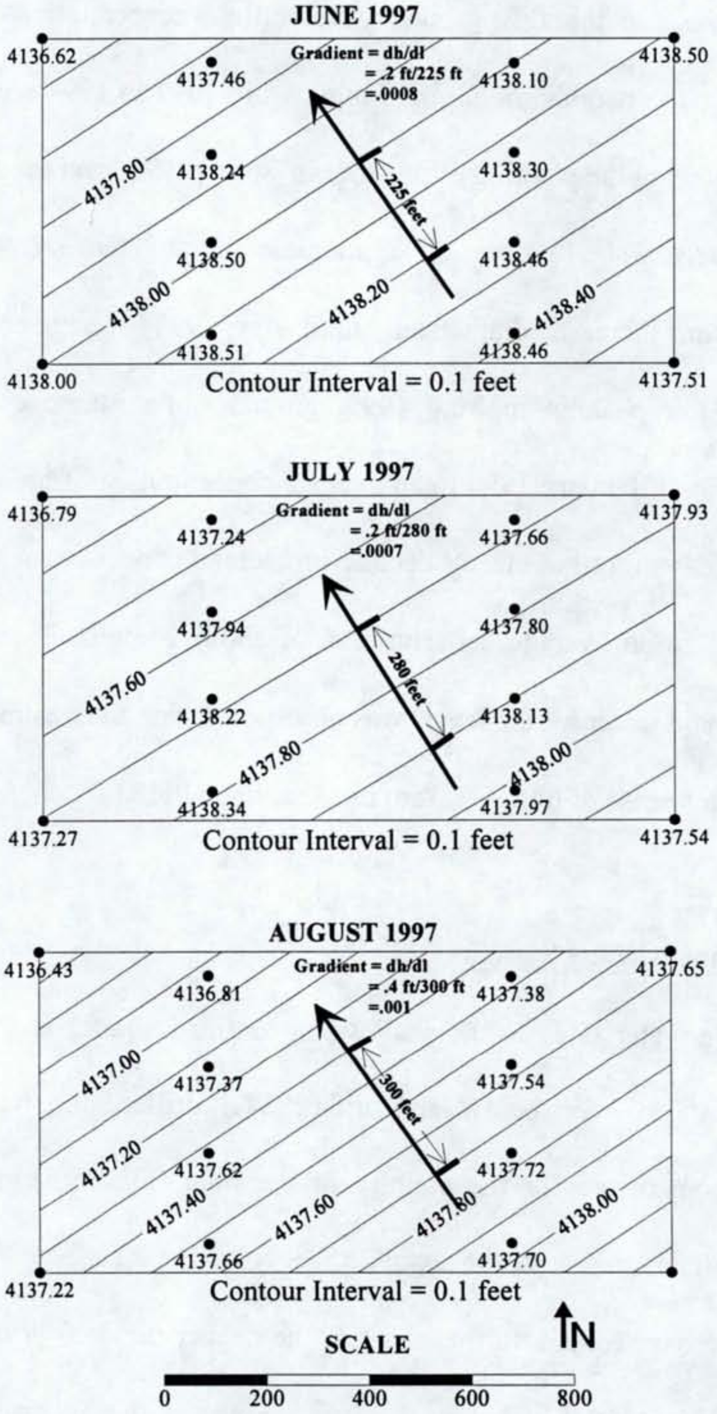


Figure 15. Trend surface contour maps of the water table in the Moncur Field for the irrigated growing season months of 1997. Plots show generalized direction of ground water flow and gradient calculations.

Aquifer coefficients were estimated for the Moncur Field during the calibration period (1992-1996). Based on slug tests conducted in 1992, the following aquifer characteristics were estimated: (1) hydraulic conductivity values ranged from about 0.04 to 0.13 ft/day, (2) and average ground water flow velocities were approximately 0.0006 ft/day. Based on an aquifer thickness of 25 feet and an average hydraulic conductivity value of 0.09 ft/day, the average transmissivity for the field is about 2.25 ft^2/day (Appendix A).

Water Quality

Sampling of the 12 monitoring wells was initiated for the Moncur Field in 1992 as part of the calibration period evaluation of baseline ground water nitrate concentrations. Ground water nitrate sampling of monitoring wells continued throughout the calibration period (1992-1996) and the effective treatment phase period (1997). Time series results of average nitrate concentrations computed for the 8 interior monitoring wells for control and treatment halves of the Moncur Field are presented in Figure 16.

Typical, averaged monthly ground water nitrate concentrations at the Moncur Field fluctuated between approximately the 5 mg/L and 17 mg/L throughout the entire period of sampling (1992-1997). Average ground water nitrate concentrations in the treatment half of the field typically were about 3 to 5 mg/L higher than those in the control half of the field over the entire period of sampling.

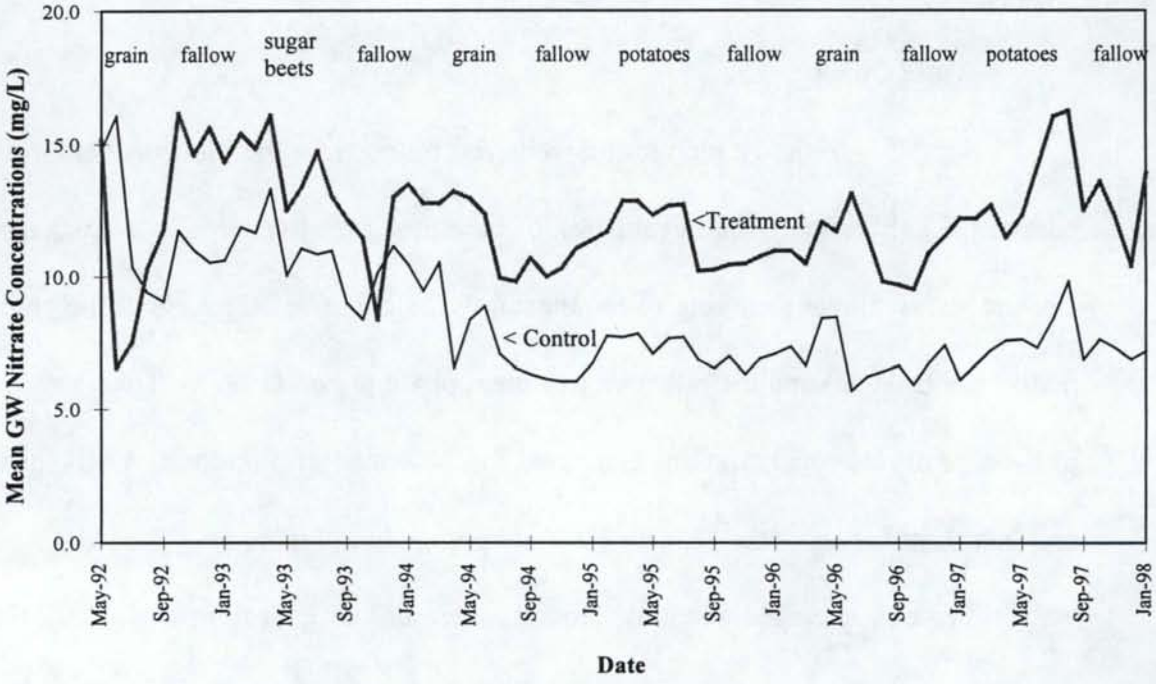


Figure 16. Time series plot of average month-to-month ground water nitrate concentrations for control and treatment halves of the Moncur Field for the entire sampling period at the field.

GEOSTATISTICAL THEORY AND FRAMEWORK

Geostatistical Overview

The field of geostatistics is not the application of statistics to geoscience problems. Rather, geostatistics is a branch of applied statistics that focuses on the characterization of spatial dependence in attributes that vary in value over space and the use of that dependence to predict values at unsampled locations (Miller, 1996b). The idea of spatial dependence implies that two data values in close proximity will be more alike than two values from distant locations.

The main goal of a geostatistical analysis is to provide an estimate of a spatially distributed attribute at unsampled locations. Estimates are modeled as a function of a set of known sample values taken at a limited number of surrounding locations. Some of the common methods currently in use include various kriging methods, trend surface analysis, nearest neighbor, and various conditional simulation techniques. Of these methods, kriging methods are the most commonly used of the estimation techniques and essentially are a form of least-squares fit linear regression (Rautman and Istok, 1996). The end result of kriging methodology is to predict a single value at each unsampled spatial location.

In recent years, probabilistic and stochastic procedures have been developed that lead to spatial simulations or stochastic images (Miller, 1996b). Simulation techniques were largely developed in response to the inadequate measures of spatial uncertainty associated with the more classical kriging methods (Rautman and Istok, 1996). Although kriging methods are still widely used, where applicable, simulation techniques are preferred. Simulated predictions are superior to various kriging methods because they produce stochastic realizations with variances similar to sample population variances and provide a better measure of uncertainty. Kriging is an interpolator; therefore considerable smoothing takes place and variances are lower.

Because of differences in sampling designs for the Moncur and Forgeon Fields, different analysis techniques are used to accommodate these designs and to provide a more thorough understanding of nitrate levels and their distributions. The existence of 35 ground water point samplers and lysimeters on a geostatistically based sampling design, allowed the use of sequential Gaussian simulation to evaluate BMP effects on groundwater and soil water nitrate concentrations at the Forgeon Field. Trend surface analysis is used to evaluate BMP effects on ground water and soil water nitrate concentrations at the Moncur Field because of limitations (fewer sampling points) in the sampling network. Data collected from the 12 monitoring wells are available for evaluation of groundwater nitrate concentrations at the Moncur Field. Monthly lysimeter samples collected at the Moncur Field, typically averaged less than 20 samples from the 25 lysimeters due to sampling limitations. Therefore, trend surface analysis also was used to evaluate soil water nitrate concentrations.

Geostatistical Procedure

Monitoring Network Design

A typical geostatistical study requires four basic steps. The first is the establishment of a geostatistically valid sampling design. A well-designed sampling network takes into account possible geological heterogeneities, but more importantly seeks to provide for various separation distances (lags for paired data) as well as perimeter control. A typical design would be constructed as follows: 50 percent of the sampling points located on a regular grid, 40 percent of the sampling points located to establish intermediate and short separation distances (lags), and 10 percent of the sampling points for very closely spaced lags (Miller, 1996c).

The number of data needed for a geostatistical evaluation is tied to many factors. The most important factor is the spatial configuration of the sampling locations. Prudently placed sampling locations can help reduce data requirements. Twenty to 30 observations are a realistic minimum in most cases (Miller, 1996b). This would provide 300 to 435 data pairs for analysis. The number of paired combinations for **n** data is calculated by **n(n-1)/2**. A generic design for 35 sampling locations is illustrated in Figure 17.

In many geostatistical studies, the sampling design has been previously established or data already collected without forethought for a geostatistical type evaluation. In such situations, the evaluator is forced to do the best he or she can with what is available. A method to evaluate the sampling design and usefulness of the data is to evaluate the pair-wise lag distribution (distribution of the separation distances between all pairs of data) (Miller, 1996b). This is accomplished by computation of lag distance for each pair of data locations and yields **n(n-1)/2** lags for a set of **n** data. Univariate descriptive methods then can be used on the lag data to evaluate the sampling design. Results obtained from this type of evaluation are independent of the actual attribute values themselves.

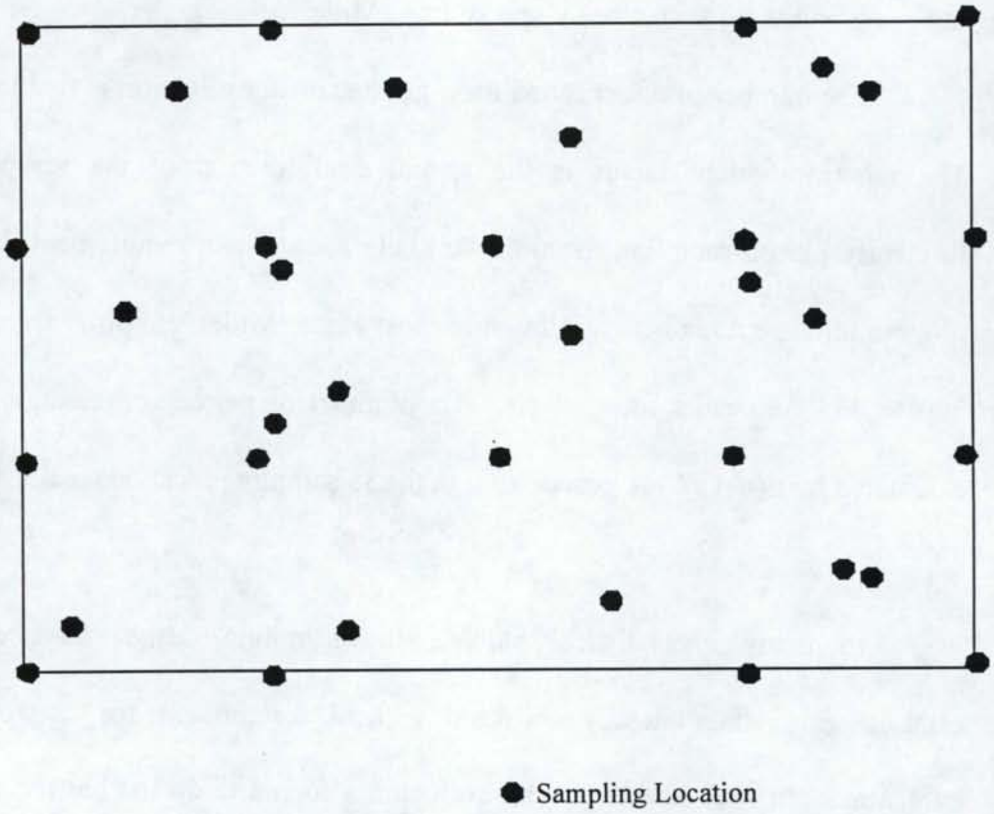


Figure 17. Generic sampling design based on 35 sampling locations.

Examination of the lag distribution can give insight into the adequacy of the sampling design and usefulness of the available data collection locations. For example, a histogram of lags that shows a high skew to the left suggests that not enough short separation distances between sampling locations are available. In addition, gaps or jumps in the relative cumulative distribution frequency plot can indicate a shortage of lags in some lag distance categories.

Exploratory Data Analysis

The second step in a geostatistical investigation is what is referred to as an exploratory data analysis (EDA). Through EDA, the investigator can develop a "feel" for the data set in a spatial context and develop a strategy for future evaluation. EDA looks specifically to identify such things as high and low valued areas, spatial trends, discontinuities, etc. EDA may include both univariate and bivariate data analysis. Typically, a univariate investigation is conducted first.

Initial univariate investigation should include map plotting of the data values. These maps include postplots, classed postplots, contour plots, and indicator maps. Maps of these types clearly illustrate the continuity and sampling regularity and can reveal apparent trends in the spatial attribute being investigated.

After trends and discontinuities have been identified, basic univariate calculations can be used to describe and help explain the spatial data set. Typical calculations include sample means, medians, variances, histograms, cumulative relative frequency plots, and standard deviations. When two or more spatial attributes are sampled simultaneously, bivariate analyses should be investigated (Miller, 1996b). Typical bivariate analyses include such things as quantile-quantile plots, scatterplots, sample covariance, correlation coefficients, and time series plots.

Spatial Dependence Characterization

The results of an experiment or sampling event for an attribute under investigation cannot be predicted with certainty, so the experiment or sampling event is said to be random. The term random in this context does not imply that the attribute (variable) itself is random or has randomly distributed values, but rather that the values occur in a probabilistic manner (Miller, 1996b). However, the variable is termed a random variable (RV) in conventional statistical terminology. The manner in which the total probability of 1 is shared between possible values of a RV is called a probability distribution (Swan and Sandilands, 1995). Two common ways to represent such a distribution are the cumulative distribution function (cdf) and the probability density function (pdf). A common measure for the dispersion in the distribution of a RV about its mean is the variance. The relationship between two RV's can be described by the covariance.

The spatial attribute of interest is modeled as a spatial random function for a spatially distributed variable. A spatial random function describes the spatial relationship of a collection of regionalized variables (ReVs). An ReV is a type of RV that is distributed over space. Thus, an ReV is one realization of the spatial random function. Typically, data for a spatial attribute of interest (data value of the ReV) are modeled as a spatial random function. This is accomplished through an experimental variogram or experimental spatial covariance model. A more detailed discussion of ReVs and random functions can be found in Deutsch and Journel (1992).

Generally stated, a variogram model describes the spatial relationship(s) of the attribute(s) being evaluated, based on the relationship of attribute pairs with respect to separation distance. Actual computation of variogram values is related directly to the moment of inertia of the point cloud about the 45 degree line on any of several specified h-scatterplots (h-scatterplots display pairs of data values that are located at a specified separation distance) (Miller, 1996b) (Figure 18). This moment of inertia is known as the semivariogram, or variogram, and is often presented in geostatistical notation as follows:

$$I_m=\gamma(h)={}^{1}\!/_{2n_h}\,\Sigma\left[(z(x_i)-z(x_{i+h})^2\right] \qquad \text{Eq.1}$$

where:

h = lag distance

$\gamma(\underline{h})$ = value of estimated variogram function at lag h

$z(x_i)$ = the i-th data value at location x_i

$z(x_{i+h})$ = the data value at location x_{i+h}

n_h = number of data values for a given lag (h).

Moment of inertia (I_m)

$I_m = n_h \Sigma d_i^2$

$2d_i = (z_i - z_{i+h})^2$

$d_i^2 = ½ (z_i - z_{i+h})^2$

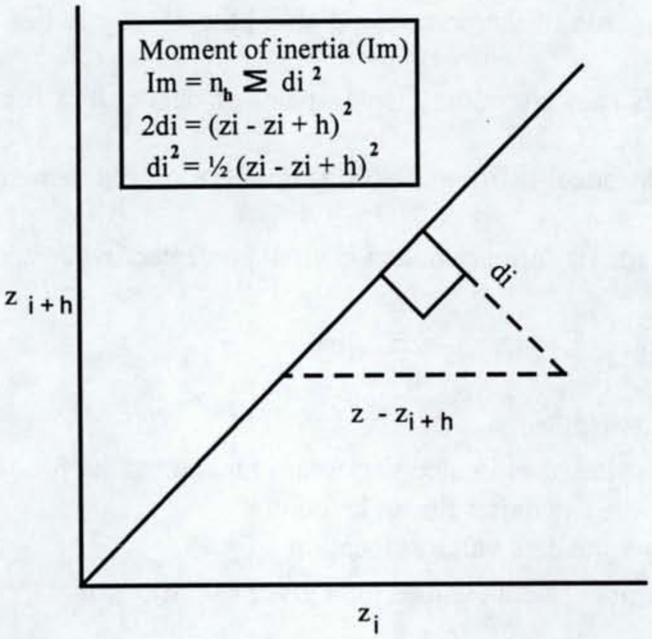


Figure 18. H-scatterplot illustrating how a single variogram value is determined.

For regularly spaced data collected along a transect, determining the estimated variogram for a given lag **h** consists of 1) identifying all data pairs separated by that specific lag (h) and computing the value for each data pair, 2) squaring that difference and summing it for all data pairs (n_h), and 3) dividing by $\mathbf{2n_h}$. The entire process is repeated for another lag (h). For irregularly spaced data sets, the summations and averaging occurs over lag bins and are typically plotted as the average lag of lags within that bin (i.e., the lag mean approach). There are two important rules that should be adhered to when computing estimates of the variogram function:

1. The number of data pairs per lag **h** for regularly spaced data or the average lag **h** for irregularly spaced data should be at least 30.
2. The largest lag used in the computations should be no greater than 50 to 60 percent of the maximum lag available in the study area.

Another technique that has gained acceptance in geostatistics is to use a moving window average to develop an experimental variogram model. This approach may be useful when data samples are limited as is the case for the Moncur Field. The procedure involves using a moving window between lag bins to compute sample data variogram values. Ultimately, this process incorporates some of the same paired data to determine variogram values at adjacent lag bins. The moving window averaging process is used to assemble an adequate number of pairs (30 or more) for each plotted variogram point.

The experimental spatial covariance is another descriptor of the ReV and is directly related to the experimental variogram model. Although convention and computer application dictate the modeling of an experimental variogram, the covariance function is actually used to develop the weights used on local neighborhood sample values to produce kriging estimates. The relationship between the estimated variogram function and covariance function is as follows (Journel, 1974):

$$C(h)=\sigma^2-\gamma(\underline{h}) \qquad \text{Eq.2}$$

where:

$C(h)$ = value of estimated covariance function at lag h
$\gamma(\underline{h})$ = value of estimated variogram function at lag h
σ^2 = estimated variance of sample data

As a result, the estimated covariance function can be obtained directly from the estimated variogram function for the attribute being evaluated.

The generalized principle of a variogram model is that at short separation distances, variogram values will be low, indicating a high degree of spatial dependency (Figure 19). The calculated experimental variogram value at zero lag is termed the nugget and corresponds to random error. As separation distances increase, variogram values will increase indicating less and less spatial dependency. Spatial dependence will continue to decrease until variogram values begin to equal the variance of the sample data. The point where the model first levels off at the sample data variance is termed the range of influence (Figure 19). This point generally defines the cutoff for those sample data that are used to determine estimates at unsampled locations (search radius). A variogram characterized by an obvious sill and range is termed a transitional variogram and represents a spatial random function that is covariance stationary (i.e., dependent only on lag not on location) (Miller, 1996b). A transitional spherical variogram model

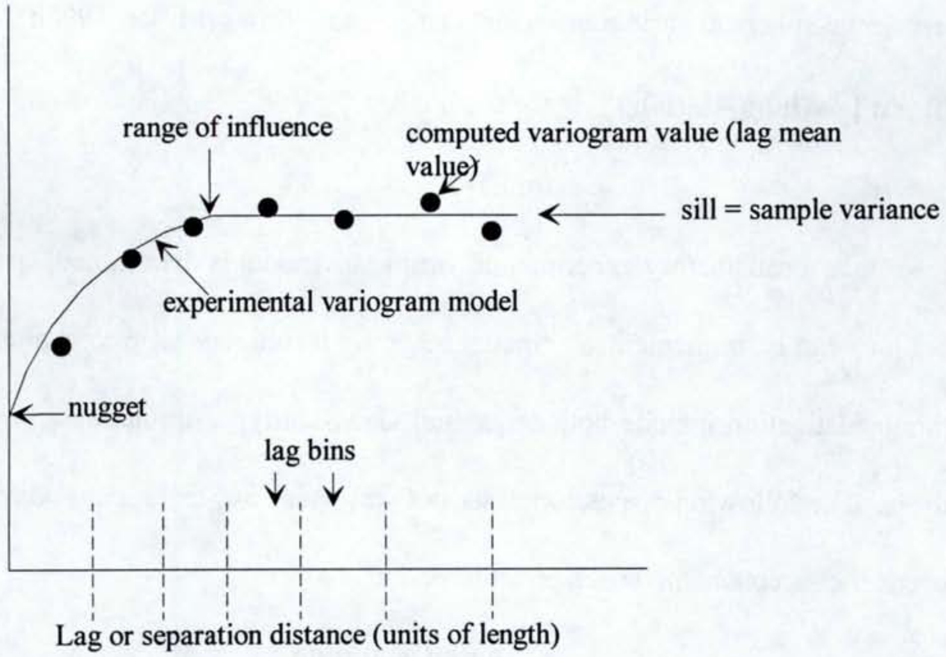


Figure 19. Schematic representation of a spherical variogram model and various components.

provided the best fit in all cases for data collected in this investigation (Figure 19). The experimental spherical variogram model is given as follows (Miller, 1996b):

$$\gamma(h) = \sigma^2[\ \tfrac{1}{2}\,(h/h_r) - \tfrac{1}{2}(h/h_r)^3 \qquad \text{for } 0 \le h \le h_r \qquad \text{Eq.3}$$

$$= \sigma^2 \qquad \text{for } h > h_r$$

Once a satisfactory experimental variogram model is determined, spatial mapping techniques can be implemented. Spatial mapping techniques used to evaluate the BMPs in this investigation include both sequential Gaussian type simulation and trend surface analysis. The following discussion describes why these two techniques where chosen and theoretical concepts behind each procedure.

Spatial Mapping

Sequential Gaussian Simulation

Sequential Gaussian simulation (SGS) was selected as the spatial mapping technique to evaluate sample data for the Forgeon Field. The 35 ground water point samplers at the site provided adequate data pairs of ground water nitrate concentration for such an analysis. The number of data pairs, and the sampling network design are appropriate for the application of various kriging methods and other simulation techniques; however, SGS was deemed the most suitable analysis technique for the following reasons: (1) SGS allows for uncertainty assessment, (2) data distributions were not highly skewed, (3) SGS is a conditional type simulation which honors hard data obtained from the point samplers, (4) SGS is appropriate for the size of the test site, and (5) SGS is relatively easy to apply compared to other simulation techniques.

SGS is one of several stochastic simulation principles used currently in geostatistics. The sequential simulation approach is a generalization of the idea that approximation allows drawing the value of an attribute from its conditional distribution given the value of the most related covariate at the same location (Deutsch and Journel, 1992). For SGS, the conditioning is extended to include all data available as well as previously generated simulation values. Also, SGS goes one step farther in the assumption that all local conditional cumulative distribution functions are Gaussian (i.e., normal distribution).

SGS is based upon a six step process (Figure 20). The simulation process begins by determination of the univariate cumulative distribution function (cdf) that is representative of the entire study area (Deutsch and Journel, 1992). The cdf is used to perform a normal score transform on the original data set. This is done to ensure the data are univariate, normally distributed. A check is then made on the transformed data set to establish bivariate normality. After bivariate normality has been ascertained, simple kriging is performed on a predetermined grid assignment to determine local neighborhood conditional cumulative distribution functions (ccdfs). These ccdfs are then randomly visited by the simulation, and normal score values are randomly drawn from each ccdf. The simulated normal score values then are back transformed to produce a stochastic realization for the attribute of interest.

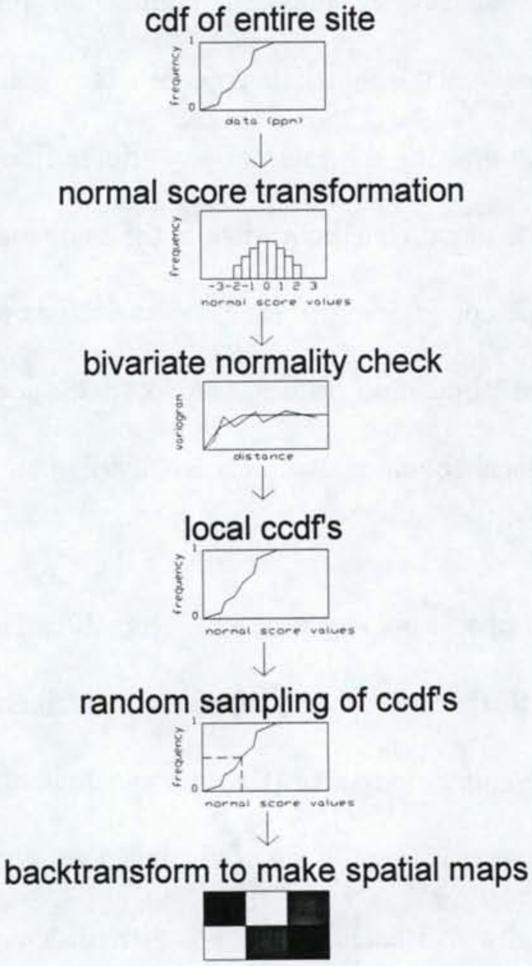


Figure 20. Simplified representation of steps involved in sequential Gaussian simulation.

A typical evaluation of SGS may include as many as several hundred simulations. Each simulation represents one possible stochastic realization of the distribution of the attribute being modeled. Each simulation will preserve the statistical character of the sample data, both in terms of univariate character and bivariate properties (Rautman and Istok, 1996). Because each simulation is a possible representation of the unknown reality, an uncertainty arises in how to evaluate and present simulation data. One typical approach for reducing the uncertainty is to average simulation data to develop Expected-value estimates at any given location (E-type estimate)(Journel, 1983). Typically, E-type estimates are illustrated as shaded cell mean maps (i.e., gray scale plots).

SGS allows for uncertainty assessment. A typical evaluation of uncertainty takes the form of establishing a threshold or cutoff level and determining the probability of exceeding such a cutoff. This is readily accomplished by counting the number of simulated values that exceed the cutoff for each node. For example, if 10 simulated values out of 100 simulated values exceed the given cutoff, the quantitative exceedence probability would be 0.10 or a 10 percent chance of exceeding the cutoff. This process can be repeated for each simulation grid node and can be presented as a probability of exceedence gray scale map.

Trend Surface Analysis

Adequate ground water data were not available to model variograms for the Moncur Field because of the absence of ground water point samplers. It was necessary to use an alternate method to evaluate BMP effectiveness geostatistically. One of the few geostatistical tools available for non-variogram geostatistical evaluation is trend surface analysis (TSA). The goal in a TSA is to best describe a regional trend that exists in the data. This is achieved by identifying and testing a "best-fit" equation. The fit is obtained through a least squares multiple linear regression (Miller, 1996b). The "best-fit" equation defines a surface that describes an attribute of interest (e.g., a dependent variable such as nitrate concentration) as a function of geographic position (Swan and Sandilands, 1995). This surface is termed a trend surface and is constrained to be planar or geometrically curved. As with variogram based geostatistical estimators, one goal of trend surface analysis is to estimate attribute values at unsampled locations. In addition, and likely of greater importance, the trend surface is used to test statistical hypotheses such as: do nitrate concentrations increase relative to the direction of measurement? This is posed against the null hypothesis that no trend does exist.

A succession of increasingly complex forms of equations are available. First order models are linear, second order models are parabolic, and third order models are cubic functions. It is important to note that the equations describing the trend surfaces can provide good regional estimates, but may provide poor local estimation due to the regression procedure. Typical mathematical notation for trend surface models is as follows:

First order trend model:

$$T_1=b_0+b_1x_1+b_2x_2 = y \qquad \text{Eq.4}$$

Second-order trend model:

$$T_2=T_1+b_3x^2{}_1+b_4x_1x_2+b_5x^2{}_2=y \qquad \text{Eq.5}$$

Third-order trend model:

$T_3=T_2+b_6x^3_1+b_7x^2_1x_2+b_8x_1x^2_2 + b_9x^3_2 = y$ Eq.6

Commonly, x_1 represents easting coordinates and x_2 represents northing coordinates. The parameter (b_0) is a constant value related to the mean of the observations; values for (b_n) are directional coordinate components (unknown coefficients) which are defined by the least-squares criterion and solved for by a series of simultaneous equations to yield the best fit trend surface estimate (y) (Davis, 1986).

The goodness-of-fit of a trend surface is tested statistically through analysis of variance (ANOVA). This is accomplished by dividing the total variation of a set of observations into two components, the trend (regression) and the residuals (error) (Davis, 1986). If we let n = the number of observations, and m = equal the number of trend model coefficients, then an ANOVA table can be developed (Table 1).

Table 1. General ANOVA table of significance of regression (after Davis, 1986).

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Square	F Test
Regression	SS_R	m	$MS_R = SS_R/m$	MS_R/MS_D
Error	SS_D	n – m -1	MS_D $= SS_D/(n-k-1)$	
Total Variation	SS_T	n - 1		

A statistical F-test is used to evaluate this “goodness-of-fit”. A null hypothesis is proposed and is rejected if the computed test value exceeds the tabulated value of F for the regression fit. A rejection implies that the trend fit surface provides a reasonable model for the regional trend of the data set at a specified significance level. If the regression is not significantly different from the random error, then (1) the spatial distribution is random and independent of location, or (2) the distribution of the dependent model may be dependent on location, but the wrong regression model was used. In a similar fashion, a statistical significance test is used to determine if a higher order trend surface fit is significantly better than lower order models. Ultimately, statistical tests of a trend surface give the analyst an idea of how well the trend surface model describes the set of observations and which order model is most appropriate to use. A more detailed discussion of ANOVA can be found in most statistics textbooks.

INITIAL GEOSTATISTICAL ASSESSMENT AND NITRATE INVESTIGATIONS

Forgeon Field Crop Rotation BMP

Monitoring Network Design and Sampling

The monitoring network at the crop rotation test field for the period of this study consisted of 12 ground water monitoring wells, 35 pressure/vacuum lysimeters (soil water solution samplers), and 35 ground water point samplers (Figure 21). Installation of the 12 monitoring wells and subsequent sampling began in the spring of 1992 to establish baseline, ground water nitrate concentrations. These wells were installed to a depth of 11 feet and extended about 4 to 6 feet below the water table. Thirty-five dedicated, lysimeters were installed at a depth of about 3 feet in 1994 to 1995 to gain a better understanding of soil water nitrate concentration distributions. A groundwater point sampler was installed below each lysimeter location in 1995 (total of 35) to allow geostatistical evaluation of ground water nitrate concentration distributions. Ground water point samplers were installed to a depth of about 1 foot below the seasonal low water table (Appendix A). Beginning in 1994 and throughout the period of this study, lysimeters and point samplers were sampled only during the growing season months and were deactivated during off-season months to allow the farmer access for cultivation and harvesting. Monitoring wells were sampled year round.

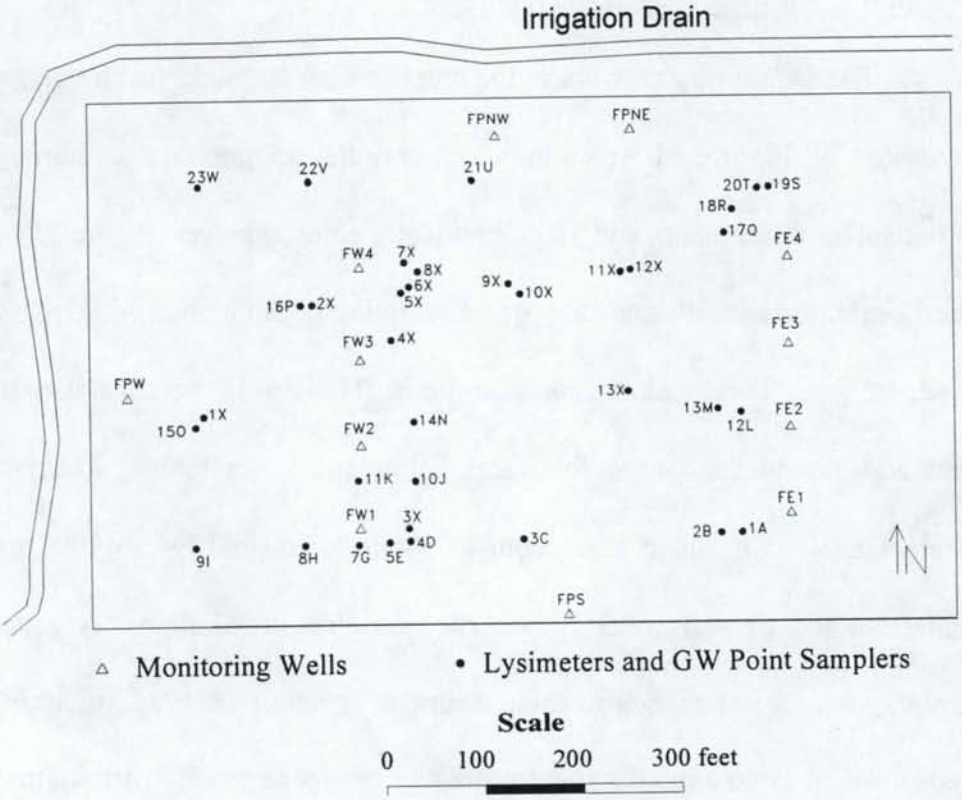


Figure 21. Monitoring network for the Forgeon Field

Ground water point samplers were installed through 2 inch diameter augered boreholes. A length of 0.25 inch outside diameter, flexible, polyethylene tubing was attached to each point sampler and run to the land surface for sample collection. Boreholes were back-filled with tamped, auger cuttings to within 4 inches of the land surface. The remainder of each auger hole was filled with a hydrated, granular bentonite, seal. Ground water samples were collected from each point sampler with a hand vacuum pump following the purging of approximately 0.5 gallons of ground water (Appendix A). Samples were collected in 125ml polyethylene bottles, acidified with sulfuric acid (pH<2) and frozen until shipment to the University of Idaho Analytical Laboratory for nitrate analysis. Monthly nitrate concentrations with a laboratory detection limit of 0.1 mg/L were determined for each ground water point sample taken over the period of this study.

The 12 monitoring wells in the test field were installed in 4-inch diameter augered boreholes (Appendix A). The wells were constructed with 2-inch diameter PVC well casing and 5-feet of 0.010-inch machine slotted screen. Each well was fitted with a dedicated 1 inch diameter PVC purge pipe and an attached length of 0.25 inch outside diameter, flexible, polyethylene tubing from the bottom of the 5 foot section of well screen to the top of the well casing (Appendix A). Samples were collected through the polyethylene tubing in each well with a hand vacuum pump following the purging of about 4 gallons of ground water by a portable centrifugal pump. Storage, shipment and laboratory analysis of ground water nitrate samples collected from the monitoring wells were completed with the same protocol as ground water point samples.

Lysimeters were installed in 4-inch diameter augered boreholes. Silica flour was placed in the bottom of each borehole and around the porous cup of the lysimeter to allow greater suction to draw water from the larger pores of the surrounding soil. Boreholes were back-filled with tamped, auger cuttings to within 4 inches of the land surface. The remainder of each auger hole was filled with a hydrated, granular bentonite, seal (Appendix A). Soil water nitrate samples were collected with a hand vacuum pump. Approximately 80 millibars of vacuum was applied to each lysimeter through a length of 0.25 inch outside diameter, flexible, polyethylene tubing attached to the lysimeter. Vacuum was maintained on the lysimeters for a 24-hour period to allow drawing of water from the soil prior to sampling. Storage, shipment and laboratory analysis of soil water, nitrate samples collected from the lysimeters were completed with the same protocol as ground water nitrate samples.

Lysimeter and ground water point sampler locations were selected for a geostatistical type analysis. Each location was evaluated for measured geological heterogeneity, needed separation distances between sampling points, and adequate perimeter control. In part, the sampling network was designed in an unbiased attempt to provide sampling locations representative of heterogeneities at each test site. Heterogeneities were evaluated based on grain size analyses conducted for both test sites prior to installation of lysimeters. Final selection of sampling locations also was made to partially accommodate established geostatistical protocol. Locations then were surveyed in by transit and mapped accordingly.

Review of the validity of the sampling network with regard to geostatistical protocol was completed at the onset of this study. Investigation into spatial lag was accomplished in GEO-EAS (Englund and Sparks, 1991) by variogram modeling of calibration period data. Analysis of spatial lag for the lysimeter and point sampler network indicated that minimum lag pair requirements (30 pairs) for short separation distances could be achieved for an averaged lag distance of 40 ft or greater. Variogram modeling also revealed that sufficient lag pairs were available for intermediate and longer lags up to and well beyond the typical range of influence (generally about 200 to 300 feet). Inspection of initial postplots indicated the network had good perimeter control. Additional sampling locations on a regular grid would have allowed for reproduction of hard data values during the spatial mapping evaluation. However, variogram modeling revealed that the typical range of influence was approximately 200 to 300 feet and the minimum average distance to achieve 30 lag pairs was 40 feet. Therefore, more than 35 point samplers would have been needed to place point samplers on a regular grid without depleting the number of pairs available for evaluation of short spatial lags.

Exploratory Data Analysis

The primary focus of exploratory data analysis of ground water and soil water, nitrate concentrations was the sampled months of 1997 and 1998 during the treatment phase period. Actual implementation of the treatment phase for the Forgeon Field began in the spring of 1997 at which time the control half of the field was planted in beans and the treatment half of the field was planted in oats. During the second year of BMP implementation (1998), the entire field, both control and treatment halves, was planted in beans in order to evaluate longer term effects of the 1997 crop rotation. The primary sources of nitrate available during the treatment phase period were residual nitrate in the soils and nitrogen released from the roots of decaying alfalfa killed during the calibration period in the fall of 1996. No fertilizer was applied during the 1997 and 1998 treatment phase period.

Univariate Analysis

Univariate analysis was directed towards data collected from ground water point samplers and lysimeters. A thorough univariate evaluation of ground water data collected for monitoring wells was not completed because of (1) distinct differences in the zones sampled compared to the ground water point samplers and (2) the focus of spatial mapping techniques on the geostatistically located ground water point samplers. Differences in the techniques used to purge, and differences in the depths of aquifer penetration between the ground water point samplers and the monitoring wells suggested that well samples were more mixed than those obtained from the point samplers. Point sampler FW1 consistently showed different nitrate concentrations than monitoring well FW1 because of stratification of nitrate in the ground water with depth. Monitoring well FW1 and point sampler FW1 were located at the same geographical coordinates.

Initial kriging of nitrate sample data was completed for all ground water point sample and soil water sample data sets using Surfer™. Kriging was selected as the initial contouring method for evaluation because early variogram analysis of pre-BMP data indicated that ground water data did exhibit a strong spatial covariance structure. The linear omni-directional variogram default option was used because it provided a quick and easy method for early evaluation of ground water nitrate concentrations. Comparison of kriging contours to posted data indicated that the default linear variogram provided an adequate representation of the spatial structure for initial assessment of ground water nitrate concentration distributions. However, a bulls-eye effect was noted on several of the plots due to contouring near high and low valued anomalous values (outliers).

Outliers visible on kriging plots for both ground water point sample data sets and lysimeter sample data sets prompted a univariate as well as bivariate assessment of their effects. Typically, outliers are interpreted to (1) represent errors in processing or some other spurious effect, or (2) to be genuine, but isolated representatives from a minor population having extreme values (Swan and Sandilands, 1995). Thus, it was deemed practical and necessary to evaluate their effects.

Ground Water Nitrate

Univariate analysis of ground water nitrate concentration data for the point samplers was completed for all sampled months over the BMP treatment phase period. This included the first year BMP months of June, July, and August 1997. Univariate analysis of second year BMP months included June, July, August, September, and October 1998. Ground water point samplers were not operational from September 1997 to May 1998 to allow the farmer access for cultivation and harvesting.

Kriging results for all ground water point sample data sets for BMP treatment phase months are presented in Figure 22. Review of these plots indicated that at the start of the BMP treatment phase (June 1997) a trend towards higher nitrate concentrations was visible in the north or treatment half of the field towards lower concentrations in the south or control half of the field (Figure 22). Maximum concentrations (46 mg/L to 58 mg/L) were measured at two northwestern perimeter point sampler locations (24W and 23V) while a minimum concentration of 5.1 mg/L was recorded at a southern perimeter sample location (4D). A trend towards higher variability of ground water nitrate within the sandy subsoils in the west also was distinctly visible in contrast to a relatively uniform distribution that ranged from 10 to 20 mg/l within the clay subsoils to the east. This uniform distribution of relatively low ground water nitrate concentrations in the east end of the field persisted throughout the point sampling period for 1997 (Figure 22).

The trend towards higher ground water nitrate concentrations within the treatment half of the field, visible at the start of BMP implementation, apparently reversed going into August 1997 (Figure 22). Posted ground water nitrate sample values indicated that most low nitrate concentration samples were collected primarily within the treatment end of the field and high concentration samples were collected in the control half of the field, especially in the southwest corner. Kriging contours confirmed this north to south, high to low ground water nitrate trend.

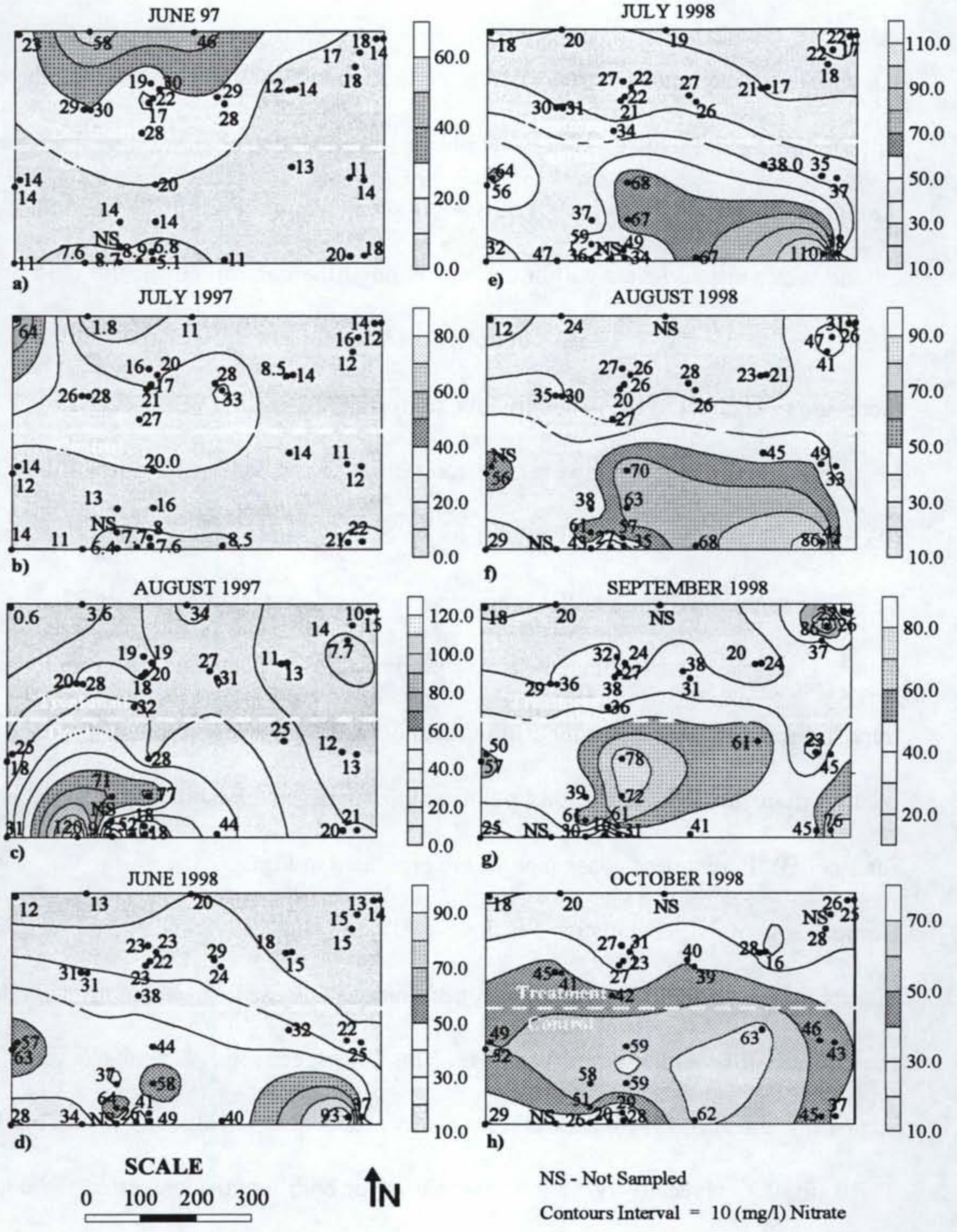


Figure 22. Kriged contour plots of ground water nitrate concentrations for the Forgeon Field for a) June 1997, b) July 1997, c) August 1997, d) June 1998, e) July 1998, f) August 1998, g) September 1998, and h) October 1998.

The visible reversed trend toward higher ground water nitrate levels in the control half of the field to lower concentrations in the treatment half of the field persisted throughout the second year (1998) of BMP implementation (Figure 22). A shift to higher ground water nitrate levels within the clay soils of the control half of the field also was visible and variability between control and treatment portions of the field in the east increased in contrast to the generally low, uniformly distributed values seen in 1997 BMP treatment period months. However, a strong influence of consistently high nitrate values (93 mg/L, 110 mg/L, and 86 mg/L) in June, July, and August 1998 at a southeast perimeter sampling location (2B) is apparent in the kriging results (Figure 22).

Univariate statistical analysis was performed to evaluate and better understand the trends, discontinuities, and effects of outliers observed after inspection of posted data and contour maps for 1997 and 1998, point sampler data sets. Results of statistical analyses for 1997 BMP treatment phase months are presented in Figure 23.

Comparison of basic statistics for June 1997 and July 1997 indicated very similar distributions of ground water nitrate concentrations (Figure 23). Mean nitrate values for the two months were 18.9 mg/L and 16.8 mg/L, respectively. Calculated variances for June 1997 and July 1997 data sets were nearly identical with values of 118.4 $(mg/L)^2$ and 117.0 $(mg/L)^2$, respectively. Skewness values for both months suggested the data to be non-normally distributed. Generally, absolute skewness values greater than 1 are considered to represent a non-normal distribution (Graybow et al., 1999). However, with the removal of two, high outlier, values in June and one, high outlier, value in July,

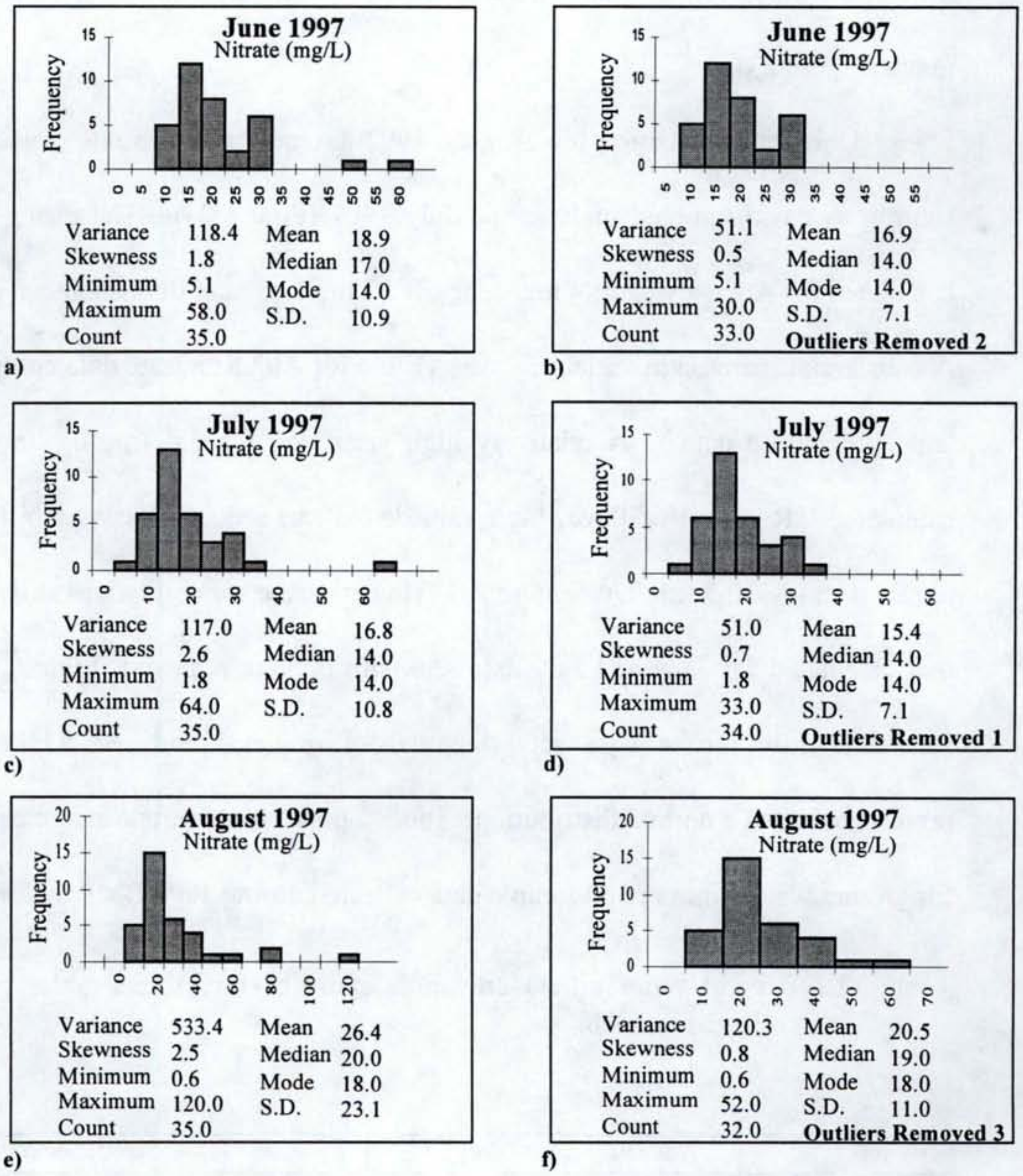


Figure 23. Histograms and univariate statistics of ground water nitrate concentrations with and without outliers for the Forgeon Field for a-b) June 1997, c-d) July 1997, and e-f) August 1997.

skewness values dropped considerably below 1 and fell within a normal distribution range (Figure 23).

Univariate statistics for August 1997 ground water nitrate values contrasted sharply to those sampled in June and July 1997 (Figure 23). The mean nitrate level calculated for August was 26.4 mg/L, nearly 10 mg/L greater than the mean in July. A substantial increase in variability was visible for August nitrate data compared to June and July nitrate data. A relatively high variance of 533.4 (mg/L)^2 for August was calculated. Removal of three, high valued, outliers reduced the variability of August nitrate data to 120.3 (mg/L)$^{2.}$ (Figure 23). However, the variability was still nearly double that calculated for June and July data sets with outliers removed (Figure 23). As with June and July nitrate data sets, removal of outliers produced a skewness value representative of a normal distribution. Table 2 presents univariate statistical calculations for ground water nitrate point sample data collected during 1998 BMP treatment phase.

Table 2. Ground water nitrate univariate statistics for ground water point samples collected in 1998.

GW NO^3	June 98		July 98		August 98		September 98		October 98	
Outliers	None	1	None	1	None	0	None	0	None	0
Mean (mg/L)	31.3	29.5	36.8	33.9	38.6	--	39.9	--	37.3	--
Median (mg/L)	27.0	26.0	32.0	31.0	33.0	--	36.0	--	35.0	--
Mode (mg/L)	15.0	15.0	22.0	22.0	26.0	--	61.0	--	28.0	--
SD (mg/L)	17.3	13.7	20.2	15.6	17.1	--	18.8	--	14.1	--
Variance (mg/L)^2	300.2	187.1	409.1	243.2	292.6	--	355.0	--	198.0	--
Skewness	1.6	0.9	1.7	1.1	1.0	--	1.0	--	0.4	--
Minimum	12.0	12.0	17.0	17.0	12.0	--	16.0	--	16.0	--
Maximum	93.0	63.0	110.0	68.0	86.0	--	86.0	--	63.0	--
Count	34.0	33.0	35.0	33.0	33.0	--	34.0	--	32.0	--

Noticeable increases in mean nitrate concentrations were visible for all months analyzed during 1998 compared to mean nitrate concentrations in 1997. Mean nitrate levels ranged from a minimum of 31.3 mg/L in June 1998 to a maximum of 39.9 mg/L in September 1998. Throughout the months evaluated in 1998, calculated variances remained moderately high with a minimum value of 292.6 $(mg/L)^2$ in October to a maximum of 409.1 $(mg/L)^2$ in August. Similar to 1997, point sample, nitrate data sets for June 1998 and July 1998 had skewness values indicative of non-normal distributions. However, removal of single, high outlier, values for each month produced skewness values representative of normally distributed data. For the months of August, September, and October 1998, the effects of outliers were not apparent and point sample data sets showed skewness values indicative of normal distributions.

Soil Water Nitrate

Univariate analysis of soil water nitrate concentration data collected for lysimeters was completed for all sampled months over the BMP treatment phase period. This included the first year BMP months of June, July, and August 1997. Univariate analysis of second year BMP months included June, July, and August 1998. Lysimeters were not sampled from September 1997 to May 1998 to allow the farmer access for cultivation and harvesting.

Kriging results of soil water, lysimeter sample, data sets for all sampled BMP treatment phase months are presented in Figure 24. Review of these results indicated that at the start of the BMP treatment phase (June 1997) the distribution of soil water

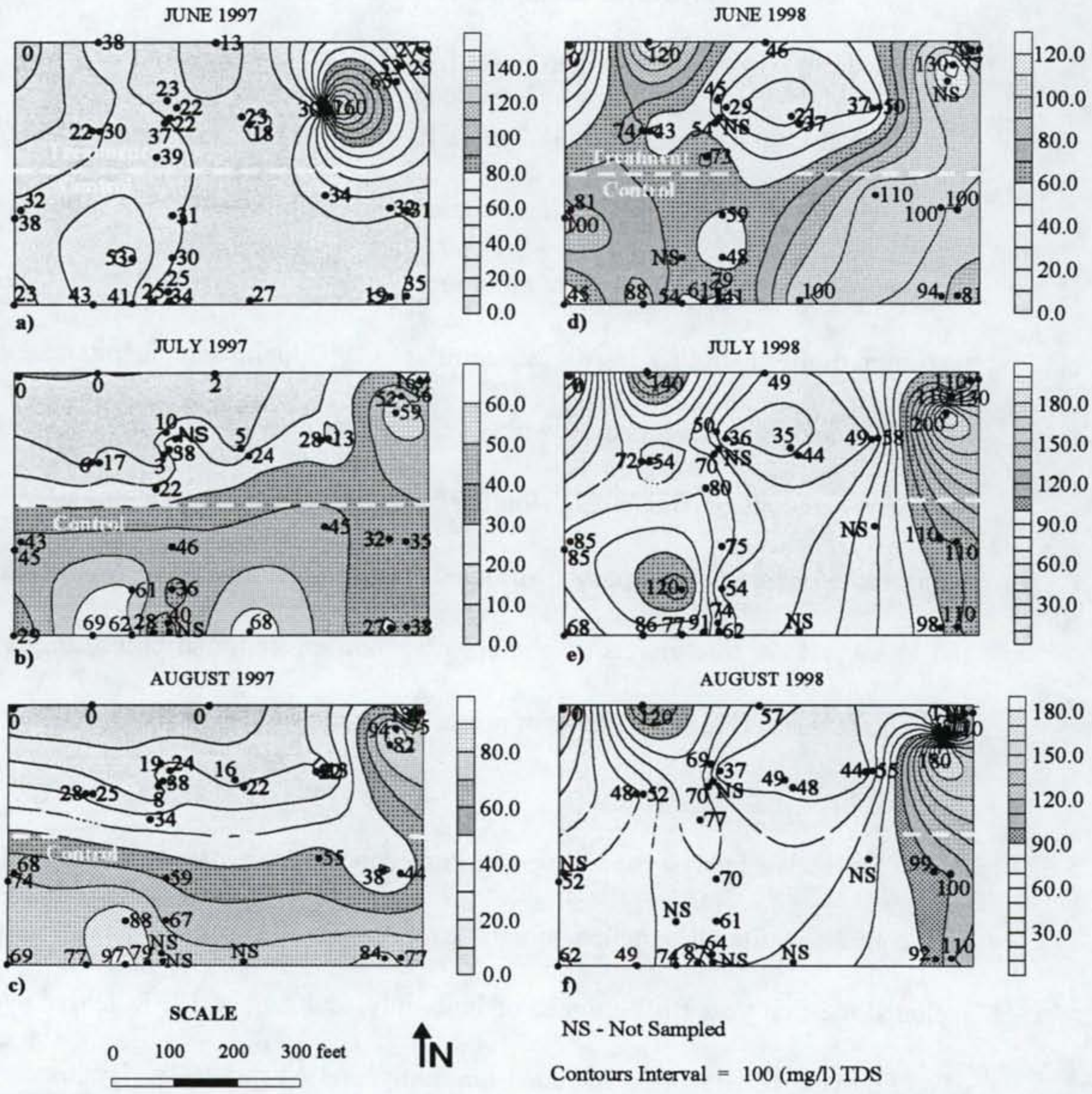


Figure 24. Kriged contour plots of soil water nitrate concentrations for the Forgeon Field for a) June 1997, b) July 1997, c) August 1997, d) June 1998, e) July 1998, and f) August 1998.

nitrate concentrations was varied across the entire field. Concentrations ranged from a minimum of nondetect at a northwest perimeter location (23W) to a maximum 160 mg/L at a northeast sample location (12X). The 160 mg/L soil water nitrate value had a strong influence on the kriged contours in the northeast corner of the treatment half of the field.

Review of the kriged contour plot for July 1997 soil water nitrate data indicated a shift from the random variability seen in June 1997 to a trend towards higher nitrate concentrations in the control half of the field to lower nitrate concentrations in the treatment half of the field (Figure 24). Maximum soil water nitrate levels (>60 mg/L) were measured at several lysimeter locations in the southwest portion of the control half of the field and minimum soil water nitrate concentrations (<10mg/L) were measured at several lysimeter locations in northwest portion of the treatment half of the field. This trend persisted and became more pronounced into August 1997 (Figure 24).

Review of the kriged contour plots for June, July, and August 1998 soil water nitrate data sets indicated a return to a more varied distribution of nitrate concentrations (Figure 24). However, noticeable nitrate increases were visible within the entire eastern portion of the demonstration field. Also, noticeable nitrate increases were apparent in most areas of the treatment half of the field. Soil water nitrate concentrations within the southwest portion of the control half of the field were similar to those observed in August 1997 and remained relatively constant throughout the sampled months of 1998. Again, the influence of high valued, outliers on kriged contours was apparent for all months sampled in 1998.

Univariate statistical analysis was performed to evaluate and better understand the trends, discontinuities, and effects of outliers seen after inspection of posted data and contour maps for 1997 and 1998 soil water nitrate data. Results of statistical analyses for 1997 BMP treatment phase months are presented in Figure 25. The histogram and univariate statistics for June 1997 soil water, nitrate sample, data values illustrated the effect that outlier values can have on sample data statistics. Statistical calculations on the original June 1997 sample data suggested a relatively high variance (618.9 $(mg/L)^2$) and relatively high skewness (4.0). However, with the removal of two apparently anomalous sample values, especially the high value of 160 mg/L, the calculated variance and skewness was reduced to 119.0 $(mg/L)^2$ and 1.1, respectively.

Comparison of histograms and univariate statistical results between the reduced, June 1997, soil water, nitrate sample, data and the entire July 1997, soil water, nitrate sample, data indicated an overall distributional shift between the two months (Figure 25). Although mean soil water, nitrate concentrations were very similar (31.5 mg/L and 31.4 mg/L, respectively), the high variance of 410.2 mg/L calculated for July 1997, soil water, nitrate concentrations was a result of the bulk distribution of the sample data and not the effects of outliers. This distributional shift in the July, soil water, nitrate concentrations was evidenced by a calculated low skewness value (0.1).

Univariate statistical analysis of soil water, sample data for August 1997 indicated an increase in all statistical categories compared to those of June and July 1997. Furthermore, an almost perfectly symmetrical bimodal distribution was apparent

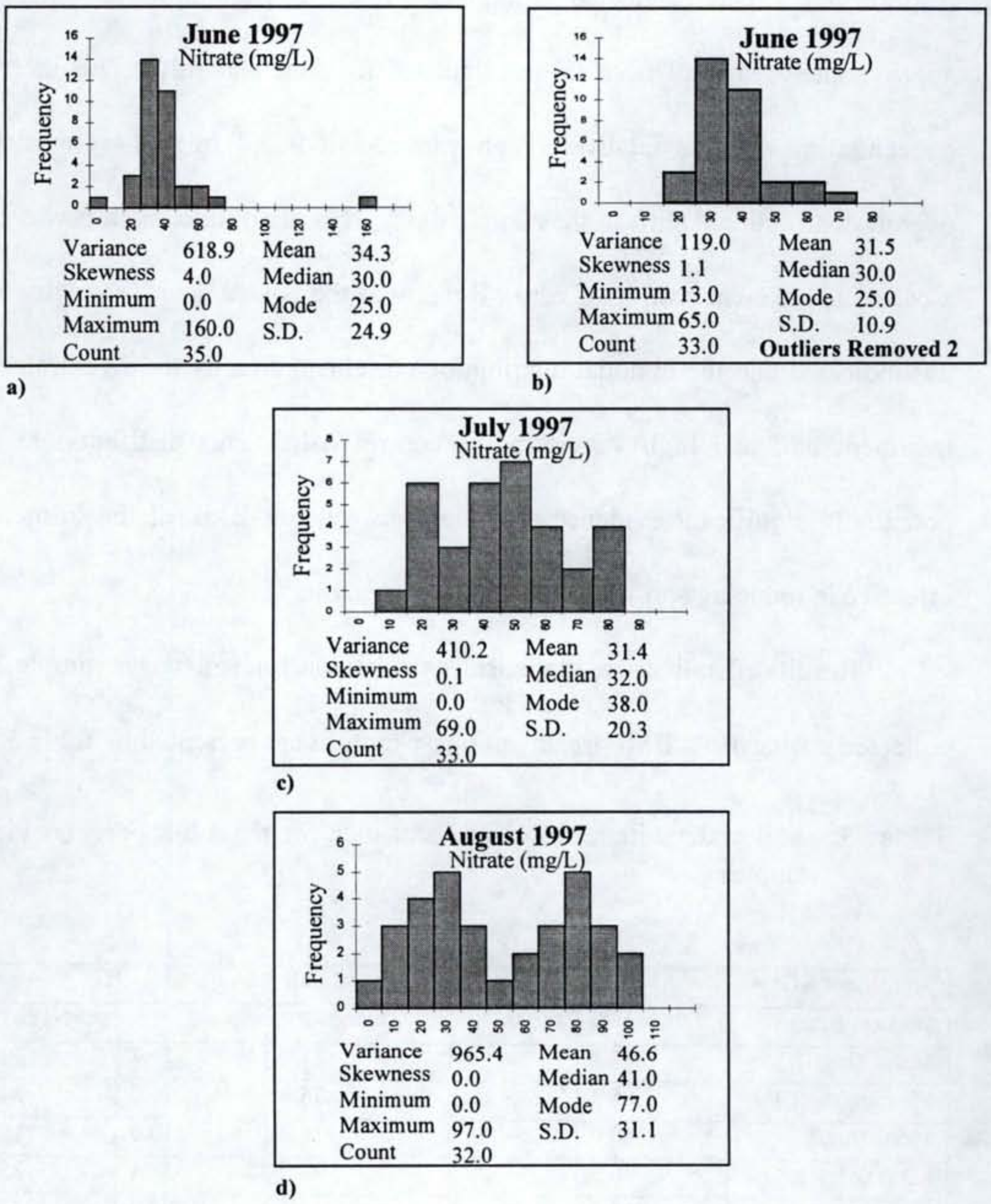


Figure 25. Histograms and univariate statistics of soil water nitrate concentrations for the Forgeon Field with or without outliers for a-b) June 1997, c) July 1997, and d) August 1997.

(Figure 25). The calculated mean soil water, concentration for August increased approximately 15 mg/l from those calculated for June and July. This increase in mean concentration and the relatively high variance of 965.4 (mg/L) were attributed to an overall distributional shift in the sample data. This distributional shift was evidenced by a calculated skewnessvalue of zero. Review of the posted data for August 1997 (Figure 24) indicated that the bimodal distribution correlated directly to low nitrate values in the treatment half and high values in the control half. This distributional shift offered potentially significant evidence that the crop rotation BMP at the Forgeon Field was effective in reducing soil water nitrate concentrations.

Results of univariate statistical calculations for soil water, nitrate sample, data collected during 1998 BMP treatment phase months are presented in Table 3.

Table 3. Soil water nitrate univariate statistics for the 1998 Forgeon Field lysimeter samples.

Soil Water NO^3	June 98		July 98		August 98	
Outliers Removed	None	0	None	2	None	0
Mean (mg/L)	67.1	--	81.0	79.7	70.7	--
Median (mg/L)	65.5	--	76.0	76.0	64.0	--
Mode (mg/L)	100.0	--	110.0	110.0	110.0	--
SD (mg/L)	30.3	--	37.7	28.4	35.9	--
Variance $(mg/L)^2$	918.7	--	1423.1	805.0	1287.9	--
Skewness	0.1	--	0.8	0.3	0.7	--
Minimum	0.0	--	0.0	35.0	0.0	--
Maximum	130.0	--	200.0	140.0	180.0	--
Count	32.0	--	32.0	30.0	29.0	--

A substantial increase in mean nitrate concentrations was visible for all months sampled in 1998 compared to mean nitrate concentrations calculated for 1997 months. Mean nitrate concentrations ranged from a minimum of 67.1 mg/L in June 1998 to a maximum of 81.0 mg/L in July 1998. Calculated variances in 1998 remained relatively high with a minimum value of 918.7 $(\mathrm{mg/L})^2$ in June and a maximum value of 1423.1 $(\mathrm{mg/L})^2$ in August. The high variability in the data sets was attributed to the overall distribution of soil water, nitrate concentrations and not the effects of outliers. However, histogram analysis of the sample data did not show the pronounced bimodal distribution seen in August 1997.

Bivariate Analysis

Bivariate analysis was performed to evaluate possible relationships that might exist between ground water nitrate concentrations and other sampled and measured attributes in the test field. The analysis was performed based on a geostatistical framework to help support spatial mapping of ground water, nitrate concentration, distributions. To a lesser extent, the analysis was performed to actually evaluate BMP effectiveness.

The goal for actual bivariate statistical evaluation of BMP effectiveness for a paired watershed, is to establish a relationship between control and treatment watersheds before and after BMP implementation (Graybow et al., 1999). The before and after results are compared to evaluate changes over the time period of interest. For this geostatistically oriented evaluation, bivariate analyses were completed on entire monthly data sets (control and treatment combined) for only BMP treatment phase months. This was done with the intention of creating spatial maps for any attribute that showed a statistically significant relationship to ground water, nitrate concentrations.

Bivariate analysis of data was conducted primarily through the use of linear regression. The validity of all linear regression models was evaluated based on (1) the coefficient of determination (R^2), (2) evaluation of model significance by a F test, and (3) visual inspection of outlier effects on linear regression scatter plots. A significance level of 0.1 for the F test was chosen prior to actual computation of linear regression models to prevent any bias during the evaluation process. Models that did not pass the 0.1 significance level for the F test were considered to be of limited use and were not evaluated further.

Linear regression was completed by comparing ground water, nitrate data and field parameter, data for each point sampler location during the same sampling period. Linear regression analysis also was completed between soil and ground water, nitrate concentrations because they were measured at the same geographic position during the same sampling period. In addition, linear regression analysis was used to evaluate observed relationships on time series plots completed for monthly precipitation-irrigation totals, fluctuating water table conditions, and average monthly nitrate concentration levels at the Forgeon Field.

Ground Water Nitrate vs. Field Parameter Data

A thorough and exhaustive linear regression evaluation of ground water nitrate vs. field parameter data was completed for all 1997 and 1998 monthly, point sample, data sets. Field parameter data used for this evaluation included total dissolved solids, specific conductance, and dissolved oxygen. No linear regression models were found to pass the 0.1 significance level criteria for the F test. Also, visual inspection of scatter plots indicated no obvious non-linear relationships existed.

Ground Water Nitrate vs. Soil Water Nitrate

A thorough and exhaustive linear regression evaluation of ground water, nitrate concentrations vs. soil water, nitrate concentrations was completed for all 1997 and 1998 monthly data sets. This evaluation included linear regression analysis of entire data sets as well as data sets with outliers removed. In addition, based on univariate analysis results of ground water and soil water, nitrate data, and bivariate analysis results obtained from evaluation of ground water nitrate vs. precipitation-irrigation totals (discussed in next section), one and two month time shifts between data sets were evaluated. For example, August 1997 ground water, nitrate data were compared to June, July and August 1997 soil water nitrate data. This evaluation was done on all applicable months sampled during 1997 and 1998.

For all data sets compared, only two linear models passed the 0.1 significance level criteria for the F test. Both models suggested a relationship existed between increasing, ground water, nitrate concentrations and decreasing, soil water, nitrate concentrations during the month of July 1997 (Figure 26). The first model was based on

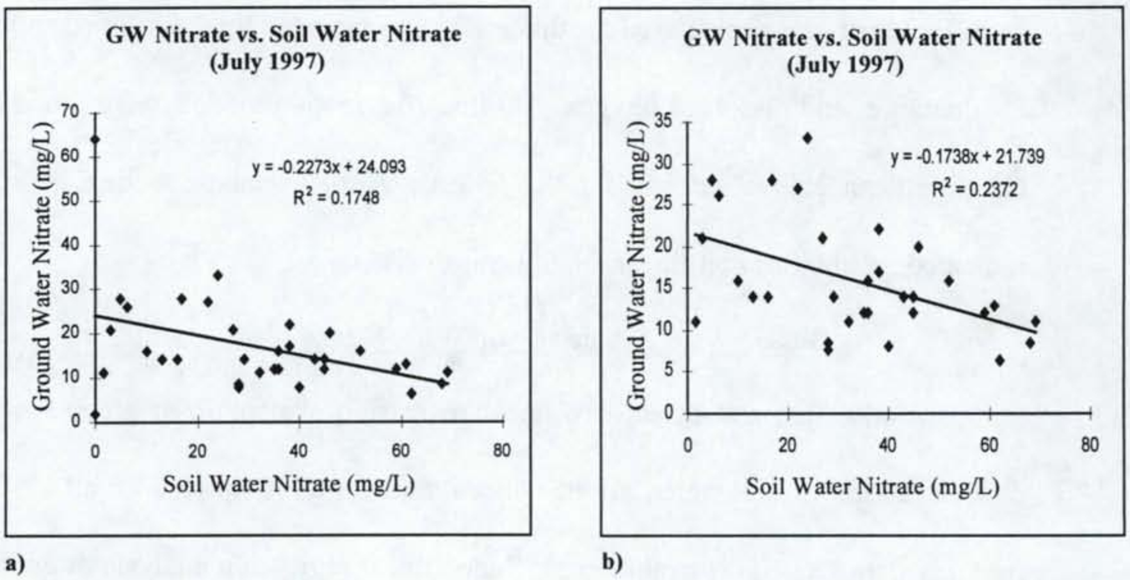


Figure 26. Linear regression and scatter plot of June 1997 ground water nitrate vs. June 1997 soil water nitrate for the Forgeon Field for a) all available data, and b) with two outliers removed.

all ground water, point sample and soil water, sample data collected in July 1997. Although the regression model passed the F test, the R^2 value was quite low (0.1748). Removal of two outliers improved the R^2 value to 0.2372. which by most standards would still be considered a low value. However, the models do hint at possible changes as result of BMP implementation. They also suggest that there is a greater than 90 percent probability that changes in soil water, nitrate concentrations explain 23.7 percent of the variability seen in ground water nitrate concentrations. The rest is explained by error.

Precipitation-Irrigation and Ground Water Nitrate

Installation of digital, recording, rain gauges at each interior monitoring well location prior to BMP implementation was completed to gain a quantifiable understanding of irrigation application rates and possible effects on ground water, nitrate concentrations. In addition, monthly precipitation totals measured at the Rupert, Idaho rain gauging station were used to aid in this investigation. Mean monthly, ground water, nitrate concentrations were calculated for the eight interior monitoring wells and average monthly irrigation amounts were calculated for the corresponding eight rain gauges, one gauge at each interior well location. Analyses of possible trends between ground water, nitrate concentrations and precipitation and/or irrigation were performed for the period of October 1996 through September 1997 to gain a better understanding of their relationship. Mean monthly, nitrate concentrations calculated for the interior monitoring wells ranged from 6.2 mg/l to 29.5 mg/l for the period of this investigation. Monthly precipitation totals and/or average monthly irrigation amounts ranged from 0.2 inches to 5.26 inches.

To evaluate the effects of precipitation-irrigation on the shallow aquifer in the Forgeon Field, precipitation-irrigation amounts, water table fluctuations, and mean, nitrate changes were compared (Figure 27). Time-series plots suggested that a relationship did exist between mean, ground water, nitrate concentrations and precipitation-irrigation with an apparent time lag of one to two months. Time-series analysis further indicated that a relationship existed between water table fluctuations and precipitation-irrigation amounts. Again, an apparent time lag was observable (approximately one month). A visual correlation between water table fluctuations and nitrate concentration changes also was visible with an approximate zero to one month time lag (Figure 27).

