AGRICULTURAL CHEMICAL TRANSPORT TO SHALLOW GROUNDWATER IN A TILE-DRAINED, FLOOD-IRRIGATED FIELD

by

TRACY L. ROTH

Submitted in Partial Fulfillment of the Requirements for the
Degree of Master of Science in Hydrology

New Mexico Institute of Mining and Technology
Socorro, NM
December, 1995

ABSTRACT

The Las Nutrias Groundwater Project was initiated in 1991 to address the impacts to shallow groundwater quality associated with agricultural practices typical of New Mexico. The field site is located on a commercial farm in the middle Rio Grande Valley and is characterized by alluvial floodplain soils with moderate drainage capabilities. A tile drain system is installed 4 - 6 ft below ground surface. Data collected over at least one growing season from this system is being used to validate a 2-dimensional, variably saturated water flow and solute transport model. The current study focuses on the mass loss of nitrogen fertilizers to the shallow groundwater as well as the development of a conceptual model to describe nutrient transport in the unsaturated zone.

In order to achieve the above objectives, extensive soil samples and tile drain groundwater samples were taken during a time period from August 1993 to May 1995. The soil samples were taken prior to the 1994 and 1995 growing seasons and were located along a transect going 38 m North and South from an instrumented tile drain line at varying depths down to the capillary fringe. These samples were analyzed for nitrate-nitrogen concentration to determine the mass loss of nitrate-nitrogen from the soil profile during the 1994 growing season. Tile drain line water samples were taken to accommodate water input events; water samples were also taken approximately twice per month from monitoring wells and piezometers located around the field site.

The soil sampling results revealed that an excessive amount (164 mg/l mean nitrate-nitrogen concentration) of soil water nitrate-nitrogen existed within the soil profile prior to the 1994 growing season. Twenty percent of this amount existed just prior to the 1995 growing season. During the 1994 irrigation season (1 March - 31 October), water input events caused rapid transport of nitrate-nitrogen to the tile drain line, indicating the occurrence of preferential flow mechanisms. Electrical conductivity and chloride concentration measurements showed a similar response. Many times, the EPA maximum contaminant level of 10 mg/l nitrate-nitrogen was exceeded. From the tile flow and nitrate concentration measurements and from estimates of evapotranspiration, a nitrate-nitrogen mass loss from the soil to the shallow groundwater of approximately 30 - 50% was estimated to have occurred during the 1994 growing season.

TABLE OF CONTENTS

PAGE

ABSTRACT i
TABLE OF CONTENTS ii
LIST OF FIGURES v
LIST OF TABLES vii
ACKNOWLEDGEMENTS viii

1. INTRODUCTION 1

2. EXPERIMENTAL SITE 6
  2.1 Location and Hydrogeology 6
  2.2 Field Description and Instrumentation 8
  2.3 Agricultural Management Practices 13
    2.3.1 Crop Schedule 13
    2.3.2 Fertilization 13
    2.3.3 Irrigation Water Applications 17

3. METHODS 19
  3.1 Sampling and Analytical Methods 19
    3.1.1 Analytical Methods 19
    3.1.2 Sample Collection and Preparation 21

4. RESULTS 25
  4.1 Soil Water Chemistry 25
    4.1.1 NO_3-N 25
    4.1.2 Soil Moisture Content 29
    4.1.3 Mass of NO3-N in the Soil Profile 29
  4.2 Irrigation Water Chemistry 33
  4.3 Groundwater Chemistry 33
    4.3.1 Monitoring Well and Piezometer Chemistry 33
      4.3.1.1 NO_3-N 33
      4.3.1.2 Conductivity 35
    4.3.2 Tile Drain Chemistry 37
      4.3.2.1 NO_3-N 37
      4.3.2.2 Conductivity 46
      4.3.2.3 Chloride 54

TABLE OF CONTENTS (CONT'D)

PAGE

4.4 Mass NO_3-N Lost to Shallow Groundwater 54
  4.4.1 Distribution of Water Inputs and Outputs 54
  4.4.2 NO_3-N Mass Losses 64

5. DISCUSSION 67
  5.1 Data Analysis 67
    5.1.1 Soils 67
    5.1.2 Wells and Piezometers 68
    5.1.3 Tile Drains 69
  5.2 Conceptual Model of NO_3-N Transport 76

6. CONCLUSIONS 77
7. RECOMMENDATIONS FOR FUTURE WORK 79
8. REFERENCES 81
9. APPENDICIES 84
  9.1 Soil Water 84
    9.1.1 NO_3-N Concentration Data 84
    9.1.2 NO_3-N Concentration Descriptive Statistics 86
    9.1.3 % Soil Moisture Data 89
    9.1.4 % Soil Moisture Descriptive Statistics 91
    9.1.5 NO_3-N Variograms 92
  9.2 Irrigation Water Chemistry Data 101
  9.3 Wells and Piezometers 102
    9.3.1 Observation Wells 102
      9.3.1.1 NO_3-N and Conductivity Data 102
      9.3.1.2 NO_3-N and Conductivity Descriptive Statistics 104
      9.3.1.3 NO_3-N Contour Maps and 3-D Surface Plots 106
      9.3.1.4 Conductivity Contour Maps and 3-D Surface Plots 123
    9.3.2 Piezometer Nests 136
      9.3.2.1 NO_3-N Data 136
      9.3.2.2 NO_3-N Concentration Gradient Graphs 137

TABLE OF CONTENTS (CONT'D)

PAGE

9.4 Tile Drains 145
  9.4.1 East and West Manholes and Riverside Drain Chemistry Data 145
9.5 Calculations relating to mass NO_3-N in soil profile 156
  9.5.1 Calculation of Volumetric Water Content from Bulk Density Measurements 156
  9.5.2 Calculations of the Mass NO_3-N/acre in the Soil Profile 162
9.6 Calculations relating to water distribution and mass loss 163
  9.6.1 Water Distributions 163
  9.6.2 Mass NO_3-N Lost Due to Recharge 166

LIST OF FIGURES

Figure Page

1. Las Nutrias fieldsite location 7

2. Geologic cross-section of the Albuquerque Basin 8

3. Plan view of Las Nutrias fieldsite instrumentation 10

4. Manhole schematic 12

5. Diagram of circular wier 14

6. Soil series map showing soil sampling transect location 22

7. Mean soil water NO_3-N concentrations 26

8. Mean percent soil gravimetric water content 30

9. Mean NO_3-N concentration in the observation wells 34

10. Mean electrical conductivity in the observation wells 36

11. 1994 NO_3-N concentrations in the upgradient manhole 38

12. 1994 NO_3-N concentrations in the downgradient manhole 39

13. NO_3-N response in the downgradient manhole for a single irrigation 41

14. 1994 NO_3-N concentrations in the Riverside Drain 43

15. 1995 NO_3-N concentrations in the upgradient manhole 44

16. 1995 NO_3-N concentrations in the downgradient manhole 45

LIST OF FIGURES (continued)

Figure Page

17. 1995 NO_3-N concentrations in the Riverside Drain 47

18. 1994 electrical conductivity in the upgradient manhole 48

19. 1994 electrical conductivity in the downgradient manhole 49

20. 1995 electrical conductivity in the upgradient manhole 50

21. 1995 electrical conductivity in the downgradient manhole 51

22. 1994 electrical conductivity in the the Riverside Drain 52

23. 1995 electrical conductivity in the the Riverside Drain 53

24. 1995 chloride concentrations in the the downgradient manhole 55

25. 1995 volumetric flow rate in the downgradient manhole 59

LIST OF TABLES

Table Page

1. Crop rotation schedule 15

2. Fertilization schedule 16

3. Center bench Irrigation dates and amounts 18

4. Precipitation measurements in 1994 and 1995 20

5. Summary of NO_3-N mass in the soil profile of the center bench 32

6. Mean hydraulic head and hydraulic gradients for the center bench 57

7. 1994 water balance for the center bench 58

8. Summary of center bench water distributions and mass of NO3-N lost to the groundwater system 66

ACKNOWLEDGEMENTS

The Las Nutrias Groundwater Project receives most of its support through the United States Department of Agriculture - Cooperative State Research Service, Special Water Quality Grant No. 92-34214-7417 as awarded to the New Mexico Institute of Mining and Technology. The project is also thankful to the landowner of the field site.

Earning a Masters Degree in Hydrology at New Mexico Tech has been the biggest challenge in my life so far. I would like to thank my undergraduate professors, Malcolm Hill, Richard Bailey, and Bill Newman for getting me here. I would also like to thank my graduate advisors, Drs. Robert Bowman, Jan Hendrickx, and Binayak Mohanty for their time, effort, and support during the last two and a half years. I am also grateful to Edith Montoya and Liz Whittworth for their words of inspiration, their patience, and assistance. My research partners, Jeff Chaves and Robert Reedy, have been instrumental in the completion of my degree, and I cannot thank them enough. Most of all, I could not have done any of this without the help of Chris Rossacker, Will Holoman, and Leo Porta, our lab/field assistants.

A very special thanks goes to my friends and family for putting up with these years of insanity - never being there and being stressed when I was. Deb, Trucker, Big Al, Ingrid, Sam, Monty, and all my other fellow hydrology students - thanks for everything. Mom, I love you for being my biggest fan!!

This Masters Degree and Thesis is dedicated to the memory of my father, Robert Louis Roth, and my grandfather, Leslie Ahlen. And let's not forget THE BOX!!!

1.0 INTRODUCTION

The rapid expansion of the Albuquerque region has given rise to many issues pertaining to the availability of groundwater. Since more than 88% of the total population of New Mexico depends on groundwater for drinking water, groundwater quality has also become important. More than one third of the total water annually withdrawn for all uses in New Mexico is groundwater. Approximately 80% of this water is used for irrigating agricultural fields (Anderholm et al, 1995).

For over 50 years, agricultural productivity in the United States has been significantly enhanced by chemical fertilizer and pesticide use. Hundreds of millions of pounds of chemicals and nutrients are applied annually to agricultural soils throughout the U. S. Unfortunately, many of these constituents and/or their by-products can leach below the root zone and be rapidly transported to shallow groundwater, eventually interacting with surface waters. Since agricultural chemicals have been detected in ground and surface waters throughout the U.S., and since the effects of human exposure to even trace amounts of pollutants are still relatively unknown, the usual course of action by government agencies has been to ban or severely limit the use of fertilizers and other chemicals in broad regions. While this helps to protect precious ground and surface water reserves, negative impacts to the economical sustainability of agriculture are evident.

In agricultural fields, nitrogen fertilizers are used to enhance crop production. Most crops need a rather large nitrogen supplement for optimal growth, however, nitrogen can undergo several conversions to other forms which may or may not be used by most crops. Oxidation of nitrogen to nitrate is of particular interest in terms of groundwater contamination, as it is a very mobile anion. Concentrations of nitrate in excess of the state and federal regulations (10 mg/l nitrate as nitrogen, NO_3-N) can cause methehemoglonemia in infants, a disease which depletes the oxygen content in the blood supply. Nitrate can also degrade surface water quality by causing excessive growth of algae.

As of late 1989, only 0.4% of New Mexico's public water supply systems exceeded the state and federal regulations for nitrate concentration (Anderholm et al, 1995). Livestock waste and/or sewage disposal systems are suspected of causing this problem. Although these are considered to be non-point sources of pollution, they are much more localized and isolated than agricultural areas, where hundreds of thousands of pounds of nitrogen fertilizers are applied annually to broad regions. Yet, in 1990 the New Mexico Water Quality Control Commission stated that "available data are inadequate to determine whether or not agricultural chemicals and practices are also causing a problem". They also said that "A comprehensive survey of the State's groundwater quality has not been done so no quantitative statement concerning groundwater quality can be made". In 1986, the National Water Quality Assessment (NAWQA) program began when Congress appropriated funds to the U.S. Geological Survey (USGS) to address a wide range of water quality issues. By 1991, after several pilot studies were near completion, the USGS implemented a full-scale NAWQA program in the Rio Grande Valley study unit, of which 83% is located in New Mexico. To date, the preliminary investigations have revealed that there is a relatively small contribution to groundwater contamination from agricultural chemicals. However, the collected data is based on only two sampling events - once during the irrigation season where groundwater flow is at a high, and once during the lower flow, non-irrigated season. Such random sampling most certainly obscures variations in nitrate concentrations that may exist. Since New Mexico still lacks a more detailed database of information pertaining to the assessment of agricultural impacts to groundwater, a significant amount of data is needed to determine if a problem with agricultural nutrients and chemicals does, in fact, exist. This will give protection to New Mexican farmers if and when regulatory agencies ban the use of fertilizers and pesticides which significantly enhance crop productivity, and may not necessarily exist in the underlying groundwaters at dangerous levels.

In 1991, the Las Nutrias Groundwater project was initiated in order to provide a detailed, mechanistic and quantitative description of the impacts irrigation return flows have on New Mexico groundwater quality. Being the first study of this kind in New Mexico, the main focus of this project has been to investigate the mechanisms by which agricultural chemicals are transported to shallow groundwater. One way the project proposes to accomplish this is by validating a variably saturated water flow and solute transport model using field data collected over at least one growing season. However, numerical modeling of the transport of solutes in unsaturated, structured field soils has proven to be a difficult task. Groundwater and solutes travelling through the vadose zone are subject to a variety of chemical and biological reactions, as well as to deviations from ideal, Darcian-type flow behavior. Previous studies have shown that modeling structured field soils as one porous medium is also a complication, since groundwater and solutes usually flow preferentially through soil cracks, earthworm burrows, root channels, or other pathways (Thomas and Phillips, 1979; Beven and Germann, 1982; Bowman and Rice, 1986; Jury et al., 1986; Butters and Jury, 1989). Such preferential flow is responsible for earlier breakthrough of solutes than as predicted by the classical, Darcian behavior of the unsaturated zone.

To adequately characterize the many aquifer properties needed to model such behavior, hundreds of point measurements of soil and groundwater characteristics would have to be made. One valuable tool that can be used to avoid such a costly and time-consuming situation and still assess solute transport in the unsaturated zone is the subsurface tile drainage system. These systems are commonly found in areas with naturally occurring high water tables. Tile drains lower the water table, which decreases the height of the capillary rise and hence the amount of soil water available for loss through evapotranspiration. This in turn prevents salt accumulation within the soil profile, which is detrimental to crop production. Since tile drainage systems collect leachate from a large area, they tend to integrate the effects of spatial variability in soil properties that create uneven distributions of soil water nitrate concentrations. Tile drains offer the opportunity to sample a much larger portion of the aquifer at a single measurement point.

Studies of the movement of agricultural chemicals have been done on experimental plots with tile drainage systems where the researchers had absolute control over nutrient, chemical, and water inputs (Baker and Johnson 1981; Kladivko et al. 1991; Owens et al. 1994; Vinten et al. 1994). These studies have been done in areas of the country with different geological and climatological settings than are found in New Mexico. The farming management practices in these areas are also quite different. The site where our research was conducted, (the Las Nutrias Groundwater Project), is specific to New Mexico in that we have utilized an operating commercial farm in the Rio Grande Valley for our investigation. This means that what we may lose in accuracy by not acquiring the resolution of a controlled experiment, we gain in validity of the results since the data is collected in a real-life situation in New Mexico, where crop, chemical, and water management practices are representative of what is actually observed in this area of the country.

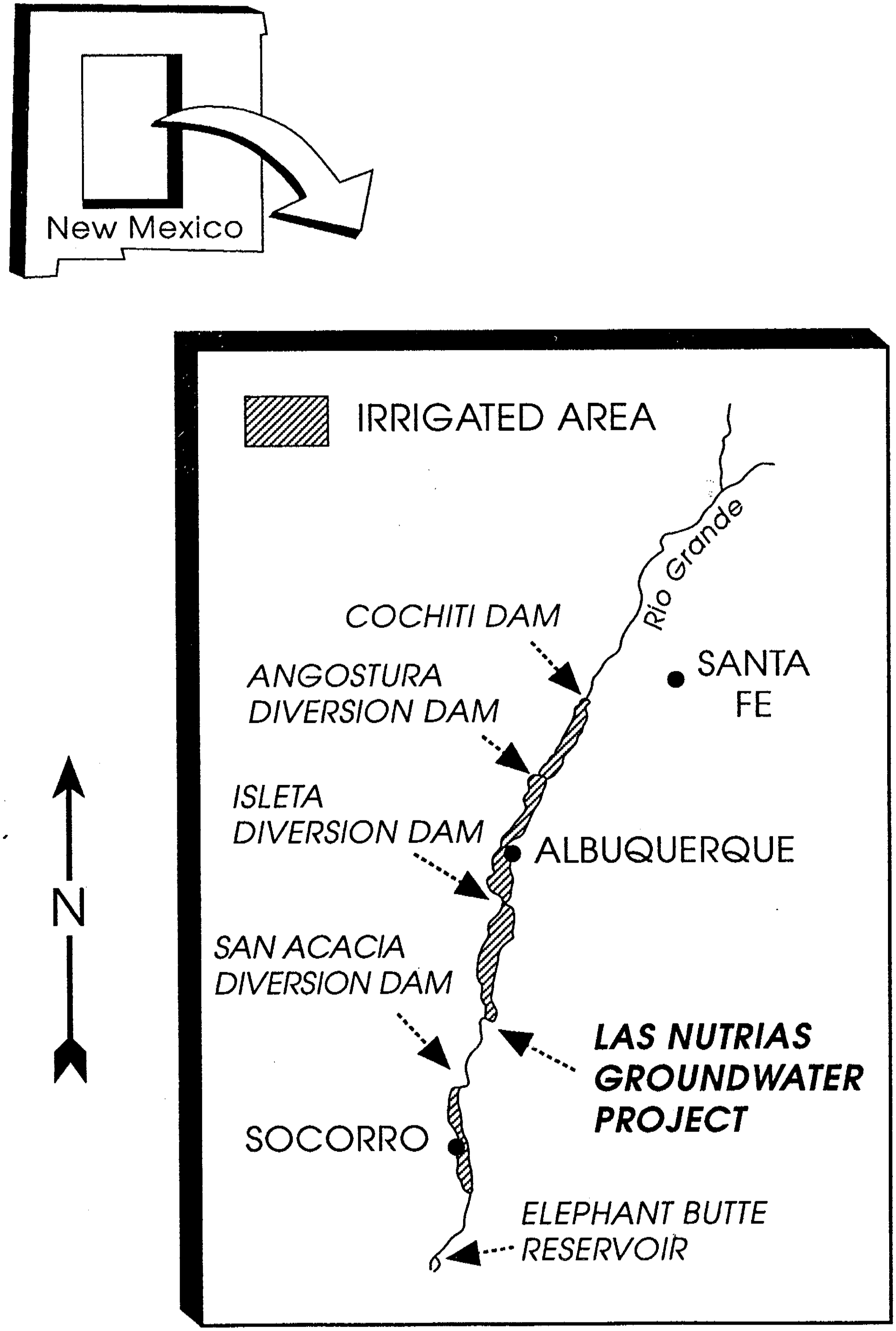
The current study focuses on the effects nitrogen fertilizers have on shallow groundwater quality. The extent to which nitrogen leaching to groundwater occurs at the Las Nutrias field site was determined by analyzing tile drain water chemistry, soil water chemistry, and background chemistry of the local and regional groundwater. This information was then used to develop a conceptual model of solute transport in unsaturated, agricultural soils, which can serve as a guide in the more complex numerical modeling efforts.

The extent to which the observations and findings of this study could be applied to describe the impacts to shallow groundwater associated with agriculture to the Rio Grande Valley as a whole. This is because the local and regional hydrogeology all along the valley is similar, the soil types are similar, and many New Mexico farmers perform similar chemical, nutrient, and water input practices. The information obtained by the continuous monitoring of irrigation return flows at the Las Nutrias field site can thus be a useful tool for regulatory agencies in the assessment of the agricultural impacts to the degradation of New Mexico groundwater quality.

2.0 EXPERIMENTAL SITE

2.1 Location and Hydrogeology

The Las Nutrias Groundwater Project site is located on an operating commercial farm at the southern end of the Albuquerque Basin, approximately 35 mi south of Albuquerque in Socorro County, New Mexico (Figure 1). The basin lies within the Rio Grande rift, a series of north-south trending half grabens oriented parallel to the course of the Rio Grande. A cross-sectional view of the basin is shown in Figure 2. Although these structural features of the basin complicate the regional groundwater flow patterns, overall recharge to the site occurs as inflow from the runoff of the eastern mountain uplifts and as drainage of the valley basins from the north. The climate is


New Mexico
▨ IRRIGATED AREA
Rio Grande
COCHITI DAM
SANTA FE
ANGOSTURA DIVERSION DAM
ISLETA DIVERSION DAM
ALBUQUERQUE
N
SAN ACACIA DIVERSION DAM
LAS NUTRIAS GROUNDWATER PROJECT
SOCORRO
ELEPHANT BUTTE RESERVOIR

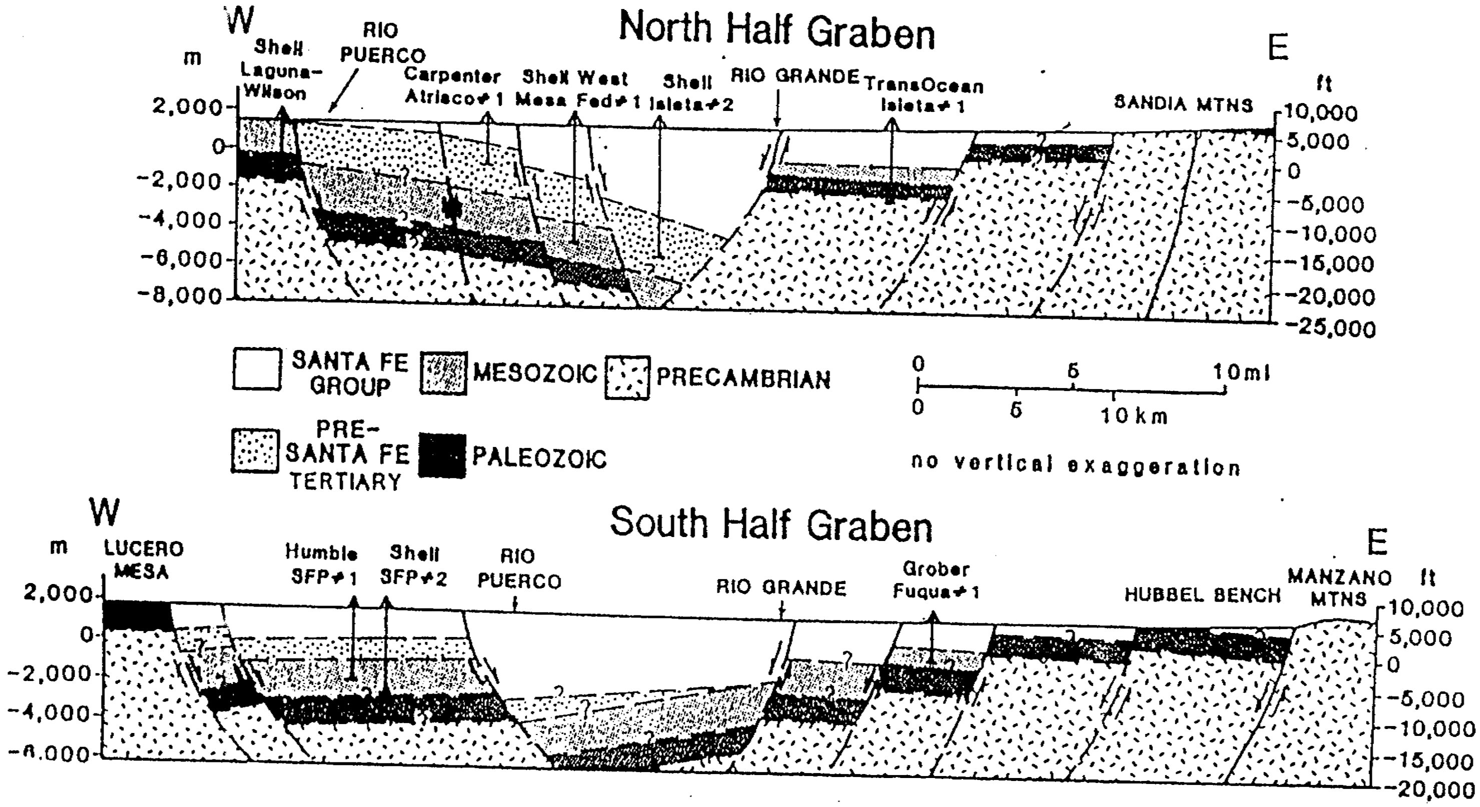


Figure 2. Geologic cross-section of the Albuquerque Basin.

arid to semiarid with average annual rainfall ranging from 210 - 370 mm, depending upon elevation (Roybal, 1991).