Several, specific, time related trends between irrigation and/or precipitation and average monthly, nitrate concentrations were observable over the period of this study. These trends suggested that a correlation existed between the flushing of the soils by precipitation and/or irrigation and measurable changes in ground water, nitrate concentrations. A visible, approximate time lag of one to two months was apparent. Peak, ground water, nitrate levels were measured in the months of January 1997 and August 1997 after heavy December 1996 precipitation and peak June 1997 irrigation, respectively. Furthermore, a gradual increase in precipitation after a relatively dry February 1997, correlated visually to a gradual increasing trend in ground water, nitrate concentrations after April 1997 (Figure 27). A declining trend in precipitation from

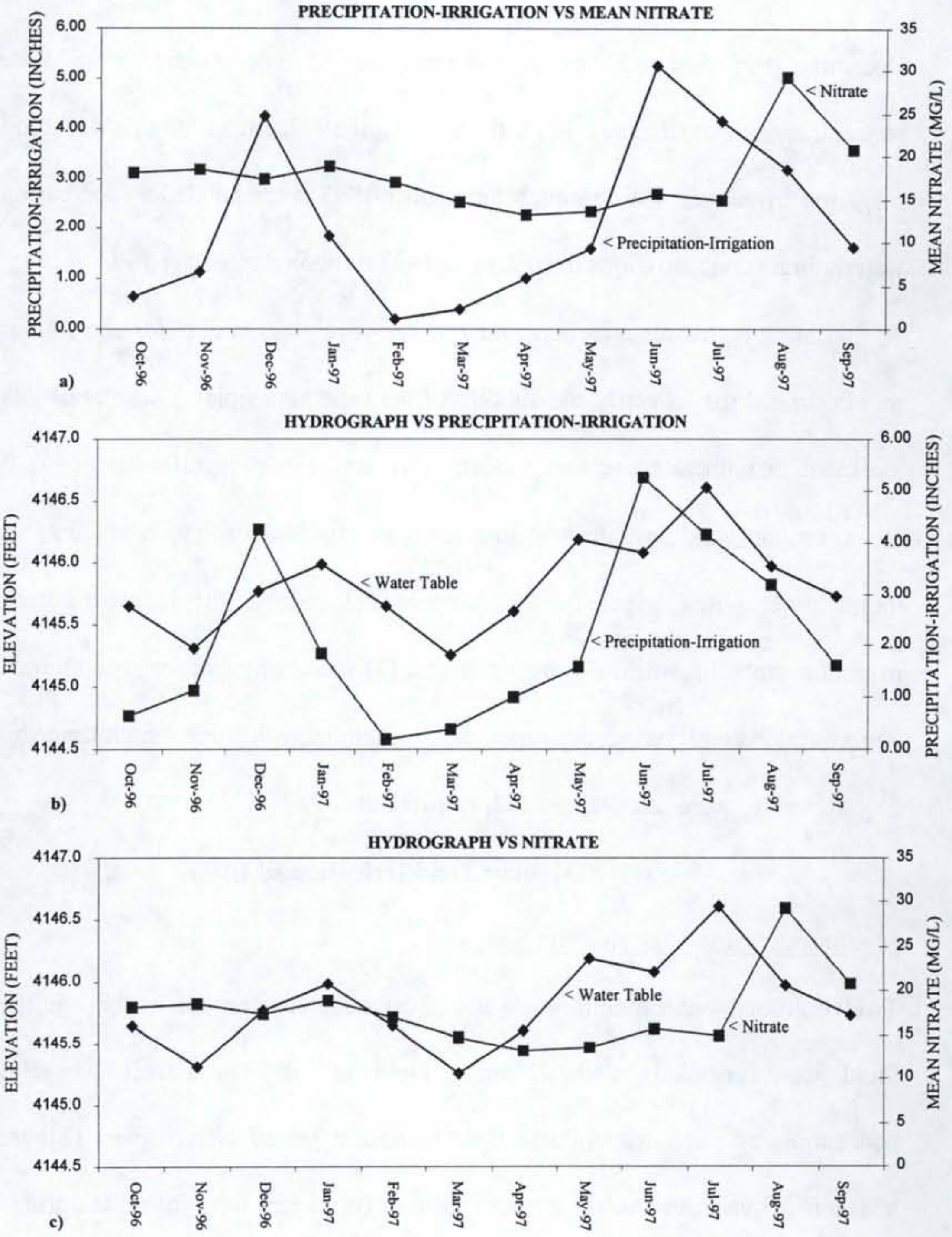


Figure 27. Time series plots for the period October 1996 to September 1997 at the Forgeon Field for a) precipitation-irrigation amounts vs. ground water nitrate concentration, b) mean water table elevation vs. precipitation-irrigation amounts, and c) water table elevation vs. mean ground water nitrate concentrations.

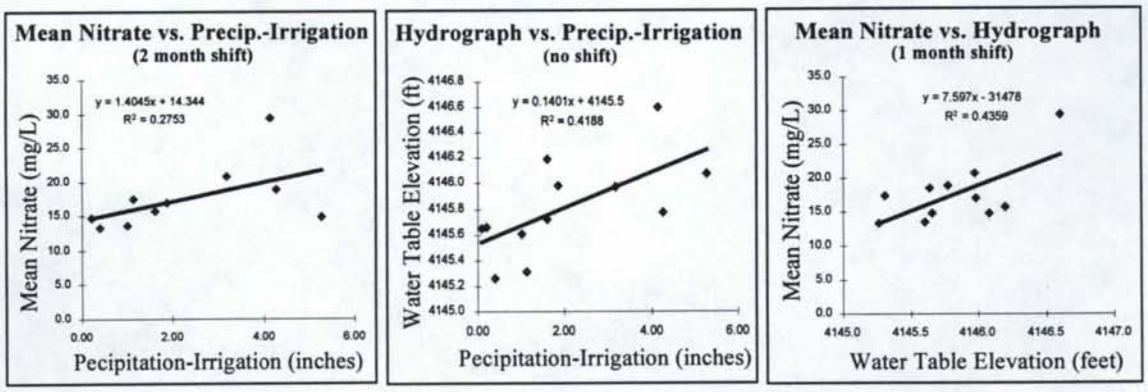
December 1996 through February 1997 corresponded to decreasing, ground water, nitrate concentrations from January 1997, through April 1997. In addition, a declining trend in irrigation from June 1997 through September 1997 corresponded to decreasing, ground water, nitrate concentrations from August 1997 through September 1997.

Linear regression was performed on the precipitation data for zero, one, and two-month time shifts to verify the validity of the time series plots. Results of this analysis indicated that linear regression models were statistically significant for (1) increasing mean, ground water, nitrate with increasing precipitation-irrigation amounts with a two month time shift, (2) increasing, water table, elevations with increasing precipitation-irrigation amounts with no time shift, and (3) increasing, mean, ground water, nitrate concentrations with increasing water table elevations with a one month time shift (Figure 28). R^2 values were .28, .42, and .44, respectively.

Moncur Field Irrigation BMP

Monitoring Network Design and Sampling

Twelve ground water monitoring wells of the same construction as those in the Forgeon Field were installed in the Moncur Field in 1992 to establish baseline nitrate concentrations and later evaluate BMP treatment period effectiveness (Figure 29). In addition, 15 vacuum and 10 pressure/vacuum lysimeters were installed during the 1995, 1996, and 1997 growing season months, using the same installation techniques as those used for the Forgeon Field to gain a better understanding of soil water nitrate concentration distributions (Appendix A). Location of the lysimeters was based on a geostatistical design using the same criteria as the monitoring network design for the



a) b) c)

Figure 28. Linear regression and scatter plot for the period October 1996 to September 1997 for a) mean ground water nitrate vs. precipitation-irrigation with a 2-month time shift, b) hydrograph versus precipitation-irrigation with no time shift, and (c) mean ground water nitrate vs. hydrograph with a 1-month time shift.

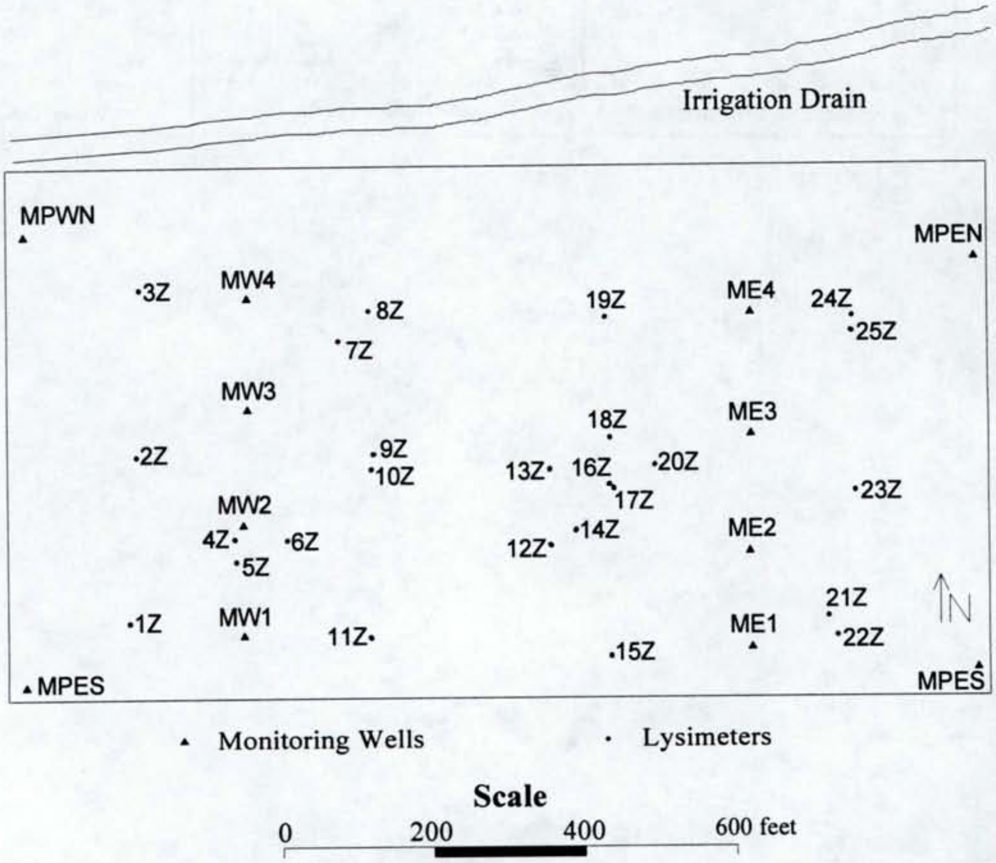


Figure 29. Monitoring network for the Moncur Field.

Forgeon Field. The predominantly clay rich soils and subsoils, and deep tillage practices by the farmer, precluded installation of ground water point samplers at the Moncur Field. Storage, shipment and laboratory analysis of ground water nitrate samples and soil water nitrate samples were completed with the same protocol as the samples collected for the Forgeon Field. Nitrate concentrations with a laboratory detection limit of 0.1 mg/L were determined for each monitoring well and lysimeter location for the period of this evaluation.

Exploratory Data Analysis

The original plan for implementation of the irrigation BMP was to initiate a 12-hour sprinkler rotation in the treatment half of the Moncur Field and maintain a traditional 24-hour sprinkler rotation in the control half of the field. Implementation of this rotation was to have begun at the start of the 1996 growing season. However, due to a miscommunication between the farmer and the person actually rotating the lines, the BMP was not implemented until the end of the irrigation season (for grain) in July 1996. Therefore, effectively the irrigation BMP was not implemented until May 1997. The primary focus of univariate and bivariate analyses of ground water and soil water, nitrate data was the sampled months of 1997 under a crop of potatoes. Granular fertilizer was spread uniformly over the entire field prior to the 1997 growing season

Univariate Analysis

Postplots of nitrate sample data were developed for all monitoring wells and soil water samplers using Surfer™. Interpolation of data (i.e. kriging) was not used in order to prevent biasing during initial evaluation because of the limited sizes of the data sets. Attempts were made using a moving window technique (Miller, 1996c) to model variograms for both ground water nitrate and soil water nitrate. However, variogram modeling showed no conclusive spatial structure for the sample data sets. Therefore, the decision was made not to use kriging during exploratory data analysis, and trend surface analysis was selected as the final spatial mapping technique to evaluate irrigation BMP effectiveness. Although 25 lysimeters were located on a geostatistical design, the nature of the clay rich soils and subsoils caused difficulty in extraction of samples at many lysimeter localities during dry periods between irrigations. Typical soil water nitrate sample data sets over the period of evaluation numbered less than 20.

Ground Water Nitrate

Univariate analysis of ground water nitrate concentration data for the monitoring wells was completed for all sampled months of 1996, 1997 and 1998 (i.e., up to and after implementation of the irrigation BMP treatment phase period in May 1997). However, initial trend surface analysis indicated that no statistically significant trend surface models were valid from 1996 through April 1997. Thus, univariate analysis of ground water nitrate data was focused on samples collected after April 1997.

Postplots for all months analyzed are presented in Figure 30. Review of these plots indicated that prior to implementation of the irrigation BMP treatment phase (May 1997) the highest nitrate concentrations (maximum value of 20 mg/L) were measured in the northeast portion of the treatment half of the demonstration field (Figure 30). The presence of these high concentrations in the northeast portion of the treatment half of the

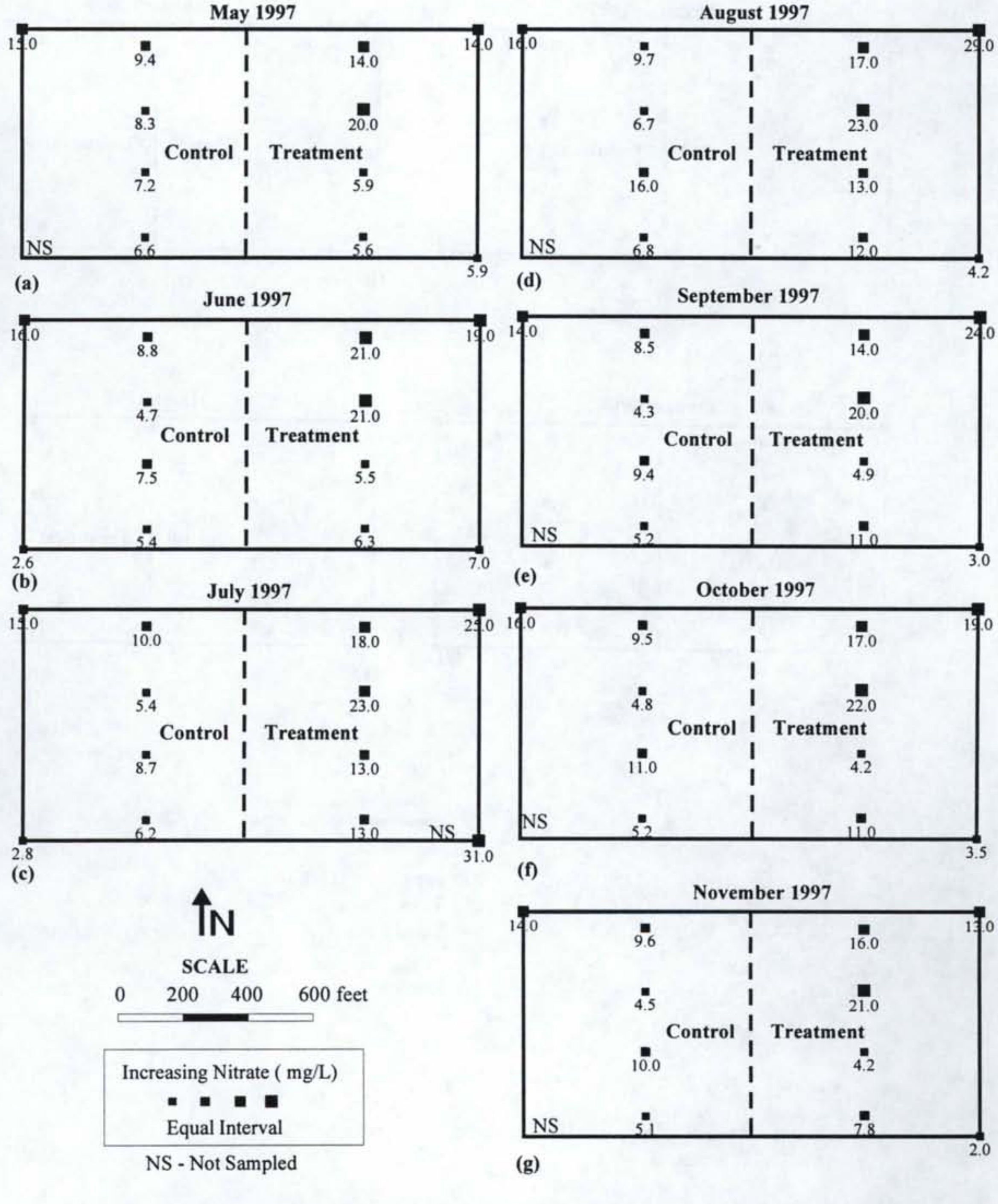


Figure 30. Postplots of ground water nitrate concentrations for the Moncur Field for a) May 1997, b) June 1997, c) July 1997, d) August 1997, e) September 1997, f) October 1997, g) November 1997, (continued on next page).

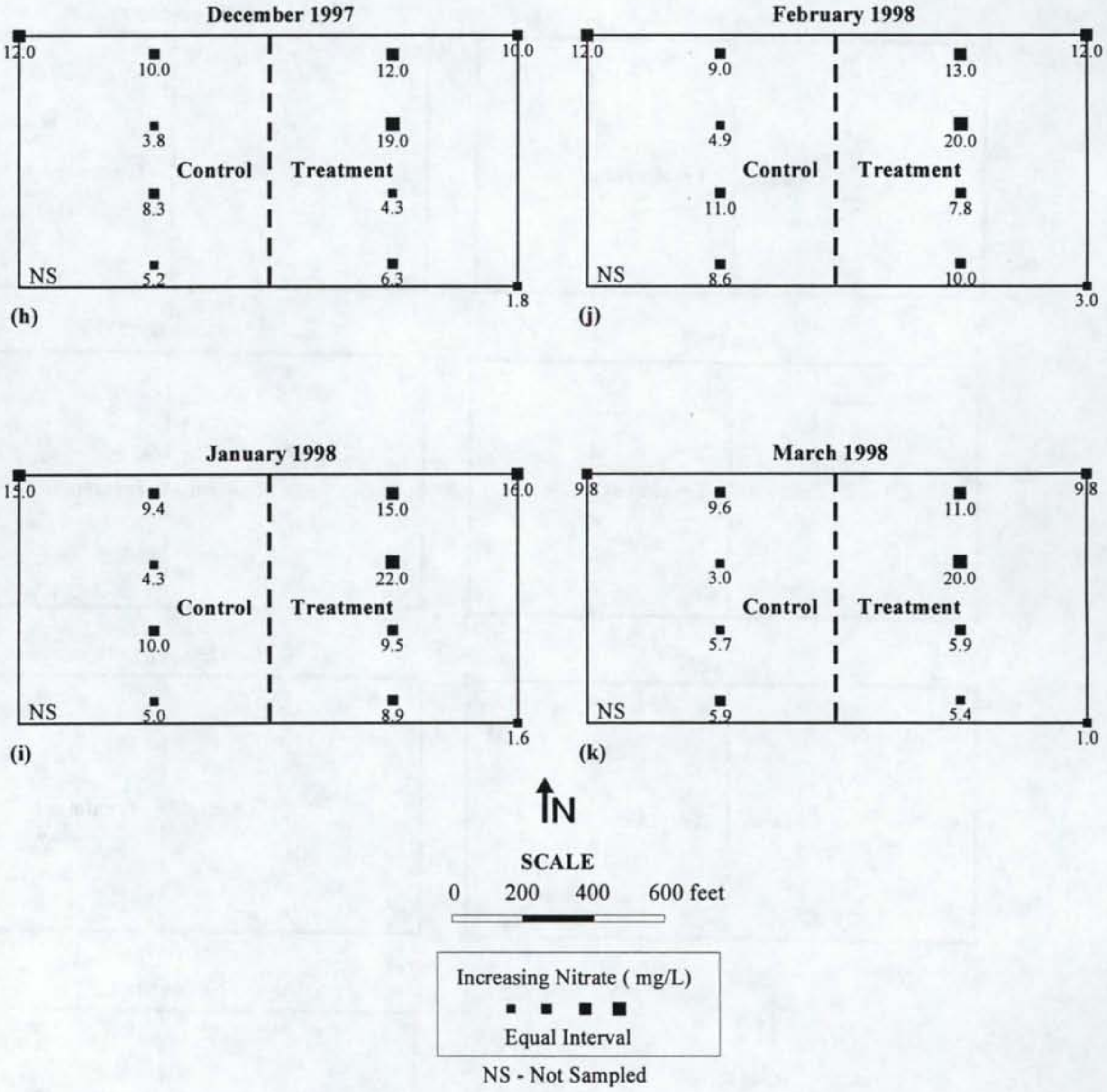


Figure 30. Postplots of ground water nitrate concentrations for the Moncur Field for, h) December 1997, i) January 1998, j) February 1998, and k) March 1998 (continued from previous page).

field was visible for all months analyzed in 1997. Lowest concentrations were measured in the southern portion of the entire field for May 1997 (minimum of 5.6 mg/L). This general trend persisted into June 1997 (Figure 30).

Ground water nitrate levels in July 1997 suggested an overall shift to higher concentrations in the treatment half of the demonstration field to lower concentrations in the control half of the field with the exception of a relatively high sampled value of 15 mg/l at perimeter location MPWN in the northeast corner of the control half of the field (Figure 30). A maximum value of 31 mg/L was recorded at southwest perimeter location MPES in the treatment half of the field for July 1997. A general east to west, high to low trend in ground water nitrate concentrations persisted through March 1998.

Univariate statistical analysis was performed to evaluate and better understand the trends and discontinuities seen during inspection of the postplots for 1997 ground water monitoring well nitrate data sets. Results of univariate statistical analyses for 1997 BMP treatment phase months are presented in Table 4.

Table 4. Univariate statistics for ground water nitrate concentrations in the Moncur Field for the period May 1997 through March 1998.

GW NO3	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar
Mean (mg/L)	10.2	10.4	14.3	13.9	10.8	11.2	9.7	10.1	10.6	10.1	7.9
Median (mg/L)	8.3	7.3	13.0	13.0	9.4	11.0	9.6	10.0	9.5	10.0	5.9
Mode (mg/L)	5.9	21.0	13.0	16.0	14.0	11.0	#N/A	12.0	15.0	12.0	5.9
SD (mg/L)	4.8	6.8	8.6	7.4	6.8	6.5	5.8	4.5	6.0	4.5	5.1
Variance	23.2	46.5	74.0	54.8	45.6	42.2	33.8	20.1	35.6	20.1	25.7
Skewness	0.9	0.7	0.6	0.7	0.8	0.3	0.6	0.7	0.4	0.7	1.2
Minimum	5.6	2.6	2.8	4.2	3.0	3.5	2.0	3.0	1.6	3.0	1.0
Maximum	20.0	21.0	31.0	29.0	24.0	22.0	21.0	20.0	22.0	20.0	20.0
Count	11.0	12.0	12.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0

Comparison of basic statistics for May and June 1997 indicated very similar distributions of ground water nitrate concentrations. Mean nitrate values for the two months were 10.2 mg/L and 10.4 mg/L, respectively. Skewness values for all months analyzed, suggested the ground water nitrate concentrations were normally distributed. Calculated variances for the June and July 1997 data sets were somewhat different with values of 23.2 $(mg/L)^2$ and 46.5 $(mg/L)^2$, respectively.

Inspection of univariate statistics for July and August 1997 ground water nitrate concentrations indicated that some changes occurred compared to those for May and June 1997. Mean ground water nitrate concentrations calculated for July and August were 14.3 mg/L and 13.9 mg/L, respectively. A noticeable increase in variability also was apparent for July ($74.0(mg/L)^2$) compared to June ($46.5\ (mg/L)^2$). A declining trend in variability was apparent thereafter (August 1997 to March 1998). Mean ground water nitrate concentrations decreased after August and leveled off between approximately 9 mg/L and 11 mg/L.

Soil Water Nitrate

Univariate analysis of soil water nitrate concentration data was performed for all sampled months over the effective BMP treatment phase period. This included the BMP treatment phase months of June, July, and August 1997. Lysimeters were not sampled after August 1997 to allow the farmer access to the field for harvesting.

Postplots of soil water sample, data sets for all sampled BMP treatment phase months are presented in Figure 31. Review of these plots indicated that at the start of the

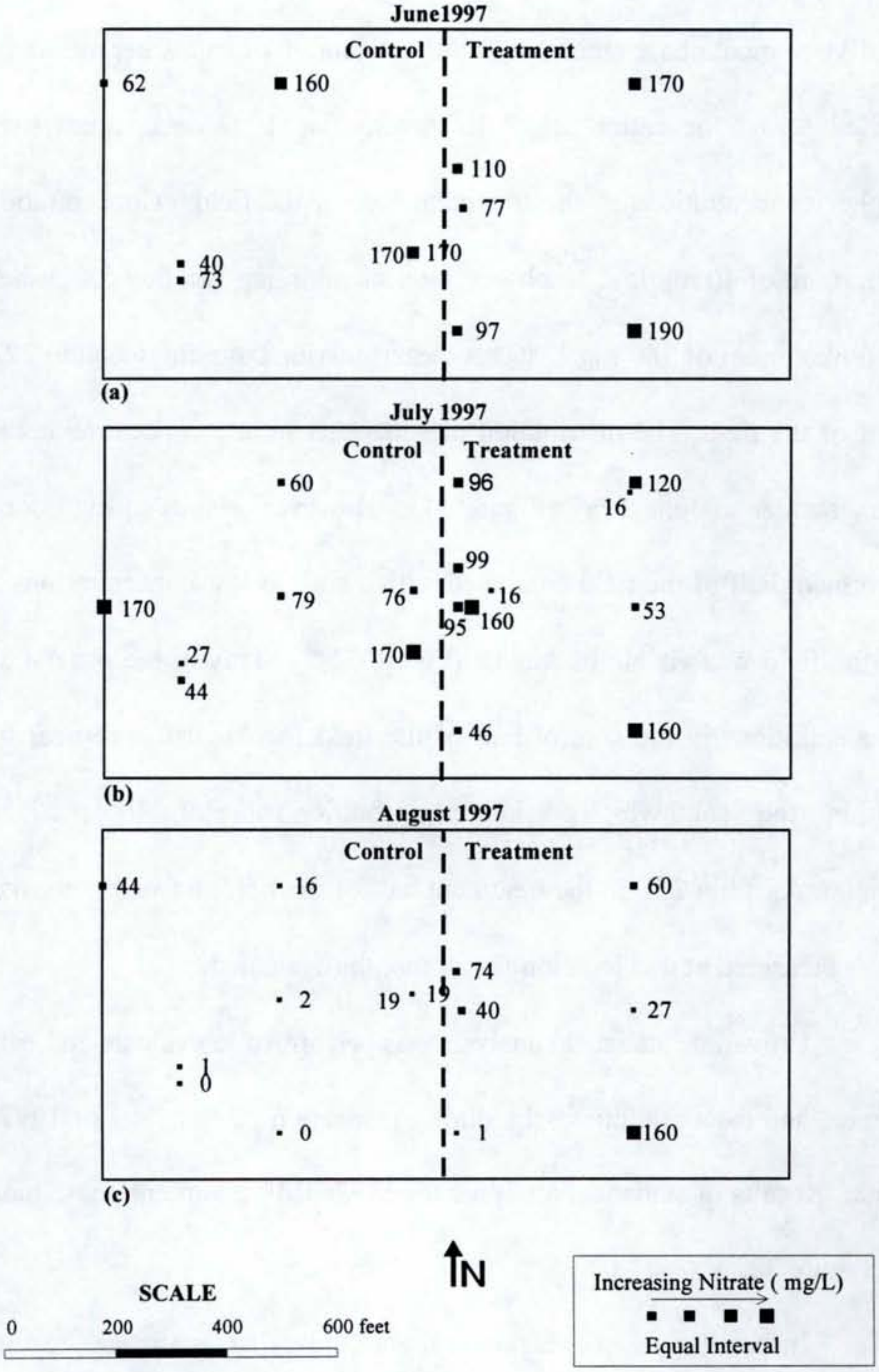


Figure 31. Postplots of soil water nitrate concentrations for the Moncur Field for a) June 1997, b) July 1997 and c) August 1997.

BMP treatment phase (June 1997) the distribution of soil water nitrate concentrations was varied across the entire field. However, June 1997 data values suggested somewhat higher concentrations in the treatment half of the field. Concentrations ranged from a minimum of 40 mg/L at southwest interior sampling location 5Z in the control half field to a maximum of 160 mg/L at southeast interior sampling location 22Z in the treatment half of the field. The distribution of soil water nitrate concentrations for July 1997 was very similar to June 1997 (Figure 31). However, a shift to high concentrations in the treatment half of the field combined with a shift to low concentrations in the control half of the field was visible in August (Figure 31). Many of the observed soil water nitrate concentrations in the control half of the field for August were near 0 mg/L, especially within the southwest portion. An outlier value of 160 mg/L was measured at southernlocation 22Z in the treatment half of the field; however, consistently high values were measured at that location for all months evaluated.

Univariate statistical analysis was performed to evaluate and better understand the trends, and discontinuities seen during inspection of postplots of 1997 soil water nitrate data. Results of statistical analyses for 1997 BMP treatment phase months are presented in Figure 32.

Inspection of the histogram and univariate statistical results for June 1997 indicated a wide spread in concentrations and a relatively high variance (2589.8 $(mg/L)^2$) (Figure 32). The calculated mean for June soil water nitrate (116.3 mg/L) was also relatively high compared to July and August mean soil water nitrate values. Comparison

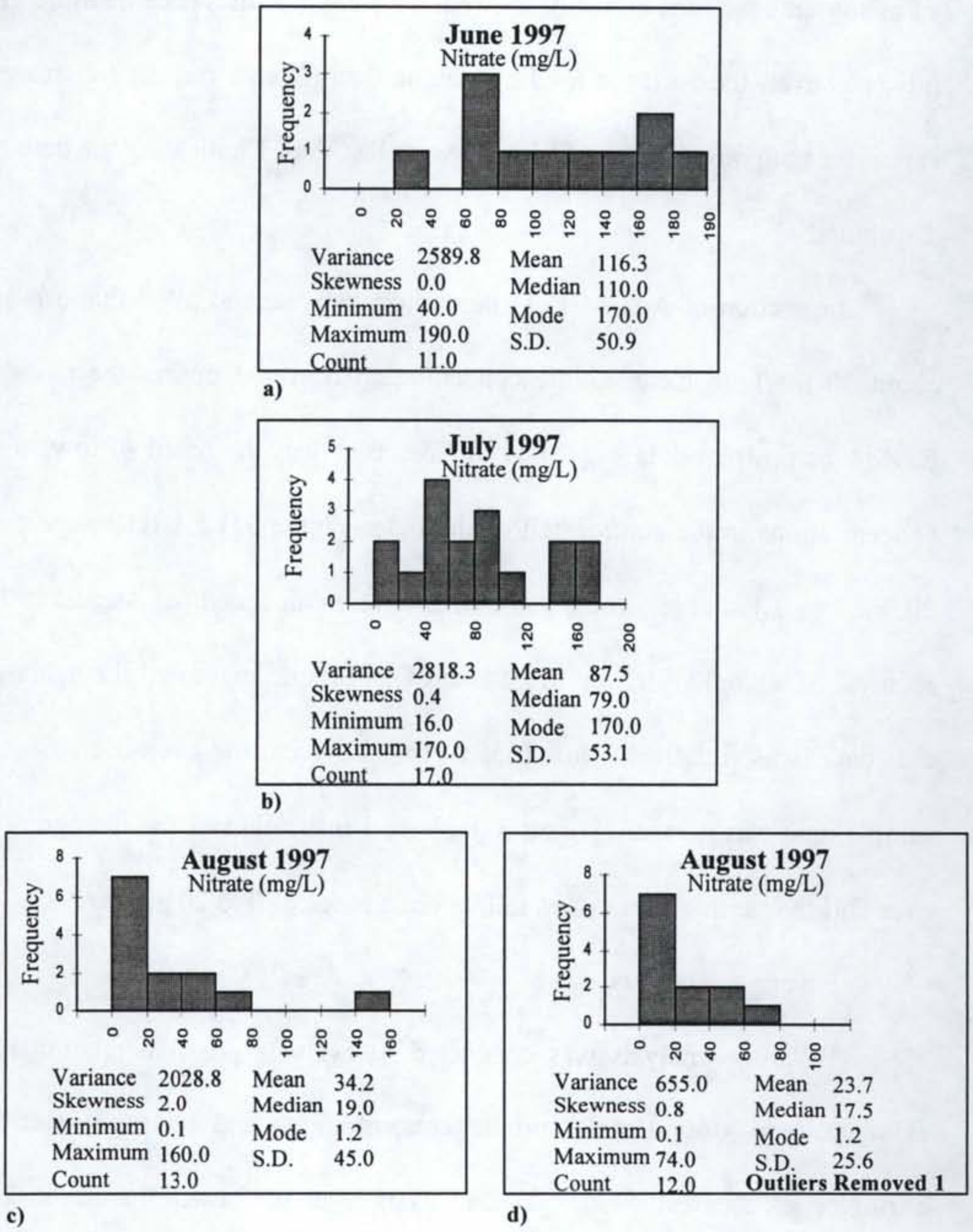


Figure 32. Histograms and univariate statistics of soil water nitrate concentrations for the Moncur Field with or without outliers for a) June 1997, b) July 1997, and c-d) August 1997.

of histograms for June and July showed that sample values became more grouped during July; however, the variance for July sample data (2818.3 $(\mathrm{mg/L})^2$) increased. Skewness values for both months (June and July) were less than 1 indicating the data were normally distributed.

Inspection of August 1997 univariate statistics indicated that a large decrease of about 50 mg/L in mean nitrate concentration occurred during the month (Figure 32). Review of postplot data suggested this decrease was the result of low soil water nitrate concentrations in the control half of the field (Figure 31). A relatively high variance of 2028.2 $(\mathrm{mg/L})^2$ and skewness value of 2.0 were calculated for August 1997. However, removal of a single, high outlier, value of 160 mg/L suggested the actual variability in the data was relatively low (655.0 $(\mathrm{mg/L})^2$) and the overall distribution of August sample data was normal (Figure 32). Visual inspection of the histogram indicated that over half the sample data values fell within a range of 0 to 20 mg/L.

Bivariate Analysis

Bivariate analysis was conducted to evaluate possible relationships that might exist between ground water nitrate concentrations and other sampled and measured attributes at the test field. The analysis was performed based on a geostatistical framework with the intent to support spatial mapping of ground water, nitrate concentration, distributions. Linear regression at a statistical significance level of 0.1 was used for the evaluation.

Linear regression was completed by comparing ground water nitrate data and field parameter data collected during the same sampling period for each monitoring well location. Linear regression analysis was not performed between soil water nitrate concentrations and monitoring well nitrate concentrations because the lysimeters were not located at the same geographic coordinates as the monitoring wells. Linear regression analysis and time series plots were used to evaluate monthly precipitation-irrigation totals, average monthly nitrate concentrations, and average water table elevations for the Moncur Field.

Ground Water Nitrate vs. Field Parameter Data

A thorough and exhaustive linear regression analysis of ground water nitrate vs. field parameter data was completed for all 1997 monthly monitoring well data sets. Field parameter data used in this evaluation included total dissolved solids, specific conductance, and dissolved oxygen. No linear regression models were found to pass the 0.1 significance level criteria for the F test. Also, visual inspection of scatter plots indicated no obvious non-linear relationships existed between the data sets.

Precipitation-Irrigation and Ground Water Nitrate

Precipitation-irrigation amounts, water table fluctuations, and mean nitrate changes were compared for the period from October 1996 to September 1997 to evaluate the effects of precipitation-irrigation on the shallow aquifer. However, linear regression analysis indicated that no statistically significant relationship existed between the available data that were analyzed.

SPATIAL MAPPING RESULTS AND BMP EFFECTIVENESS

Forgeon Field Crop Rotation BMP - Sequential Gaussian Simulation

Sequential Gaussian simulations (SGSs) were used to evaluate all treatment phase months in which ground water point samplers and lysimeters were sampled at the Forgeon Field. The variogram modeling methods, number of simulations, grid setup, and computer applications and methods were identical for each month that SGSs were used to evaluate ground water and soil water nitrate distributions.

SGS requires the normal-score transform of data values to ensure that sample data have a univariate normal distribution. These normal score transformed values are used to model variograms whose parameters aid in computing normal score estimates during the simulation process. Normal-score transformed values for these analyses were computed using the computer program NSCORE from the software library GSLIB (Deutsch and Journel, 1992). Variogram modeling of normal-score values was completed using the computer programs PREVAR and VARIO in the computer software package GEOEAS (Englund and Sparks, 1991). Insufficient data pairs were available to model anisotropic variograms; thirty pairs per sample variogram value are needed as an acceptable minimum. Therefore, isotropic, omni-directional variograms were modeled and subsequently fit as a combination of nugget and spherical structures. These models were checked subsequently for bivariate normality using the computer program BIGAUS in GSLIB.

Parameters determined from variogram models for each month evaluated were used with the GSLIB program SGSIM to begin each sequential Gaussian simulation. One hundred simulation passes were completed across the dimensional area of the Forgeon Field for each month evaluated. The dimensional area was divided into 40 feet x 40 feet grid units to create 221 grid node estimate locations. The SGS approach was used to produce 100 normal-score nitrate concentration estimates per grid node for each evaluated month. Normal score estimates were back transformed to actual nitrate concentration estimates using the computer program BACKTR in GSLIB. The 100 estimates for each grid node were averaged to create a mean nitrate concentration estimate for each of the 221 grid node locations and to subsequently construct shaded cell estimate maps of nitrate concentration distributions for the months evaluated.

Point sampler and lysimeter location 9I (located in the southwest corner of the Forgeon Field) was used as the starting point for the simulation grid. Location 9I also served as a control point to verify that no errors where made during the labor intensive data setup and data post processing procedures as well as the somewhat complicated SGS routine. SGS honors hard data that are located on a simulation grid node. Therefore, sample data taken at 9I were always reproduced. All other grid node locations corresponded to locations that were unsampled as a result of the irregular grid spacing of the point samplers and lysimeters.

A probabilistic assessment of 1997 SGS results also was completed to (1) help validate SGS results, (2) to graphically and numerically provide a measure of the uncertainty in the ground water nitrate and soil water concentration distributions, and (3) to provide a measure of the uncertainty in the BMP effectiveness. Typically, for a probabilistic assessment of a group of stochastic simulations, a threshold is selected and the probability of exceeding that particular threshold is computed by counting the number of simulations with estimates greater than the cutoff. The first year of BMP implementation (1997) was selected for the evaluation during this probabilistic assessment, because the simulated results suggested that dramatic changes occurred in response to the implementation of the grain-bean BMP crop rotation. A probabilistic assessment was completed for each monthly set (June 1997 to August 1997) of 100 SGS estimates of the ground water and soil water nitrate concentrations. The mean sample nitrate concentration calculated for each point sampler data set was selected as the exceedence threshold for the point sampler data. The mean sample nitrate concentration calculated for each lysimeter data set was selected as the exceedence threshold for the lysimeter data. The mean was selected as the exceedence threshold because it represented the centroid of each data set distribution and provided a reasonable criterion for a probabilistic assessment of suspected high and low valued areas of ground water nitrate concentrations.

A difference technique was used to examine month-to-month changes in ground water and soil water nitrate concentrations across the site (Carlson and Osiensky, 1998). This technique involved taking estimates created from the averaged sequential Gaussian simulations for one month and subtracting them from the averaged sequential Gaussian simulations for the following month to evaluate estimated net changes over that one month period. The net changes computed for each grid node were used to create spatial net difference maps (SNDMs) between all months evaluated for both ground water nitrate and soil water nitrate estimations.

Ground Water Nitrate

1997 Results

Variogram models computed from normal-score transformed ground water nitrate values for the months of June, July, and August 1997 after initiation of the crop rotation BMP treatment phase are presented in Figure 33. These variogram models indicated relatively good spatial correlation and a plausible range of influence for ground water nitrate. Range of influence values for June, July, and August were computed to be 280 ft, 225 ft, and 390 ft, respectively. Nugget values for June (0 $(mg/L)^2$) and July (0.05 $(mg/L)^2$) were low which indicated that nitrate concentrations were well correlated spatially, even at very short separation distances. The nugget effect modeled for August was moderately high (0.35 $(mg/L)^2$). This was possibly due to outlier, ground water nitrate concentrations of 71 mg/L, 77 mg/L, and 120 mg/ in the southwest portion of the field (point samplers 11K, 10J, and 8H, respectively). Overall, estimated variogram models fit well with sample variogram values and justified the use of geostatistical estimation analysis.

Shaded cell estimate maps based on mean SGS results for the months evaluated for 1997 are presented in Figure 34. The shaded cell estimate map for June 1997 suggested that mean simulated nitrate concentrations ranged from 7 mg/L to 28 mg/L in a localized distribution pattern in the shallow aquifer. High nitrate concentrations appeared

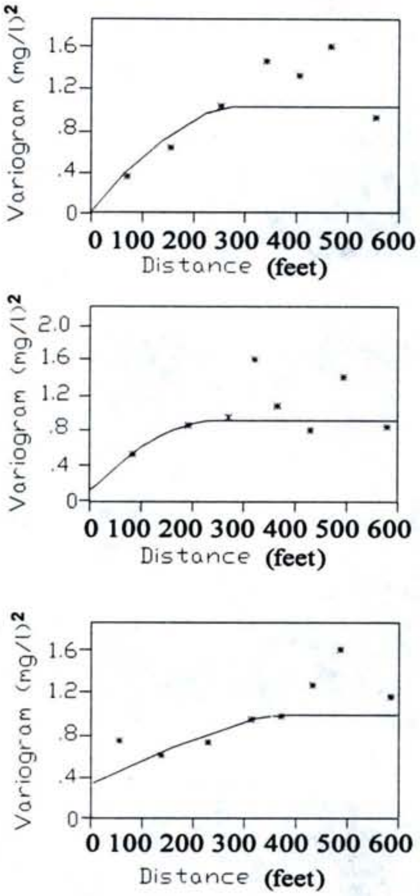


Figure 33. Variograms of normal-score, ground water nitrate values for the Forgeon Field for the BMP treatment phase months of a) June 1997, b) July 1997, and c) August 1997

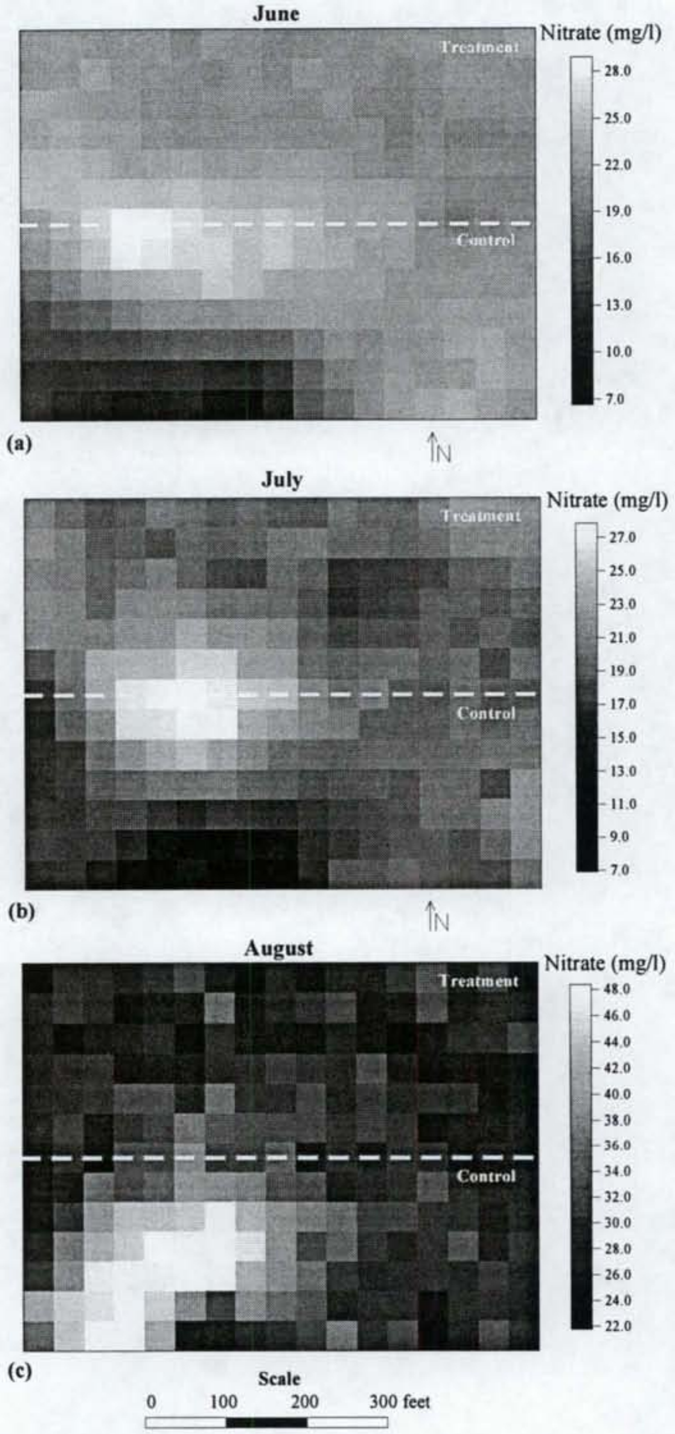


Figure 34. SGS shaded cell maps of ground water nitrate concentration distributions in the Forgeon Field for a) June 1997. b) July 1997, and c) August 1997.

in west-central locations within the sandy subsoils area of the field. Low concentrations appeared along the southwestern boundary of the demonstration field within the clay rich subsoils. The shaded cell estimate map for July 1997 showed similar mean nitrate concentrations (7 mg/L to 27 mg/L) and a similar overall distribution (Figure 34). However, dramatic changes in the concentrations appeared on the shaded cell estimate map for August 1997 when simulated mean nitrate concentrations ranged from 22 mg/L to 48 mg/L. The highest concentrations appeared primarily within the sandy subsoils of the shallow aquifer within the western portion of the control half of the Forgeon Field.

SNDMs of nitrate concentrations for the Forgeon Field for the periods of June-July 1997 and July-August 1997 are presented in Figure 35. Figure 35 showed that no discernible visual patterns developed over the June-July period. Net changes in mean simulated nitrate concentrations ranged from a decrease of 6.0 mg/L (positive values) to an increase of 5.0 mg/L (negative values). However, Figure 35 showed notable changes in mean simulated nitrate concentrations across the site for the July-August period. Figure 35 suggested that nitrate concentrations increased between 2.0 mg/L and 34 mg/L across the entire site during the July-August period. The most dramatic changes were visible on the west half of the field within the sandy subsoils of the shallow aquifer. The greatest nitrate concentration increases were visible in southwestern areas within the control half of the field. The smallest increases appeared in northwestern portions of the field within and along the boundary separating the two halves of the field (Figure 35).

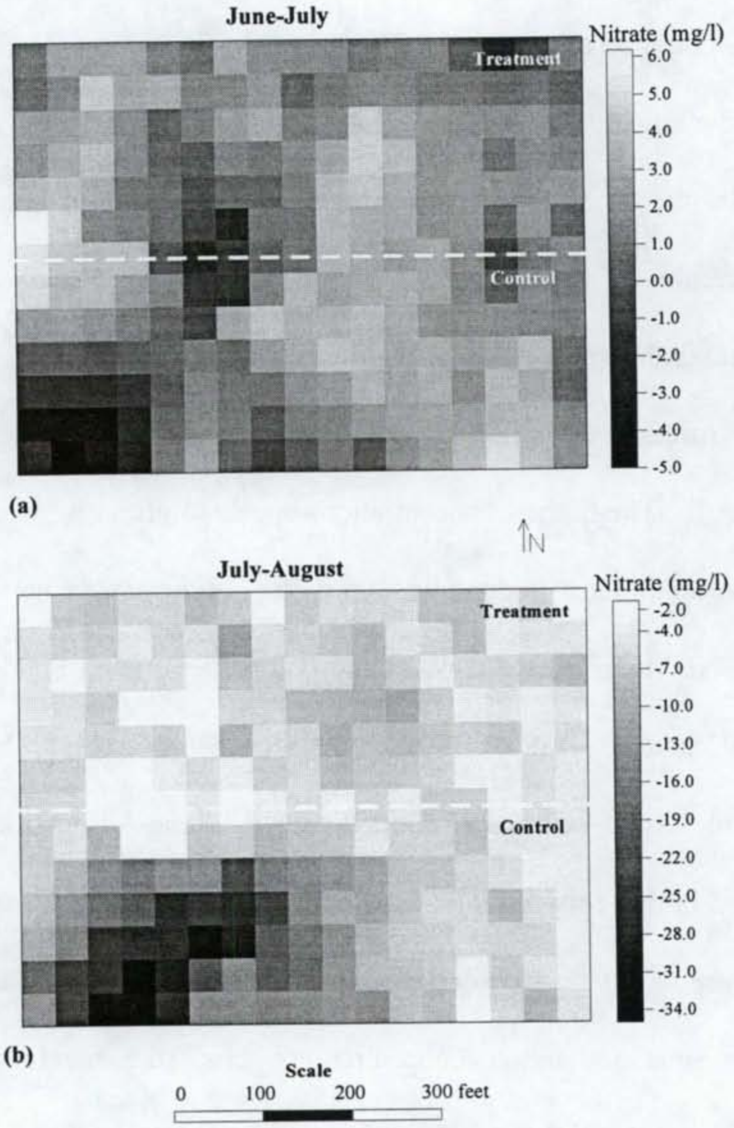


Figure 35. Spatial net difference maps (SNDMs) of ground water nitrate concentrations for the Forgeon Field for a) June-July 1997, and b) July-August 1997.

Actual ground water sample data and simulation results indicated relatively low ground water nitrate concentrations existed in June and July 1997 compared to August 1997. June and July simulation results suggested the highest ground water nitrate concentrations were present within the treatment half of the field. Simulation of August, ground water, point sampler data suggested ground water nitrate concentrations increased across the entire site. Comparison of precipitation-irrigation data and the ground water nitrate concentrations suggested this was a function of high irrigation amounts in June. However, Figure 35 indicated only slight increases in ground water nitrate concentrations during the July-August period within the treatment half of the field, especially within the sandy subsoils, where the greatest increases might be expected. These results and relatively large increases in August ground water nitrate concentrations within the sandy soils of the control half of the field indicated that the BMP may have had a positive influence on the ground water quality in the shallow aquifer.

Probabilistic Assessment of 1997 Results

The mean ground water nitrate concentration calculated for each point sampler data set was selected as the exceedence threshold for a probabilistic assessment of ground water nitrate levels. Actual ground water nitrate sample data and simulation results indicated that relatively low ground water nitrate concentrations existed in June and July, 1997 with mean concentrations of 18.9 mg/L and 16.8 mg/L, respectively. August 1997 ground water nitrate concentrations were comparatively higher with a mean of 26.4 mg/L. Using these 3 mean levels as threshold criteria, probabilities of exceeding the corresponding sample mean were determined for each grid node for each month evaluated. Probability shaded cell maps were constructed to graphically and numerically evaluate the uncertainty of nitrate concentration distributions (Figure 36).

Visual evaluation of these maps indicated that high exceedence probabilities (generally from about 60 to greater than 80 percent) appeared in west-central locations within the sandy subsoils of the shallow aquifer in June and July 1997 (Figure 36). Low probabilities (generally less than 20 percent) of exceeding the mean nitrate concentration appeared along the southwestern boundary of the field within and near the clay rich subsoils that form the southern boundary of the field. The remainder of the field for June and July showed probabilities distributed about the 50 percent probability level. A shift to high probabilities (generally 70 percent to 90 percent or greater) for exceeding the mean sample nitrate concentration appeared in the southwest portion of the field with comparatively lower probabilities in all other areas of the field for August 1997. These results appeared to verify simulation results. Areas with high probabilities for exceeding mean nitrate concentrations showed a visual correlation to simulated areas of high ground water nitrate concentrations. Results suggested that the simulated nitrate distributions were verifiable and suggested that positive BMP effects from the grain-bean rotation were highly probable.

1998 Results

Variogram models were completed from normal-score transformed nitrate values for the 1998 treatment period months of June, July, August, September, and October. Variogram model parameters for the 1998 treatment period months are presented in Table 5.

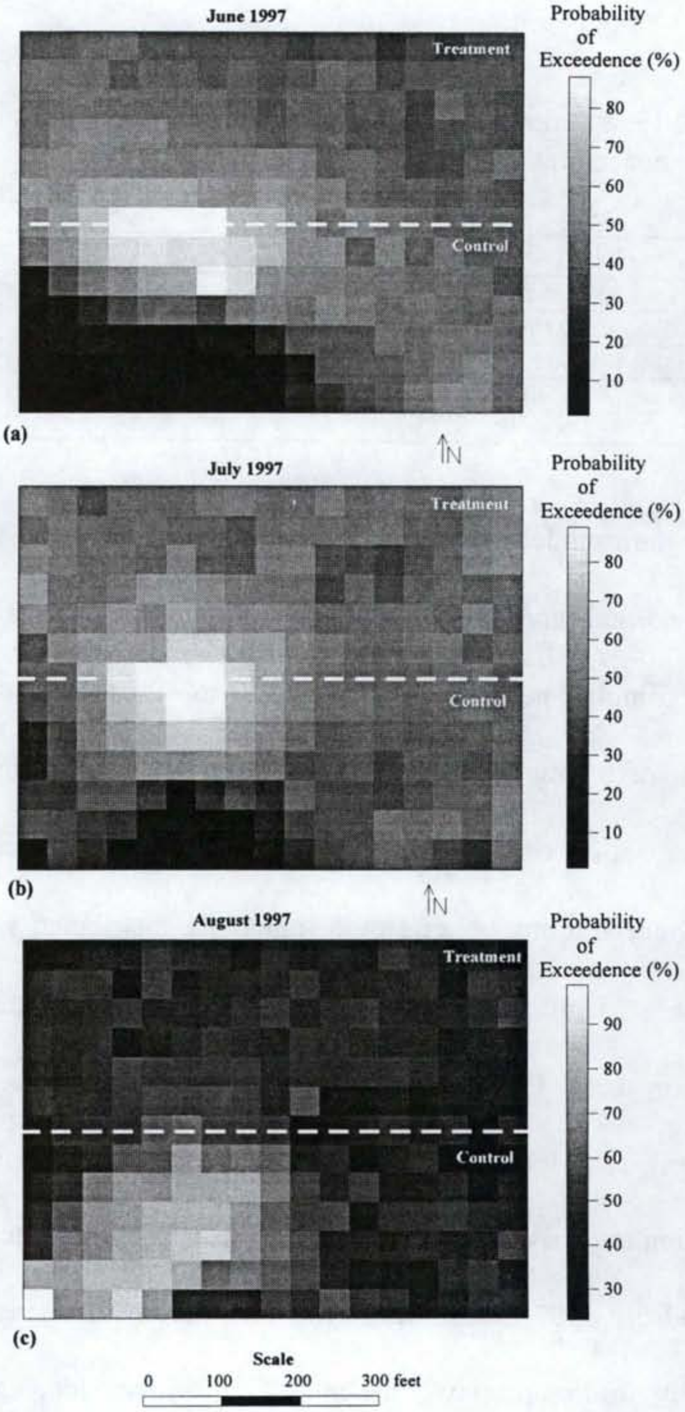


Figure 36. Probability of exceedence, shaded cell, maps of nitrate concentrations in the shallow unconfined aquifer in the Forgeon Field for the months of a) June 1997 (18.9 mg/L), b) July 1997 (16.8 mg/L) and August 1997 (26.4 mg/L). The mean threshold cutoff for each month is presented in parentheses.

Table 5. 1998 variogram parameters for normal-score transformed ground water nitrate concentrations.

	June	July	August	September	October
Model	spherical	spherical	spherical	spherical	spherical
Nugget	0 $(mg/L)^2$	.15 $(mg/L)^2$	.3 $(mg/L)^2$	.68 $(mg/L)^2$	.6 $(mg/L)^2$
Variance (sill)	1.0 $(mg/L)^2$	.96 $(mg/L)^2$	.96 $(mg/L)^2$	.96 $(mg/L)^2$	1.0 $(mg/L)^2$
R of Influence	400 ft	380 ft	320 ft	380 ft	350 ft

All variogram models fit well with calculated experimental variogram values computed for 1998 normal-score transformed, ground water nitrate data. Range of influence values over the 5-month period ranged from 320 to 400 feet. Nugget values ranged from a minimum of 0 $(mg/L)^2$ in June to 0.68 $(mg/L)^2$ in September. A distinct increase in nugget values over the 5-month period was apparent suggesting that the ground water nitrate concentrations became more randomly distributed with a less definable spatial relationship. Univariate analysis of data sets indicated little or no effect from outlier values for these 1998 months. High nugget values were also seen in pre-BMP variograms for 1996 sample data. Therefore, this trend towards a more random distribution may have been indicative of a departure from the positive effects of the BMP suggested in 1997, combined with the effects of increased nitrate mobility (i.e., availability for leaching) over the entire field while under a crop of beans.

Shaded cell estimate maps based on SGS results for the 1998 period are presented in Figure 37. Ground water nitrate concentrations for June 1998 through August 1998 were very similar in magnitude and distribution. Typical mean simulated nitrate

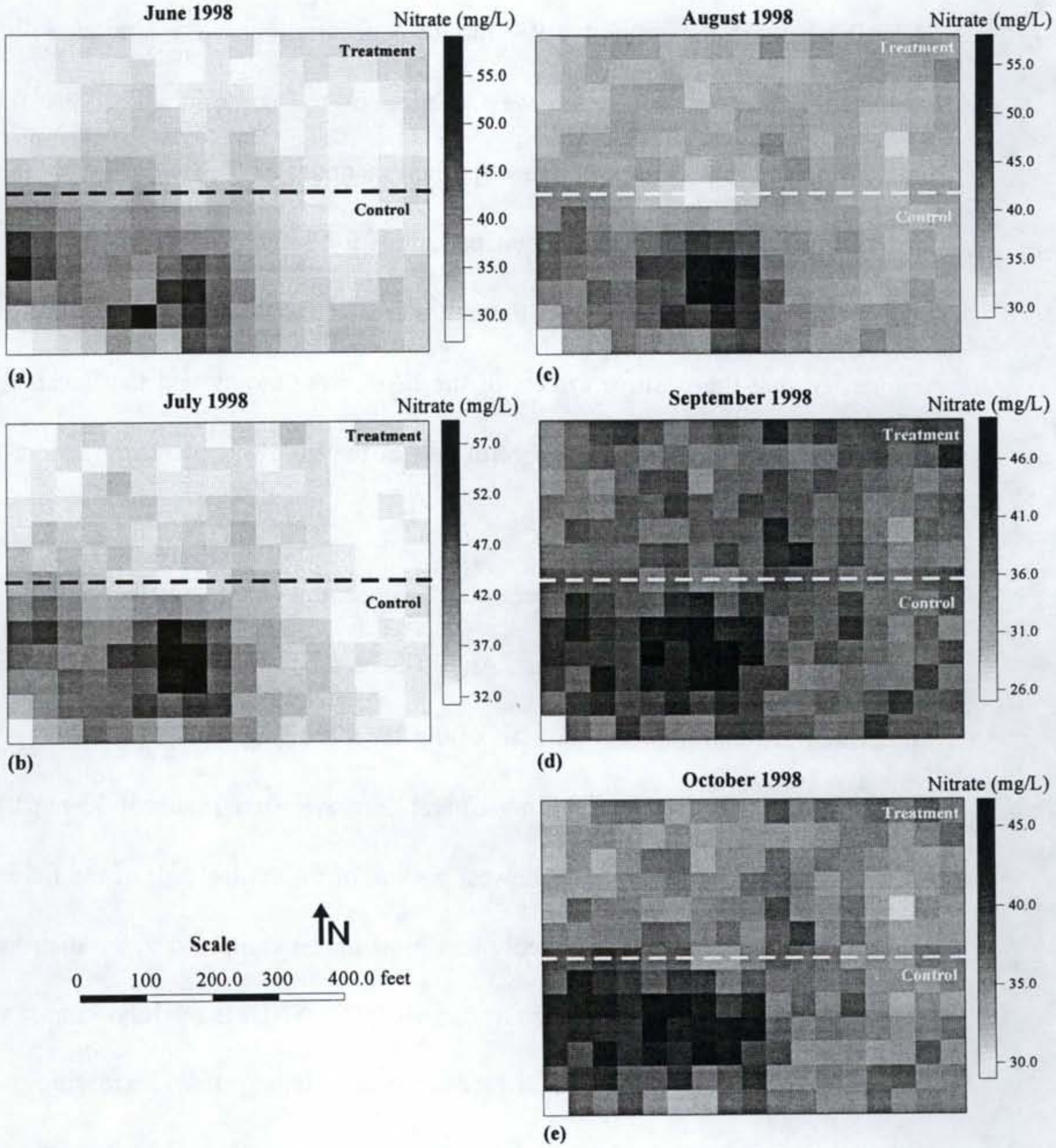


Figure 37. SGS shaded cell, estimate maps of ground water nitrate concentration distributions for the Forgeon Field for the months of a) June, b) July, c) August, d) September, and e) October, 1998.

concentrations ranged from approximately 30 mg/L to 60 mg/L for all three months. Distributions of the ground water nitrate concentrations were similar with persistent, elevated concentrations in the west portion of the control half of the field and an increasing trend in concentrations over the remainder of the field (Figure 37). Estimate maps of mean simulated nitrate concentrations for September and October 1998 showed fairly uniform distributions over the entire area of the field. These uniform distributions suggested that the positive effects of the BMP were fading and that leaching of nitrate into the shallow aquifer of the control half of the field was increasing under the crop of beans (Figure 37).

SNDMs of ground water nitrate concentrations in the Forgeon Field for the periods of June-July, July-August, August-September, and September-October 1998 are presented in Figure 38. At the start of the 1998 growing season (June-July), the highest net increases (maximum of 8.0 mg/L) and decreases (maximum of 13 mg/L) in ground water nitrate occurred in the southwest portion of the control half of the field. However, the extent of changes was markedly less pronounced compared to the distribution of net ground water nitrate changes seen in August 1997. SNDMs for July-August and August-September 1998 suggested that a reversal was underway from increasing to decreasing ground water nitrate in the western portion of the control half of the field to primarily increasing concentrations (maximum of 6.0 mg/L) over the remainder of the field (Figure 38). This reversal may have been an indicator of the last detectable effects of the 1997

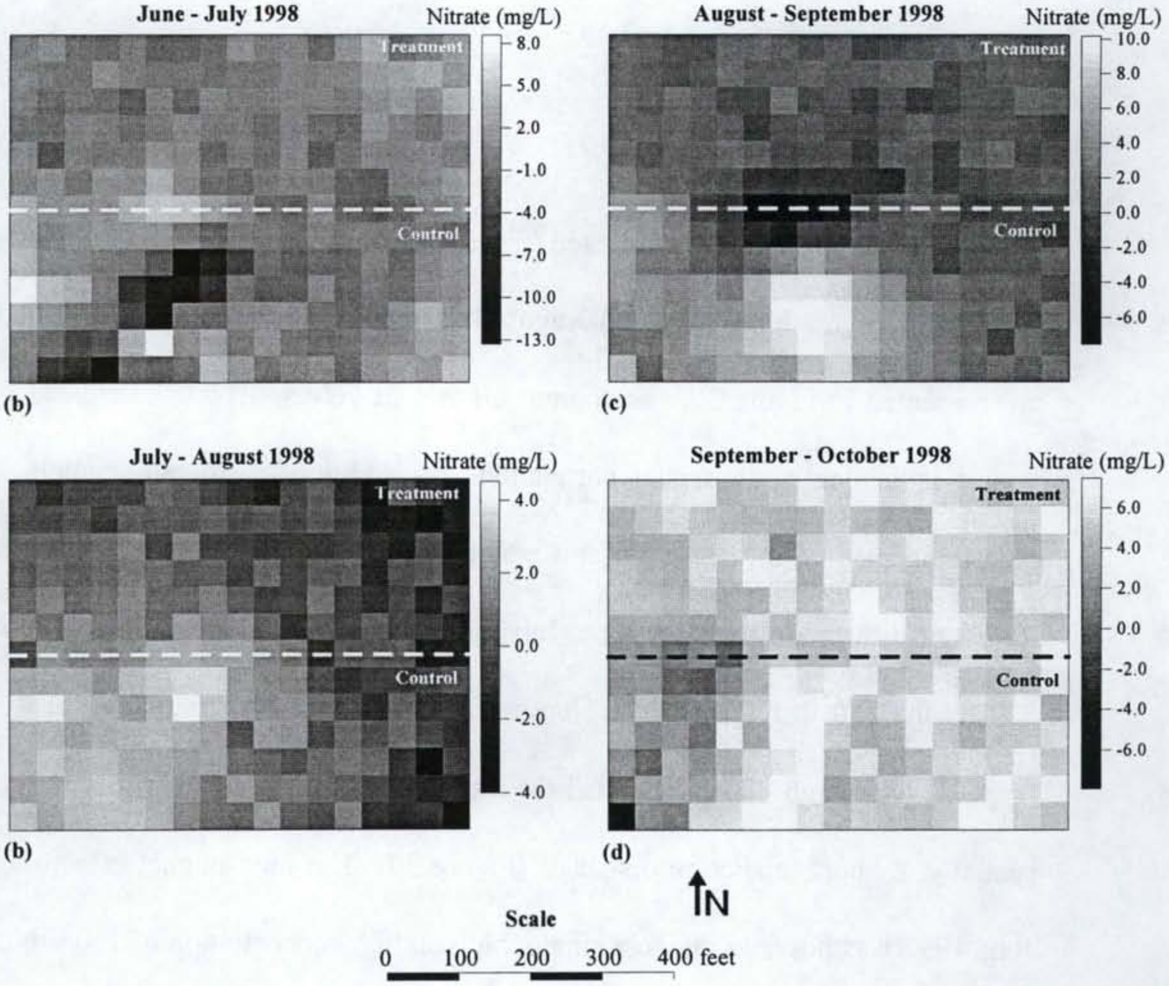


Figure 38. Spatial, net difference, maps of ground water nitrate concentrations for the Forgeon Field for a) June-July 1998, b) July-August 1998, c) August-September 1998, and d) September-October 1998.

grain-bean split at the Forgeon Field. The SNDM for September-October 1998 showed generally decreasing ground water nitrate concentrations for the entire field

Soil Water Nitrate

1997 Results

Variogram models computed from normal-score values of soil water nitrate concentrations for June, July, and August 1997 after initiation of the crop rotation BMP are presented in Figure 39. Variogram models fit very well with calculated variogram values indicating good spatial correlation. In addition, variogram models showed a plausible range of influence for soil water nitrate over the area of the Forgeon Field. Range of influence values for June, July, and August 1997 were computed to be 300 ft, 320 ft, and 380 ft, respectively. Nugget values for June (0.5 $(mg/L)^2$) and August (0.5 $(mg/L)^2$) were high which indicated the nitrate concentrations where not well correlated spatially at short separation distances (Figure 39). The high nugget effect modeled for June 1997 was possibly due to a single, high outlier, concentration of 160 mg/L that was noted during univariate analysis of June 1997 soil water nitrate data. The high nugget effect seen in August 1997 was possibly influenced by the distinct bimodal distribution also noted during univariate analysis of the August 1997 soil water nitrate data. The low nugget effect seen in July 1997 ($0.15(mg/L)^2$) corresponded to no outlier values and a generally normal soil water nitrate distribution.

Shaded cell estimate maps for 1997, soil water, nitrate distributions based on SGS results are presented in Figure 40. The shaded cell estimate map for June 1997 indicated

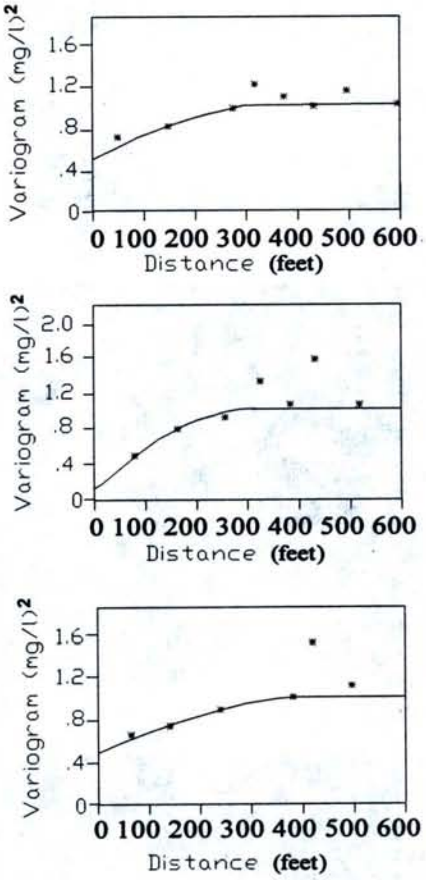


Figure 39. Variograms of normal score, soil water nitrate concentrations in the Forgeon Field for the 1997 BMP treatment phase months of a) June, b) July, and c) August, 1997.

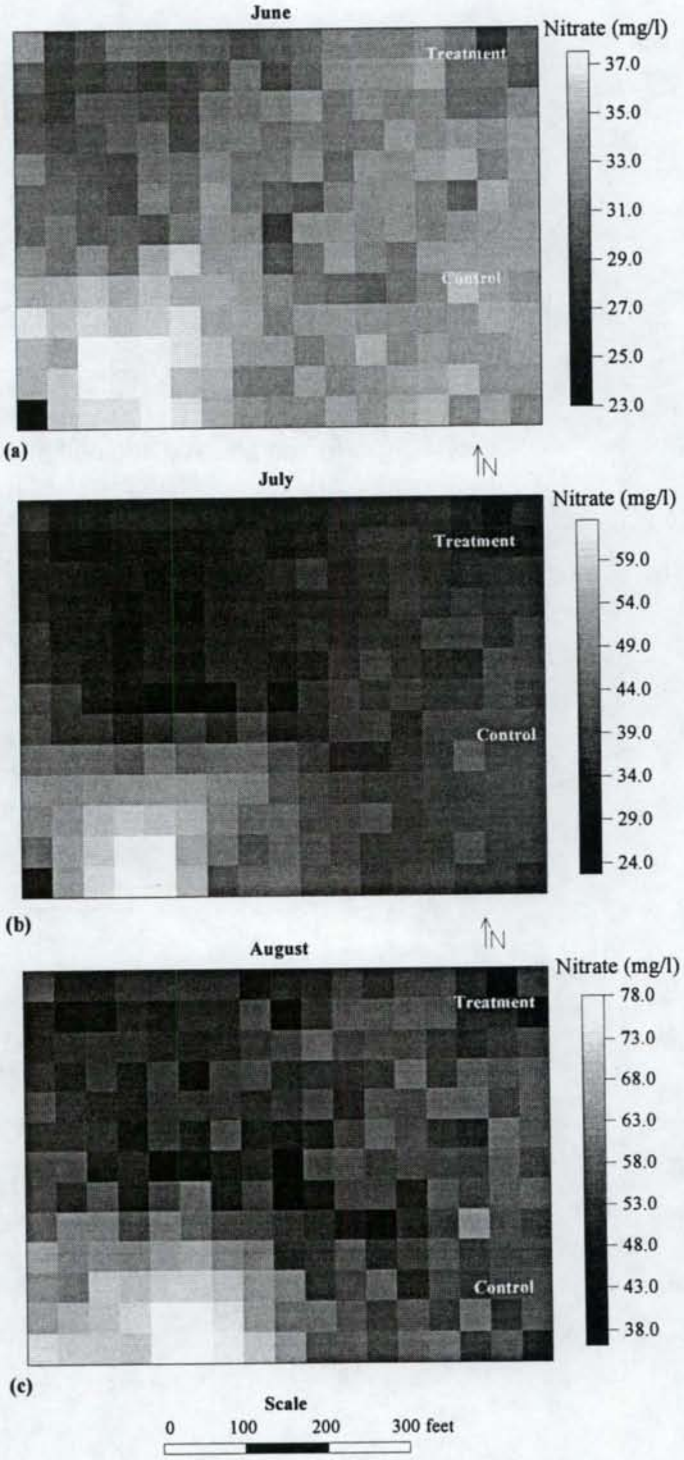


Figure 40. SGS shaded cell, estimate maps of soil water nitrate concentration distributions in the Forgeon Field for the months of a) June, b) July, and c) August, 1997.

that mean simulated soil water nitrate concentrations ranged from 23 mg/L to 37 mg/L. The map also depicted areas with high nitrate concentrations in the southwest portion of the field and low concentrations in the northwest portion of the field. These June 1997 results hinted at almost immediate effects of the grain-bean split within the sandy subsoils of the western half of the demonstration field. The shaded cell estimate map for July 1997, mean, simulated soil water nitrate depicted a generally uniform distribution with the exception of high nitrate concentrations in the west portion of the control half of the field. Results also suggested an increase in nitrate concentrations with maximum simulated values of 63 mg/L. This trend towards higher simulated values persisted into August 1997. August 1997, mean, simulated results suggested increases across the entire site with values ranging from just less than 38 mg/L to a high of 78.0 mg/L. However, the highest soil water nitrate concentrations were visible in the control half of the field for August 1997, which further suggested a positive BMP influence in the treatment half of the field.

SNDMs of soil water nitrate concentrations in the Forgeon Field for the periods of June-July, and July-August 1997 are presented in Figure 41. At the start of the 1997 growing season (June-July), the highest net increases (maximum greater than 25.0 mg/L) in ground water nitrate occurred in the western portion of the control half of the field. The SNDM for July-August 1997 indicated that soil water nitrate concentrations increased from 5 to 40 mg/L across the entire field. With the exception of small isolated areas of high net changes in soil water nitrate concentrations in the control area of the field, the distribution of net, soil water nitrate changes was fairly uniform across the entire field.

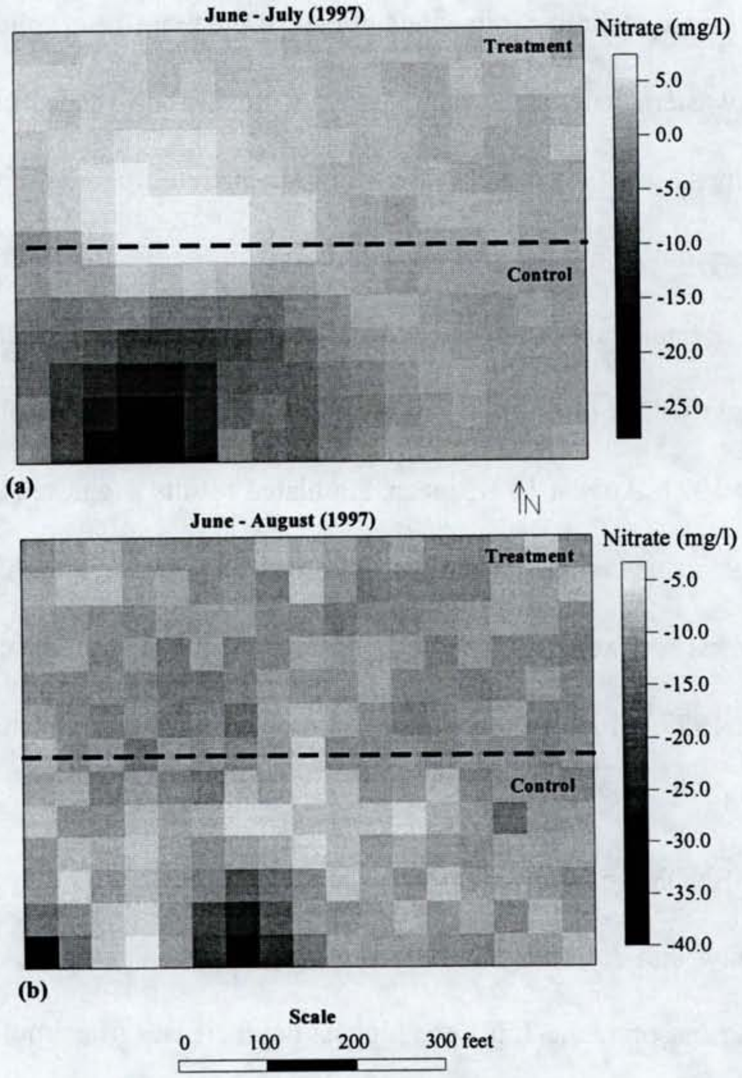


Figure 41. Spatial, net difference, maps of soil water nitrate concentrations for the Forgeon Field for a) June-July 1997, and b) July-August 1997.

Probabilistic Assessment of 1997 Results

A probabilistic assessment of 1997 SGS, soil water, nitrate results was completed. The mean, soil water, nitrate concentration calculated for each monthly, lysimeter sample data set was selected as the exceedence threshold. Calculated mean soil water concentrations for June, July, and August 1997 were 34.3 mg/L, 31.4 mg/L, and 46.6 mg/L, respectively.

Actual, soil water, nitrate sample data and simulation results, and SNDMs indicated a trend towards increasing nitrate concentrations from June through August, 1997 with highest concentrations visible in western portions of the control half of the field. This general pattern was apparent in probability distributions over the 3-month period (Figure 42). Beginning in June 1997, the probabilities for exceeding the mean sample, soil water, nitrate concentration were highest in the western portion of the control half of the field, but were somewhat isolated and not higher than 50 percent. However, the probabilities for exceeding the mean sample, nitrate concentration for July and August 1997 increased and were generally greater than 85 percent for a large portion of the control half of the field. High probabilities of exceeding the mean concentration persisted into August 1997; however, they were constrained more to the southwest portion of the control half of the field. These results appeared to verify the simulation results and placed high probabilities for exceeding mean nitrate concentrations in portions of the field that corresponded to areas of high, simulated, soil water, nitrate

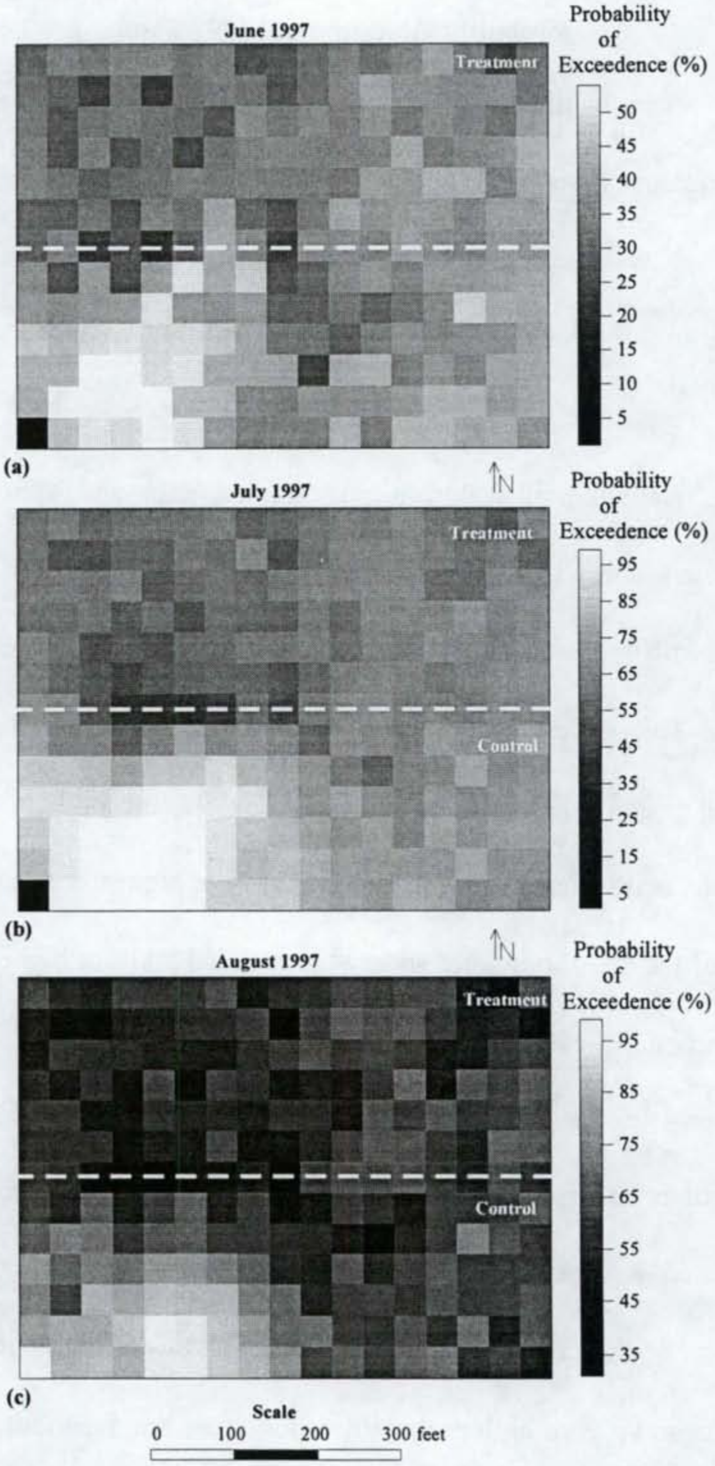


Figure 42. Probability of exceedence, maps of soil water nitrate concentrations in the Forgeon Field for the months of a) June 1997 (34.1mg/L), b) July 1997 (31.4 mg/L), and c) August 1997 (46.6 mg/L). The mean threshold cutoff is presented in parentheses.

concentrations. Results suggested that the simulated, soil water, nitrate distributions were verifiable. The results also suggested that it was highly probable that detectable improvements in the water quality were due to the implementation of the grain-bean rotation.

1998 Results

Parameters for variogram models computed from normal-score transformed, soil water nitrate values for the months of June, July, and August 1998 are presented in Table 6.

Table 6. Variogram parameters for 1998 for normal-score transformed, soil water nitrate concentrations.

	June	July	August
Model	spherical	spherical	spherical
Nugget	.2 $(mg/L)^2$	.1 $(mg/L)^2$	.4 $(mg/L)^2$
Variance (sill)	1.0 $(mg/L)^2$	.96 $(mg/L)^2$	.96 $(mg/L)^2$
R of Influence	400 ft	380 ft	320 ft

Nugget values for June (0.2 $(mg/L)^2$) and July (0.1 $(mg/L)^2$) were low which indicated the nitrate concentrations where well correlated spatially, even at very short separation distances. The nugget effect modeled for August was moderately high (0.4 $(mg/L)^2$). This was possibly due a single, high outlier, concentration of 180 mg/L, but also may have been indicative of fading effects from BMP noted previously in variograms of 1998, normal-score transformed, ground water nitrate concentrations.

Shaded cell estimate maps based on 1998 SGS, soil water, nitrate results are presented in Figure 43. The shaded cell estimate map for June 1998 indicated that mean,

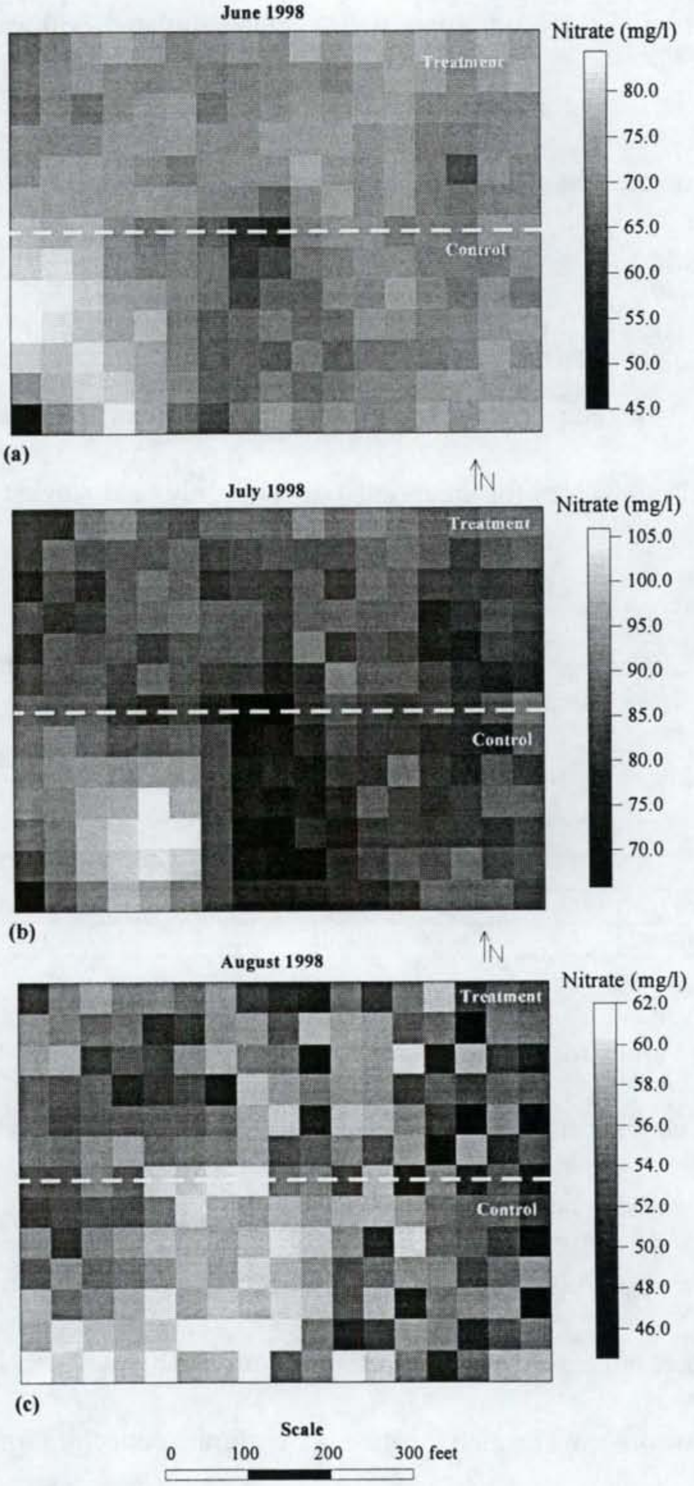


Figure 43. SGS shaded cell, estimate maps of soil water nitrate concentration distributions in the Forgeon Field for the months of a) June, b) July, and c) August, 1998.

simulated, soil water, nitrate concentrations ranged from 45 mg/L to greater than 80 mg/L. The map further showed the presence of an isolated area of high, soil water, nitrate concentrations in the western portion of the control half of the field. July 1998 results suggested that increased soil water, nitrate levels ranged from approximately 70 mg/L to 105 mg/L (Figure 43). Maximum concentrations again were visible in sandy subsoils in an isolated, western portion of the control half of field. The shaded cell estimate map for August 1998, mean, simulated, soil water nitrate depicted somewhat random soil water, nitrate concentrations that were comparatively lower than nitrate levels observed for June and July 1998 (Figure 43). This trend towards lower, simulated, soil water, nitrate levels in 1998 may have been indicative of a decrease in total nitrate available for leaching; the more random distribution of nitrate concentrations suggested the possible fading of positive BMP effects beginning in August 1998.

SNDMs of soil water, nitrate concentrations in the Forgeon Field for the periods of June-July, and July-August 1998 are presented in Figure 44. At the start of the 1998 growing season (June-July), the highest net increases (maximum of 36.0 mg/L) in ground water nitrate occurred in the west portion of the control half of the field. However, the extent of changes was markedly less pronounced compared to the distribution of net, ground water, nitrate changes seen in August 1997. The remainder of the field showed comparatively small increases in soil water, nitrate levels (generally less than 16.0 mg/L) and an overall uniform distribution in net increases. The SNDM for July-August 1998 suggested that a reversal occurred from increasing to decreasing soil water, nitrate over

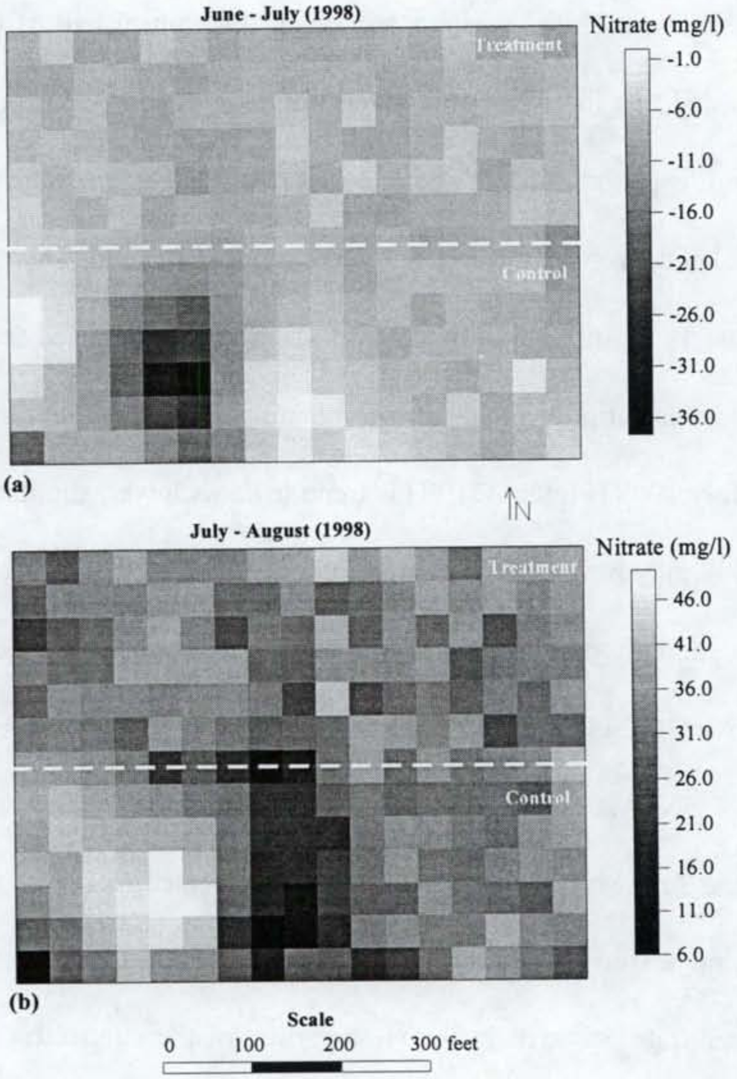


Figure 44. Spatial, net difference, maps of soil water nitrate concentrations in the Forgeon Field for a) June-July 1998, and b) July-August 1998.

the entire demonstration field. This reversal may have been an indicator of decreasing amounts of total nitrate available for leaching in the subsoils.

Moncur Field Irrigation BMP – Trend Surface Analysis

Trend surface analysis (TSA) was used to evaluate ground water nitrate data for ground water monitoring wells in the Moncur Field. Statistical significance testing of trend surface models at a significance level of 0.05 was completed for all sampled months in 1996, 1997, and 1998. The only months to pass significance testing criteria were the months of May, June, July, August, and September 1997, and January 1998. Trend surface models for the other months sampled did not pass testing and are not presented in this report. Soil water nitrate data collected during 1997 were evaluated using TSA in the same manner as ground water nitrate data. The months of June and August 1997 were the only months to pass testing criteria for soil water nitrate. The statistical testing methods, grid setup, computer applications, and computer methods used to evaluate 1997 data were identical for both the ground water and soil water analyses.

Trend surface estimates and statistical f-distribution values were produced using the program UITRENR (Miller, 1996c). Higher order TSA models also were tested statistically at a significance level of 0.05 or better to evaluate whether they described the distribution of nitrate data significantly better than lower order trend surface models. Due to the small sizes of the data sets and the limited number of degrees of freedom, trend surface models were limited to first order (Eq.3) and second order models (Eq. 4). Visual analysis of residuals (difference between TSA estimates and hard sample data at sample locations) also was completed to evaluate the predictive capability of monthly trend surface models.

The dimensional area of the Moncur Field was divided into 100 feet x 100 feet grid units to produce 91 grid nodes. Trend surface estimates then were made at each grid node to develop spatial maps of nitrate concentration distributions for the months evaluated that passed statistical significance testing criteria. Similar to SGS procedures for the Forgeon Field, spatial trend net difference maps (STNDMs) were developed through subtraction of TSA estimates to evaluate month to month net ground water and soil water nitrate changes at the Moncur Field (Carlson and Osiensky, 1998).

Ground Water Nitrate

Spatial trend surface maps (STSMs) of the estimated nitrate concentration distributions for May, June, July, August, September 1997 and January 1998 are presented in Figure 45. The STSM for May (month prior to irrigation) indicated the existence of a general trend from lower nitrate concentrations in the southwest area of the test site to higher concentrations to the northeast. Nitrate estimates ranged from nondetect to 20.0 mg/L. Lowest estimated concentrations for May were visible in the southwest corner of the control half of the field. Highest estimated concentrations for May were visible in the northeast corner within the treatment half of the field. This general trend persisted throughout the period of study except for the month of July 1997 (Figure 45). Estimated maximum nitrate concentrations peaked in July (28mg/L). Ground water nitrate concentrations decreased steadily thereafter through January 1998. In addition, beginning in August 1997 and continuing through to March 1998, a subtle shift to a more

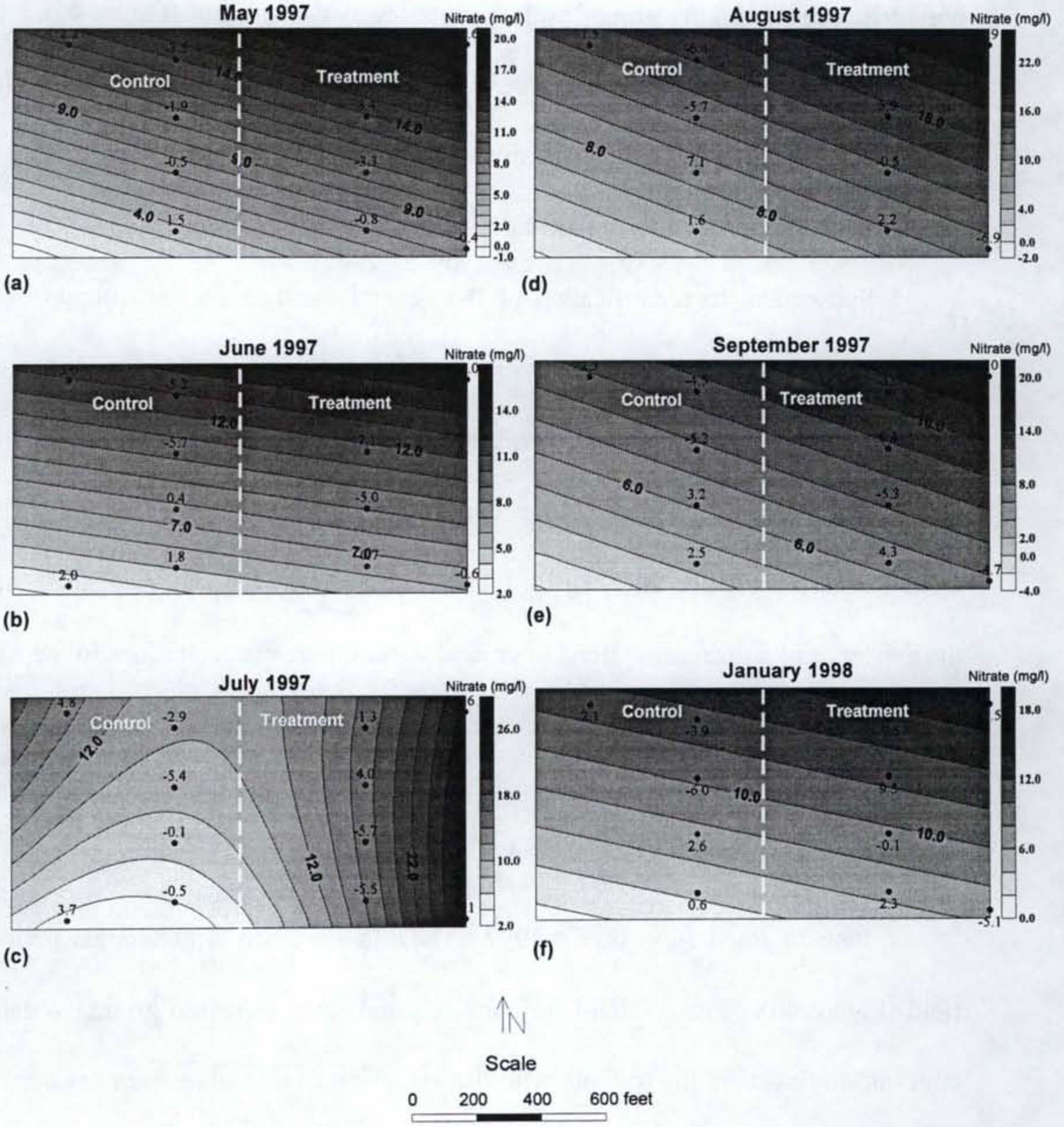


Figure 45. Spatial, trend surface, maps (STSMs) of estimated ground water nitrate concentration distributions for the Moncur Field for the 1997 months of a) May, b) June, c) July, d) August, e) September, and f) January 1998.

northerly trend in higher ground water nitrate levels was evident (Figure 45). Overall, residual values determined for each trend surface map were low to moderate. However, consistently high residuals (generally greater than 6.0 mg/L) were noted at the northeastern interior monitoring location (ME3) for most of the STSMs.

Subsequent to identification of the general trend in the distribution of ground water nitrate concentrations, monthly trend surface estimates were subtracted to evaluate net monthly nitrate changes and possible BMP influence. Spatial trend net difference maps (STNDMs) (Figure 46) were constructed using the same monthly difference technique developed for the Forgeon Field. The STNDM for May-June 1997 suggested the existence of a decreasing trend in ground water nitrate concentrations in the southwest and an increasing trend in nitrate concentrations in the northeast at the start of BMP implementation. Estimated net changes ranged from a minimum decrease of 3.5 mg/L to maximum increases of 5 mg/L.

June-July and July-August 1997 STNDMs identified a transitional period at the field (Figure 46). The STNDM for June-July indicated increased ground water, nitrate concentrations across the test site with the exception of a small area in the north central portion. Estimated maximum net increases of 22.0 mg/L were detected within the treatment half of the field. The STNDM for July-August suggested that a general shift from increasing nitrate concentrations to decreasing nitrate concentrations began in a large portion of the field with an estimated maximum decrease of 18.0 mg/L in the treatment half. This shift suggested possible initial effects of the irrigation BMP.

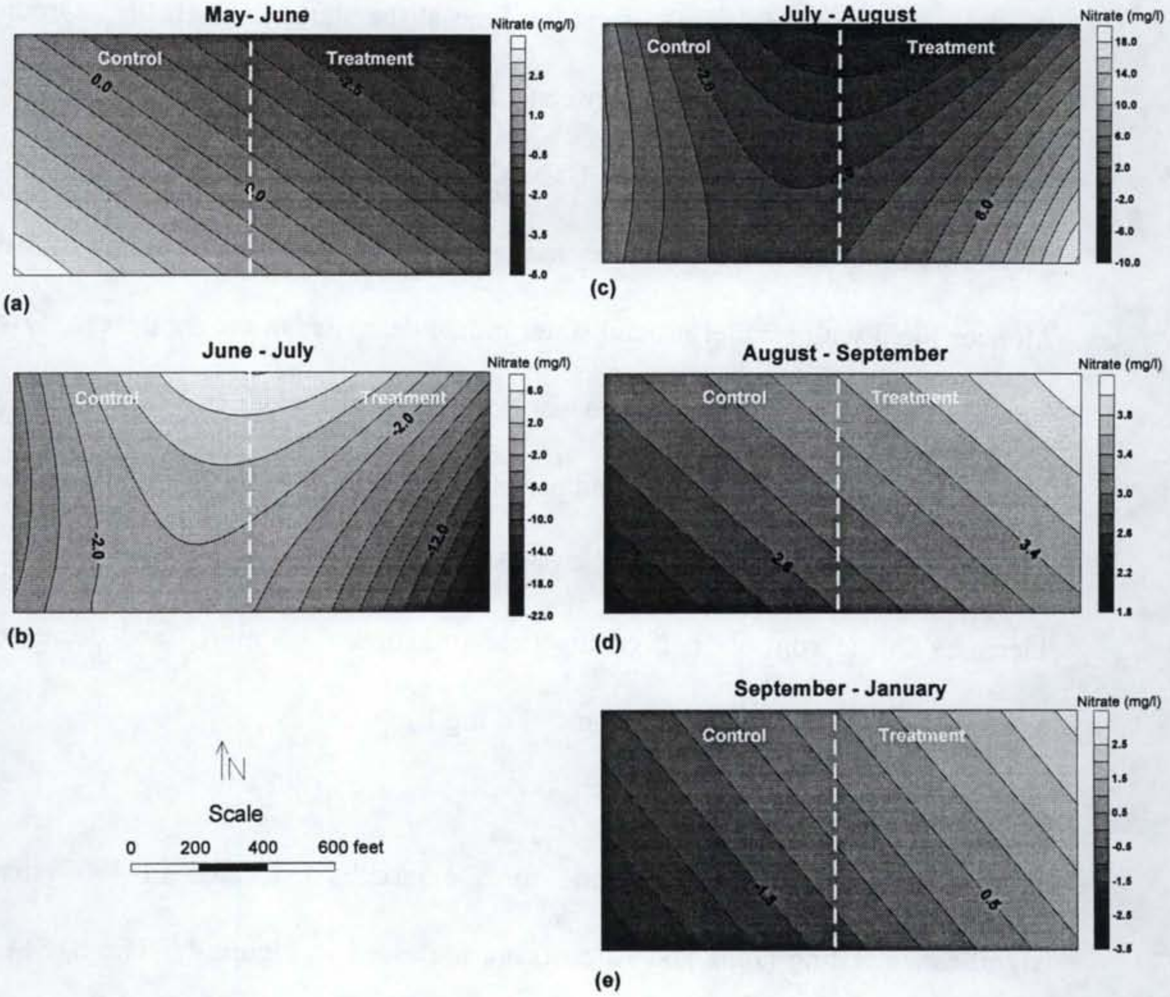


Figure 46. Spatial trend, net difference, surface maps (STNDMs) of estimated ground water nitrate changes at the Moncur Field for a) May-June 1997, b) June-July 1997, c) July-August 1997, d) August-September 1997, and e) September 1997-January 1998.

STNDMs after August (Figure 46) suggested that a complete reversal occurred from the spatial trend depicted for May-June at the start of the BMP. Ground water nitrate concentrations decreased between 1.8 and 4.0 mg/L over the entire field from August to September 1997. The STNDM for August-September showed the greatest ground water nitrate decreases in the northeast portion of the treatment half of the Moncur Field with smaller ground water nitrate decreases to the southwest. Overall, the smallest ground water nitrate decreases occurred in the southwest corner of the control half of the field. This reversed trend persisted for September 1997 through January 1998. The September 1997-January 1998 period also showed general, ground water nitrate increases in the control half of the field (maximum 3.5 mg/L) and decreases in the treatment half of the field (maximum > 2.5 mg/L).

Soil Water Nitrate

STSMs of soil water nitrate for the months evaluated in 1997 that passed significance testing (June and August) are presented in Figure 47. The STSM for June 1997 indicated that a trend was present from lower nitrate concentrations in the southwest area of the field to higher concentrations to the northeast. Nitrate estimates ranged from nondetect to 200.0 mg/l. Lowest concentrations for June 1997 were present in the southwest corner of the control half of the field. Highest concentrations for June 1997 were present in the northeast corner within the treatment half of the field. The STSM for August 1997 suggested a shift to a more east to west trend with lowest concentrations in the east and highest concentrations in the west (Figure 47). High residual values seen in both STSMs corresponded to locations of extremely high, outlier, values discovered

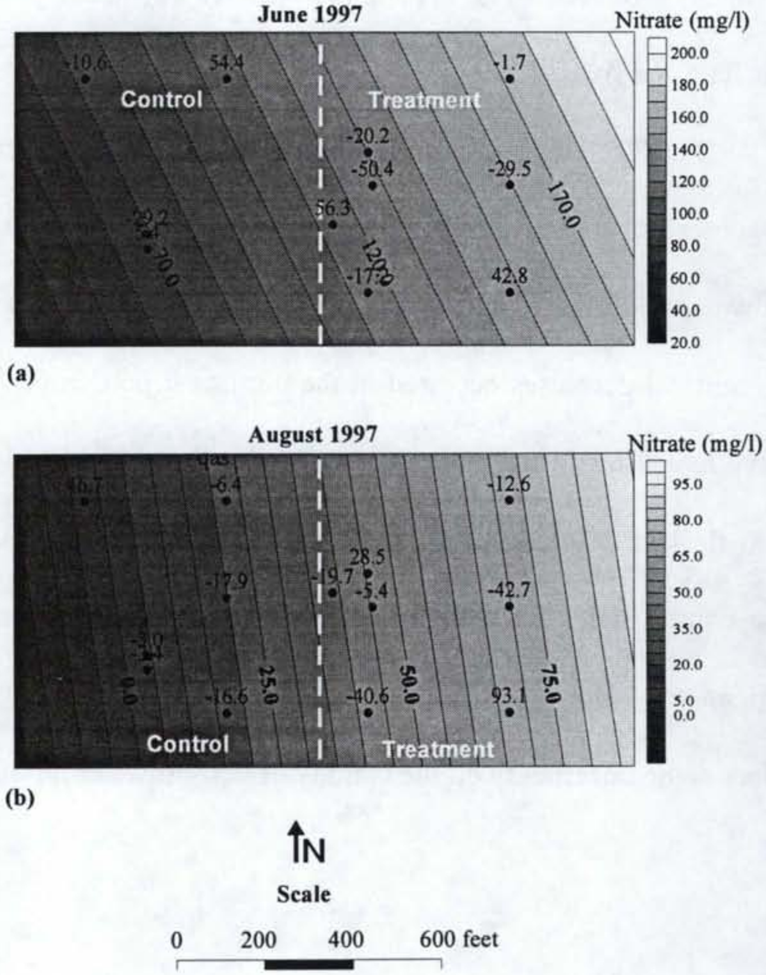


Figure 47. Spatial trend, surface maps (STSMs) of estimated soil water nitrate concentration distributions for the Moncur Field for the months of a) June, and b) August 1997. Note: July 1997 soil water nitrate data did not pass significance testing.

during EDA. The presence of these extremely high outliers and corresponding high residuals produced some uncertainty with respect to the predictive capability of STSMs for June and August 1997.

The STNDM produced for June-August 1997 is presented in Figure 48. The map suggested overall reduced net soil water nitrate concentrations across the entire field. Lowest net decreases occurred in the southwest portion of the control half of the field and highest net decreases occurred in the northwest portion of the field. These results may have represented the initial effects of the irrigation BMP. It is believed that less nitrate was flushed to the depth of the lysimeters in the treatment half of the field compared to the control half of the field because of the reduced water available with the 12-hour irrigations. However, the high residuals seen on STSMs for June and August 1997 place some uncertainty on the validity of net soil water nitrate changes depicted in Figure 48.

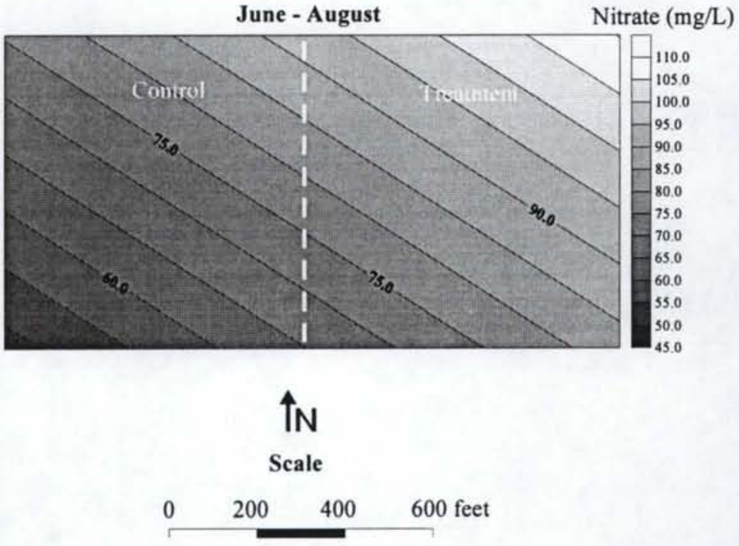


Figure 48. Spatial trend, net difference, map (STNDM) of estimated soil water nitrate changes in the Moncur Field for June-August 1997.

CONCLUSIONS

Forgeon Field Crop Rotation BMP

Based on the results of this study the following conclusions concerning the leaching of nitrate to the ground water and the effectiveness of the crop rotation BMP at the Forgeon Field are presented:

1. Monthly sampling of monitoring wells in the Forgeon Field showed that significant increases in ground water nitrate concentrations were measured after the growing of potatoes, a crop requiring large amounts of fertilizer. Greater increases in ground water nitrate concentrations after heavily fertilization of potatoes were measured for monitoring wells in the west half of the field (FW1, FW2, FW3, and FW4) than for the monitoring wells in the east half of the field (FE1, FE2, FE3, and FE4). Coarser grained soils in the west half of the field most likely allowed a greater mass of fertilizer to leach to ground water. Finer grained soils in the east half of the field reduced the mass of fertilizer leached to ground water.

2. Regression analysis of monthly mean nitrate concentrations for the control and treatment portions of the Forgeon Field showed that no quantifiable relationship existed for the calibration period.

3. Leaching of nitrate to the ground water in the field was a function of irrigation-precipitation amounts with an approximate 1 to 2 month time lag between increased irrigation-precipitation amounts and increased levels of ground water nitrate.

4. The rate and amount of nitrate leached to the ground water in the field were dependent upon the properties of the subsoils. Higher ground water nitrate concentrations were observed in the shallow aquifer within the sandy subsoils area of the field following increased irrigation with an approximate 1 to 2 month time lag.

5. The rate and amount of nitrate leached to the ground water in the field were dependent upon the crop grown. Higher ground water nitrate concentrations and higher net nitrate increases were observed in the control half of the field under beans. Lower ground water nitrate concentrations and lower net nitrate increases were observed in the treatment half of the field under grain. These results suggested that the crop rotation BMP implemented at the Forgeon Field for one year had a positive effect on the ground water quality.

6. Crop type had a significant effect on soil water nitrate concentrations during the growing season. SGS results for 1997 suggested that comparatively high soil water nitrate concentrations and larger net nitrate increases occurred under beans compared to low soil water nitrate concentrations and smaller net nitrate increases under grain. This occurrence is significant from the standpoint of reducing the nonpoint source of soil nitrate available to leach to the ground water over time.

7. The positive effects of growing grain for a single season were relatively short term. Net changes in the distribution of nitrate in the ground water apparently reversed from July to August 1998, one year after BMP implementation. Crop rotation BMP's must be used on a regular basis to improve the long-term ground water quality significantly in the area.

8. Probabilistic evaluation suggested a high probability that the crop rotation BMP used at the Forgeon Field had a positive effect on the ground water quality (reduced nitrate).

9. Following the crop of potatoes by two years of alfalfa significantly reduced the amount of residual nitrate in the soil water and effectively reduced nitrate concentrations in the shallow ground water.

10. Education of farmers on the significance of crop rotation BMP's and work to increase farmer acceptance of BMP's should continue. Results from this study suggest the crop rotation BMP had a positive influence on the soil water and ground water quality.

Moncur Field Irrigation BMP

Based on the results of this study the following conclusions concerning the leaching of nitrate to the ground water and the effectiveness of the irrigation BMP at the Moncur Field are presented:

1. Monthly sampling of monitoring wells in the Moncur Field showed no significant increases in ground water nitrate after the planting of potatoes or sugar beets. Both crops required large amounts of fertilizer. The low variance in ground water nitrate concentrations and lack of significant increases in nitrate concentrations after the growing season for crops requiring heavy fertilization suggest that fertilizer applications over a one year period had very little effect on ground water nitrate concentrations in the Moncur Field under sprinkler irrigation. The greatest changes in ground water nitrate concentrations were measured under furrow irrigation. Conversion from furrow to sprinkler irrigation of the fine grained (silty) soils in the

Moncur Field reduced the leaching of nitrate to the ground water over the period of this investigation. Conversion to sprinkler irrigation probably is a best management practice to reduce ground water nitrate concentrations in fields with predominantly fine grained (silty) soils.

2. A reversed trend in net ground water concentrations was observed over the BMP period evaluated. These results were the best evidence suggesting that the irrigation water management BMP had a positive influence on the ground water quality.

3. More work may be required to thoroughly evaluate effects of reduced irrigation amounts on ground water nitrate concentrations. However, results for the Forgeon Field crop rotation BMP showed that irrigation amounts probably influenced leaching of nitrate to the ground water.

4. Continued work on improving irrigation BMP logistics should be on going. Results from this study suggest positive BMP influence to reduce nitrate leaching to the ground water.

5. Grouping of the monitoring wells in the Moncur and Forgeon Field by predominant soil type in the unsaturated zone revealed that the highest concentrations and greatest variability in ground water nitrate was measured for monitoring wells located in the coarsest grained soils.

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Appendix A:

Hydrogeologic Investigations of the Forgeon and Moncur Fields

The hydrogeologic investigations in the Forgeon and Moncur Fields included an evaluation of the saturated and vadose zones. Soil samples from each field were visually examined to characterize the grain size ranges and the areal and vertical distribution of different types of soil in each field. Slug tests were conducted in the Moncur Field and two aquifer tests were conducted in the Forgeon Field to estimate the transmissivity and hydraulic conductivity of the sediments in the saturated zones in each field. Monthly ground water elevation measurements were used to evaluate the direction of ground water flow and hydraulic gradients in each field. Parameters determined from the hydraulic tests and an evaluation of the ground water elevation measurements were used to estimate the ground water velocities in each field.

Forgeon Field

Lithologic Descriptions

Composite well cutting samples were collected in one-foot intervals from three to eleven feet below ground surface during installation of each of the twelve monitoring wells in the Forgeon Field. The locations of the monitoring wells are shown in Figure A-1. Lithologic logs derived from a visual inspection of the well cuttings are presented in Figures A-2a, A-2b, and A-2c.

Lithologies include well sorted, fine to medium sands with varying percentages of gravel. The sand is subangular while the gravel is subrounded to well-rounded. Sands in the Forgeon Field can be divided into two groups based on composition. Brown sand composed of 90% clear, rose and smoky quartz and 10% lithics is present from land surface to a depth of two feet. A salt and pepper colored sand composed of approximately 50% brown and black basaltic glass and 50% clear and milky quartz is present from four to eleven feet below land surface. Lithologies were also described from land surface to a depth of approximately six feet during installation of 35 ground water point samplers. Three different lithologies of varying thickness exist between approximately two and four feet below ground surface; brown sand, clayey sand, and clay (Figure A-3).

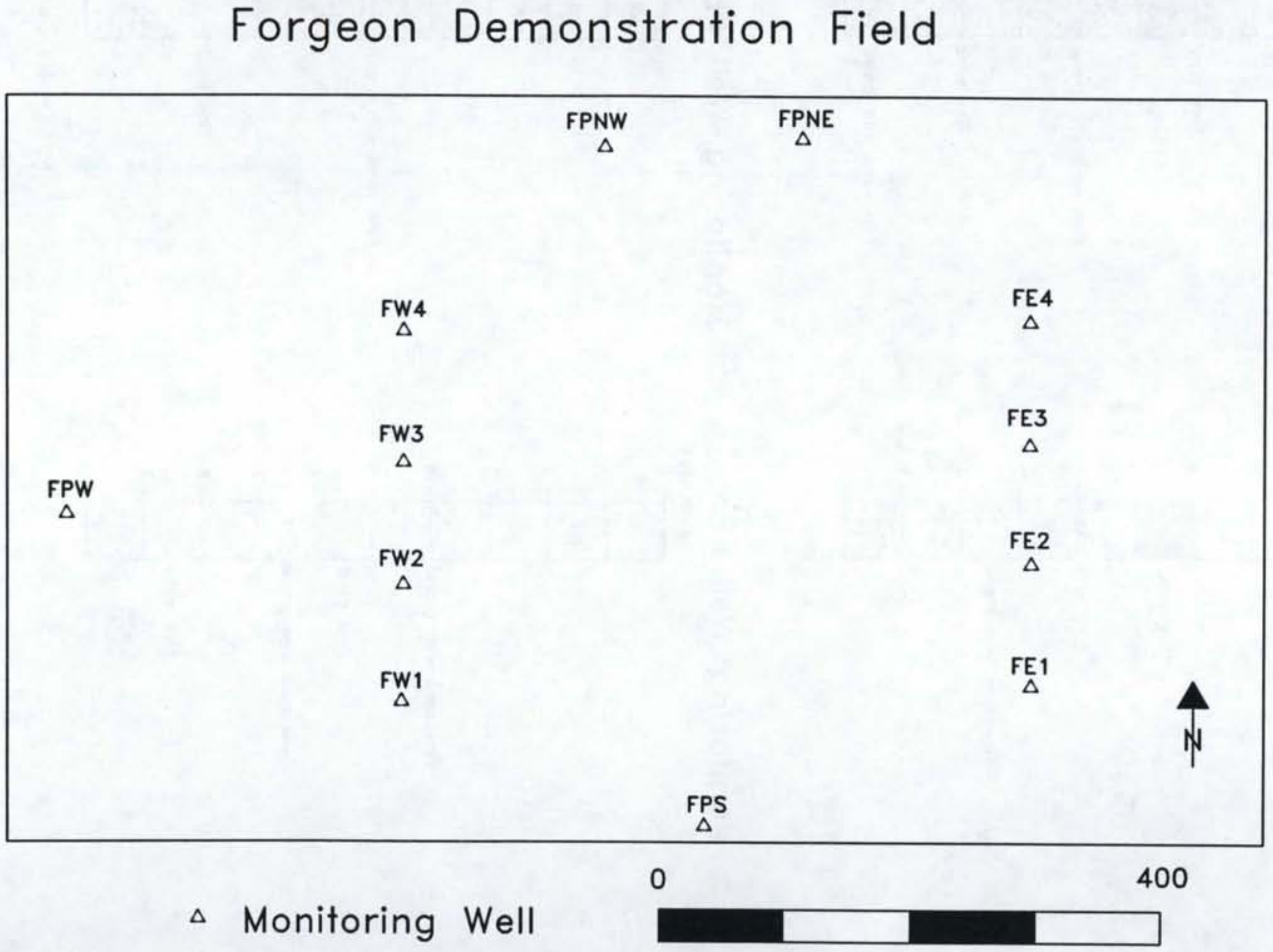


Figure A-1. Location of monitoring wells in the Forgeon Field.

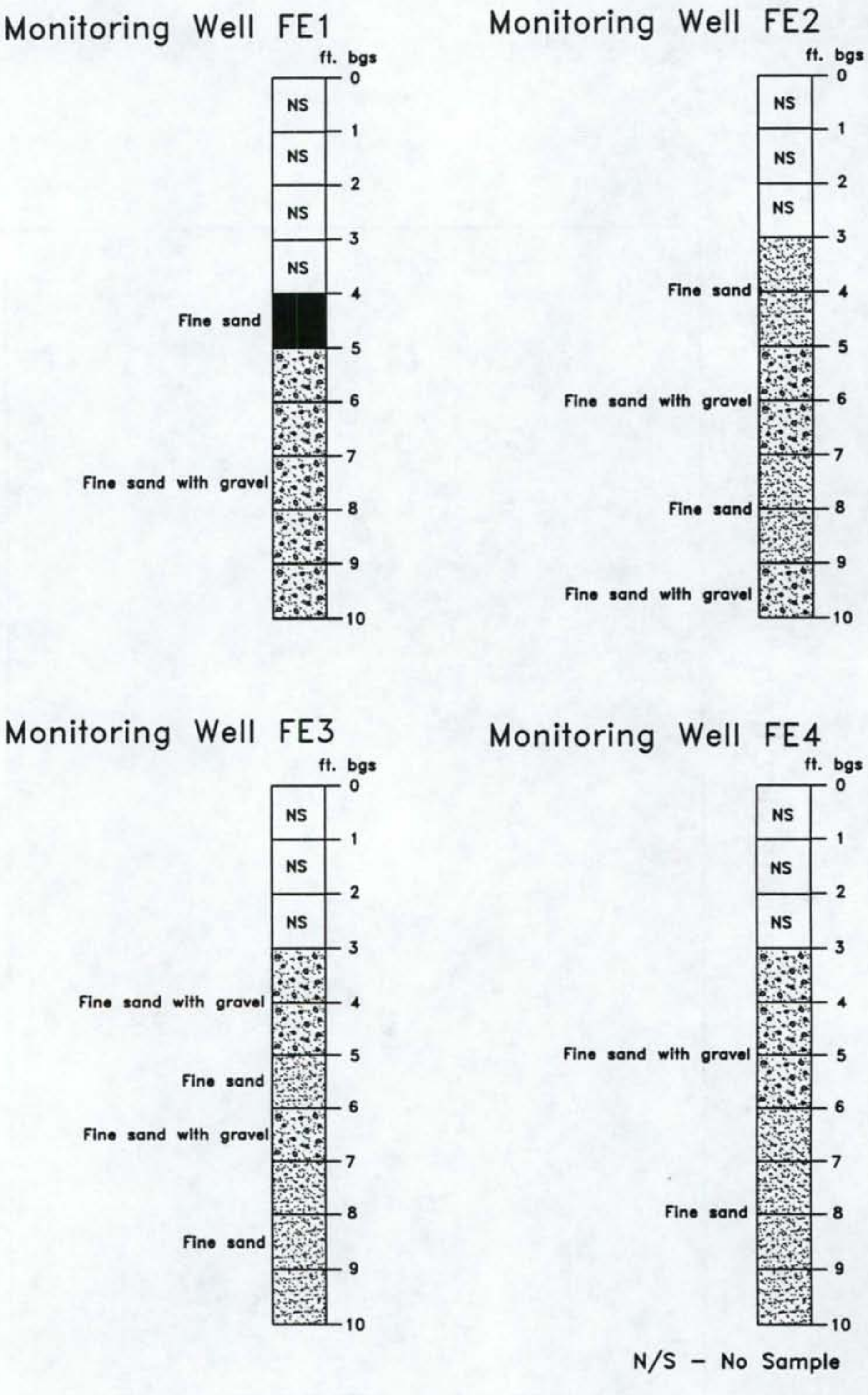


Figure A-2a. Forgeon Field: Lithologic logs of east monitoring wells.

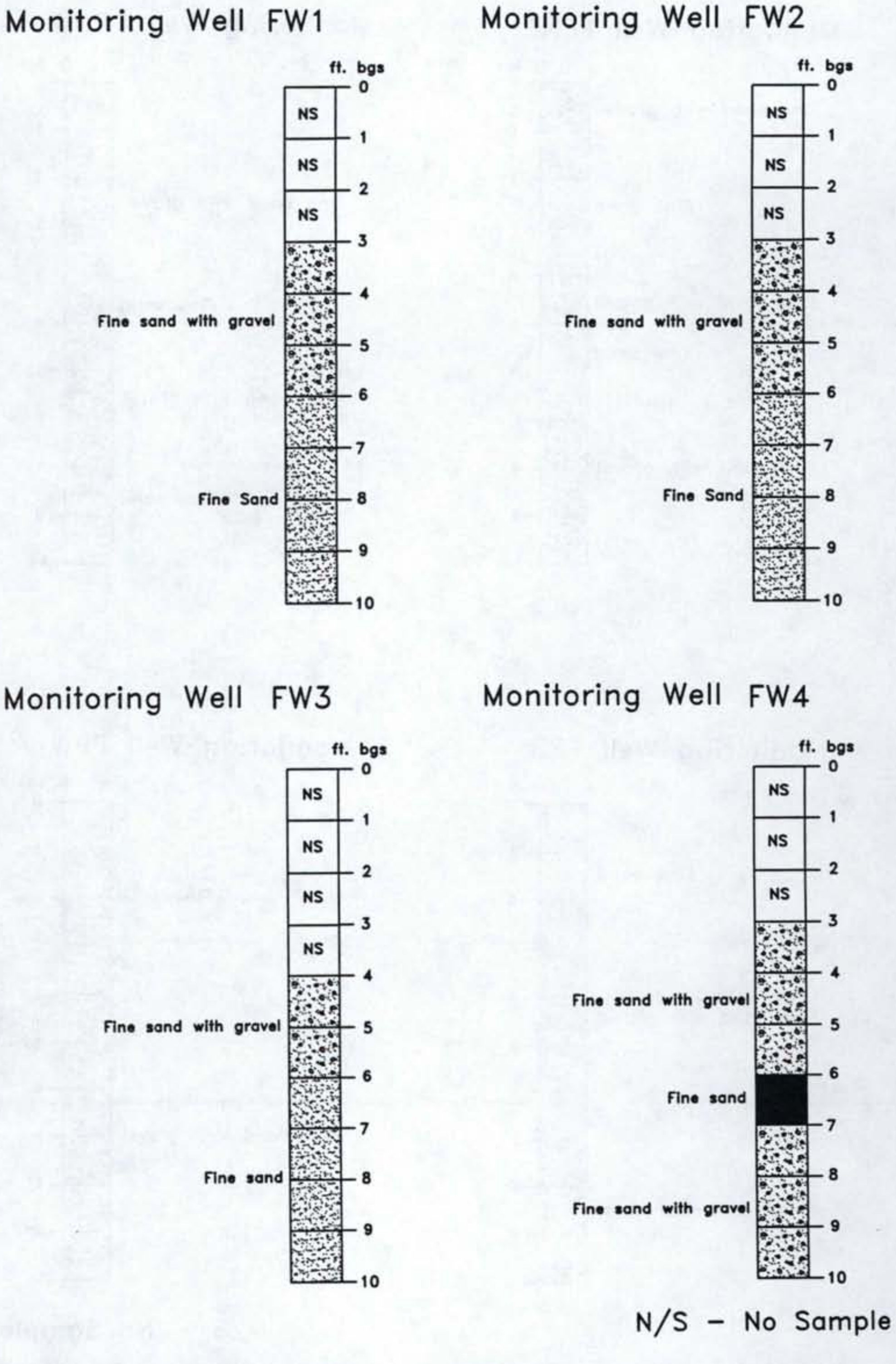


Figure A-2b. Forgeon Field: Lithologic logs of west monitoring wells.

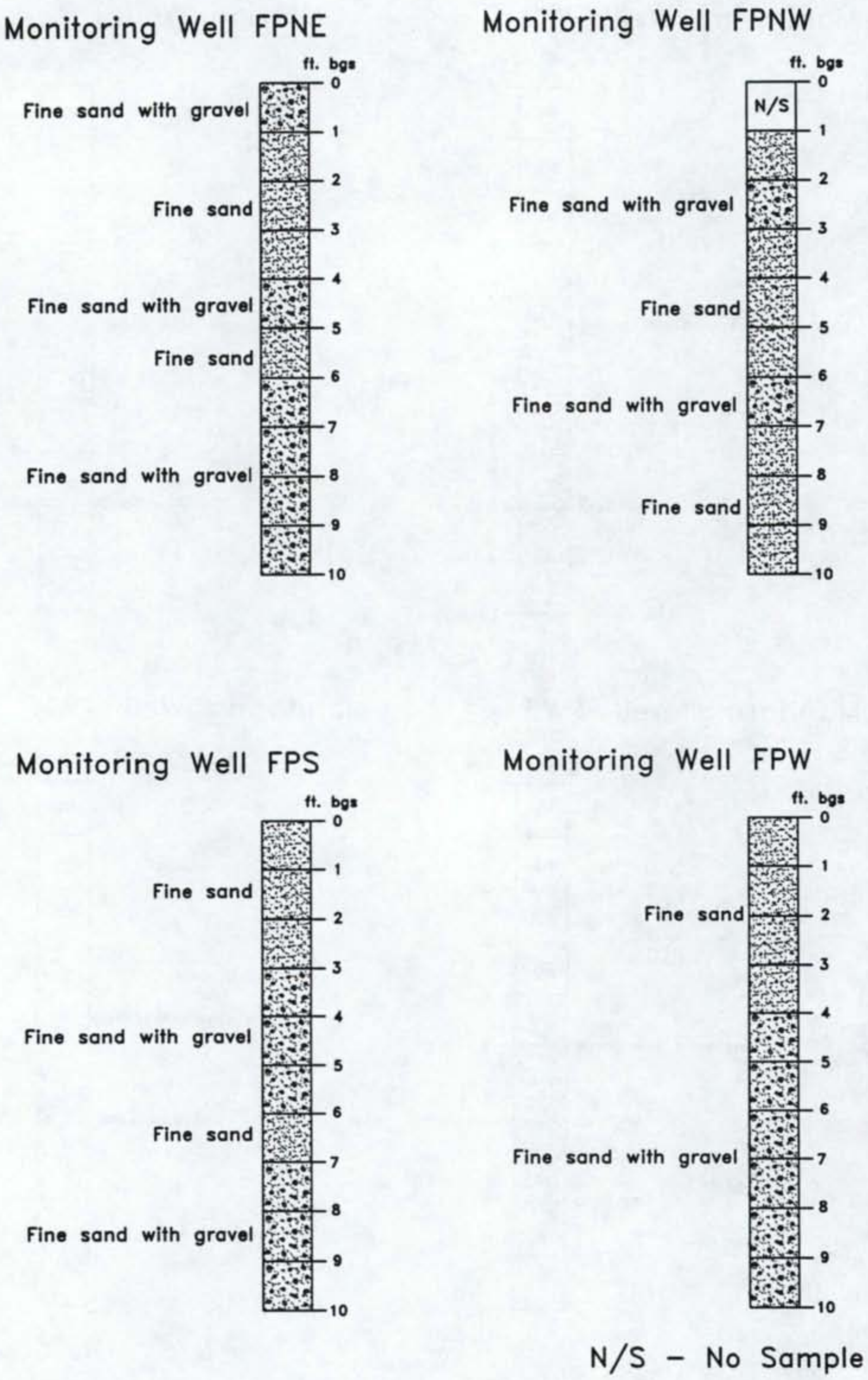


Figure A-2c. Forgeon Field: Lithologic logs of perimeter monitoring wells.

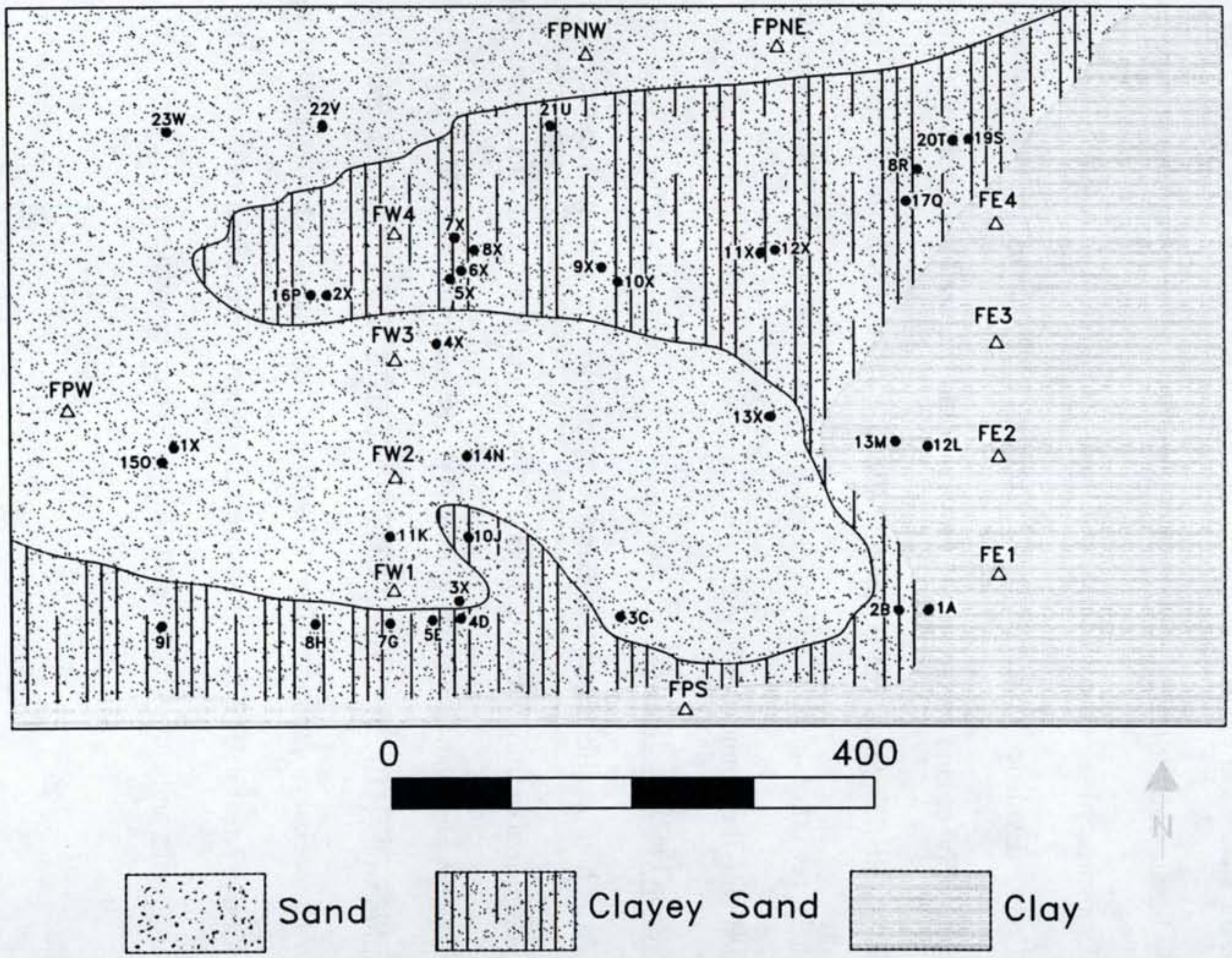
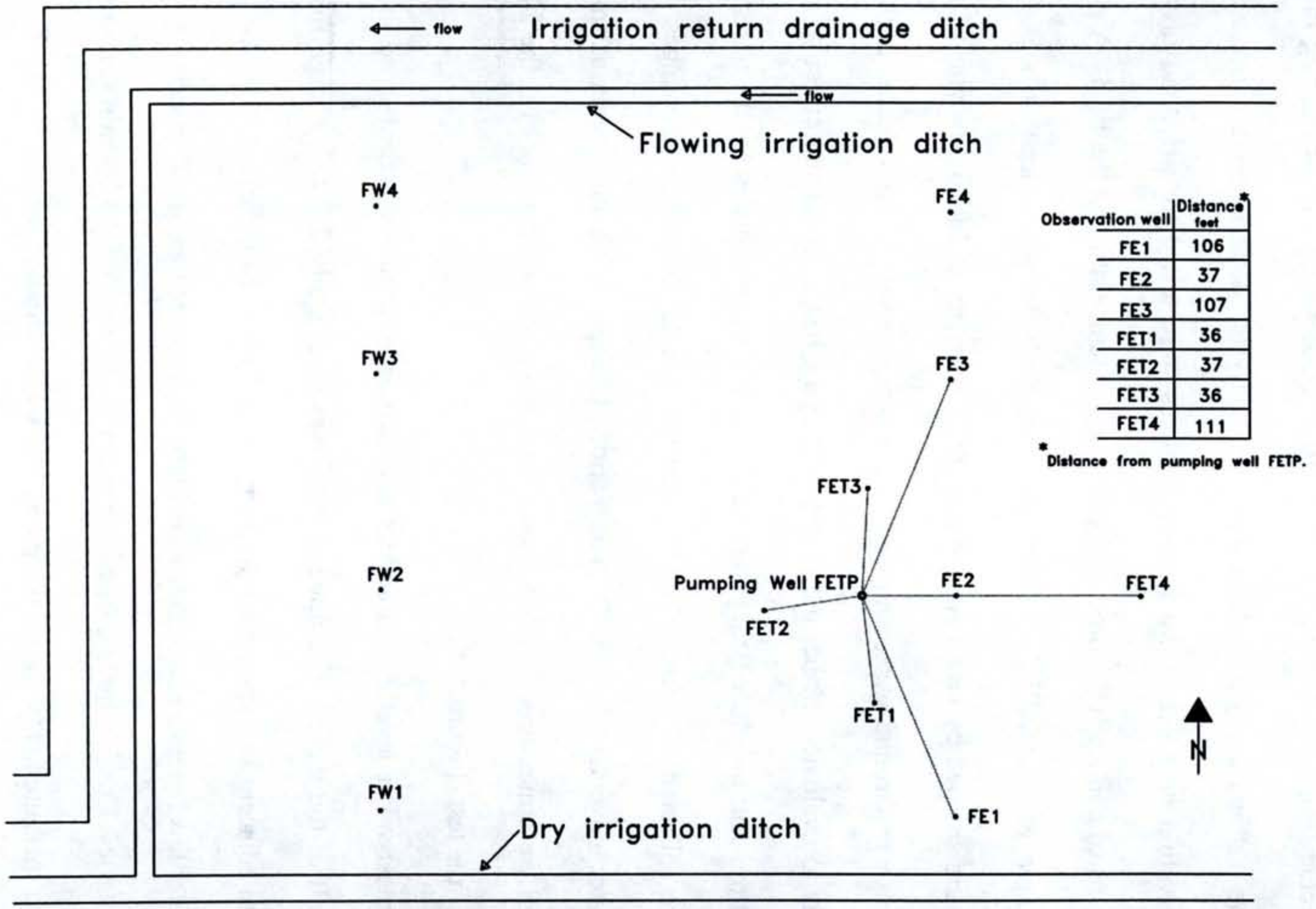


Figure A-3. Predominant soil types from two to four feet below ground surface in the Forgeon Field.

Boling (1992) described the sediments in the Forgeon Field as sandy loam, loam, and gravelly sand. Boling noted an abrupt boundary between the salt and pepper sand and the overlying units. This compositional boundary could indicate an abrupt change in the source of the sediments deposited in the field. Boling (1992) indicated a slackwater environment of deposition based on the sorting and stratification of the sediments. She believed the slackwater environment was a product of intermittent damming of the Snake River by basalt flows. Stearns et al. (1938) identified sediments at land surface and the shallow subsurface in southern Minidoka County as alluvium from the Snake River and Goose Creek. Evidence presented by O' Connor (1993) places sands deposited by the Bonneville Flood at land surface in the Forgeon Field (Figure 4). Damming of the Snake River by basalt flows was pre-Bonneville Flood. Sediments in the Forgeon Field are most likely reworked older alluvium originally deposited in a slackwater environment associated with the Bonneville Flood.

East Forgeon Field Aquifer Test

A 24 hour aquifer test was conducted by previous investigators in the east half of the Forgeon Field on July 9 and 10, 1993. The east aquifer test consisted of one pumping well and seven observation wells (Figure A-4). The pumping well (FETP) and the seven observation wells (FE1, FE2, FE3, FET1, FET2, FET3, and FET4) were completed to a depth of 10 feet below ground surface. Observation well distances from the pumping well ranged from 37 feet to 112 feet. Pressure transducers were placed in three of the seven monitoring wells and connected to a data logger to measure water levels.



Observation well	Distance* feet
FE1	106
FE2	37
FE3	107
FET1	36
FET2	37
FET3	36
FET4	111

*Distance from pumping well FETP.

Figure A-4. East aquifer test: location of pumping well and observation wells. (See Figure A-1 for the location of FE1 and FE2 within the field.)

Water levels in the remaining four observation wells and the pumping well were measured by hand. A portable, electric powered, centrifugal pump was used to pump a constant discharge of 0.67 ft^3/minute for the duration of the test. Ground water samples were collected from the pumping well at 5, 10, 15, 30, and 60 minutes during the first hour of the test and every hour thereafter. Ground water samples were collected from each observation well every two hours. Samples were tested for pH, total dissolved solids, electrical conductivity, dissolved oxygen, and temperature in the field. A portion of the sample was placed in a 125-ml polyethylene bottle and placed on ice. These samples were shipped by Greyhound Bus to the University of Idaho Analytical Lab for nitrate analysis. Ground water samples for the pumping well were collected during the aquifer test to evaluate whether the length of purging had a significant effect on nitrate concentrations and the other field parameters. Ground water samples for the observation wells were collected to evaluate the potential for nitrate concentration changes due to ground water movement over the 24-hour period. Changes in nitrate concentrations from 2 to 6 mg/l were measured in the pumping well and observation wells over the 24-hour duration of the test (Figure A-5).

Pretest water level measurements revealed an upward antecedent trend in water levels in all of the wells. The upward trend was most likely due to recharge from the water in an adjacent irrigation ditch to the north and west of the field (Figure A-4). The pretest water level measurements were analyzed by linear regression to determine the rate of the water level rise. The rate of rise in water levels was 8×10^{-5} ft/min (Figure A-6). Drawdown measurements during the pump test were corrected for this trend. Failure to remove the trend would have resulted in less drawdown and higher transmissivity values.

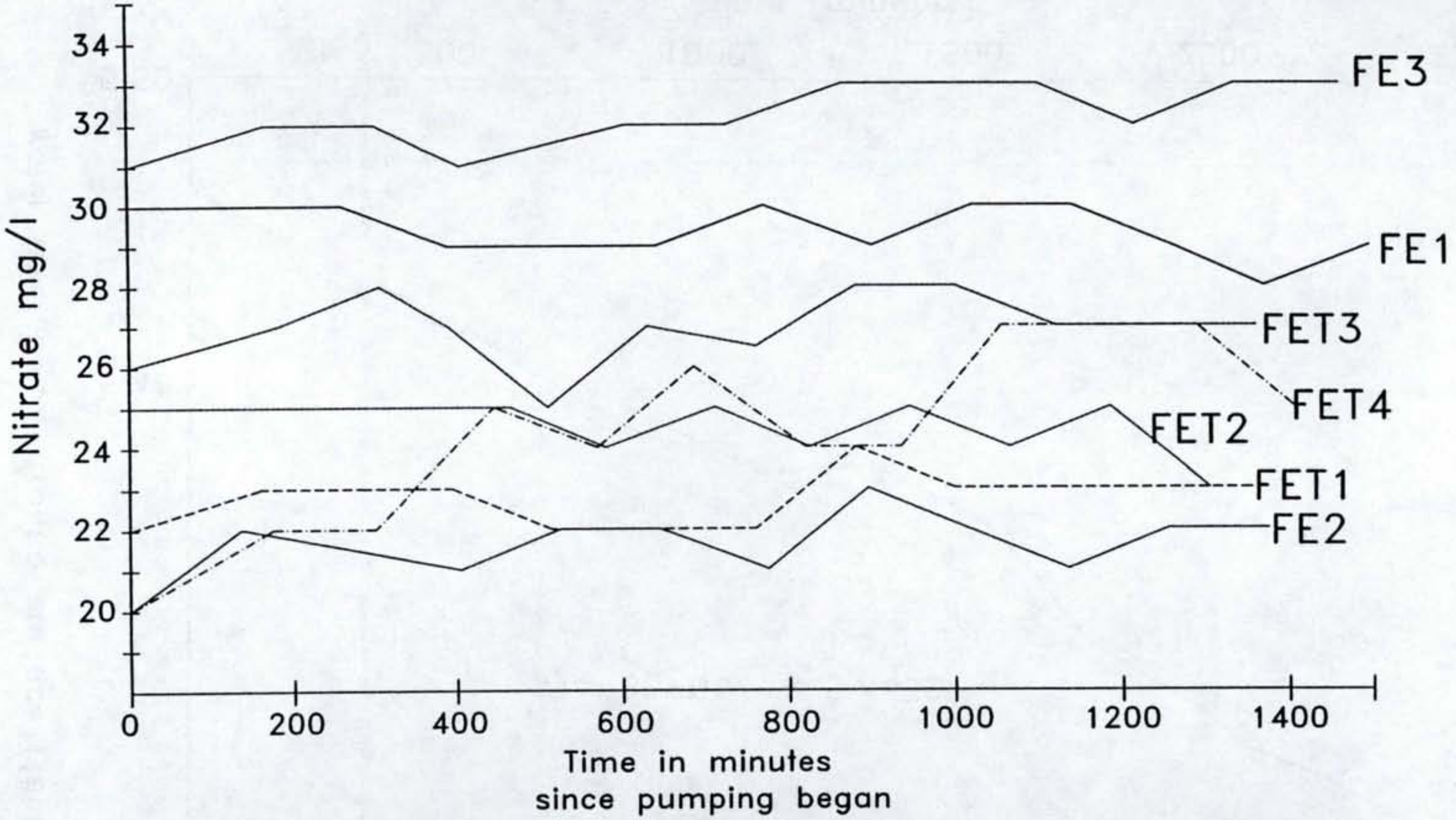


Figure A-5. Nitrate concentrations for the pumping well and observation wells observed during the east aquifer test.

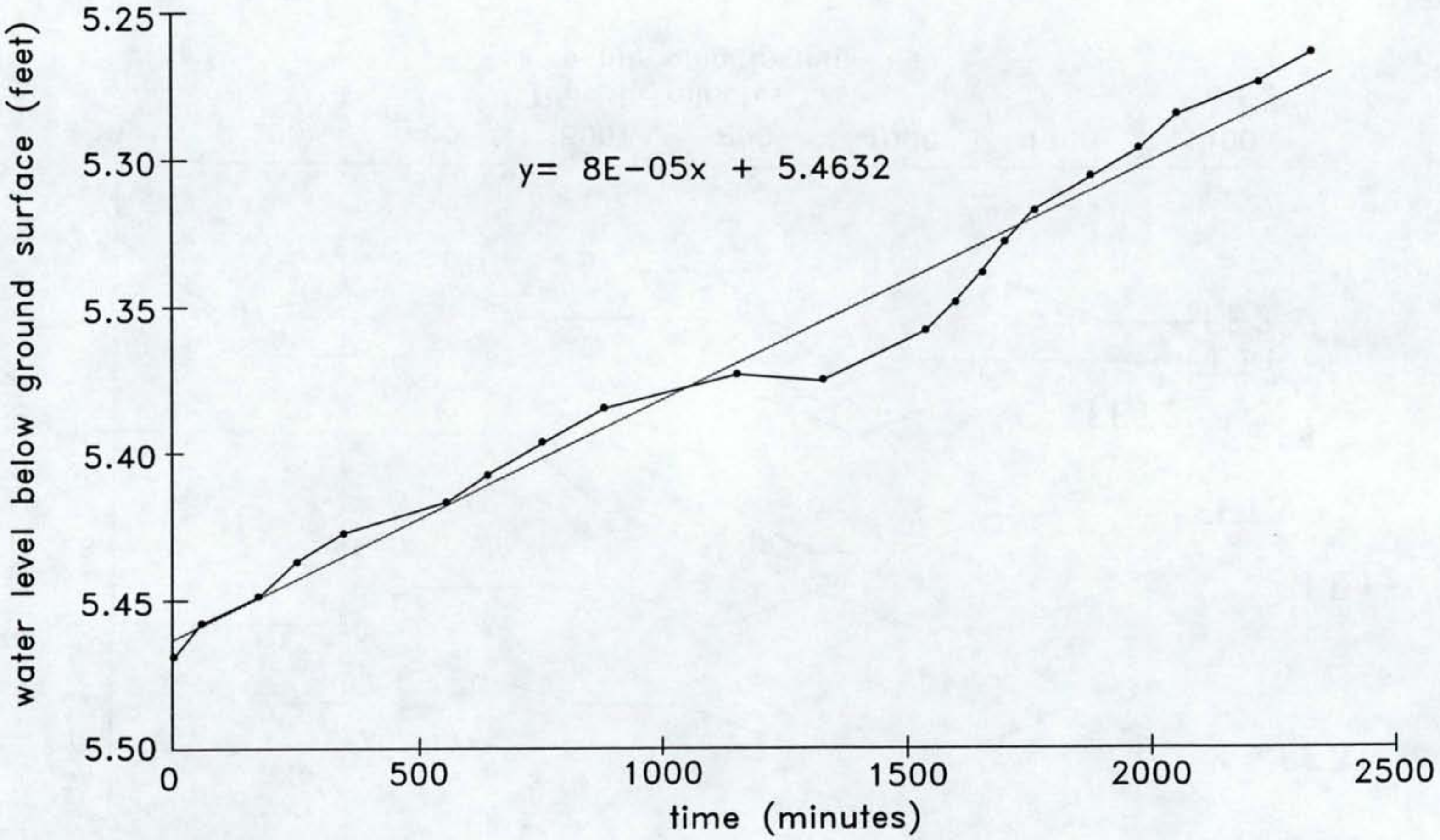


Figure A-6. Water level trend prior to east aquifer test.

Transmissivity values were calculated using the Neuman (1974) method for unconfined aquifers and the Theis (1935) for confined aquifers. According to Kruseman and deRidder (1991), the Theis the method assumes the following:

- The aquifer is confined.
- The aquifer is of infinite aerial extent.
- The aquifer is homogeneous, isotropic and of uniform thickness.
- Prior to pumping the piezometric surface is horizontal.
- The aquifer is pumped at a constant discharge rate.
- The well penetrates the entire thickness of the aquifer and flow to the well is horizontal.

The aquifer is unconfined but because of the short duration of the test (24 hours) and the low pumping rate not enough time existed for delayed yield to occur. Therefore the data are matched to the type A curve of Neuman which is the same as the Theis type curve. Matching to this curve represents the elastic response of the aquifer to pumping. Therefore the transmissivity values are good but the storativity value would be due to compaction of the aquifer and expansion of water, not the specific yield of the unconfined aquifer. Figure A-7 shows that similar curve matches were observed for the Theis (1935) type curve and the Neuman (1974) type A curve for monitoring wells FE1 and FE2. The estimated transmissivity values were identical.

Theis curve matches for the seven observation wells suggest a negative boundary was encountered by the cone of depression at approximately 120 minutes in to the test (Figures A-8a and A-8b). The negative boundary is most likely the drainage ditch adjacent north and west of the field (Figure A-4).

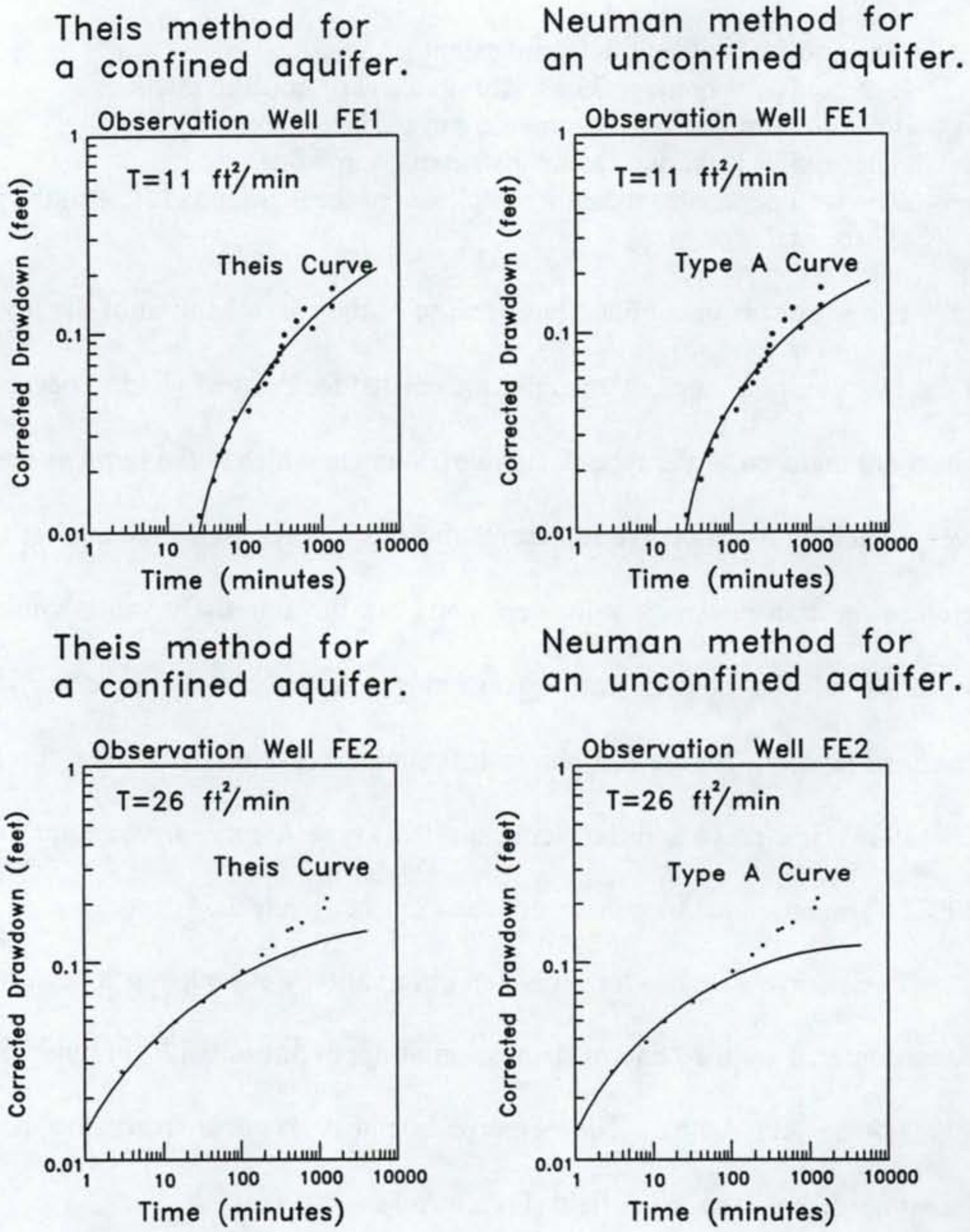


Figure A-7. Comparison of type curves generated from Neuman (1972) method for unconfined aquifer and Theis method for confined aquifer.