A major portion of the Rio Grande Valley is used for agricultural purposes. Flood-irrigated fields are located all along the valley and surrounding the Las Nutrias field site. Several dairies with cattle feedlots are also located nearby.

2.2 Field Description and Instrumentation

A soil survey done in 1992 by the Natural Resource Conservation Service (NRCS) has shown that the site consists of silty clay loam sediments with moderate to poor drainage capabilities underlain by fine sands, with no impeding strata to a depth of 7 m. A shallow water table exists at only 1.5 m below ground surface due to the fact that the site is at a low elevation relative to the Rio Grande. In 1979, the field site was equipped with a sub-surface tile drainage system in an attempt to lower the water table. Figure 3 shows a plan view of the Las Nutrias field site. A concrete-lined irrigation canal is located along the northern border. The site is divided into three fields by two berms. These fields are referred to as the east, center, and west benches, with areas of 16, 16, and 31 acres, respectively. The four drains, consisting of 4- to 6- inch diameter perforated PVC, are installed approximately 1.5 m below ground surface. Irrigation return flows which drain below the soil surface as well as shallow groundwater flowing in from off site are collected by this system. The individual tiles connect to a single collection drain which empties into an off site surface canal called the Riverside Drain.

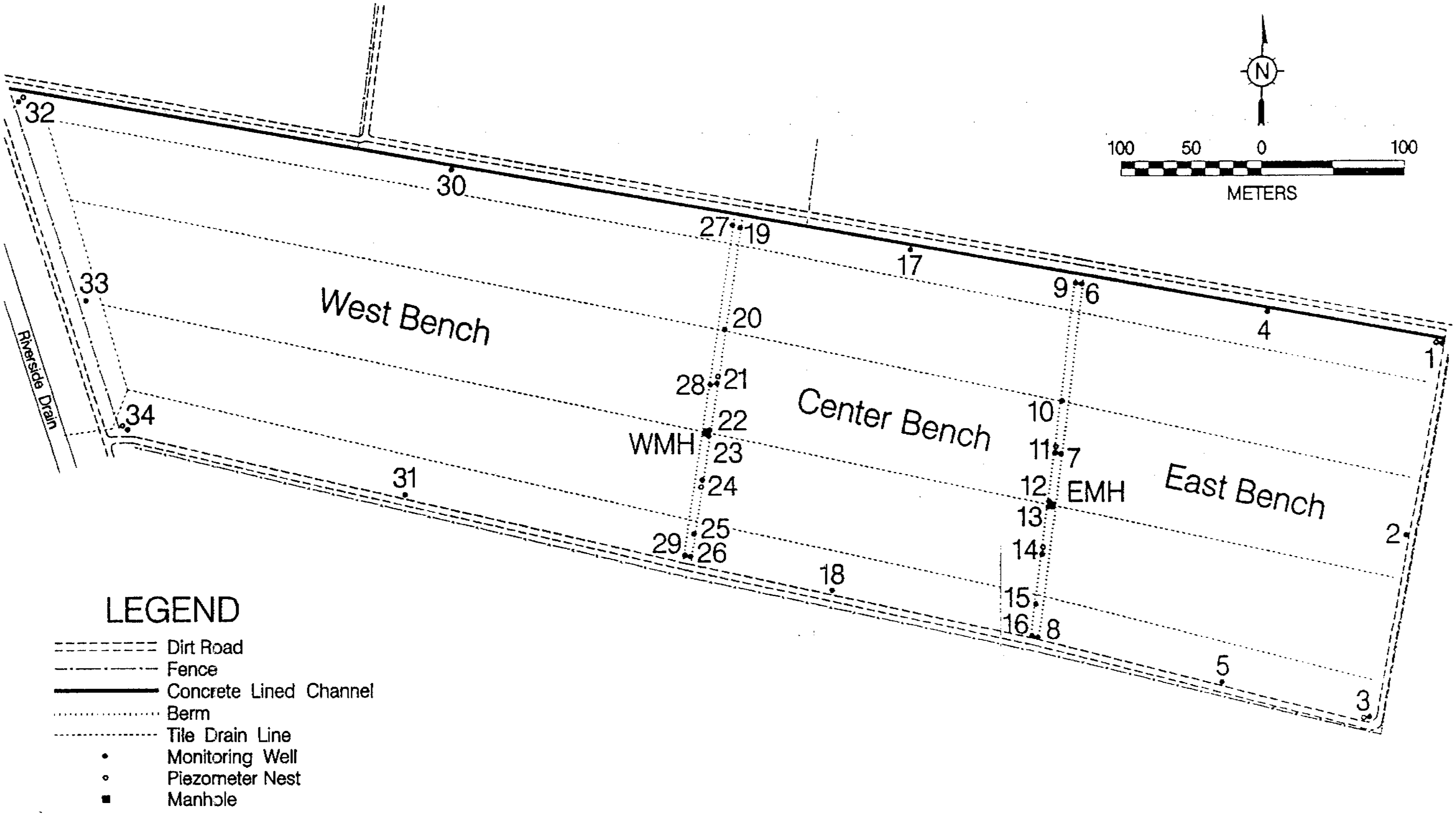
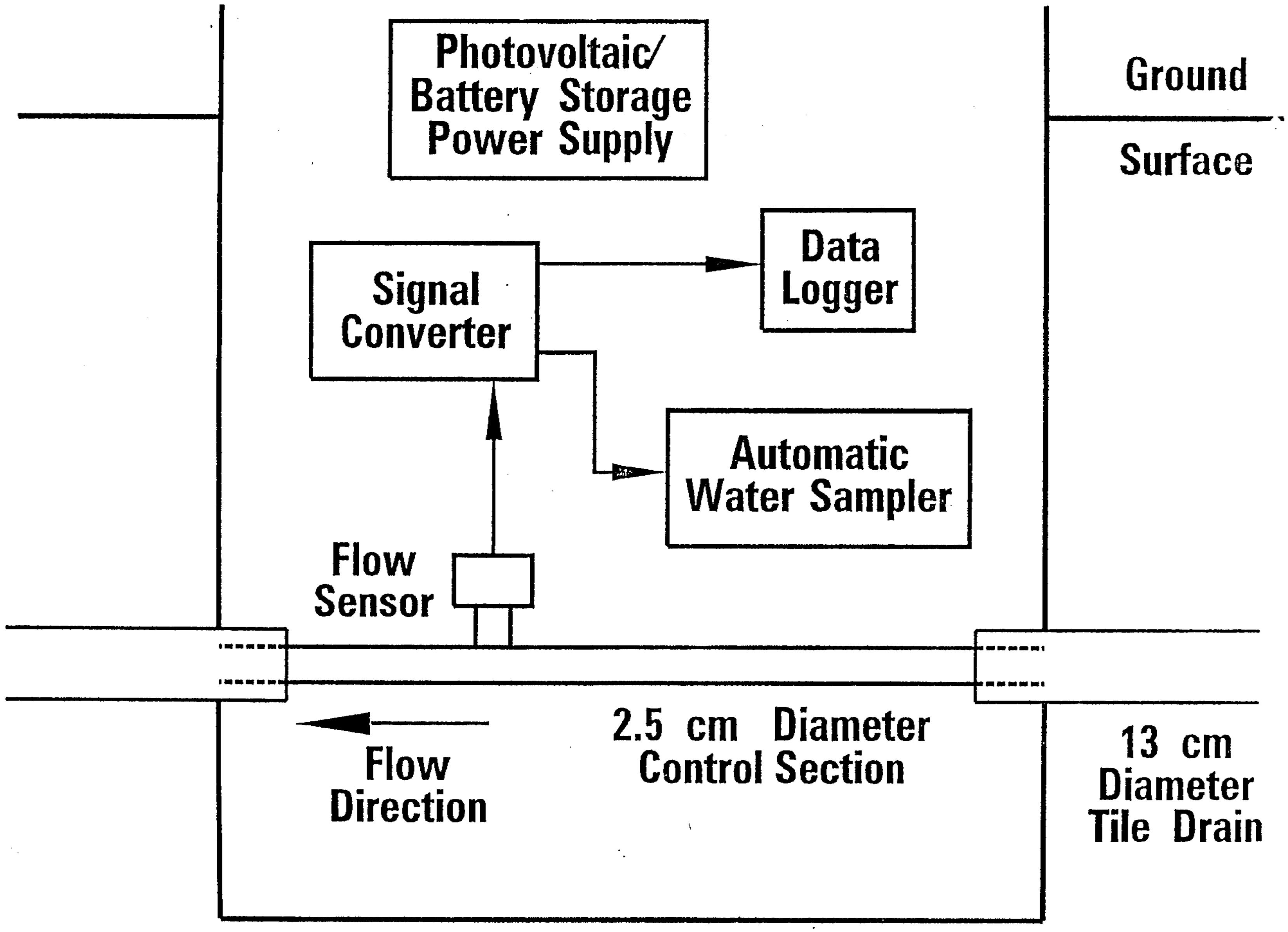


Figure 3. Plan view of the Las Nutrias field site and instrumentation.

An 800-foot section of a single tile drain line has been isolated by installing two manholes, one on the eastern berm and one on the western berm. This allows us to measure the quantity and quality of water entering and leaving the drain line. The manholes are currently equipped with flow measurement systems and ISCO® (Lincoln, NE) automatic water samplers (Figure 4). The flow measurement system consists of a Signet© (El Monte, CA) model 2530 low flow insertion sensor fitted to a 1-in PVC pipe that connects the upstream tile drain to the downstream tile drain in each manhole. The sensor paddle wheel measures flow velocities between 0.3 and 10 ft/sec. A flow controller converts this velocity to a volumetric flow rate as well as to a total volume of water passed in a given time. Data loggers are installed to automatically record the voltage output from the flow controller at 3-min intervals. A standpipe (Figure 4) exists to determine any head losses in the flow system imposed by downsizing the tile drain line. Currently, the water samplers collect samples on a time proportional basis which can be set to accommodate variable water input events.

Monitoring wells and piezometer nests, installed by the U.S. Bureau of Reclamation in February and March of 1993, are located along the border of the field site and along both berms so as to hinder the landowner as little as possible (Figure 3). The monitoring wells have a diameter of 2-in and are installed to a depth of 2 m. The wells are slotted for their entire length starting 10 cm below ground surface. The 1-in diameter piezometers are nested at 3, 5, and 7 m and are slotted at the bottom 20 cm. For more information on the construction of the wells, see Chaves (1995).


Photovoltaic/
Battery Storage
Power Supply
Ground
Surface
Signal
Converter
Data
Logger
Automatic
Water Sampler
Flow
Sensor
Flow
Direction
2.5 cm Diameter
Control Section
13 cm
Diameter
Tile Drain

The center bench portion of the irrigation canal is equipped with a 10-in outer diameter PVC circular weir (Figure 5). A critical flow condition is created by the presence of the weir; this is related to the net volumetric flow rate of water applied to that field during an irrigation (Sammani, 1993). Rain gauges have also been installed at several locations around the center bench to measure the amount of water input from precipitation. These consist of plastic funnels which empty into plastic cylinders marked with a calibrated millimeter scale.

2.3 Agricultural Management Practices

2.3.1 Crop Schedule

Since the initial data collection for the project began in the spring of 1993, the east bench has been planted to alfalfa, while the center and west bench crops have included alfalfa, corn, winter wheat, and a sorghum-sudan cross. Currently all three benches are planted to alfalfa. Table 1 lists the crop rotation during the 1993, 94, and 95 irrigation seasons.

2.3.2 Nitrogen Fertilization

Table 2 lists the fertilization schedule for 1993 - 1995. Different crop types require different formulations and amounts of nitrogen fertilizers for optimal production. Plant uptake requirements of nitrogen are generally well known, and so fertilizer application rates are relatively standard for each crop type. In New Mexico, the most

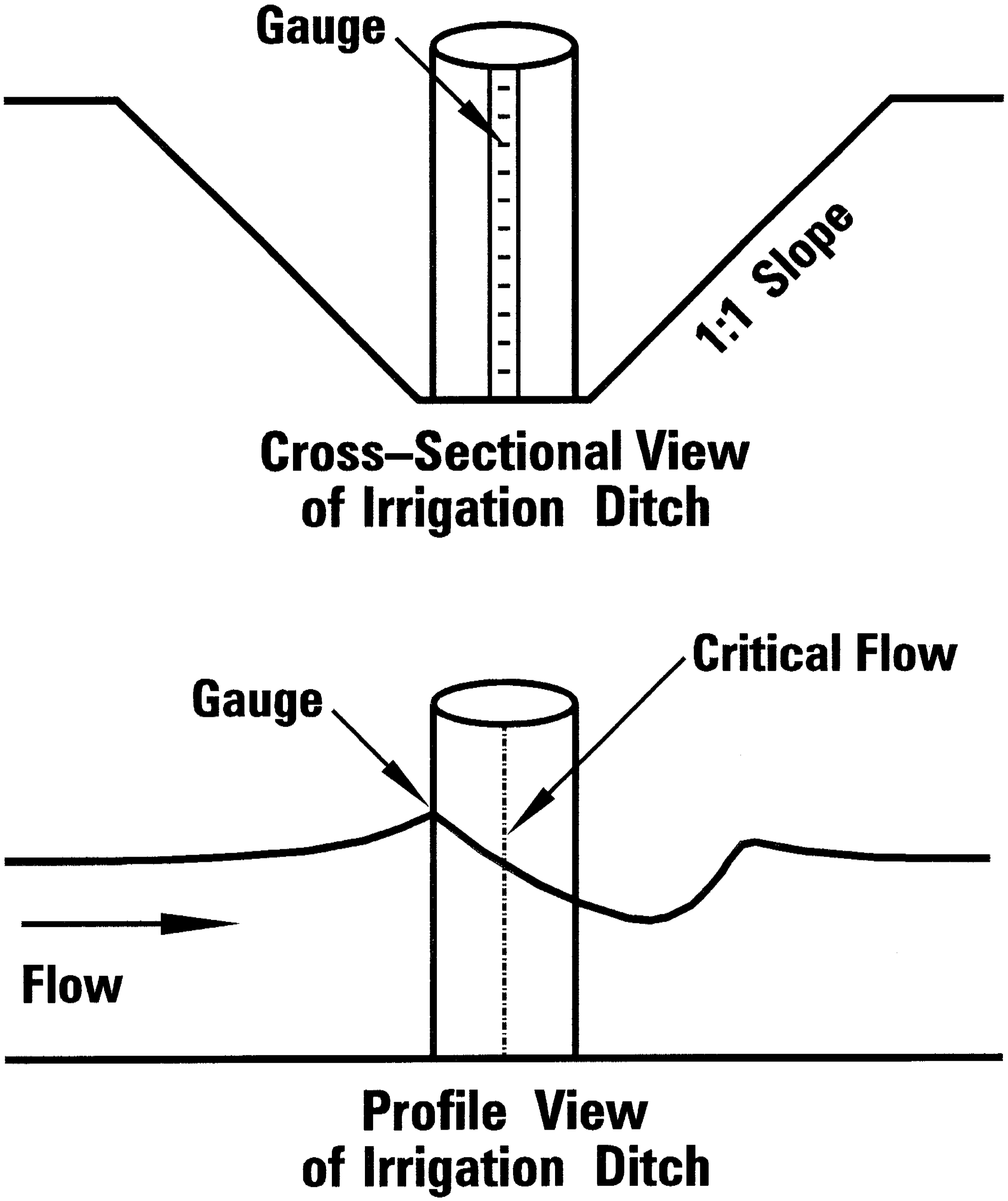


Figure 5. Diagram of circular weir.

Table 1
Crop Rotation Schedule

Bench	Crop	Planting Date	Harvest Dates
East	Alfalfa	Pre - 1991	30-May-94
			29-May-95
			2-Jun-95
			5-Jul-95
			6-Aug-95
			6-Sep-95
			15-Oct-95
Center	Corn	Pre - 1991	5-Oct-93
	Winter Wheat	10-Oct-93	-
	Sorgum-Sudan Cross	13-May-94	19-Jul-94
	Alfalfa	25-Sep-94	29-May-95
			2-Jun-95
			5-Jul-95
			6-Aug-95
			6-Sep-95
			15-Oct-95
West	Corn	Pre - 1991	5-Oct-93
	Winter Wheat	10-Oct-93	13-May-94
	Sorgum-Sudan Cross	13-May-94	19-Jul-94
	Alfalfa	25-Aug-94	30-May-95
			2-Jun-95
			5-Jul-95
			6-Aug-95
			6-Sep-95
			15-Oct-95

Table 2
Fertilization Schedule for the Period of June 1993 - October 1995

			Application Rate		**Total N applied**	
Bench	**Date**	**Compound**	**lb N/acre**	**kg N/ha**	**lbs**	**kg**
East	4-Mar-95	8-36-4 N-P-K	20	22.4	320	145
Center	25-Jun-93	$(NH_4)_2SO_4$	84.8	95.0	1,402	636
	15-Oct-93	Urea	90	100.9	1,488	675
	4-Mar-95	8-36-4 N-P-K	20	22.4	320	145
West	25-Jun-93	$(NH_4)_2SO_4$	84.8	95.0	2,453	1,113
	25-Oct-93	Urea	90	100.9	2,604	1,181
	7-Mar-94	$(NH_4)_2SO_4$	84.8	95.0	2,453	1,113
	13-May-94	Urea	90	100.9	2,604	1,181
	4-Mar-95	8-36-4 N-P-K	20	22.4	620	281
			Total N added:	East	320	145
				Center	3,209	1456
				West	10,114	4588

commonly used nitrogen fertilizers are ammonium sulfate and urea. Ammonium sulfate is approximately 21% nitrogen by weight and was applied to the center and west benches at a rate of 84.8 lbs N/acre. Urea is 45% nitrogen by weight, and is applied to the fields at a rate of 90 lbs N/acre. However, although ultimately the same amount of nitrogen is applied with the use of either formulation, the two forms of nitrogen are different. When ammonium sulfate is used, the inorganic ammonium ions present are relatively quickly oxidized by *Nitrosomas* bacteria to nitrite, which is oxidized by *Nitrobacter* to nitrate almost as rapidly as it is formed. The nitrogen is then susceptible to mobility after only a few days or weeks. Urea, on the other hand, contains nitrogen in an organic form that first must be converted to ammonium before the oxidation to nitrate can occur. This is a much slower process, and so the nitrogen persists in the soil profile for longer periods of time. Besides the presence of bacterial populations, other factors affect the transformation of nitrogen, such as soil temperature, soil water content, and soil pH (National Research Council, 1978).

2.3.3 Water Applications

The center bench is the most heavily instrumented portion of the site, as this is where all of our field sampling and experiments have taken place. Table 3 lists, for each irrigation since the installation of the circular weir, the amount of water applied to the center bench per irrigation. Irrigations of the entire field site are done by flooding. In general, all three benches receive water on the same day. Occasionally, for a

Table 3
Irrigation Dates and Volumes Applied to the Center Bench
1994 and 1995 Irrigation Seasons

	Total Elapsed	Total Volume of Water Applied		Total Depth of Applied Water	
Date	**Time (hrs)**	**liters**	**cubic feet**	**mm**	**in**
8-Jun-94	4.5	4.14E+06	1.46E+05	61.22	2.41
27-Jun-94	7.0	4.56E+06	1.61E+05	67.43	2.65
8-Aug-94	6.0	5.10E+06	1.80E+05	75.41	2.97
28-Sep-94	7.5	5.88E+06	2.08E+05	86.93	3.42
10-Apr-95	6.0	6.47E+06	2.29E+05	95.76	3.77
26-Apr-95	6.5	5.37E+06	1.90E+05	79.48	3.13
15-May-95	6.0	6.77E+06	2.39E+05	100.09	3.94
5-Jun-95	6.0	6.17E+06	2.18E+05	91.23	3.59
19-Jun-95	7.5	6.18E+06	2.18E+05	91.46	3.60
10-Jul-95	7.0	6.84E+06	2.42E+05	101.26	3.99
28-Jul-95	7:22	6.65E+06	2.35E+05	98.41	3.87
8-Aug-95	4:46	4.98E+06	1.76E+05	73.62	2.90
7-Sep-95	4:13	4.08E+06	1.44E+05	60.37	2.38
26-Sep-95	4:52	5.07E+06	1.79E+05	75.03	2.95
23-Oct-95	7:10	7.78E+06	2.75E+05	115.03	4.53
Average:	**4.35**	**5.74E+06**	**2.03E+05**	**84.85**	**3.34**

variety of reasons, the watering is done over a two day period. The usual approach is to water the east and west benches concurrently, followed by watering of the center bench. This order does, however, vary with the availability of the water, the crop status, and the time of year. Based on the circular weir measurements, an average of 85 mm of water is applied to the 16 acres of the center bench per irrigation. This is equivalent to 3.59E5 l/acre.

Table 4 lists the precipitation in mm as registered by the rain gauges surrounding the center bench. From 8 March 1994 through 17 December 1994, precipitation measured 276.52 mm. For 1995, as of 24 September, 102.4 mm of precipitation was measured. These values are equivalent to 9.81E5 l/acre and 4.33E5 l/acre for 1994 and 1995, respectively.

3.0 METHODS

3.1 Sampling and Analytical Methods

3.1.1 Analytical Methods

Groundwater as well as soil samples were analyzed for NO_3-N and other inorganic compounds by High Performance Liquid Chromatography (HPLC). The HPLC system was fully automated and consisted of a Waters (a division of Millepore Corporation, Milford, Massachusetts) 501 solvent delivery system, a Perkin-Elmer© (San Jose, CA) ISS 200 autosampler, a Waters Lambda-Max Model 481 variable wavelength UV detector, and a Hewlett-Packard© (Avondale, PA) 3396A integrator.