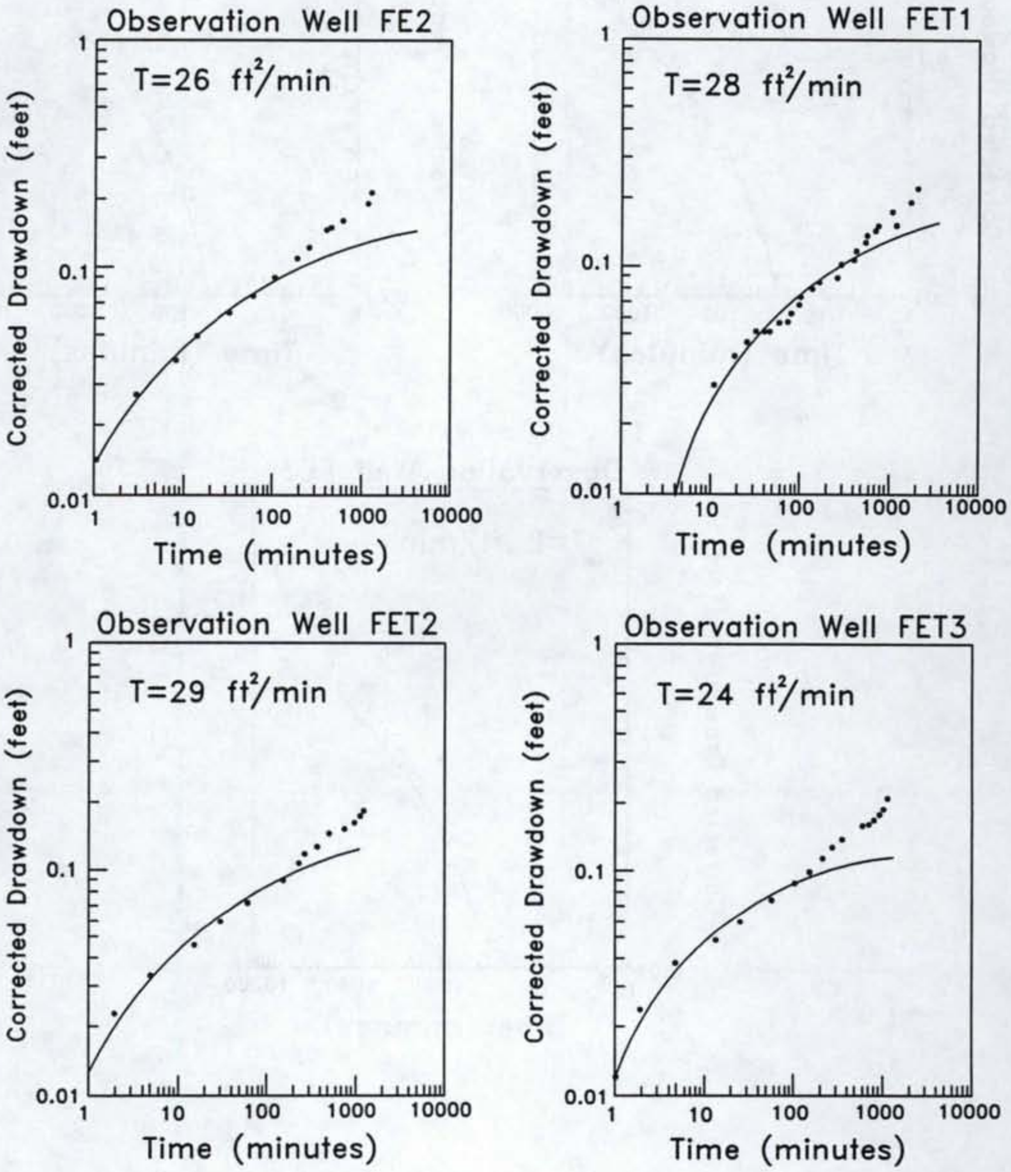


Figure A-8a. East aquifer test: Theis curve matches for observation wells within 40 feet of the pumping well.

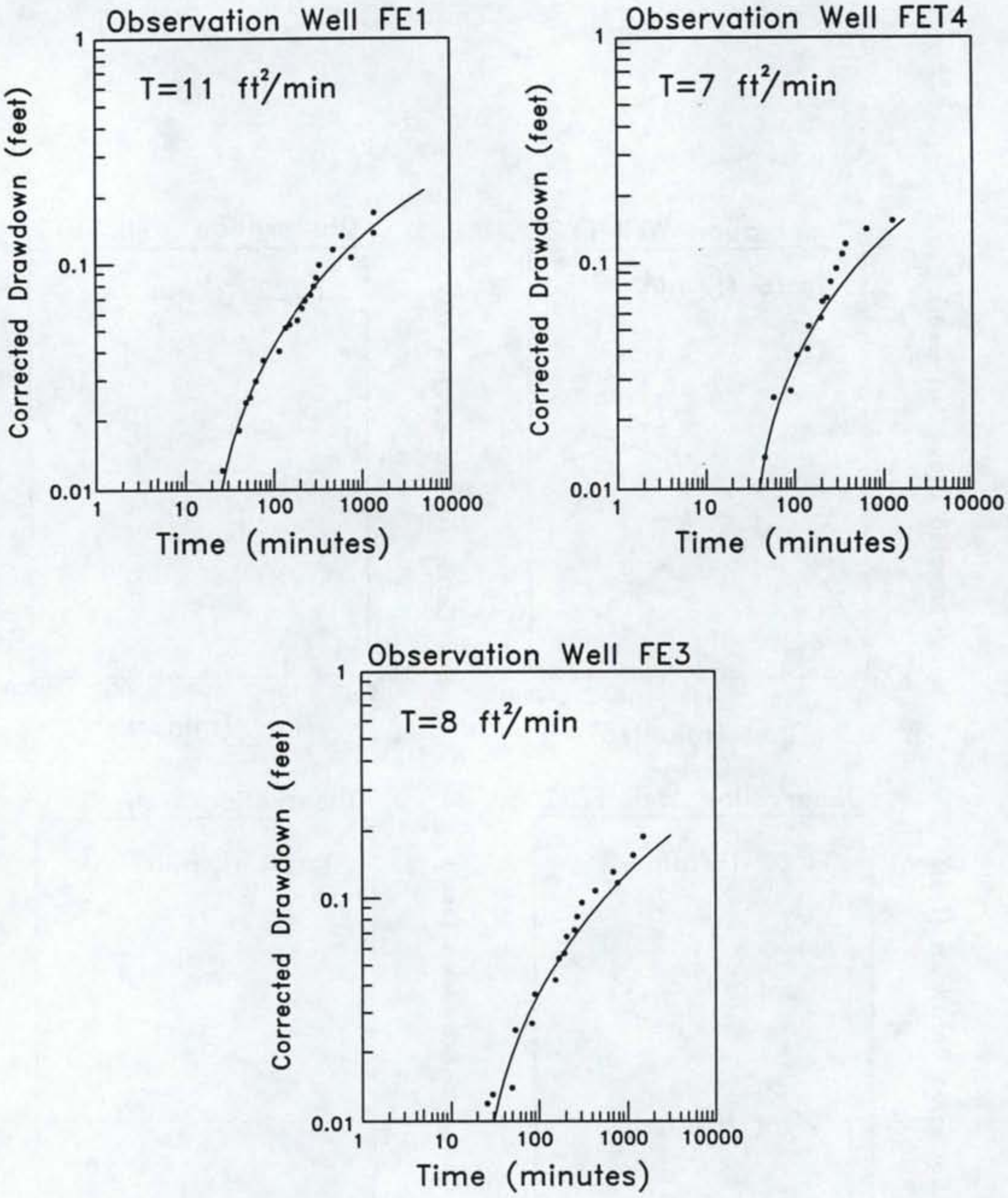


Figure A-8b. East aquifer test: Theis curve matches for observation wells more than 100 feet from the pumping well.

Transmissivity values and calculated hydraulic conductivity values for each monitoring well are presented in Table A-1.

Table A-1. Transmissivity and Hydraulic Conductivity values for Observation Wells: East Aquifer Test:

Observation Well	Distance from Pumping well (feet)	Transmissivity (ft^2/day)	Hydraulic Conductivity (ft/day)
FE1	106	15,840	634
FE2	37	37,440	1,498
FE3	107	11,520	461
FET1	37	40,320	1,613
FET2	38	41,760	1,670
FET3	37	34,560	1,382
FET4	112	10,080	403
Mean	---	27,360	1,094

The pumping well and observation wells used in the aquifer test do not fully penetrate the saturated thickness of the sand unit in the Forgeon Field. Lithologic logs for domestic wells near the Forgeon field were obtained from the Idaho Department of Water Resources to establish the saturated thickness of the sand unit. A clay layer was noted in well logs at approximately 20 to 30 feet below the ground surface. A depth of 30 feet to the clay layer was chosen, as this was noted in the log of a domestic well located closest to the field (Figure A-9). Initial water levels in the observation wells ranged from four to six feet below ground surface, therefore an aquifer thickness of 25 feet was chosen for hydraulic conductivity calculations. A very tight range of hydraulic conductivity values (K) was calculated for all of the observation wells (Table A-1). According to Fetter (1988) the magnitude of hydraulic conductivity calculated corresponds to a well-sorted sand.

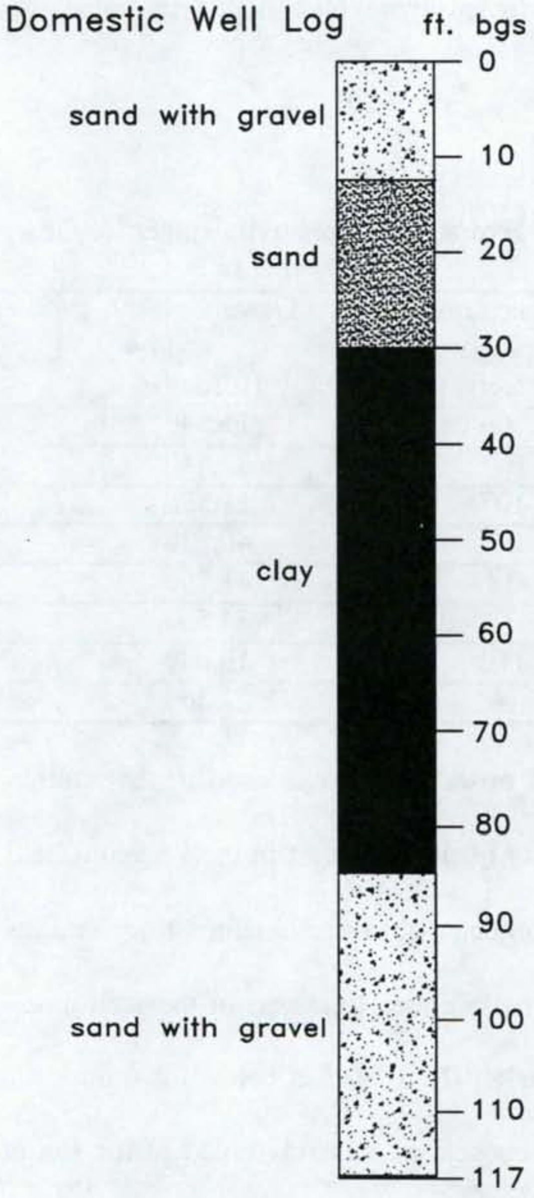
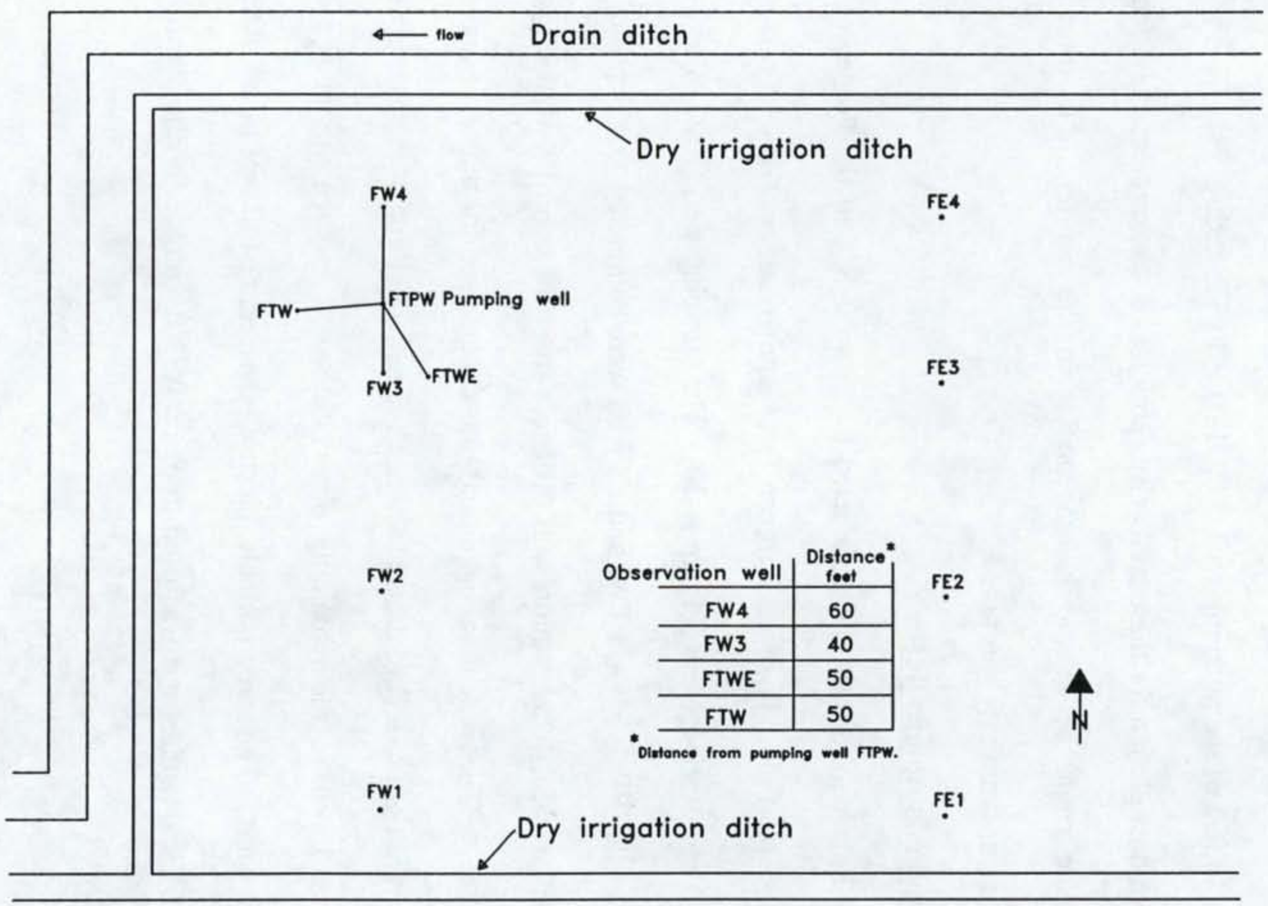


Figure A-9. Lithologic log of a domestic well near the Forgeon field used to determine the thickness of the aquifer for the two pump tests in the Forgeon field.

Freeze and Cherry (1979) also indicate the magnitude of the hydraulic conductivity calculated from the pumping test data corresponds to a clean sand. Both of these agree with the lithologies described from well cuttings for the Forgeon field. Transmissivity values for the three observation wells located over 100 feet from the pumping well (FE1, FE3, and FET4) are less than the transmissivity values calculated from the observation wells within 40 feet of the pumping well (FE2, FET1, FET2, and FET3). Curve matches for drawdown data plotted for these wells also show less deviation from the Theis curve. This difference could be due to heterogeneities in the aquifer. No directionality component of transmissivity was noted.

West Forgeon Field Aquifer Test

A 23 hour aquifer test was conducted in the west half of the Forgeon Field on August 13 and 14, 1993. The west Forgeon Field aquifer test consisted of one pumping well and four observation wells (Figure A-10). The pumping well (FWTP) and the four observation wells (FW3, FW4, FTW, and FTWE) were completed to a depth of 10 feet below ground surface. Observation well distances from the pumping well ranged from 40 feet to 60 feet. The same data logger and transducers used for the east Forgeon Field aquifer test were used to record drawdown measurements in three of the four observation wells. Water levels in the remaining observation well and the pumping well were measured by hand. The same portable, electric powered, centrifugal pump used for the east Forgeon Field aquifer test was used to pump 0.33 ft^3/minute for the duration of the test.



Observation well	Distance* feet
FW4	60
FW3	40
FTWE	50
FTW	50

*Distance from pumping well FTPW.

Figure A-10. West aquifer test: Location of pumping well and observation wells.

Ground water samples were collected from the pumping well at 10, 30, and 60 minutes during the first hour of the test and every two hours thereafter. Ground water samples were collected from each observation well every two hours. Ground water samples were tested for pH, total dissolved solids, electrical conductivity, dissolved oxygen, and temperature in the field. A portion of each sample was placed in a 125-ml polyethylene bottle and placed on ice. These samples were shipped by Greyhound Bus to the University of Idaho Analytical Lab for nitrate analysis. Ground water samples were collected from the pumping well during the aquifer test to evaluate whether the length of purging had a significant effect on nitrate concentrations and the other field parameters. As with the east Forgeon Field aquifer test nitrate concentrations for the pumping well and each of the observations wells did not show a significant change in nitrate concentrations over the 24 hour duration of the test (Figure A-11). Water levels measured in all the observation wells used for the west Forgeon Field aquifer test showed an upward trend in water table elevation prior to the aquifer test (Figure A-12). The upward trend in water levels prior to the test could be the result of regional recharge to the shallow aquifer from irrigation. Transmissivity values were estimated by matching drawdown data to the Neuman (1974) type A curve. Curve matches for data collected for each of the four observation wells is presented in Figure A-13.

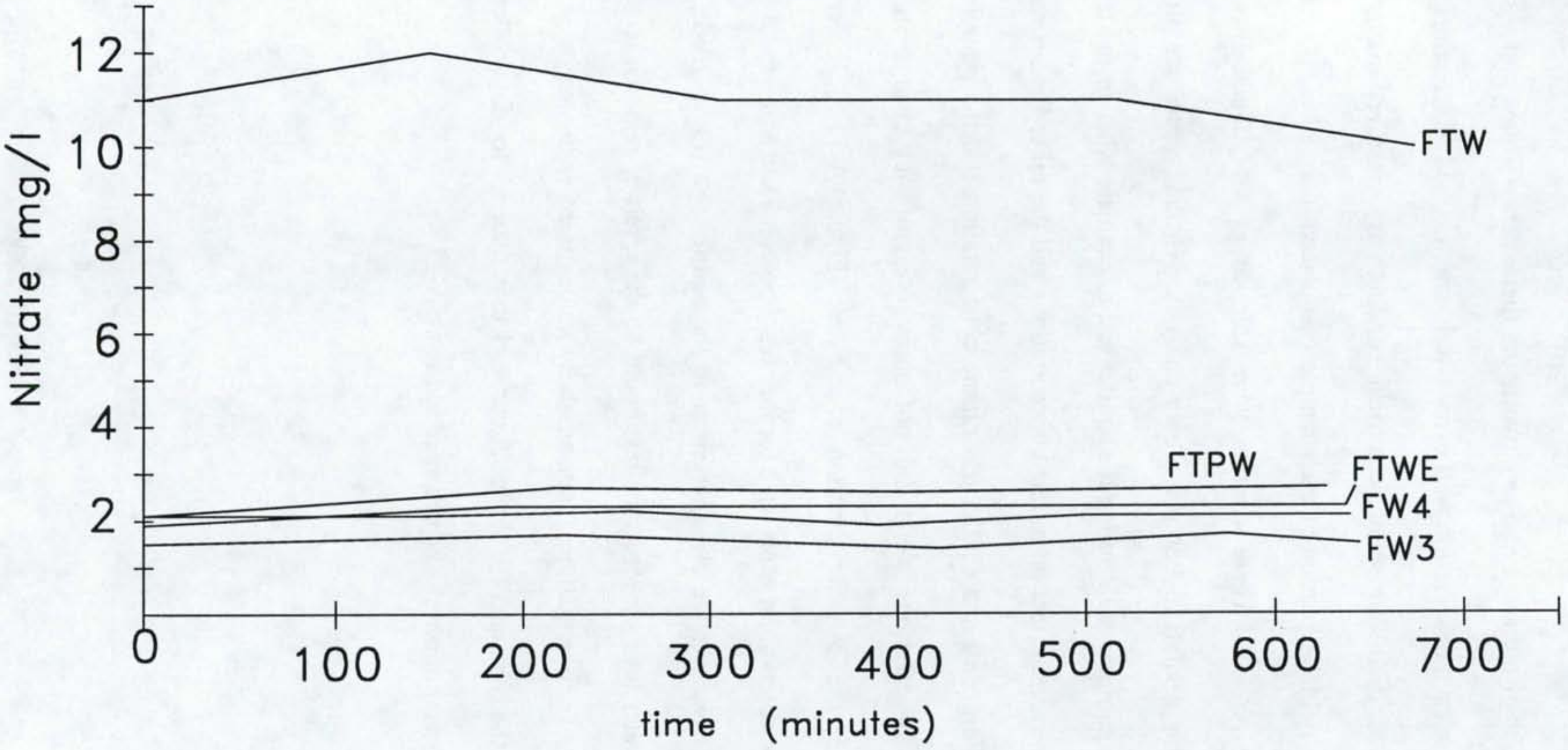


Figure A-11. Nitrate concentrations for the pumping well and observation wells measured during the aquifer test in the west half of Forgeon Field.

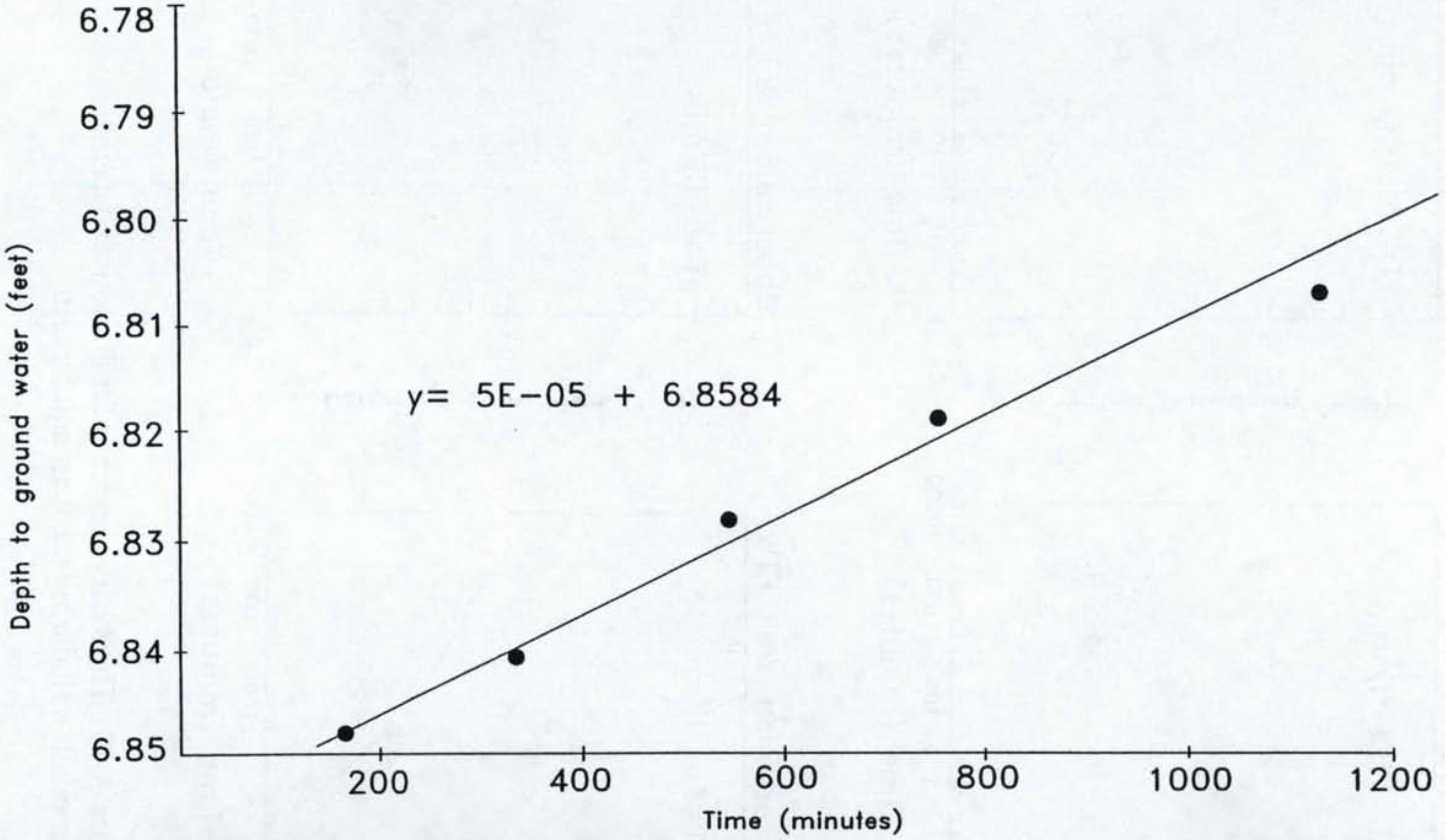


Figure A-12. Water level in the monitoring wells in the west half of the Forgeon Field prior to the west aquifer test.

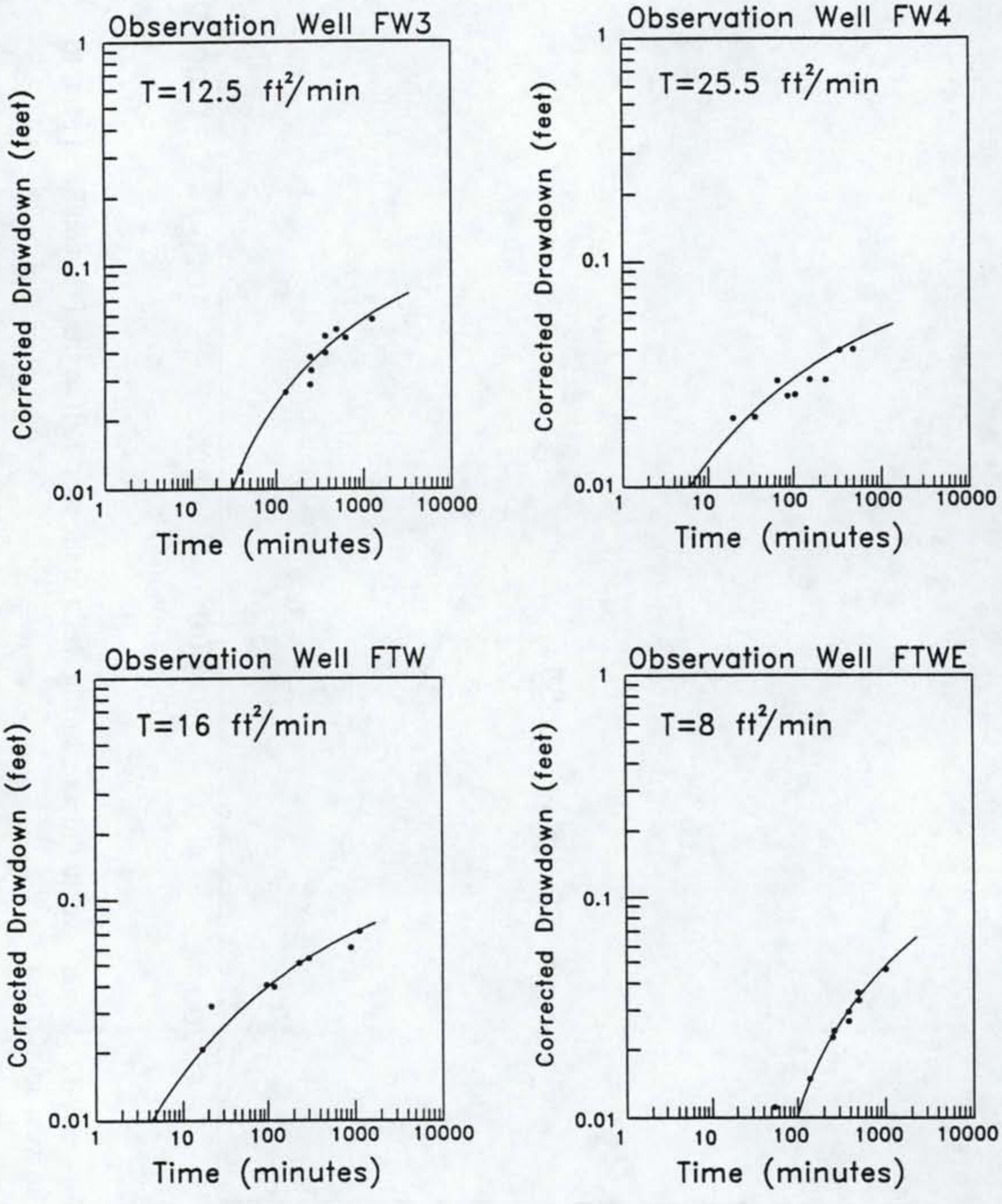


Figure A-13. Theis curve matches for drawdown data measured in the observation well during the west aquifer test.

Transmissivity and hydraulic conductivity values for each observation well are presented in Table A-2.

Table A-2. Transmissivity and Hydraulic Conductivity for Observation Wells: West Aquifer Test.

Observation Well	Distance from Pumping Well (feet)	Transmissivity (ft^2/day)	Hydraulic Conductivity (ft/day)
FW3	40	18,000	720
FW4	60	36,720	1,469
FTW	50	23,040	922
FTWE	50	11,520	461
Mean	---	22,320	893

Hydraulic Gradient and Ground Water Velocity:

Ground water elevations for each monitoring well were collected monthly since May of 1992. Monthly water level measurements were contoured in Surfer^{TM} using the minimum curvature option (Briggs, 1974). Water table contour maps for each month were evaluated to determine an average gradient and general ground water flow direction. A sample water table map and gradient calculation for the Forgeon Field is presented in Figure A-14.

Ground water gradients in the Forgeon Field ranged from 0.0001 to 0.005. The mean gradient was 0.001. Estimations of ground water velocity were made using the minimum, maximum, and mean gradients. The ground water velocity estimates are presented in Table A-3.

Table A-3. Calculations of Ground Water Velocities: Forgeon Field

Hydraulic Gradient	Ground water velocity (ft/day)
Minimum: 0.0001	0.29
Mean: 0.001	2.9
Maximum: 0.005	14.5

The values presented in Table A-3 are based on the following equation:

$$\text{Ground Water Velocity} = v = \frac{K}{n_e}\frac{dh}{dl} \qquad \text{Eq.} \quad [1.0]$$

Where:

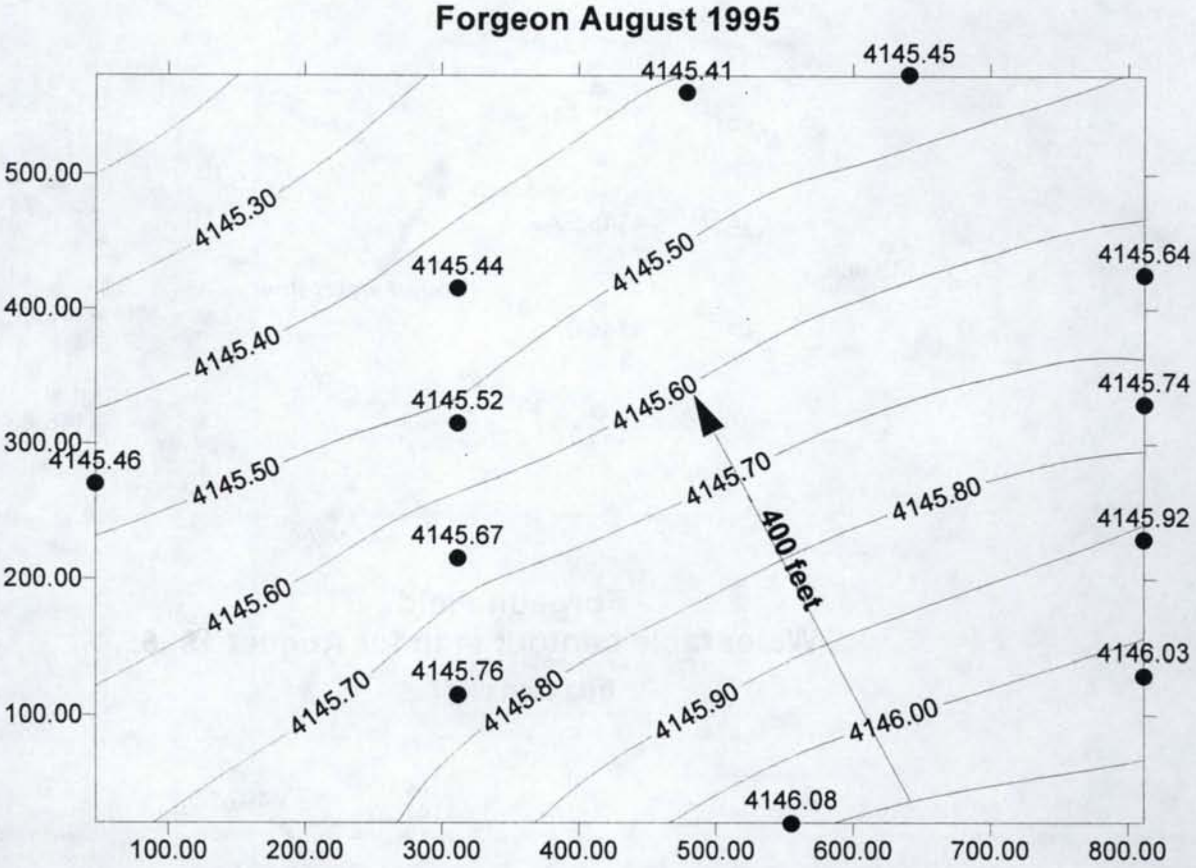
K = hydraulic conductivity [1,021ft/day (average of all pumping tests)]

n_e = effective porosity (0.35)

$\frac{dh}{dl}$ = hydraulic gradient $= \frac{0.5\,feet}{400\,feet} = 0.001$.

Direction of Ground Water Flow:

General ground water flow direction is to the northwest, following the slope of the land surface (Figure A-14). The general direction of ground water flow is reversed temporarily during periods of flow in the irrigation ditch along the north and west edges of the field (Figure A-15).



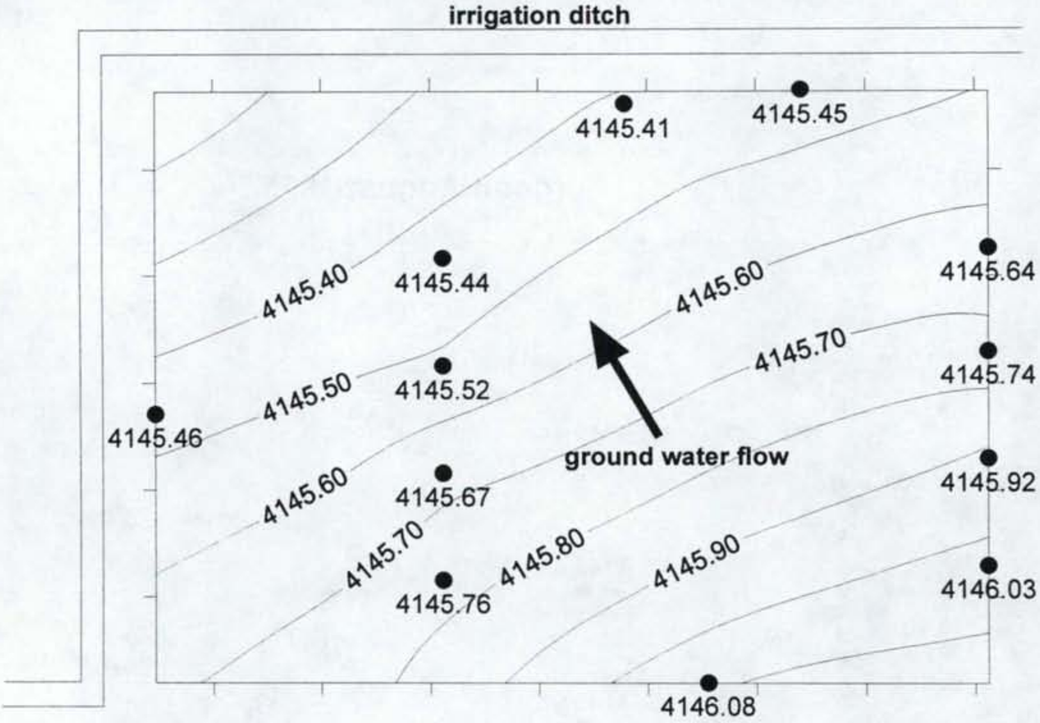
Forgeon August 1995

Gradient = 0.5 feet (change in water table elevation)
400 feet (distance)

Gradient = 0.001

Figure A-14. Hydraulic gradient present in August 1995 in the Forgeon field.

Forgeon Field:
Water table contour map for August 1995.



Forgeon Field
Water table contour map for August 1996.

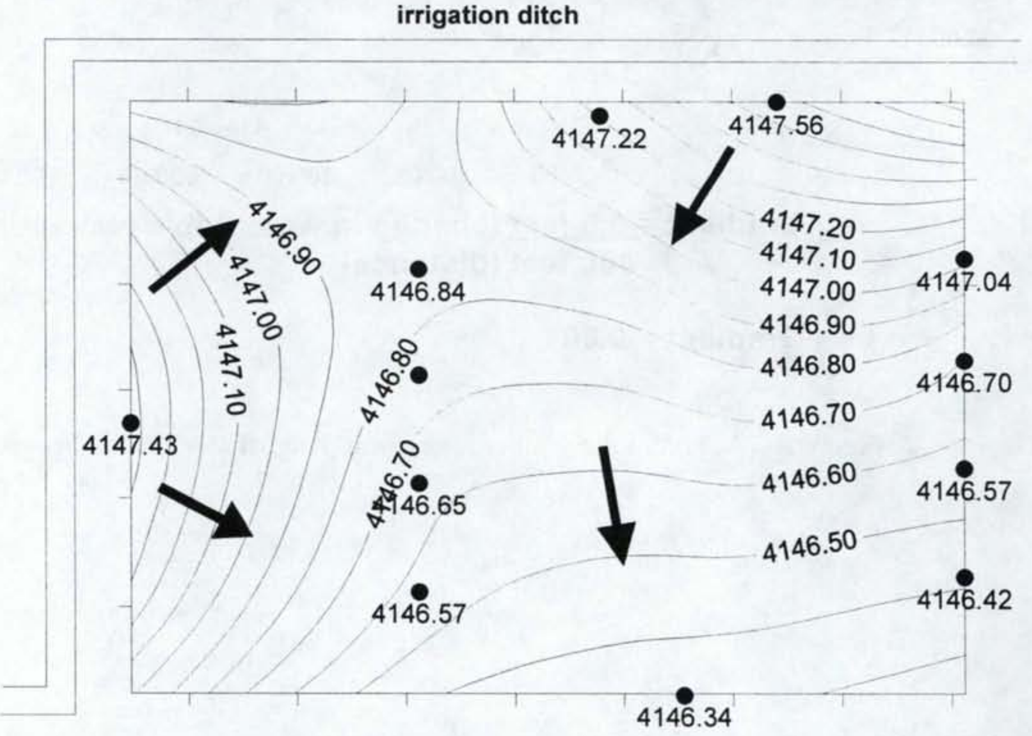


Figure A-15. Hydraulic gradient present in August 1996 in the Forgeon field showing the effect of leakage from the irrigation ditch along the north and west sides of the field.

Moncur Field

Lithologic Descriptions

Composite well cutting samples were collected in one-foot intervals from three to eleven feet below ground surface during installation of each of the twelve monitoring wells in the Moncur Field (Figure A-16). Lithologic logs derived from visual inspection of the well cuttings are presented in Figures A-17a, A-17b, and A-17c. Lithologies in the Moncur Field are predominantly silts. Very fine sand was encountered at a depth of nine to ten feet in monitoring wells MW1, MW2, and ME3. A domestic well is present at the Moncur residence adjacent to the southeast corner of the demonstration field. This well is completed at a depth of approximately 40 feet. Discussion with Stan Moncur, owner and proprietor, revealed that this well has pumped fine sand in the past.

Boling (1992) described the sediments in the Moncur Field as silty clay loam, silt loam, and very fine sandy loam. She noted perched water at varying depths in the vadose zone and described the sediments in the Moncur Field as stratified slackwater deposits rich in silt and very fine sand. Boling (1992) associated slackwater deposits with the intermittent damming of the Snake River by basalt flows. However, evidence presented by O'Connor (1993) places the Moncur Field within the maximum stage of the Bonneville Flood (Figure 4). This suggests sediments in the Moncur Field could be associated with the waning stages of the Bonneville Flood.

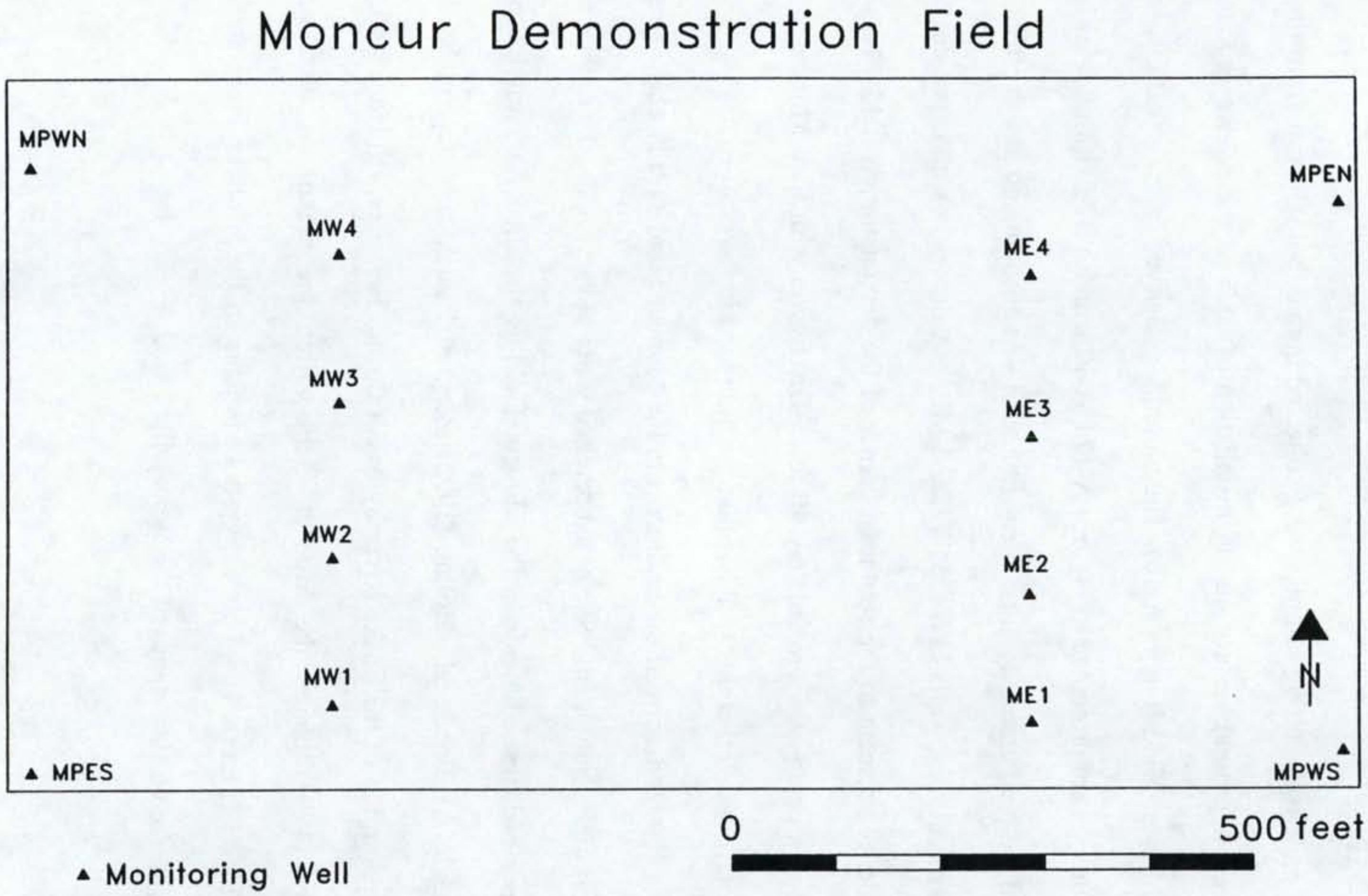


Figure A-16. Location of the monitoring wells in the Moncur Field.

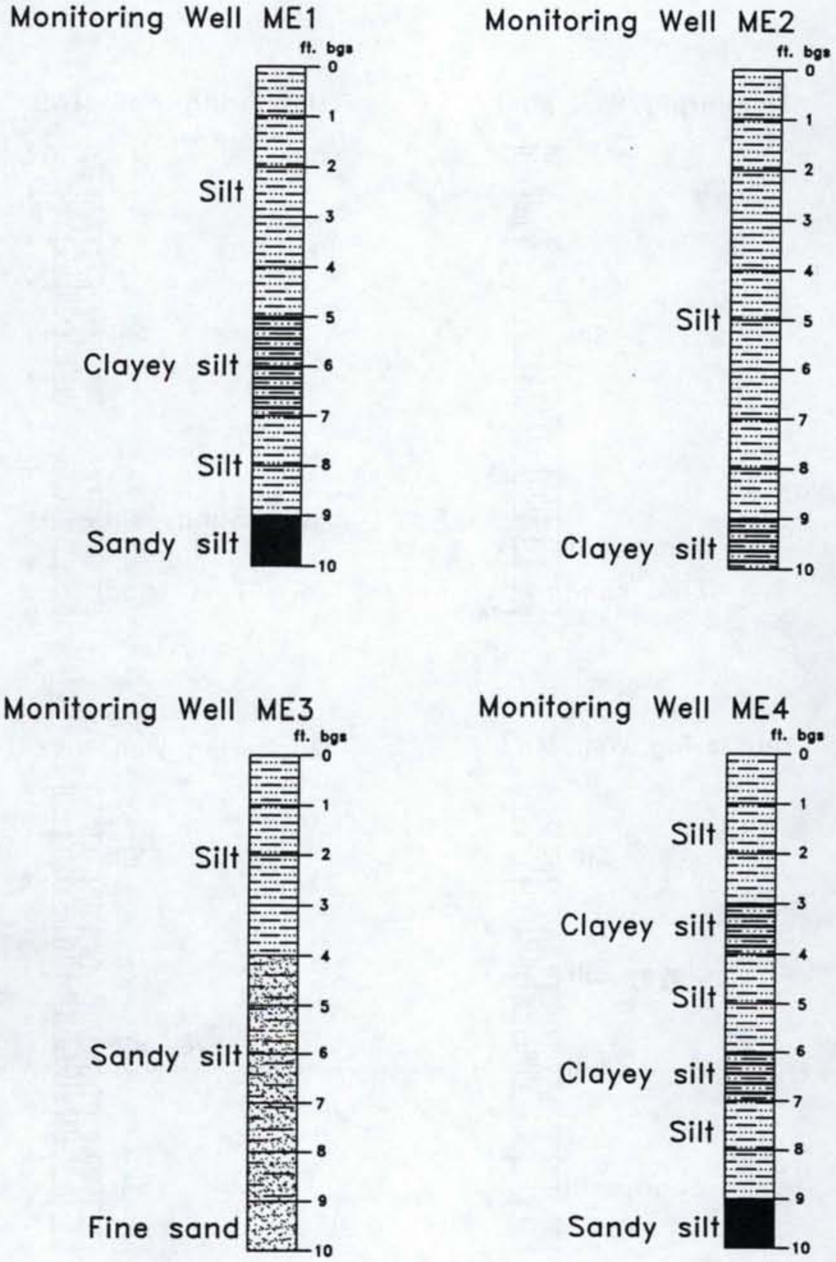


Figure A-17a. Moncur Field: Lithologic logs for east monitoring wells.

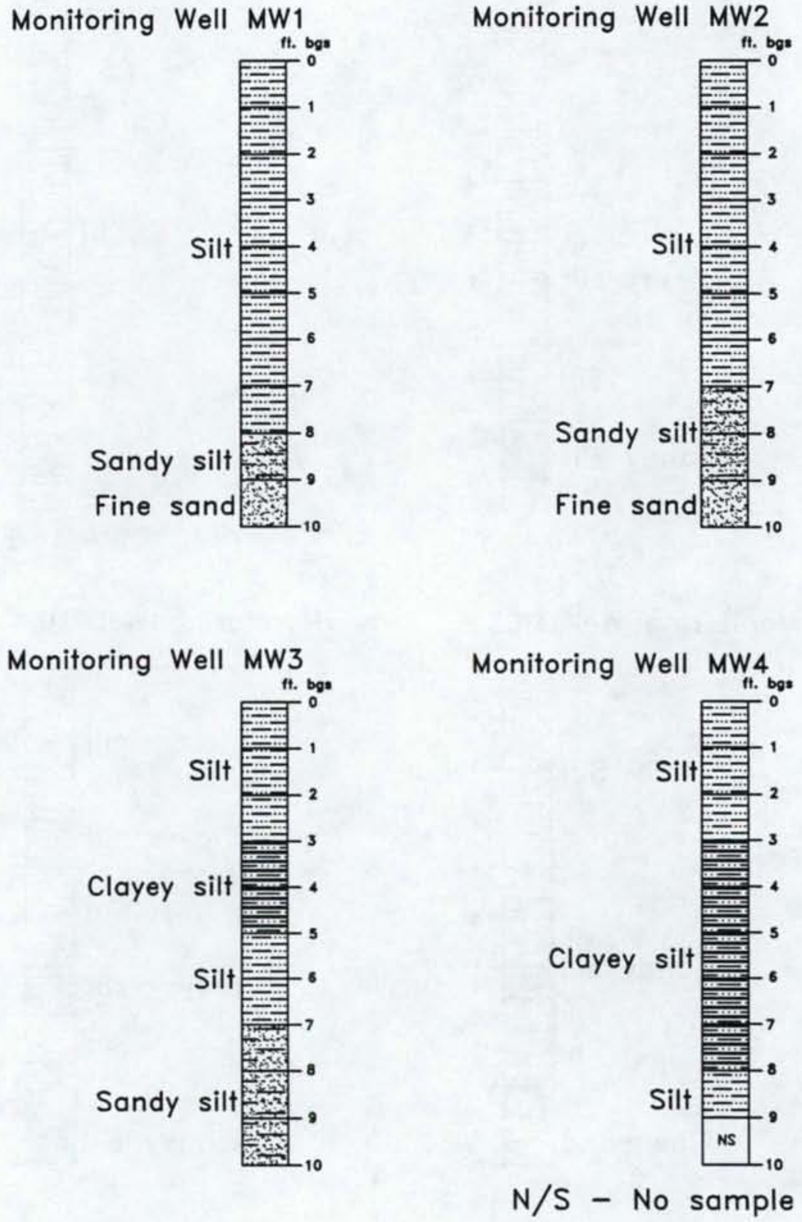
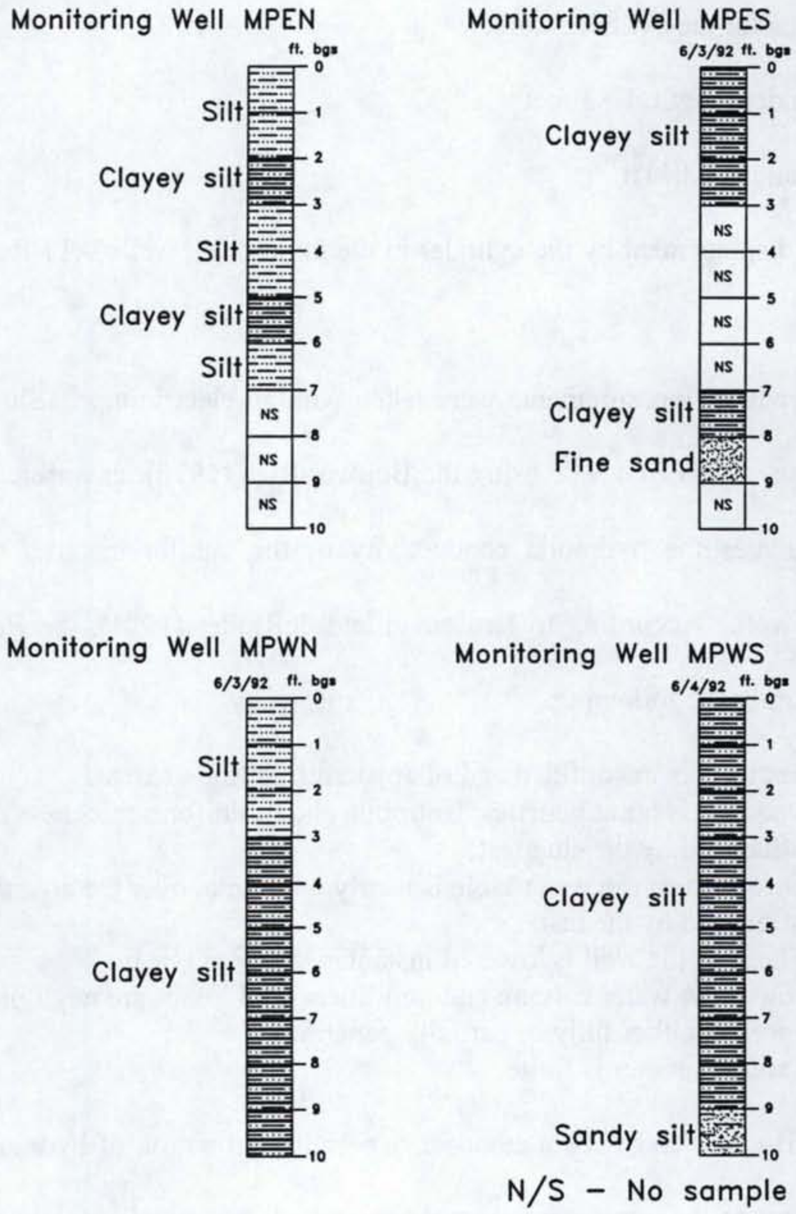


Figure A-17b. Moncur Field: Lithologic logs for west monitoring wells.



Monitoring Well MPEN

Monitoring Well MPES

Monitoring Well MPWN

Monitoring Well MPWS

Figure A-17c. Moncur Field: Lithologic logs of perimeter monitoring wells.

Slug Tests

Slug tests were conducted in monitoring wells in the Moncur Field during the summer of 1992. The tests were conducted with a slug testing apparatus that consisted of a sealed, weighted, cylinder of one-inch diameter PVC pipe.

Specifications for the cylinder were:

Cylinder length: 1.83 feet

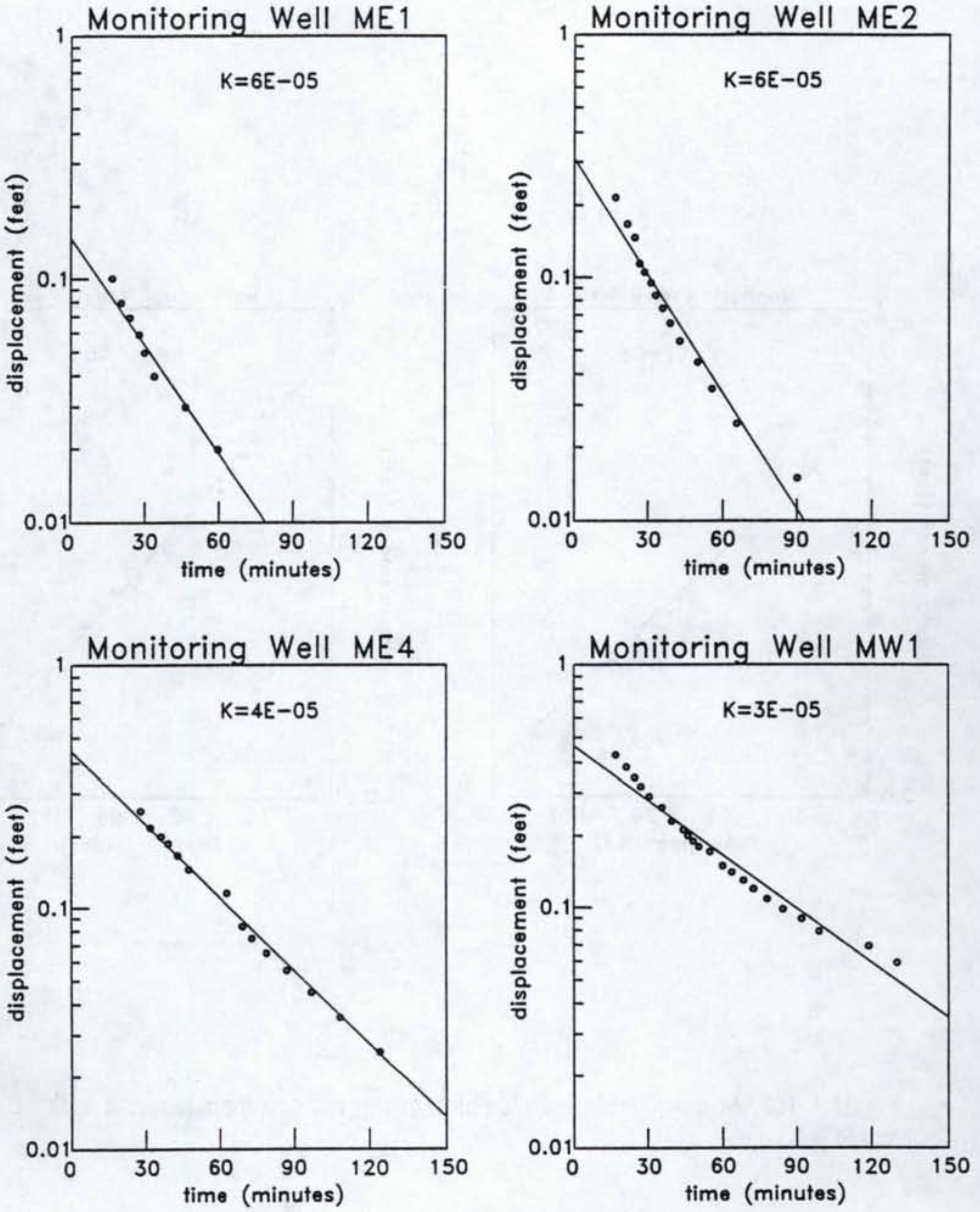
Volume is $0.011 \mathrm{ft}^3$

Water level displacement by the cylinder in the monitoring wells(0.17 feet diameter) was 0.519 feet.

Water level measurements were taken with an electric tape. Slug test data were analyzed with AQTESOLV™ using the Bouwer-Rice (1976) unconfined solution. This method estimates the hydraulic conductivity of the aquifer material surrounding the screen of a well. According to Kruseman and deRidder (1991), the Bouwer and Rice solution assumes the following:

-The aquifer is unconfined and of apparently infinite extent.
-The aquifer is homogeneous, isotropic, and of uniform thickness over the area influenced by the slug test.
-Prior to the test the water table is nearly horizontal over the area that will be influenced by the test.
-The head in the well is lowered instantaneously at $t_o = 0$.
-Inertia of the water column and non-linear well losses are negligible.
-The well is either fully or partially penetrating.
-The well diameter is finite.

The Bouwer and Rice method only permits estimation of hydraulic conductivity for the portion of the aquifer penetrated by the well screen. Semi-log plots of the slug test data are presented in Figures A-18a and A-18b. Hydraulic conductivity values calculated from the slug test analyses are presented in Table A-4.



Bouwer–Rice analyses of slug test data.

Figure A-18a. Moncur Field: Semi-log plots of the slug test data for monitoring wells ME1, ME2, ME4, and MW1.

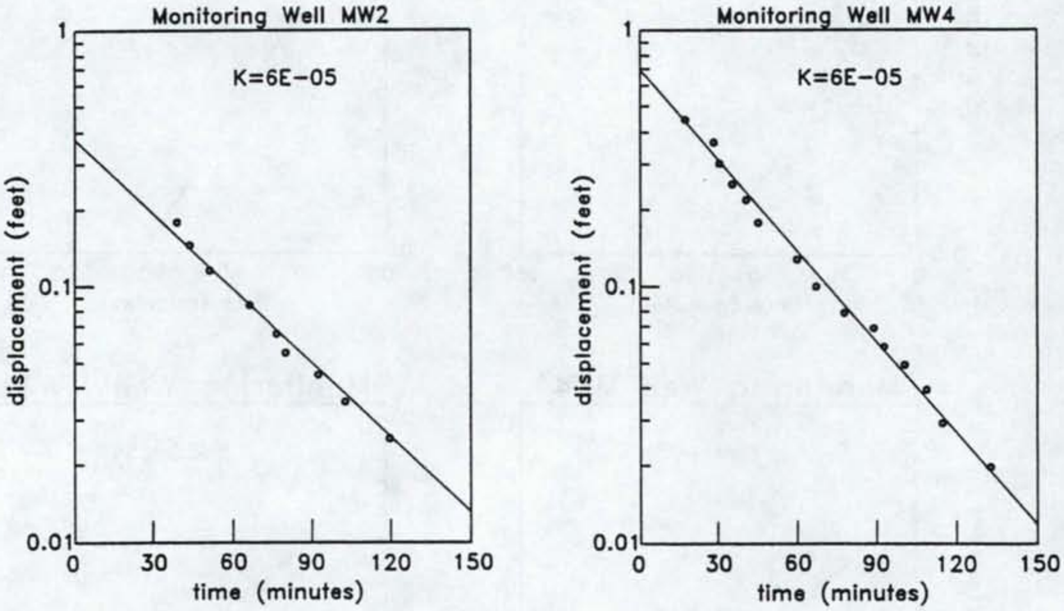


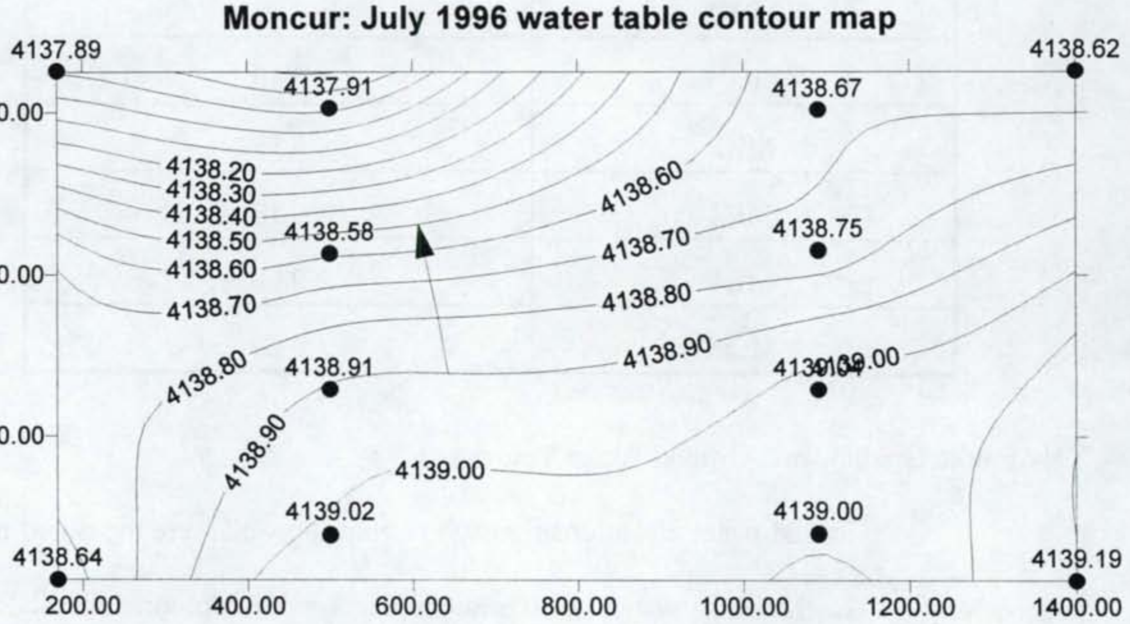
Figure A-18b. Moncur Field: Semi-log plots of slug test data for monitoring wells MW2 and MW4.

Table A-4. Slug Test Results: Moncur Field.

Monitoring Well	Hydraulic Conductivity (ft/day)
MW1	0.04
MW2	0.08
MW4	0.10
ME1	0.13
ME2	0.13
ME4	0.06
Mean	0.09

Hydraulic Gradient and Ground Water Velocity:

Ground water elevations for each monitoring well were measured monthly since May 1992. Monthly water level measurements were contoured in SURFER™ using the minimum curvature contouring option (Briggs, 1974). Water table contour maps for each month were evaluated to estimate an average gradient and general ground water flow direction. A sample water table map and gradient calculation for the Moncur test field is presented in Figure A-19.



Gradient = 0.5 feet (change in water table elevation)
200 feet (distance)

Gradient = 0.003

Figure A-19. Hydraulic gradient present in July 1996 in the Moncur field.

Hydraulic gradients in the Moncur field ranged from 0.0004 to 0.004. The mean gradient was 0.002. Estimations of ground water velocity were made using the minimum, maximum, and mean gradients. A mean hydraulic conductivity value of 0.09 feet per day from the slug test data was used in the calculations. Effective porosity was estimated to be 0.30. The calculated ground water velocity values based on Eq. 1.0 are presented in Table A-5.

Table A-5. Calculated Ground Water Velocities: Moncur field

Gradient	Ground water velocity (ft/day)
Minimum: 0.0004	0.0001
Mean: 0.002	0.0006
Maximum: 0.004	0.0012

Direction of Ground Water Flow:

Fine grained soils in the Moncur field drain slowly. Therefore, irrigation timing and location prior to water level measurements could affect water levels at individual monitoring wells. The general direction of ground water flow is north/northwest. However, ground water flow in some months was to the east and west (Figure A-20).

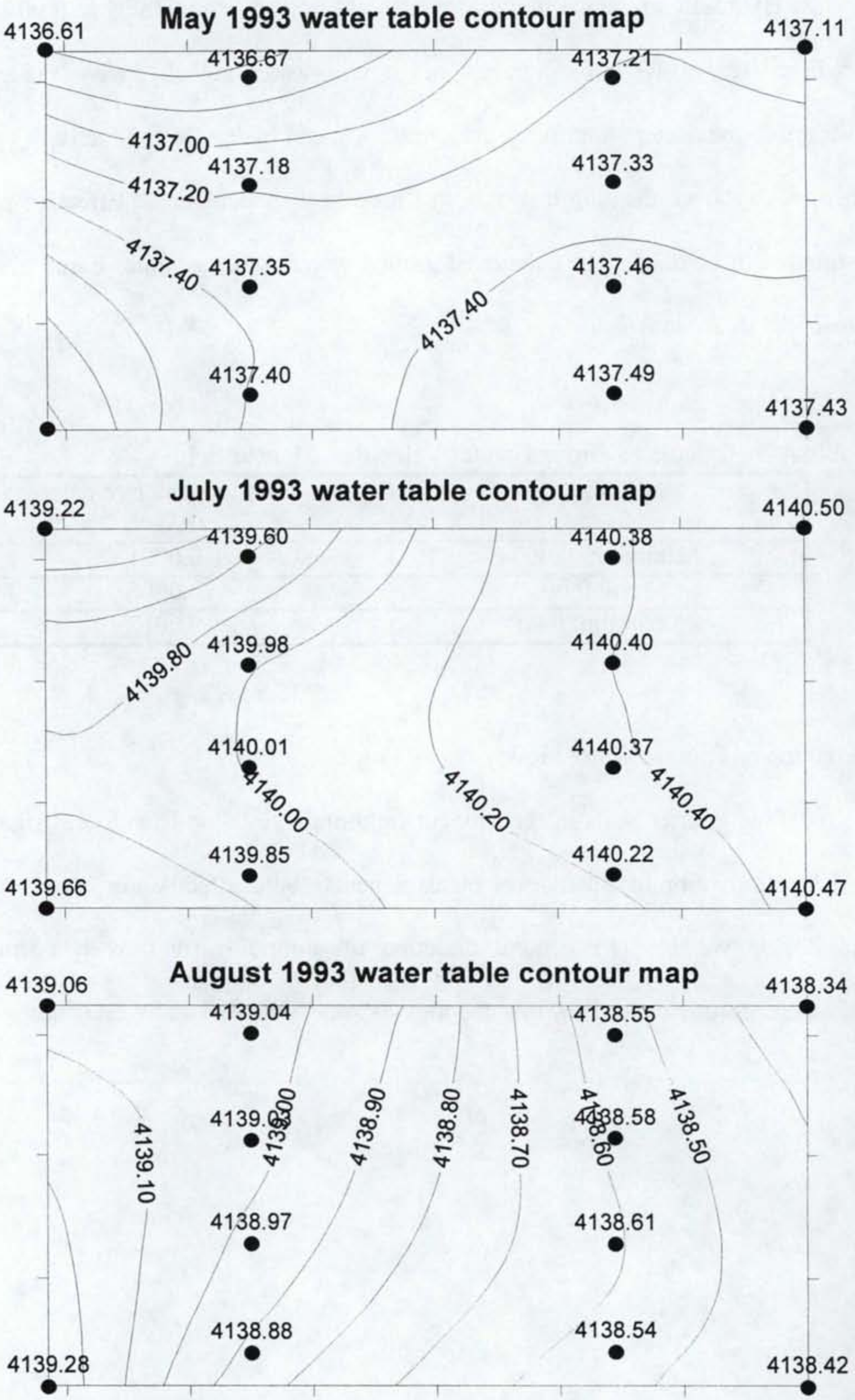


Figure A-20. Contour maps of water table elevations showing the typical variability in ground water flow directions in the Moncur field.

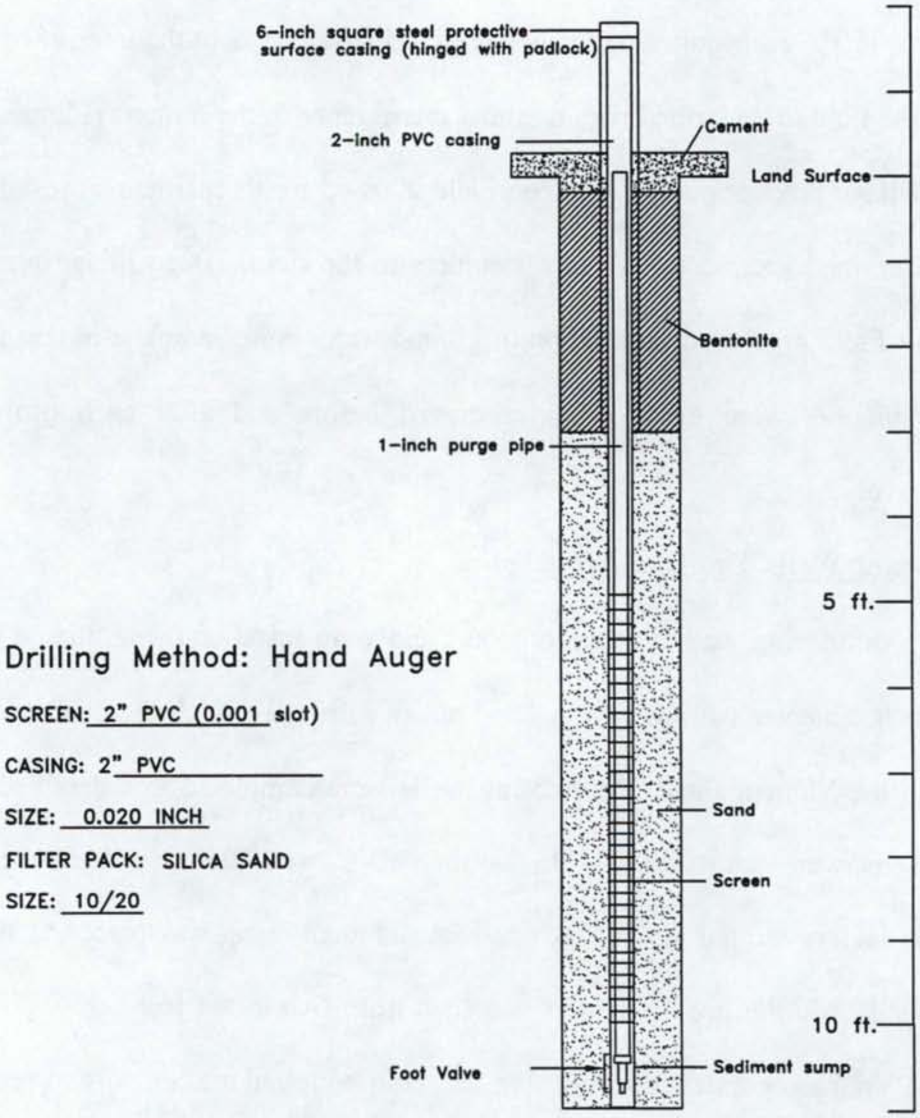
SOIL WATER AND SOIL WATER DATA COLLECTION AND ANALYSES

Sampling Network Design and Installation

The twelve monitoring wells in both the Moncur and Forgeon Fields were installed in 1992. Monitoring wells were installed in rows in the interior of the fields to allow the field to be farmed with minimal interference to the farmers (Figures A-1 and A-16). Tillage practices in the Forgeon Field allowed for the permanent installation of the lysimeters and ground water point samplers in the field. Deep tillage practices in the Moncur Field precluded installation of ground water point samplers in that test field and the lysimeters were installed and removed before and after each growing season, respectively.

Monitoring Wells: Design and Installation

Monitoring wells in the Forgeon Field were installed using a hand auger with a four-inch diameter cutting bit. A hand auger with a five-inch diameter cutting bit was used in the Moncur Field. Monitoring wells were completed to a depth of eleven feet. The wells were constructed with two-inch PVC well casing and number ten (0.010 inches) factory slotted screen. A one-foot sediment sump was placed at the bottom of each well. Monitoring wells were screened from five to ten feet below ground surface. Solid PVC casing extended from five feet below ground surface to two feet above land surface. A filter pack of Colorado 10/20 silica sand was placed from eleven to four feet below ground surface at the Forgeon Field and 20/40 sand was used at the Moncur Field. A seal of bentonite chips was placed from four feet to one foot below ground surface and hydrated. A cement surface cap was poured at the land surface (Figure A-21).



Drilling Method: Hand Auger

SCREEN: 2" PVC (0.001 slot)

CASING: 2" PVC

SIZE: 0.020 INCH

FILTER PACK: SILICA SAND

SIZE: 10/20

Figure A-21. Monitoring well design for wells installed in the Moncur and Forgeon Fields.

A dedicated one-inch diameter PVC purge pipe was fitted inside the two inch casing in each monitoring well to preclude cross contamination during ground water sampling. A foot valve was attached to the down hole end of the purge pipe to prevent back flow. The upper two inches of the one-inch purge pipe was threaded. A twelve inch galvanized steel nipple was attached to the threaded end of the one inch purge pipe during purging prior to sample collection. This nipple was used to connect the purge pipe to an intake hose from a small gasoline powered centrifugal pump, used to purge water from the monitoring well prior to sampling. This design provided an efficient means of purging the monitoring wells with limited equipment. A 0.25 inch outside diameter polyethylene, plastic tube was attached to the outside of the purge pipe to a depth of ten feet. This tubing was used to withdraw a sample from the monitoring well using a flask, two-holed stopper, and hand vacuum pump (Figure A-22).

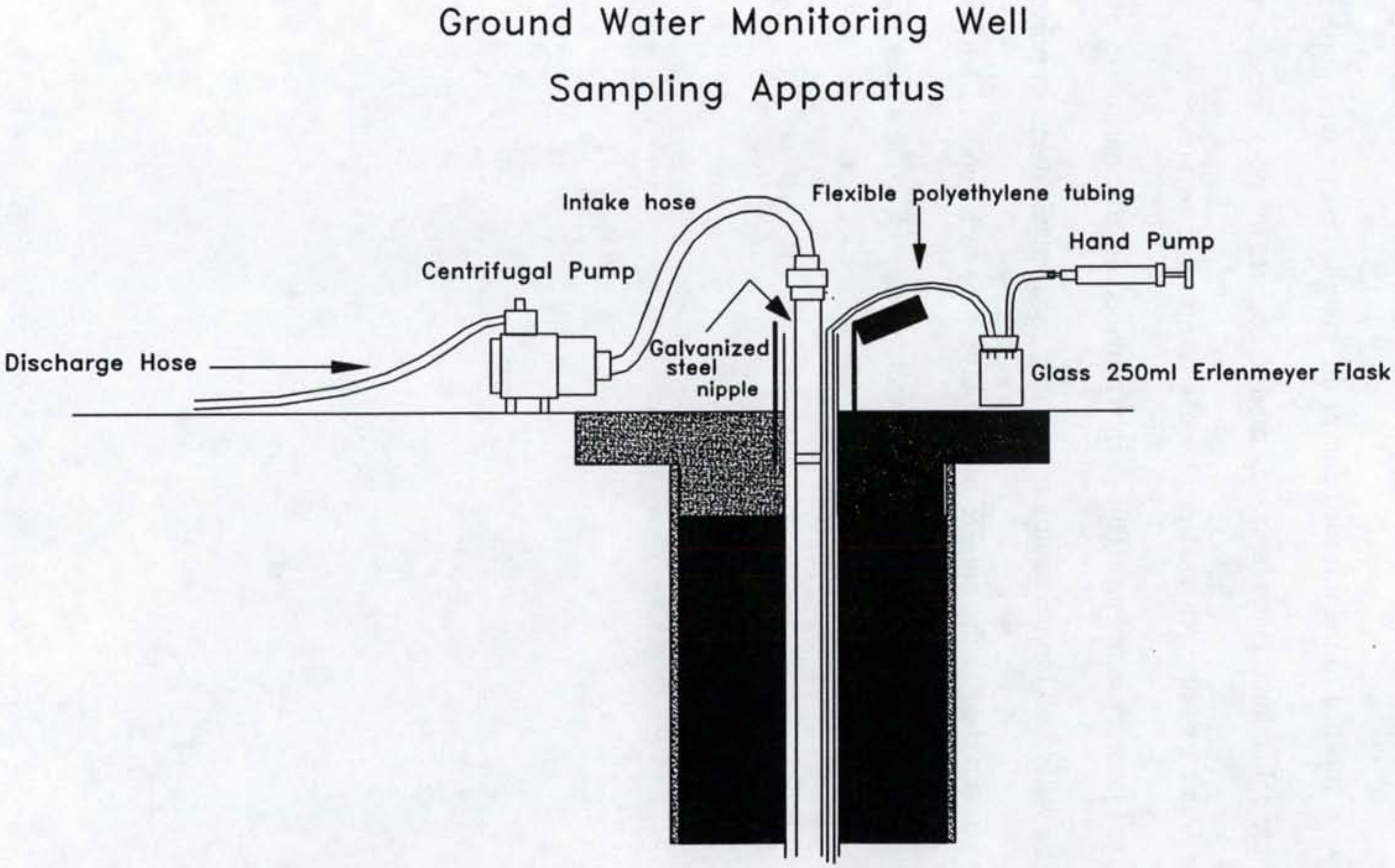


Figure A-22. Schematic of monitoring well ground water sampling apparatus.

Lysimeters: Design and Installation

Lysimeter locations were based on grain size analyses of soil samples collected in each of the fields. A soil survey was conducted at 24 locations on a grid with 150-foot spacings in the Forgeon Field. Twelve samples were collected on a grid at 200-foot spacings in the Moncur Field. Soil samples were collected at depths of 0.3 meters, 0.6 meters, and 1 meter for each location. Each sample collected was sieved. A grain size distribution curve for each sample was developed. Curves were used to derive the uniformity coefficient for each sample based on the following equation.

$$\text{Uniformity Coefficient} = \frac{\text{D60 (60\% passing size)}}{\text{D10 (10\% passing size)}}$$

Uniformity coefficients provided a numerical range characterizing each sampling location. A series of sample locations representative of the spectrum of grain size distributions in each test field was selected for lysimeter installation. Additional locations were selected until a workable distribution of lags was obtained for geostatistical analyses. A lag is the separation distance between a given sample location and another sample location. Locations for the lysimeters were selected based upon a workable distribution of lags that helped ensure that if spatial dependence of the parameter of interest existed, it would be recognized.

Twenty-three pressure-vacuum type lysimeters were installed in the Forgeon Field in 1994 at a depth of 1 meter (Figure A-23). Twelve additional pressure-vacuum lysimeters were installed in the Forgeon Field in 1995 and one of the original 23 lysimeters was moved. Lysimeter 6F was eliminated and moved to the location 1X in 1995 (Figure A-23).

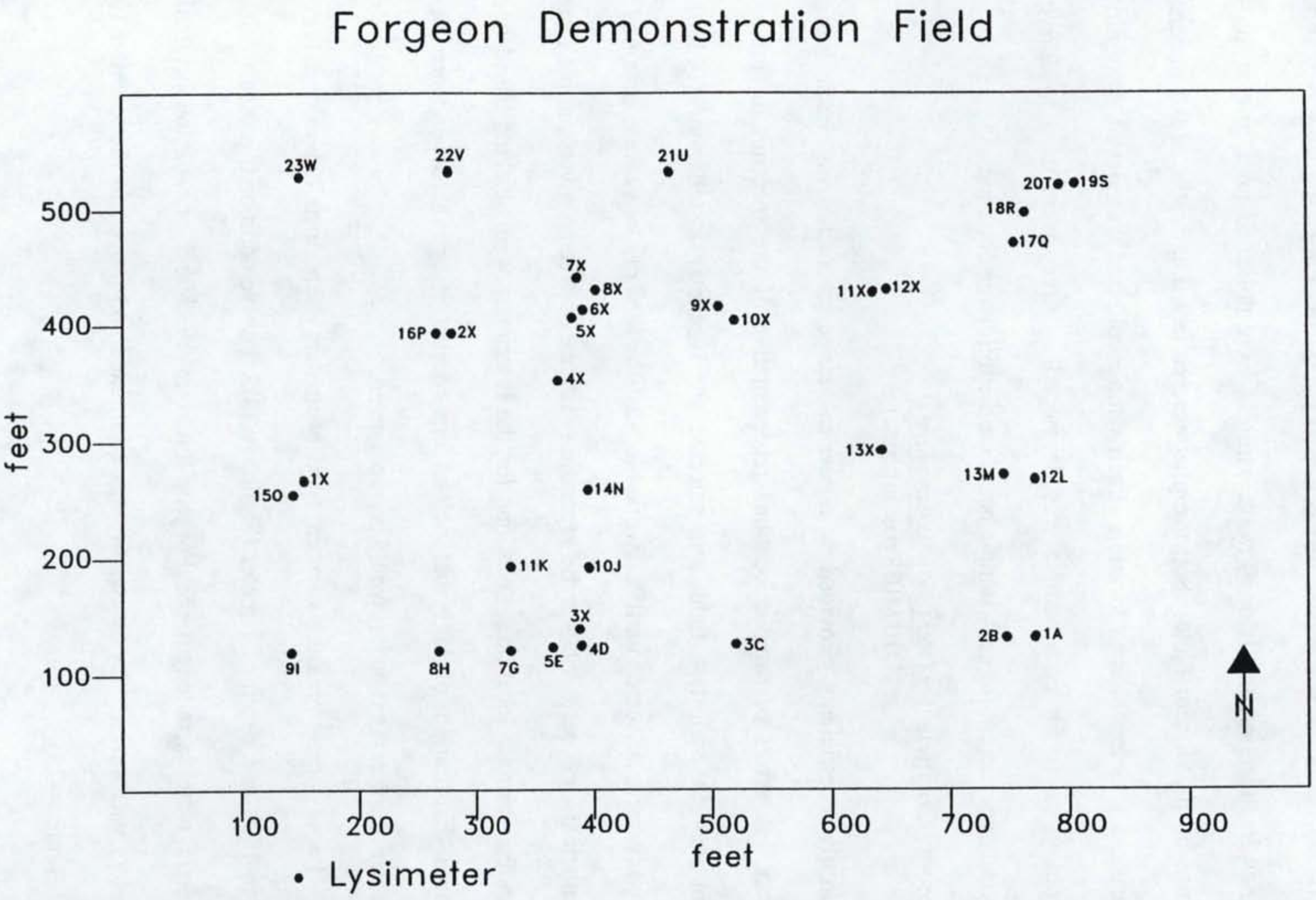


Figure A-23. Location of lysimeters in the Forgeon Field for the 1994 through 1998 growing seasons.

The thirty-five lysimeters installed in the Forgeon Field remained in place throughout the study period. All lysimeters installed in the Forgeon Field were twelve inches long and two inches in diameter.

Twenty-five lysimeters were installed in the Moncur Field for the 1995 through 1997 growing seasons at a depth of 0.5 meters (Figure A-24). Shallow installation depth of the lysimeters and deep tillage practices by the farmer precluded permanent installation of the lysimeters in the Moncur Field. Lysimeters were installed at the beginning of each growing season and removed before harvest. Fifteen vacuum lysimeters and ten pressure-vacuum lysimeters were installed at the Moncur Field. The type of lysimeter used was based on availability. Lysimeters in both fields were installed using a hand auger with a four-inch cutting bit. Lysimeters were installed as shown in Figure A-25. Approximately 0.4 feet of silica flour was placed at the bottom of each hole. The porous cup end of the lysimeter was placed in the silica flour and additional silica flour was placed to a minimum of four inches above the top of the porous cup. The smaller pore size of the silica flour allowed application of greater suction to pull water from the larger pores of the soil. Excavated auger cuttings were used to backfill the holes. A dowel rod was used to pack the silica flour and backfill material. Bentonite chips were placed approximately four inches below land surface and covered with soil.

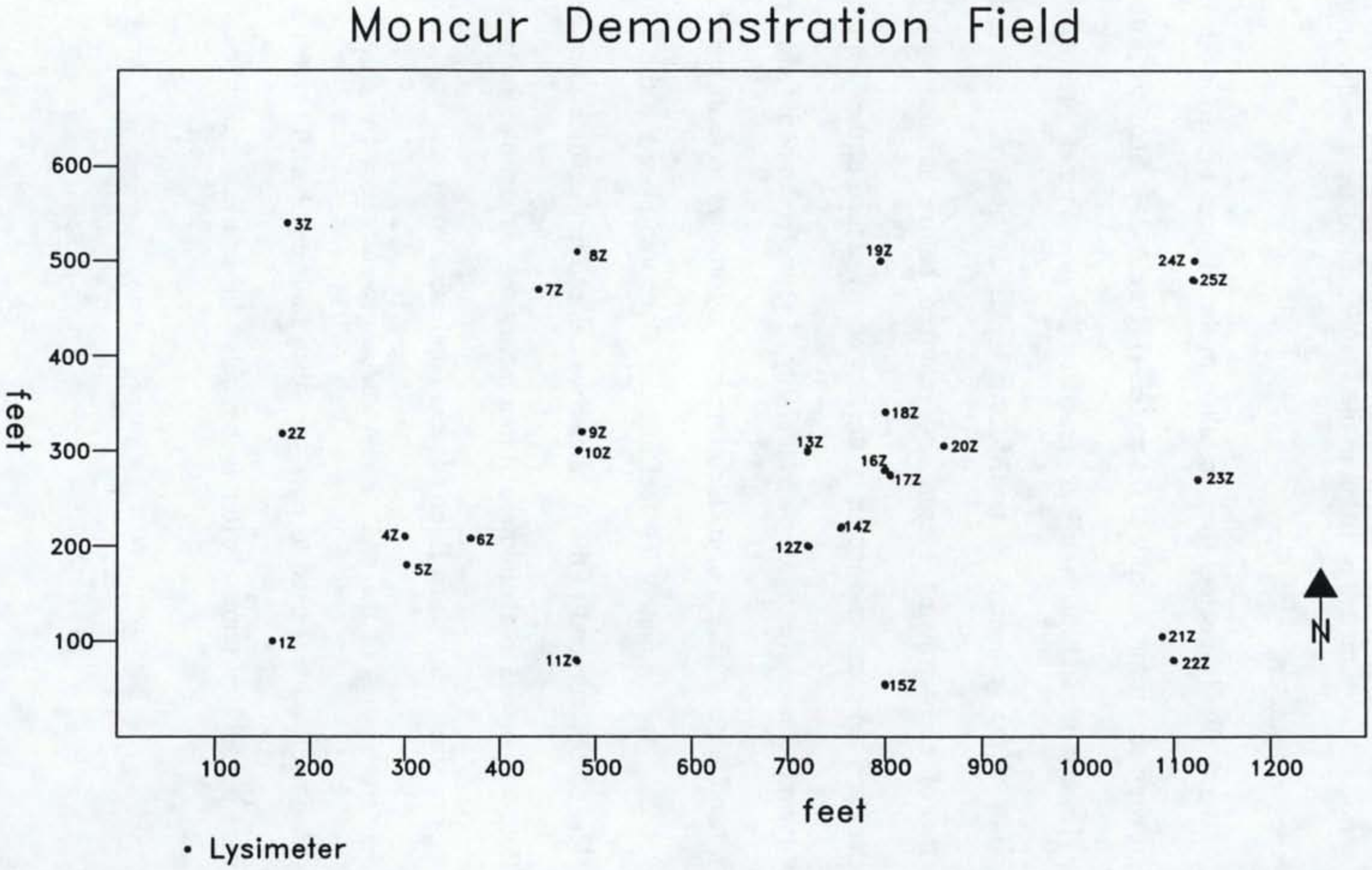
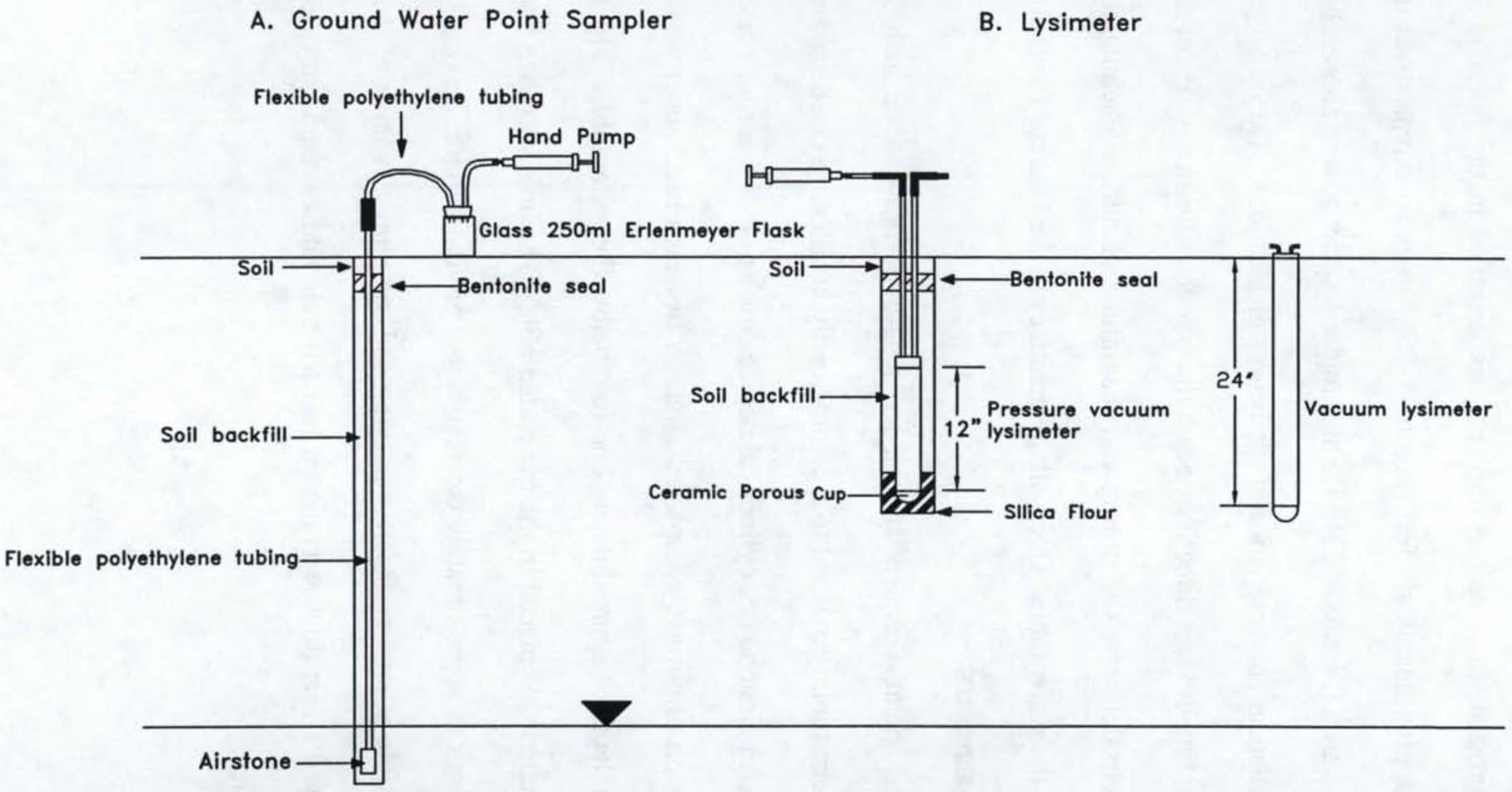


Figure A-24. Location of lysimeters in the Moncur Field for the 1995 through 1997 growing seasons.


A. Ground Water Point Sampler

B. Lysimeter

Figure A-25. Schematic of lysimeter and ground water point sampler installation in the Moncur and Forgeon Fields.

Ground Water Point Samplers; Design and Installation

Thirty-five ground water point samplers were installed in the Forgeon Field in 1995 at a depth of approximately six feet (Figure A-25). A point sampler was installed at each lysimeter location (Figure A-23). Point sampler locations were chosen based on the workable geostatistical characteristics of the lysimeter locations. They also provided a second tier of sampling devices directly beneath the lysimeter locations. Point samplers were installed to help delineate the timing and magnitude of nitrate leaching from the unsaturated zone to the water table. Deep tillage practices in the Moncur Field precluded installation of point samplers.

Ground water point samplers included a length of one-quarter inch, outside diameter, polyethylene tubing attached to a commercially available pressed sand airstone used in aquariums. An airstone is a cylindrical device consisting of a porous plastic stem surrounded by a sheath of porous, compacted sand. A two-inch hand auger was used to excavate a hole to a depth of approximately one-foot below the water table. The airstone with the tubing attached was placed in the excavated hole. The hole was then backfilled with the auger cuttings to approximately 0.5 feet below ground surface, leaving one end of the tubing accessible at land surface for purging and sampling. A layer of bentonite chips approximately 0.2 feet thick was placed in each hole and covered with excavated soil to the land surface.

Appendix B:

Monitoring Well Data

FW1 DATA

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen		SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
							(%)	(mg/l)				
May-92	3.55	4149.33	0.7						0.2	570		14.0
Jun-92	6.72	4146.16	0.2						0.5	600		12.5
Jul-92	6.41	4146.47	0.2	BDL	0.5	7.48			0.5	720		22.5
Aug-92	6.18	4146.70	0.4			6.94			0.3	720		22.2
Sep-92	7.14	4145.74	0.4			7.21	32	3.5	0.2	705		19.0
Oct-92	7.21	4145.67	0.7			7.33	29	2.5	0.5	680		15.2
Nov-92	7.63	4145.25	3.5			7.12	44	5.3	0.4	620		11.0
Dec-92	7.60	4145.28	2.7			7.43	61	7.1	0.4	550		8.0
Jan-93	7.78	4145.10	2.0	0.2	0.2	7.38	51	6.6	0.4	550		6.0
Feb-93	7.82	4145.06	1.5			7.39				1015	510	6.4
Mar-93	6.10	4146.78	0.9			7.06	77	8.9		1006	527	9.3
Apr-93	7.13	4145.75	1.7	BDL	1.3	6.89	20	2.1		1097	551	10.0
May-93	7.36	4145.52	1.7			6.71	25	2.4		1038	519	14.1
Jun-93	6.88	4146.00	1.3			6.34	24	2.1		1052	529	17.1
Jul-93	6.96	4145.92	1.1	BDL	BDL	6.94	26	1.7		1110	556	18.6
Aug-93	7.02	4145.86	0.9			7.16	32	2.7		990	500	16.1
Sep-93	7.14	4145.74	4.7			7.04	24	2.1				16.2
Oct-93	7.37	4145.51	3.4	BDL	0.7	7.13	19	1.5		874	438	13.6
Nov-93	7.66	4145.22	4.8			7.14	27	2.9		890	444	9.7
Dec-93	7.87	4145.01	7.2			7.00	15	1.7		921	460	9.5
Jan-94	8.02	4144.86	6.8	BDL	BDL	7.21	21	2.0		608	305	7.6
Feb-94	8.10	4144.78	5.0			7.20	22	2.6		818	409	6.6
Mar-94	7.93	4144.95	6.5			7.11	24	2.5		823	411	8.7
Apr-94	8.02	4144.86	7.1	BDL	0.5	7.10	26	2.5		820	413	15.3
May-94	6.08	4146.80	13.0			7.16	14	1.5		938	471	17.3
Jun-94	6.45	4146.43	10.0			7.42	11	0.7		926	465	16.1
Jul-94	6.84	4146.04	11.0	BDL	1.6	7.46	33	2.5		1199	605	21.8
Aug-94	6.71	4146.17	15.0			7.49	38	2.0		1099	556	19.9
Sep-94	6.77	4146.11	15.0			6.85	39	2.7		995	497	16.7
Oct-94	7.36	4145.52	20.0	BDL	BDL	6.86	29	2.5		1083	543	15.1
Nov-94	7.69	4145.19	16.0			7.29	47	5.5		956	482	8.8
Dec-94	8.02	4144.86	19.0			6.78	38	4.5		994	496	6.9
Jan-95	7.81	4145.07	19.0	BDL		8.50	49	5.6		838	422	10.2
Feb-95	7.69	4145.19	50.0			7.45	28	3.5		1480	743	8.3
Mar-95	7.82	4145.06	62.0			7.23	46	5.3		1489	748	8.5
Apr-95	7.77	4145.11	90.0	BDL		7.27	59	6.4		1879	965	9.5
May-95	6.60	4146.28	60.0			7.25	45	4.5		1378	723	9.8
Jun-95	6.70	4146.18	42.0			7.22	31	2.8		1172	589	8.6
Jul-95	5.10	4147.78	50.0	BDL		7.06	40	3.8		1320	663	15.3
Aug-95	7.12	4145.76	49.0			7.27	48	4.2		1267	634	13.8
Sep-95	7.27	4145.61	34.0			7.11	25	2.6		1175	586	11.7
Oct-95	7.38	4145.50	34.0			7.44	0.5	10.0		592	301	6.9
Nov-95	7.53	4145.35	20.0			6.83	33	3.3		1172	589	9.5
Dec-95	7.50	4145.38	37.0			7.50	22	2.6		1256	627	6.0
Jan-96	7.75	4145.13	30.0			7.14	28	3.4		1172	588	4.4
Feb-96	7.34	4145.54	18.0			7.25	17	2.0		1183	593	4.8
Mar-96	7.53	4145.35	24.0			7.48	18	2.1		1186	595	2.9
Apr-96	7.78	4145.10	18.0			7.60	12	1.1		1157	580	5.5
May-96	7.03	4145.85	16.0			7.34	38	3.9		986	495	9.0
Jun-96	7.29	4145.59	20.0			6.55	31	2.8		1223	612	13.2
Jul-96	6.68	4146.20	20.0			6.95				1205	603	16.7
Aug-96	6.31	4146.57	19.0			6.31	25	2.2		1170	585	17.5
Sep-96	7.39	4145.49	16.0			7.27	21	1.6		1070	537	16.2
Oct-96	6.46	4146.42	19.0			6.96	27	3.1		1098	548	9.1
Nov-96	7.68	4145.20	17.0			7.53	16	1.9		1158	575	6.7
Dec-96	6.59	4146.29	15.0			7.82				1067	528	6.4
Jan.97	6.92	4145.96	13.0			7.41	32	3.7		1226	610	5.6
Feb-97	7.27	4145.61	12.0			7.52	30	3.1		1114	557	8.4
Mar-97	7.91	4144.97	11.0			8.05				122.3	612	9.0
Apr-97	7.75	4145.13	6.1			7.39	41	2.9				12.5
May-97	6.70	4146.18	9.1			7.18	9	0.0		1477	743	15.5
Jun-97	6.76	4146.12	7.7			7.03	14	1.4		1774	887	17.1
Jul-97	6.00	4146.88	5.2			7.20	0	0.0		1242	623	17.5
Aug-97	6.80	4146.08	68.0			7.48	39.0	2.8		1282	646.0	21.9
Sep-97	7.15	4145.73	17.0			7.04				1396	701.0	13.3

FW1 DATA cont.

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen (%)	Dissolved Oxygen (mg/l)	SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
Oct-97	7.44	4145.44	24.0			7.21	7.0	0.3		1594	789.0	9.7
Nov-97	7.66	4145.22	12.0			7.21	18.0	1.7		1324	660.0	8.1
Dec-97	7.82	4145.06	23.0			7.12	33.0	3.5		1387	691.0	7.1
Jan-98	7.44	4145.44	22.0			6.94	36.0	4.0		1291	641.0	5.6
Feb-98	7.64	4145.24	38.0			7.11	0.0	0.0		1240	615.0	5.5
Mar-98	7.80	4145.08	16.0			7.42	0.0	0.0		1228	618.0	7.8
Apr-98	7.90	4144.98	19.0			7.39	35.0	3.8		1182	594.0	12.5
May-98	6.72	4146.16	26.0			8.00	29.0	2.7		1197	602.0	11.0
Jun-98	6.79	4146.09	43.0			7.24	61.0	5.6		1306	655.0	12.8
Jul-98	6.45	4146.43	38.0			8.27	63.0	4.4		1304	653.0	22.2
Aug-98	6.65	4146.23	31.0			7.57	54.0	4.1		1257	627.0	19.1
Sep-98	6.97	4145.91	35.0			7.01	49.0	4.3		1349	676.0	18.8
Oct-98	7.32	4145.56	37.0			7.07	0.0	0.0		1245	625.0	15.2
Nov-98	7.61	4145.27	36.0			7.88	1.0	0.0		1232	610.0	9.7
Dec-98	7.70	4145.18	34.0			7.66	0.0	0.0		1175	591.0	9.4

FW2 DATA

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen (%)	(mg/l)	SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
May-92	2.39	4150.12	1.2						0.2	530		14.8
Jun-92	6.48	4146.03	2.1						0.5	590		12.9
Jul-92	6.13	4146.38	0.8	BDL	BDL	7.51			0.4	625		19.5
Aug-92	5.88	4146.63	1.5			7.12			0.3	620		21.5
Sep-92	6.85	4145.66	2.8			7.32	30	2.9	0.3	620		18.3
Oct-92	6.88	4145.63	2.2			7.40	11	1.1	0.5	610		11.5
Nov-92	7.30	4145.21	1.3			7.32	34	4.6	0.3	500		11.5
Dec-92	7.30	4145.21	1.4			7.62	60	6.7	0.3	450		9.0
Jan-93	7.43	4145.08	0.6	0.6	BDL	7.54	51	6.4	0.4	450		6.7
Feb-93	7.50	4145.01	1.5			7.38				717	360	7.0
Mar-93	5.95	4146.56	1.7			7.31	10	0.7		730	367	9.0
Apr-93	6.90	4145.61	2.9	BDL	1.3	7.21	19	1.5		720	360	10.7
May-93	7.07	4145.44	2.6			7.00	15	1.5		750	375	15.3
Jun-93	6.64	4145.87	2.1			6.65	13	1.1		759	380	17.6
Jul-93	6.70	4145.81	1.8	BDL	0.7	7.20	10	0.0		786	396	18.4
Aug-93	6.77	4145.74	1.6			7.38	15	1.6		702	352	15.7
Sep-93	6.86	4145.65	7.1			7.23	19	1.5		777	391	16.5
Oct-93	7.06	4145.45	0.9	BDL	0.4	7.35	21	1.8		686	342	13.7
Nov-93	7.35	4145.16	1.0			7.32	20	2.2		683	340	10.1
Dec-93	7.54	4144.97	1.6			7.19	13	1.3		712	356	9.6
Jan-94	7.68	4144.83	2.1	BDL	BDL	7.36	10	1.0		738	369	7.8
Feb-94	7.75	4144.76	1.9			7.35	20	1.8		738	369	6.9
Mar-94	7.60	4144.91	1.9			7.18	13	0.9		765	383	8.6
Apr-94	7.66	4144.85	2.6	BDL	0.5	7.22	13	1.0		772	386	14.6
May-94	5.75	4146.76	5.7			7.18	19	1.4		908	456	16.5
Jun-94	6.19	4146.32	2.1			7.34	5	0.0		871	437	16.1
Jul-94	6.55	4145.96	11.0	BDL	1.5	7.82	26	1.9		944	473	18.6
Aug-94	6.45	4146.06	51.0			7.51	31	2.9		1331	667	18.9
Sep-94	6.51	4146.00	28.0			7.04	4	0.0		1200	602	17.0
Oct-94	7.09	4145.42	64.0	BDL	BDL	6.95	33	3.1		1363	683	15.7
Nov-94	7.38	4145.13	48.0			6.98	26	2.9		1333	666	9.2
Dec-94	7.66	4144.85	26.0			7.25	44	4.7		1213	606	7.0
Jan-95	7.48	4145.03	22.0	BDL		8.59	17	1.6		904	456	10.7
Feb-95	7.38	4145.13	65.0			7.41	15	1.6		1480	742	9.4
Mar-95	7.47	4145.04	65.0			7.28	38	4.1		1511	757	9.4
Apr-95	7.46	4145.05	76.0	BDL		7.30	33	3.3		1635	822	9.7
May-95	6.22	4146.29	70.0			7.15	28	2.5		1458	723	9.6
Jun-95	6.49	4146.02	46.0			7.40	16	1.2		1227	614	9.0
Jul-95	4.85	4147.66	55.0	BDL		6.36	23	1.8		1350	708	19.6
Aug-95	6.84	4145.67	67.0			7.18	23	2.2		1472	751	15.5
Sep-95	6.88	4145.63	30.0			7.13	21	2.1		1131	568	12.6
Oct-95	7.12	4145.39	40.0			7.32	0	0.0		708	356	8.3
Nov-95	7.33	4145.18	49.0			6.86	20	1.8		1458	731	8.9
Dec-95	7.19	4145.32	50.0			7.36	21	2.1		1363	679	6.0
Jan-96	7.41	4145.10	24.0			7.11	16	2.1		990	492	4.4
Feb-96	7.12	4145.39	29.0			7.23	16	0.8		1138	571	4.3
Mar-96	6.84	4145.67	30.0			7.48	17	2.2		1204	605	3.4
Apr-96	7.55	4144.96	34.0			7.75	0	0.0		1268	665	6.3
May-96	6.71	4145.80	24.0			7.38	16	1.6		984	493	9.4
Jun-96	6.88	4145.63	25.0			6.35	18	1.3		1163	586	14.3
Jul-96	6.31	4146.20	28.0			7.00				1188	596	17.2
Aug-96	5.86	4146.65	18.0			7.27	12	1.1		1019	511	16.8
Sep-96	7.18	4145.33	18.0			7.11	8	0.5		1084	544	16.5
Oct-96	7.12	4145.39	16.0			7.26	17	2.1		1034	514	8.6
Nov-96	7.35	4145.16	26.0			7.44	12	1.3		1121	556	7.7
Dec-96	7.11	4145.40	28.0			7.58				1349	669	6.3
Jan-97	6.68	4145.83	26.0			7.30	23	2.8		1383	688	4.0
Feb-97	7.00	4145.51	19.0			7.54	8	0.8		1101	572	10.0
Mar-97	7.34	4145.17	19.0			7.80				1359	681	8.9
Apr-97	7.49	4145.02	15.0			7.40	52	5.3		469	51.4	11.1
May-97	6.44	4146.07	15.0			6.44	0	0.0		1074	540	16.2
Jun-97	6.51	4146	21.0			7.30	4	0.0		1173	587	19.0
Jul-97	5.94	4146.57	22.0			7.32	0	0.0		1269	638	16.4
Aug-97	6.54	4145.97	52.0			7.13	39	2.7		1389	697	20.1
Sep-97	6.85	4145.66	50.0			7.05				1319	663	13.9

FW2 DATA cont.

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen		SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
							(%)	(mg/l)				
Oct-97	7.11	4145.4	29.0			7.37	0	0.0		1182	586	9.2
Nov-97	7.35	4145.16	28.0			7.21	17	0.7		1226	610	8.1
Dec-97	7.41	4145.1	51.0			7.07	27	1.6		1317	657	7.0
Jan-98	7.04	4145.47	26.0			7.08	16	1.7		1178	586	5.6
Feb-98	7.31	4145.2	63.0			7.35	0	0.0		1257	624	5.4
Mar-98	7.48	4145.03	44.0			7.26	0	0.0		2270	1030	7.8
Apr-98	7.49	4145.02	30.0			7.48	20	2.0		1166	586	11.7
May-98	6.44	4146.07	27.0			7.97	0	0.0		1132	567	10.6
Jun-98	6.54	4145.97	54.0			7.27	36	2.9		1312	658	14.4
Jul-98	6.60	4145.91	52.0			7.79	32	2.2		1281	646	19.3
Aug-98	6.62	4145.89	46.0			7.54	24	1.9		1251	633	18.3
Sep-98	6.65	4145.86	28.0			6.90	29	2.3		1219	613	17.3
Oct-98	7.03	4145.48	35.0			7.06	0	0.0		1208	606	15.1
Nov-98	7.27	4145.24	26.0			7.87	13	0.0		1171	582	9.6
Dec-98	7.35	4145.16	34.0			7.44	0	0.0		1194	594	9.3

FW3 DATA

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen		SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
							(%)	(mg/l)				
May-92	2.61	4149.90	1.8						0.2	580		15.5
Jun-92	6.65	4145.86	1.2						0.4	530		12.0
Jul-92	6.31	4146.20	2.7	BDL	5.3	7.55			0.5	700		18.0
Aug-92	6.05	4146.46	1.5			7.14			0.5	700		20.5
Sep-92	6.96	4145.55	1.3			7.31	33	3.1	0.5	690		18.0
Oct-92	6.98	4145.53	1.8			7.40	59	5.2	0.5	710		15.5
Nov-92	7.39	4145.12	1.1			7.24	31	3.7	0.4	605		11.5
Dec-92	7.39	4145.12	1.8			7.54	66	7.3	0.4	570		8.7
Jan-93	7.51	4145.00	2.1	0.5	0.3	7.40	52	6.4	0.4	540		7.4
Feb-93	7.55	4144.96	2.3			7.41				821	410	7.0
Mar-93	6.20	4146.31	1.9			7.32	9	0.8		774	390	8.7
Apr-93	7.05	4145.46	1.7	BDL	1.2	7.18	11	1.3		773	389	11.2
May-93	7.18	4145.33	1.4			7.11	8	0.7		741	371	15.1
Jun-93	6.80	4145.71	1.1			6.65	14	1.3		725	362	18.6
Jul-93	6.83	4145.68	1.1	BDL	BDL	7.23	0	0.0		713	359	18.3
Aug-93	6.90	4145.61	1.7			7.30	18	1.3		745	374	17.0
Sep-93	6.98	4145.53	2.6			7.37	27	2.6		696	351	16.9
Oct-93	7.16	4145.35	1.9	BDL	1.1	7.33	15	1.3		728	364	13.3
Nov-93	7.45	4145.06	2.5			7.36	17	2.0		739	369	10.0
Dec-93	7.63	4144.88	2.5			7.17	14	1.2		751	375	9.3
Jan-94	7.75	4144.76	1.8	BDL	BDL	7.40	9	1.2		730	365	7.8
Feb-94	7.80	4144.71	1.5			7.40	17	1.9		743	371	6.7
Mar-94	7.68	4144.83	2.1			7.22	9	0.6		778	388	9.1
Apr-94	7.74	4144.77	1.8	BDL	0.6	7.17	12	1.0		741	372	15.4
May-94	5.89	4146.62	2.0			7.23	13	1.1		819	410	18.7
Jun-94	6.37	4146.14	2.2			7.44	0	0.0		773	398	16.1
Jul-94	6.65	4145.86	2.0	BDL	1.9	7.60	20	1.7		817	412	19.6
Aug-94	6.60	4145.91	2.5			7.53	32	2.5		835	420	20.6
Sep-94	6.68	4145.83	2.2			7.18	5	0.0		829	416	17.1
Oct-94	7.20	4145.31	15.5	BDL	0.6	7.33	30	2.8		895	450	14.9
Nov-94	7.44	4145.07	23.0			7.07	47	5.5		966	485	8.7
Dec-94	7.74	4144.77	32.0			7.35	35	5.0		1056	529	6.3
Jan-95	7.55	4144.96	47.0	BDL		7.99	41	4.6		990	496	9.5
Feb-95	7.48	4145.03	82.0			7.48	35	4.0		1664	834	8.5
Mar-95	7.55	4144.96	130.0			7.19	49	5.6		2050	1020	9.3
Apr-95	7.53	4144.98	84.0	BDL		7.27	25	2.9		1692	848	9.6
May-95	6.30	4146.21	46.0			7.24	21	1.4		1270	637	9.7
Jun-95	6.69	4145.82	22.0			7.33	9	0.8		1050	526	8.3
Jul-95	4.79	4147.72	15.0	BDL		6.46	20	1.6		904	470	17.5
Aug-95	6.99	4145.52	25.0			7.27	35	3.0		1037	541	15.9
Sep-95	7.00	4145.51	32.0			7.23	14	1.4		1159	583	13.4
Oct-95	7.13	4145.38	35.0			7.26	0	0.0		1149	585	8.3
Nov-95	7.43	4145.08	27.0			6.92	10	1.0		1144	573	8.4
Dec-95	7.28	4145.23	27.0			7.46	12	1.4		1109	550	5.8
Jan-96	7.45	4145.06	28.0			7.12	18	2.0		1039	492	4.3
Feb-96	6.96	4145.55	32.0			7.33	0	0.0		1166	585	5.2
Mar-96	7.34	4145.17	33.0			7.36	0	0.0		1400	703	4.8
Apr-96	7.62	4144.89	32.0			7.60	0	0.0		1239	621	6.2
May-96	6.83	4145.68	30.0			7.30	14	1.2		1015	508	9.5
Jun-96	6.71	4145.80	38.0			6.42	2	0.0		1185	595	14.3
Jul-96	6.36	4146.15	33.0			7.17				1132	589	17.5
Aug-96			20.0			7.24	8	0.6		1026	514	17.1
Sep-96	7.19	4145.32	31.0			7.21	9	0.6		1139	571	16.0
Oct-96	7.18	4145.33	25.0			7.29	16	1.8		1125	560	9.0
Nov-96	7.46	4145.05	27.0			7.51	22	1.7		1172	584	6.5
Dec-96	7.20	4145.31	25.0			7.71				1173	582	6.3
Jan-97	6.86	4145.65	27.0			7.37	19	2.3		1431	713	4.6
Feb-97	7.17	4145.34	28.0			7.46	12	0.3		1375	689	9.3
Mar-97	7.46	4145.05	23.0			7.90				1249	627	9.1
Apr-97	7.43	4145.08	22.0			7.90	13	1.1		1201	625	12.0
May-97	6.23	4146.28	24.0			7.14	0	0.0		438	234	19.6
Jun-97	6.70	4145.81	25.0			7.28	0	0.0		1127	565	17.9
Jul-97	6.03	4146.48	23.0			7.32	0	0.0		1144	598	16.0
Aug-97	6.70	4145.81	29.0			7.08	4	0.2		1235	619	19.1
Sep-97	6.96	4145.55	26.0			7.22				1207	599	11.3

FW3 DATA cont.

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen		SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
							(%)	(mg/l)				
Oct-97	7.22	4145.29	33.0			7.33	0	0		1274	633	9.2
Nov-97	7.43	4145.08	32.0			7.33	8	0.9		1316	655	7.6
Dec-97	7.55	4144.96	29.0			7.39	12	1.2		1245	619	6.2
Jan-98	7.16	4145.35	24.0			7.14	26	2.7		1228	611	5.9
Feb-98	7.43	4145.08	22.0			7.47	0	0		1221	606	5.4
Mar-98	7.56	4144.95	22.0			7.80	0	0.0		1336	671	7.9
Apr-98	7.62	4144.89	32.0			7.62	20	1.9		1258	658	14.1
May-98	6.60	4145.91	28.0			7.88	18	1.5		1241	623	10.2
Jun-98	6.59	4145.92	23.0			7.40	25	2.2		1206	601	11.4
Jul-98	6.65	4145.86	28.0			6.95	20	1.1		1192	595	18.4
Aug-98	6.14	4146.37	23.0			7.57	26	2.5		1134	568	18.5
Sep-98	6.76	4145.75	21.0			7.27	22	1.6		1224	616	17.3
Oct-98	7.11	4145.4	31.0			7.02	0	0.0		1285	646	14.8
Nov-98	7.33	4145.18	28.0			8.01	0	0.0		1306	649	9.1
Dec-98	7.40	4145.11	30.0			7.59	0	0.0		1321	659	10.0

FW4 DATA												
DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen (%)	(mg/l)	SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
May-92	3.09	4149.17	1.1						0.2	620		17.4
Jun-92	6.57	4145.69	0.8						0.5	600		11.6
Jul-92	6.36	4145.90	1.7	BDL	2.6	7.54			0.4	700		18.5
Aug-92	6.07	4146.19	2.5			7.13			0.3	650		20.5
Sep-92	6.84	4145.42	3.2			7.32	37	3.5	0.5	705		17.3
Oct-92	6.83	4145.43	4.4			7.27	49	5.9	0.5	705		15.5
Nov-92	7.23	4145.03	3.4			7.19	36	4.3	0.5	650		11.0
Dec-92	7.25	4145.01	3.0			7.30	48	5.4	0.5	580		7.8
Jan-93	7.34	4144.92	3.0	0.6	0.7	7.27	55	7.1	0.5	570		6.5
Feb-93	7.38	4144.88	3.6			7.29				894	449	6.6
Mar-93	6.22	4146.04	3.4			7.17	10	0.7		897	452	7.9
Apr-93	6.97	4145.29	3.0	BDL	1.5	7.06	13	1.2		987	492	11.4
May-93	7.03	4145.23	1.5			6.97	17	1.6		918	459	14.1
Jun-93	6.71	4145.55	2.0			6.56	18	1.6		921	459	18.3
Jul-93	6.74	4145.52	1.9	BDL	0.4	7.10	11	0.0		870	438	18.3
Aug-93	6.81	4145.45	1.9				12	1.2		860	432	15.8
Sep-93	6.85	4145.41	1.8			7.22	26	2.4		767	387	16.6
Oct-93	7.00	4145.26	1.7	BDL	0.7	7.25	16	2.0		770	387	13.7
Nov-93	7.29	4144.97	2.0			7.26	26	2.6		794	397	10.3
Dec-93	7.45	4144.81	3.1			7.15	15	1.5		826	412	9.1
Jan-94	7.55	4144.71	1.9	BDL	BDL	7.32	13	1.8		763	382	7.8
Feb-94	7.60	4144.66	1.5			7.24	13	1.5		786	392	6.4
Mar-94	7.49	4144.77	2.1			7.14	7	1.0		825	411	8.9
Apr-94	7.55	4144.71	2.3	BDL	0.5	7.11	14	1.0		787	396	15.3
May-94	5.92	4146.34	2.3			7.18	26	1.8		843	426	16.9
Jun-94	6.36	4145.90	2.5			7.38	0	0.0		791	398	15.8
Jul-94	6.53	4145.73	2.2	BDL	2.1	7.59	22	1.7		801	402	19.4
Aug-94	6.53	4145.73	7.1			7.53	37	3.1		850	425	19.5
Sep-94	6.65	4145.61	4.6			7.42	62	4.9		687		
Oct-94	7.11	4145.15	10.0	BDL	0.3	7.26	27	2.4		930	465	15.3
Nov-94	7.30	4144.96	11.0			7.11	30	3.3		881	441	7.2
Dec-94	7.55	4144.71	14.0			7.23	58	5.3		894	445	7.0
Jan-95	7.37	4144.89	16.0	BDL		8.09	22	2.1		745	376	9.9
Feb-95	7.31	4144.95	34.0			7.50	20	1.9		1139	572	9.0
Mar-95	7.38	4144.88	30.0			7.35	38	4.3		1101	552	8.9
Apr-95	7.40	4144.86	31.0	BDL		7.44	45	4.8		1148	575	9.4
May-95	6.20	4146.06	42.0			7.06	25	2.2		1277	641	8.7
Jun-95	6.61	4145.65	41.0			7.22	13	0.9		1151	577	8.6
Jul-95	4.59	4147.67	29.0	BDL		6.49	27	2.2		1153	577	17.4
Aug-95	6.82	4145.44	23.0			6.73	27	2.0		1048	548	17.9
Sep-95	6.88	4145.38	22.0			7.14	20	2.0		1079	540	11.1
Oct-95	7.09	4145.17	16.0			7.34	0	0.0		1024	510	8.2
Nov-95	7.26	4145.00	19.0			5.67	27	2.7		1059	536	8.6
Dec-95	7.15	4145.11	20.0			7.30	16	2.1		1016	506	5.7
Jan-96	7.33	4144.93	16.0			7.24	20	2.3		919	457	4.2
Feb-96	6.99	4145.27	20.0			7.34	10	1.0		1129	566	3.7
Mar-96	7.33	4144.93	21.0			7.46	0	0.0		1136	569	4.8
Apr-96	7.29	4144.97	24.0			7.60	0	0.0		1073	539	6.2
May-96	6.59	4145.67	31.0			7.57	13	1.3		1007	510	10.2
Jun-96	6.85	4145.41	25.0			6.84	16	0.8		1067	535	12.6
Jul-96	6.09	4146.17	26.0			7.21				1142	573	18.0
Aug-96	5.42	4146.84	21.0			7.16	9	0.7		1012	508	17.0
Sep-96	7.00	4145.26	24.0			7.27	10	0.9		1201	602	16.6
Oct-96	7.00	4145.26	21.0			7.21	20	2.2		1275	633	7.6
Nov-96	7.28	4144.98	20.0			7.53	1.6	14.0		1047	535	6.8
Dec-96	7.08	4145.18	20.0			7.94				1074	534	5.9
Jan-97	6.79	4145.47	20.0			7.42	22	2.6		1232	614	5.1
Feb-97	7.06	4145.20	16.0			7.54	7	0.1		1186	594	9.0
Mar-97	7.33	4144.93	15.0			8.12				1143	571	8.8
Apr-97	7.06	4145.20	16.0			7.53	27	2.5		424	224	10.4
May-97	6.44	4145.82	13.0			7.16	0	0.0		1016	511	15.2
Jun-97	6.55	4145.71	14.0			7.25	0	0.0		1028	546	19.3
Jul-97	5.94	4146.32	14.0			7.29	0	0.0		1048	527	18.4
Aug-97	6.56	4145.70	18.0			7.17	14	0.6		1047	557	19.5
Sep-97	6.81	4145.45	15.0			7.33				1018	489	9.7

FW4 DATA cont.

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen (%)	Dissolved Oxygen (mg/l)	SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
Oct-97	7.07	4145.19	16.0			7.45	0	0.0		1006	500	8.2
Nov-97	7.25	4145.01	19.0			7.33	25	1.6		1122	558	7.9
Dec-97	7.38	4144.88	16.0			7.22	24	2.1		1086	541	7.0
Jan-98	7.04	4145.22	19.0			7.22	22	2.5		1115	555	5.3
Feb-98	7.27	4144.99	18.0			7.61	0	0.0		1109	550	5.0
Mar-98	7.39	4144.87	16.0			7.52	0	0.0		1180	591	7.5
Apr-98	7.41	4144.85	23.0			7.55	18	1.6		1134	573	12.2
May-98	6.52	4145.74	18.0			7.90	5	0.0		1033	519	10.8
Jun-98	6.50	4145.76	19.0			7.37	38	3.7		1087	545	12.0
Jul-98	6.47	4145.79	23.0			6.83	21	1.3		1184	590	18.3
Aug-98	5.61	4146.65	21.0			7.57	22	1.6		453	231	27.1
Sep-98	6.63	4145.63	25.0			7.72	25	1.9		1231	621	17.5
Oct-98	6.97	4145.29	26.0			6.91	0	0.0		1331	670	14.9
Nov-98	7.13	4145.13	25.0			7.96	0	0.0		1290	642	10.2
Dec-98	7.24	4145.02	30.0			7.58	0	0.0		1317	659	9.8

FE1 DATA

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen (%)	Dissolved Oxygen (mg/l)	SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
May-92	6.35	4146.23	21.5						0.5	850		15.2
Jun-92	6.08	4146.50	28.5						0.5	410		13.5
Jul-92	6.34	4146.24	27.0	BDL	0.2	7.77			0.7	990		17.0
Aug-92	5.84	4146.74	25.0			7.29			0.7	980		17.0
Sep-92	6.59	4145.99	27.0			7.64	24	2.9	0.6	940		16.9
Oct-92	6.54	4146.04	26.0			7.63	21	2.9	0.7	895		13.0
Nov-92	6.99	4145.59	19.0			7.57	31	3.5	0.5	680		8.0
Dec-92	6.89	4145.69	21.0			7.86	26	3.1	0.6	670		6.8
Jan-93	7.18	4145.40	20.0	0.4	BDL	7.48	51	6.4	0.6	680		5.5
Feb-93	7.20	4145.38	19.0			7.52	21	2.5		1091	546	5.9
Mar-93	4.82	4147.76	15.0			7.18	13	1.3		1033	499	6.8
Apr-93	6.36	4146.22	23.0	BDL	0.8	7.31	14	1.5		1199	599	9.3
May-93	6.68	4145.90	20.0			7.05	20	1.7		1210	607	16.2
Jun-93	6.25	4146.33	21.0			6.71	21	1.7		1118	563	18.6
Jul-93	6.44	4146.14	24.0	BDL	0.6	7.27	18	0.5		1112	557	19.2
Aug-93	6.33	4146.25	9.4			7.68	33	3.2		817	411	16.0
Sep-93	6.54	4146.04	11.0			7.41	16	1.3		831	417	13.0
Oct-93	6.68	4145.90	8.8	BDL	0.4	7.52	19	1.1		927	465	14.1
Nov-93	7.01	4145.57	22.0			7.44	24	2.7		1157	578	8.9
Dec-93	7.23	4145.35	17.0			7.41	18	2.2		1053	527	8.2
Jan-94	6.94	4145.64	19.5	BDL	BDL	7.46	12	1.4		1040	520	7.7
Feb-94	7.49	4145.09	17.0			7.52	17	1.9		1060	531	6.5
Mar-94	7.29	4145.29	9.6			7.45	19	1.5		883	443	8.0
Apr-94	7.45	4145.13	10.0	BDL	0.7	7.41	13	1.2		851	428	12.0
May-94	5.48	4147.10	12.0			7.59	10	0.7		863	434	13.3
Jun-94	5.69	4146.89	11.0			7.61	0	0.0		871	437	15.6
Jul-94	6.35	4146.23	16.0	BDL	1.7	7.73	22	1.7		1049	528	19.7
Aug-94	6.20	4146.38	13.0			7.86	22	1.4		953	480	19.0
Sep-94	5.91	4146.67	25.0			7.51	20	1.4		1260	631	18.8
Oct-94	6.65	4145.93	36.0	BDL	0.4	7.42	32	2.9		1521	762	15.8
Nov-94	7.04	4145.54	20.0			7.44	33	3.6		1226	613	8.7
Dec-94	7.45	4145.13	24.0			7.59	39	7.5		1221	612	4.2
Jan-95	7.11	4145.47	28.5	BDL		6.64	31	3.7		1038	520	8.4
Feb-95	7.03	4145.55	28.0			7.65	12	1.4		1238	621	7.8
Mar-95	7.15	4145.43	51.0			7.37	33	4.0		1647	825	7.8
Apr-95	7.19	4145.39	54.0	BDL		7.60	23	2.6		1761	885	9.9
May-95	5.91	4146.67	31.0			7.36	26	2.2		1293	651	9.1
Jun-95	5.71	4146.87	22.0			7.44	18	1.9		981	491	9.1
Jul-95	4.98	4147.60	7.8	BDL		7.69	18	1.6		737	390	14.8
Aug-95	6.55	4146.03	6.8			7.54	29	2.6		767	386	14.1
Sep-95	6.47	4146.11	6.1			7.42	21	2.1		810	413	13.3
Oct-95	6.69	4145.89	6.6			7.56	0	0.0		862	420	6.2
Nov-95	6.87	4145.71	6.4			7.15	16	1.6		803	404	9.7
Dec-95	6.51	4146.07	8.1			7.44	15	1.4		825	412	5.7
Jan-96	6.98	4145.60	8.3			7.30	16	1.7		765	384	5.1
Feb-96	6.42	4146.16	7.9			7.43	1	0.0		856	430	5.7
Mar-96	6.68	4145.90	9.7			7.52	14	1.5		1046	525	2.3
Apr-96	7.29	4145.29	13.0			7.50	0	0.0		1204	604	7.5
May-96	6.09	4146.49	12.0			7.35	16	1.6		916	461	9.2
Jun-96	6.64	4145.94	14.0			6.56	13	0.1		964	484	12.5
Jul-96	6.20	4146.38	14.0			7.14				992	496	16.9
Aug-96	6.16	4146.42	15.0			7.50	8	0.7		921	461	17.3
Sep-96	6.76	4145.82	16.0			7.41	11	0.9		1241	623	16.5
Oct-96	6.79	4145.79	13.0			7.40	12	1.7		1040	515	10.4
Nov-96	6.96	4145.62	13.0			7.62	22	1.9		1105	553	7.1
Dec-96	6.39	4146.19	12.0			7.88				1114	555	6.9
Jan-97	6.10	4146.48	13.0			7.32	19	2.2		1473	733	5.0
Feb-97	6.48	4146.10	14.0			7.41	22	1.4		1899	950	7.4
Mar-97	6.94	4145.64	14.0			7.65				1734	870	9.2
Apr-97	7.11	4145.47	13.0			7.56	18	1.6		1192	620	12.0
May-97	6.05	4146.53	15.0			7.43	0	0.0		1394	692	16.9
Jun-97	6.07	4146.51	18.0			7.64	0	0.0		1344	672	19.3
Jul-97	5.68	4146.90	19.0			7.23	23	1.6		1570	784	19.5
Aug-97	6.34	4146.24	24.0			7.25	10	0.8		1478	743	18.2
Sep-97	6.59	4145.99	18.0			7.32	0	0.0		1127	561	9.6

FE1 DATA cont.

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen (%)	Dissolved Oxygen (mg/l)	SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
Oct-97	6.70	4145.88	26.0			7.99				1193	596	8.5
Nov-97	7.04	4145.54	26.0			7.79	23	2.0		1147	569	7.8
Dec-97	7.20	4145.38	20.0			7.58	15	1.2		1047	520	6.9
Jan-98	6.52	4146.06	20.0			7.19	19	1.9		1065	527	4.8
Feb-98	6.95	4145.63	21.0			7.22	0	0.0		1010	503	4.2
Mar-98	7.20	4145.38	20.0			7.74	0	0.0		1130	567	7.7
Apr-98	7.17	4145.41	36.0			7.19	28	2.9		1206	604	11.0
May-98	5.93	4146.65	28.0			7.73	10	0.9		1155	581	10.6
Jun-98	5.98	4146.60	32.0			7.94	52	5.7		1291	649	13.2
Jul-98	6.53	4146.05	22.0			6.81	21	1.1		1083	539	17.7
Aug-98	6.28	4146.30	39.0			7.53	32	2.4		1202	603	19.4
Sep-98	6.31	4146.27	29.0			7.46	29	2.2		1196	600	17.9
Oct-98	6.65	4145.93	22.0			7.66	0	0.0		1079	541	15.9
Nov-98	6.96	4145.62	23.0			8.93	0	0.0		1122	559	9.4
Dec-98	7.04	4145.54	22.0			8.66	0	0.0		1050	529	10.8

FE2 DATA

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen (%)	(mg/l)	SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
May-92	6.15	4146.11	24.0						0.6	850		13.8
Jun-92	5.86	4146.40	29.4						0.7	900		12.8
Jul-92	6.00	4146.26	27.0	BDL	2.1	7.80			0.7	980		19.0
Aug-92	5.47	4146.79	27.0			7.21			0.7	995		17.0
Sep-92	6.35	4145.91	31.0			7.56	26	2.8	0.7	980		15.2
Oct-92	6.27	4145.99	33.0			7.51	12	1.6	0.7	950		12.5
Nov-92	6.71	4145.55	31.0			7.35	23	2.8	0.7	800		8.0
Dec-92	6.63	4145.63	22.0			7.68	53	6.4	0.6	710		7.0
Jan-93	6.88	4145.38	20.0	0.4	BDL	7.59	53	6.5	0.6	670		5.6
Feb-93	6.89	4145.37	27.0			7.41				1092	448	5.1
Mar-93	4.73	4147.53	18.0			7.30	9	0.4		1052	526	8.6
Apr-93	6.15	4146.11	22.0	BDL	1.2	7.25	7	0.6		1101	550	9.4
May-93	6.47	4145.79	20.0			7.12	14	1.2		1086	544	15.4
Jun-93	6.07	4146.19	20.0			6.75	9	0.8		1089	543	15.6
Jul-93	6.22	4146.04	22.0	BDL	0.6	7.04	7	0.0		1397	705	17.4
Aug-93	6.11	4146.15	19.0			7.67	41	3.7		1127	564	15.6
Sep-93	6.32	4145.94	22.0			7.36	17	1.2		1052	528	12.8
Oct-93	6.41	4145.85	16.0	BDL	0.8	7.44	13	0.9		1054	529	14.5
Nov-93	6.74	4145.52	16.0			7.47	24	2.5		982	491	9.3
Dec-93	6.95	4145.31	16.0			7.34	12	1.3		1005	502	8.4
Jan-94	6.85	4145.41	20.0	BDL	BDL	7.56	10	1.0		1085	541	7.5
Feb-94	7.17	4145.09	19.0			7.46	17	1.7		952	476	6.5
Mar-94	7.00	4145.26	14.0			7.30	8	0.7		938	500	9.3
Apr-94	7.16	4145.10	9.2	BDL	BDL	7.33	11	1.0		855	428	11.9
May-94	5.18	4147.08	11.0			7.43	21	1.8		837	421	14.1
Jun-94	5.47	4146.79	14.0			7.65	0	0.0		933	471	14.4
Jul-94	6.10	4146.16	17.0	BDL	1.2	7.74	15	1.4		1004	505	20.9
Aug-94	5.96	4146.30	16.0				20	1.5		1069	537	16.8
Sep-94	5.67	4146.59	24.0			7.40	24	1.7		1374	693	18.4
Oct-94	6.41	4145.85	25.0	BDL	BDL	7.41	44	3.8		1325	663	15.7
Nov-94	6.77	4145.49	26.5			7.28	40	4.3		1576	786	8.7
Dec-94	7.16	4145.10	33.0			7.24	38	5.1		1649	826	4.4
Jan-95	6.83	4145.43	34.0	BDL		6.89	36	3.1		1297	651	8.2
Feb-95	6.77	4145.49	31.0			7.57	18	2.1		1480	743	8.1
Mar-95	6.87	4145.39	41.0			7.31	30	3.2		1688	845	8.5
Apr-95	6.92	4145.34	32.0	BDL		7.44	24	2.4		1522	764	8.7
May-95	5.57	4146.69	30.0			7.34	24	2.1		1444	724	9.3
Jun-95	5.63	4146.63	28.0			7.26	18	1.9		1230	618	8.8
Jul-95	4.62	4147.64	26.0	BDL		7.57	23	2.0		1102	586	12.6
Aug-95	6.34	4145.92	21.0			7.40	20	1.6		1152	578	13.8
Sep-95	6.23	4146.03	22.0			7.35	17	1.6		1210	607	13.7
Oct-95	6.44	4145.82	13.0			7.51	0	0.0		1028	511	6.4
Nov-95	6.56	4145.70	8.8			7.13	10	1.1		907	456	8.8
Dec-95	6.51	4145.75	11.0			7.50	16	1.8		943	469	6.2
Jan-96	6.65	4145.61	9.1			7.25	20	2.2		831	417	
Feb-96	6.19	4146.07	8.6			7.39	6	0.3		878	440	6.8
Mar-96	6.52	4145.74	9.6			7.62	11	1.2		1011	507	6.1
Apr-96	6.97	4145.29	17.0			7.90	0	0.0		1263	634	6.5
May-96	5.79	4146.47	12.0			7.64	11	1.1		904	454	7.6
Jun-96	6.38	4145.88	13.0			7.04	25	2.2		1318	659	14.0
Jul-96	5.75	4146.51	12.0			7.33				1147	579	16.7
Aug-96	5.69	4146.57	13.0			7.33	16	1.4		1098	551	17.7
Sep-96	6.48	4145.78	13.0			7.27	14	2.8		1311	656	16.5
Oct-96	6.57	4145.69	16.0			7.46	11	1.6		1250	630	10.5
Nov-96	6.71	4145.55	14.0			7.57	11	1.1		1305	650	6.7
Dec-96	6.09	4146.17	14.0			8.04				1190	590	7.0
Jan-97	5.90	4146.36	17.0			7.42	15	1.6		1401	697	3.8
Feb-97	6.25	4146.01	17.0			7.73	9	1.0		1445	725	7.7
Mar-97	6.68	4145.58	13.0			7.85				1644	823	9.0
Apr-97	6.84	4145.42	14.0			7.30	27	2.1		1571	787	10.3
May-97	5.86	4146.4	14.0			6.95	0	0.0		1581	769	16.4
Jun-97	5.91	4146.35	16.0			7.38	0	0.0		1481	745	18.0
Jul-97	5.56	4146.7	14.0			7.16	29	2.4		1424	711	18.9
Aug-97	6.07	4146.19	18.0			7.23	9	0.5		1540	770	17.0
Sep-97	6.34	4145.92	18.0			7.18	0	0.0		1479	747	8.6

FE2 DATA cont.

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen		SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
							(%)	(mg/l)				
Oct-97	6.51	4145.75	20.0			7.46				1478	736	7.9
Nov-97	6.75	4145.51	18.0			8.14	10	1.0		1423	706	7.7
Dec-97	6.91	4145.35	14.0			7.64	32	2.6		1253	620	7.1
Jan-98	6.28	4145.98	17.0			7.08	24	2.6		1181	585	5.5
Feb-98	6.68	4145.58	20.0			7.14	0	0.0		1227	609	4.6
Mar-98	6.92	4145.34	14.0			7.98	0	0.0		1312	658	7.9
Apr-98	6.87	4145.39	32.0			7.13	25	2.6		1388	697	13.4
May-98	5.71	4146.55	29.0			7.65	24	2.1		1355	680	9.5
Jun-98	5.78	4146.48	28.0			7.81	32	3.4		1341	672	12.5
Jul-98	6.21	4146.05	32.0			6.21	24	1.6		1346	671	17.2
Aug-98	5.97	4146.29	32.0			7.75	32	2.3		1330	665	19.3
Sep-98	6.07	4146.19	29.0			7.95	28	2.1		1023	630	16.0
Oct-98	6.4	4145.86	17.0			7.02	9	0.5		1065	534	14.6
Nov-98	6.68	4145.58	50.0			8.45	38	4.7		1406	692	9.4
Dec-98	6.65	4145.61	39.0			8.12	0	0.0		1252	626	10.1

FE3 DATA

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen (%)	Dissolved Oxygen (mg/l)	SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
May-92	5.65	4146.25	12.0						0.5	750		15.0
Jun-92	5.70	4146.20	12.5						0.6	810		14.1
Jul-92	5.69	4146.21	13.0	BDL	0.1	7.84			0.6	770		18.0
Aug-92	5.10	4146.80	12.0			7.16			0.6	750		16.5
Sep-92	6.15	4145.75	12.0			7.64	45	4.7	0.5	1000		14.9
Oct-92	6.05	4145.85	14.0			7.58	16	2.8	0.5	630		12.9
Nov-92	6.51	4145.39	13.0			7.51	21	2.6	0.5	625		8.0
Dec-92	6.42	4145.48	15.0			7.80	57	6.8	0.6	490		6.7
Jan-93	6.64	4145.26	15.0	0.7	0.4	7.68	36	4.7	0.5	600		5.1
Feb-93	6.65	4145.25	18.0			7.60				1003	505	4.6
Mar-93	4.69	4147.21	20.0			7.48	11	0.3		1072	538	9.6
Apr-93	6.00	4145.90	26.0	BDL	1.2	7.30	9	0.9		1151	576	9.5
May-93	6.29	4145.61	25.0			7.09	12	1.1		1159	579	15.2
Jun-93	5.95	4145.95	25.0			6.99	11	0.9		1165	581	16.4
Jul-93	6.05	4145.85	26.0	BDL	0.4	7.29	6	0.0		1192	600	17.3
Aug-93	5.96	4145.94	23.0			7.61	31	2.5		1140	570	15.0
Sep-93	6.13	4145.77	25.0			7.44	16	1.3		1061	533	13.3
Oct-93	6.21	4145.69	20.0	BDL	1.1	7.43	6	1.0		1168	587	14.4
Nov-93	6.52	4145.38	23.0			7.47	21	2.2		1166	583	9.0
Dec-93	6.71	4145.19	23.0			7.38	15	1.5		1167	585	8.2
Jan-94	7.10	4144.80	13.0	BDL	BDL	7.52	16	1.1		964	483	8.1
Feb-94	6.92	4144.98	22.0			7.52	15	1.8		1095	547	6.8
Mar-94	6.78	4145.12	19.0			7.35	15	1.7		1132	571	7.9
Apr-94	6.92	4144.98	11.1	BDL	1.2	7.35	16	1.4		1005	504	12.5
May-94	4.95	4146.95	11.5			7.38	10	1.0		874	439	12.8
Jun-94	5.32	4146.58	12.0			7.74	0	0.0		860	433	14.9
Jul-94	5.89	4146.01	14.0	BDL	1.5	7.75	2	30.0		1003	502	19.3
Aug-94	5.76	4146.14	34.0			7.96	15	0.9		1389	698	17.6
Sep-94	5.52	4146.38	15.0			7.49	27	2.0		1021	522	19.2
Oct-94	6.23	4145.67	13.0	BDL	0.4	7.78	39	3.6		943	473	15.8
Nov-94	6.55	4145.35	13.0			7.42	23	2.7		959	481	6.6
Dec-94	6.92	4144.98	13.0			7.58	41	5.2		1000	500	5.0
Jan-95	6.56	4145.34	18.0	BDL		7.29	18	1.5		934	469	7.8
Feb-95	6.56	4145.34	22.0			7.65	13	1.8		1228	617	7.6
Mar-95	6.52	4145.38	17.0			7.57	30	3.4		1058	533	7.8
Apr-95	6.69	4145.21	20.0	BDL		7.55	21	2.0		1191	598	9.6
May-95	5.32	4146.58	19.0			7.46	19	2.0		1183	596	8.3
Jun-95	5.56	4146.34	25.0			7.43	20	1.8		1237	622	9.2
Jul-95	4.26	4147.64	23.0	BDL		7.55	25	2.3		1293	649	13.7
Aug-95	6.16	4145.74	25.0			7.54	27	2.7		1286	671	13.7
Sep-95	6.05	4145.85	14.0			7.43	19	1.8		986	496	13.2
Oct-95	6.26	4145.64	14.0			7.67	0	0.0		1009	506	5.9
Nov-95	7.13	4144.77	22.0			7.20	19	1.4		1226	615	8.2
Dec-95	6.22	4145.68	27.0			7.70	24	1.5		1272	638	5.7
Jan-96	6.51	4145.39	8.3			7.22	15	1.8		1193	598	5.7
Feb-96	6.04	4145.86	23.0			7.35	3	0.2		1251	630	7.5
Mar-96	6.31	4145.59	22.0			7.72	25	3.1		1313	654	6.2
Apr-96	6.78	4145.12	24.0			8.00	0	0.0		1200	603	6.4
May-96	5.88	4146.02	20.0			7.66	20	1.9		1043	523	8.5
Jun-96	6.17	4145.73	14.0			6.81	11	0.6		936	474	14.8
Jul-96	5.19	4146.71	11.0			7.61				904	455	16.9
Aug-96	5.20	4146.70	9.6			7.70	7	0.6		752	395	17.6
Sep-96	6.29	4145.61	9.9			7.80	16	0.9		850	428	17.0
Oct-96	6.26	4145.64	14.0			7.56	15	1.3		1207	601	9.7
Nov-96	6.36	4145.54	12.0			7.86	19	2.3		1085	537	7.0
Dec-96	6.01	4145.89	10.0			8.34				996	496	6.6
Jan-97	5.75	4146.15	15.0			7.45	27	3.0		1719	857	4.7
Feb-97	6.07	4145.83	14.0			8.13	18	1.6		1317	666	7.7
Mar-97	6.47	4145.43	12.0			8.42				1511	757	9.3
Apr-97	6.50	4145.40	13.0			7.57	19	1.4		1560	782	13.0
May-97	5.75	4146.15	10.0			7.06	0	0.0		1393	700	14.9
Jun-97	5.79	4146.11	12.0			7.30	0	0.0		1358	685	18.1
Jul-97	5.38	4146.52	12.0			7.28	0	0.0		1374	689	19.3
Aug-97	5.93	4145.97	15.0			7.35	11	0.8		1467	737	16.6
Sep-97	6.10	4145.80	14.0			7.34	0	0		1487	739	8.5

FE3 DATA cont.

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen		SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
							(%)	(mg/l)				
Oct-97	6.32	4145.58	17.0			7.6				1532	762	7.9
Nov-97	6.53	4145.37	15.0			8.84	13	0.9		1378	683	7.5
Dec-97	6.56	4145.34	14.0			7.96	7	0.7		1609	803	6.6
Jan-98	6.10	4145.80	13.0			7.90	13	1.4		1287	649	6.4
Feb-98	6.47	4145.43	17.0			8.99	0	0.0		1450	727	6.2
Mar-98	6.69	4145.21	12.0			8.89	0	0.0		1386	6.95	8.7
Apr-98	6.62	4145.28	22.0			7.23	22	2.0		1507	7.58	11.6
May-98	5.56	4146.34	20.0			7.76	5	0.1		1429	717	11.3
Jun-98	5.62	4146.28	21.0			7.65	53	3.9		1497	748	12.2
Jul-98	5.98	4145.92	21.0			6.65	24	1.8		1539	771	18.2
Aug-98	5.68	4146.22	23.0			7.43	32	2.7		1532	768	19.2
Sep-98	5.87	4146.03	19.0			7.52	23	2.1		1562	786	15.9
Oct-98	6.21	4145.69	20.0			7.52	0	0.0		1471	737	14.2
Nov-98	6.44	4145.46	27.0			8.38	13	0.7		1558	775	8.9
Dec-98	6.68	4145.22	23.0			8.10	0	0.0		1380	692	9.2

FE4 DATA

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen (%)	(mg/l)	SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
May-92	6.00	4145.92	7.4						0.3	690		15.2
Jun-92	5.19	4146.73	8.2						0.5	620		13.8
Jul-92	5.78	4146.14	5.5	BDL	2.0	7.74			0.8	1020		19.0
Aug-92	4.99	4146.93	3.5			7.07			0.6	805		18.5
Sep-92	6.30	4145.62	4.4			7.29	62	5.9	0.5	890		16.2
Oct-92	6.17	4145.75	5.5			7.24	41	4.3	0.5	800		13.9
Nov-92	6.64	4145.28	4.2			7.23	54	6.6	0.5	705		8.9
Dec-92	6.58	4145.34	3.8			7.54	69	8.3	0.7	690		7.0
Jan-93	6.75	4145.17	4.0	0.8	0.4	7.25	54	6.7	0.5	650		5.2
Feb-93	6.74	4145.18	4.7			7.22				1096	552	6.3
Mar-93	5.09	4146.83	9.4			7.24	19	1.5		1135	583	9.9
Apr-93	6.20	4145.72	11.0	BDL	1.5	6.98	14	1.6		1114	557	8.9
May-93	6.45	4145.47	11.0			6.87	24	2.3		1124	561	14.7
Jun-93	6.13	4145.79	8.8			6.73	15	1.6		1024	509	15.2
Jul-93	6.20	4145.72	9.3	BDL	BDL	7.27	16	0.0		878	441	18.9
Aug-93	6.14	4145.78	9.9			7.54	30	2.7		840	423	15.3
Sep-93	6.29	4145.63	12.0			7.39	18	1.1		804	406	13.9
Oct-93	6.35	4145.57	5.4	BDL	0.7	7.48	12	1.2		884	445	14.5
Nov-93	6.64	4145.28	17.0			7.41	16	1.7		946	473	9.3
Dec-93	6.81	4145.11	20.0			7.34	12	1.3		1010	505	8.7
Jan-94	7.40	4144.52	10.0	BDL	BDL	7.61	9	1.0		883	441	7.7
Feb-94	6.98	4144.94	21.0			7.49	12	1.3		1031	517	6.7
Mar-94	6.87	4145.05	16.0			7.27	16	1.3		1043	526	10.6
Apr-94	7.00	4144.92	23.0	BDL	0.6	7.19	0	0.0		1043	523	10.8
May-94	5.05	4146.87	20.0			7.29	11	1.1		961	483	12.8
Jun-94	5.54	4146.38	20.0			7.72	4	0.0		978	491	16.1
Jul-94	6.04	4145.88	17.0	BDL	1.9	7.51	21	1.7		1053	527	19.0
Aug-94	5.92	4146.00	16.0			7.72	19	3.0		919	462	19.2
Sep-94	5.75	4146.17	28.0			7.46	5	0.4		1042	522	19.0
Oct-94	6.39	4145.53	20.0	BDL	BDL	7.56	37	3.4		952	478	17.2
Nov-94	6.56	4145.36	12.0			7.42	30	3.5		858	428	6.9
Dec-94	7.00	4144.92	17.0			7.44	47	5.1		962	484	5.1
Jan-95	6.64	4145.28	20.0	BDL		7.63	16	1.7		827	416	8.4
Feb-95	6.67	4145.25	16.0			7.69	13	1.3		1043	522	7.4
Mar-95	6.69	4145.23	23.0			7.51	24	2.7		1046	525	7.9
Apr-95	6.8	4145.12	26.0	BDL		7.51	23	2.1		1172	586	8.6
May-95	5.39	4146.53	41.0			7.47	36	3.7		1334	670	8.4
Jun-95	5.83	4146.09	16.0			7.35	10	1.0		882	441	9.2
Jul-95	4.09	4147.83	22.0	BDL		7.68	27	2.2		1061	531	15.8
Aug-95	6.28	4145.64	13.0			6.77	24	2.1		875	453	13.6
Sep-95	6.19	4145.73	14.0			7.42	12	1.3		569	288	12.0
Oct-95	6.41	4145.51	11.0			8.00	0	0.0		734	363	6.8
Nov-95	6.58	4145.34	11.0			7.42	14	1.4		954	480	8.5
Dec-95	6.34	4145.58	14.0			7.80	17	1.6		977	490	6.4
Jan-96	6.63	4145.29	16.0			7.28	27	2.5		1058	533	7.4
Feb-96	6.18	4145.74	18.0			7.12	4	0.0		1249	626	6.1
Mar-96	6.48	4145.44	23.0			8.28	8	0.8		1483	744	6.7
Apr-96	6.84	4145.08	25.0			8.25	0	0.0		1488	747	6.5
May-96	6.00	4145.92	23.0			7.90	17	1.3		1141	572	8.5
Jun-96	6.27	4145.65	22.0			7.29	18	1.3		1195	597	14.9
Jul-96	5.04	4146.88	19.0			8.03				1082	546	17.5
Aug-96	4.88	4147.04	21.0			7.71	16	1.3		1194	599	17.1
Sep-96	6.36	4145.56	18.0			7.65	9	0.7		1225	616	17.4
Oct-96	6.29	4145.63	21.0			8.10	**51**	1.0		1294	644	10.2
Nov-96	6.55	4145.37	19.0			8.24	15	1.9		1306	649	6.9
Dec-96	6.17	4145.75	16.0			8.80				1175	586	6.7
Jan-97	5.95	4145.97	20.0			7.80	21	2.5		1721	855	5.4
Feb-97	6.28	4145.64	16.0			9.00	3	0.1		1218	612	8.1
Mar-97	6.59	4145.33	11.0			9,40				1274	638	10.4
Apr-97			7.3			7.74	14	1.4		514	288	10.5
May-97	5.8	4146.12	8.5			7.13	0	0.0		1215	608	17.4
Jun-97	5.9	4146.02	12.0			7.22	0	0.0		1369	688	18.5
Jul-97	5.45	4146.47	9.8			7.22	0	0.0		1309	655	18.6
Aug-97	6.09	4145.83	11.0			7.16	22	1.2		1424	714	18.2
Sep-97	6.21	4145.71	8.5			7.20				1119	556	9.4

FE4 DATA cont.