Table 4

Measured Precipitation during 1994 and 1995

	Precipitation	
Date	**mm**	**in**
8-Mar-94	6.93	0.27
11-Mar-94	6.27	0.25
22-Mar-94	2.30	0.09
29-Mar-94	1.40	0.06
11-May-94	12.17	0.48
22-May-94	1.20	0.05
23-May-94	11.17	0.44
28-May-94	5.80	0.23
2-Jun-94	1.40	0.06
25-Jul-94	3.07	0.12
27-Jul-94	15.93	0.63
29-Jul-94	10.70	0.42
1-Aug-94	4.07	0.16
3-Aug-94	0.50	0.02
15-Aug-94	38.33	1.51
30-Aug-94	18.80	0.74
31-Aug-94	13.53	0.53
3-Sep-94	28.37	1.12
7-Sep-94	17.57	0.69
11-Sep-94	0.30	0.01
17-Sep-94	7.20	0.28
21-Sep-94	0.20	0.01
4-Oct-94	1.05	0.04
15-Oct-94	23.83	0.94
9-Dec-94	23.13	0.91
17-Dec-94	21.30	0.84
Total in 1994:	**276.52**	**10.89**
22-Jan-95	4.40	0.17
27-Jan-95	6.00	0.24
29-Jan-95	0.90	0.04
16-Feb-95	2.60	0.10
3-Mar-95	11.50	0.45
10-Apr-95	4.70	0.19
19-Apr-95	3.50	0.14
22-Apr-95	4.15	0.16
30-May-95	4.90	0.19
16-Jun-95	4.00	0.16
19-Jun-95	2.15	0.08
2-Jul-95	2.15	0.08
16-Jul-95	4.00	0.16
17-Jul-95	0.50	0.02
19-Jul-95	5.90	0.23
1-Aug-95	0.70	0.03
15-Aug-95	0.75	0.03
19-Aug-95	5.90	0.23
1-Sep-95	14.00	0.55
12-Sep-95	2.90	0.11
?	15.00	0.59
24-Sep-95	1.80	0.07
Total in 1995:	**102.40**	**4.03**

The integrator is interfaced with ChromPerfect software (Version 6), created by Justice Innovations, Inc. (Mountainview, CA), run on an Everex 360is computer for chromatograph analysis. Two types of HPLC ion-exchange columns are used, depending upon the particular application. One was a Phenomenex® (Torrance, CA) spherex 5 sax 4.60 mm x 250 mm silica-based ion exchange column, with a 0.03 M K_2HPO_4 buffer at a pH of 2.66 with 18% (by volume) acetonitrile as the mobile phase. The flow rate for this analysis was 1.3 ml/min, and optimal analysis time ranged from 15-25 minutes per sample. The other column was a Vydac™ (Hesperia, CA) 302 IC ion exchange column with a 0.02 M KH_2PO_4 mobile phase buffer at a pH of 3.8. No organic modifier was required in this mobile phase. The flow rate for this analysis was 2.0 ml/min, and optimal analysis time was 22 minutes. The Vydac™ column was used when bromide tracer tests were performed at the site because of the inability of the Phenomenex® column to sufficiently separate bromide from nitrate.

All groundwater samples were analyzed for electrical conductivity (umhos/cm) using a YSI® (Yellow Springs, OH) Model 35 conductance meter equipped with a Model 3401 conductance probe.

3.1.2 Sample Collection and Preparation

In late February and early March of 1994 and 1995, soil samples were collected on the center bench along a transect shown in Figure 6. The U.S. Department of Agriculture (USDA) classified soil series are also indicated in this figure. Samples were

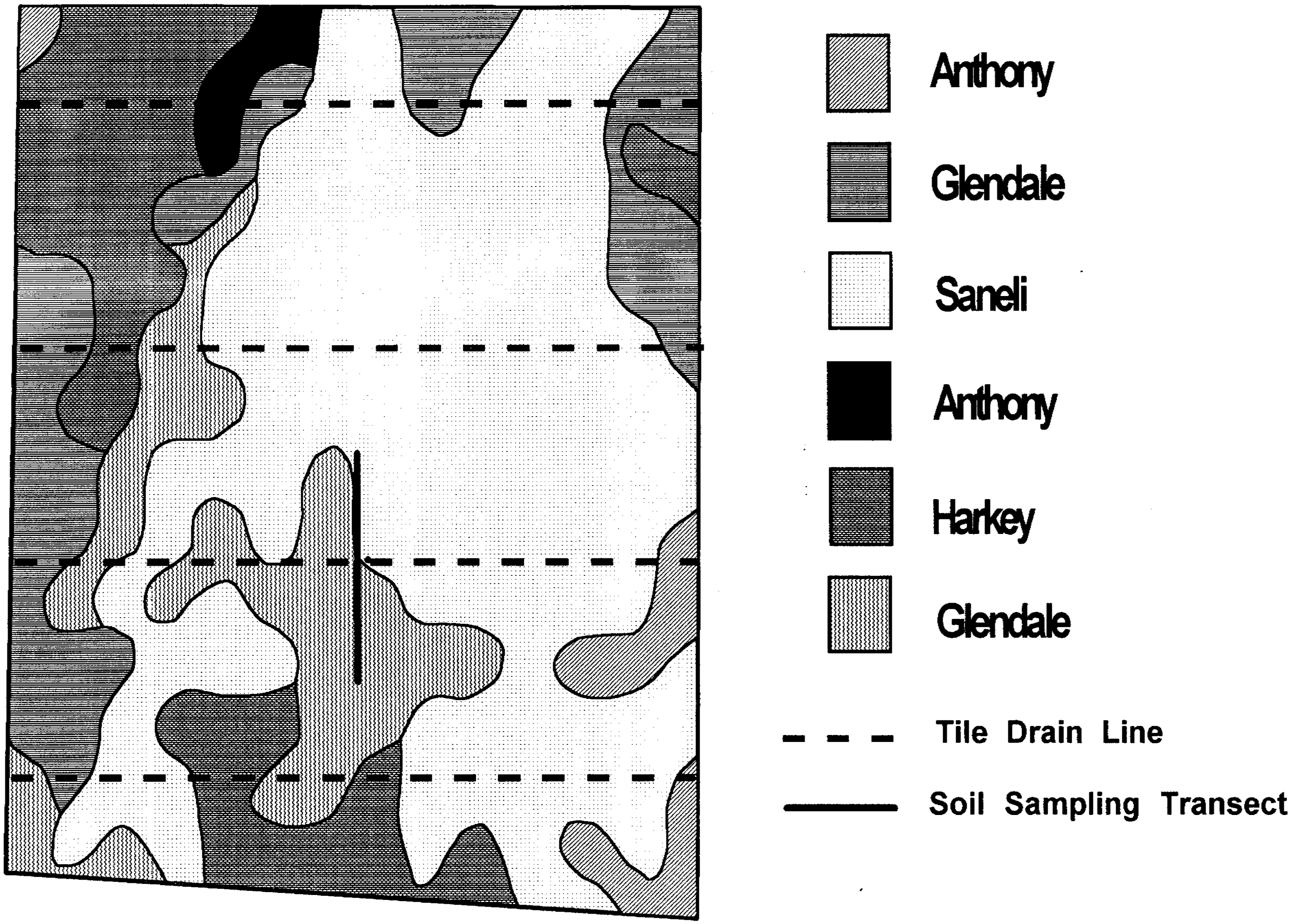


Figure 6. Soil series map showing soil sampling transect

collected at approximately 1.5 m-increments away from the monitored tile drain in the north and south directions, for a total of 54 locations. In 1994, samples were collected at 10 cm increments from ground surface to 120 cm depth using 4- and 8-ft Vehimeyer soil sampling tubes. Samples were later composited to intervals of 0-30 cm, 30-60 cm, 60-90 cm, and 90-120 cm for analysis purposes. In 1995, 2-in diameter soil augers were used to sample at the four depths mentioned above. The total number of samples analyzed each year was 216. All samples were double-bagged in plastic and frozen until laboratory analysis. At that time, the bags were thawed out overnight. Ten gram portions were weighed and oven-dried for 24 h at 105 deg C to determine the gravimetric water contents. Five or ten gram portions of the sample were shaken for 245 h with a 1:1 sample weight to water volume ratio (g:ml) of Type I water produced from a Milli-Q system (Millipore Corporation). Samples were then centrifuged at 13,776 *g* for 30 min. The aqueous portion was then vacuum filtered through a 0.45 micron filter and transferred to a 2 ml glass autosampler vial for HPLC analysis.

The observation wells and piezometers were sampled approximately once per month to determine the spatial distribution and temporal variations of nutrient concentrations in the shallow groundwater, as well as for the detection of any vertical nutrient gradients. To avoid obtaining stagnant well water, approximately five well volumes were bailed before samples were actually collected. The total number of samples collected from the observation wells in 1994 was 544. A total of 416 samples of the piezometer nests were taken over a period of time from 1994 - 1995.

Prior to the installation of the automatic water samplers, the tile drainage water was sampled bi-weekly between irrigations and daily during irrigation events. Once the autosamplers were running, the sampling frequency increased to once daily between irrigations. During irrigations, samples were taken every 2 h for the first 48 h, then once every 4 h for the next 48 h, then once every 6 h for 72 h. The Riverside Drain was sampled whenever personnel was out in the field. Samples were also taken from the irrigation canal during irrigation events. The total number of groundwater samples taken in 1994 from the tile drain line was: west manhole - 242 for NO_3-N, 202 for electrical conductivity; east manhole - 173 for NO_3-N, 132 for electrical conductivity; riverside drain - 45 for NO_3-N, and 32 for electrical conductivity. As of May 1995, 205 samples were taken in the west manhole for NO_3-N analysis and as of July 1995, 301 samples were taken in the west manhole for electrical conductivity. The east manhole had 21 samples and 204 samples for NO_3-N analysis and electrical conductivity, respectively. The riverside drain was sampled 24 times for NO_3-N analysis and 39 times for electrical conductivity.

All samples to be analyzed for inorganic ions and electrical conductivity were collected in 250 ml high density polyethylene bottles and refrigerated upon arrival at the lab. Forty ml aliquots of the samples were placed in a centrifuge for 30 minutes at 13,776 *g*. This volume was used due to the size of the openings in the centrifuge rotor. A portion of the sample was then transferred into a 2 ml glass autosampler vial for HPLC analysis.

4.0 RESULTS

4.1 Soil Water Chemistry

4.1.1 NO_3-N

Figure 7 shows the mean soil water NO_3-N concentrations with depth for the samples taken in late February/early March of 1994 and 1995. These values represent the soil reservoir of nitrogen prior to the 1994 growing season. The concentrations were determined from the soil extractions by HPLC and were then back-calculated to their original water contents. The error bars represent the 95% confidence intervals, which states that one is 95% confident that the sample values fall between this range about the mean. The descriptive statistics for each sample interval for each year are given in Appendix 9.1.2. Normal quantile plots and Kolomogornov-Smirnov (K-S) tests were done for all the data sets, and indicate that some of the distributions are, in fact, normal at the 0.10 confidence interval only. In addition, the descriptive reveal that the median and mean do not correlate as well as they should for a normally distributed data set and that the standard deviation of the sample increases with increasing sample mean. These observations indicated that perhaps the data sets were log-normally distributed. K-S tests were performed on the log-transformed data, and all the data sets are, in fact, log-normally distributed with a 0.01 confidence interval of the null hypothesis (i.e., the observed distribution is the same as the theoretical, normal distribution). The K-S test statistics are included in Appendix 9.1.2. As can be seen from Figure 7, for both years the highest mean NO_3-N concentration is found in the 0-

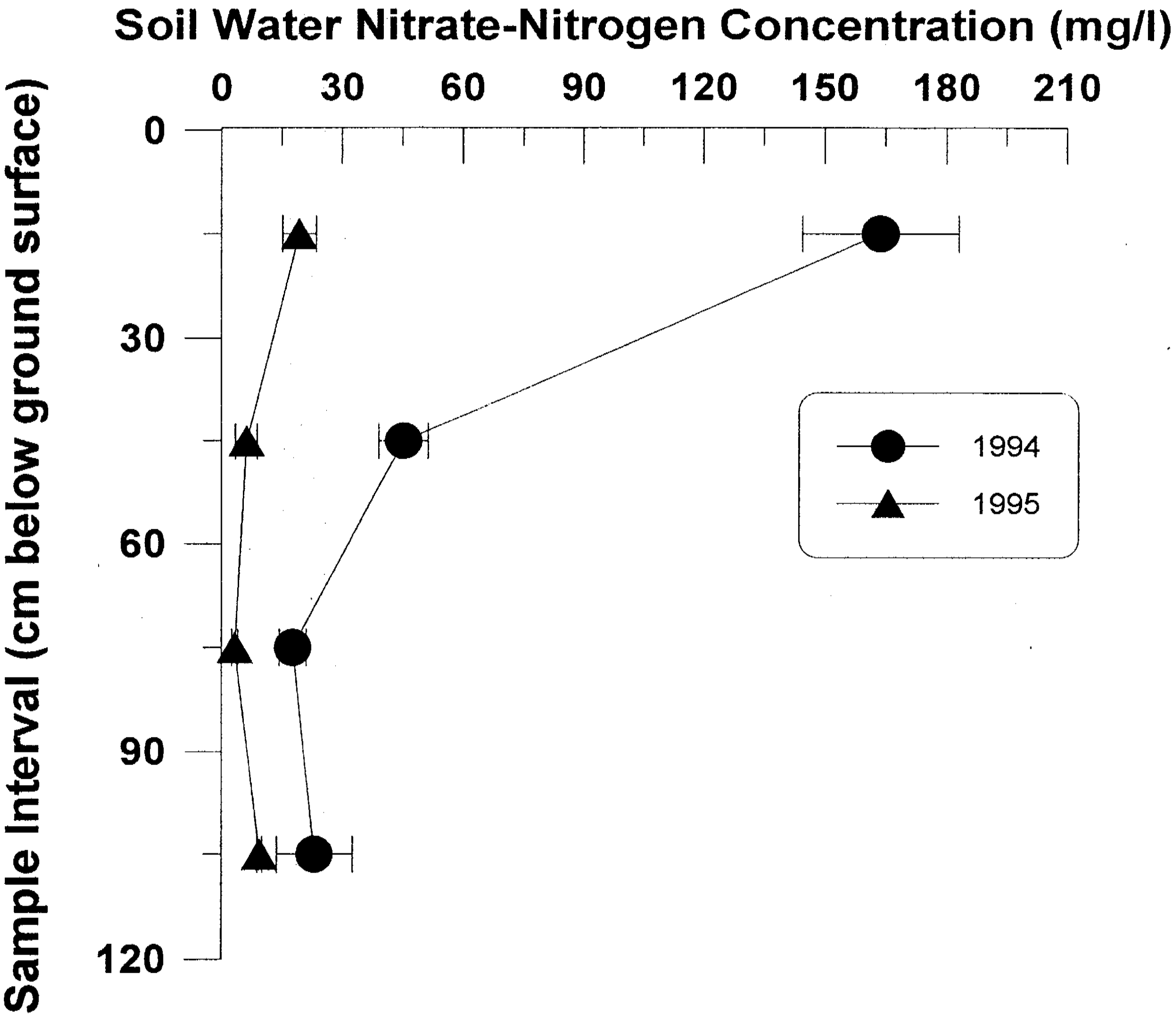


Figure 7. Mean soil water NO3-N concentrations

30 cm interval, with the next highest concentration in the 30-60 cm interval. Concentrations are relatively lower in the next two intervals to the total sample depth of 120 cm.

The coefficient of variation (CV) of the mean, or the relative standard deviation, is often used as a way to compare different populations that have different ranges of values. It is a normalized standard deviation, expressed as the ratio of standard deviation to the population mean. CV's well below unity indicate that the sample distribution is narrow and that the mean is therefore, an accurate estimate of the actual expected value. CV's closer to and above unity indicate that there are outliers in the data which broaden the distribution and therefore significantly affect the accuracy of the mean. As can be seen from the descriptive statistics, the sample populations have somewhat high CV, with the highest values associated with the 60-90 cm and 90-120 cm sampling intervals for each year. For both years, the 90-120 cm interval has a CV greater than one. Several factors could explain this, such as sampling variability, analytical error, or the heterogeneity of the soil profile. The pattern of variation that exists with depth is consistent between years, i.e. the lower CV's are associated with the upper sampling interval, with increasing CV's associated with increasing depth. For the log of the data sets (descriptive statistics also located in Appendix 9.1.2), the CV's are much smaller for the 1994 data and for the two shallower sample intervals in 1995, indicating less spread about the log-transformed data. However, for the two deeper sample intervals in 1995, the CV increased significantly. The log-transformed data for both years also shows increasing CV with increasing sample depth.

Solutes are transported vertically downward through unsaturated soils by advective, dispersive, and diffusive processes. As solutes move advectively downward through the soil profile with irrigation water, the concentration distribution is irregularly spread out by the dispersion and diffusion as a result of horizontal and vertical spatial heterogeneities within the soil profile. In addition, preferential flow of solutes through macropores which also vary spatially contributes to the irregularities. However, semi-variograms calculated with the raw data for each depth in each year indicate that no horizontal spatial correlation exists for the NO_3-N concentrations (see Appendix 9.1.5). This information, along with the fact that the CV's for the upper 30 cm of the soil profile are relatively low, leads to the assumption that nutrient applications are uniformly distributed over the soil surface. Based on this assumption, the mean concentrations for each depth are considered to be representative for the center bench soils at the time of these sampling events.

Calculations were performed to determine whether or not the log of the soil water nutrient concentrations within each sampled interval were correlated between the 1994 and 1995 sampling events. These results are located in Appendix 9.1.2. The tests indicated that the 0 - 30 cm and 90 - 120 cm intervals are slightly negatively correlated (correlation coefficient < 0) with the 30 - 60 cm and 60 - 90 cm intervals showing a slight positive correlation (correlation coefficient > 0). However, for all depths, the values are so close to zero so that for all practical purposes, none of the sampled depths show any correlation between the 1994 and 1995 sampling events. In addition, scatterplots calculated for each sample interval indicated the independence in soil water NO_3-N concentrations between 1994 and 1995.

4.1.2 Soil Moisture Content

Figure 8 shows the mean percent soil gravimetric water content with depth for the late February/early March 1994 and 1995 sampling events. For both events, the upper 30 cm of the soil profile contains approximately 16% soil water, with approximately 23% for the 30-60 cm interval, 27% for the 60-90 cm interval, and 21% or so for the 90-120 cm interval. The descriptive statistics are presented in Appendix 9.1.4. For both events, the 95% confidence intervals (represented by the error bars) are small, which indicates the sample population values fall closely within the mean value. Note also that the CV's are much lower than that for the NO_3-N concentrations, further indicating a lack of variability about the mean.

4.1.3 Mass of NO_3-N in the Soil Profile

Appendix 9.5.1 lists the soil type for each soil sample taken from the center bench as determined by the USDA classification scheme (USDA 1988).The soil sampling transect (Figure 6) is located on an area consisting of Glendale and Saneli Soil Series. The USDA classification scheme includes ranges for bulk density, which

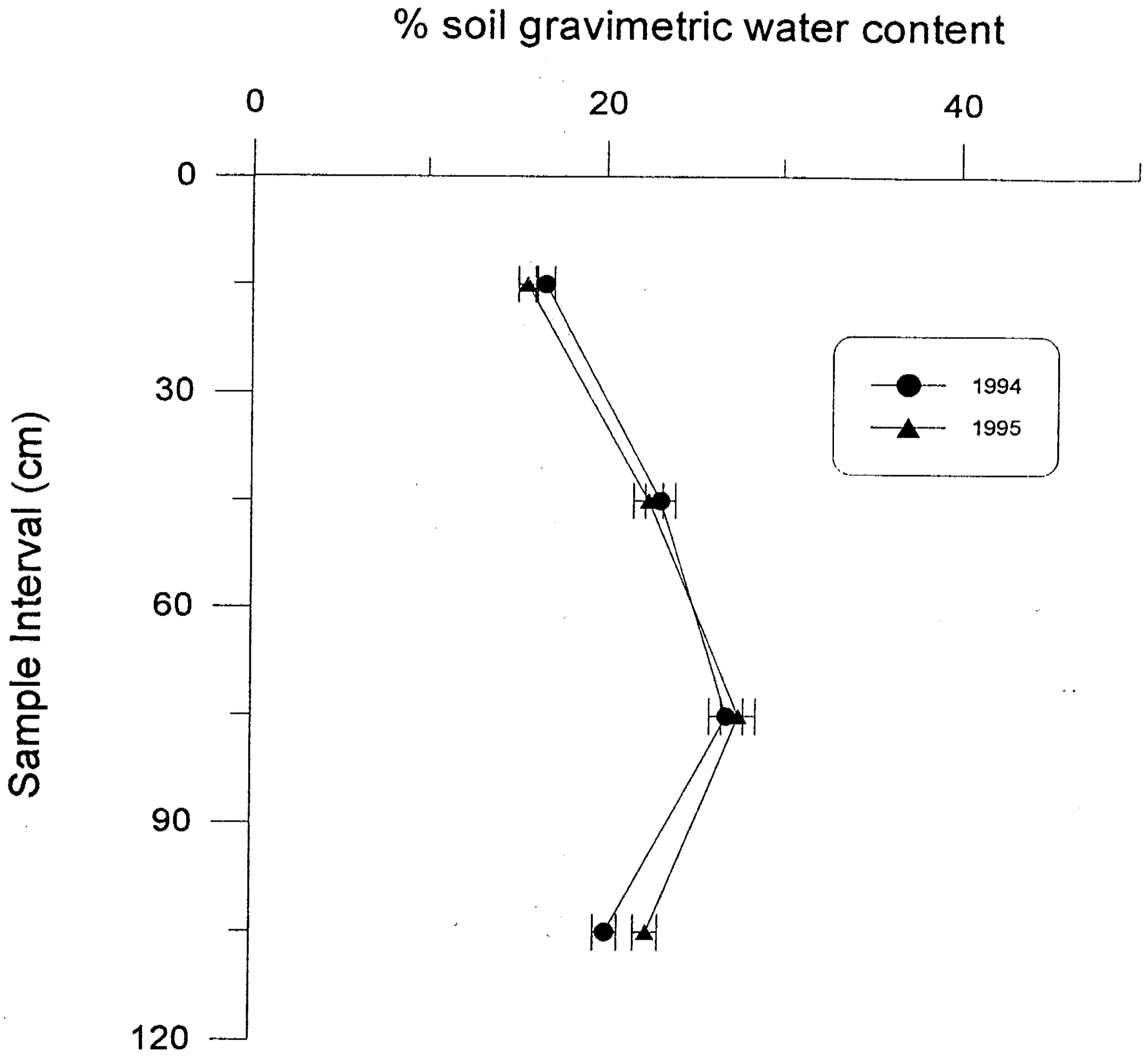


Figure 8. Mean % soil moisture content with depth

are based on a percent clay content. This is based on thorough investigations of the soil properties within each series. The NRCS survey done at the Las Nutrias field site included estimates of the percentages of clay within each soil type. Therefore, it was possible to estimate a bulk density for each soil sample taken based on a combination of the above information. For the upper 0 - 30 cm intervals, bulk densities were obtained from a previous experiment at the site (Chaves 1995). Where more than one soil type was found within a sample interval, the sample was split up to accommodate the change in bulk density. These values were then used with the laboratory determined gravimetric water contents to estimate the volumetric water contents of the soil samples, and hence the volume of water stored within the upper 120 cm of the soil profile. This was then used with the NO_3-N concentration data to calculate an estimate of the mass of NO_3-N per acre on the center bench at the time of each sampling event. Calculations for this are given in Appendix 9.5.2, and a summary of the results is given in Table 5. The results show that although the total NO_3-N mass per acre on the center bench present each year has decreased from approximately 161 lbs (60 kg) to 31 lbs (11.6 kg), the percent mass in each interval within the soil profile is approximately the same. The upper 0-30 cm contains more than 50% of the total mass, and more than 20% is located in the 30-60 cm interval. The remaining 20% or so is located in the lower profiles. The NO_3-N mass calculated for 1995 is approximately 18.9% of the 1994 mass. This means that about 81% of the soil water nutrients were lost to plant

1994 Samples:

Sample Interval	Mean Volumetric Water Content (cm^3/cm^3)	Total Water Storage		Mean Soil Water NO_3-N Concentration (mg/l)	Mass NO_3-N per Volume of Soil		Mass NO_3-N		% of Total Mass Present
		liters/acre	ft^3/ha		lbs/ft^3	kg/m^3	lbs/acre	kg/ha	
0 - 30 cm	0.22	2.79E+05	2.43E+04	163.75	2.25E-03	3.60E-02	96.44	108.09	59.87
30 - 60 cm	0.30	3.80E+05	3.32E+04	45.28	8.48E-04	1.36E-02	36.38	40.78	22.59
60 - 90 cm	0.36	4.56E+05	3.98E+04	17.74	3.99E-04	6.39E-03	17.13	19.20	10.63
90 - 120 cm	0.18	2.28E+05	1.99E+04	23.14	2.60E-04	4.16E-03	11.13	12.48	6.91
Totals:	-	1.34E+06	1.17E+05	-	3.76E-03	6.02E-02	161.08	180.55	100

1995 Samples:

Sample Interval	Mean Volumetric Water Content (cm^3/cm^3)	Total Water Storage		Mean Soil Water NO_3-N Concentration (mg/l)	Mass NO_3-N per Volume of Soil		Mass NO_3-N		% of Total Mass Present
		liters/acre	ft^3/ha		lbs/ft^3	kg/m^3	lbs/acre	kg/ha	
0 - 30 cm	0.23	2.91E+05	2.54E+04	29.29	4.20E-04	6.73E-03	18.00	20.18	57.25
30 - 60 cm	0.29	3.68E+05	3.21E+04	12.42	2.20E-04	3.52E-03	9.44	10.58	30.03
60 - 90 cm	0.35	4.44E+05	3.87E+04	3.11	6.80E-05	1.09E-03	2.94	3.30	9.35
90 - 120 cm	0.2	2.54E+05	2.22E+04	2.01	2.51E-05	4.02E-04	1.06	1.19	3.37
Totals:	-	1.36E+06	1.18E+05	-	7.33E-04	1.17E-02	31.44	35.24	100

Table 5. Summary of NO_3-N Mass in the Soil Profile of the Center Bench

uptake, microbial denitrification initiated by the upward movement of water due to capillary rise, or vertical migration with infiltrating irrigation water.