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen		SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
							(%)	(mg/l)				
Oct-97	6.42	4145.50	9.3			8.63				1235	612	8.3
Nov-97	6.57	4145.35	10.0			10.27	11	1.0		1211	607	8.9
Dec-97	6.78	4145.14	8.9			8.35	12	1.1		1170	585	7.3
Jan-98	6.21	4145.71	9.5			7.40	26	2.2		1143	5.69	5.3
Feb-98	6.6	4145.32	12.0			8.31	0	0.0		1211	601	4.5
Mar-98	6.81	4145.11	5.6			7.35	0	0.0		1249	626	7.7
Apr-98	6.72	4145.20	12.0			7.28	18	1.2		1336	669	12.2
May-98	5.78	4146.14	13.0			7.79	13	1.2		1290	645	10.2
Jun-98	5.83	4146.09	13.0			7.50	59	6.9		1508	754	12.1
Jul-98	6.05	4145.87	13.0			6.54	23	1.4		1358	668	18.0
Aug-98	5.58	4146.34	14.0			7.73	25	2.2		1387	695	19.2
Sep-98	6.04	4145.88	14.0			7.49	26	2.4		1520	758	16.5
Oct-98	6.34	4145.58	13.0			7.93	0	0.0		1442	724	15.7
Nov-98	6.53	4145.39	16.0			8.28	12	1.1		1579	763	11.3
Dec-98	6.62	4145.30	18.0			7.96	0	0.0		1500	744	9.0

FPNW DATA

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen		SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
							(%)	(mg/l)				
Jun-92	6.70	4145.56	1.4						0.5	605		13.0
Jul-92	6.59	4145.67	0.0	BDL	2.7	7.93			0.4	560		21.5
Aug-92	6.28	4145.98	0.5			7.36			0.3	530		23.0
Sep-92	6.92	4145.34	1.7			7.29	33	3.1	0.3	540		17.1
Oct-92	6.86	4145.40	1.8			7.57	25	2.7	0.4	550		16.0
Nov-92	7.27	4144.99	4.4			7.23	25	2.9	0.3	560		11.8
Dec-92	7.30	4144.96	2.2			7.47	35	3.9	0.3	490		9.1
Jan-93	7.35	4144.91	1.9	0.4	0.3	7.49	63	7.3	0.4	495		8.1
Feb-93	7.38	4144.88	2.0			7.45				735	368	7.5
Mar-93	6.33	4145.93	2.8			7.34	17	1.0		726	365	9.8
Apr-93	7.07	4145.19	7.5	BDL	1.3	6.94	18	1.8		826	414	11.7
May-93	7.10	4145.16	4.2			7.03	9	1.1		796	398	13.4
Jun-93	6.59	4145.67	5.8			6.86	30	2.7		752	374	18.8
Jul-93	6.84	4145.42	0.4	BDL	0.4	7.57	30	1.9		471	238	21.2
Aug-93	6.95	4145.31	2.0			7.69	37	3.1		513	257	21.5
Sep-93	6.93	4145.33	0.6			7.64	38	3.4		463	233	18.7
Oct-93	7.03	4145.23	10.0	BDL	0.5	7.52	20	1.5		678	339	16.9
Nov-93	7.34	4144.92	7.3			7.48	24	2.4		589	294	11.5
Dec-93	7.47	4144.79	7.5			7.37	17	1.7		601	300	10.4
Jan-94	7.56	4144.70	6.2	BDL	BDL	7.51	14	1.5		590	297	10.0
Feb-94	7.60	4144.66	3.9			7.54	20	2.1		583	292	8.5
Mar-94	7.53	4144.73	8.6			7.23	16	1.3		629	315	11.7
Apr-94	7.57	4144.69	9.9	BDL	0.8	7.33	17	1.3		628	315	13.1
May-94	6.11	4146.15	0.3			7.73	40	3.9		475	237	16.2
Jun-94	6.51	4145.75	0.3			7.57	20	1.5		484	241	17.0
Jul-94	6.62	4145.64	15.0	BDL	1.2	7.41	40	3.3		681	342	21.1
Aug-94	6.68	4145.58	0.3			7.91	40	3.1		483	245	26.0
Sep-94	6.79	4145.47	0.6			7.63	37	3.1		494	246	20.9
Oct-94	7.16	4145.10	51.0	BDL	BDL	7.18	41	3.7		1242	621	17.4
Nov-94	7.39	4144.87	27.0			7.09	33	3.4		1293	647	9.3
Dec-94	7.57	4144.69	33.0			7.09	46	5.1		1284	640	7.8
Jan-95	7.38	4144.88	49.0	BDL		8.15	48	4.1		952	480	9.8
Feb-95	7.36	4144.90	45.0			7.52	33	3.7		1276	641	8.7
Mar-95	7.40	4144.86	70.0			7.24	49	5.4		1386	696	9.0
Apr-95	7.41	4144.85	37.0	BDL		7.37	24	2.5		1186	621	9.6
May-95	6.31	4145.95	0.4			7.52	60	6.0		527	264	9.4
Jun-95	6.76	4145.50	82.0			7.34	39	3.8		1609	805	10.1
Jul-95	4.38	4147.88	0.2	BDL		7.59	59	4.8		488	244	21.6
Aug-95	6.85	4145.41	0.4			7.69	56	4.7		431	219	19.1
Sep-95	6.95	4145.31	1.4			7.61	34	2.8		509	257	16.1
Oct-95	7.13	4145.13	8.4			7.44	0	0.0		798	394	12.0
Nov-95	7.29	4144.97	5.9			7.11	13	1.3		693	344	10.4
Dec-95	7.10	4145.16	12.0			7.49	10	1.2		799	403	6.6
Jan-96	7.35	4144.91	17.0			7.23	18	2.3		901	446	4.6
Feb-96	7.06	4145.20	15.0			7.40	4	0.5		892	448	4.5
Mar-96	7.25	4145.01	12.0			7.43	11	1.1		800	402	7.8
Apr-96	7.46	4144.80	9.4			7.75	0	0.0		831	417	4.1
May-96	6.74	4145.52	0.8			7.79	58	5.8		400	202	8.7
Jun-96	6.94	4145.32	5.6			7.27	52	4.8		520	533	12.7
Jul-96	5.98	4146.28	0.4			7.94				443	223	23.1
Aug-96	5.04	4147.22	0.2			7.66	35	3.1		393	197	21.9
Sep-96	6.97	4145.29	8.6			7.51	21	1.8		664	330	18.3
Oct-96	6.92	4145.34	9.7			7.51	21	1.9		758	376	9.9
Nov-96	7.29	4144.97	13.0			7.56	23	2.4		869	431	10.0
Dec-96	7.09	4145.17	11.0			7.75				801	398	6.9
Jan-97	6.90	4145.36	8.1			7.34	26	3.0		888	441	5.7
Feb-97	7.15	4145.11	7.2			7.31	8	0.7		869	436	8.8
Mar-97	7.38	4144.88	6.7			7.50				1045	523	8.6
Apr-97			7.3			7.23	22	1.2		1057	529	11.8
May-97	6.55	4145.71	0.8			7.75	13	0.5		480	242	18.6
Jun-97	6.75	4145.51	0.6			7.99	24	1.6		456	220	22.4
Jul-97	5.75	4146.51				7.81	25	1.8		429	223	22.7
Aug-97	6.70	4145.56	3.6			7.47	34	2.5		617	311	21.5
Sep-97	6.86	4145.40	0.2			7.54				340	168	15.3
Oct-97	7.00	4145.26	0.9			7.83	20	1.7		438	209	9.4

FPNW DATA cont.

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen		SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
							(%)	(mg/l)				
Nov-97	7.27	4144.99	6.4			7.63	12	1.1		562	277	9.3
Dec-97	7.38	4144.88	14.0			7.55	9	0.8		682	336	7.3
Jan-98	7.11	4145.15	25.0			7.43	32	2.8		780	387	6.9
Feb-98	7.32	4144.94	22.0			7.79	0	0.0		791	390	5.8
Mar-98	7.42	4144.84	20.0			7.40	0	0.0		828	417	8.1
Apr-98	7.42	4144.84	33.0			7.38	19	1.1		884	445	14.2
May-98	6.63	4145.63	22.0			7.75	14	1.0		931	469	11.2
Jun-98	6.63	4145.63	20.0			7.44	30	2.6		950	477	12.2
Jul-98	6.46	4145.80	BDL			7.26	51	3.8		395	201	22.9
Aug-98	5.18	4147.08	1.0			8.00	67	4.8		453	231	27.1
Sep-98	6.70	4145.56	BDL			7.76	44	3.8		442	218	20.9
Oct-98	7.03	4145.23	0.3			7.39	0	0.0		449	225	17.8
Nov-98	6.97	4145.29	17.0			8.34	6	0.2		996	493	11.1
Dec-98	7.05	4145.21	16.0			7.88	0	0.0		1158	576	10.2

FPNE DATA

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen (%)	Dissolved Oxygen (mg/l)	SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
Jun-92	6.49	4145.61	2.6						0.5	560		12.2
Jul-92	6.30	4145.80	0.4	BDL	0.3	7.94			0.4	560		21.5
Aug-92	5.77	4146.33	0.5			7.22			0.4	605		22.5
Sep-92	6.75	4145.35	3.9			7.34	38	3.6	0.4	630		16.5
Oct-92	6.67	4145.43	1.6			7.41	28	3.6	0.3	625		15.2
Nov-92	7.08	4145.02	3.2			7.26	30	3.5	0.3	540		12.9
Dec-92	7.09	4145.01	0.7			7.57	52	7.6	0.4	440		8.8
Jan-93	7.14	4144.96	0.1	0.6	0.4	7.31	42	5.1	0.4	405		7.5
Feb-93	7.18	4144.92	0.7			7.57				645	324	7.7
Mar-93	6.06	4146.04	1.2			7.35	18	1.2		652	328	9.3
Apr-93	6.82	4145.28	3.3	BDL	1.4	7.06	16	1.7		718	358	11.9
May-93	6.90	4145.20	2.0			7.17	20	1.9		752	378	14.4
Jun-93	6.80	4145.30	20.0			7.09	50	4.2		692	347	20.5
Jul-93	6.65	4145.45	6.5	BDL	1.1	7.27	33	2.1		707	357	20.4
Aug-93	6.72	4145.38	8.9			7.40	42	3.5		674	338	20.4
Sep-93	6.74	4145.36	3.9			7.32	36	3.1		560	280	17.1
Oct-93	6.83	4145.27	11.0	BDL	0.4	7.31	15	1.5		677	339	16.0
Nov-93	7.13	4144.97	5.5			7.28	24	2.9		728	364	11.2
Dec-93	7.27	4144.83	5.4			7.19	12	1.2		855	426	9.8
Jan-94	7.36	4144.74	4.8	BDL	BDL	7.29	8	0.8		918	459	8.5
Feb-94	7.39	4144.71	5.8			7.24	12	1.5		951	471	6.7
Mar-94	7.49	4144.61	6.1			7.17	27	1.9		883	440	10.6
Apr-94	7.39	4144.71	16.0	BDL	0.5	7.09	18	1.3		1011	506	12.7
May-94	5.78	4146.32	1.1			7.33	47	4.4		523	261	14.8
Jun-94	6.23	4145.87	2.6			7.30	22	2.0		593	293	16.6
Jul-94	6.42	4145.68	13.0	BDL	1.2	7.39	34	2.7		662	336	21.1
Aug-94	6.47	4145.63	0.6			7.73	37	2.8		578	290	24.4
Sep-94	6.52	4145.58	31.0			7.51	33	2.4		926	460	20.6
Oct-94	6.93	4145.17	36.0	BDL	BDL	7.21	29	2.7		1384	695	17.9
Nov-94	7.29	4144.81	27.0			7.18	32	4.9		1311	652	9.2
Dec-94	7.39	4144.71	33.0			7.20	46	5.7		1354	677	6.7
Jan-95	7.14	4144.96	49.0	BDL		7.81	35	3.6		1213	605	8.5
Feb-95	7.14	4144.96	45.0			7.44	15	1.4		1491	752	9.3
Mar-95	7.20	4144.90	51.0			7.11	25	2.7		1479	742	8.8
Apr-95	7.22	4144.88	56.0	BDL		7.29	25	2.6		1535	770	9.4
May-95	5.94	4146.16	1.0			7.21	63	6.3		559	282	10.5
Jun-95	6.84	4145.26	110.0			6.85	50	4.5		1687	848	12.7
Jul-95	4.97	4147.13	0.3	BDL		7.08	59	5.0		488	245	20.7
Aug-95	6.65	4145.45	0.7			7.51	35	2.9		466	268	19.0
Sep-95	6.70	4145.40	0.9			7.52	27	2.0		505	253	16.9
Oct-95	7.89	4144.21	5.5			7.39	2	0.2		659	331	12.8
Nov-95	7.09	4145.01	37.0			7.08	17	1.9		1303	653	9.7
Dec-95	6.95	4145.15	38.0			7.26	21	2.4		1326	661	6.6
Jan-96	7.10	4145.00	35.0			7.24	26	3.8		1244	621	3.5
Feb-96	6.77	4145.33	34.0			7.54	16	1.5		1249	630	3.5
Mar-96	7.02	4145.08	33.0			7.42	0	0.0		1320	662	7.1
Apr-96	7.34	4144.76	34.0			7.50	5	0.4		1285	648	4.9
May-96	6.46	4145.64	6.4			7.58	57	6.3		488	246	8.6
Jun-96	6.75	4145.35	33.0			6.94	29	3.2		1075	560	12.4
Jul-96	5.50	4146.60	2.1			7.49				552	278	19.8
Aug-96	4.54	4147.56	0.5			7.49	45	3.6		467	235	22.2
Sep-96	6.79	4145.31	22.0			7.40	14	1.1		944	471	18.5
Oct-96	6.69	4145.41	22.0			7.36	23	2.5		938	467	9.3
Nov-96	7.64	4144.46	29.0			7.64	14	1.8		1102	546	8.5
Dec-96	6.61	4145.49	29.0			7.84				1132	561	7.0
Jan-97			11.0									
Feb-97	6.88	4145.22	8.8			7.40	10	0.4		937	470	9.0
Mar-97	7.09	4145.01	12.0			7.60				1134	569	8.8
Apr-97	6.49	4145.61	17.0			7.34	17	1.6		1202	607	10.1
May-97	6.27	4145.83	9.3			7.40	11	0.1		610	305	17.6
Jun-97	6.72	4145.38	5.9			7.46	15	0.5		403	235	22.8
Jul-97	5.64	4146.46	2.9			7.57	29	1.4		546	274	24.5
Aug-97	6.51	4145.59	30.0			7.12	33	2.5		775	389	22.9
Sep-97	6.65	4145.45	1.2			7.60				482	226	11.6
Oct-97	6.61	4145.49	18.0			7.52	0	0		720	361	8.5

FPNE DATA cont.

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen (%)	(mg/l)	SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
Nov-97	7.07	4145.03	26.0			7.26	32	3.2		852	422	8.7
Dec-97	7.18	4144.92	22.0			7.28	28	2.8		880	434	7.3
Jan-98	6.85	4145.25	19.0			7.23	19	1.9		1098	545	6.1
Feb-98	7.10	4145.00	15.0			7.84	0	0		1078	535	5.2
Mar-98	7.22	4144.88	13.0			7.15	0	0		1227	617	8.3
Apr-98	7.21	4144.89	21.0			7.14	19	1.7		1184	594	13.7
May-98	6.40	4145.70	15.0			7.65	5	0.1		1174	589	12.0
Jun-98	6.44	4145.66	15.0			7.47	23	1.9		1130	556	11.7
Jul-98	6.36	4145.74	14.0			7.00	67	4.4		611	309	19.7
Aug-98	5.00	4147.10	1.2			7.94	60	4.7		494	249	23.0
Sep-98	6.52	4145.58	bdl			7.74	43	3		563	268	19.3
Oct-98	6.83	4145.27	10.0			7.15	0	0.0		749	377	18.8
Nov-98	7.14	4144.96	5.2			8.60	0	0.0		542	269	11.5
Dec-98	7.25	4144.85	15.0			7.99	0	0.0		721	357	10.7

FPW DATA

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen (%)	Dissolved Oxygen (mg/l)	SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
Jun-92	6.82	4145.67	3.7						0.5	590		11.8
Jul-92	6.72	4145.77	3.2	BDL	BDL	7.54			0.4	700		18.0
Aug-92	6.36	4146.13	0.3			7.25			0.3	520		21.5
Sep-92	7.11	4145.38	3.7			7.10	38	3.5	0.4	705		17.0
Oct-92	7.14	4145.35	3.8			7.26	38	3.9	0.5	700		14.8
Nov-92	7.55	4144.94	3.4			7.08	31	3.7	0.4	650		10.7
Dec-92	7.56	4144.93	3.5			7.41	67	7.5	0.5	610		9.9
Jan-93	7.65	4144.84	3.3	0.4	0.5	7.32	64	7.7	0.5	595		8.0
Feb-93	7.71	4144.78	3.7			7.33				867	437	8.4
Mar-93	6.47	4146.02	6.5			7.15	26	2.5		904	447	10.1
Apr-93	7.26	4145.23	4.8	0.1	1.4	7.03	25	2.7		829	415	10.4
May-93	7.23	4145.26	4.2			6.90	18	1.5		836	415	14.3
Jun-93	6.99	4145.50	8.0			6.84	63	5.2		704	354	20.4
Jul-93	7.02	4145.47	0.6	BDL	0.8	7.38	38	2.8		568	287	21.6
Aug-93	7.13	4145.36	12.0			7.44	39	3.4		752	379	18.5
Sep-93			0.4			7.35	46	3.8		646	325	19.0
Oct-93	7.32	4145.17	15.0	BDL	0.7	7.19	28	2.8		848	420	13.6
Nov-93	7.59	4144.90	5.0			7.11	23	2.6		852	425	10.1
Dec-93	7.77	4144.72	3.6			7.01	22	2.4		828	415	8.3
Jan-94	7.88	4144.61	2.6	BDL	BDL	7.03	19	1.5		806	403	7.3
Feb-94	7.92	4144.57	1.9			7.10	11	1.4		795	396	6.6
Mar-94	7.80	4144.69	2.7			6.84	12	1.1		809	404	8.5
Apr-94	7.84	4144.65	4.0	BDL	0.6	7.02	9	0.7		762	403	18.0
May-94	5.20	4147.29	0.0			7.42	54	4.4		477	240	19.5
Jun-94	6.72	4145.77	5.1			7.70	25	2.0		631	320	16.9
Jul-94	6.79	4145.70	5.8	BDL	1.5	7.48	38	3.1		726	365	20.5
Aug-94	6.72	4145.77	0.2			7.87	38	2.9		552	273	24.5
Sep-94	6.96	4145.53	0.5			6.04	38	3.1		554	279	19.3
Oct-94	7.39	4145.10	72.0	BDL	BDL	6.23	25	2.3		1409	700	14.7
Nov-94		4152.49	17.0			7.54	27	3.0		953	476	9.8
Dec-94	7.84	4144.65	13.0			6.46	48	4.9		908	450	8.0
Jan-95	7.70	4144.79	22.0	BDL		8.11	35	3.7		776	391	10.1
Feb-95	7.59	4144.90	36.0			7.48	24	2.8		1067	537	9.0
Mar-95	7.68	4144.81	57.0			7.24	46	5.1		1174	590	9.3
Apr-95	7.66	4144.83	76.0	BDL		7.23	41	4.2		1382	695	11.2
May-95	6.51	4145.98	0.2			7.60	52	5.7		514	258	10.1
Jun-95	5.91	4146.58	79.0			7.25	44	4.5		1844	927	10.8
Jul-95	4.20	4148.29	0.4	BDL		7.80	57	4.8		563	283	21.2
Aug-95	7.03	4145.46	4.9			7.50	45	3.9		594	299	17.8
Sep-95	7.32	4145.17	7.8			7.36	34	3.5		730	362	13.1
Oct-95	7.39	4145.10	21.0			7.39	12	0.8		1051	524	9.1
Nov-95	7.54	4144.95	20.0			6.96	11	0.8		1068	533	8.7
Dec-95	7.41	4145.08	24.0			7.46	21	2.4		1081	538	5.6
Jan-96	7.66	4144.83	23.0			7.20	17	1.9		1000	495	3.2
Feb-96	7.21	4145.28	25.0			7.34	1	0.0		1103	555	4.0
Mar-96	7.59	4144.90	26.0			7.50	1	0.0		1132	568	8.0
Apr-96	7.55	4144.94	25.0			7.75	0	0.0		1043	528	7.2
May-96	6.93	4145.56	1.1			7.74	63	6.7		430	217	9.1
Jun-96	7.07	4145.42	21.0			6.84	20	1.6		1027	514	12.9
Jul-96	6.18	4146.31	0.3							475	239	22.2
Aug-96	5.06	4147.43	0.2			7.59	19	3.8		437	217	21.3
Sep-96	7.34	4145.15	4.1			7.44	25	2.1		584	291	17.2
Oct-96	7.39	4145.10	14.0			7.22	23	2.8		977	487	7.7
Nov-96	7.57	4144.92	11.0			7.50	16	1.8		1074	535	7.9
Dec-96	7.79	4144.70	22.0			7.69				1146	572	7.8
Jan-97	7.09	4145.40	9.8			7.45	20	2.1		1125	561	6.8
Feb-97	7.35	4145.14	16.0			7.48	26	2.5		1148	578	9.3
Mar-97	7.59	4144.90	12.0			7.35				1247	625	9.1
Apr-97	7.73	4144.76	13.0			7.33	20	1.9		150	71.2	11.8
May-97	6.72	4145.77	0.7			7.71	7	0.2		444	246	16.3
Jun-97	6.75	4145.74	2.9			7.56	14	0.2		583	295	18.7
Jul-97	5.67	4146.82	0.4			7.87	20	1.2		426	215	19.5
Aug-97	6.77	4145.72	2.1			7.15	33	3.0		1020	513	22.0
Sep-97	7.08	4145.41	0.3			7.57				453	223	14.1
Oct-97	7.39	4145.10	2.3			7.57	0	0.0		761	377	9.5

FPW DATA cont.

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen (%)	Dissolved Oxygen (mg/l)	SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
Nov-97	7.57	4144.92	26.0			7.32	21	1.4		1081	538	7.7
Dec-97	7.68	4144.81	20.0			7.20	16	1.7		1144	570	7.5
Jan-98	7.36	4145.71	20.0			7.05	19	2.2		1113	554	6.5
Feb-98	7.55	4144.94	18.0			7.27	0	0.0		1115	556	6.1
Mar-98	7.69	4144.80	23.0			7.23	0	0.0		1210	609	8.1
Apr-98	7.73	4144.76	37.0			7.36	17	1.5		1137	597	13.4
May-98	6.78	4145.71	30.0			7.92	6	0.4		1103	553	11.4
Jun-98	6.73	4145.76	28.0			7.36	39	2.7		1120	564	14.6
Jul-98	6.69	4145.80	0.2			7.73	58	4.1		427	217	22.8
Aug-98	5.19	4147.30	0.4			7.98	47	3.9		428	214	23.9
Sep-98	6.90	4145.59	BDL			7.64	41	3.3		506	247	19.1
Oct-98	7.26	4145.23	15.0			7.39	0	0.0		762	378	15.6
Nov-98	7.47	4145.02	4.5			8.07	8	0.0		1021	508	9.2
Dec-98	7.57	4144.92	20.0			7.59	0	0.0		1051	522	10.7

FPS DATA

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen (%)	(mg/l)	SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
Jun-92	6.97	4146.47	0.2						0.2	520		15.2
Jul-92	6.89	4146.55	0.0	BDL	BDL	7.46			0.4	695		21.0
Aug-92	6.59	4146.85	0.2			6.89			0.3	720		21.2
Sep-92	7.46	4145.98	0.2			7.42	45	4.2	0.3	670		18.0
Oct-92	7.47	4145.97	3.2			7.42	40	3.9	0.5	620		16.5
Nov-92	7.95	4145.49	14.0			7.30	36	4.5	0.5	660		9.9
Dec-92	7.89	4145.55	16.0			7.47	51	5.9	0.5	660		8.3
Jan-93	8.11	4145.33	15.0	1.0	0.2	7.41	54	6.9	0.7	680		7.0
Feb-93	8.18	4145.26	19.0			7.51	57	7.2		1143	573	7.3
Mar-93	5.93	4147.51	4.5			7.42	47	4.6		933	471	7.7
Apr-93	7.33	4146.11	10.0	BDL	1.2	7.36	53	5.8		860	430	8.9
May-93	7.60	4145.84	27.0			7.03	45	4.3		1292	646	15.3
Jun-93	7.07	4146.37	45.0			6.63	41	3.6		1355	682	16.0
Jul-93	7.25	4146.19	35.5	BDL	BDL	7.27	34	2.4		1405	706	17.8
Aug-93	7.23	4146.21	43.0			7.46	46	3.7		1537	774	16.1
Sep-93	7.41	4146.03	48.0			7.11	26	2.4		1515	760	13.1
Oct-93	7.64	4145.80	34.0	BDL	0.9	7.35	31	2.3		1433	718	14.0
Nov-93	7.96	4145.48	33.0			7.31	23	2.6		1349	674	8.6
Dec-93	8.20	4145.24	33.0			7.17	20	2.0		1323	664	9.6
Jan-94	8.37	4145.07	24.0	BDL	BDL	7.39	13	1.4		1204	602	7.3
Feb-94	8.48	4144.96	28.0			7.36	19	2.2		1349	675	6.7
Mar-94	8.26	4145.18	28.0			7.21	28	3.1		1298	647	8.5
Apr-94	8.38	4145.06	29.0	BDL	BDL	7.19	37	3.0		1307	654	12.1
May-94	6.39	4147.05	16.0			7.34	20	2.0		1013	506	13.3
Jun-94	6.65	4146.79	20.0			7.62	14	1.0		1101	553	15.5
Jul-94	7.18	4146.26	19.0	BDL	1.5	7.71	30	2.0		1103	555	21.3
Aug-94	7.04	4146.40	16.0			7.73	22	1.8		1116	559	17.6
Sep-94	6.94	4146.50	16.0			6.80	8	0.3		1015	509	15.8
Oct-94	7.60	4145.84	16.0	BDL	BDL	7.41	38	3.3		1052	527	15.4
Nov-94	8.00	4145.44	17.0			7.44	28	2.9		1107	552	9.3
Dec-94	8.38	4145.06	21.0			7.43	40	5.1		1127	556	4.5
Jan-95	8.10	4145.34	19.0	BDL		8.22	31	3.6		915	460	9.9
Feb-95	8.00	4145.44	20.0			7.70	24	2.7		1204	604	8.7
Mar-95	8.12	4145.32	26.0			7.51	36	4.0		1182	593	9.1
Apr-95	8.11	4145.33	31.0	BDL		7.67	28	3.2		1252	628	8.7
May-95	6.89	4146.55	22.0			7.40	33	3.1		1198	602	9.9
Jun-95	6.68	4146.76	10.0			7.30	40	4.0		1092	548	11.1
Jul-95	5.78	4147.66	12.0	BDL		7.59	35	3.2		1054	553	14.9
Aug-95	7.36	4146.08	17.0			7.32	25	2.2		1120	564	13.0
Sep-95	7.39	4146.05	17.0			7.00	26	2.3		1118	559	14.4
Oct-95	7.14	4146.30	21.0			7.36	0	0.0				6.5
Nov-95	7.89	4145.55	22.0			6.92	28	2.2		1269	638	9.4
Dec-95	7.62	4145.82	22.0			7.47	21	2.3		1246	621	6.2
Jan-96	8.02	4145.42	22.0			7.15	27	3.2		1202	600	5.4
Feb-96	6.78	4146.66	27.0			7.30	16	1.2		1350	677	4.6
Mar-96	7.75	4145.69	5.8			7.37	34	4.3		1444	725	6.7
Apr-96	7.32	4146.12	16.0			7.62	15	1.3		1519	760	4.8
May-96	6.03	4147.41	34.0			7.48	45	4.8		1303	653	8.6
Jun-96	7.58	4145.86	37.0			6.53	25	2.3		1640	820	13.1
Jul-96	7.23	4146.21	40.0			7.15				1585	795	16.6
Aug-96	7.10	4146.34	27.0			7.25	23	1.6		1272	637	17.0
Sep-96	7.70	4145.74	17.0			7.28	16	1.4		1213	609	16.9
Oct-96	7.75	4145.69	12.0			7.33	15	1.9		1033	514	10.1
Nov-96	7.96	4145.48	19.0			7.57	16	1.9		1158	575	6.7
Dec-96	7.60	4145.84	22.0			7.75				1167	579	6.9
Jan-97	7.09	4146.35	17.0			7.38	30	3.2		1170	604	7.8
Feb-97	7.48	4145.96	25.0			7.17	17	1.7		1229	615	9.3
Mar-97	7.91	4145.53	27.0			7.72				1658	832	9.6
Apr-97	8.08	4145.36	31.0			7.50	42	3.9		1542	774	11.2
May-97	7.00	4146.44	35.0			7.00	0	0.0		1164	591	12.9
Jun-97	6.95	4146.49	44.0			7.15	0	0.0		1462	765	16.2
Jul-97	6.46	4146.98	40.0			7.41	5	0.0		1481	743	16.5
Aug-97	7.53	4145.91	41.0				1	0.0		1458	733	16.2
Sep-97	7.50	4145.94	26.0			7.13				1238	625	12.7

FPS DATA cont.

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen		SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
							(%)	(mg/l)				
Oct-97	7.73	4145.71	38			7.49	0	0		1414	703	8.1
Nov-97	7.99	4145.45	29.0			7.59	7	0.5		1295	644	7.5
Dec-97	8.14	4145.30	32.0			7.43	18	1.8		1386	685	7.5
Jan-98	7.46	4145.98	46.0			6.98	33	3.2		1543	768	6.6
Feb-98	7.92	4145.52	38.0			6.94	0	0.0		1384	691	5.2
Mar-98	8.16	4145.28	33.0			7.64	0	0.0		1454	730	8.2
Apr-98	8.28	4145.16	52.0			7.72	17	1.8		1521	761	12.1
May-98	6.87	4146.57	41.0			8.45	12	0.5		1404	706	10.3
Jun-98	6.87	4146.57	46.0			7.27	46	3.7		1593	757	11.6
Jul-98	7.40	4146.04	40.0			6.62	27	1.8		1505	750	16.2
Aug-98	7.21	4146.23	36.0			7.56	22	1.9		1462	726	16.7
Sep-98	7.23	4146.21	2.2			7.19	40	3.4		1135	571	17.0
Oct-98	7.59	4145.85	15.0			6.66	0	0.0		1245	626	14.2
Nov-98	7.91	4145.53	20.0			7.71	16	1.9		1266	630	8.9
Dec-98	8.03	4145.41	26.0			7.46	0	0.0		1280	634	8.4

MW1 DATA

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen		SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
							(%)	(mg/l)				
May-92	7.66	4136.60	18.0						2.0	2770		13.5
Jun-92	5.30	4138.96	21.6						2.4	3190		14.0
Jul-92	6.06	4138.20	8.0	BDL	3.7				1.0	1430		21.5
Aug-92	6.14	4138.12	5.0			7.96			0.7	1160		17.0
Sep-92	7.11	4137.15	5.0			8.22	12	1.1	0.8	1150		16.5
Oct-92	6.06	4138.20	15.0			7.93	41	4.2	3.8	3640		13.7
Nov-92	8.13	4136.13	11.0			7.95	33	3.9	1.9	2040		7.3
Dec-92	8.05	4136.21	8.9			8.20	77	8.5	1.9	1890		7.9
Jan-93	8.59	4135.67	8.8	0.6	0.5	8.15	76	8.9	1.2	1595		7.1
Feb-93	8.55	4135.71	10.0			8.09	61	5.5		2520	1270	5.6
Mar-93	3.40	4140.86	19.0			7.65	53	5.9		5500	2075	10.4
Apr-93	7.20	4137.06	20.0	BDL	2.1	7.89	42	4.5		4570	2300	8.9
May-93	6.86	4137.40	16.0			7.82	50	4.7		4070	2050	13.2
Jun-93	5.59	4138.67	15.0			7.96	47	4.5		3590	1810	14.3
Jul-93	4.41	4139.85	12.0	BDL	0.9	7.96	28	0.0		2910	1480	16.7
Aug-93	5.38	4138.88	14.0			7.72	36	2.9		4270	2160	17.0
Sep-93	6.57	4137.69	13.0			7.79	33	3.1		3790	1940	14.7
Oct-93	7.00	4137.26	10.0	BDL	1.5	7.83	39	3.9		3020	1510	13.5
Nov-93	7.84	4136.42	12.0			7.91	20	2.0		3050	1500	11.1
Dec-93	8.44	4135.82	13.0			7.94	18	1.9		2970	1480	10.6
Jan-94	8.81	4135.45	10.0	BDL	BDL	7.95	14	1.8		2570	1290	6.6
Feb-94	8.89	4135.37	5.0			8.08	20	2.4		2470	1240	6.1
Mar-94	9.00	4135.26	8.1			7.87	30	3.2		2270	1150	11.3
Apr-94	9.07	4135.19	7.7	BDL	1.2	7.87	23	2.2		2280	1160	14.6
May-94	7.16	4137.10	6.1			8.08	0	0.1		1849	925	11.0
Jun-94	5.26	4139.00	9.9			7.82	0	0.0		2980	1510	15.3
Jul-94	5.60	4138.66	6.4	BDL	1.5	8.19	40	2.8		1977	989	18.9
Aug-94	4.88	4139.38	6.0			8.62	16	1.1		1752	879	17.7
Sep-94	5.19	4139.07	4.9			7.98	7	0.7		1515	759	15.6
Oct-94	6.49	4137.77	4.6	BDL	0.5	7.47	24	2.0		1389	692	11.7
Nov-94	7.85	4136.41	3.4			8.10	15	1.7		1575	790	10.8
Dec-94	9.07	4135.19	4.9			7.00	43	5.6		1509	751	5.6
Jan-95	8.12	4136.14	5.3	BDL		7.18	19	1.9		1622	814	7.8
Feb-95	8.14	4136.12	6.2			8.23	25	2.7		1813	909	8.2
Mar-95	8.17	4136.09	6.3			8.01	36	3.5		1767	885	12.5
Apr-95	8.53	4135.73	6.1	BDL		8.02	32	3.2		1899	951	8.6
May-95	7.80	4136.46	5.8			8.04	28	3.9		1908	959	6.5
Jun-95	5.81	4138.45	5.0			7.80	55	5.0		2520	1290	8.6
Jul-95	5.11	4139.15	5.3	BDL		7.65	47	3.9		2910	1480	16.2
Aug-95	5.18	4139.08	5.5			8.12	38	3.6		1878	939	13.2
Sep-95	6.18	4138.08	4.6			8.20	16	1.5		1497	749	9.4
Oct-95	7.04	4137.22	4.7			8.20	0	0.0		1455	730	12.3
Nov-95	7.98	4136.28	4.3			8.63	24	2.5		1522	760	9.4
Dec-95	7.21	4137.05	4.8			8.08	25	3.0		1527	760	5.9
Jan-96	8.50	4135.76	5.9			7.81	25	2.7		1699	854	4.6
Feb-96	6.49	4137.77	6.1			7.97	23	2.8		1960	990	4.4
Mar-96	7.54	4136.72	7.0			7.82	8	0.1		1990	1100	3.9
Apr-96	8.66	4135.60	7.4			8.19	0	0.0		2140	1080	6.6
May-96	5.90	4138.36	5.9			7.87	28	2.6		1700	858	6.8
Jun-96	5.62	4138.64	5.7			7.48	30	2.7		4080	2070	11.5
Jul-96	5.24	4139.02	4.5			7.87				2160	1110	20.0
Aug-96	5.50	4138.76	4.6			7.91	15	1.1		646	347	19.2
Sep-96	6.11	4138.15	4.9			8.27	25	2.3		1633	840	16.9
Oct-96	6.98	4137.28	4.2			7.84	5	0.7		1550	773	9.6
Nov-96	7.89	4136.37	5.2			8.01	27	2.9		1633	813	7.4
Dec-96	6.05	4138.21	5.1			7.87				1822	909	6.8
Jan-97	6.16	4138.10	5.1			7.73	35	4.3		2990	1470	4.4
Feb-97	7.10	4137.16	6.9			8.20	28	2.5		1914	957	8.4
Mar-97	8.48	4135.78	7.8			7.97	0	0.0		1270	638	11.5
Apr-97	8.14	4136.12	6.8			8.38	39	3.7		2390	1240	13.4
May-97	7.03	4137.23	6.6			8.04	65	3.1		1984	999	18.3
Jun-97	5.75	4138.51	5.4			8.16	0	0.0		1980	1010	15.0
Jul-97	5.92	4138.34	6.2			7.98	0	0.0		1829	923	16.8
Aug-97	6.60	4137.66	6.8			7.71	8	3.1		2820	1430	18.8
Sep-97	6.81	4137.45	5.2			7.88	0	0.0		1831	913	11.7
Oct-97	7.79	4136.47	5.2			8.11	0	0.0		1755	875	8.6
Nov-97	8.47	4135.79	5.1			7.80	4	0.4		1678	834	6.5
Dec-97	8.75	4135.51	5.2			7.96	58	6.4		1632	812	7.7
Jan-98	7.38	4136.88	5.0			7.63	43	4.9		2100	955	4.6
Feb-98	8.60	4135.66	8.6			7.51	0	0.0		2080	1010	4.4
Mar-98	8.92	4135.34	5.9			8.16				2030	1060	9.3

MW2 DATA

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen		SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
							(%)	(mg/l)				
May-92	6.54	4137.91	16.0						1.0	1020		11.0
Jun-92	5.55	4138.90	15.5						0.9	1120		15.0
Jul-92	6.32	4138.13	9.1	BDL	3.3	7.70			0.7	1050		23.5
Aug-92	6.37	4138.08	8.8			7.05			0.9	1120		16.5
Sep-92	7.33	4137.12	8.2			7.45	14	1.2	0.8	1150		16.7
Oct-92	6.29	4138.16	8.1			7.67	40	4.1	0.8	1025		13.2
Nov-92	8.34	4136.11	8.4			7.53	36	3.4	0.8	830		7.5
Dec-92	8.24	4136.21	9.8			7.64	62	6.9	0.9	870		8.1
Jan-93	8.77	4135.68	9.9	0.3	0.7	7.70	72	7.9	0.5	870		8.0
Feb-93	8.72	4135.73	11.0			7.51	46	5.3		1474	714	6.2
Mar-93	3.61	4140.84	9.1			7.58	58	5.8		1463	731	10.0
Apr-93	7.46	4136.99	10.2	BDL	1.5	7.57	42	5.0		1428	713	9.8
May-93	7.10	4137.35	11.0			7.34	40	4.1		1466	732	12.2
Jun-93	5.78	4138.67	7.6			7.40	51	4.6		1478	741	14.7
Jul-93	4.44	4140.01	11.5	BDL	7.5	7.43	29	2.0		1488	747	16.9
Aug-93	5.48	4138.97	8.8			7.38	32	2.8		1565	783	16.1
Sep-93	6.79	4137.66	8.8			7.36	31	3.1		1546	775	14.9
Oct-93	6.80	4137.65	10.0	BDL	1.5	7.83	39	3.9		3020	1510	13.5
Nov-93	8.03	4136.42	9.8			7.36	21	2.3		1415	708	10.7
Dec-93	8.62	4135.83	9.0			7.41	22	2.2		1461	731	11.0
Jan-94	8.99	4135.46	10.0	BDL	BDL	7.40	12	1.4		1418	735	6.7
Feb-94	9.08	4135.37	7.8			7.43	16	1.9		1485	743	6.2
Mar-94	9.19	4135.26	8.0			7.32	19	2.2		1414	712	12.2
Apr-94	9.27	4135.18	8.5	BDL	1.0	7.28	29	2.6		1454	728	11.8
May-94	7.39	4137.06	7.2			7.28	15	1.2		1375	689	10.6
Jun-94	5.58	4138.87	6.5			7.62	22	1.8		1334	682	13.6
Jul-94	5.78	4138.67	5.0	BDL	2.1	7.63	26	2.1		1292	649	20.0
Aug-94	5.09	4139.36	4.6			7.77	25	1.5		1296	646	16.8
Sep-94	5.50	4138.95	5.0			7.48	16	1.2		1308	655	16.6
Oct-94	6.70	4137.75	4.8	BDL	0.8	7.51	26	2.5		1251	628	11.7
Nov-94	8.05	4136.40	4.7			7.82	13	1.4		1324	665	10.6
Dec-94	9.27	4135.18	5.5			7.00	45	5.5		1277	640	5.0
Jan-95	8.23	4136.22	5.5	BDL		7.37	28	3.3		1318	661	7.8
Feb-95	8.34	4136.11	6.3			7.64	22	2.5		1363	685	8.4
Mar-95	8.38	4136.07	6.3			7.39	23	1.9		1313	659	12.2
Apr-95	8.72	4135.73	6.6	BDL		7.40	28	3.1		1374	688	9.2
May-95	7.99	4136.46	6.2			7.43	32	3.2		1343	675	7.6
Jun-95	6.12	4138.33	5.9			7.56	51	5.2		1350	677	10.4
Jul-95	5.20	4139.25	6.5	BDL		7.32	26	2.4		1368	683	15.2
Aug-95	5.49	4138.96	5.1			7.61	43	4.0		1506	744	15.3
Sep-95	6.44	4138.01	6.1			7.49	19	2.1		1820	905	8.6
Oct-95	7.26	4137.19	6.3			7.24	0	0.0		1357	679	10.7
Nov-95	8.18	4136.27	6.0			7.40	16	1.7		1374	690	8.5
Dec-95	7.53	4136.92	6.3			7.44	18	1.9		1369	679	5.9
Jan-96	8.46	4135.99	6.5			7.20	25	2.6		1298	650	5.7
Feb-96	6.63	4137.82	6.3			7.39	14	1.6		1408	704	3.9
Mar-96	7.74	4136.71	5.1			7.46	20	2.1		1476	738	3.3
Apr-96	8.69	4135.76	5.4			7.57	17	1.4		1392	721	5.4
May-96	6.25	4138.20	6.4			7.40	21	1.9		1263	635	6.6
Jun-96	5.88	4138.57	2.2			7.25	46	4.5		1950	970	11.2
Jul-96	5.54	4138.91	5.9			7.26				1520	760	16.2
Aug-96	5.72	4138.73	7.9			7.06	23	1.8		1352	677	16.7
Sep-96	6.29	4138.16	7.4			7.61	26	2.4		1480	742	13.8
Oct-96	7.09	4137.36	6.1			7.27	14	1.2		1568	781	10.4
Nov-96	8.11	4136.34	7.0			7.59	21	2.6		1462	726	6.2
Dec-96	6.33	4138.12	7.2			7.69				1452	700	6.7
Jan-97	6.39	4138.06	5.5			7.68	41	4.7		1910	943	3.7
Feb-97	7.32	4137.13	5.6			7.90	27	3.0		1669	834	8.3
Mar-97	8.34	4136.11	5.8			7.39	0	0.0		1652	831	10.1
Apr-97	8.40	4136.05	6.7			7.68	37	3.0		805	414	13.9
May-97	7.21	4137.24	7.2			7.34	0	0.0		1595	798	16.7
Jun-97	5.95	4138.5	7.5			7.52	0	0.0		1546	777	14.7
Jul-97	6.23	4138.22	8.7			7.40	0	0.0		1550	779	16.1
Aug-97	6.83	4137.62	16.0			7.36	41	2.9		2070	990	17.6
Sep-97	7.02	4137.43	9.4			7.31	0	0.0		1636	814	11.0
Oct-97	7.95	4136.5	11.0			7.63	0	0.0		1192	268	8.8
Nov-97	8.64	4135.81	10.0			7.58	17	1.1		1555	780	6.6
Dec-97	8.93	4135.52	8.3			7.59	43	4.9		1626	811	8.0
Jan-98	7.41	4137.04	10.0				40	3.5		1517	955	5.8
Feb-98	8.79	4135.66	11.0			7.81	0	0.0		1461	741	5.0
Mar-98	8.96	4135.49	5.7			8.41	0	0.0		1596	792	8.2

MW3 DATA

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen		SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
							(%)	(mg/l)				
May-92	5.90	4138.91	6.0						0.8	1010		11.0
Jun-92	6.09	4138.72	6.3						0.9	1100		14.7
Jul-92	6.83	4137.98	5.2	BDL	3.2	7.83			0.7	980		23.0
Aug-92	6.85	4137.96	4.7			7.18			0.9	1060		17.2
Sep-92	7.80	4137.01	5.0			7.49	12	1.1	0.7	1070		17.0
Oct-92	6.90	4137.91	6.8			7.64	63	6.7	0.8	1105		13.2
Nov-92	8.78	4136.03	5.7			7.65	58	6.8	0.9	940		7.5
Dec-92	8.67	4136.14	6.4			7.72	61	7.5	0.9	910		7.5
Jan-93	9.18	4135.63	5.8	0.3	0.7	7.73	71	5.3	0.7	895		5.9
Feb-93	9.07	4135.74	6.5			7.72	57	5.4		1410	707	6.0
Mar-93	4.24	4140.57	6.4			7.43	52	5.2		1607	830	10.1
Apr-93	7.92	4136.89	8.9	BDL	1.4	7.56	35	3.9		1496	748	11.4
May-93	7.63	4137.18	4.3			7.45	42	4.5		1515	757	12.0
Jun-93	6.14	4138.67	7.6			7.36	55	5.8		1523	767	16.0
Jul-93	4.83	4139.98	6.8	BDL	1.3	7.41	23	1.8		1426	717	17.6
Aug-93	5.78	4139.03	7.0			7.43	27	2.6		1482	743	16.8
Sep-93	7.25	4137.56	6.8			7.47	29	2.8		1423	708	14.7
Oct-93	7.39	4137.42	5.7	BDL	1.0	7.39	36	3.6		1399	700	13.1
Nov-93	8.42	4136.39	6.6			7.45	25	2.5		1416	710	10.5
Dec-93	8.99	4135.82	7.6			7.50	27	2.8		1447	722	11.5
Jan-94	9.36	4135.45	9.7	BDL	BDL	7.48	13	1.4		1429	714	7.2
Feb-94	9.45	4135.36	13.0			7.53	17	2		1446	724	6.5
Mar-94	9.58	4135.23	12.0			7.53	30	2.6		1421	709	11.3
Apr-94	9.71	4135.10	10.0	BDL	BDL	7.49	30	2.9		1428	714	13.9
May-94	7.92	4136.89	6.1			7.40	11	1.2		1261	634	13.2
Jun-94	6.17	4138.64	4.0			7.80	18	1.8		1194	597	14.6
Jul-94	6.19	4138.62	2.8	BDL	2.2	7.73	22	1.4		1102	553	18.1
Aug-94	5.52	4139.29	2.6			7.92	18	1.9		1064	552	19.1
Sep-94	6.13	4138.68	2.4			7.85	10	0.7		1057	530	16.1
Oct-94	7.10	4137.71	3.2	BDL	BDL	7.51	20	2.1		1070	539	12.2
Nov-94	8.45	4136.36	3.0			7.53	21	1.5		1120	560	12.1
Dec-94	9.71	4135.10	2.8			6.81	41	4.9		1059	533	5.3
Jan-95	8.73	4136.08	3.0	BDL		7.58	26	2.9		1091	548	7.8
Feb-95	8.76	4136.05	3.5			7.75	23	2.5		1152	581	8.4
Mar-95	8.80	4136.01	3.1			7.62	30	2.8		1100	552	11.4
Apr-95	9.09	4135.72	3.6	BDL		7.46	30	3.0		1182	592	9.0
May-95	8.44	4136.37	3.3			7.50	31	3.0		1117	561	7.3
Jun-95	6.69	4138.12	4.7			7.59	35	3.6		1257	631	9.3
Jul-95	5.74	4139.07	4.0	BDL		7.30	35	3.1		1196	601	16.1
Aug-95	6.05	4138.76	4.7			7.70	45	3.9		1124	565	15.3
Sep-95	6.88	4137.93	4.5			7.51	24	2.4		1518	758	8.4
Oct-95	7.63	4137.18	5.9			7.35	0	0.0		1249	625	9.6
Nov-95	8.59	4136.22	4.9			7.43	22	2.3		1218	610	8.5
Dec-95	8.11	4136.70	5.5			7.65	20	1.9		1236	615	6.0
Jan-96	8.86	4135.95	4.9			7.27	20	2.4		1129	567	4.6
Feb-96	7.09	4137.72	4.9			7.47	17	1.8		1276	641	3.3
Mar-96	8.15	4136.66	6.4			7.38	2	0.0		1348	676	3.2
Apr-96	9.09	4135.72	6.7			7.58	0	0.0		1273	642	6.4
May-96	6.95	4137.86	8.7			7.43	27	2.9		1186	600	6.5
Jun-96	6.47	4138.34	6.1			7.30	17	0.8		1299	681	9.8
Jul-96	6.23	4138.58	5.5			6.23				1284	644	15.6
Aug-96	6.29	4138.52	3.6			7.12	13	0.9		1285	642	16.4
Sep-96	6.74	4138.07	4.1			7.66	18	1.7		1157	579	13.9
Oct-96	7.50	4137.31	4.3			7.34	6	0.6		1223	608	9.1
Nov-96	8.51	4136.30	4.9			7.62	27	2.4		1189	593	6.6
Dec-96	7.00	4137.81	4.8			7.56				1222	609	6.4
Jan-97	6.89	4137.92	5.3			7.69	29	3.5		1387	691	4.9
Feb-97	7.79	4137.02	6.3			7.81	16	1.6		1297	650	8.0
Mar-97	8.77	4136.04	9.2			7.57	0	0.0		1442	721	9.4
Apr-97	8.75	4136.06	13.0			7.72	40	3.4		1472	738	11.2
May-97	7.79	4137.02	8.3			7.39	0	0.0		1426	716	19.2
Jun-97	6.57	4138.24	4.7			7.73	0	0.0		1215	610	15.2
Jul-97	6.87	4137.94	5.4			7.44	0	0.0		1303	651	17.4
Aug-97	7.44	4137.37	6.7			7.46	57	5.0		-1280	-660	19.9
Sep-97	7.48	4137.33	4.3			7.29	0	0.0		1303	658	10.7
Oct-97	8.40	4136.41	4.8			7.64	0	0.0		1293	643	7.8
Nov-97	9.08	4135.73	4.5			7.50	5	0.6		1273	635	6.7
Dec-97	9.32	4135.49	3.8			7.61	78	8.0		1252	623	8.0
Jan-98	8.00	4136.81	4.3			7.32	30	4.1		1212	606	5.9
Feb-98	9.28	4135.53	4.9			7.48	0	0.0		1176	598	4.5
Mar-98	9.23	4135.58	3.0			8.01	0	0.0		1226	616	8.1

MW4 DATA

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen		SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
							(%)	(mg/l)				
May-92	5.64	4139.56	19.0						0.7	1110		11.5
Jun-92	7.06	4138.14	20.9						0.9	1220		14.9
Jul-92	7.63	4137.57	19.0	BDL	0.7	7.90			0.9	1250		23.5
Aug-92	7.61	4137.59	19.0			7.21			1.0	1300		16.0
Sep-92	8.54	4136.66	18.0			7.69	15	1.3	1.0	1295		16.0
Oct-92	7.98	4137.22	17.0			7.76	65	6.9	0.9	1160		12.7
Nov-92	9.49	4135.71	19.0			7.73	55	6.7	0.9	1010		7.0
Dec-92	9.43	4135.77	17.0			7.96	94	6.8	0.9	890		4.0
Jan-93	9.80	4135.40	18.0	0.4	0.7	7.94	82	5.4	0.6	1005		7.8
Feb-93	9.63	4135.57	20.0			7.85	53	5.6		1586	796	7.3
Mar-93	5.52	4139.68	12.0			7.40	59	6.0		1682	840	12.2
Apr-93	8.80	4136.40	14.0	BDL	1.4	7.64	42	4.7		1479	742	12.9
May-93	8.53	4136.67	8.8			7.57	48	5.0		1539	768	12.8
Jun-93	6.75	4138.45	14.0			7.48	66	6.5		1577	787	14.0
Jul-93	5.60	4139.60	13.0	BDL	0.5	7.53	41	3.2		1577	789	17.2
Aug-93	6.16	4139.04	14.0			7.59	53	3.7		1541	774	17.8
Sep-93	7.84	4137.36	7.3			7.51	46	3.8		1535	770	15.1
Oct-93	7.93	4137.27	7.8	BDL	1.0	7.48	47	4.9		1478	740	14.3
Nov-93	9.03	4136.17	12.0			7.61	41	4.2		1483	743	10.7
Dec-93	9.60	4135.60	15.0			7.61	31	3.2		1464	731	11.8
Jan-94	9.97	4135.23	12.0	BDL	0.4	7.72	34	3.4		1506	752	7.5
Feb-94	10.07	4135.13	12.0			7.71	38	4.2		1548	772	6.5
Mar-94	10.17	4135.03	14.0			7.62	36	4.1		1507	754	12.4
Apr-94												
May-94	8.85	4136.35	14.0			7.47	33	2.9		1481	742	12.8
Jun-94	7.28	4137.92	15.0			7.60	41	4.0		1477	741	14.2
Jul-94	6.85	4138.35	14.0	BDL	1.7	7.80	52	4.1		1485	743	19.6
Aug-94	6.32	4138.88	13.0			7.86	41	2.5		1477	741	16.4
Sep-94	7.15	4138.05	13.0			7.73	26	2.3		1504	753	16.7
Oct-94	7.81	4137.39	12.0	BDL	BDL	7.40	58	3.4		1393	698	12.2
Nov-94	9.11	4136.09	13.0			7.94	26	2.8		1467	735	8.8
Dec-94			11.0			6.45	43	5.9		1454	725	6.4
Jan-95	9.40	4135.80	13.0	BDL		7.00	29	3.5		1478	742	8.3
Feb-95	9.50	4135.70	15.0			7.80	30	3.3		1517	761	8.6
Mar-95	9.57	4135.63	15.0			7.61	44	4.5		1480	744	12.4
Apr-95	9.82	4135.38	15.0	BDL		7.56	39	4.4		1494	753	10.5
May-95	9.24	4135.96	13.0			7.75	61	6.3		1489	748	7.0
Jun-95	7.69	4137.51	15.0			7.65	48	5.0		1457	732	10.1
Jul-95	6.50	4138.70	15.0	BDL		7.31	40	3.6		1466	736	13.7
Aug-95	7.02	4138.18	12.0			7.65	36	3.2		1402	697	14.8
Sep-95	7.67	4137.53	11.0			7.55	23	2.2		1903	949	8.2
Oct-95	8.19	4137.01	11.0			7.45	0	2.0		1465	733	9.9
Nov-95	9.24	4135.96	10.0			7.48	24	2.5				8.6
Dec-95	8.91	4136.29	11.0			7.54	32	4.0		1220	616	6.0
Jan-96	9.50	4135.70	11.0			7.33	28	3.1		1395	694	5.6
Feb-96	8.09	4137.11	12.0			7.59	17	1.6		1509	751	3.8
Mar-96	8.89	4136.31	7.9			7.43	19	2.4		1521	759	3.3
Apr-96	9.72	4135.48	11.0			7.56	19	2.1		1500	753	5.7
May-96	8.29	4136.91	12.0			7.49	41	4.7		1346	675	6.3
Jun-96	7.54	4137.66	8.7			7.14	48	4.5		1656	832	12.5
Jul-96	7.29	4137.91	9.0			7.08				1712	858	15.1
Aug-96	7.26	4137.94	9.5			7.17	34	2.7		1285	642	16.4
Sep-96	7.54	4137.66	10.0			7.54	40	3.7		1433	718	15.3
Oct-96	8.23	4136.97	9.1			7.36	21	2.3		1451	726	8.9
Nov-96	9.13	4136.07	9.8			7.55	30	2.9		1483	739	7.6
Dec-96	8.33	4136.87	10.0			7.67				1439	717	6.7
Jan-97	6.93	4138.27	8.3			7.73	46	5.3		1840	910	3.7
Feb-97	8.56	4136.64	8.6			7.76	25	3.5		1548	776	8.3
Mar-97	9.49	4135.71	9.5			7.57	0	0.0		1444	721	9.5
Apr-97	9.48	4135.72	10.0			7.76	46	4.1		1605	803	11.9
May-97	8.87	4136.33	9.4			7.47	10	0.6		1635	819	19.0
Jun-97	7.74	4137.46	8.8			7.66	0	0.0		1630	818	16.0
Jul-97	7.96	4137.24	10.0			7.40	9	0.2		1597	800	16.4
Aug-97	8.39	4136.81	9.7			7.41	41	3.0		1577	786	17.7
Sep-97	8.36	4136.84	8.5			7.27	0	0.0		1535	761	9.7
Oct-97	9.02	4136.18	9.5			7.62	0	0.0		1471	741	9.1
Nov-97	9.50	4135.7	9.6			7.47	37	3.6		1455	733	6.0
Dec-97	9.93	4135.27	10.0			7.45	52	6.6		1510	749	7.9
Jan-98	8.73	4136.47	9.4			7.24	43	5.1		1393	700	6.3
Feb-98	9.89	4135.31	9.0			7.34	0	0.0		1387	688	5.2
Mar-98	9.90	4135.3	9.6			7.87	15	0.0		1488	735	8.0

ME1 DATA

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen		SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
							(%)	(mg/l)				
May-92	6.74	4137.16	6.7						1.0	1250		10.0
Jun-92	4.93	4138.97	7.9						1.1	1610		14.9
Jul-92	5.72	4138.18	4.4	BDL	0.2	7.90			0.5	940		24.5
Aug-92	5.77	4138.13	3.9			7.46			0.7	950		15.0
Sep-92	6.79	4137.11	3.9			7.60	8	0.7	0.7	930		14.5
Oct-92	5.73	4138.17	5.1			7.40	32	3.4	1.1	1500		14.0
Nov-92	7.75	4136.15	4.4			7.47	35	3.8	0.8	970		9.9
Dec-92	7.63	4136.27	4.4			7.78	75	8.8	0.9	900		7.1
Jan-93	8.22	4135.68	4.2	0.3	0.2	7.68	72	8.8	0.5	830		6.3
Feb-93	8.17	4135.73	4.6			7.56	49	5.3		1363	686	8.3
Mar-93	3.11	4140.79	6.7			7.24	52	5.4		3060	1570	10.8
Apr-93	6.91	4136.99	7.3	BDL	1.2	7.23	36	3.5		2750	1380	10.3
May-93	6.41	4137.49	6.0			7.19	38	3.4		2340	1190	15.5
Jun-93	5.29	4138.61	5.0			7.26	21	2.0		1670	833	14.1
Jul-93	3.68	4140.22	4.9	BDL	0.5	7.28	18	0.9		1962	981	17.5
Aug-93	5.36	4138.54	6.0			7.19	24	1.9		3260	1640	16.7
Sep-93	6.14	4137.76	5.6			7.12	19	1.5		2230	1120	16.5
Oct-93	6.54	4137.36	4.1	BDL	0.4	7.28	11	0.9		1466	741	15.1
Nov-93	7.52	4136.38	4.8			7.37	13	1.3		1384	696	12.1
Dec-93	8.06	4135.84	4.4			7.41	12	1.2		1335	664	12.4
Jan-94	8.43	4135.47	4.0	BDL	BDL	7.44	8	0.7		1252	626	9.3
Feb-94	8.55	4135.35	2.0			7.50	21	1.8		1251	624	7.0
Mar-94	8.64	4135.26	4.6			7.39	21	1.9		1265	635	12.0
Apr-94	8.70	4135.20	4.0	BDL	0.9	7.38	16	1.4		1229	616	13.0
May-94	6.45	4137.45	5.1			7.23	28	2.8		1592	802	12.8
Jun-94	4.48	4139.42	5.1			7.65	19	1.7		1450	727	14.7
Jul-94	5.28	4138.62	4.6	BDL	1.8	7.66	31	2.0		1264	632	18.8
Aug-94	4.39	4139.51	4.1			7.83	17	1.3		1506	750	18.9
Sep-94	4.77	4139.13	5.2			8.11	21	1.2		1461	731	18.5
Oct-94	6.21	4137.69	4.0	BDL	BDL	7.49	14	1.3		1381	691	12.1
Nov-94	7.48	4136.42	3.4			7.82	13	1.1		1423	714	10.8
Dec-94	8.70	4135.20	4.6			7.07	49	6.0		1405	705	7.3
Jan-95	7.73	4136.17	4.7	BDL		7.58	25	2.7		1546	776	8.7
Feb-95	7.76	4136.14	4.4			7.52	40	2.9		1581	794	8.6
Mar-95	7.81	4136.09	4.8			7.33	27	2.7		1637	830	10.6
Apr-95	8.14	4135.76	4.1	BDL		7.24	32	3.5		1671	838	10.5
May-95	7.24	4136.66	4.1			7.26	44	4.4		1753	879	7.4
Jun-95	6.67	4137.23	2.7			7.27	38	4.2		2170	1120	9.6
Jul-95	4.59	4139.31	2.6	BDL		6.97	37	3.7		3300	1660	11.3
Aug-95	6.01	4137.89	3.5			7.13	23	2.1		2140	1100	13.2
Sep-95	7.19	4136.71	4.6			7.36	19	2.2		1871	935	8.9
Oct-95	6.72	4137.18	5.0			7.20	0	0.0		1812	912	11.4
Nov-95	7.59	4136.31	4.6			6.97	15	1.5		1792	895	8.0
Dec-95	6.90	4137.00	4.1			7.31	37	4.3		1850	921	5.7
Jan-96	7.93	4135.97	4.0			7.00	21	2.4		1782	899	5.8
Feb-96	6.18	4137.72	3.0			7.19	31	3.7		2220	1150	3.7
Mar-96	7.21	4136.69	2.8			7.10	74	8.6		2460	1250	4.1
Apr-96	8.10	4135.80	3.6			7.29	13	1.1		2500	1270	6.1
May-96	5.56	4138.34	3.6			7.05	36	4.1		2350	1200	7.6
Jun-96	5.04	4138.86	8.0			6.75	30	2.1		4280	2150	11.0
Jul-96	4.91	4138.99	5.8			6.98				2560	1300	16.2
Aug-96	4.91	4138.99	6.0			7.26	18	1.4		1439	724	17.8
Sep-96	5.68	4138.22	5.2			7.70	18	1.6		1480	740	12.9
Oct-96	6.55	4137.35	4.9			7.38	10	0.7		1421	707	9.1
Nov-96	7.25	4136.65	5.5			7.56	19	2.2		1470	733	6.2
Dec-96	5.67	4138.23	5.1			7.42				1622	808	6.6
Jan-97	5.53	4138.37	6.3			7.17	32	2.6		2620	1280	5.4
Feb-97	6.75	4137.15	5.6			7.61	10	1.0		2460	1220	6.2
Mar-97	7.77	4136.13	5.4			7.07	0	0.0		2250	1170	11.5
Apr-97	8.09	4135.81	5.7			7.46	29	2.1		2080	1060	9.3
May-97	6.51	4137.39	5.6			7.28	0	0.0		1765	883	17.2
Jun-97	5.44	4138.46	6.3			7.38	0	0.0		2020	1040	15.2
Jul-97	5.93	4137.97	13.0			7.08	0	0.0		4180	2100	18.2
Aug-97	6.20	4137.70	12.0			7.13	17	2.0		4230	2120	19.0
Sep-97	6.42	4137.48	11.0			6.86	0	0.0		4080	2000	12.4
Oct-97	7.40	4136.50	11.0			7.29	0	0.0		3100	1640	7.9
Nov-97	8.00	4135.90	7.8			7.43	13	1.5		2006	1110	6.7
Dec-97	8.18	4135.72	6.3			7.40	43	5.5		1640	813	7.1
Jan-98	6.99	4136.91	8.9			6.95	51	5.8		2420	1260	5.9
Feb-98	8.21	4135.69	10.0			7.20	0	0.0		1723	865	5.2
Mar-98	8.47	4135.43	5.4			7.58	0	0.0		1514	750	8.2

ME2 DATA

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen		SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
							(%)	(mg/l)				
May-92	6.07	4138.29	14.0						0.5	840		10.8
Jun-92	5.41	4138.95	14.6						0.5	990		14.6
Jul-92	6.22	4138.14	8.6	BDL	0.3	7.60			0.8	1100		21.5
Aug-92	6.22	4138.14	7.3			7.23			0.8	1110		16.0
Sep-92	7.25	4137.11	9.2			7.32	7	0.6	0.8	1120		15.3
Oct-92	6.24	4138.12	15.0			7.39	57	5.7	0.8	1080		14.5
Nov-92	8.19	4136.17	13.0			7.29	40	4.9	0.6	905		9.5
Dec-92	8.02	4136.34	15.0			7.60	71	8.0	0.8	960		9.5
Jan-93	8.57	4135.79	12.0	0.5	BDL	7.49	71	5.6	0.6	850		7.5
Feb-93	8.54	4135.82	13.0			7.45	46	5.1		1379	686	8.7
Mar-93	3.62	4140.74	13.0			7.33	63	6.2		1591	798	9.5
Apr-93	7.35	4137.01	12.0	BDL	1.6	7.38	44	4.4		1563	777	12.1
May-93	6.90	4137.46	12.0			7.13	58	5.5		1560	782	15.1
Jun-93	5.69	4138.67	12.0			7.14	47	4.6		1473	737	13.7
Jul-93	3.99	4140.37	13.0	BDL	0.7	7.21	48	3.6		1468	737	17.7
Aug-93	5.75	4138.61	11.0			7.35	44	3.7		1501	750	15.9
Sep-93	6.67	4137.69	10.0			7.24	30	2.7		1394	696	16.0
Oct-93	6.97	4137.39	7.8	BDL	0.9	7.22	28	2.3		1305	656	14.3
Nov-93	7.92	4136.44	5.6			7.26	24	2.5		1281	642	11.7
Dec-93	8.44	4135.92	6.5			7.30	18	1.9		1321	660	12.0
Jan-94	8.79	4135.57	7.8	BDL	BDL	7.34	18	2.2		1316	658	9.3
Feb-94	8.90	4135.46	6.0			7.44	24	2.7		1319	663	6.6
Mar-94	9.01	4135.35	7.4			7.35	24	2.6		1288	648	12.1
Apr-94	9.09	4135.27	7.8	BDL	3.8	7.23	32	2.8		1319	662	12.5
May-94	6.91	4137.45	7.6			7.25	17	1.6		1294	652	12.3
Jun-94	4.94	4139.42	6.3			7.62	19	1.5		1290	647	15.2
Jul-94	5.73	4138.63	4.2	BDL	2.1	7.60	27	1.9		1264	632	18.8
Aug-94	4.72	4139.64	4.1			7.69	24	1.6		1230	616	16.2
Sep-94	5.34	4139.02	4.5			8.17	13	0.9		1176	589	16.3
Oct-94	6.63	4137.73	3.9	BDL	0.3	7.53	28	2.2		1099	551	12.4
Nov-94	7.89	4136.47	3.8			7.58	14	1.0		1125	565	9.9
Dec-94	9.09	4135.27	4.6			7.60	52	6.1		1126	565	6.2
Jan-95	8.12	4136.24	4.7	BDL		7.69	24	2.7		1134	569	8.2
Feb-95	8.16	4136.20	4.4			7.57	37	4.4		1292	647	8.9
Mar-95	8.22	4136.14	5.6			7.42	40	3.8		1209	607	9.9
Apr-95	8.54	4135.82	6.2	BDL		7.34	50	5.1		1263	632	9.1
May-95	7.68	4136.68	5.1			7.40	42	4.3		1182	591	7.1
Jun-95	7.02	4137.34	10.0			7.43	51	5.1		1463	735	10.5
Jul-95	5.07	4139.29	9.2	BDL		7.28	58	5.8		1411	710	12.9
Aug-95	5.53	4138.83	5.3			7.36	28	2.6		1131	567	12.4
Sep-95	6.22	4138.14	3.3			7.52	24	1.9		1051	521	8.8
Oct-95	7.12	4137.24	3.7			7.34	0	0.0		1104	555	11.5
Nov-95	9.13	4135.23	3.2			7.26	16	1.6		1126	565	8.3
Dec-95	7.48	4136.88	3.8			7.57	30	3.7		1105	549	5.7
Jan-96	8.32	4136.04	4.9			7.39	30	3.4		1106	554	6.3
Feb-96	6.59	4137.77	6.9			7.55	33	4.0		1230	623	2.6
Mar-96	7.64	4136.72	9.0			7.36	***81***	11.5		1344	681	3.6
Apr-96	8.49	4135.87	8.5			7.51	14	1.0		1355	680	5.9
May-96	6.18	4138.18	6.2			7.35	37	3.9		1076	540	8.8
Jun-96	5.63	4138.73	8.4			7.16	19	1.7		1402	703	9.3
Jul-96	5.32	4139.04	4.2			7.35				1147	594	17.0
Aug-96	5.62	4138.74	3.3			7.31	11	0.6		940	472	16.7
Sep-96	6.09	4138.27	3.4			7.50	17	1.4		1058	530	13.8
Oct-96	6.96	4137.40	3.0			7.42	9	0.6		1060	526	8.3
Nov-96	7.85	4136.51	4.0			7.91	25	2.9		1111	550	5.4
Dec-96	6.19	4138.17	4.0			7.71				1080	537	6.2
Jan-97	6.36	4138.00	7.3			7.51	34	3.7		1280	637	6.0
Feb-97	7.21	4137.15	8.1			7.89	20	2.1		1241	616	6.3
Mar-97	8.21	4136.15	7.2			7.48	0	0.0		1283	666	10.9
Apr-97	8.48	4135.88	7.8			7.69	37	3.4		1290	651	8.6
May-97	7.04	4137.32	5.9			7.35	0	0.0		1187	618	19.2
Jun-97	5.90	4138.46	5.5			7.60	0	0.0		1232	619	16.1
Jul-97	6.23	4138.13	13.0			7.28	13	0.8		1592	797	15.7
Aug-97	6.64	4137.72	13.0			7.41	49	3.7		1575	779	17.6
Sep-97	6.88	4137.48	4.9			7.28	0	0.0		1217	615	12.1
Oct-97	7.82	4136.54	4.2			7.63	0	0.0		1172	583	7.7
Nov-97	8.47	4135.89	4.2			7.80	13	1.8		1151	572	7.0
Dec-97	8.75	4135.61	4.3			7.63	58	6.1		1192	602	7.2
Jan-98	7.32	4137.04	9.5			7.37	52	6.6		1404	696	5.4
Feb-98	8.60	4135.76	7.8			7.67	0	0.0		1311	652	4.8
Mar-98	8.68	4135.68	5.9			8.02	0	0.0		1303	655	8.1

ME3 DATA

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen		SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
							(%)	(mg/l)				
May-92	5.63	4139.01	19.0						1.0	1250		11.0
Jun-92	5.79	4138.85	1.8						0.8	1320		15.0
Jul-92	6.63	4138.01	1.1	BDL	0.4	7.89			0.7	1130		21.0
Aug-92	6.55	4138.09	16.0			7.43			1.0	1290		15.5
Sep-92	7.56	4137.08	18.0			7.56	8	0.7	0.9	1300		16.4
Oct-92	6.62	4138.02	21.5			7.60	60	6.3	1.1	1470		14.3
Nov-92	8.48	4136.16	21.0			7.58	38	4.6	1.0	1140		9.0
Dec-92	8.31	4136.33	21.0			8.02	77	9.2	1.2	1110		7.3
Jan-93	8.85	4135.79	20.0	0.3	0.5	7.71	76	9.5	0.9	1060		6.5
Feb-93	8.78	4135.86	22.0			7.66	71	5.3		1781	896	7.7
Mar-93	4.09	4140.55	21.5			7.50	63	6.1		2190	1090	10.1
Apr-93	7.69	4136.95	24.0	BDL	1.2	7.72	44	4.7		2000	1000	9.2
May-93	7.31	4137.33	21.0			7.44	45	4.6		1935	976	14.2
Jun-93	5.97	4138.67	30.0			7.45	45	4.3		1942	973	13.7
Jul-93	4.24	4140.40	21.0	BDL	0.5	7.46	34	3.0		1885	936	18.3
Aug-93	6.06	4138.58	22.0			7.59	47	4.3		1885	944	16.1
Sep-93	7.09	4137.55	20.0			7.42	36	3.4		1947	979	15.5
Oct-93	7.26	4137.38	18.0	BDL	0.8	7.45	32	3.0		1734	871	14.3
Nov-93	8.20	4136.44	11.0			7.47	36	3.9		1785	893	11.3
Dec-93	8.72	4135.92	23.0			7.49	29	3.0		1817	910	11.9
Jan-94	9.07	4135.57	21.0	BDL	BDL	7.57	23	2.6		1772	892	10.3
Feb-94	9.19	4135.45	21.0			7.66	31	3.6		1729	868	6.3
Mar-94	9.31	4135.33	21.0			7.50	35	3.4		1709	857	12.2
Apr-94	9.38	4135.26	22.0	BDL	0.7	7.41	37	3.5		1729	867	12.5
May-94	7.27	4137.37	21.0			7.43	18	1.8		1685	845	11.3
Jun-94	5.24	4139.40	21.0			7.60	25	2.1		1672	836	13.3
Jul-94	6.07	4138.57	17.0	BDL	1.7	7.64	27	2.0		1634	819	18.8
Aug-94	5.00	4139.64	18.0			7.81	22	1.1		1672	849	19.4
Sep-94	5.79	4138.85	19.0			7.55	15	1.1		1690	848	17.3
Oct-94	6.92	4137.72	19.0	BDL	BDL	7.46	34	3.5		1631	818	12.8
Nov-94	8.17	4136.47	19.0			7.47	25	2.0		1698	854	8.2
Dec-94	9.38	4135.26	21.0	BDL		7.38	59	6.4		1695	849	7.2
Jan-95	8.41	4136.23	21.0			7.37	28	2.9		1690	847	8.2
Feb-95	8.45	4136.19	21.0			7.77	30	3.4		1754	880	9.0
Mar-95	8.52	4136.12	23.0			7.56	29	2.8		1677	840	10.5
Apr-95	8.80	4135.84	24.0	BDL		7.54	28	2.8		1711	860	9.7
May-95	8.02	4136.62	24.0			7.59	50	5.3		1687	843	7.9
Jun-95	5.63	4139.01	24.0			7.48	50	5.1		1992	970	10.3
Jul-95	5.42	4139.22	26.0	BDL		7.47	57	5.7		2000	1000	13.0
Aug-95	7.02	4137.62	20.0			7.41	40	3.4		1976	988	13.4
Sep-95	6.58	4138.06	21.0			7.55	30	3.4		1831	911	9.0
Oct-95	7.45	4137.19	20.0			7.35	16	1.5		1860	932	11.3
Nov-95	8.29	4136.35	20.0			7.13	34	3.4		1895	947	8.6
Dec-95	7.90	4136.74	20.0			7.75	36	4.4		1821	905	5.6
Jan-96	8.60	4136.04	19.0			7.30	24	3.1		1633	819	4.1
Feb-96	6.95	4137.69	20.0			7.69	39	4.0		1849	924	2.3
Mar-96	7.95	4136.69	15.0			7.42	77	10.0		1960	980	3.6
Apr-96	8.75	4135.89	19.0			7.52	14	1.2		1895	950	5.9
May-96	6.67	4137.97	21.0			7.46	36	4.0		1727	864	8.5
Jun-96	5.98	4138.66	21.0			7.31	37	3.7		2080	1090	10.4
Jul-96	5.89	4138.75	22.0			7.25				2030	1030	17.1
Aug-96	5.87	4138.77	20.0			7.35	22	1.8		1534	768	16.6
Sep-96	6.44	4138.20	20.0			7.55	25	2.3		1666	834	12.6
Oct-96	7.24	4137.40	19.0			7.42	21	2.4		1752	870	9.3
Nov-96	8.17	4136.47	20.0			7.86	20	2.6		1800	889	5.3
Dec-96	6.60	4138.04	20.0			7.66				1735	865	6.4
Jan-97	6.70	4137.94	21.0			7.61	37	4.5		1973	989	6.4
Feb-97	7.53	4137.11	19.0			8.00	14	1.7		1893	945	6.6
Mar-97	8.48	4136.16	19.0			7.80	0	0.0		1930	966	9.6
Apr-97	8.68	4135.96	16.0			7.89	27	2.8		1806	905	9.0
May-97	7.44	4137.20	20.0			7.62	0	0.0		1806	904	14.6
Jun-97	6.34	4138.30	21.0			7.73	0	0.0		1855	952	14.4
Jul-97	6.84	4137.80	23.0			7.52	6	0.4		2090	1070	15.9
Aug-97	7.10	4137.54	23.0			7.65	46	4.4		2010	1020	19.0
Sep-97	7.21	4137.43	20.0			7.42	0	0.0		1390	960	12.2
Oct-97	8.00	4136.64	22.0			7.70	8	0.0		1950	1010	7.0
Nov-97	8.73	4135.91	21.0			7.88	27	2.4		1844	970	5.2
Dec-97	9.00	4135.64	19.0			7.69	51	6.1		1873	934	7.4
Jan-98	7.62	4137.02	22.0			7.52	56	5.4		1841	1000	3.0
Feb-98	8.88	4135.76	20.0			7.70	0	0.0		1748	882	4.6
Mar-98	9.12	4135.52	20.0			8.18	0	0.3		1894	940	8.3