4.2 Irrigation Water Chemistry

Appendix 9.2 contains the NO_3-N concentration and electrical conductivity data for the applied irrigation water. Samples were collected in the irrigation canal for most irrigation events and had an average NO_3-N concentration of 0.50 mg/l. The average electrical conductivity was 368 umhos/cm.

4.3 Groundwater Chemistry

4.3.1 Monitoring Well and Piezometer Groundwater Chemistry

4.3.1.1 NO_3-N

As stated previously, all observation wells and piezometers are sampled on a more or less monthly basis for the determination of the spatial and temporal distribution of NO_3-N. Figure 9 shows the mean NO_3-N concentrations of all observation wells (2 m depth) sampled over time. The error bars represent the 95% confidence intervals, which indicate the high confidence in the sample values being close to the mean. Average concentrations range from 0.1 - 1 mg/l NO_3-N. The software Surfer for Windows by Golden Software, Inc. was used to create NO_3-N concentration contour maps and three dimensional surface plots for each sampling event (see Appendix 9.3.1.2). The spatial distribution of NO_3-N in the observation wells reveals that

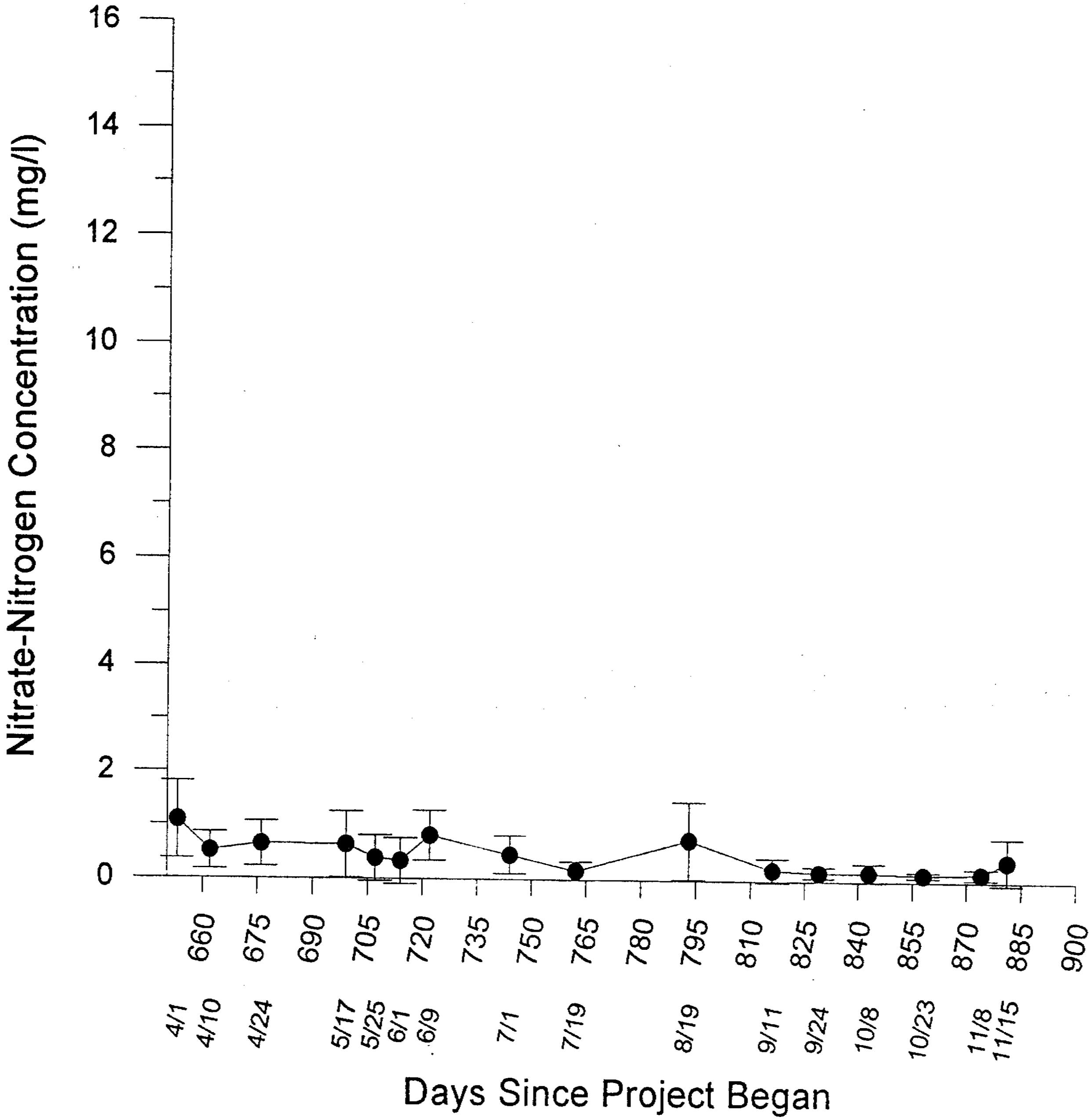


Figure 9. Mean nitrate-nitrogen concentration in the observation wells

somewhat higher concentrations persist in the wells located on the east bench, and that these concentration highs seem to migrate in the direction of the regional groundwater flow (northeast to southwest trend).

The NO_3-N concentrations in the piezometer nests (2, 3, 5, and 7 m depths) are also very low. Concentration gradients at each nest for each sampling event are located in Appendix 9.3.2.2. These figures indicate that if any significant concentration gradient exists, it is downward from the shallower, 2 m depth wells to the deeper piezometers. This is because the 2 m depth wells are screened throughout all but the top 10 cm of their length. Therefore, the concentrations in these wells represent integrated values from the vadose zone to approximately 0.5 m below the water table. Most of the NO_3-N is located in the upper portion of the soil profile, and serves as a source for the upper surface of the groundwater table.

4.3.1.2 Electrical Conductivity

Figure 10 shows the mean electrical conductivity of all observation wells (2 m depth) sampled over time. Again, the error bars represent the 95% confidence intervals. These intervals are somewhat larger than those which describe the mean NO_3-N concentrations. Such variability in the sample values is due to the fact that the electrical conductivity is a function of all the ions present in the sample, and is therefore subject to more processes that may occur and effect the sample values.

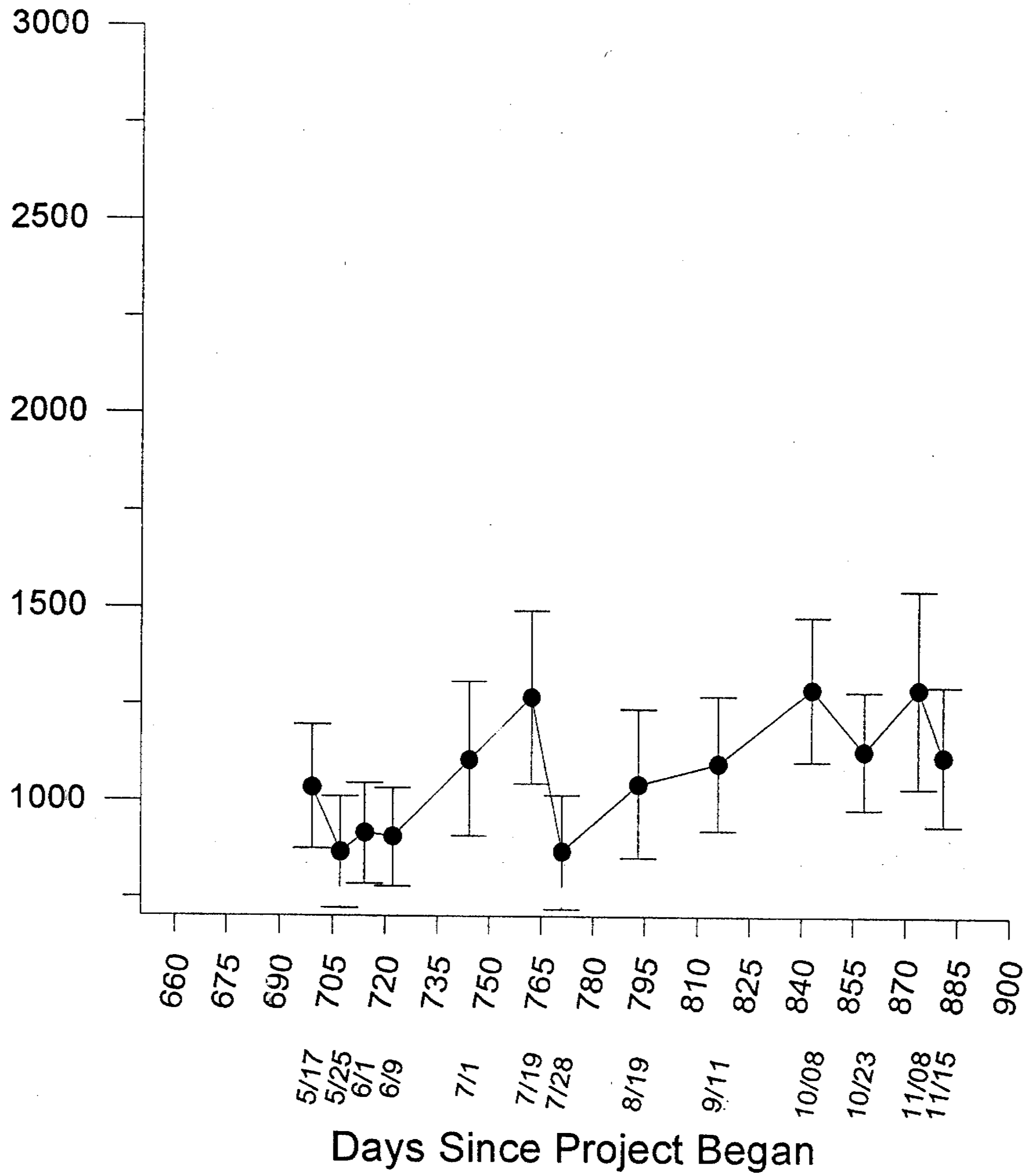


Figure 10. Mean electrical conductivity in observation wells

4.3.2 Tile drain chemistry

4.3.2.1 NO_3-N

NO_3-N concentrations versus time in the upgradient (east) and downgradient (west) manholes for the 1994 irrigation season are presented in Figures 11 and 12, respectively. Although the landowner applied nitrogen fertilizer to the center bench only once before the start of the 1994 irrigation season, and not at all to the upgradient (east) bench, increases in the tile drain NO_3-N concentration occur with the irrigation events early on in the season, from March 10 through July 23, 1994. The EPA maximum contaminant level of 10 mg/L NO_3-N is exceeded several times, and more likely than not exceeds this level for every water input event. Equipment failure and therefore missing data (indicated by breaks in the curves of Figures 11 and 12) occurred several times during the season, and so a few nitrate peaks are likely absent or incomplete. Precipitation events (see Table 4) did not have an impact on the concentrations of nutrients in the tile drainage water at any time. Although the sampling frequency was unable to be increased during the sudden rainfall events in this area, the absence of any concentration increases is likely is due to the fact that the water added from precipitation at any one time was very small relative to the magnitude of an irrigation event (refer to Tables 3 and 4).

The increase in concentration occurs a few hours after the irrigation starts, peaks after 0.5 - 3 days, and returns to background concentrations (in between irrigations) of <1 mg/l approximately 4 - 8 days after the water input event. A typical

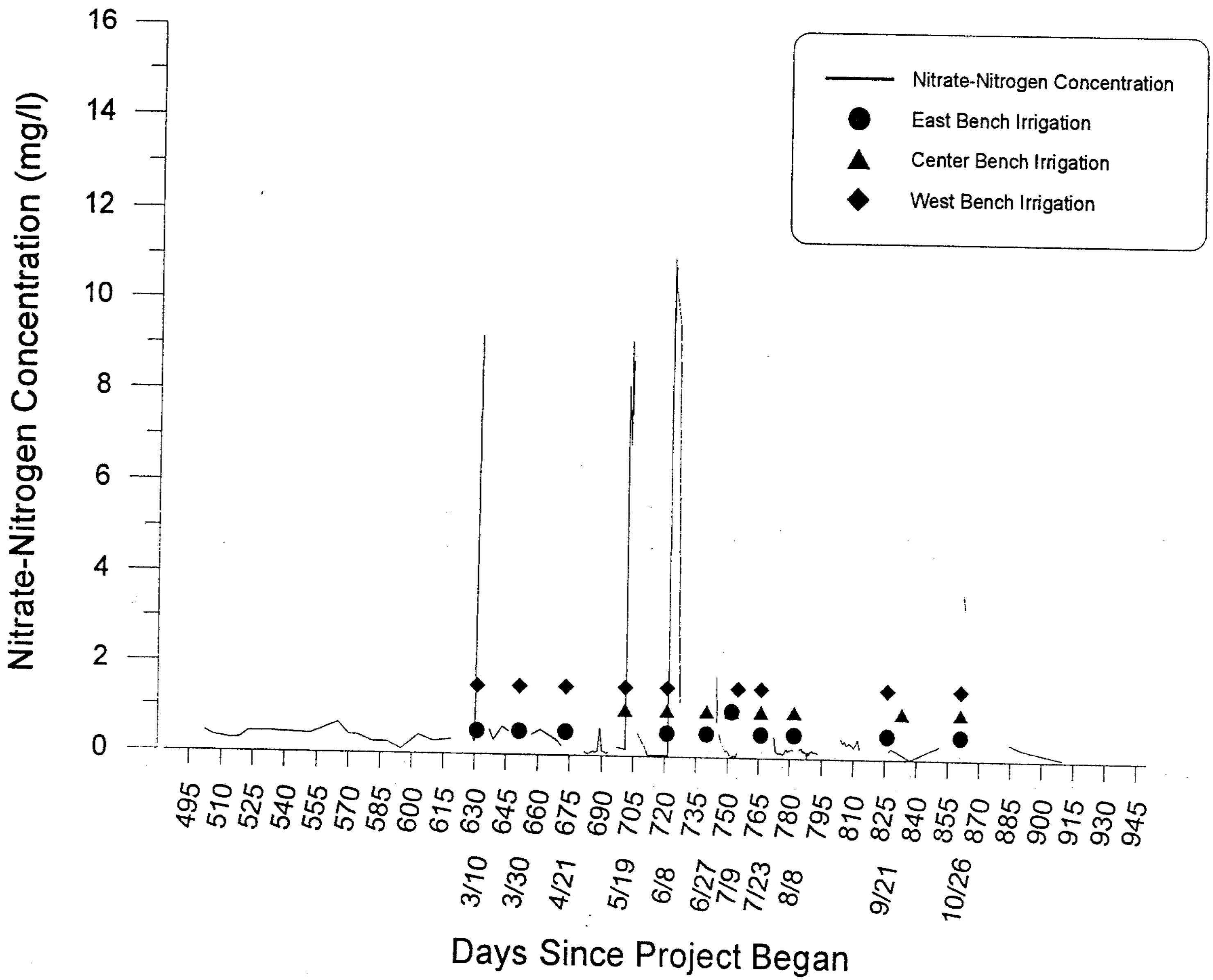
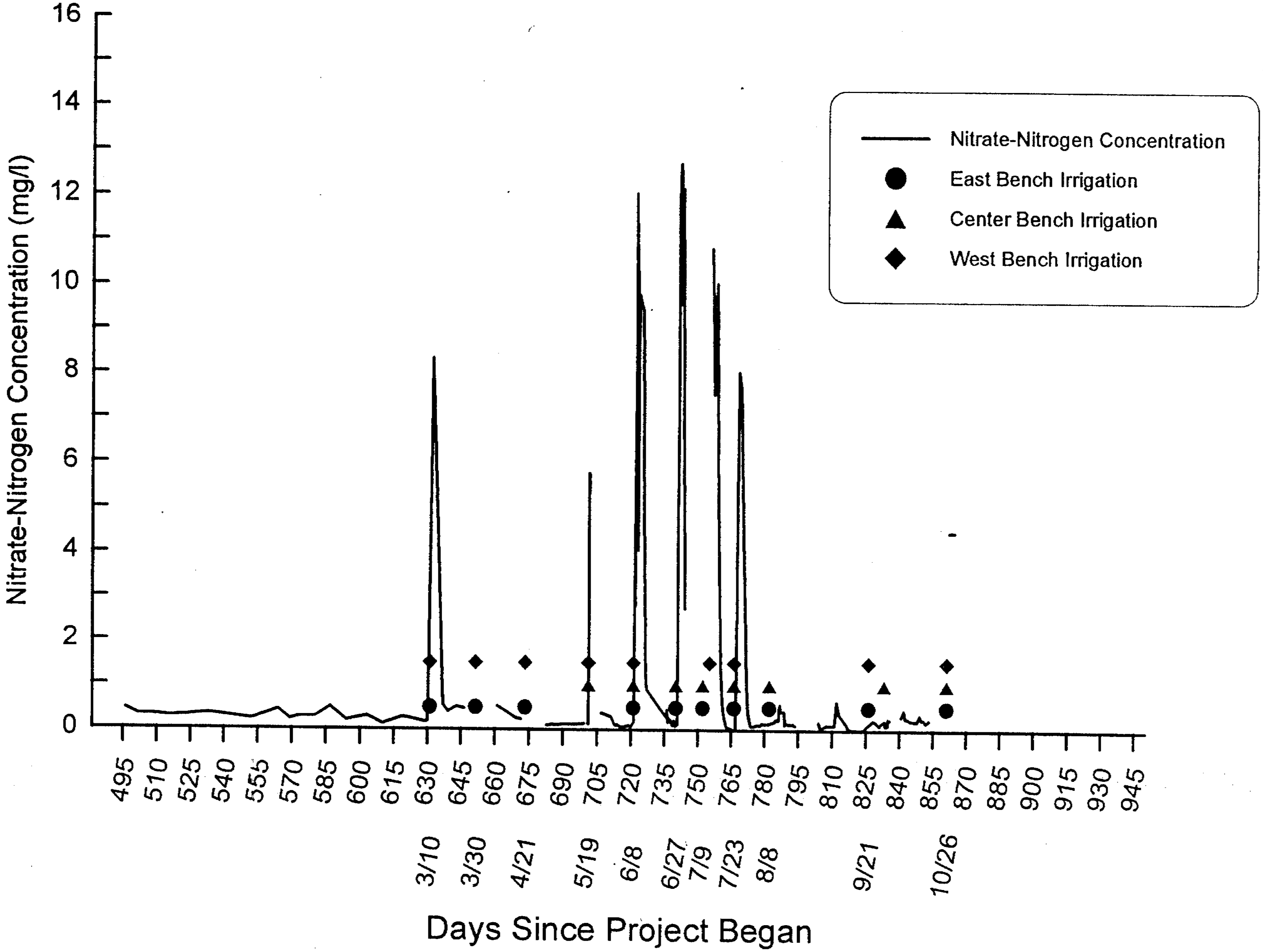


Figure 11. Nitrate-nitrogen concentration with time at the upgradient (east) manhole


Nitrate-Nitrogen Concentration (mg/l)
0
2
4
6
8
10
12
14
16
Nitrate-Nitrogen Concentration
East Bench Irrigation
Center Bench Irrigation
West Bench Irrigation
495
510
525
540
555
570
585
600
615
630
645
660
675
690
705
720
735
750
765
780
795
810
825
840
855
870
885
900
915
930
945
3/10
3/30
4/21
5/19
6/8
6/27
7/9
7/23
8/8
9/21
10/26
Days Since Project Began

response of the NO_3-N at the downgradient (west) manhole is given in Figure 13. This data is the result of the 8 June 1994 irrigation event, in which all three benches received water. The east and west benches started receiving water early in the morning, and the center bench was irrigated from approximately 11 am to 3:30 pm (approximately 721.5 - 721.625 days since the project began). As can be seen, within a few hours of the center bench irrigation, NO_3-N concentrations rapidly increase to approximately 12 mg/l. With the exception of a few outliers in the data set, the concentrations stay somewhat high for almost 4 d, and then rapidly decrease with very little tailing of the breakthrough curve.

The irrigations that did not cause high amounts of nutrients to appear in the drain water reflect the fact that towards the end of the irrigation season, most of the nutrients concentrated within the upper soil surface had already been depleted due to the leaching of NO_3-N with infiltrating irrigation water. Given the soil water nutrient concentrations in 1994 and the magnitude of the concentration peaks in the tile drain flow, dilution by the irrigation water decreases the source concentrations in the soil profile by up to 93%. In other words, as the mass of NO3-N in the soil water decreases, and more and more irrigation water is added, the dilution factor becomes more and more prominent. This leads to the drain water containing lower concentrations, such as those that are seen in between irrigations and during the winter months.

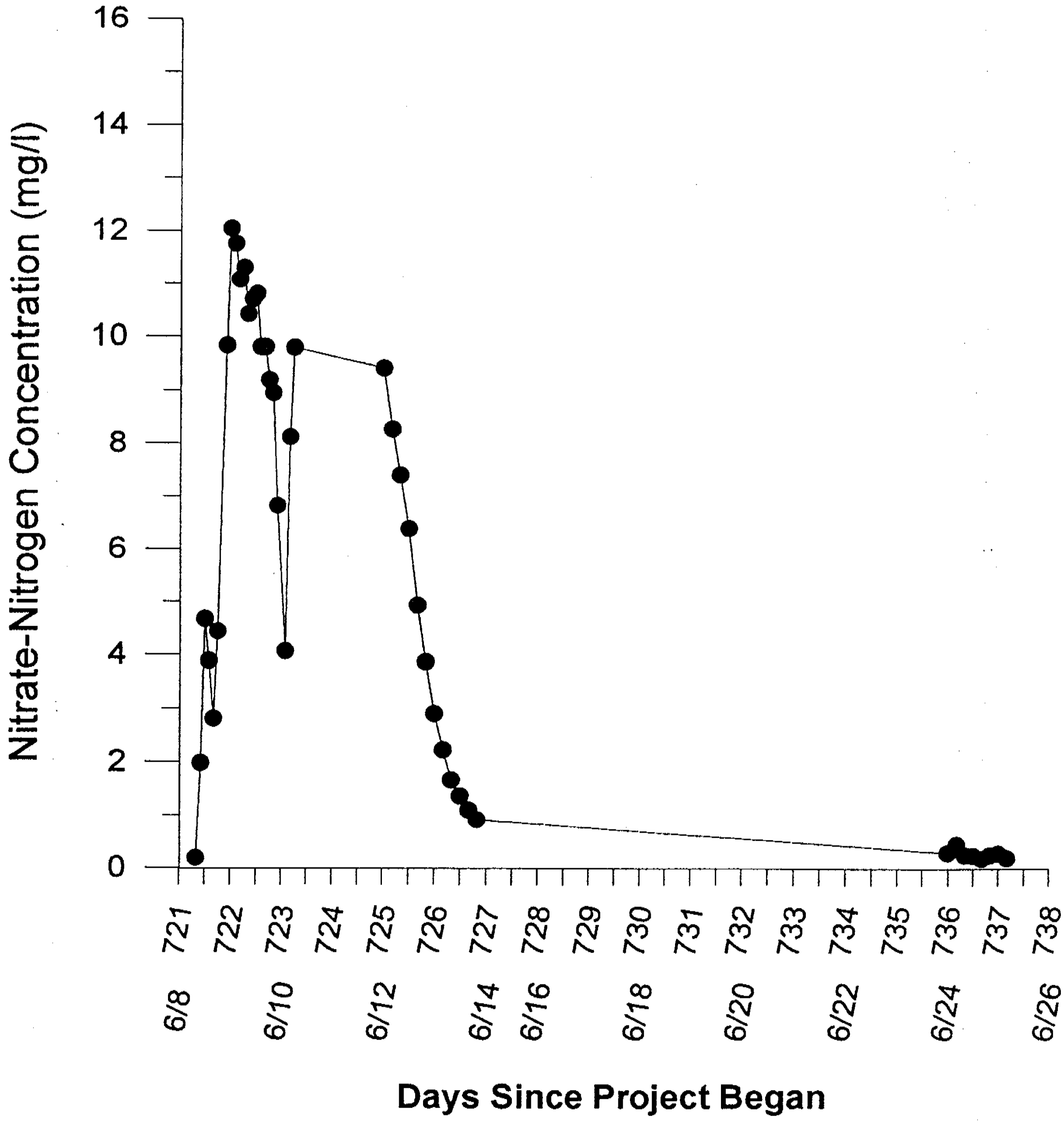


Figure 13. **Nitrate-nitrogen concentration with time at the downgradient manhole for the 6/8/94 irrigation event**

Figure 14 shows the NO_3-N concentrations at the Riverside Drain. This sampling was not automated and so the data has a much lower resolution than that from the manhole tile drain samples. However, the results show that the NO_3-N concentrations also increase here as a result of water input events. The background concentrations are significantly higher than the tile drain below the center bench, with an average range of 2.1 - 7.5 mg/l. This is due to the fact that the Riverside Drain collects return flows containing the NO_3-N mass from all four tiles. If the monitored tile drain line is located below different soil types with different transport properties, one tile could contribute more mass than another. In particular, the water flowing out the Riverside Drain is a reflection of the return flows from all three benches, not just the east and center benches as is the west manhole. The west bench is the largest and most heavily fertilized area at the site, receiving a total of 370 lbs N/acre (415 kg N/ha) from June 1993 to October 1995 (Table 2). The center bench received only 195 lbs N/acre (218.6 kg N/ha) during this time, with only 20 lbs N/acre (22.4 kg N/ha) added to the east bench.

Figures 15 and 16 show the NO_3-N concentrations over the 1995 irrigation season at the up- and downgradient manholes, respectively. In contrast to the 1994 chemical data, in 1995 there were no significant increases in NO_3-N concentrations as a result of irrigation events. Just prior to the start of the 1995 irrigation season, the east bench was fertilized with a nitrogen-phosphorous-potassium fertilizer (Table 2). This formulation is very low in nitrogen content as compared to urea and ammonium

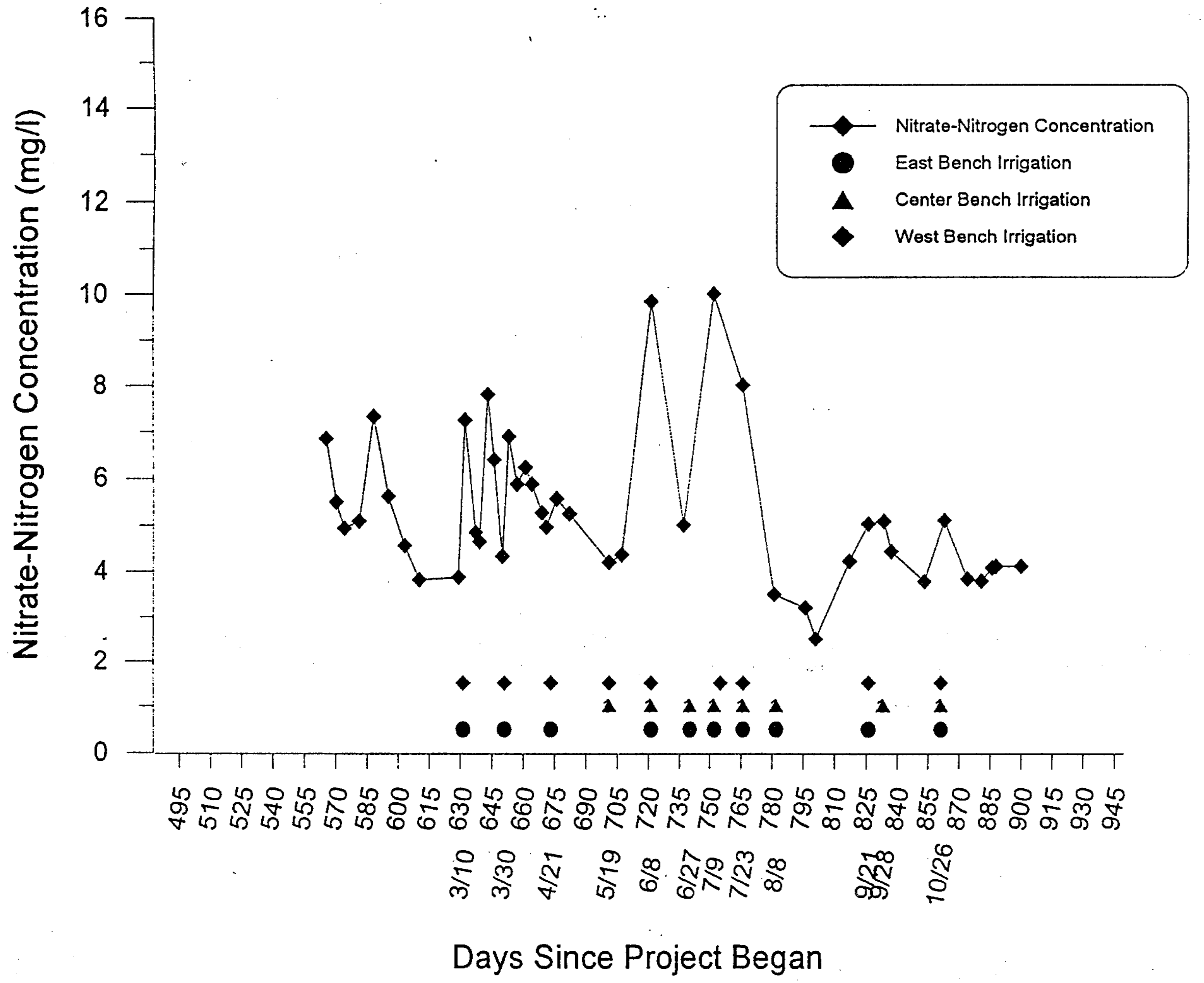


Figure 14. Nitrate-nitrogen concentrations with time at the Riverside Drain for the

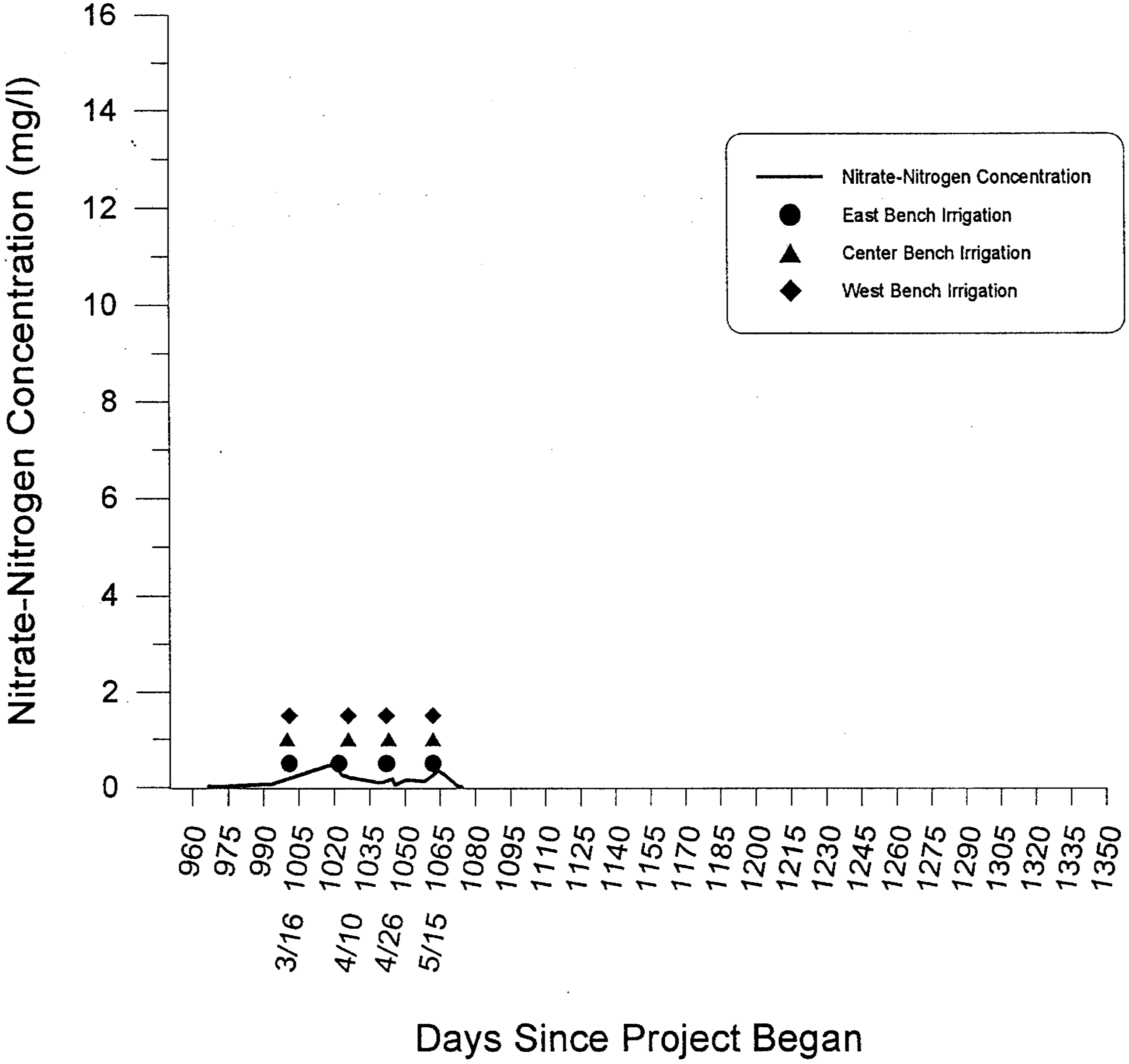


Figure 15. Nitrate-nitrogen concentration with time at the upgradient (east) manhole

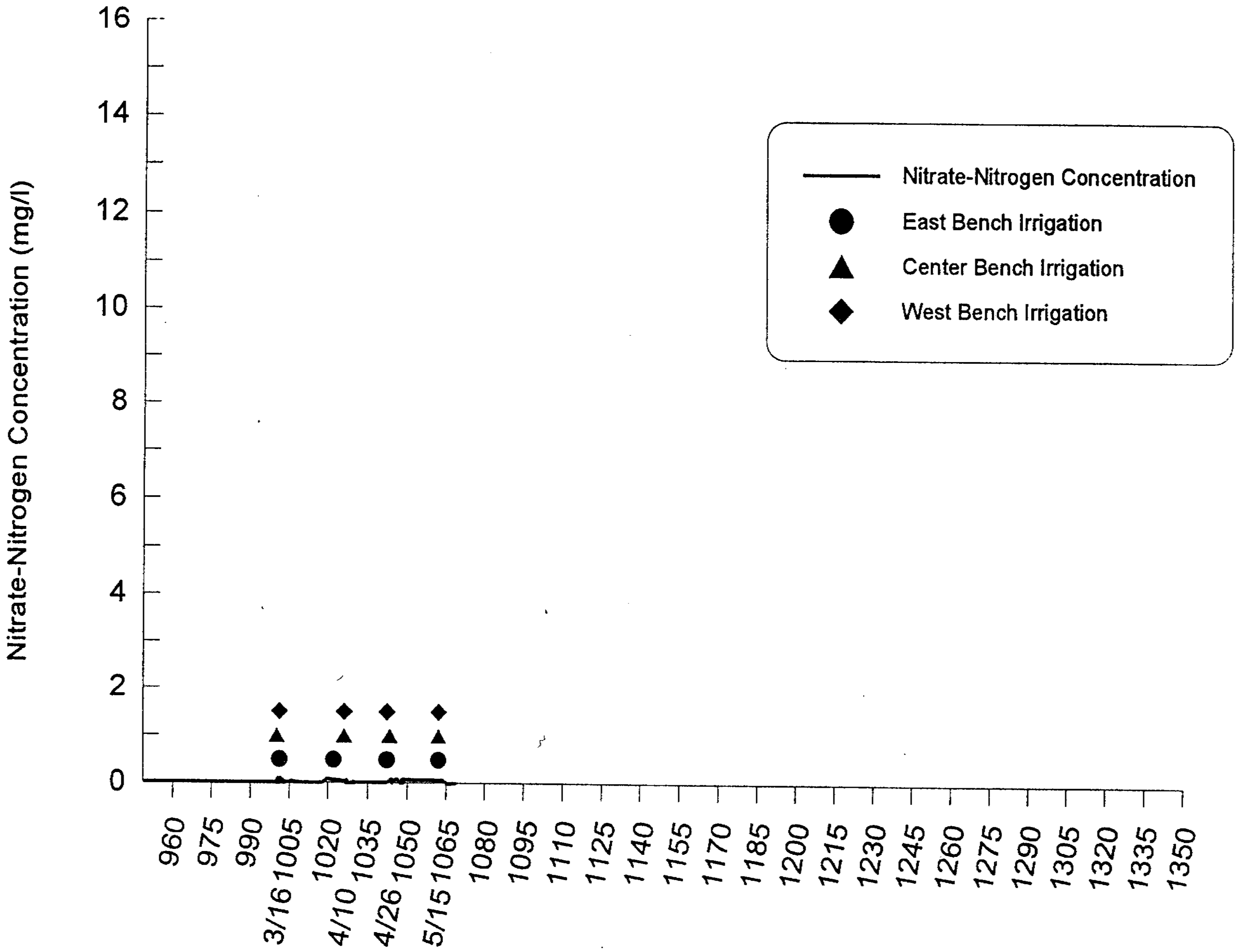


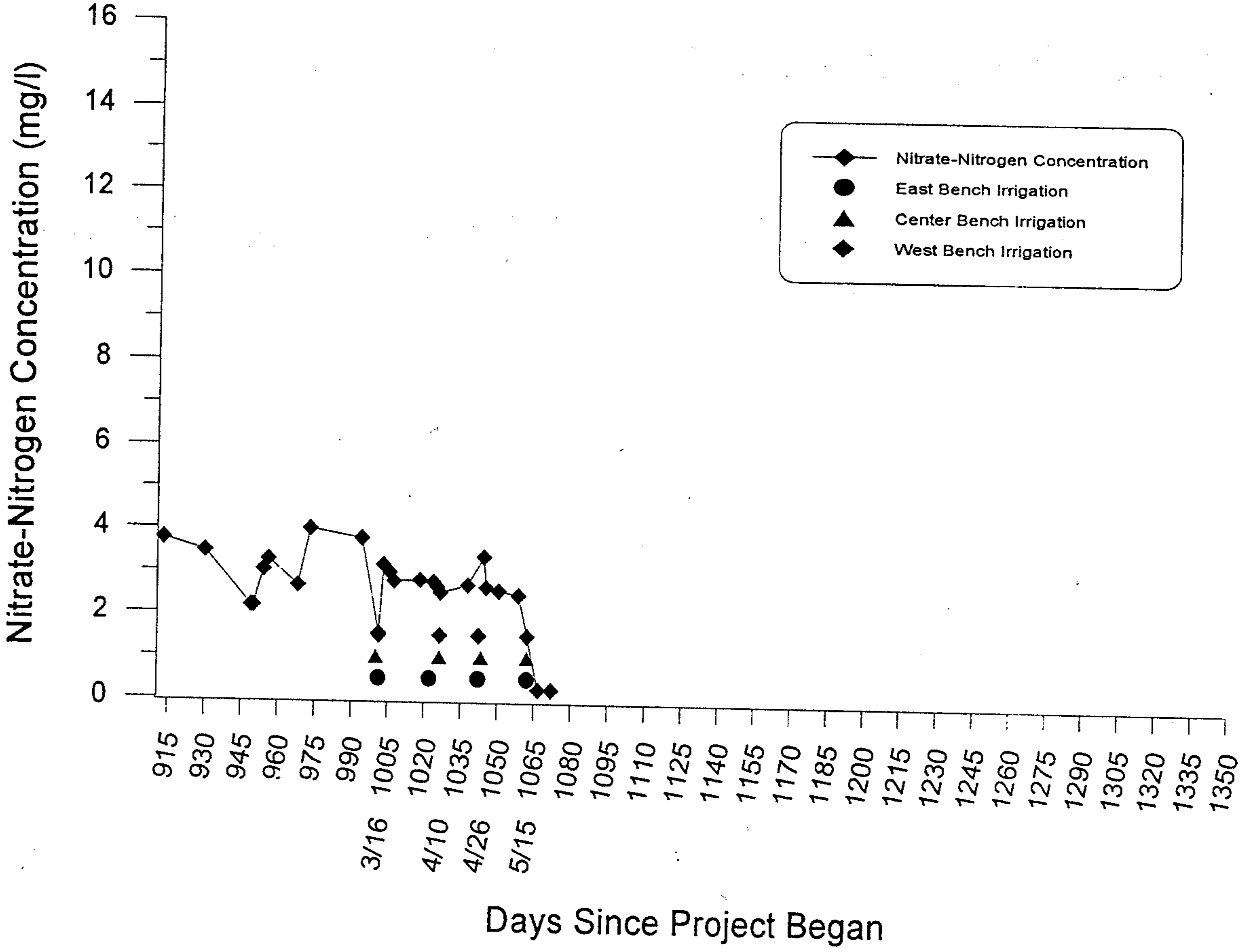
Figure 16. Nitrate-nitrogen concentration with time at the downgradient (west) manhole

sulfate (only 8% by weight), and therefore resulted in only 20 lbs N/acre (22.4 kg N/ha) applied to the bench. This was an inadequate replenishment of the mass of nitrogen that would be required to see the same response as that in 1994. Therefore, although irrigation practices during this season were similar to those in 1994, the chemical and nutrient management were not and so no significant increases in nutrients were seen in the tile drainage water.

The Riverside Drain samples taken in 1995 have background NO_3-N concentrations comparable to those taken in 1994, and are presented in Figure 17.

4.3.2.2 Electrical Conductivity

The electrical conductivity of the tile drainage water for the up- and downgradient manholes during 1994 is presented in Figures 18 and 19, respectively. As can be seen, there are fluctuations in the conductivity at both manholes, yet these fluctuations are much more erratic than the nutrient concentration increases, and do not seem to be a result of irrigation applications alone. The entire response for the variation in conductivity occurs over a shorter time period as compared to that for NO_3-N, ranging from 0.6 - 3 days. Average background conductivities are approximately 900-1200 umhos/cm, with peak values ranging from 1500-2500 umhos/cm. Figures 20 and 21 show the conductivity for each manhole during the 1995 irrigation season. The response to water inputs is similar in 1995 as to that in 1994. Figures 22 and 23 depict the electrical conductivity in the riverside drain for the 1994 and 1995 irrigation


Nitrate-Nitrogen Concentration (mg/l)
0
2
4
6
8
10
12
14
16
915
930
945
960
975
990
1005
1020
1035
1050
1065
1080
1095
1110
1125
1140
1155
1170
1185
1200
1215
1230
1245
1260
1275
1290
1305
1320
1335
1350
3/16
4/10
4/26
5/15
Days Since Project Began
Nitrate-Nitrogen Concentration
East Bench Irrigation
Center Bench Irrigation
West Bench Irrigation