ME4 DATA

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen		SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
							(%)	(mg/l)				
May-92	5.09	4140.02	21.0						1.5	1830		12.0
Jun-92	6.39	4138.72	1.9						1.1	1800		15.5
Jul-92	7.20	4137.91	16.0	BDL	1.0	8.27			0.9	1340		20.6
Aug-92	7.14	4137.97	14.0			7.80			1.0	1350		16.0
Sep-92	8.14	4136.97	16.0			7.84	6	0.5	1.0	1425		16.0
Oct-92	7.29	4137.82	23.0			8.09	63	6.3	1.5	2030		15.2
Nov-92	9.01	4136.10	20.0			7.95	40	4.5	1.4	1610		9.0
Dec-92	8.83	4136.28	22.0			8.17	70	8.4	1.6	1590		8.9
Jan-93	9.30	4135.81	21.0	0.2	1.2	8.12	79	5.4	1.1	1500		8.0
Feb-93	9.24	4135.87	22.0			7.96	46	5.3		2460	1230	7.0
Mar-93	4.91	4140.20	18.0			7.74	54	5.4		2870	1470	9.2
Apr-93	8.26	4136.85	21.0	BDL	2.1	7.97	48	5.1		2860	1430	9.0
May-93	7.90	4137.21	11.0			7.71	49	4.3		2730	1390	15.1
Jun-93	6.47	4138.64	6.4			7.71	41	4.0		2560	1290	14.1
Jul-93	4.73	4140.38	20.0	BDL	1.1	7.75	33	2.8		2600	1310	17.7
Aug-93	6.56	4138.55	13.0			7.87	48	4.1		2600	1330	16.2
Sep-93	7.68	4137.43	13.0			7.78	39	3.8		2400	1240	16.3
Oct-93	7.76	4137.35	16.0	BDL	2.0	7.75	26	2.2		2220	1120	15.1
Nov-93	8.71	4136.40	12.0			7.81	30	2.6		2350	1180	11.3
Dec-93	9.19	4135.92	18.0			7.81	23	2.5		2450	1230	12.3
Jan-94	9.54	4135.57	21.0	BDL	0.9	7.88	21	2.2		2560.0	1270	9.5
Feb-94	9.68	4135.43	22.0			7.94	25	3.0		2250.0	1270	5.7
Mar-94	9.75	4135.36	18.0			7.81	29	3.0		2240.0	1180	13.4
Apr-94	9.87	4135.24	19.0	BDL	1.6	7.73	38	3.6		2460.0	1220	13.4
May-94	7.72	4137.39	18.0			7.67	22	2.0		2130.0	1080	10.4
Jun-94	5.92	4139.19	17.0			7.87	23	2.2		1879	943	15.2
Jul-94	6.65	4138.46	14.0	BDL	2.1	8.09	28	2.5		1597	802	20.6
Aug-94	5.53	4139.58	13.0			8.05	32	2.7		1594	797	16.1
Sep-94	6.43	4138.68	14.0			7.84	11	0.8		1569	786	17.5
Oct-94	7.43	4137.68	13.0	BDL	0.5	7.67	33	2.2		1174	740	14.3
Nov-94	8.66	4136.45	15.0			7.54	20	1.9		1717	862	7.8
Dec-94	9.87	4135.24	14.0			7.17	58	6.5		1773	893	6.0
Jan-95	8.90	4136.21	15.0	BDL		7.29	27	30.0		1844	928	8.3
Feb-95	8.95	4136.16	17.0			8.14	28	3.1		1939	989	9.2
Mar-95	9.03	4136.08	18.0			7.98	38	3.9		1892	952	9.9
Apr-95	9.30	4135.81	17.0	BDL		7.92	47	4.7		1951	981	9.8
May-95	8.54	4136.57	16.0			7.92	27	2.5		1808	907	7.6
Jun-95	5.08	4140.03	14.0			7.84	55	5.0		1909	956	10.7
Jul-95	6.05	4139.06	13.0	BDL		7.61	59	5.5		2190	1110	15.1
Aug-95	6.63	4138.48	12.0			6.63	39	2.9		1950	970	13.1
Sep-95	7.19	4137.92	12.0			7.83	25	2.3		1787	886	9.5
Oct-95	7.94	4137.17	13.0			7.60	0	0.0		1797	901	13.2
Nov-95	8.80	4136.31	14.0			7.40	20	2.0		1894	949	9.2
Dec-95	8.42	4136.69	15.0			8.02	24	2.6		1859	927	5.8
Jan-96	9.10	4136.01	16.0			7.57	27	2.9		1872	943	7.6
Feb-96	7.53	4137.58	14.0			7.84	27	3.4		1972	986	2.5
Mar-96	8.48	4136.63	15.0			7.75	70	8.4		2150	1080	3.6
Apr-96	9.22	4135.89	17.0			7.73	12	0.6		2090	1080	6.5
May-96	7.38	4137.73	16.0			7.59	29	2.7		1738	876	10.0
Jun-96	6.62	4138.49	15.0			7.59	27	2.2		2230	1130	9.6
Jul-96	6.44	4138.67	14.0			7.50				1970	1000	17.5
Aug-96	6.44	4138.67	9.9			7.67	14	1.1		1297	651	18.1
Sep-96	6.98	4138.13	10.0			7.90	19	1.6		1473	739	15.2
Oct-96	7.75	4137.36	11.0			7.84	8	0.4		1528	760	10.7
Nov-96	8.72	4136.39	14.0			7.91	26	3.1		1759	876	7.1
Dec-96	7.29	4137.82	12.0			7.29				1676	834	6.9
Jan-97	7.29	4137.82	12.0			7.84	53	5.4		2250	1080	5.5
Feb-97	7.51	4137.60	13.0			8.05	24	2.4		2040	1010	6.8
Mar-97	9.00	4136.11	15.0			7.92	0	0.0		1513	763	10.7
Apr-97	9.01	4136.10	12.0			8.20	31	3.7		2110	1090	9.0
May-97	8.03	4137.08	14.0			8.02	0	0.0		1994	999	16.5
Jun-97	7.01	4138.10	21.0			8.00	0	0.0		1996	0.98	16.0
Jul-97	7.45	4137.66	18.0			7.68	19	1.4		2770	1400	15.9
Aug-97	7.73	4137.38	17.0			7.83	41	3.4		2590	1260	17.2
Sep-97	7.80	4137.31	14.0			7.52	0	0.0		2140	1060	12.8
Oct-97	8.64	4136.47	17.0			7.76	0	0.0		2330	1140	7.9
Nov-97	9.25	4135.86	16.0			7.84	18	2.5		2400	1150	6.2
Dec-97	9.46	4135.65	12.0			7.65	61	6.2		2340	1210	6.3
Jan-98	8.17	4136.94	15.0			7.39	39	5.3		2350	1140	4.2
Feb-98	9.35	4135.76	13.0			7.32	0	0.0		2250	1100	3.9
Mar-98	9.61	4135.50	11.0			7.50	0	0.0		2300	1170	8.7

MPWN DATA

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen		SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
							(%)	(mg/l)				
Jun-92	6.88	4137.43	22.6						0.5	850		12.7
Jul-92	7.02	4137.29	20.0	BDL	3.9	7.63			0.6	920		15.5
Aug-92	7.07	4137.24	17.0			6.93			0.8	1000		18.0
Sep-92	8.15	4136.16	23.0			7.28	15	1.3	0.7	990		17.5
Oct-92	8.02	4136.29	23.0			7.27	54	5.5	0.7	990		16.0
Nov-92	9.16	4135.15	19.0			7.61	45	4.9	0.7	840		10.5
Dec-92	9.25	4135.06	21.0			7.47	65	8.0	0.8	770		5.0
Jan-93	9.48	4134.83	17.0	0.3	0.2	7.36	84	10.8	0.3	700		4.3
Feb-93	9.21	4135.10	21.0			7.64	64	7.1		1208	607	7.2
Mar-93	6.25	4138.06	32.0			7.46	62	6.4		1294	649	9.3
Apr-93	8.56	4135.75	30.0	BDL	1.1	7.25	52	4.5		1244	630	9.0
May-93	7.70	4136.61	21.0			7.27	56	5.3		1257	629	14.0
Jun-93	6.04	4138.27	23.0			7.34	58	5.7		615	225	14.9
Jul-93	5.09	4139.22	22.0	BDL	0.6	7.15	35	3.1		1185	596	17.0
Aug-93	5.25	4139.06	20.0			7.13	54	4.0		1124	587	18.9
Sep-93	5.53	4138.78	21.0			7.13	40	3.6		1163	581	15.7
Oct-93	7.17	4137.14	17.0	BDL	1.5	7.12	41	4.7		1166	583	13.4
Nov-93	8.40	4135.91	9.8			7.20	31	4.9		1186	593	11.2
Dec-93	9.04	4135.27	21.0			7.20	27	2.9		1196	598	10.8
Jan-94												
Feb-94												
Mar-94												
Apr-94												
May-94	7.22	4137.09	12.5			7.04	48	5.3		1100	578	14.2
Jun-94	5.43	4138.88	15.0			7.09	0	0.0		1147	575	14.0
Jul-94	5.29	4139.02	16.0	BDL	1.8	7.35	37	3.0		1208	603	18.9
Aug-94	5.98	4138.33	16.0			7.91	27	2.4		1230	614	19.3
Sep-94	6.49	4137.82	16.0			7.21	31	2.8		1209	607	16.1
Oct-94	7.31	4137.00	16.0	BDL	BDL	7.38	53	3.4		1092	548	14.7
Nov-94	8.45	4135.86	17.0			7.71	27	3.0		1176	585	12.2
Dec-94	8.78	4135.53	18.0			5.61	40	5.0		1158	583	8.9
Jan-95	8.93	4135.38	18.0	BDL		7.29	37	4.7		1169	582	8.4
Feb-95	9.14	4135.17	20.0			7.51	37	4.2		1172	588	8.5
Mar-95	9.27	4135.04	22.0			7.42	59	5.2		1143	575	12.5
Apr-95	9.42	4134.89	19.0	BDL		7.44	43	4.9		1136	571	8.0
May-95	8.87	4135.44	19.0			7.53	56	6.8		1147	575	7.0
Jun-95	7.53	4136.78	19.0			7.58	70	7.6		923	463	10.3
Jul-95	6.26	4138.05	17.0	BDL		6.96	42	3.7		1182	592	15.3
Aug-95	6.62	4137.69	14.0			7.35	47	4.3		1155	578	15.5
Sep-95	7.25	4137.06	13.0			7.25	30	3.6		1228	612	9.3
Oct-95	7.98	4136.33	14.0			7.20	9	0.7		1220	609	11.0
Nov-95	8.80	4135.51	14.0			7.10	33	3.0		1187	596	9.2
Dec-95	8.41	4135.90	14.0			7.36	57	6.7		1090	543	7.0
Jan-96	9.05	4135.26	15.0			7.11	33	4.4		1047	520	4.4
Feb-96	7.88	4136.43	16.0			7.28	31	3.9		1081	544	4.1
Mar-96	8.51	4135.80	11.0				13	1.6		1069	535	3.6
Apr-96	9.31	4135.00	16.0			7.75	16	1.4		1080	545	6.5
May-96	8.29	4136.02	17.0			7.27	40	4.5		1031	517	6.8
Jun-96	7.31	4137.00	17.0			6.98	23	2.0		1198	606	12.0
Jul-96	6.42	4137.89	15.0			6.90				1220	613	17.2
Aug-96	6.25	4138.06	16.0			6.95	24	1.5		1079	540	18.8
Sep-96	6.96	4137.35	14.0			7.20	26	2.2		1220	606	13.9
Oct-96	7.77	4136.54	15.0			7.09	12	0.8		1189	597	13.4
Nov-96	8.60	4135.71	15.0			7.38	30	2.6		1195	594	8.4
Dec-96	8.09	4136.22	16.0			7.59				1113	554	7.4
Jan-97	7.58	4136.73	15.0			7.70	43	5.4		1136	558	5.5
Feb-97	8.24	4136.07	18.0			7.77	24	3.1		1001	502	8.6
Mar-97	9.04	4135.27	15.0			7.57	0	0.0		1064	556	13.6
Apr-96	9.18	4135.13	16.0			8.08	44	4.1		1079	575	12.2
May-97	8.71	4135.60	15.0			7.70	21	1.6		1185	596	20.7
Jun-97	7.69	4136.62	16.0			7.39	4	0.0		1207	630	16.4
Jul-97	7.52	4136.79	15.0			7.35	16	0.6		1253	628	18.5
Aug-97	7.88	4136.43	16.0			7.29	24	2.7		1296	649	20.5
Sep-97			14.0			7.02	0	0.0		1252	635	11.7
Oct-97	8.55	4135.76	16.0			7.50	0	0.0		1252	621	9.5
Nov-97	9.52	4134.79	14.0			7.52	23	2.4		1225	613	5.4
Dec-97	9.61	4134.70	12.0			7.53	65	8.1		1283	639	7.4
Jan-98	8.90	4135.41	15.0			7.35	50	7.2		1088	537	6.8
Feb-98	9.29	4135.02	12.0			7.68	0	0.0		1082		6.2
Mar-98	9.71	4134.60	9.8			8.27	24	1.7		560	260	9.1

MPWS DATA

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen		SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
							(%)	(mg/l)				
Jun-92	5.99	4138.08	22.7						0.9	770		13.0
Jul-92	6.22	4137.85	24.0	BDL	0.7	8.00			1	1470		16.8
Aug-92	6.50	4137.57	13.0			7.38			0.9	1290		20.0
Sep-92												
Oct-92	6.85	4137.22	8.9			7.49	56	5.5	0.8	1090		15.1
Nov-92												
Dec-92												
Jan-93												
Feb-93												
Mar-93	4.09	4139.98	30.0			8.00	54	5.9		1535	765	6.2
Apr-93	7.30	4136.77										
May-93												
Jun-93	5.50	4138.57	8.0			7.73	59	5.7		1274	642	14.1
Jul-93	4.41	4139.66	8.2	BDL	0.7	7.57	0	0		1210	607	16.8
Aug-93	4.79	4139.28	6.2			7.49	35	2.9		1209	605	18.9
Sep-93	6.58	4137.49	5.8			7.41	31	2.7		1166	585	17.1
Oct-93	6.78	4137.29	5.4	BDL	1.2	7.12	32	3.4		1066	539	14.2
Nov-93												
Dec-93												
Jan-94												
Feb-94												
Mar-94												
Apr-94												
May-94												
Jun-94	5.27	4138.80	4.8			7.70	17	1.1		1069	536	15.0
Jul-94	5.36	4138.71	3.4	BDL	1.5	7.56	69	5.8		1142	573	19.1
Aug-94	5.43	4138.64				7.82	51	4.1		1345	677	21.9
Sep-94	5.59	4138.48	2.8			7.24	35	3.2		1206	600	16.4
Oct-94	6.72	4137.35	3.8	BDL	BDL	6.54	43	3.6		1172	587	13.2
Nov-94												
Dec-94												
Jan-95												
Feb-95												
Mar-95												
Apr-95												
May-95												
Jun-95	6.64	4137.43	22.0			7.89	49	5.1		1330	667	9.6
Jul-95	5.26	4138.81	3.6	BDL		7.42	61	5.6		1175	590	16.6
Aug-95	5.66	4138.41	2.9			7.68	42	3.8		1171	585	16.0
Sep-95	6.56	4137.51	3.1			7.65	44	4.6		1216	607	9.7
Oct-95	7.53	4136.54	3.2			7.44	14	1.2		1249	622	10.5
Nov-95												
Dec-95												
Jan-96												
Feb-96												
Mar-96												
Apr-96												
May-96												
Jun-96	6.41	4137.66	4.2			7.52	46	4.7		1106	575	9.9
Jul-96	5.43	4138.64	3.1			7.4				1277	639	18.1
Aug-96	6.12	4137.95	2.8			7.38	61	4		1149	580	19.5
Sep-96												
Oct-96												
Nov-96												
Dec-96												
Jan-97												
Feb-97												
Mar-97												
Apr-97												
May-97												
Jun-97	6.56	4137.51	2.6			7.93	21	1.1		467	239	18.7
Jul-97	6.53	4137.54	2.8			7.58	24	1.6		1364	684	18.7
Aug-97	7.08	4136.99	2.8			8.03	43	3.1		1374	688	23.5
Sep-97	7.30	4136.77										
Oct-97												
Nov-97												
Dec-97												
Jan-98												
Feb-98												
Mar-98												

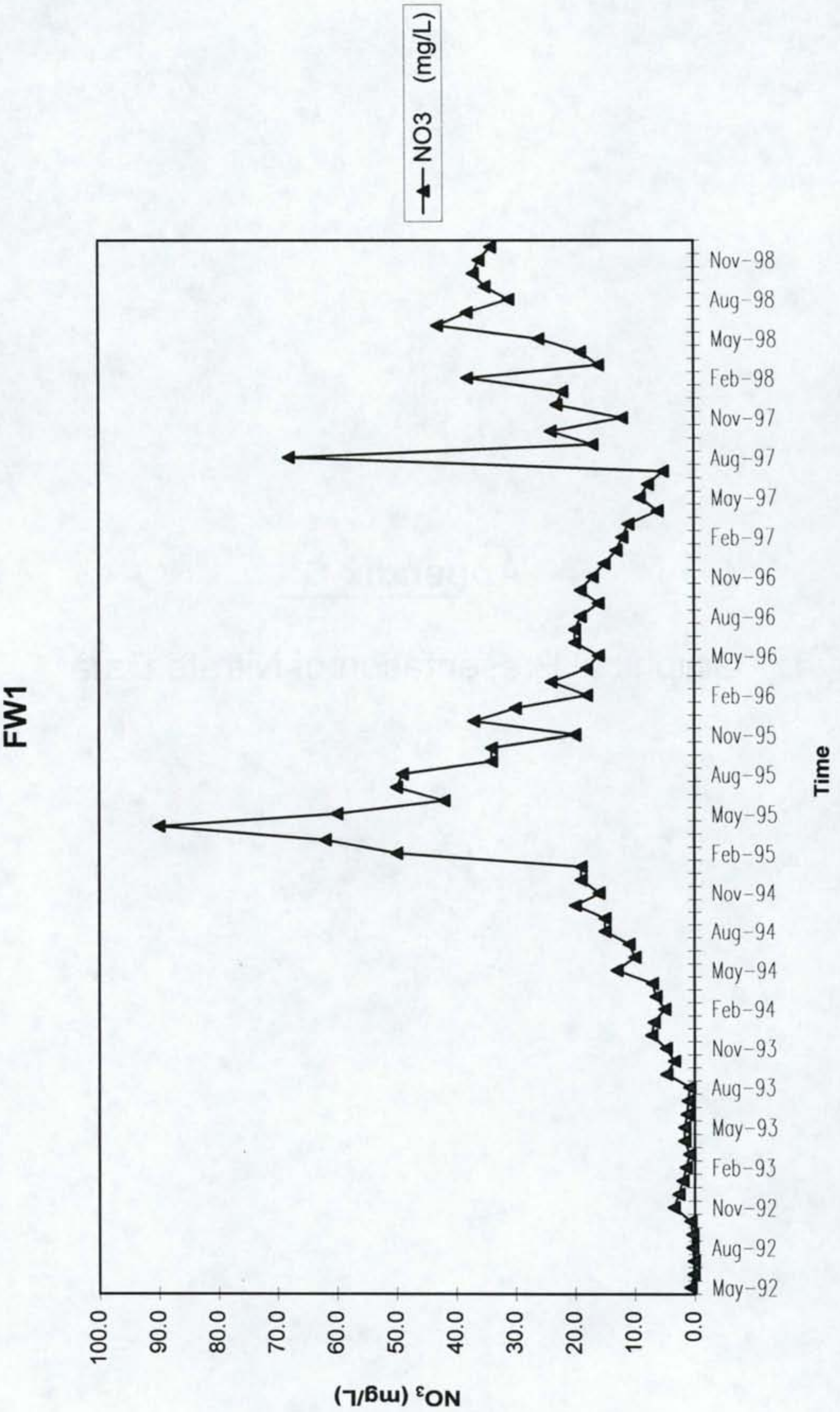
MPEN DATA												
DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen		SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
							(%)	(mg/l)				
Jun-92	5.68	4138.59	0.7						0.0	500		16.5
Jul-92	6.52	4137.75	0.3	BDL	0.3	7.89			0.2	550		18.3
Aug-92	6.42	4137.85	0.3			7.26			0.3	590		21.0
Sep-92	7.43	4136.84	0.2			7.50			0.2	505		16.1
Oct-92	6.63	4137.64	4.5			7.30	53	5.1	0.5	605		17.1
Nov-92	8.35	4135.92	1.8			8.29	87	11.4	0.4	495		3.5
Dec-92	8.52	4135.75	4.2			7.91	76	9.0	0.4	490		9.0
Jan-93	8.55	4135.72	4.2	0.8	0.2	7.50	65	8.0	0.1	430		7.5
Feb-93	8.86	4135.41	4.6			7.76	75	6.3		721	362	9.9
Mar-93	4.24	4140.03	37.0			7.44	46	5.1		1115	561	9.9
Apr-93	7.46	4136.68	25.0	BDL	1.2	7.41	37	4.0		959	480	13.4
May-93	7.11	4137.11	17.0			7.19	35	3.3		873	437	17.2
Jun-93	5.59	4138.63	13.0			7.21	38	3.5		908	455	15.2
Jul-93	3.72	4140.50	13.0	BDL	1.2	7.22	31	2.2		890	446	19.3
Aug-93	5.88	4138.34	22.0			7.28	24	2.1		1008	506	17.2
Sep-93	6.25	4137.97	21.0			7.14	41	3.9		1065	537	16.8
Oct-93	6.87	4137.35	17.0	BDL	0.9	7.01	24	1.8		1095	551	14.6
Nov-93	7.94	4136.28	16.0									
Dec-93	8.44	4135.78	13.0			7.07	27	2.4		1000	496	12.1
Jan-94	8.82	4135.32	11.0	BDL	BDL	7.18	23	2.8		895	452	11.4
Feb-94	8.92	4135.22	9.8			7.27	31	3.7		930	467	5.9
Mar-94	8.00	4136.14	7.6			7.80	41	3.5		828	415	15.3
Apr-94	9.38	4134.76	6.5	BDL	0.6	6.91	43	3.9		800	402	13.8
May-94	6.84	4137.30	6.6				32	2.3		882	415	13.7
Jun-94	4.60	4139.54	5.9			7.68	32	3.1		758	380	15.3
Jul-94	5.72	4138.42	4.1	BDL	1.8	7.63	44	3.5		727	366	19.6
Aug-94	4.49	4139.73	3.5			7.72	24	1.6		746	369	21.8
Sep-94	5.60	4138.62	5.5			7.60	19	1.6		752	378	17.3
Oct-94	6.55	4137.67	7.8	BDL	BDL	7.50	47	4.6		820	413	14.3
Nov-94	7.75	4136.47	6.5			7.83	36	3.6		829	419	9.4
Dec-94	9.38	4134.84	6.5			7.70	59	5.9		727	397	9.7
Jan-95	8.09	4136.13	4.3	BDL		8.01	39	4.5		764	386	8.8
Feb-95	8.19	4136.03	4.4			7.67	45	2.2		777	391	9.7
Mar-95	8.15	4136.07	4.0			7.51	48	5.3		739	374	11.2
Apr-95	8.46	4135.76	3.9	BDL		7.48	65	6.2		702	356	14.5
May-95	7.65	4136.57	3.1			7.37	45	4.3		683	344	8.1
Jun-95	5.99	4138.23	7.1			7.05	44	3.9		773	388	9.7
Jul-95	5.13	4139.09	5.2	BDL		7.53	52	4.4		760	383	15.2
Aug-95	5.93	4138.29	5.8			7.25	25	2.3		746	374	15.6
Sep-95	6.23	4137.99	6.4			7.32	21	2.2		777	386	8.9
Oct-95	7.09	4137.13	7.4				16	1.5		842	426	12.4
Nov-95	8.79	4135.43	6.4			6.80	41	4.5		792	400	9.6
Dec-95	8.59	4135.63	6.2			7.45	29	3.8		818	404	5.9
Jan-96	8.64	4135.58	5.0			6.84	29	4.0		686	344	4.4
Feb-96	6.76	4137.46	5.3			7.69	19	2.4		779	387	3.6
Mar-96	8.02	4136.20	24.0			7.44	62	5.8		1057	532	4.9
Apr-96	9.15	4135.07	25.0			7.50	22	2.0		1129	566	7.5
May-96	6.65	4137.57	22.0			7.54	44	4.5		941	473	9.1
Jun-96	5.75	4138.47	13.0			7.50	37	3.6		920	462	12.4
Jul-96	5.60	4138.62	10.0			7.48				877	441	18.0
Aug-96	6.43	4137.79	9.0			7.45	44	3.2		681	368	19.4
Sep-96	6.18	4138.04	9.5			7.56	40	3.5		825	416	14.5
Oct-96	6.86	4137.36	9.5			7.33	19	1.7		836	415	11.0
Nov-96	7.88	4136.34	8.1			7.84	26	3.0		817	406	6.6
Dec-96	6.49	4137.73	6.8			7.60				774	382	7.2
Jan-97	6.54	4137.68	15.0			7.80	41	4.9		1110	553	5.0
Feb-97	7.29	4136.93	23.0			8.07	23	2.5		1014	506	7.5
Mar-97	8.28	4135.94	17.0			7.90	0	0.0		1027	535	11.6
Apr-97	8.38	4135.84	16.0			7.96	35	3.3		550	288	11.5
May-97	7.10	4137.12	14.0			7.70	0	0.0		1003	505	17.1
Jun-97	6.22	4138.00	19.0			7.64	3	0.2		979	491	16.5
Jul-97	6.95	4137.27	25.0			7.32	14	0.7		1113	558	17.4
Aug-97	7.00	4137.22	29.0			7.41	25	3.3		1119	561	17.2
Sep-97	6.88	4137.34	24.0			7.37	0	0.0		1065	534	13.3
Oct-97	7.94	4136.28	19.0			7.74	2	0.0		957	487	8.8
Nov-97	8.53	4135.69	16.0			8.09	33	2.6		923	460	6.6
Dec-97	8.78	4135.44	10.0			7.96	58	6.3		956	474	7.0
Jan-98	7.37	4136.85	16.0			7.54	36	4.8		909	461	5.1
Feb-98	8.69	4135.53	12.0			8.15	0	0.0		865	429	4.0
Mar-98	8.83	4135.39	9.8			8.18	4	0.3		927	466	8.7

MPES DATA

DATE	WATER LEVEL (ft)	G.W. ELEV. (ft)	NO3 (mg/l)	NH3 (mg/l)	KJELDAHL	pH	Dissolved Oxygen		SALINITY (%)	COND. (uS)	TDS (mg/l)	TEMP (C)
							(%)	(mg/l)				
Jun-92	4.62	4138.99	0.8						0.5	625		15.2
Jul-92	5.38	4138.23	0.4	BDL	4.2	8.18			0.2	570		19.0
Aug-92	5.40	4138.21	0.6			7.53			0.3	580		20.0
Sep-92	6.51	4137.10	0.5			7.93	13	1.2	0.2	530		16.0
Oct-92	5.49	4138.12	1.7			7.61	48	4.9	0.4	620		16.3
Nov-92	7.49	4136.12	0.7			7.82	36	4.6	0.2	470		9.5
Dec-92	7.34	4136.27	0.7			7.92	66	7.7	0.4	470		8.8
Jan-93	7.90	4135.71	0.4	0.3	0.4	7.69	49	6.6	0.1	400		8.3
Feb-93	7.87	4135.74	0.6			7.71	47	5.4		653	329	9.4
Mar-93	2.79	4140.82	3.4			7.52	46	4.9		1002	503	11.0
Apr-93	6.62	4136.99	7.8	BDL	1.2	7.51	31	3.4		1055	530	12.0
May-93	6.18	4137.43	4.2			7.45	17	1.7		770	383	15.3
Jun-93	5.01	4138.60	1.7			7.51	21	2.1		832	417	13.7
Jul-93	3.14	4140.47	1.0	BDL	0.5	7.45	22	1.2		714	361	18.0
Aug-93	5.19	4138.42	3.3			7.46	20	1.3		841	424	15.8
Sep-93	5.89	4137.72	4.6			7.36	28	2.6		936	469	16.6
Oct-93	6.24	4137.37	9.8	BDL	0.8	7.21	20	2.0		1093	552	15.4
Nov-93	7.24	4136.37	3.2			7.28	23	2.5		875	438	11.5
Dec-93	7.75	4135.86	2.0			7.44	22	2.0		763	382	11.6
Jan-94	8.14	4135.47	0.8	BDL	BDL	7.48	19	1.4		694	351	9.7
Feb-94	8.33	4135.28	0.3			7.56	27	2.7		692	346	6.2
Mar-94	8.70	4134.91	0.6			7.38	21	2.1		605	327	14.2
Apr-94	8.43	4135.18	0.5	BDL	0.7	7.25	37	3.2		669	337	13.2
May-94	6.06	4137.55	0.6				13	1.3		650	327	13.1
Jun-94	3.95	4139.66	0.7			7.93	20	2.0		637	319	14.7
Jul-94	4.97	4138.64	0.6	BDL	1.9	7.75	32	2.6		647	320	20.1
Aug-94	4.01	4139.60	0.7			8.01	31	2.1		669	336	20.8
Sep-94	4.46	4139.15	0.6			7.98	24	1.9		676	340	18.2
Oct-94	5.95	4137.66	1.0	BDL	BDL	7.57	24	2.3		696	350	14.6
Nov-94	7.46	4136.15	0.4			7.70	43	5.1		717	361	11.1
Dec-94	8.43	4135.18	0.5			7.92	47	5.1		743	370	8.2
Jan-95	7.45	4136.16	0.9	BDL		7.80	36	5.3		740	372	8.9
Feb-95	7.45	4136.16	1.0			7.73	32	3.5		777	389	9.5
Mar-95	7.53	4136.08	1.2			7.54	38	4.1		762	382	9.8
Apr-95	7.86	4135.75	1.1	BDL		7.40	56	4.3		776	393	11.1
May-95	6.92	4136.69	1.5			7.19	27	2.9		806	407	7.7
Jun-95	4.53	4139.08	4.6			7.40	56	5.5		1017	510	11.4
Jul-95	4.32	4139.29	59.0	BDL		7.28	60	5.1		1979	988	17.5
Aug-95	4.75	4138.86	24.0			7.27	41	2.9		1235	615	17.1
Sep-95	5.44	4138.17	50.0			7.18	20	2.2		1608	808	10.8
Oct-95	6.48	4137.13	41.0			6.48	0	0.0		1528	766	12.5
Nov-95	7.40	4136.21	20.0			6.69	25	2.4		1204	603	10.8
Dec-95	8.03	4135.58	12.0			7.70	23	2.1		1052	523	7.0
Jan-96	8.11	4135.50	11.0			6.00	23	2.5		929	461	3.5
Feb-96	5.91	4137.70	16.0			7.97	37	4.6		1387	695	3.5
Mar-96	6.98	4136.63	11.0			7.35	63	5.9		1444	725	5.3
Apr-96	7.89	4135.72	26.0			7.69	0	0.0		1214	633	8.8
May-96	5.35	4138.26	6.2			7.51	27	3.0		738	372	10.6
Jun-96	4.64	4138.97	6.2			7.71	3	0.0		797	405	12.4
Jul-96	4.42	4139.19	5.7			7.93				863	432	17.2
Aug-96	4.52	4139.09	3.8			7.76	29	2.3		863	432	20.2
Sep-96	5.36	4138.25	7.0			8.20	20	1.7		888	446	14.2
Oct-96	6.19	4137.42	7.0			7.53	6	0.5		881	445	11.2
Nov-96	7.38	4136.23	6.1			8.27	25	3.0		892	442	8.2
Dec-96	5.41	4138.20	3.6			7.91				889	446	7.4
Jan-97	5.50	4138.11	33.0			8.63	38	4.4		1475	734	6.3
Feb-97	6.48	4137.13	35.0			8.08	28	2.9		737	368	8.8
Mar-97	7.68	4135.93	16.0			8.15	0	0.0		752	382	9.5
Apr-97	7.68	4135.93	15.0			7.65	23	1.7		1112	557	10.3
May-97	6.20	4137.41	5.9				47	4.2		920	463	17.2
Jun-97	5.11	4138.50	7.0			7.87	25.2	0.0		976	491	20.0
Jul-97	5.68	4137.93	31.0			7.45	1	0.0		1292	646	17.4
Aug-97	7.78	4135.83	4.2			7.78	17	1.1		846	425	16.6
Sep-97	6.14	4137.47	3.0			8.18	0	0.0		556	285	14.1
Oct-97	7.10	4136.51	3.5			7.78	0	0.0		854	425	8.2
Nov-97	7.68	4135.93	2.0			8.70	3	0.4		796	395	7.2
Dec-97	8.04	4135.57	1.8			8.39	34	3.6		770	383	7.9
Jan-98	6.65	4136.96	1.6			8.24	45	3.0		788	392	4.0
Feb-98	7.90	4135.71	3.0			8.89	0	0.0		776	384	4.4
Mar-98	8.35	4135.26	1.0			8.43	0	0.0		801	403	8.6

Appendix C:

Graphical Presentation of Nitrate Data


FW1
NO3 (mg/L)
NO$_3$ (mg/L)
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80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
May-92
Aug-92
Nov-92
Feb-93
May-93
Aug-93
Nov-93
Feb-94
May-94
Aug-94
Nov-94
Feb-95
May-95
Aug-95
Nov-95
Feb-96
May-96
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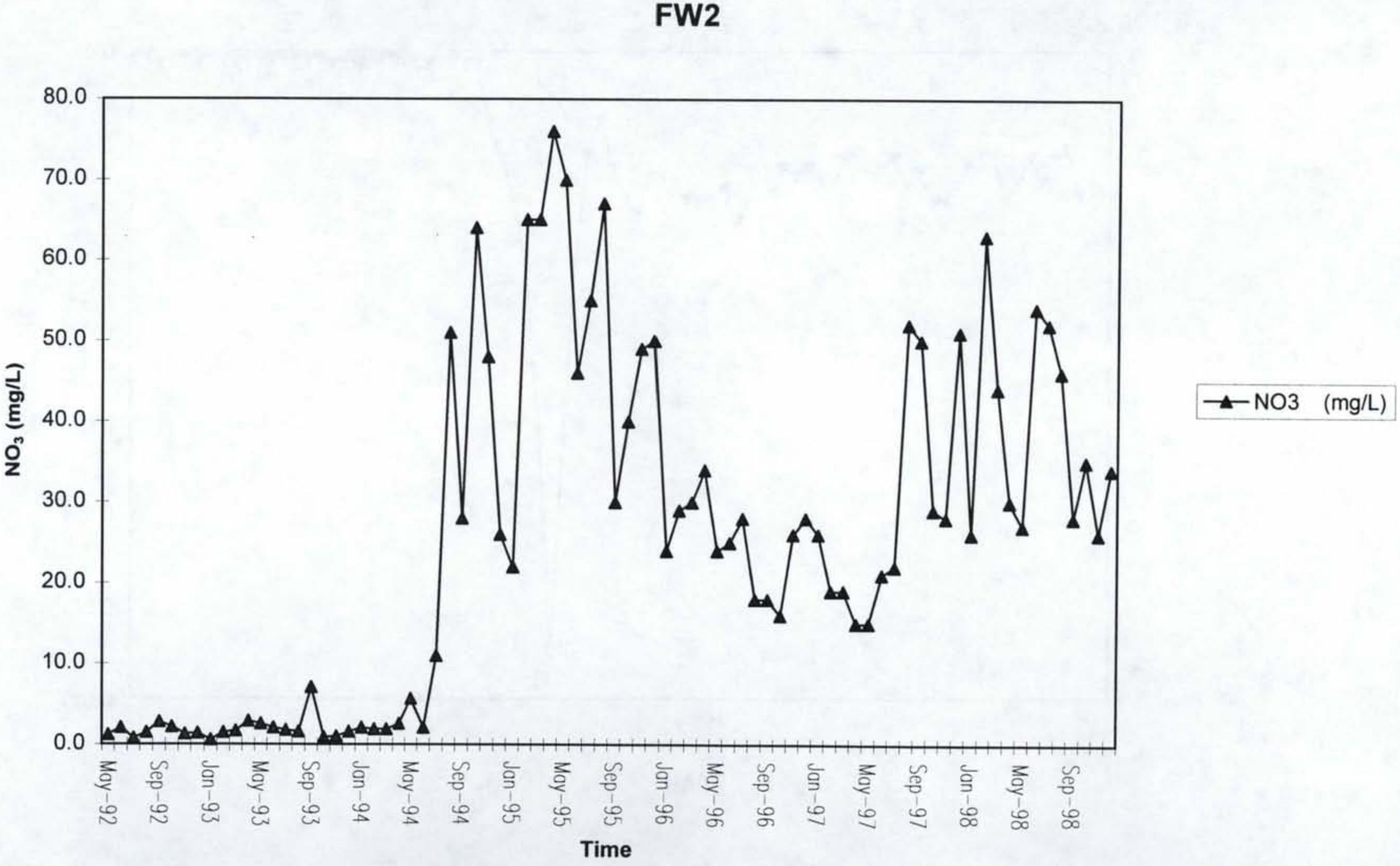
Nov-96
Feb-97
May-97
Aug-97
Nov-97
Feb-98
May-98
Aug-98
Nov-98
Time


FW2
NO₃ (mg/L)
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70.0
60.0
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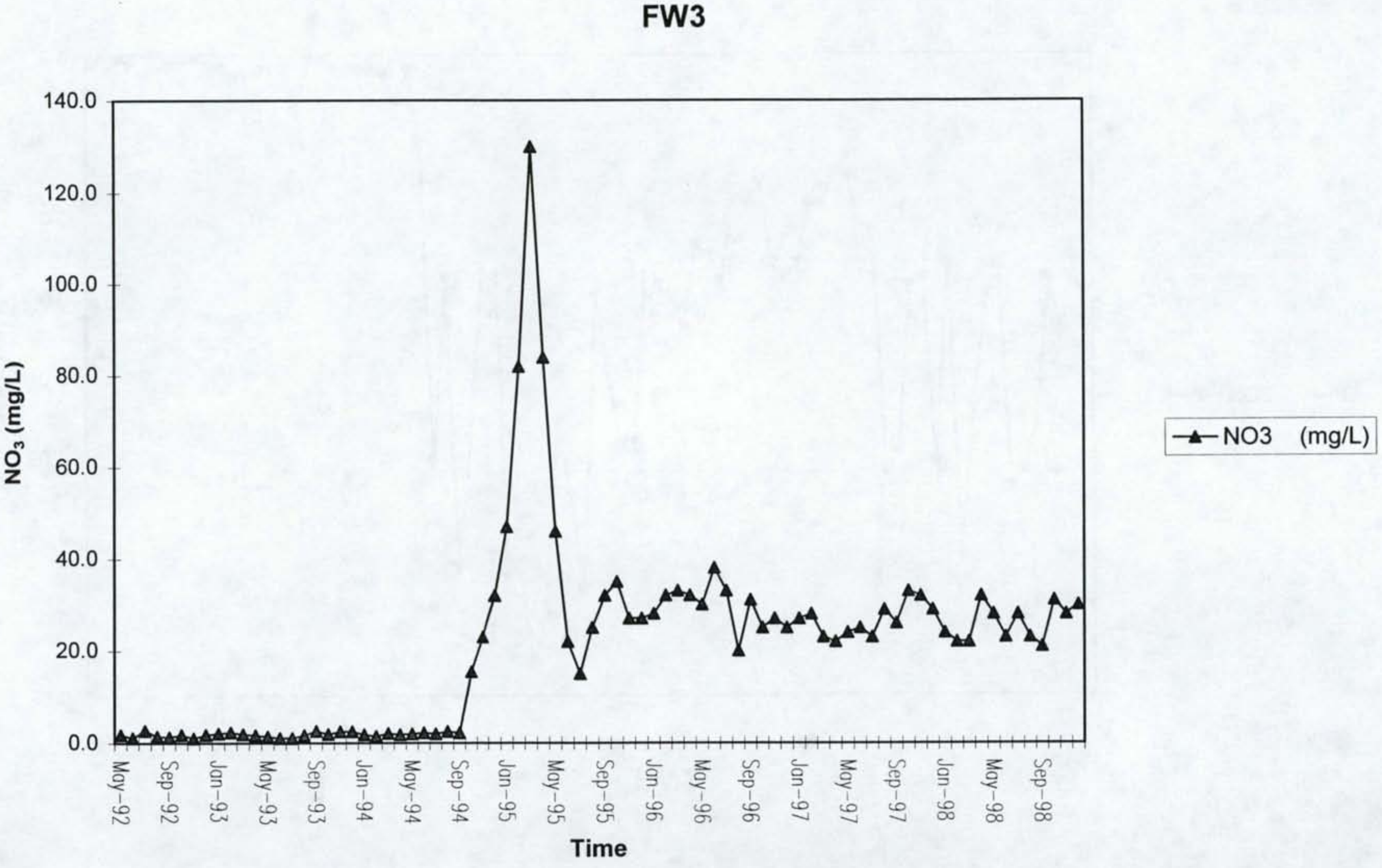
30.0
20.0
10.0
0.0
May-92
Sep-92
Jan-93
May-93
Sep-93
Jan-94
May-94
Sep-94
Jan-95
May-95
Sep-95
Jan-96
May-96
Sep-96
Jan-97
May-97
Sep-97
Jan-98
May-98
Sep-98
Time
NO3 (mg/L)


FW3
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100.0
80.0
60.0
40.0
20.0
0.0
NO_3 (mg/L)
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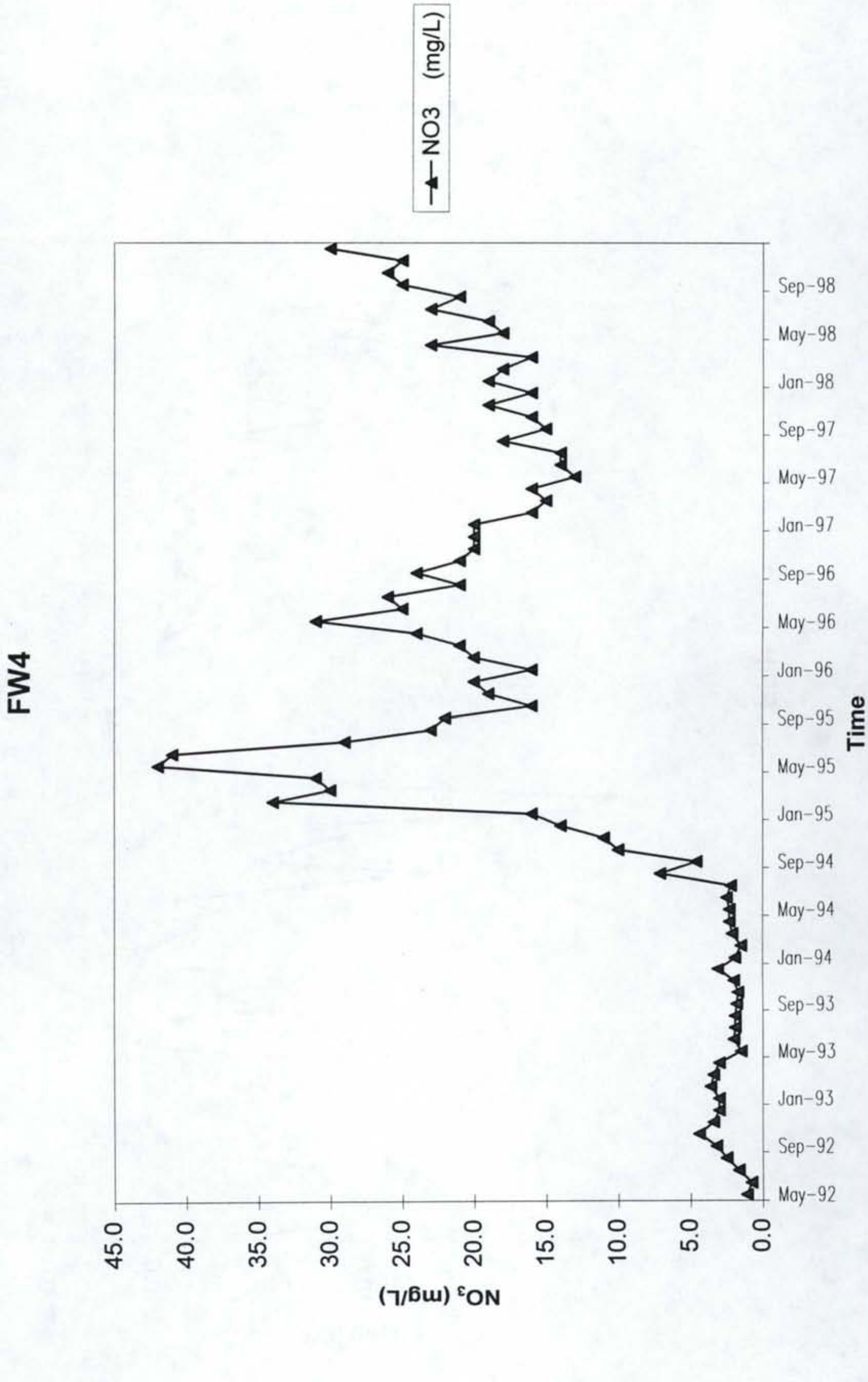
Sep-92
Jan-93
May-93
Sep-93
Jan-94
May-94
Sep-94
Jan-95
May-95
Sep-95
Jan-96
May-96
Sep-96
Jan-97
May-97
Sep-97
Jan-98
May-98
Sep-98
Time
NO3 (mg/L)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NO_3 (mg/L)
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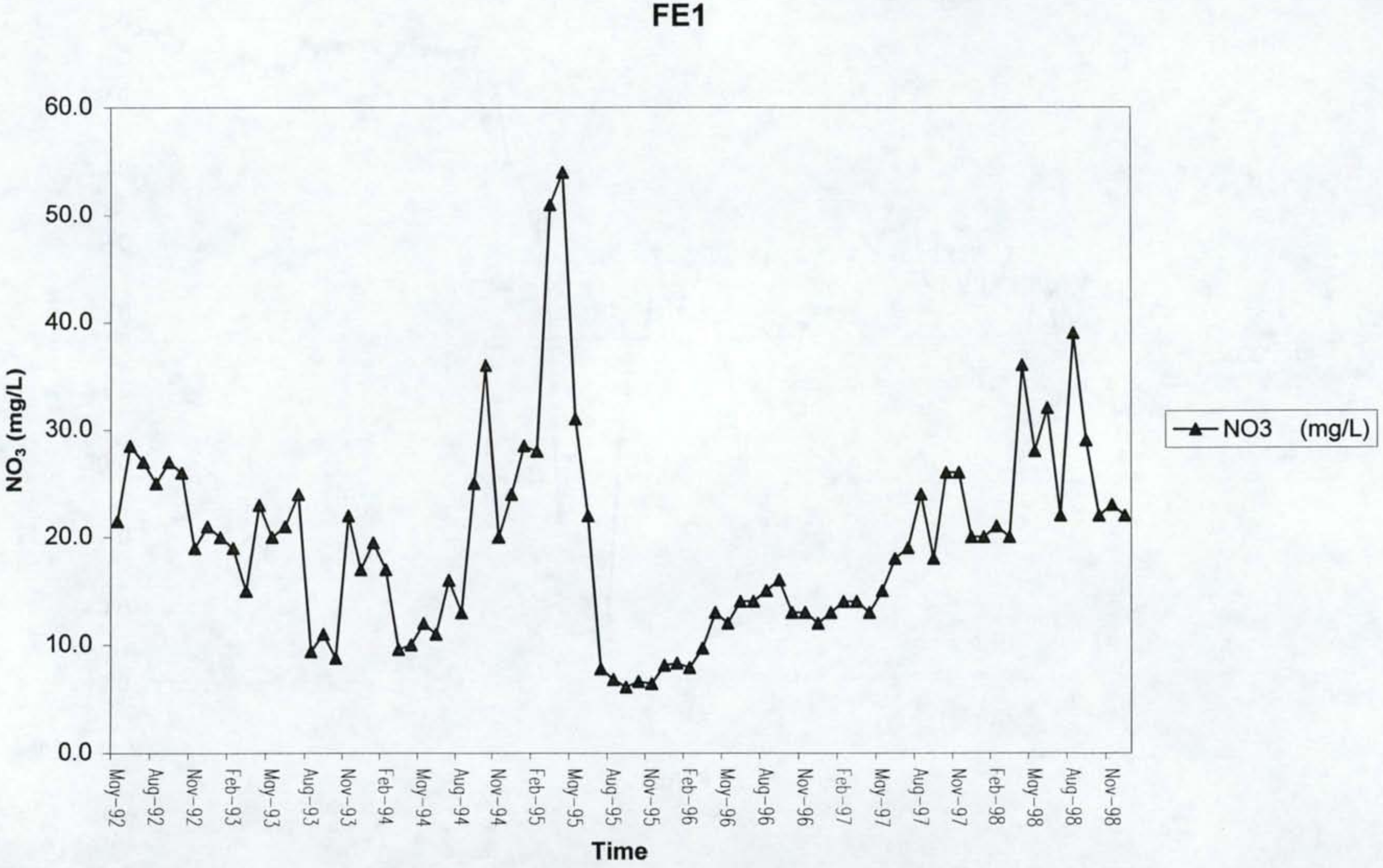
20.0
15.0
10.0
5.0
0.0
May-92
Sep-92
Jan-93
May-93
Sep-93
Jan-94
May-94
Sep-94
Jan-95
May-95
Sep-95
Jan-96
May-96
Sep-96
Jan-97
May-97
Sep-97
Jan-98
May-98
Sep-98
Time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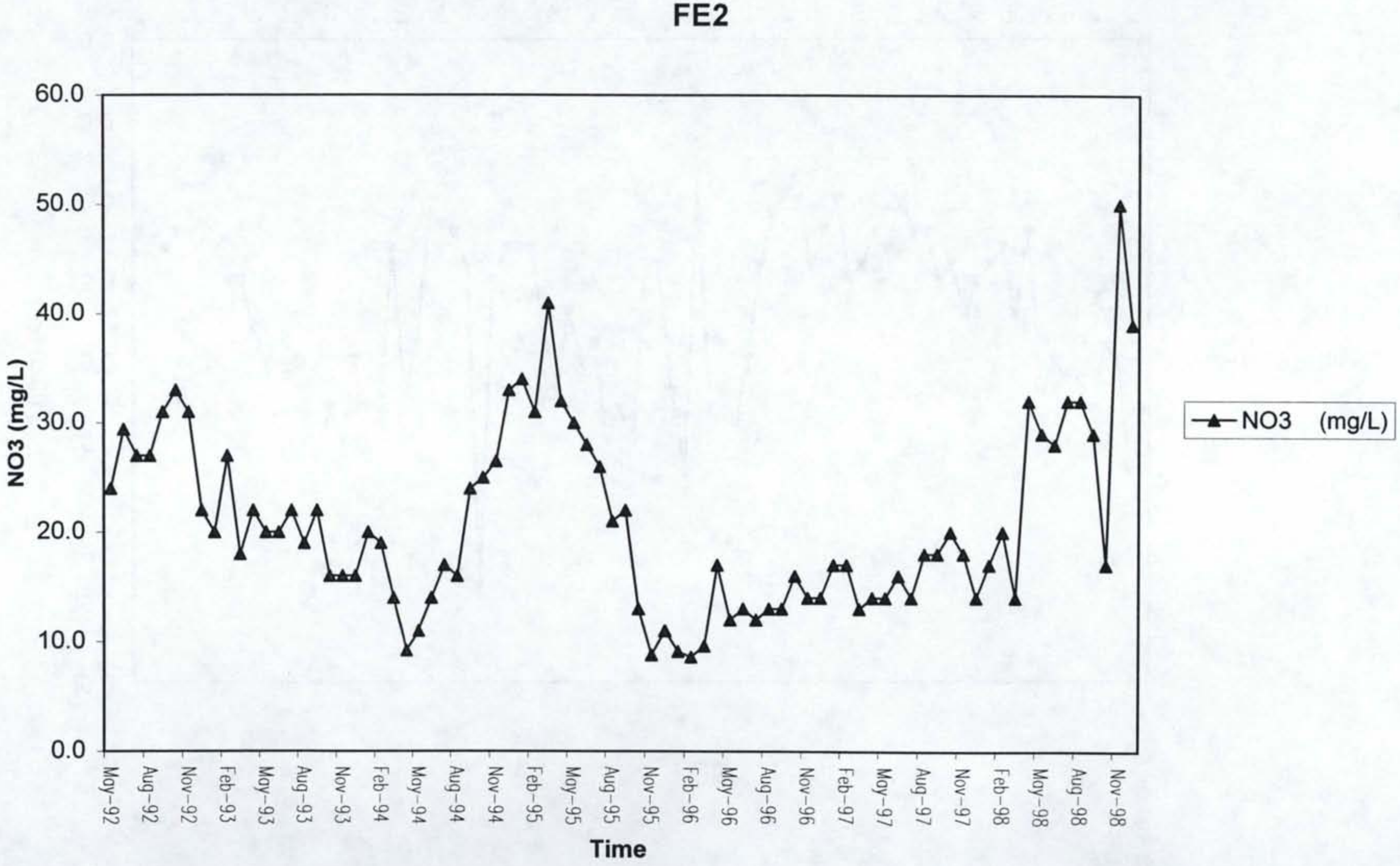
40.0
30.0
20.0
10.0
0.0
May-92
Aug-92
Nov-92
Feb-93
May-93
Aug-93
Nov-93
Feb-94
May-94
Aug-94
Nov-94
Feb-95
May-95
Aug-95
Nov-95
Feb-96
May-96
Aug-96
Nov-96
Feb-97
May-97
Aug-97
Nov-97
Feb-98
May-98
Aug-98
Nov-98
Time
NO3 (mg/L)


FE2
NO3 (mg/L)
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10.0
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Aug-92
Nov-92
Feb-93
May-93
Aug-93
Nov-93
Feb-94
May-94
Aug-94
Nov-94
Feb-95
May-95
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Feb-96
May-96
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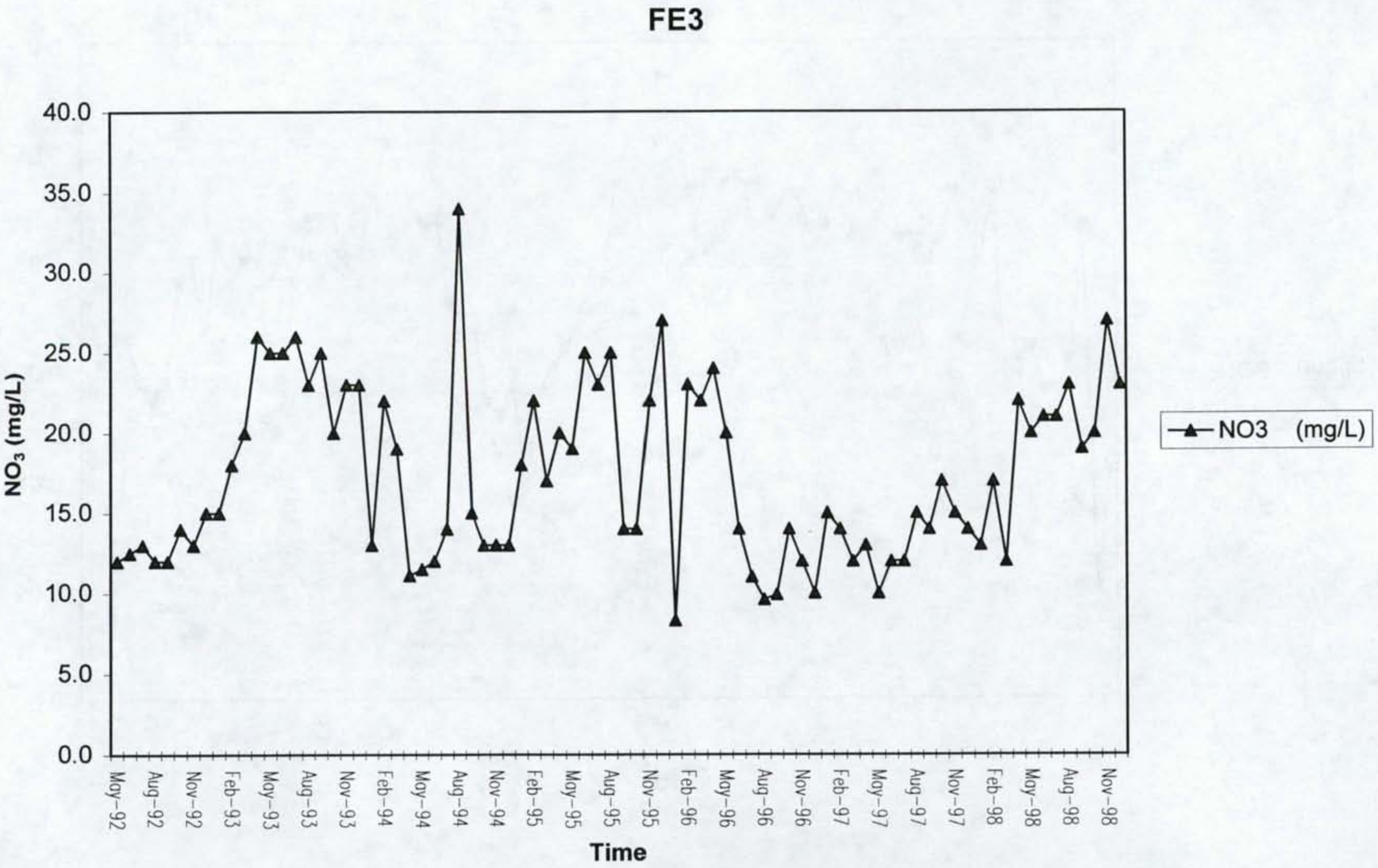
Aug-98
Nov-98
Time
NO3 (mg/L)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NO_3 (mg/L)
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30.0
25.0
20.0
15.0
10.0
5.0
0.0
May-92
Aug-92
Nov-92
Feb-93
May-93
Aug-93
Nov-93
Feb-94
May-94
Aug-94
Nov-94
Feb-95
May-95
Aug-95
Nov-95
Feb-96
May-96
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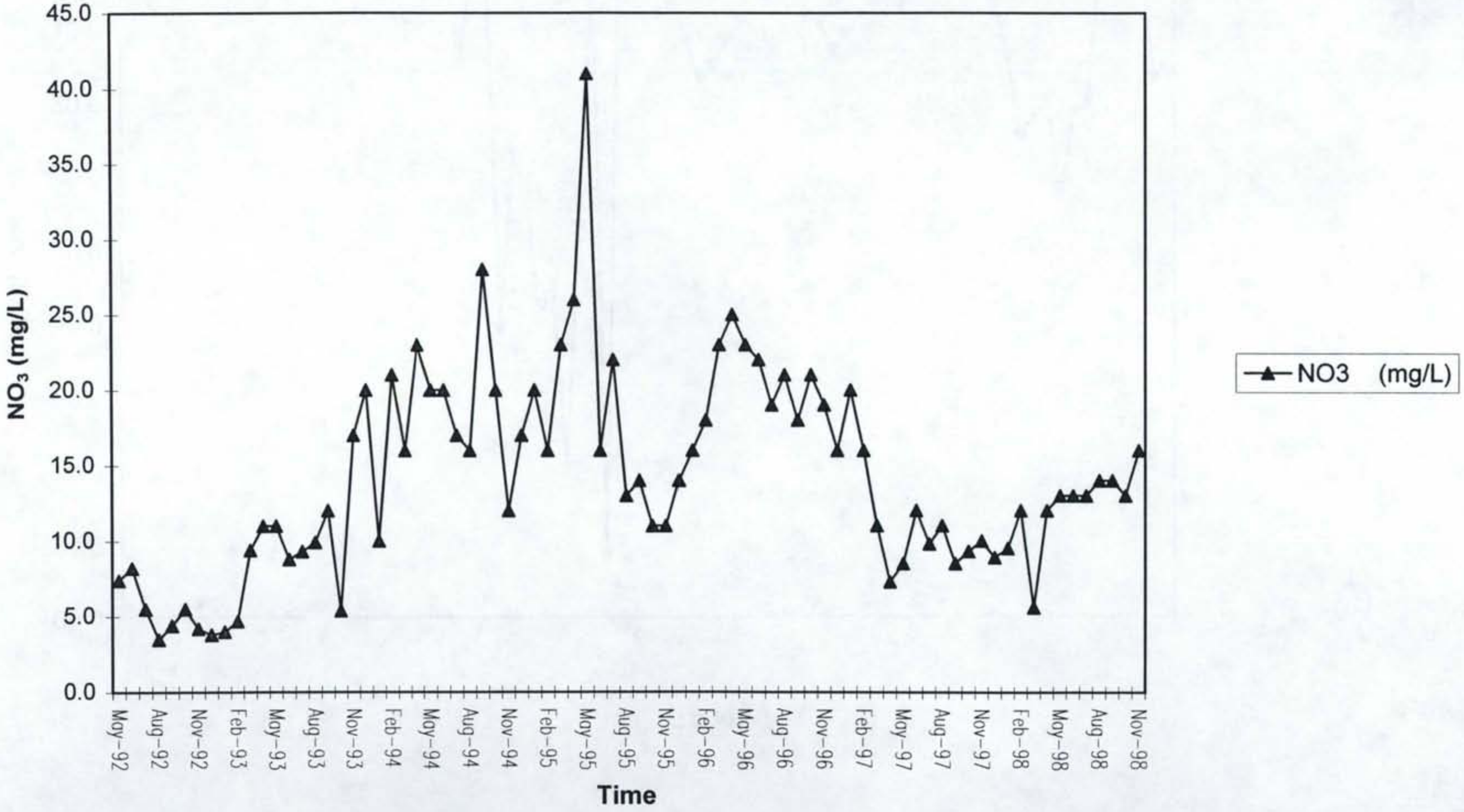
Aug-97
Nov-97
Feb-98
May-98
Aug-98
Nov-98
Time

FE4



NO$_3$ (mg/L)
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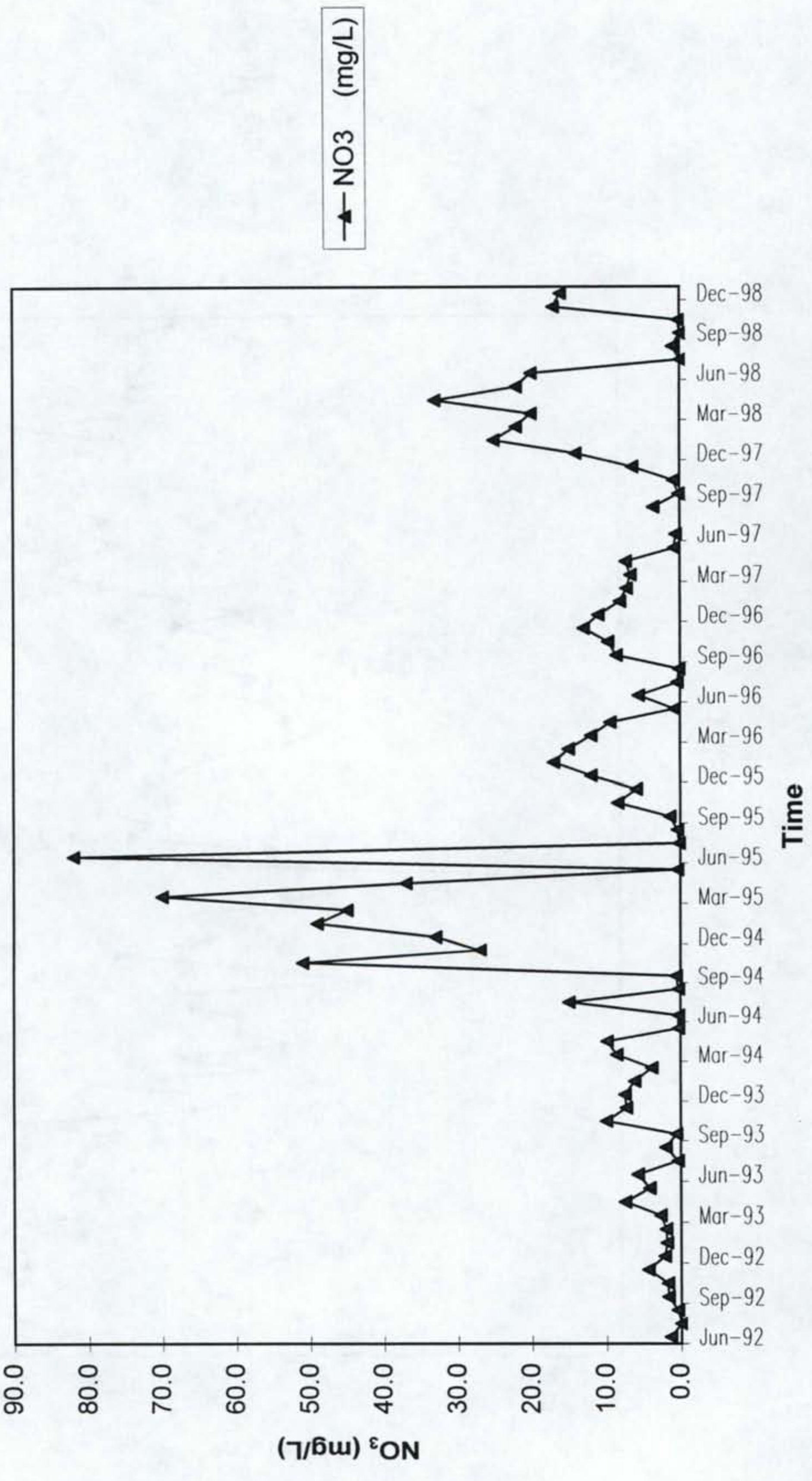
30.0
25.0
20.0
15.0
10.0
5.0
0.0
May-92
Aug-92
Nov-92
Feb-93
May-93
Aug-93
Nov-93
Feb-94
May-94
Aug-94
Nov-94
Feb-95
May-95
Aug-95
Nov-95
Feb-96
May-96
Aug-96
Nov-96
Feb-97
May-97
Aug-97
Nov-97
Feb-98
May-98
Aug-98
Nov-98
Time
NO3 (mg/L)

FPNW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NO₃ (mg/L)
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40.0
30.0
20.0
10.0
0.0
Jun-92
Sep-92
Dec-92
Mar-93
Jun-93
Sep-93
Dec-93
Mar-94
Jun-94
Sep-94
Dec-94
Mar-95
Jun-95
Sep-95
Dec-95
Mar-96
Jun-96
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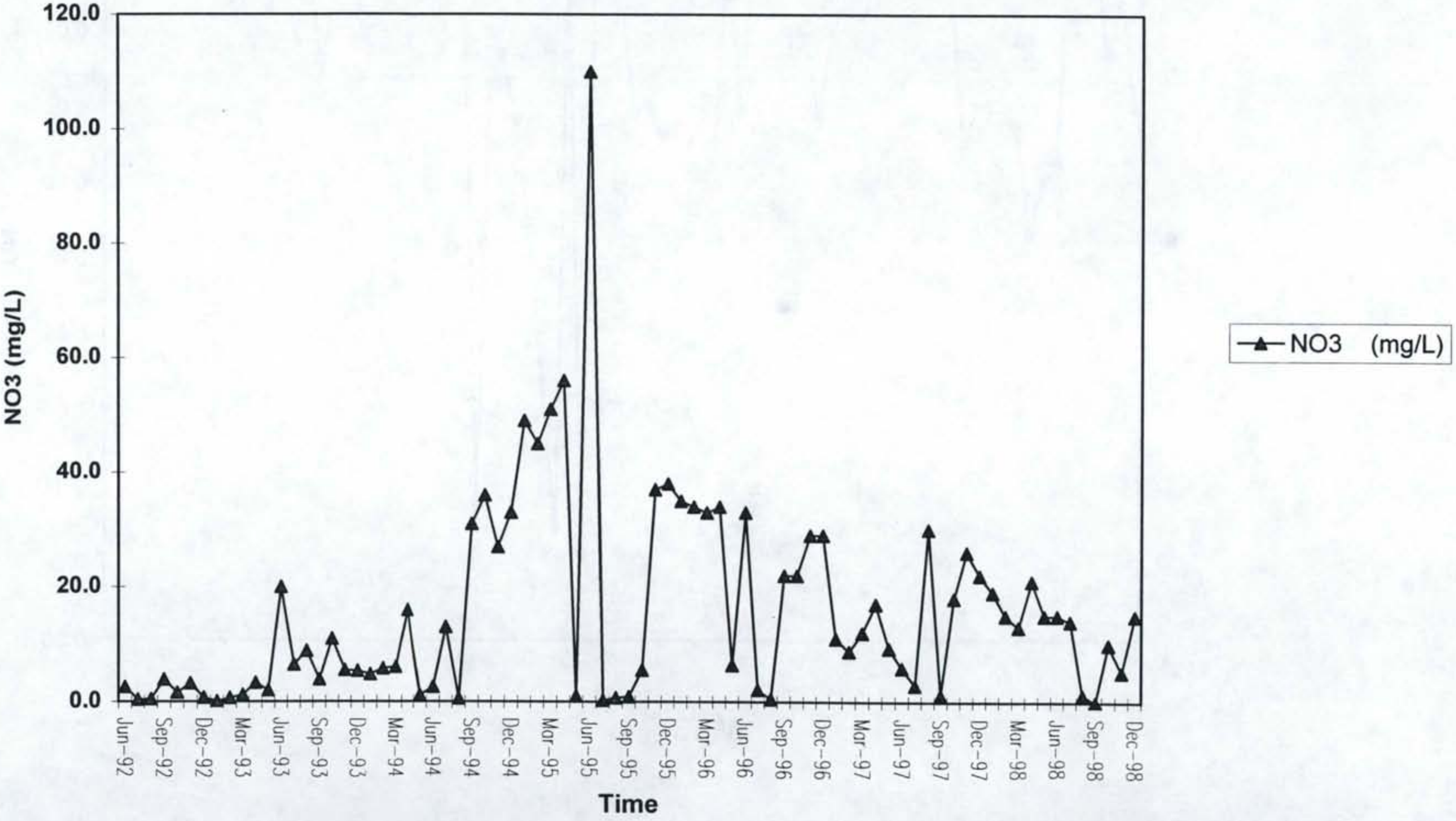
Sep-97
Dec-97
Mar-98
Jun-98
Sep-98
Dec-98
Time