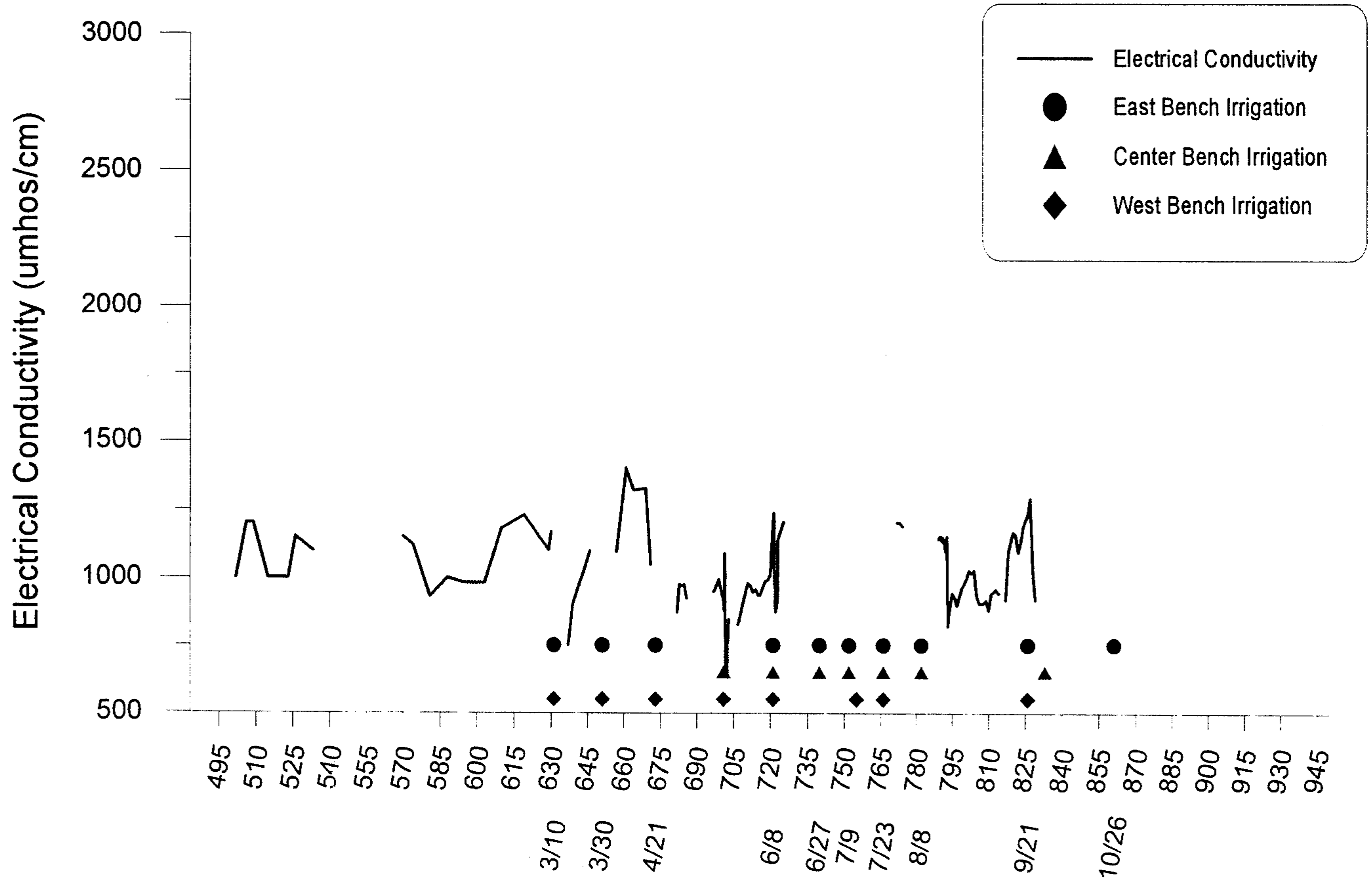


Figure 18. Electrical conductivity with time at the upgradient manhole

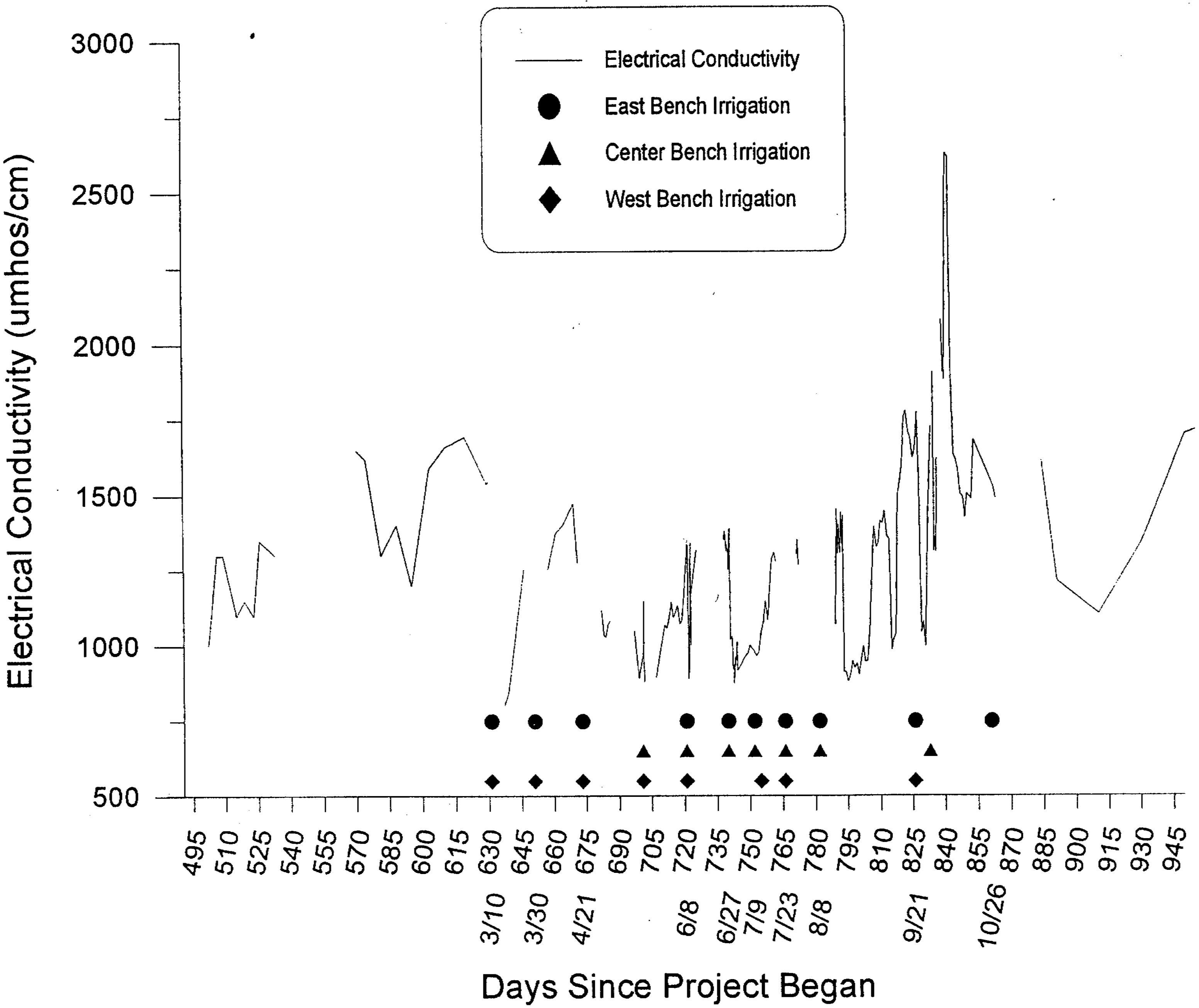


Figure 19. Electrical conductivity with time at the downgradient (west) manhole

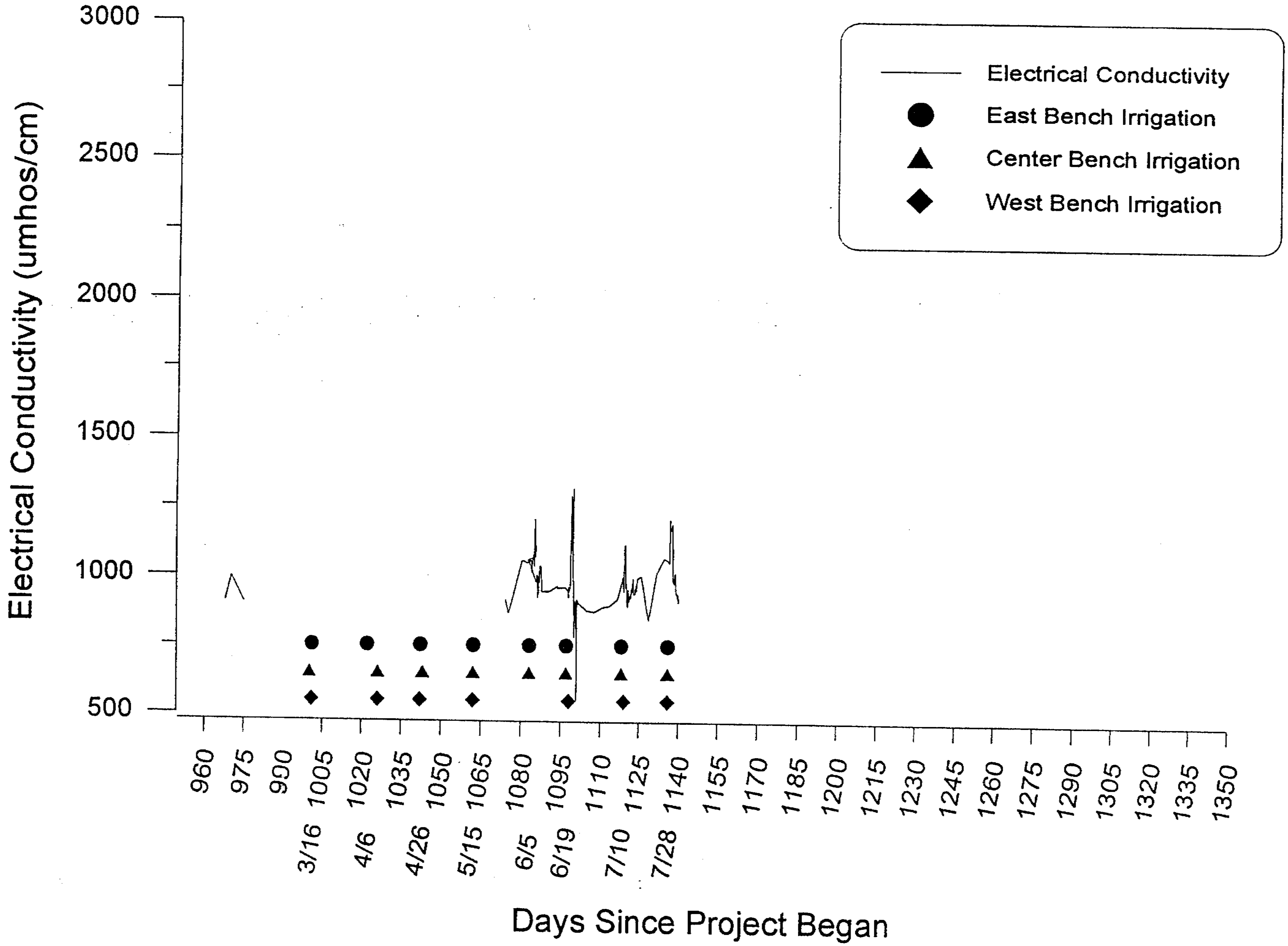


Figure 20 Electrical conductivity with time at th

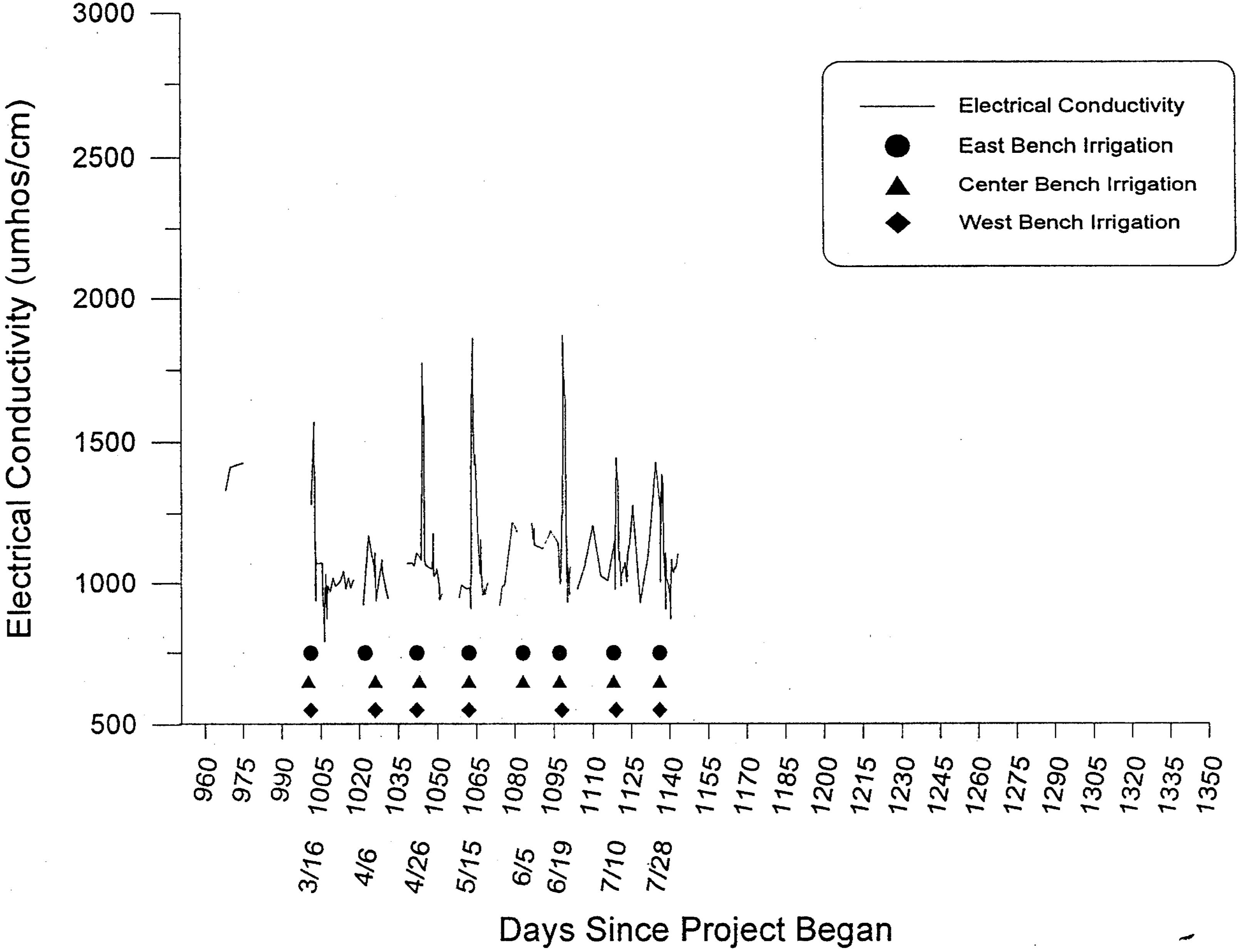


Figure 21. Conductivity with time at the downgradient (west) manhole

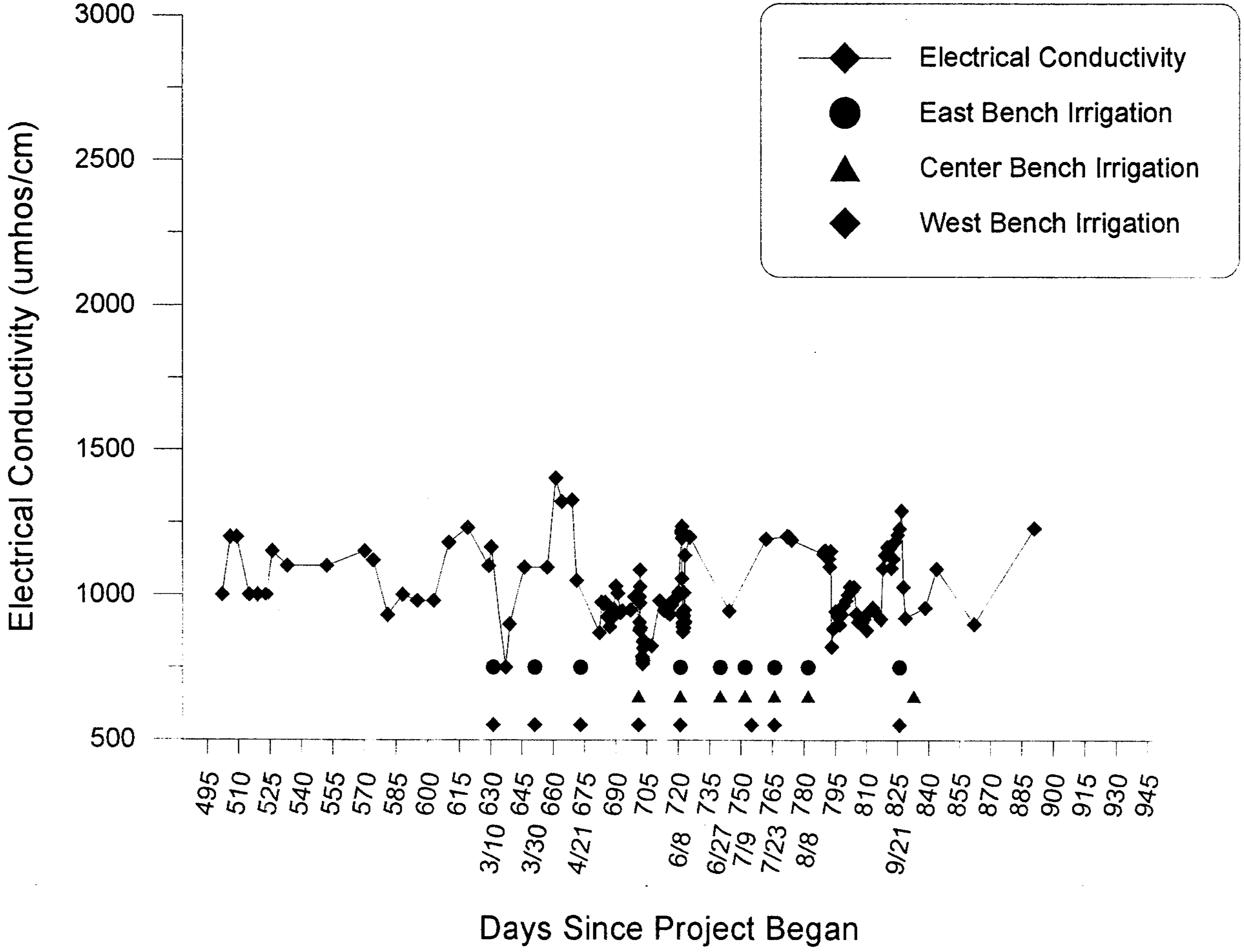


Figure 22. Electrical conductivity with time at the Riverside Drain

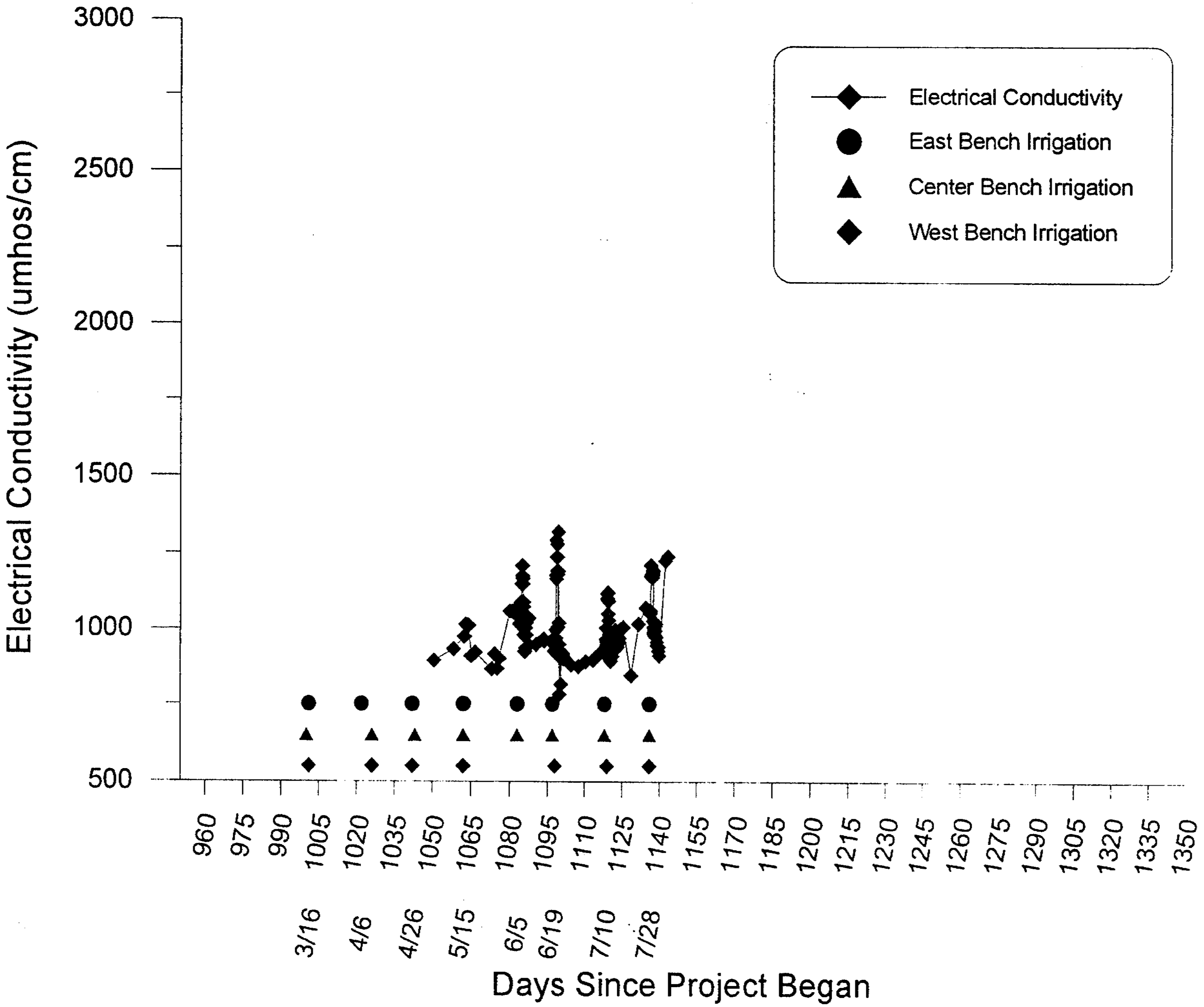


Figure 23. Electrical conductivity with time at the Riverside Drain

seasons, respectively. Background levels in this outlet drain are in the same range as for the manhole tile drain samples. All of these values correlate very well with data obtained from a study done in the San Acacia area located approximately 15 mi south of the Las Nutrias site (Wierenga and Patterson, 1974).

4.3.2.3 Chloride

Since the NO_3-N concentrations in the tile drainage water did not increase during irrigations in 1995 as they did in 1994, samples were analyzed for chloride to see if any concentration peaks occurred with irrigations. These results are for the downgradient manhole only and are presented in Figure 24. The breakthrough behavior for chloride is very similar to that for the other solute peaks, with rapid increases in concentration due to the water input events. The entire response seems to be approximately two days, however, a lack of data exists and so this is only a gross estimate. The few samples analyzed for chloride concentration in the Riverside Drain are in the same range of the tile drain background levels, and are not presented due to the lack of available information.

4.4 Mass of NO_3-N Lost to Shallow Groundwater

4.4.1 Distribution of Water Inputs and Outputs

Since the flow measurement systems were not installed in the manholes during the 1994 irrigation season, flow information obtained from the 1995 season was used with the 1994 nutrient concentration data to estimate a range for the mass lost to the

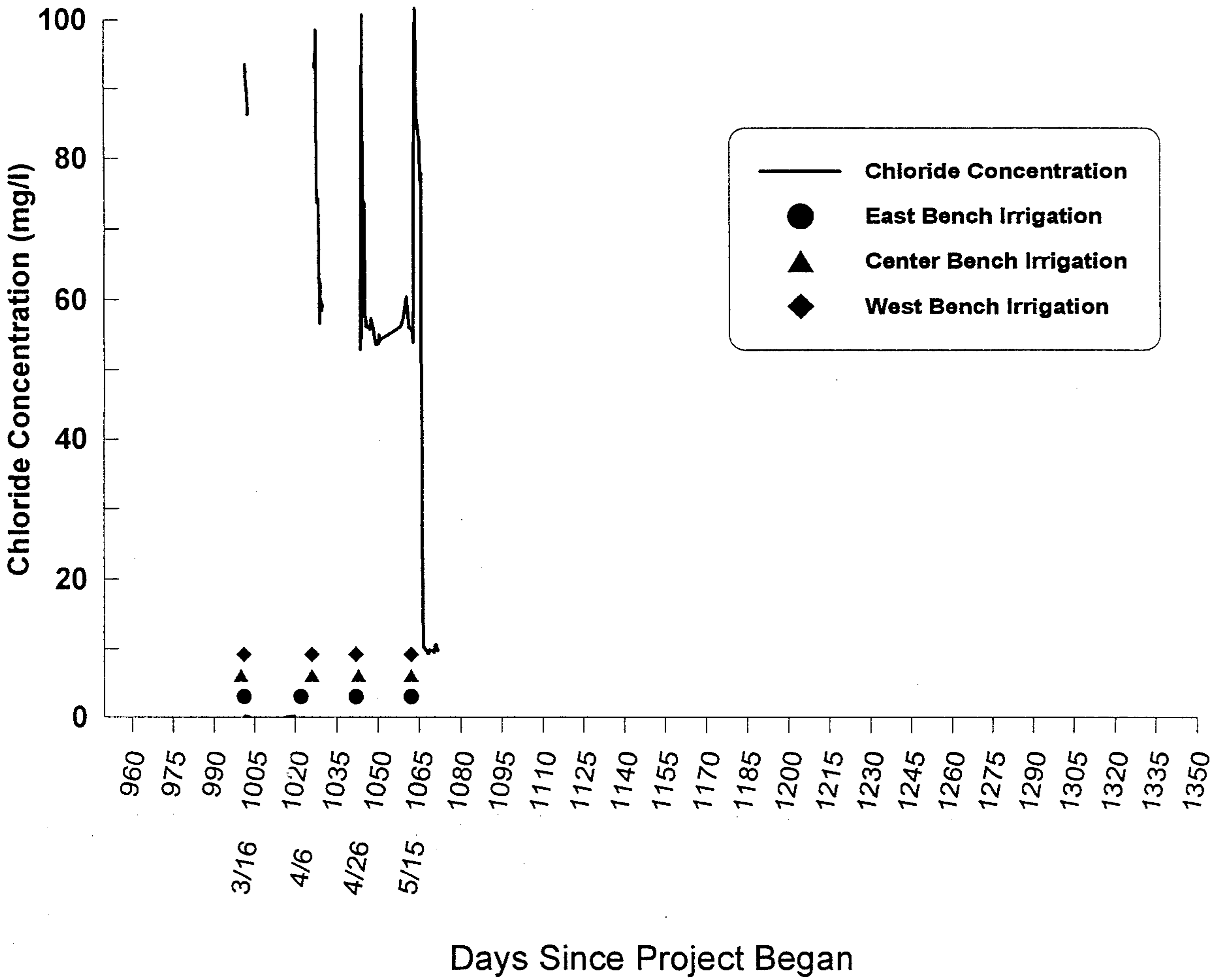


Figure 24. Chloride concentration with time at the downgradient (west) manhole

tile drain during the 1994 irrigation season. In doing this, the assumption is made that the water flow dynamics at the site do not change from one year to the next and that the differences seen in the tile drain chemistry occur mainly as a result of chemical management practices. Table 6 shows the mean water level and hydraulic head gradients per month calculated from data collected in the observation wells over 1994 and 1995. The hydraulic head for each well was determined by measuring the depth to water in each well and calculating the height of water in the well relative to a local datum of 100 m. This datum consists of a 6 in long, 1/4 in thick nail located in the southwest corner of the west bench, as determined by an NRCS well head survey done in the winter of 1994. The hydraulic gradients are calculated from the ratio of the change in hydraulic head to the distance (m) over which this change occurs. This distance was taken to be from the northeast corner of the center bench to the southwest corner of the center bench, as this is the prominent groundwater flow direction. As can be seen, the mean head and gradients vary only slightly between years. Comparisons of the total volume of water applied to the center bench per irrigation and per season (refer to Table 3) also show that this assumption is valid.

A water balance consists of a comparison of water inputs and outputs. Table 7 lists the monthly water balance for the center bench in 1994, with the recharge to the shallow groundwater system calculated by three different methods. The following discussion addresses how this balance was calculated. The flow data collected in the west manhole tile drain for the 1995 irrigation season is presented in Figure 25. The

Table 6
Mean hydraulic head and hydraulic gradients for the center bench

	mean head		
Date (month,year)	m	ft	mean gradient
Feb-94	98.79	324.130	4.30E-04
Mar-94	99.39	326.099	5.10E-04
Apr-94	99.24	325.606	1.00E-03
May-94	99.17	325.377	6.50E-04
Jun-94	99.2	325.475	7.20E-04
Jul-94	99.28	325.738	8.00E-04
Aug-94	-	-	-
Sep-94	99.17	325.377	6.30E-04
Oct-94	98.95	324.655	8.00E-04
Nov-94	98.9	324.491	7.20E-04
Dec-94	98.85	324.327	7.20E-04
Jan-95	98.78	324.097	6.90E-04
Feb-95	98.75	323.999	8.00E-04
Mar-95	98.95	324.655	5.80E-04
Apr-95	-	-	-
May-95	99.01	324.852	8.30E-04
Jun-95	99.1	325.147	8.70E-04
Jul-95	99.18	325.410	7.40E-04
Aug-95	99.26	325.672	5.10E-04
Sep-95	99.2	325.475	5.80E-04

Month	Precipitation*		Irrigation		Capillary Rise		ET**:				Groundwater Recharge:					
							1		2		1		2		3	
	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in
January	11.3	0.4	-	-	2.5	0.1	13.8	0.5	-	-	0.0	0.0	-	-	-	-
February	2.6	0.1	-	-	2.2	0.1	4.8	0.2	-	-	0.0	0.0	-	-	-	-
March	16.9	0.7	-	-	2.5	0.1	19.4	0.8	-	-	0.0	0.0	-	-	-	-
April	12.4	0.5	-	-	2.4	0.1	14.8	0.6	-	-	0.0	0.0	-	-	-	-
May	30.3	1.2	84.9	3.3	-	-	83.1	3.3	-	-	32.1	1.3	-	-	-	-
June	1.4	0.1	169.7	6.7	-	-	109.2	4.3	-	-	61.9	2.4	-	-	-	-
July	29.7	1.2	169.7	6.7	-	-	193.3	7.6	-	-	6.1	0.2	-	-	-	-
August	75.2	3.0	84.9	3.3	2.5	0.1	77.7	3.1	-	-	7.1	0.3	-	-	-	-
September	53.6	2.1	84.9	3.3	2.4	0.1	56.0	2.2	-	-	28.8	1.1	-	-	-	-
October	24.9	1.0	84.9	3.3	-	-	48.4	1.9	-	-	61.4	2.4	-	-	-	-
November	-	-	-	-	-	-	52.2	2.1	-	-	0.0	0.0	-	-	-	-
December	21.3	0.8	-	-	-	-	42.7	1.7	-	-	0.0	0.0	-	-	-	-
Yearly Totals:	**279.6**	**11.0**	**678.8**	**26.7**	**14.5**	**0.6**	**715.3**	**28.2**	**640.5**	**25.2**	**197.4**	**7.8**	**317.9**	**12.5**	**245.0**	**9.6**

Notes:

* - Precipitation in January and February was taken from 1995 measurements since the rain gages were not installed untill March 1994.

** - ET was calculated in two different ways:

1 - weather data and the upward flux due to capillary rse (as calculated by CAPSEV)

2 - WRRI technical report # 191 where the seasonal ET was calculated based on crop yield of sorghum in New Mexico

Table 7. 1994 Water Balance for the Center Bench

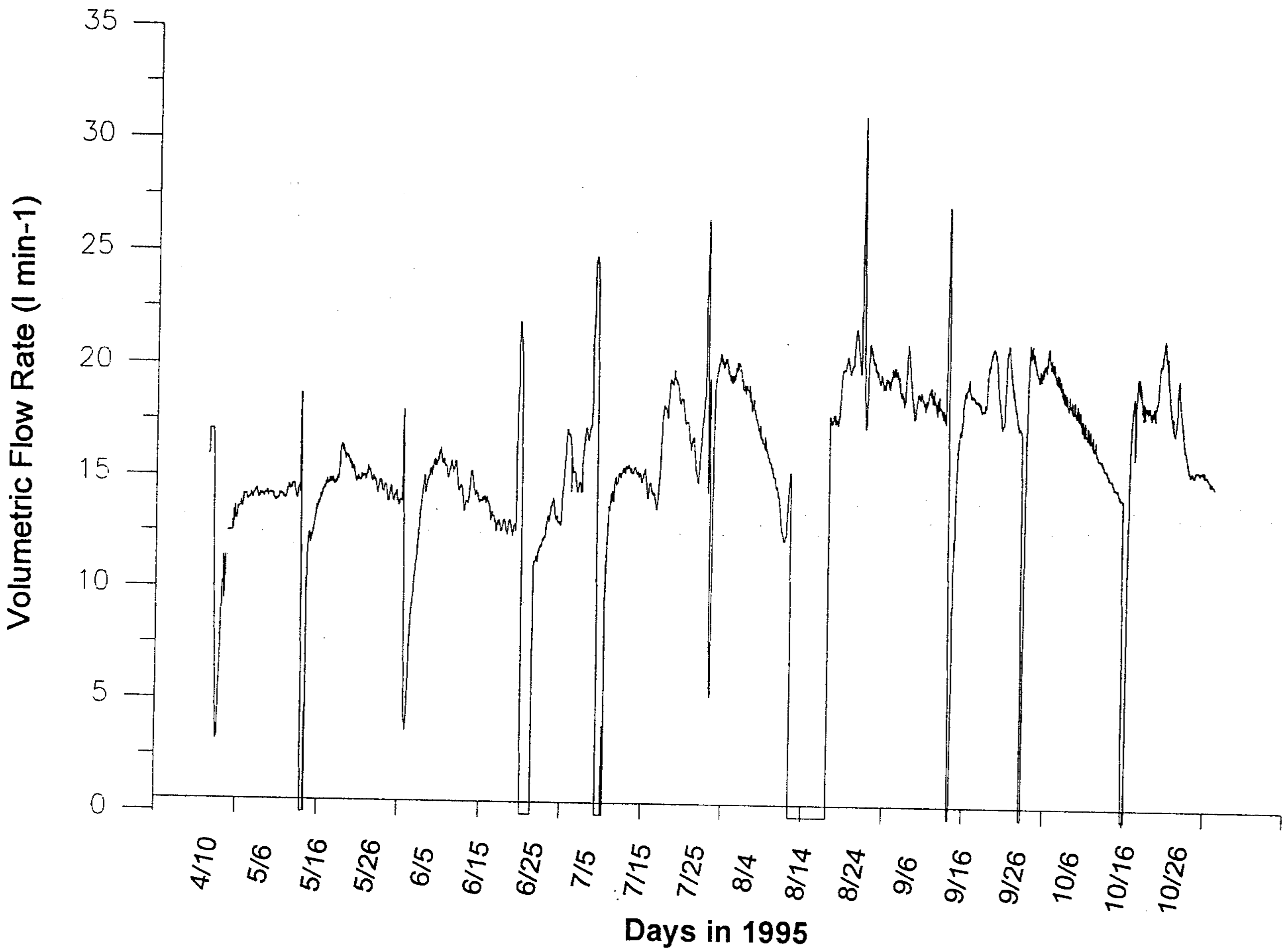


Figure 25. Volumetric flow rate vs time at the downgradient (west) manhole for the

perturbations in flow rates are the result of irrigation events. Increases in tile drain flow rates occur within a few hours after the water is applied and peak after only 5 - 15 h. The lower flow rates resume within 9 - 30 hours. As the irrigation season progresses, these background flow rates show a slight increase, with an average of about 15 l min^{-1} in March up to approximately 18 l min^{-1} by August and 20 l min^{-1} by September. This is due to the fact that agricultural areas all along the Rio Grande Valley during these regional low flow periods are irrigating on a regular schedule, and so a significant volume of water is entering the local groundwater system, increasing the hydraulic head and hence the water table elevations.

As Figure 25 shows, after several of the irrigations, flow rates rapidly decreased, eventually reaching zero flow. The flow measurement systems in the manholes are only capable of measuring fluxes of 2 l min^{-1} or greater. Therefore, the flow was not necessarily zero. However, this sudden decrease in flow rates indicates that the flow dynamics in this tile drain system are somewhat different than expected. These observations will be further addressed in the discussion section, as they can be used to analyze observations of the tile drain chemistry.

As stated previously, the total amount of precipitation measured at the field site was 276.52 mm (10.89 in) in 1994 and 102.40 mm (4.03 in) as of 24 September, 1995. This is the only other water input to the surface of the fields. Although these events, including the heavy ones during the summer monsoons (July through September), have never indicated a significant increase in tile drain flow or nutrient concentrations, the rainfall may contribute somewhat to the downward migration of nutrients through the upper portion of the soil profile. However, the evapotranspiration (ET) rates of this semi-arid climate peak at this time of year and so there is a significant flux of water upwards towards the soil surface. Therefore, it is likely that the precipitation is lost to ET at this time and that most of the nutrients stay concentrated in the upper soil profile between irrigations. It is possible that the sampling frequency in the drains during these precipitation events was not sufficient to indicate concentration increases. However, the magnitude of a precipitation event is much less than that of an irrigation, and so together with the ET loss, it is likely that the precipitation events do not contribute significantly to the mass transport of NO_3-N to the groundwater system.

ET and percolation to the deeper subsurface groundwater are the only water outflows from the system. The calculated ET for this study was estimated from two sources. The first is based on an empirical function relating crop yield to crop water consumption in New Mexico (WRRI 1985). The other method uses the potential evapotranspiration (P_{ET}) rate calculated from measured weather data obtained from the U.S. Department of Agriculture Plant Science Center in Los Lunas, New Mexico. Los Lunas is located approximately 20 mi north of the Las Nutrias field site. The measurements are made daily using information on air temperature, percent relative humidity, soil temperature, wind speed, and solar radiation. The data was converted to a mean monthly average for the purposes of this study. Since the P_{ET} is defined as the water loss that will occur if there is always a sufficient amount of water available to the crop (Thornthwaite 1944), an adjustment has to be made to account for the actual volume of water that a crop will use for a given field situation. This is done by multiplying the P_{ET} by an empirically determined consumptive use crop coefficient (Doorenbos et al, 1979). For the months where the crop cover was absent, the ET was estimated to be equal to the upward flux due to capillary rise, which was calculated using the computer program CAPSEV (Wesseling 1991), and added to the precipitation amounts for those times. Appendix 9.6.1 consists of all calculations and supporting data used for both ET estimates.

Appendix 9.6.2 contains all calculations and supporting data for the water distribution and mass loss estimates for the center bench in 1994. The average amount of water added to the center bench by irrigations during the 1994 season obtained from the circular weir measurements is estimated as approximately 679 mm (26.73 in). Adding the year long 1994 precipitation measurements indicates that a total volume of approximately 973 mm (38.31 in) was added to the center bench. Of this total volume added, 66 - 75% is lost to ET and the upward flux due to capillary rise. The remaining 25 - 34% of the applied water is, therefore, recharged to the shallow groundwater system. To determine what percentage of this groundwater recharge that is captured by the tile drain system, the up- and downgradient (east and west, respectively) manhole flow data was analyzed. As indicated by Figure 25, each irrigation event resulted in an increase in tile drain flow rates in the downgradient manhole. Data for the upgradient manhole was collected from 5 June 1995 to 26

September 1995; the response is similar to the downgradient manhole data. Since backflow occurred in the drain, the flow rates existing previous to the irrigation event were projected through the flow responses. This enabled us to estimate an area under the curve which corresponded to the total volume of water recharged to the drain. The volume in the upgradient manhole was subtracted from the volume in the downgradient manhole to determine the volume of water reaching the tile drain line below the center bench as a result of the center bench water applications only. Using the six irrigations which occurred from 5 June 1995 to 26 September 1995, flow volumes in the tile drains below the center bench were estimated to range from 0.63 mm (0.025 in) to 1.05 mm (0.041 in) per irrigation. Totaling this for the eight irrigations which occurred on the center bench in 1994 indicated that 5.04 mm (0.20 in) to 8.4 mm (0.33 in) was recharged to the tile drains. This corresponds to only 0.52 - 0.86% of the total water input. Therefore, most of the water recharged to the shallow groundwater system was not captured by the tile drains.

The recharge to the shallow groundwater system was also calculated by multiplying the amount of applied water with the ratio of the electrical conductivity in the applied water to the electrical conductivity in the tile drain water. The result falls close to the average of the other water balance calculations that were used to determine the NO_3-N mass losses. Again, all supporting data and calculations for each method are given in Appendix 9.6.2. The high correlation of recharge values estimated by the three different methods indicates that the recharge to the shallow groundwater is fairly uniform over the field site and therefore the NO_3-N losses seen in the instrumented tile drain are representative of the center bench as a whole. This is further supported when one considers the fact that the electrical conductivity in the drain correlated very well with the electrical conductivity found in the 2 m depth observation wells (Figures 10, 18, and 19).

4.4.2 NO_3-N Mass Losses

The mass of NO_3-N lost from the soil profile of the center bench to the instrumented tile drain per irrigation in 1994 was calculated using the average range of the water flow response in 1995. The results were multiplied by the four tile drains and the eight irrigations that occurred on the center bench to obtain a total mass lost from the center bench due to the 1994 irrigations. Calculations of the mass lost in between irrigations were done using the average seasonal tile drain flow rates and NO_3-N concentrations. These two results were added together to obtain the total mass lost to the tile drains during 1994. Since measurements of the tile drain flow indicate that the drains collect only a small portion of the water actually recharged to the groundwater system, the mass lost from the tile drains was used to calculate the total mass lost from the center bench due to groundwater recharge. The average range of NO_3-N mass loss per irrigation from all four tiles is 1.4 - 3.73 lbs (0.64 - 1.69 kg), and the mass in these four drains in between irrigations is approximately 1 - 4.5 lbs (0.45 - 2.04 kg). The cumulative total of the mass lost from the center bench during the 1994 irrigation season then ranges from 12.34 - 35.55 lbs (5.6 - 16.13 kg). This is only 0.5 - 1.4% of the mass found from samples collected from the soil profile prior to the 1994 irrigation season. However, the chemical composition of the tile drain water is an indicator of the quality of the water that moves between and below the drains. The following discussion explains how this mass was calculated.

The total recharge to the shallow groundwater is the difference between the water inflows and outflows. Assuming there is relatively little change in the soil water storage over the coarse of a year, the total recharge applied to the center bench during the 1994 irrigation season minus the ET is equal to the volume of water recharging the drains and the shallow groundwater system. This is a valid assumption if one considers the fact that the percent soil gravimetric water contents did not change significantly from the 1994 and 1995 soil sampling events (Figure 8). Therefore, by dividing the difference between the total water inputs and ET by the range in the volume of water actually captured by the tile drains gives the range of the fraction of recharge lost to shallow groundwater that is not intercepted by the drains. When this is multiplied by the ranges for the NO_3-N mass lost in the tile drain, the result is an estimate of the total mass lost to the shallow groundwater. Table 8 gives a summary of the water distributions for the center bench along with the mass of NO_3-N lost to the groundwater system. Again, Appendix 9.6.2 contains all supporting calculations. This total mass loss then was calculated to range from approximately 633 - 1413 lbs (287 - 640 kg), which corresponds to approximately 25 - 55% of the total mass in the soil

Table 8
Summary of 1994 Center Bench Water Distributions and Mass of NO_3-N Lost to the Groundwater System

Water Input:

Average volume of water added to the center bench per irrigation: 5.86E6 liters (84.85 mm; 3.34 in)
Total of eight irrigations: 4.69E7 liters (678.80 mm; 26.72 in)

1994 Precipitation: 1.89E7 liters (279.64 mm; 11.01 in)

Total Water Input: 6.58E7 liters (973.43 mm; 38.32 in)

Discharge:

Evapotranspiration (WRRI Report #191): 4.33E7 liters (640.53 mm; 25.22 in)
(Los Lunas weather data): 4.84E7 liters (715.3 mm; 28.16 in)

Volume of water lost to the four tile drains (low estimate): 3.39E5 liters (5.04 mm; 0.20 in)
(high estimate): 5.66E5 liters (8.4 mm; 0.33 in)

Mass of NO_3-N lost to tile drains:

low estimate: 5.6 kg; 12.34 lbs
high estimate: 16.13 kg; 35.55 lbs

Total mass of NO_3-N lost to groundwater recharge:

low estimate: 287 kg; 633 pounds (approximately 25% of initial mass)
high estimate: 641 kg; 1413 pounds, approximately 55% of initial mass
average mass loss: 40% of initial mass

profile of the center bench just prior to the 1994 irrigation season. The average mass loss is then 40%. This also represents approximately 44 - 98% of the nitrogen fertilizer added to the center bench just prior to the 1994 growing season.

5.0 DISCUSSION

5.1 Data Analysis

5.1.1 Soils

The concentrations of NO_3-N in the upper soil profile in 1994 are extremely high for irrigated agricultural soils (Rudy Garcia, NRCS, pers. comm.). Soil nitrate is of several forms and comes from a variety of sources, such as mineralization of soil organic matter, nitrification mediated by bacteria, degradation of crop residues, and nitrogen fertilization. The majority of the soil water nitrogen on the center bench of the Las Nutrias site is likely a direct result of nitrogen fertilization. The center and west benches were planted to winter wheat on October 10, 1993, which was near the end of the irrigation season. Both benches were then fertilized with urea, which resulted in approximately 90 lbs N/acre (100.9 kg N/ha; 1500 lbs or 680 kg N total to the center bench) added to what was left over from the earlier 1993 applications. Unfortunately, the wheat did not grow on this bench during the winter of 1993/1994. This was probably due to high soil salinities, since wheat is very sensitive to high soil water electrical conductivities. Electromagnetic induction surveys performed frequently at the site as well as visual inspection of the field have indicated that this has usually been a problem on the center bench. Therefore, during the winter months, there was essentially no plant uptake of the nitrogen that was available from the urea fertilizer, and so a large mass of nitrogen remained in the soil profile for quite some time. Eventually, in May of 1994, the landowner planted the center bench to a sorghum-sudan cross. This crop did quite well and likely utilized the 45 - 75% of soil water nitrogen not lost to the groundwater system.

There are several other pathways by which soil nitrogen can be lost or depleted. One such mechanism that is perhaps second only to plant uptake is bacterial denitrification, which is the reduction of nitrate to gaseous forms of nitrogen. Organic matter can also be responsible for the immobilization of nitrate through assimilation. These mechanisms are controlled by soil moisture content, crop cover, and the type of nitrogen fertilizer used (National Research Council, 1978).

The overall lower concentrations present in 1995 reflect the fact that most of the nitrate in the soil profile was depleted as a result of leaching, plant uptake, and denitrification during the 1994 irrigation season. Since at the end of the 1994 irrigation season all three benches were planted to alfalfa, nitrogen fertilization was not required, and so there was no significant source of soil nitrogen replenishment after the 1994 water inputs.

5.1.2 Wells and piezometers

The NO_3-N concentrations in the 2- m- deep wells on the east bench which are generally higher than those found in the remaining wells (see Appendix 9.3.1.2) could be related to former land usage, considering the high density of fertilized areas surrounding the site as well as the existence of a dairy approximately 1 mi east of the site. Nitrogen buildup in the soil profile as a result of several years of alfalfa, which is a nitrogen- fixing plant, could also account for the higher NO_3-N concentrations in these east bench wells. However, given that there were no significant increases in NO_3-N concentration in the tile drain water during the time of alfalfa cultivation in the 1995 irrigation season, this does not seem to be the case at the Las Nutrias field site. There is relatively little evidence that alfalfa releases large amounts of the nitrogen that it fixes, and that more likely than not, nitrogen release under alfalfa fields is a product of plant decomposition (Lory et. al., 1992). It is more likely then that the fertilization of upgradient fields (north and east of the site) causes these higher NO_3-N concentrations in the observation wells of the east bench. However, these solute concentrations in the groundwater are extremely low and do not exceed the EPA maximum contaminant level of 10 mg/l NO_3-N. Given this information as well as the fact that the piezometer concentrations are also very low, it can be concluded that the regional groundwater does not contribute any significant amount of nitrogen mass to the local groundwater below the Las Nutrias site.

5.1.3 Tile drains

Several factors contribute to NO_3-N leaching in unsaturated soil profiles, such as the climatic conditions of the region, the vertical infiltration of the soil water storage to the groundwater, and soil-nutrient interactions. In arid regions, the spring and early summer irrigations and rainfall events are much greater than ET, and so in general, the soil water held in storage is lost to downward percolation. During the late summer, fall, and winter months, this reserve of stored soil water becomes lost to ET as a result of decreased precipitation and irrigation inputs. Water loss from evapotranspiration is greater than percolation losses for cropped soils, whereas percolation losses are greater than ET losses for bare soils.

The above concepts can be used to explain the 1994 breakthrough patterns of NO_3-N in the tile drainage water (Figures 11 and 12). As stated previously, the winter wheat crop on the center bench in 1993-1994 did not grow, and so the soil was bare until May 1994. During this winter, the evapotranspiration was low because no crop was present, however, percolation losses were also low because there was relatively little precipitation and no irrigation events. As a result, the major portion of the NO_3-N present in the soil profile was preserved. When the center bench was planted to sorghum in May of 1994 and started receiving irrigation water, the nutrients not immediately used by the plant were easily flushed through the soil to the groundwater. As the sorghum grew, the plants utilized more and more of the soil water nitrogen, and so by the end of the season, irrigations did not result in excessive amounts of nutrients leaching from the upper soil horizons.