FPNE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40.0
20.0
0.0
NO3 (mg/L)
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Sep-92
Dec-92
Mar-93
Jun-93
Sep-93
Dec-93
Mar-94
Jun-94
Sep-94
Dec-94
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Jun-95
Sep-95
Dec-95
Mar-96
Jun-96
Sep-96
Dec-96
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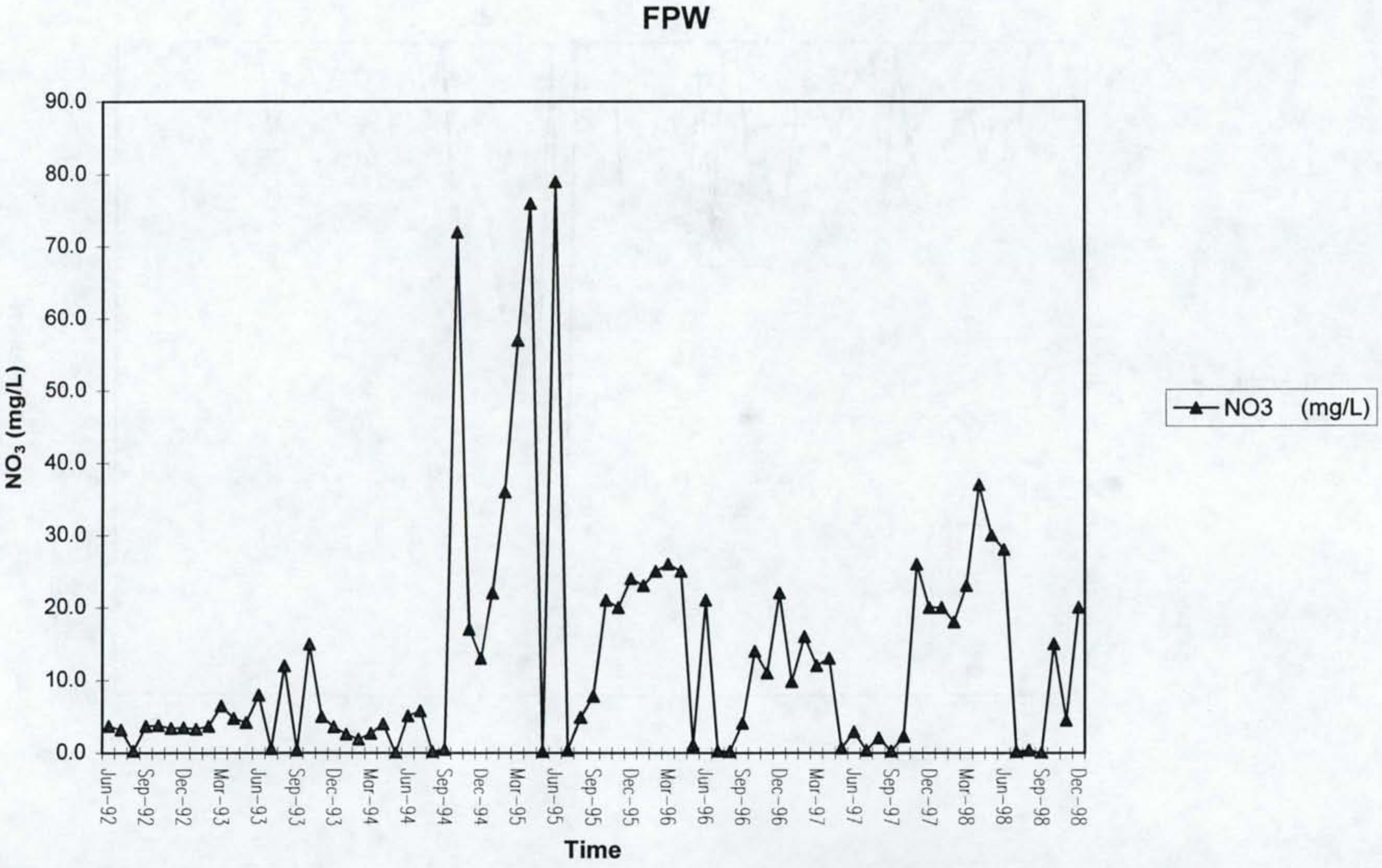
Jun-97
Sep-97
Dec-97
Mar-98
Jun-98
Sep-98
Dec-98
Time
NO3 (mg/L)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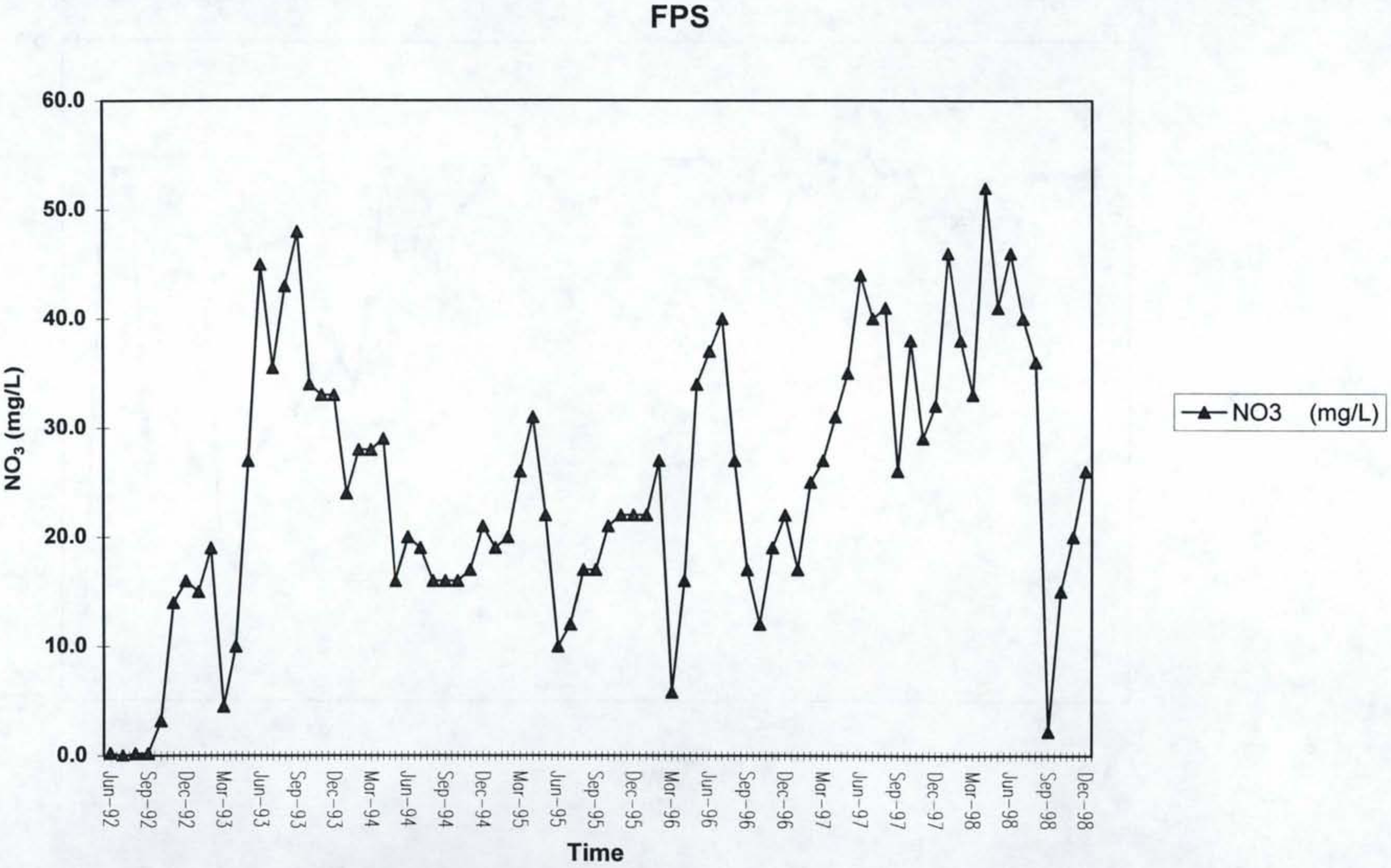
30.0
20.0
10.0
0.0
Jun-92
Sep-92
Dec-92
Mar-93
Jun-93
Sep-93
Dec-93
Mar-94
Jun-94
Sep-94
Dec-94
Mar-95
Jun-95
Sep-95
Dec-95
Mar-96
Jun-96
Sep-96
Dec-96
Mar-97
Jun-97
Sep-97
Dec-97
Mar-98
Jun-98
Sep-98
Dec-98
Time
NO3 (mg/L)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20.0
10.0
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Sep-92
Dec-92
Mar-93
Jun-93
Sep-93
Dec-93
Mar-94
Jun-94
Sep-94
Dec-94
Mar-95
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Sep-95
Dec-95
Mar-96
Jun-96
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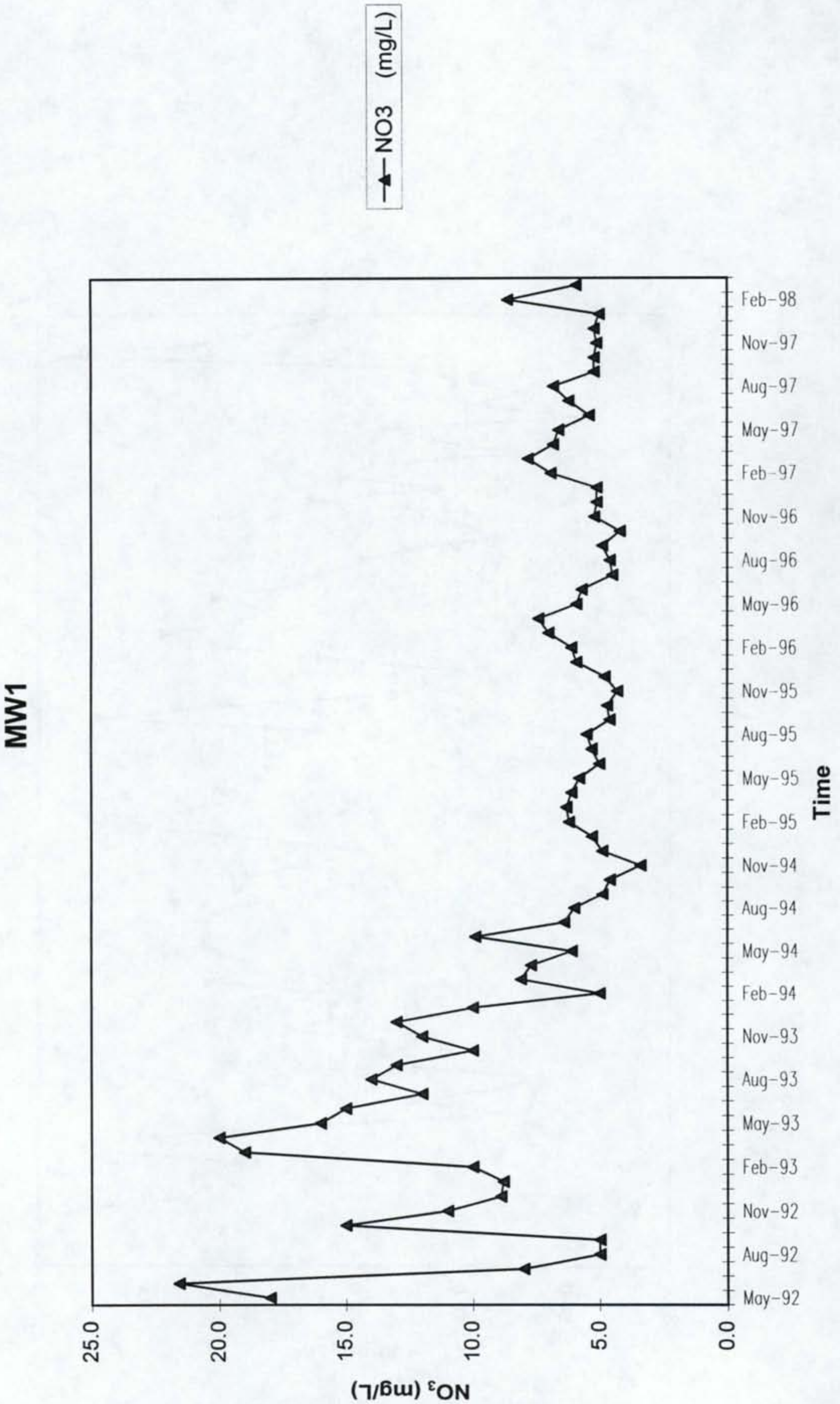
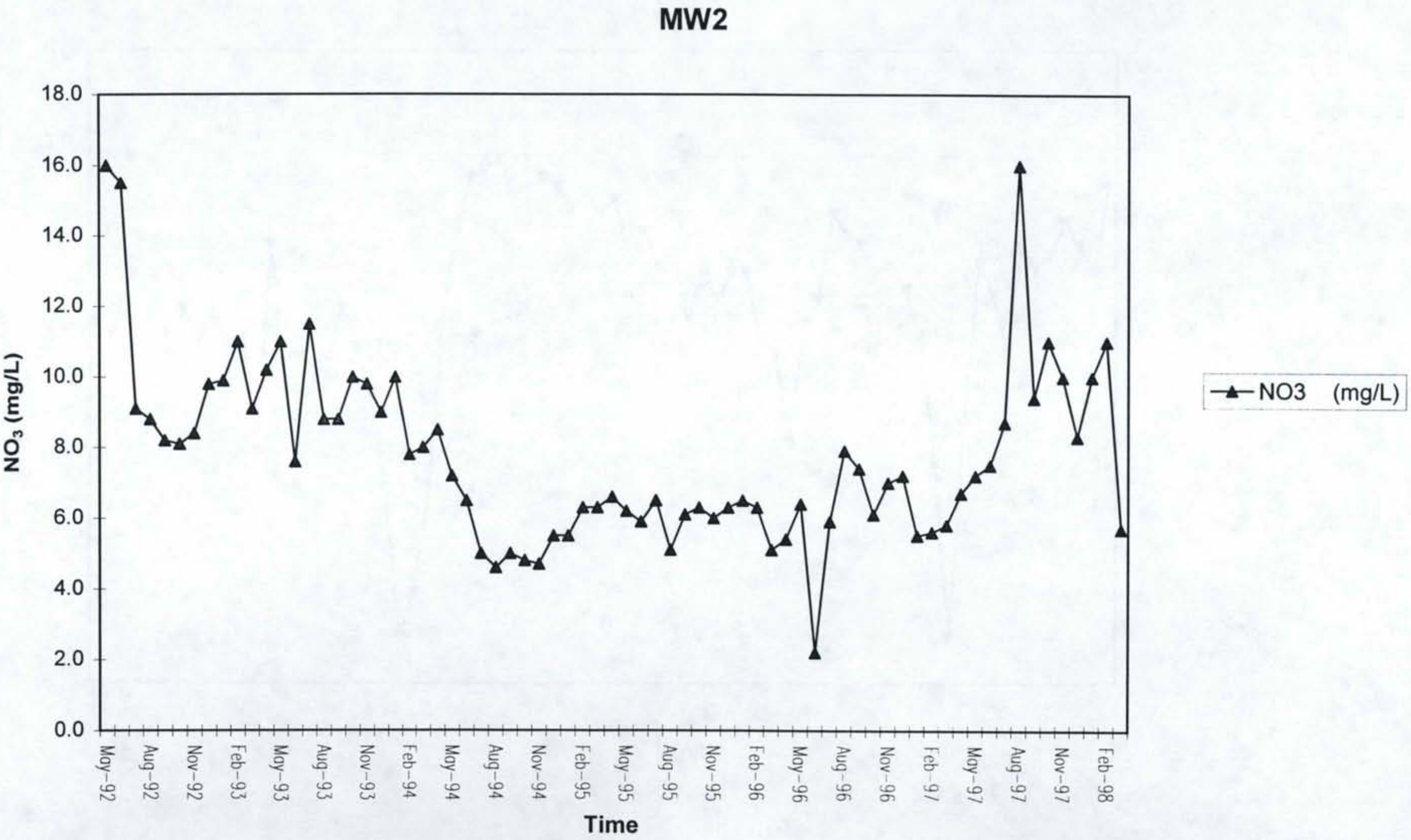
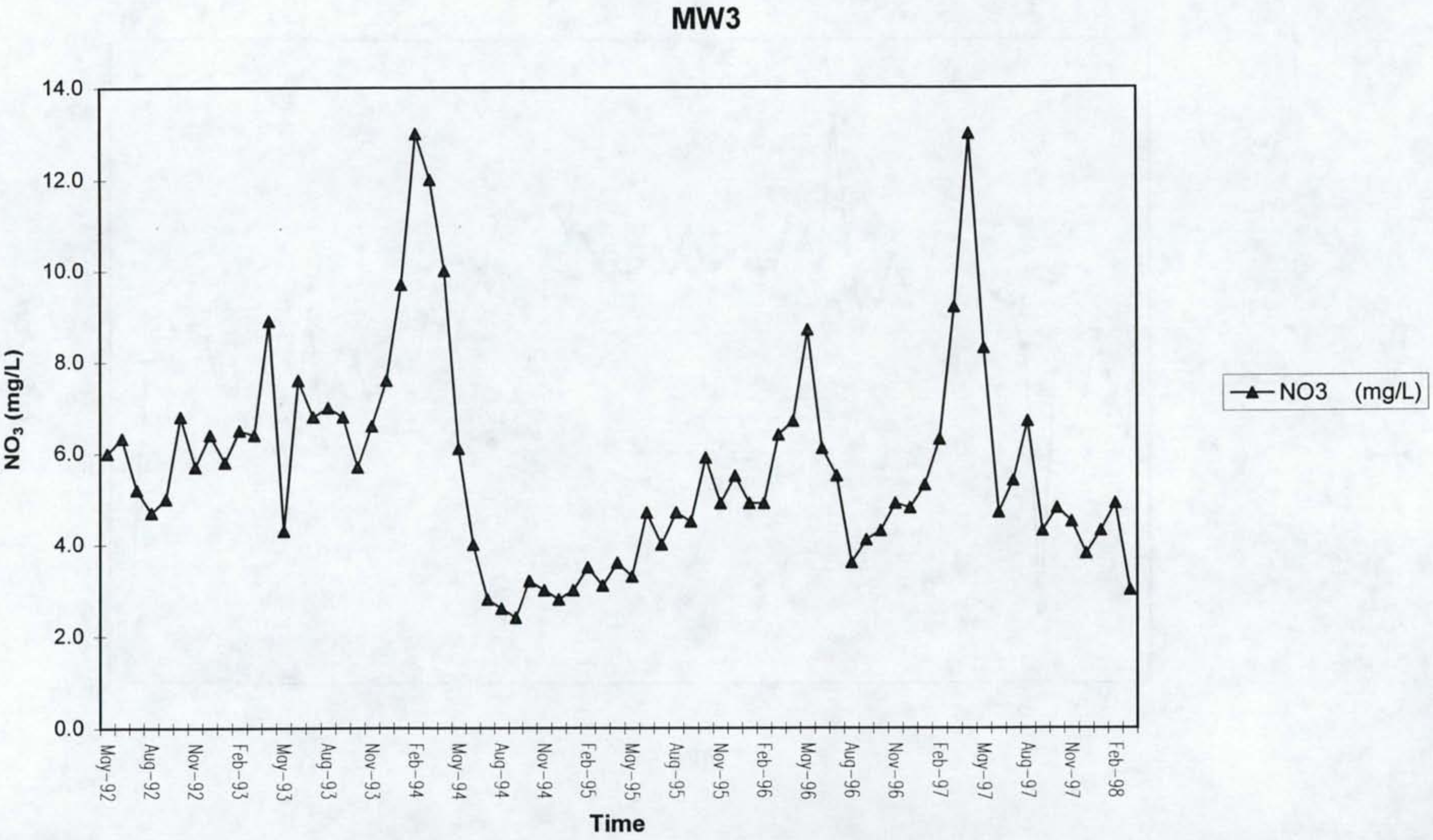
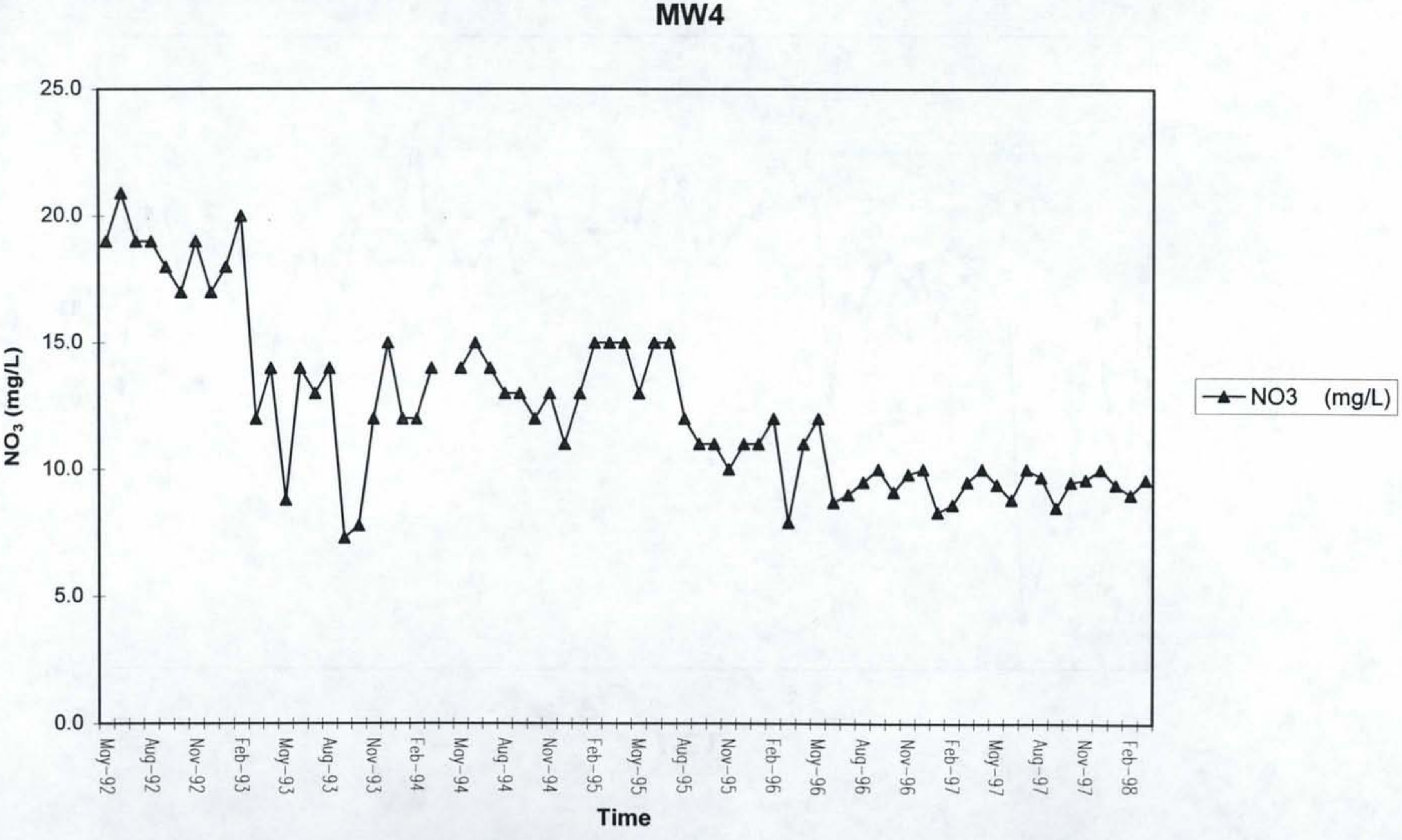
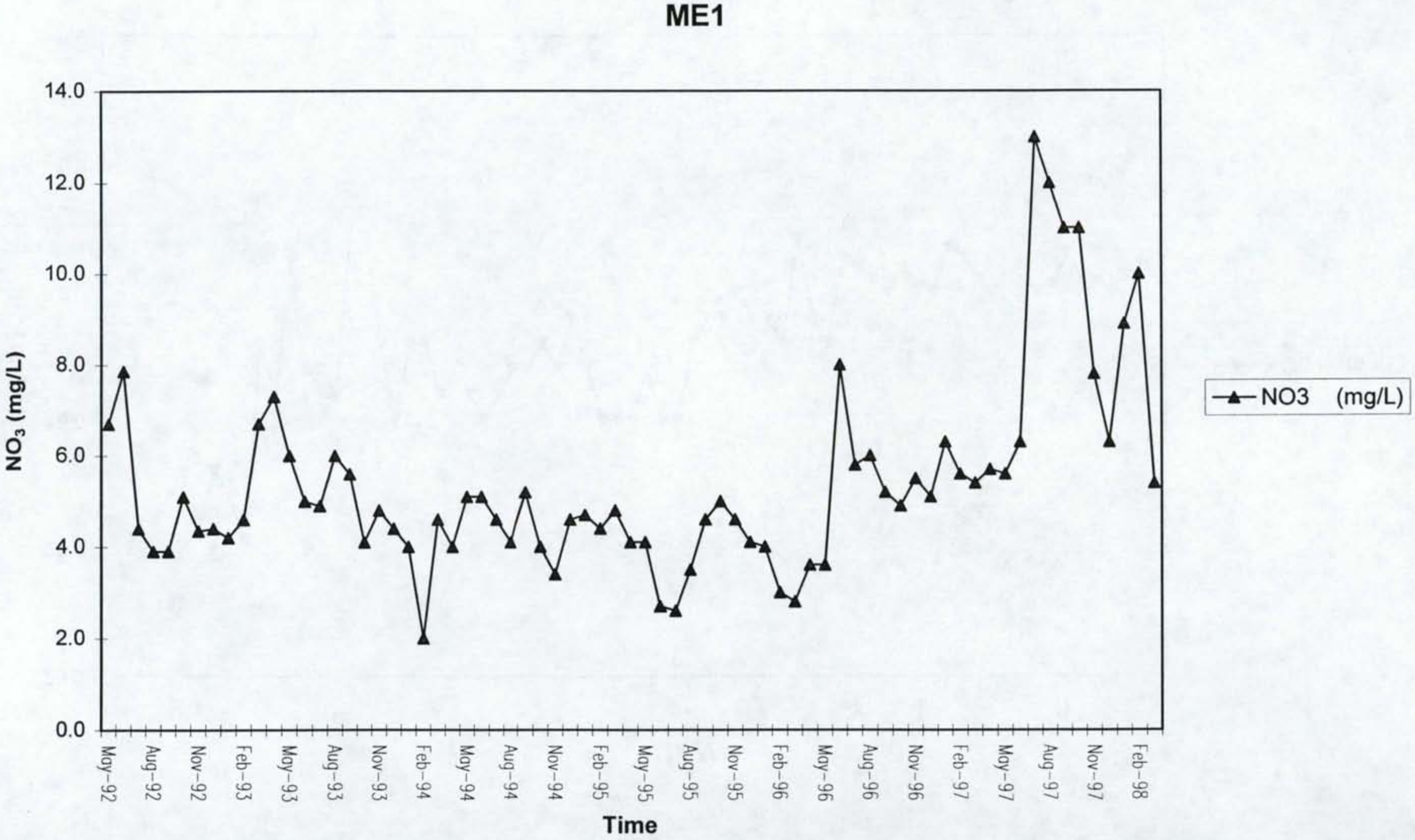
Dec-98
Time
NO3 (mg/L)

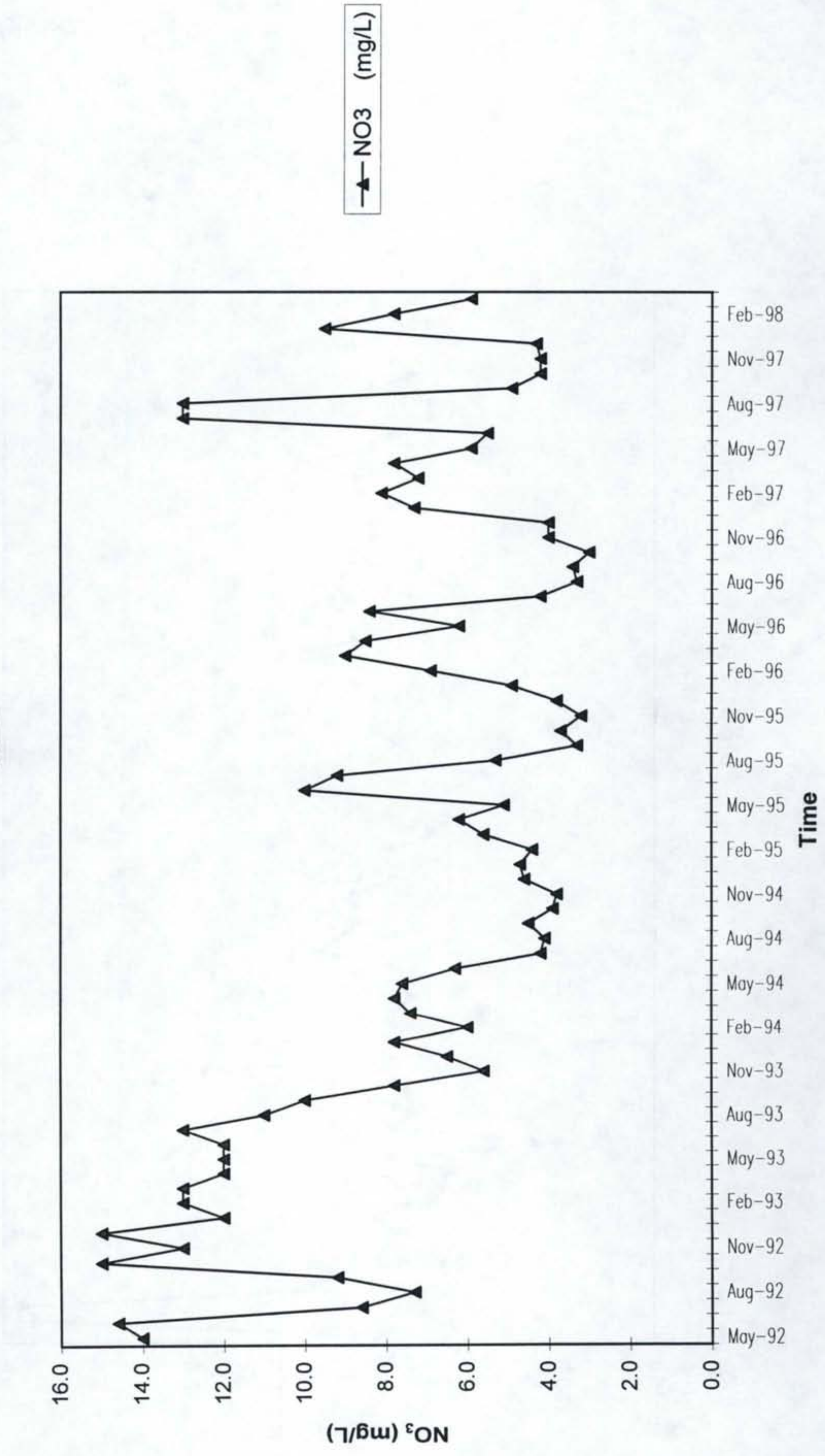

MW1
NO3 (mg/L)
NO$_3$ (mg/L)
25.0
20.0
15.0
10.0
5.0
0.0
May-92
Aug-92
Nov-92
Feb-93
May-93
Aug-93
Nov-93
Feb-94
May-94
Aug-94
Nov-94
Feb-95
May-95
Aug-95
Nov-95
Feb-96
May-96
Aug-96
Nov-96
Feb-97
May-97
Aug-97
Nov-97
Feb-98
Time

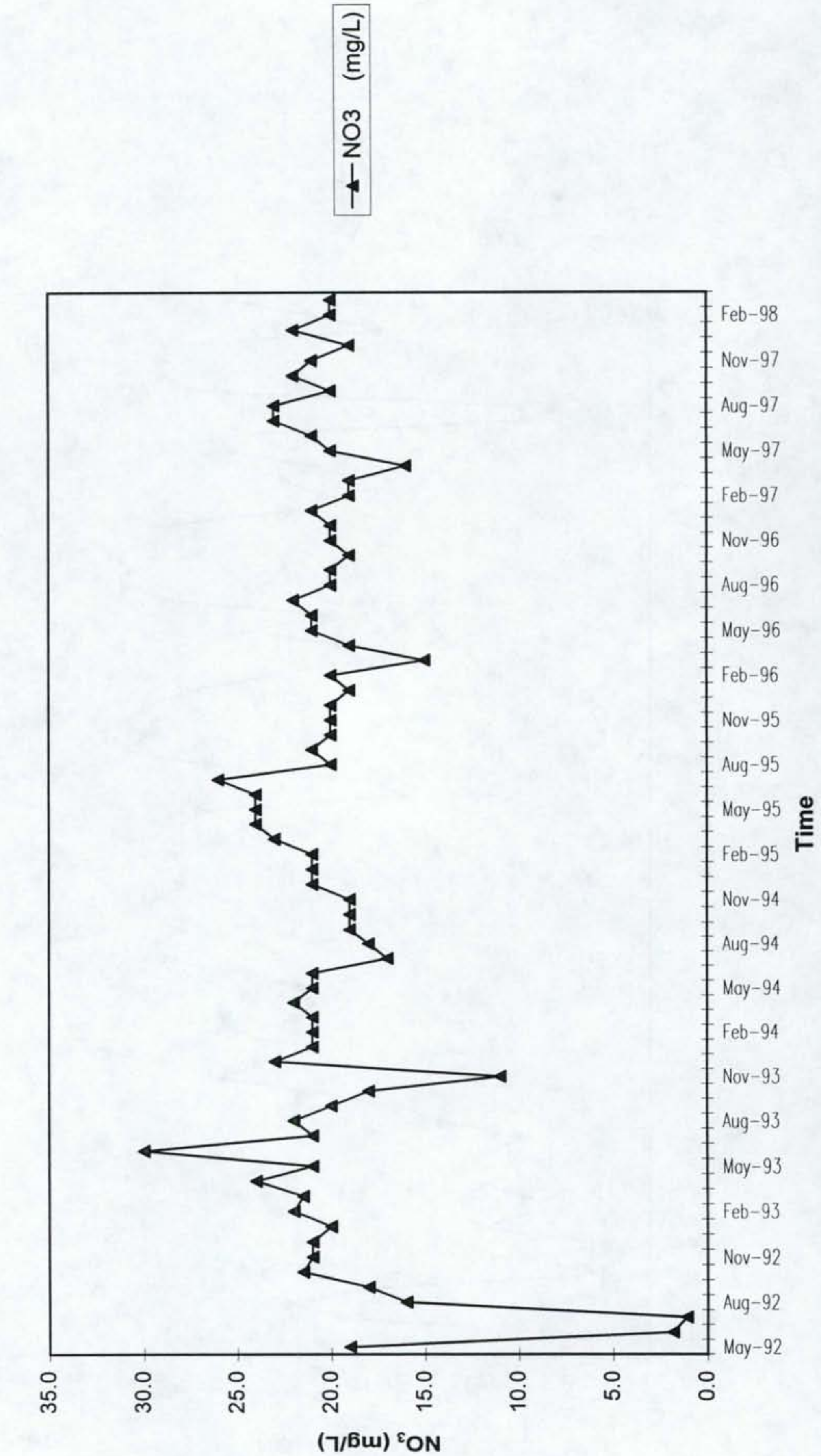

MW2
NO₃ (mg/L)
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
May-92
Aug-92
Nov-92
Feb-93
May-93
Aug-93
Nov-93
Feb-94
May-94
Aug-94
Nov-94
Feb-95
May-95
Aug-95
Nov-95
Feb-96
May-96
Aug-96
Nov-96
Feb-97
May-97
Aug-97
Nov-97
Feb-98
Time
NO3 (mg/L)


MW3
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
NO$_3$ (mg/L)
May-92
Aug-92
Nov-92
Feb-93
May-93
Aug-93
Nov-93
Feb-94
May-94
Aug-94
Nov-94
Feb-95
May-95
Aug-95
Nov-95
Feb-96
May-96
Aug-96
Nov-96
Feb-97
May-97
Aug-97
Nov-97
Feb-98
Time
NO3 (mg/L)

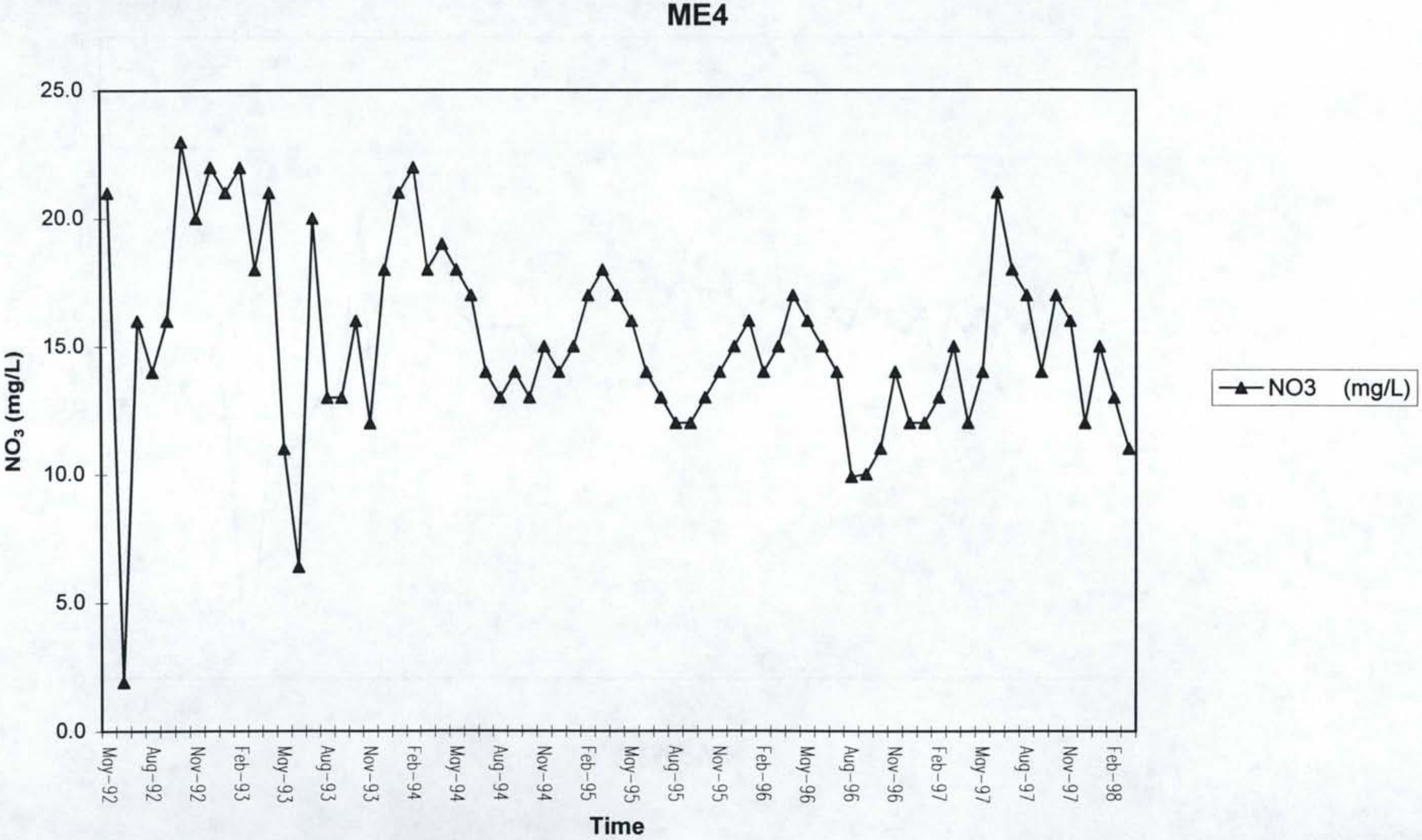

MW4
25.0
20.0
15.0
10.0
5.0
0.0
NO_3 (mg/L)
May-92
Aug-92
Nov-92
Feb-93
May-93
Aug-93
Nov-93
Feb-94
May-94
Aug-94
Nov-94
Feb-95
May-95
Aug-95
Nov-95
Feb-96
May-96
Aug-96
Nov-96
Feb-97
May-97
Aug-97
Nov-97
Feb-98
Time
NO3 (mg/L)

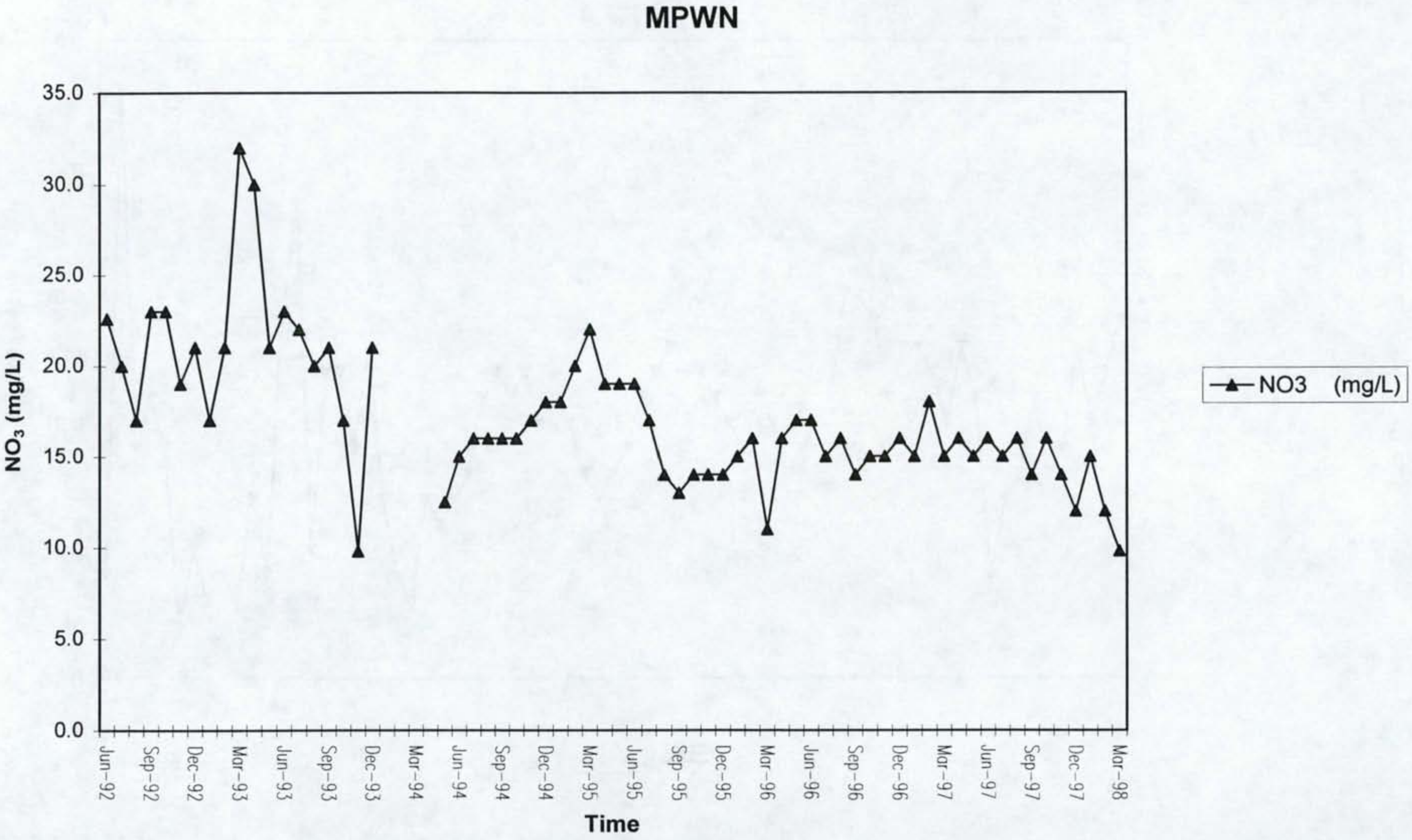

ME1
NO3 (mg/L)
NO$_3$ (mg/L)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
May-92
Aug-92
Nov-92
Feb-93
May-93
Aug-93
Nov-93
Feb-94
May-94
Aug-94
Nov-94
Feb-95
May-95
Aug-95
Nov-95
Feb-96
May-96
Aug-96
Nov-96
Feb-97
May-97
Aug-97
Nov-97
Feb-98
Time

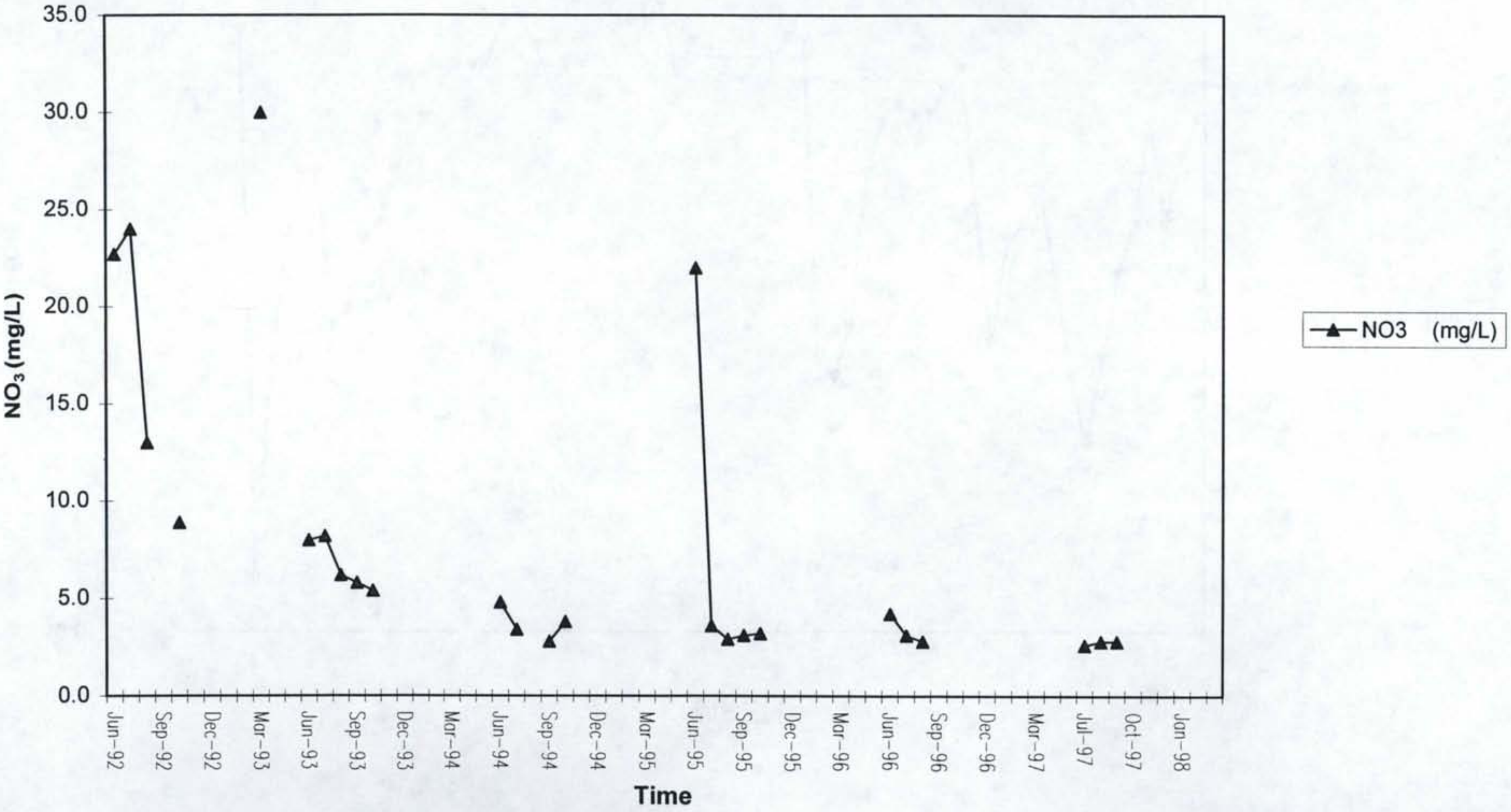

ME2
NO3 (mg/L)
NO$_3$ (mg/L)
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
May-92
Aug-92
Nov-92
Feb-93
May-93
Aug-93
Nov-93
Feb-94
May-94
Aug-94
Nov-94
Feb-95
May-95
Aug-95
Nov-95
Feb-96
May-96
Aug-96
Nov-96
Feb-97
May-97
Aug-97
Nov-97
Feb-98
Time


NO3 (mg/L)
NO₃ (mg/L)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
May-92
Aug-92
Nov-92
Feb-93
May-93
Aug-93
Nov-93
Feb-94
May-94
Aug-94
Nov-94
Feb-95
May-95
Aug-95
Nov-95
Feb-96
May-96
Aug-96
Nov-96
Feb-97
May-97
Aug-97
Nov-97
Feb-98
Time

ME3

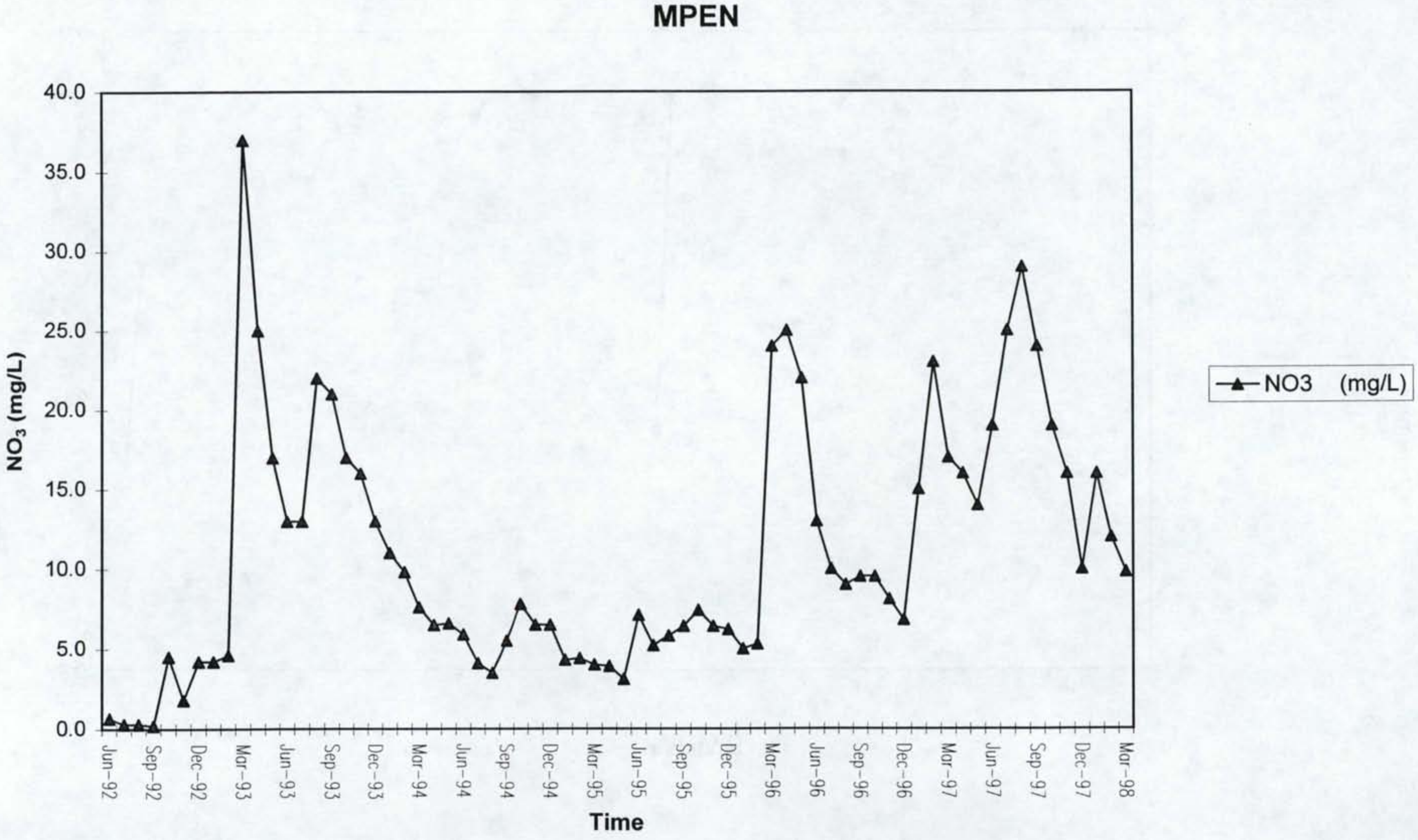

ME4
NO$_3$ (mg/L)
25.0
20.0
15.0
10.0
5.0
0.0
May-92
Aug-92
Nov-92
Feb-93
May-93
Aug-93
Nov-93
Feb-94
May-94
Aug-94
Nov-94
Feb-95
May-95
Aug-95
Nov-95
Feb-96
May-96
Aug-96
Nov-96
Feb-97
May-97
Aug-97
Nov-97
Feb-98
Time
NO3 (mg/L)

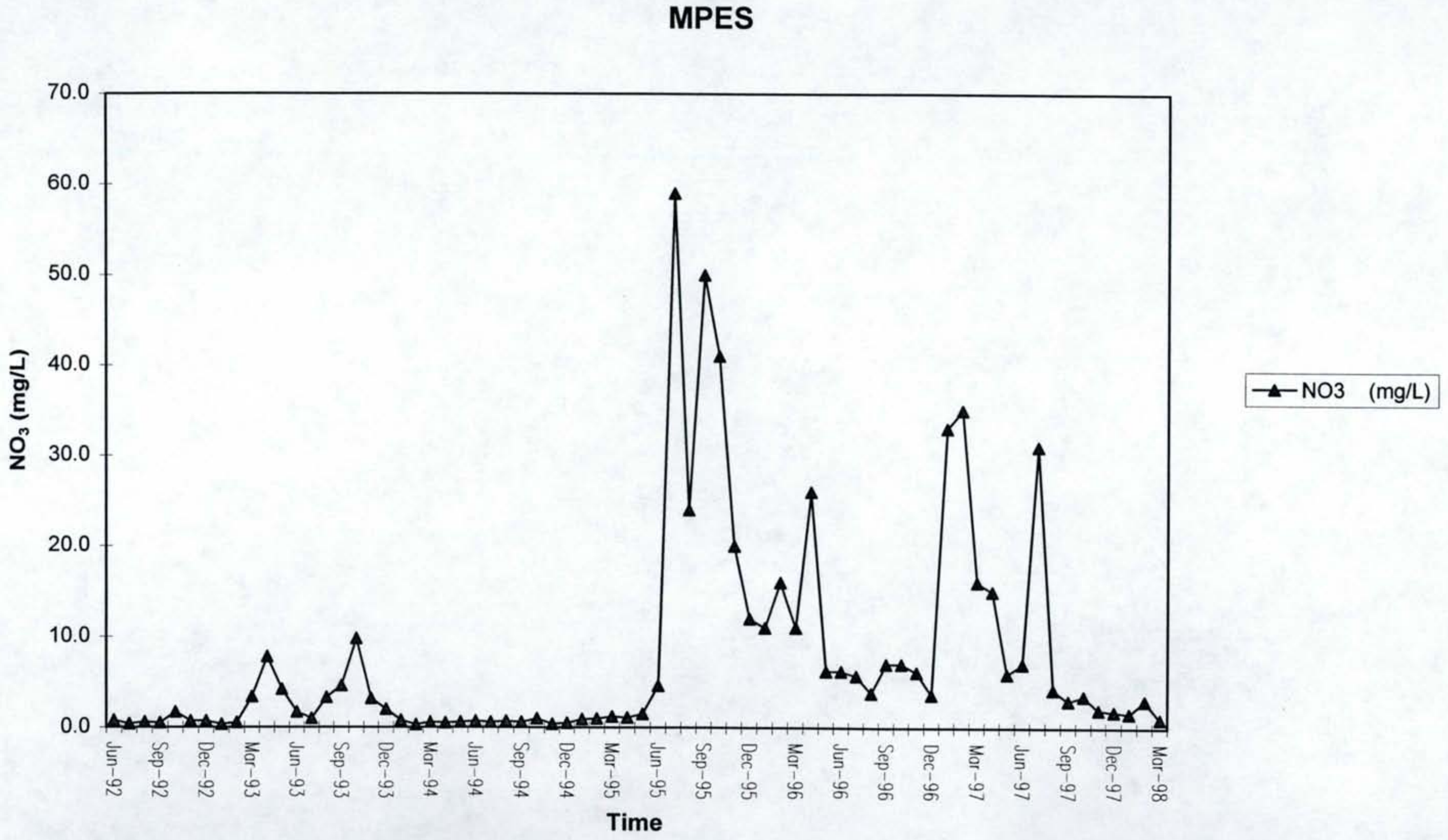

MPWN
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
NO$_3$ (mg/L)
Jun-92
Sep-92
Dec-92
Mar-93
Jun-93
Sep-93
Dec-93
Mar-94
Jun-94
Sep-94
Dec-94
Mar-95
Jun-95
Sep-95
Dec-95
Mar-96
Jun-96
Sep-96
Dec-96
Mar-97
Jun-97
Sep-97
Dec-97
Mar-98
Time
NO3 (mg/L)



MPWS

35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
NO_3 (mg/L)
Jun-92
Sep-92
Dec-92
Mar-93
Jun-93
Sep-93
Dec-93
Mar-94
Jun-94
Sep-94
Dec-94
Mar-95
Jun-95
Sep-95
Dec-95
Mar-96
Jun-96
Sep-96
Dec-96
Mar-97
Jul-97
Oct-97
Jan-98
Time
NO3 (mg/L)


MPEN
NO3 (mg/L)
NO$_3$ (mg/L)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Jun-92
Sep-92
Dec-92
Mar-93
Jun-93
Sep-93
Dec-93
Mar-94
Jun-94
Sep-94
Dec-94
Mar-95
Jun-95
Sep-95
Dec-95
Mar-96
Jun-96
Sep-96
Dec-96
Mar-97
Jun-97
Sep-97
Dec-97
Mar-98
Time


MPES
NO₃ (mg/L)
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Jun-92
Sep-92
Dec-92
Mar-93
Jun-93
Sep-93
Dec-93
Mar-94
Jun-94
Sep-94
Dec-94
Mar-95
Jun-95
Sep-95
Dec-95
Mar-96
Jun-96
Sep-96
Dec-96
Mar-97
Jun-97
Sep-97
Dec-97
Mar-98
Time
NO3 (mg/L)

Appendix D:

Lysimeter and Ground Water Point Sampler Data

1994 Soil Water Nitrate Data
Forgeon Field

Lysimeter	Jul-94 Nitrate (mg/L)	Aug-94 Nitrate (mg/L)	Sep-94 Nitrate (mg/L)	Oct-94 Nitrate (mg/L)
1A	35.0	46.0	39.0	42.0
2B	98.0	85.0	66.0	51.0
3C	8.7	40.0	38.0	83.0
4D	132.0	58.0	56.0	47.0
5E	42.0	82.0	110.0	110.0
7G	31.0	45.0	95.0	230.0
8H	39.0	41.0	52.0	89.0
9I	47.0	51.0	81.0	95.0
10J	47.0	50.0	50.0	54.0
11K	51.0	120.0	250.0	150.0
12L	77.0	105.0	140.0	160.0
13M	79.0	88.0	170.0	230.0
14N	57.0	130.0	160.0	320.0
150	200.0	240.0	160.0	110.0
16P	42.0	44.0	98.0	250.0
17Q	30.0	110.0	132.0	132.0
18R	98.0	110.0	110.0	800.0
19S	17.5	44.0	68.0	72.0
20T	74.0	45.0	75.0	98.0
21U	95.0	96.0	85.0	91.0
22V	19.0	32.0	132.0	65.0
23W	64.0	63.0	13.0	9.5

NS - No Sample
BDL - Below Detection Limit

1995 Soil Water Nitrate Data
Forgeon Field

Lysimeter	Jun-95 Nitrate (mg/L)	Jul-95 Nitrate (mg/L)	Aug-95 Nitrate (mg/L)	Sep-95 Nitrate (mg/L)
1A	68.0	83.0	11.0	1.2
2B	81.0	170.0	180.0	63.0
3C	0.1	2.2	132.0	0.9
4D	100.0	110.0	132.0	26.0
5E	170.0	200.0	78.0	34.0
7G	68.0	74.0	132.0	2.1
8H	0.5	3.4	58.0	1.0
9I	0.2	1.2	30.0	8.9
10J	13.0	15.0	132.0	1.5
11K	0.0	38.0	1000.0	44.0
12L	3.1	31.0	4.2	0.7
13M	63.0	97.0	34.0	4.5
14N	0.5	48.0	132.0	NS
150	0.5	22.0	67.0	52.0
16P	290.0	170.0	30.0	2.4
17Q	19.0	84.0	120.0	13.0
18R	1.2	280.0	370.0	310.0
19S	15.0	62.0	190.0	40.0
20T	0.3	34.0	84.0	7.6
21U	1.6	3.5	16.0	0.4
22V	0.4	11.0	170.0	45.0
23W	132.0	1.0	0.0	0.0
1X	3.7	20.0	9.1	0.4
2X	200.0	110.0	61.0	1.4
3X	61.0	71.0	440.0	3.3
4X	290.0	120.0	68.0	3.7
5X	71.0	69.0	19.0	132.0
6X	96.0	82.0	70.0	0.5
7X	110.0	77.0	132.0	0.6
8X	80.0	71.0	67.0	26.0
9X	64.0	30.0	20.0	3.4
10X	12.0	15.0	21.0	5.6
11X	120.0	170.0	120.0	72.0
12X	49.0	52.0	31.0	14.0
13X	81.0	84.0	75.0	132.0

NS - No Sample

BDL - Below Detection Limit

1996 Soil Water Nitrate Data
Forgeon Field

	May-96	Jun-96	Jul-96	Aug-96	Sep-96
Lysimeter	Nitrate (mg/L)	Nitrate (mg/L)	Nitrate (mg/L)	Nitrate (mg/L)	Nitrate (mg/L)
1A	0.7	0.7	0.0	0.5	0.5
2B	1.1	9.4	4.4	0.9	2.9
3C	NS	NS	NS	NS	NS
4D	NS	NS	NS	NS	NS
5E	NS	NS	NS	NS	0.1
7G	NS	NS	NS	7.2	0.0
8H	NS	NS	NS	0.5	NS
9I	0.1	0.8	0.1	0.6	0.3
10J	0.0	NS	NS	1.4	0.5
11K	NS	73.0	NS	0.2	NS
12L	0.3	1.5	1.8	0.1	0.1
13M	1.1	6.1	5.0	2.3	0.7
14N	NS	NS	NS	NS	NS
150	2.0	3.0	7.3	2.0	0.4
16P	0.5	NS	17.0	NS	NS
17Q	NS	NS	NS	NS	NS
18R	NS	NS	NS	NS	NS
19S	NS	4.6	9.0	7.0	0.1
20T	0.4	3.4	0.0	0.0	0.0
21U	0.0	0.5	3.2	0.2	0.4
22V	0.2	0.2	1.2	0.5	0.0
23W	0.0	BDL	0.0	0.0	0.0
1X	NS	NS	NS	NS	NS
2X	0.0	NS	13.0	NS	0.6
3X	NS	NS	NS	1.2	0.0
4X	NS	NS	NS	NS	NS
5X	0.3	0.2	2.4	4.3	0.0
6X	NS	NS	NS	NS	NS
7X	NS	NS	NS	1.6	0.0
8X	0.2	NS	9.4	0.2	0.0
9X	0.4	0.4	3.4	3.1	1.0
10X	0.0	0.0	0.6	0.9	0.0
11X	2.2	2.2	7.9	14.0	NS
12X	6.0	8.0	5.1	6.3	0.2
13X	NS	NS	NS	NS	NS

NS - No Sample
BDL - Below Detection Limit

1997 Soil Water Nitrate Data
Forgeon Field

Lysimeter	Jun-97 Nitrate (mg/L)	Jul-97 Nitrate (mg/L)	Aug-97 Nitrate (mg/L)
1A	35.0	38.0	77.0
2B	19.0	27.0	84.0
3C	27.0	68.0	NS
4D	34.0	NS	NS
5E	25.0	28.0	79.0
7G	41.0	62.0	97.0
8H	43.0	69.0	77.0
9I	23.0	29.0	69.0
10J	30.0	36.0	67.0
11K	53.0	61.0	88.0
12L	31.0	35.0	44.0
13M	32.0	32.0	38.0
14N	31.0	46.0	59.0
150	38.0	45.0	74.0
16P	22.0	6.2	28.0
17Q	65.0	59.0	82.0
18R	53.0	52.0	94.0
19S	25.0	NS	75.0
20T	27.0	16.0	13.0
21U	13.0	1.6	0.4
22V	38.0	0.1	0.3
23W	BDL	BDL	BDL
1X	32.0	43.0	68.0
2X	30.0	17.0	25.0
3X	25.0	40.0	NS
4X	39.0	22.0	34.0
5X	37.0	2.9	8.3
6X	22.0	38.0	38.0
7X	23.0	10.0	19.0
8X	22.0	NS	24.0
9X	23.0	4.8	16.0
10X	18.0	24.0	22.0
11X	30.0	28.0	22.0
12X	160.0	13.0	13.0
13X	34.0	45.0	55.0

NS - No Sample

BDL - Below Detection Limit

1998 Soil Water Nitrate Data
Forgeon Field

	Jun-98	Jul-98	Aug-98
Lysimeter	Nitrate (mg/L)	Nitrate (mg/L)	Nitrate (mg/L)
1A	81.0	110.0	110.0
2B	94.0	98.0	92.0
3C	100.0	NS	NS
4D	41.0	62.0	NS
5E	61.0	91.0	87.0
7G	54.0	77.0	74.0
8H	88.0	76.0	49.0
9I	45.0	68.0	62.0
10J	48.0	54.0	61.0
11K	NS	120.0	NS
12L	100.0	110.0	100.0
13M	100.0	110.0	99.0
14N	59.0	75.0	70.0
150	100.0	85.0	52.0
16P	74.0	72.0	48.0
17Q	NS	200.0	180.0
18R	130.0	110.0	4.0
19S	77.0	130.0	110.0
20T	70.0	110.0	110.0
21U	46.0	49.0	57.0
22V	120.0	140.0	120.0
23W	NS	BDL	BDL
1X	81.0	85.0	NS
2X	43.0	54.0	52.0
3X	79.0	74.0	64.0
4X	73.0	80.0	77.0
5X	54.0	70.0	70.0
6X	NS	NS	NS
7X	45.0	50.0	69.0
8X	29.0	36.0	37.0
9X	21.0	35.0	49.0
10X	37.0	44.0	48.0
11X	37.0	49.0	44.0
12X	50.0	58.0	55.0
13X	110.0	NS	NS

NS - No Sample

BDL - Below Detection Limit

1995 Soil Water Nitrate Data
Moncur Field

Lysimeter	Jun-95 Nitrate (mg/L)	Jul-95 Nitrate (mg/L)	Aug-95 Nitrate (mg/L)
1Z	170.0	290.0	NS
2Z	610.0	640.0	300.0
3Z	580.0	210.0	NS
4Z	220.0	170.0	170.0
5Z	81.0	150.0	NS
6Z	110.0	140.0	91.0
7Z	NS	6.0	72.0
8Z	78.0	130.0	100.0
9Z	NS	230.0	NS
10Z	76.0	240.0	450.0
11Z	62.0	97.0	77.0
12Z	95.0	94.0	130.0
13Z	77.0	200.0	190.0
14Z	58.0	16.0	110.0
15Z	380.0	230.0	170.0
16Z	64.0	160.0	160.0
17Z	180.0	330.0	190.0
18Z	NS	NS	NS
19Z	140.0	180.0	130.0
20Z	77.0	300.0	320.0
21Z	80.0	110.0	270.0
22Z	230.0	330.0	200.0
23Z	310.0	NS	250.0
24Z	73.0	NS	370.0
25Z	130.0	NS	290.0

NS - No Sample
BDL - Below Detection Limit

1996 Soil Water Nitrate Data
Moncur Field

Lysimeter	May-96 Nitrate (mg/L)	Jun-96 Nitrate (mg/L)	Jul-96 Nitrate (mg/L)
1Z	66.0	NS	NS
2Z	120.0	NS	6.2
3Z	120.0	0.6	0.7
4Z	140.0	29.0	4.0
5Z	100.0	15.0	6.8
6Z	62.0	1.9	1.2
7Z	NS	NS	NS
8Z	68.0	NS	8.2
9Z	84.0	16.0	13.0
10Z	110.0	51.0	20.0
11Z	NS	NS	61.0
12Z	70.0	29.0	6.1
13Z	220.0	140.0	100.0
14Z	130.0	52.0	28.0
15Z	58.0	31.0	8.1
16Z	79.0	35.0	12.0
17Z	280.0	210.0	99.0
18Z	59.0	NS	NS
19Z	100.0	15.0	0.4
20Z	NS	NS	NS
21Z	150.0	NS	NS
22Z	150.0	130.0	120.0
23Z	150.0	NS	37.0
24Z	180.0	NS	11.0
25Z	NS	NS	NS

NS - No Sample
BDL - Below Detection Limit

1997 Soil Water Nitrate Data
Moncur Field

Lysimeter	Jun-97 Nitrate (mg/L)	Jul-97 Nitrate (mg/L)	Aug-97 Nitrate (mg/L)
1Z	NS	NS	NS
2Z	NS	170.0	NS
3Z	62.0	NS	44.0
4Z	40.0	27.0	1.2
5Z	73.0	44.0	0.4
6Z	NS	NS	NS
7Z	NS	NS	NS
8Z	160.0	60.0	16.0
9Z	NS	79.0	1.9
10Z	NS	NS	NS
11Z	NS	NS	0.1
12Z	170.0	170.0	NS
13Z	NS	76.0	19.0
14Z	NS	NS	NS
15Z	97.0	46.0	1.2
16Z	NS	95.0	NS
17Z	77.0	160.0	40.0
18Z	110.0	99.0	74.0
19Z	NS	96.0	NS
20Z	NS	16.0	NS
21Z	NS	NS	NS
22Z	190.0	160.0	160.0
23Z	130.0	53.0	27.0
24Z	170.0	120.0	60.0
25Z	NS	68.0	NS

NS - No Sample
BDL - Below Detection Limit

1995 Ground Water Point Sampler Data
Forgeon Field

PS ID	Aug-95 Nitrate (mg/L)	Jul-95 Nitrate (mg/L)
1AAS	15.0	9.9
2BAS	17.0	13.0
3CAS	7.8	25.0
4DAS	45.0	22.0
5EAS	47.0	21.0
7GAS	44.0	25.0
8HAS	69.0	24.0
9IAS	18.0	83.0
10JAS	57.0	39.0
11KAS	45.0	37.0
12LAS	29.0	32.0
13MAS	26.0	34.0
14NAS	55.0	57.0
15OAS	39.0	31.0
16PAS	50.0	26.0
17QAS	41.0	28.0
18RAS	62.0	40.0
19SAS	41.0	55.0
20TAS	56.0	48.0
21UAS	56.0	49.0
22VAS	29.0	38.0
23WAS	61.0	36.0
1XAS	87.0	29.0
2XAS	38.0	28.0
3XAS	25.0	27.0
4XAS	9.5	12.0
5XAS	57.0	86.0
6XAS	42.0	31.0
7XAS	53.0	42.0
8XAS	35.0	49.0
9XAS	13.0	31.0
10XAS	19.0	5.9
11XAS	48.0	30.0
12XAS	21.0	42.0
13XAS	48.0	37.0

NS - No Sample
BDL - Below Detection Limit

1996 Ground Water Point Sampler Data
Forgeon Field

PS ID	May-96 Nitrate (mg/L)	Jun-96 Nitrate (mg/L)	Jul-96 Nitrate (mg/L)	Aug-96 Nitrate (mg/L)	Sep-96 Nitrate (mg/L)
1AAS	13.0	13.0	17.0	16.0	21.0
2BAS	16.0	18.0	18.0	29.0	28.0
3CAS	6.1	9.5	13.0	17.0	22.0
4DAS	13.0	8.2	7.9	10.0	8.4
5EAS	16.0	16.0	12.0	9.7	6.7
7GAS	11.0	13.0	5.5	12.0	9.5
8HAS	25.0	17.0	20.0	15.0	9.7
9IAS	11.0	12.0	15.0	13.0	7.0
10JAS	46.0	37.0	32.0	32.0	27.0
11KAS	28.0	27.0	24.0	23.0	21.0
12LAS	19.0	9.2	9.9	13.0	12.0
13MAS	22.0	7.3	7.1	9.2	7.9
14NAS	41.0	31.0	33.0	33.0	32.0
15OAS	16.0	16.0	15.0	14.0	19.0
16PAS	40.0	35.0	35.0	39.0	41.0
17QAS	NS	37.0	30.0	29.0	22.0
18RAS	NS	29.0	27.0	18.0	12.0
19SAS	32.0	15.0	25.0	NS	9.4
20TAS	21.0	29.0	21.0	NS	16.0
21UAS	27.0	30.0	5.0	4.2	5.3
22VAS	39.0	38.0	41.0	52.0	28.0
23WAS	37.0	39.0	24.0	33.0	33.0
1XAS	33.0	14.0	21.0	26.0	23.0
2XAS	26.0	34.0	36.0	37.0	10.0
3XAS	7.1	8.9	4.4	12.0	9.3
4XAS	43.0	47.0	43.0	43.0	32.0
5XAS	26.0	23.0	22.0	26.0	34.0
6XAS	30.0	38.0	34.0	30.0	21.0
7XAS	37.0	37.0	27.0	28.0	31.0
8XAS	27.0	32.0	34.0	29.0	26.0
9XAS	16.0	13.0	18.0	24.0	24.0
10XAS	4.8	7.0	18.0	26.0	9.3
11XAS	33.0	32.0	32.0	24.0	22.0
12XAS	26.0	21.0	21.0	22.0	20.0
13XAS	NS	20.0	18.0	14.0	14.0

NS - No Sample
BDL - Below Detection Limit

1997 Ground Water Point Sampler Data
Forgeon Field

	Jun-97	Jul-97	Aug-97
PS ID	Nitrate (mg/L)	Nitrate (mg/L)	Nitrate (mg/L)
1AAS	18.0	22.0	21.0
2BAS	20.0	21.0	20.0
3CAS	11.0	8.5	44.0
4DAS	5.1	7.6	18.0
5EAS	8.9	7.7	52.0
7GAS	8.7	6.4	9.5
8HAS	7.6	11.0	120.0
9IAS	11.0	14.0	31.0
10JAS	14.0	16.0	77.0
11KAS	14.0	13.0	71.0
12LAS	14.0	12.0	13.0
13MAS	11.0	11.0	12.0
14NAS	20.0	20.0	28.0
15OAS	14.0	12.0	18.0
16PAS	29.0	26.0	20.0
17QAS	18.0	12.0	7.7
18RAS	17.0	16.0	14.0
19SAS	14.0	12.0	15.0
20TAS	18.0	14.0	10.0
21UAS	46.0	11.0	34.0
22VAS	58.0	1.8	3.6
23WAS	23.0	64.0	0.6
1XAS	14.0	14.0	25.0
2XAS	30.0	28.0	28.0
3XAS	6.8	8.0	18.0
4XAS	28.0	27.0	32.0
5XAS	17.0	21.0	18.0
6XAS	22.0	17.0	20.0
7XAS	19.0	16.0	19.0
8XAS	30.0	20.0	19.0
9XAS	29.0	28.0	27.0
10XAS	28.0	33.0	31.0
11XAS	12.0	8.5	11.0
12XAS	14.0	14.0	13.0
13XAS	13.0	14.0	25.0
FW1AS	NS	NS	21.0

NS - No Sample
BDL - Below Detection Limit

1998 Ground Water Point Sampler Data
Forgeon Field

PS ID	Jun-98 Nitrate (mg/L)	Jul-98 Nitrate (mg/L)	Aug-98 Nitrate (mg/L)	Sep-98 Nitrate (mg/L)	Oct-98 Nitrate (mg/L)
1AAS	37.0	38.0	44.0	76.0	37.0
2BAS	93.0	110.0	86.0	45.0	45.0
3CAS	40.0	67.0	68.0	41.0	62.0
4DAS	49.0	34.0	35.0	31.0	28.0
5EAS	26.0	36.0	27.0	16.0	20.0
7GAS	NS	NS	NS	30.0	26.0
8HAS	34.0	47.0	43.0	NS	NS
9IAS	28.0	32.0	29.0	25.0	29.0
10JAS	58.0	67.0	63.0	72.0	59.0
11KAS	37.0	37.0	38.0	39.0	58.0
12LAS	25.0	37.0	33.0	45.0	43.0
13MAS	22.0	35.0	49.0	23.0	46.0
14NAS	44.0	68.0	70.0	78.0	59.0
15OAS	63.0	56.0	56.0	57.0	52.0
16PAS	31.0	30.0	35.0	29.0	45.0
17QAS	15.0	18.0	41.0	37.0	28.0
18RAS	15.0	22.0	47.0	86.0	NS
19SAS	14.0	17.0	26.0	26.0	25.0
20TAS	13.0	22.0	31.0	22.0	26.0
21UAS	20.0	19.0	NS	NS	NS
22VAS	13.0	20.0	24.0	20.0	20.0
23WAS	12.0	18.0	12.0	18.0	18.0
1XAS	57.0	64.0	NS	50.0	49.0
2XAS	31.0	31.0	30.0	36.0	41.0
3XAS	41.0	49.0	57.0	45.0	29.0
4XAS	38.0	34.0	27.0	36.0	42.0
5XAS	23.0	21.0	20.0	38.0	27.0
6XAS	22.0	22.0	26.0	27.0	23.0
7XAS	23.0	27.0	27.0	32.0	27.0
8XAS	23.0	22.0	26.0	24.0	31.0
9XAS	29.0	27.0	28.0	38.0	40.0
10XAS	24.0	26.0	26.0	31.0	39.0
11XAS	18.0	21.0	23.0	20.0	28.0
12XAS	15.0	17.0	21.0	24.0	16.0
13XAS	32.0	38.0	45.0	61.0	63.0
FW1AS	64.0	59.0	61.0	NS	51.0

NS - No Sample

BDL - Below Detection Limit

Appendix E:

Recording Tipping Bucket Rain Gauge Data

Forgeon Rain Gauge Data
1/100 inches

Wells Date	FW1	FW2	FW3	FW4	FE1	FE2	FE3	FE4
05/27/97	14	12	12	187	12	11	1	145
06/03/97	31	29	28	207	30	28	3	166
06/16/97	36	66	35	43	36	35	1	41
06/22/97	76	75	72	85	109	108	2	85
07/03/97	166	264	408	241	215	250	3	217
07/17/97	263	288	195	185	185	170	1	110
07/22/97	288	0	0	0	123	0	0	0
07/31/97	326	174	29	31	212	284	1	37
08/05/97	100	13	13	11	102	36	0	15
08/08/97	6	228	0	1	0	74	0	0
08/25/97	481	501	38	41	235	421	2	45
07/22/98	342	372	279*	232*	307	307	517	302*
8/12/98	447	963	499	768	427	987	392	975

* Upon discovery, holes in rain gauge cup were repaired at time of data collection.

Moncur Rain Gauge Data
1/100 inches

Wells Date	MW1	MW2	MW3	MW4	ME1	ME2	ME3	ME4
05/27/97	17	20	18	15	21	23	21	24
06/03/97	109	175	130	112	261	374	328	236
06/16/97	61	74	77	65	106	113	94	86
06/22/97	44	51	97	67	203	259	224	281
07/03/97	134	162	216	196	457	515	503	488
07/17/97	211	216	262	199	189	50	246	280
07/22/97	193	191	114	150	265	625	242	274
08/05/97	279	275	187	305	67	206	56	76
08/08/97	0	2	6	2	23	7	27	22
08/25/97	31	32	31	34	121	251	91	94

Table E-1. Rain gauge data for the Forgeon and Moncur test fields.