The crop type present on an irrigated field has a significant impact on the mass of nutrients leaching through the unsaturated soils to the tile drains. Crops use nitrogen at different rates, depending upon the type of plant, the degree of plant maturity, the availability of other nutrients, and other properties which are related to the quality of the soil and soil water. As presented earlier in Table 1, several crop rotations have taken place on the center and west benches since 1993. The east bench, however, has been planted to alfalfa for more than three years. Since alfalfa is a nitrogen-fixing plant, i.e. it produces most of the nitrogen it needs, the east bench did not receive any significant amount of nitrogen fertilizer during the course of this study (see Table 2). However, as Figures 11 and 12 show, NO_3-N concentration increases in the east manhole during the 1994 irrigation season almost mimic those seen in the downgradient tile flow. The first irrigation of the 1994 season was done on the east and west benches only, and so theoretically, the water chemistry in the upgradient manhole would reflect only the leaching from the east bench. However, given the fact that no significant nutrient losses occurred from either bench in 1995 reflects the fact that the presence of the alfalfa does not produce large quantities of nitrogen that would be susceptible to leaching. In addition, an irrigation of all three benches performed in October 1993 at the end of the irrigation season also did not cause increases in NO_3-N concentrations at either manhole. This indicates that the nutrient concentrations observed in the east manhole tile drain water in 1994 is a reflection of the center bench soil water chemistry. Analysis of the harvesting records (Table 2) has indicated that harvesting does not contribute to the availability of nutrients to leaching. The 1995 flow data for the tile drain (Figure 25) indicated that after irrigations, flow rates rapidly decreased to levels which could not be accurately resolved by the flow measurement system. This indicates that the local groundwater flow directions can be reversed for short periods during and after irrigations and that water from downgradient benches can backflow into the drains. This depends on the order in which the fields are irrigated; for example, water will flow west to east on the center bench if the west bench only is irrigated, yet the extent to which this happens depends on the irrigation of the east bench. In most cases, this may result in water being forced out of the drains and into the surrounding soil matrix. If the east bench were irrigated later enough so that the head gradient could reverse on the center bench, or if it were irrigated at a much lower rate, an irrigation on the west bench could eventually cause backflow into the east manhole, and hence the chemistry would reflect the center bench soil water nutrient levels.

The fact that infiltrated water may stagnate at and around the drains as a result of irrigation would explain the somewhat long period of time where NO_3-N concentrations stay at a peak although the tile drain flow perterbation has ceased. The same groundwater with high concentrations of nutrients would be sampled repeatedly, as this is what reaches the tile drain at the initial stages of the irrigation response. If this is the case, the mass of NO_3-N that is actually lost to the groundwater system would be somewhat less than that calculated. By disregarding the high NO_3-N concentrations during times of backflow, calculations of mass loss to the tile drains decrease by 24 - 75% to a range of 3.08 - 27.02 lbs (1.4 - 12.26 kg) N. The wide range in this estimate is a result of variations in the amount of time that stagnation around the drains could have occurred (refer to Figure 25). The decrease in the mass loss to the tile drains per irrigation results in a new range for the total mass lost due to groundwater recharge of 6 - 42%. This is a much lower range than that previously calculated, with an average of 24% mass loss as opposed to an average of 40% loss. This backflow theory would also explain the absence of any tailing of the breakthrough curve. Once all the higher concentration water re-entered the drain and moved downgradient, the water near the drain would then be low in concentration such as is seen in between irrigations, and so the NO_3-N concentrations would appear to suddenly decrease, as opposed to gradually tailing off.

The calculated ranges in the mass of nitrogen lost from the center bench (25 - 55% not accounting for water stagnation around the drains; 6 - 42% accounting for stagnation) are somewhat high as compared to other agricultural areas in the country. For example, similar studies done in Indiana (Kladivko et. al., 1991) and Ohio (Owens et. al., 1994) have shown that nitrogen mass losses are in the range of 6 - 26%, and 16 - 47% of fertilizer nitrogen (lbs N/acre) applied to the soil surface, respectively. However, these studies have indicated that these losses occur annually, whereas for the Las Nutrias site, the calculated mass loss ranges may have occurred only once as a special case when the winter wheat crop did not grow and a large percentage of the nitrogen mass was available for leaching to the groundwater. Twenty percent of the mass of nitrogen present in the soil profile of the center bench at the 1994 soil sampling event was still present after the 1994 irrigation season. Since the total mass lost to the groundwater ranged from approximately 6 - 55% (the range when including the backflow theory), this means that approximately 25 - 74% of the nitrogen went to plant uptake and/or denitrification. Calculations were done to determine the nitrogen uptake by the sorghum based on the reported crop yield and a carbon:nitrogen ratio of 12:1 (Hartmann et al., 1981). Since the sorghum yield of 180 tons/47 acres (3.83 tons/acre) was harvested as a moist or wet grain, the water content of the plant had to be subtracted out from the weight before the carbon:nitrogen ratio method could be applied. With limited knowledge of the actual sorghum grain yield or weight, a range of 75 - 95% water contents were used in the calculations (Mengel and Kirkby, 1978). This resulted in 35.18 lbs/acre (39.51 kg/ha) to 175.91 lbs/acre (197.58 kg/ha) of nitrogen uptake by the sorghum. This represents 27 - 136% of the calculated nitrogen lost from the soil profile during the 1994 irrigation season. Therefore, it is not only difficult to determine the actual mass of nitrogen utilized by the sorghum, but it is also difficult to determine whether or not denitrification is an important process at the Las Nutrias field site. If the data from the instrumented tile drain line is not as representative of nutrient leaching as has been determined, then a lower amount of mass could have leached below the field site. If there are errors associated with the calculations of the mass of NO_3-N in the soil profile prior to the 1994 growing season, or the soils sampled along the transect were not representative of the entire center bench, a greater or lesser mass may have been present and so a greater or lesser portion of NO_3-N could have been lost to denitrification and/or groundwater percolation. In reference to Figure 6, which shows the soil types for the center bench, it can be seen that the upper soil profile contains rather high percentages of clay and/or silt. Denitrification, an anaerobic process, usually occurs in clay or silt soils with high moisture contents. It is likely then that for the first couple of months of the 1994 irrigation season, when the soil was still rather bare, excess nitrogen could have been lost as gaseous forms. Once the sorghum crop (planted in May 1994; figure 1) grew and started utilizing the nitrogen, perhaps the nitrogen available to denitrification would decrease, yet the rate of denitrification would increase with the application of irrigation water and the subsequent increase in soil moisture contents.

As stated previously, the agricultural areas of the Rio Grande Valley exhibit many of the same soil characteristics. The main crops grown in this area are corn, chile, sorghum/sudan cross, wheat, and alfalfa. Most areas practice flood-irrigation on nitrogen fertilized fields (excluding the alfalfa crops). Based on the above data analysis, it appears that no real threat on the groundwater quality due to agricultural practices exists in this area. However, under certain circumstances this may not be the case. As with the Las Nutrias site, excessive soil salinities or the possible lack of essential nutrients other than nitrogen may prohibit crop production. In such a situation, localized contamination of the groundwater may occur.

Mass loading of nitrate from broad, non-point sources such as found in agricultural areas can also impact surface water bodies. Nitrate fluxes to lakes and streams cause increased plant growth and changes in the dominant plant species. This can lead to a deterioration in water quality by pH changes or increases in eutrophication (organic nutrient growth) that may be lethal to many types of fish species.

5.2 Conceptual Model of NO_3-N Transport

The period of time associated with the complete NO_3-N breakthrough in the tile drainage water indicates that the nutrient response to water inputs is shorter than would be expected from the usual processes of dispersion and diffusion. Therefore, several other factors must be considered. Agricultural soils contain gopher and earthworm burrows, degraded plant roots, and soil cracks from the shrinking and swelling of clays. The presence of these macropores then defines the soil as bimodal in character - one domain is the soil matrix, where water flow can be described by Darcy's Law, and the other consists of a series of macropores with a significant degree of vertical continuity where flow is due to gravitational forces only. When the soil is fertilized, the nutrients are concentrated in the upper 5 cm or so of the soil profile. With each irrigation, infiltrating water flows through the soil profile, yet the larger pores conduct water much faster, and so the nutrients located there are rapidly transported to the water table. The bulk of the nutrients, however, are concentrated within the less permeable soil matrix, and so are only redistributed throughout the soil profile. In between irrigations, nutrients in the soil matrix diffuse into the macropores by mass transfer as a result of concentration gradients. Then, during the next irrigation, solutes rapidly reach the drain as these macropores are again drained more easily. Therefore, in terms of mass losses, only the macropores which conduct water the fastest are significant. This hypothesis also explains why high concentrations of nutrients are detected with subsequent irrigation events although only one surface application of fertilizer to the center bench had been performed.

The preferential flow hypothesis is further supported when one considers the rapid increase in chloride concentrations at the downgradient manhole during 1995 (figure 24). Since the chloride concentrations stay high for a couple of days as do the NO_3-N concentrations and then rapidly decrease, the hypothesis of backflow in the tile drains and subsequent stagnation of water around the drain lines is also supported. In effect, since the flow data indicates that water may stagnate around the drains for quite some time after an irrigation, the water chemistry of the samples taken during this interval of time is representative of water that would have normally passed through the drains at a previous time.

6.0 CONCLUSIONS

The high concentrations of NO_3-N that appeared in the tile drainage water during the 1994 irrigation season were due to the chemical management practices. However, since the high amount of NO_3-N in the soil profile prior to the 1994 irrigation season was a result of the winter wheat not growing, this is a special case and should not be considered the norm. The landowner dealt with this situation the best he could by not re-fertilizing the center bench before planting the sorghum and by holding off on irrigating that field until the crop could utilize the nitrogen leftover in the soil. The landowner was obviously aware of the potential for nitrogen leaching, and wanted to prevent this from happening.

The ranges in the percent of nitrogen lost from the soil profile of the center bench in 1994 are somewhat high yet are more or less comparable to other areas of the country where nutrient leaching is a problem. Yet, as indicated above, this was a special case of the lack of growth of the winter wheat, and so it can probably be assumed that overall, mass losses of nitrogen from the soil in this area are usually fairly low and perhaps insignificant in terms of groundwater contamination.

Rapid transport of nutrients and chemicals at the Las Nutrias fieldsite occurrs through preferential flow mechanisms. Water and solutes flow preferentially through the larger pores during an irrigation event. The nutrients contained within the slower moving matrix water are redistributed with depth during an irrigation event. In between irrigations, a mass transfer of nutrients occurrs from the matrix into the macropores, and the cycle begins again. Eventually, the nutrients are depleted to levels where the applied irrigation water effectively dilutes them and no more significant mass loss occurs from the soil profile.

At Las Nutrias, the low efficiency of the tile drains to effectively drain the soil profile also has an impact on the transport of nutrients. The observations of backflow indicate that perhaps the nutrient peaks last for several days because water has moved from the drains back into the soil matrix. Once the flow rates slow down and the volume of water entering the tile drain decreases, the higher concentration water that initially stagnated around the drains re-enters the tile and is sampled again. Once the head gradient is reversed back to its normal direction (east to west), the concentrations sharply decrease, masking any tailing effects that more likely than not would have normally occurred.

7.0 RECOMMENDATIONS FOR FUTURE WORK

Several aspects of the groundwater chemistry data collection could be improved if the Riverside Drain canal were dredged out. Since the project began, this outlet drain has been submerged by the deposition of fine sediments. Dredging this canal would not be likely to increase the efficiency of the tile drain system by lowering the water table. Free-fall is not possible at the drain outlet, however, a sump - and - pump system may improve the situation, yet this is a very expensive instrumentation. Flow measurement systems and automatic water samplers could be installed with this kind of instrumentation, and a much better analysis of nutrient and/or chemical leaching from the field site as a whole could be accomplished. In particular, the influence that the west bench fertilizations has on the groundwater quality could be investigated.

Seasonal soil sampling at the field site would give more information on the time-dependant nitrogen leaching within the soil profile. Implementation of this work could also serve as a way to investigate nitrogen losses from the soil profile due to denitrification processes.

Measurements of evapotranspiration on-site would enable investigators to more accurately predict mass losses of fertilizer nitrogen to the groundwater system by improving the water balance calculations.

As stated previously, the drains collect only 0.5 - 1% of applied water. If even this small percentage of water does not drain properly and water flows out of the drains and stagnates within the surrounding soil matrix, then perhaps the drains should be larger in diameter or more closely spaced. This would enhance their drainage capacities and therefore their representation of solute leaching from the field as a whole.

Tracer tests using several groundwater tracers would give information not only on the transport properties of the soil, but also on the pathways of groundwater movement to and around the tile drain lines. If at least two different types of tracers could be used with one on each side of the drain, information could be obtained on what portion of the center bench contributed water to that particular tile line.

8.0 REFERENCES

Anderholm, S.K., M.J. Radell, and S.F. Richey. 1995. Water quality assessment of the Rio Grande Valley study unit, Colorado, New Mexico, and Texas -- analysis of selected nutrient, suspended-sediment, and pesticide data. U.S. Geological Survey, Water-Resources Investigations Report 94-4061.

Baker, J.L., and H.P. Johnson. 1981. Nitrate-nitrogen in tile drainage as affected by fertilization. *J. Environ. Qual.* 10:519-522.

Beven, Keith, and Peter Germann. 1982. Macropores and water flow in soils. *Water Resour. Res.* 18:1311-1325.

Bowman, R.S. and R.C. Rice. 1986. Accelerated herbicide leaching resulting from preferential flow phenomena and its implications for groundwater contamination. *In* Proc. Conf. on Southwestern Groundwater Issues, Phoenix, AZ. 20-22 October. National Water Well Assoc., Dublin, OH.

Butters, G.L., and W.A. Jury. 1989. Field scale transport of bromide in an unsaturated soil. II. Dispersion modeling. *Water Resour. Res.* 25:1583-1589.

Chaves, Jeffrey S. 1995. Variability in hydraulic conductivity and soil salinity in a flood-irrigated field: The Las Nutrias groundwater project. Unpublished M.S. Thesis, New Mexico Institute of Mining and Technology, Socorro, NM

Doorenbos, J., and A.H. Kassam. 1979. Yield response to water. Food and Agriculture Organization of the United Nations, Irrigation and Drainage paper 33.

Greenholtz, D. E., T. C. Jim-Yeh, M. S. B. Nash, and P. J. Wierenga. 1988. Geostatistical analysis of soil hydraulic properties in a field plot. *J. Cont. Hydr.* 3:227-250.

Hartmann, H.T., William J. Flocker, and Anton M. Kofranek. Growth, Development, and Utilization of Cultivated Plants. New Jersey: Prentice-Hall, Inc. 1981.

Jury, W. A., H. Elabd, and M. Resketo. 1986. Field study of napropamide movement through unsaturated soil. *Water Resour. Res.* 22:749-755.

8.0 REFERENCES (CONT'D):

Kladivko, E.J., G.E. Van Scoyoc, E.J. Monke, K.M. Oates, and W. Pask. 1991. Pesticide and nutrient movement into subsurface tile drains on a silt loam soil in Indiana. *J. Environ. Qual.* 20:264-270.

Kool, J.B., and J.C. Parker. 1987. Development and evaluation of closed-form expressions for hysteretic soil hydraulic properties. *Water Resour. Res.*, 23(1): 105 - 114.

Mapel, Crain L. and T.W. Sammis. 1985. Estimating crop water production functions based on transpiration and crop growth curves through modeling. Water Resources Research Institute, Technical Completion Report 191.

Mengel, K. and E.A. Kirkby. Principals of Plant Nutrition. Switzerland: Der Bund, 1978.

Neuman, S. P. 1973. Saturated-unsaturated seepage by finite elements. *J. Hydraul. Div.*, ASCE 99 (HY12):2233-2250.

Owens, L.B., W.M. Edwards, and R. W. Van Keuren. 1994. Groundwater nitrate levels under fertilized grass-legume pastures. *J. Environ. Qual.* 23:752-758.

Pinder, G. F., W. G. Gray. 1977. Finite element simulation in surface and subsurface hydrology., Academic Press, New York.

Roybal, F. E. 1991. Ground-water resources of Socorro County, New Mexico. Report 89-4083. 32 pp. U. S. Geological Survey, Water Resources Investigations. Albuquerque, New Mexico.

Samani, Zohrab and Henry Magallanez. 1993. Measuring water in trapezoidal canals. *J. Irrigation and Drainage Engineering.* 119:181-186.

Thomas, G.W., and R.E. Phillips. 1979. Consequences of water movement in macropores. *J. Environ. Qual.* 8:149-152.

Thornthwaite, C.W. "Report of the Committee on Transpiration and Evaporation, 1943-1944." *Transactions, American Geophysical Union*, 25 (1944):687.

United States Department of Agriculture, Soil Conservation Service. 1988. Soil Survey of Socorro County Area, New Mexico. United States Government Printing Office, Washington, D.C. pp: 328.

8.0 REFERENCES (CONT'D):

Vinten, A.J.A., B.J. Vivian, F. Wright, and R.S. Howard. 1994. A comparative study of nitrate leaching from soils of differing textures under similar climatic and cropping conditions. *J. of Hydrology* 159:197-213.

Wesseling, J.G., 1991. CAPSEV; steady state moisture flow theory; program description; user manual. Wageningen (The Netherlands), The Winand Staring Centre. Report 37. 51p.; 8 figs.; 3 tables; 3 app.; 14 ref.

Yates, S. R., and M. V. Yates. 1990. Geostatistics for waste management: A user's manual for the GEOPACK (Version 1.0) geostatistical software system. Robert S. Kerr Environmental Research Laboratory, Office of Research and Development, U. S. Environmental Protection Agency, Ada, Oklahoma.

Appendix 9.1 Soil Water Data

Appendix 9.1.1 Soil Water NO_3-N Concentration Data (mg/l)

1994 Samples - Sampled 25 - 26 February 1994 and 4 - 5 March 1994

Sample Location	Sample Depth Interval:			
(m from tile line)	0-30 cm	30-60 cm	60-90 cm	90-120 cm
38 North	144.01	17.37	12.97	2.02
36.5	125.38	0.00	12.62	1.52
35.0	159.79	23.60	12.84	18.96
33.5	191.42	48.12	25.88	6.95
32.0	153.56	37.65	10.14	4.48
30.5	193.82	49.65	12.83	1.20
29.0	94.51	1.04	14.74	4.35
27.5	186.91	55.21	5.64	1.34
26.0	144.06	49.34	9.66	65.48
24.5	174.39	55.88	44.20	27.50
23.0	127.88	70.35	30.94	6.72
21.5	430.13	39.62	6.36	3.19
20.0	161.80	22.70	7.86	50.96
18.5	182.18	73.15	8.36	7.48
17.0	112.33	51.43	17.29	64.97
15.5	280.21	95.80	24.40	149.21
14.0	160.30	50.18	4.59	29.27
12.5	180.19	74.61	17.52	74.95
11.0	118.48	48.04	5.81	61.83
9.5	152.25	79.24	27.40	18.99
8.0	112.73	27.76	7.72	1.15
6.5	186.56	51.55	8.42	1.54
5.0	130.40	40.01	22.42	1.14
3.5	132.64	33.81	4.18	30.27
2.0	168.23	57.93	7.63	1.28
1.0	158.48	32.48	4.74	2.99
0.5	173.36	48.93	23.14	8.08
0.5 South	173.36	78.55	23.24	153.29
1.0	135.19	66.94	24.63	0.17
2.0	116.24	63.53	32.52	3.90
3.5	470.82	86.98	16.74	15.41
5.0	163.27	35.65	5.62	0.95
6.5	158.47	34.63	10.83	11.95
8.0	73.03	22.03	53.27	2.38
9.5	278.19	33.31	23.25	39.04
11.0	159.70	52.32	23.89	121.72
12.5	139.46	50.50	11.69	1.58
14.0	131.02	38.25	29.75	1.44
15.5	193.85	22.45	15.91	27.10
17.0	232.87	32.83	14.37	1.95
18.5	222.05	90.63	50.50	10.95
20.0	208.30	100.87	40.77	47.44
21.5	167.17	26.29	47.65	14.97
23.0	98.61	17.82	7.82	2.47
24.5	98.62	19.42	14.82	1.62
26.0	132.89	49.83	34.12	0.96
27.5	122.11	64.83	14.41	21.66
29.0	100.61	36.46	3.16	21.21
30.5	105.86	41.62	9.88	12.65
32.0	82.91	28.16	6.39	19.95
33.5	119.75	12.51	12.89	1.85
35.0	93.13	16.53	2.79	0.22
36.5	106.13	30.72	19.19	57.56
38.0	223.14	56.26	17.58	7.26

Appendix 9.1.1 (cont'd): Soil Water NO_3-N Concentration Data (mg/l)

1995 Samples - Sampled 26 February 1995 and 5 March 1995

Sample Location (m from tile line)	Sample Depth Interval:			
	0-30 cm	30-60 cm	60-90 cm	90-120 cm
38 North	4.10	0.31	13.20	6.40
36.5	34.89	5.94	4.09	0.83
35.0	22.68	4.21	0.92	0.76
33.5	50.29	5.27	0.53	1.23
32.0	50.10	19.11	2.39	0.67
30.5	78.51	17.76	7.44	2.37
29.0	17.14	4.57	0.46	1.46
27.5	32.46	4.51	2.16	1.70
26.0	35.83	1.89	2.41	0.68
24.5	30.32	6.86	3.53	1.65
23.0	35.62	22.87	4.82	0.63
21.5	19.49	10.90	0.23	0.00
20.0	37.44	4.19	1.10	1.40
18.5	18.33	3.70	1.41	1.49
17.0	23.05	2.71	2.92	0.27
15.5	44.08	10.54	0.95	1.52
14.0	42.48	4.52	2.09	0.84
12.5	18.38	1.74	6.60	2.24
11.0	40.50	1.94	0.68	0.61
9.5	44.22	18.30	0.86	4.75
8.0	14.66	0.66	1.10	0.43
6.5	0.04	0.48	0.39	0.80
5.0	19.71	1.21	0.71	0.58
3.5	63.00	29.32	9.66	4.72
2.0	45.38	18.21		3.87
1.0	39.94	31.27	2.90	6.88
0.5	30.92	4.25	5.71	3.57
0.5 South	10.35	18.93	1.55	1.12
1.0	28.22	22.29	5.16	5.96
2.0	1.20	26.58	2.50	1.03
3.5	32.22	33.71	2.82	1.07
5.0	33.80	9.77	2.06	7.72
6.5	32.80	21.19	0.60	11.03
8.0	26.58	7.17	0.85	1.23
9.5	46.12	10.92	1.27	0.66
11.0	29.19	3.48	1.96	2.04
12.5	38.90	9.71	3.80	0.77
14.0	38.24	2.74	4.90	1.76
15.5	39.54	16.79	13.16	1.50
17.0	6.18	7.74	2.69	1.11
18.5	22.83	8.89	2.71	1.38
20.0	27.93	21.40	1.31	1.33
21.5	37.69	5.34	2.48	0.92
23.0	28.08	18.55	0.50	0.79
24.5	33.54	23.37	8.79	1.43
26.0	23.03	18.45	4.04	0.87
27.5	28.12	4.83	2.48	0.69
29.0	6.33	35.74	0.71	1.60
30.5	6.33	35.74	0.71	1.60
32.0	33.91	1.90	2.95	1.33
33.5	26.94	18.88	4.87	2.23
35.0	45.21	23.65	1.99	0.83
36.5	3.97	11.45	6.95	0.90
38.0	0.64	14.51	1.90	3.31

Appendix 9.1.2
Descriptive Statistics for Soil Water NO_3-N Concentrations with Depth

1994 Samples:

Statistic	0 - 30 cm	30 - 60 cm	60 - 90 cm	90 - 120 cm
Mean	163.75	45.28	17.74	23.14
Standard Error of the Mean	9.83	3.14	1.71	4.80
Median	156.01	44.83	14.39	7.37
Standard Deviation of the Sample	72.23	23.10	12.54	35.25
Sample Minimum Value	73.03	0.00	2.79	0.17
Sample Maximum Value	470.82	100.87	53.27	153.29
Sample Range	397.79	100.87	50.48	153.12
Number of Samples	54	54	54	54
Confidence Level (95%) of the Mean	19.26	6.16	3.34	9.40
Coefficient of Variation of the Mean	0.44	0.51	0.71	1.52

1995 Samples:

Statistic	0 - 30 cm	30 - 60 cm	60 - 90 cm	90 - 120 cm
Mean	29.29	12.42	3.11	2.01
Standard Error of the Mean	2.16	1.37	0.41	0.29
Median	30.62	9.74	2.39	1.33
Standard Deviation of the Sample	15.88	10.06	2.98	2.13
Sample Minimum Value	0.04	0.31	0.23	0.00
Sample Maximum Value	78.51	35.74	13.20	11.03
Sample Range	78.48	35.43	12.97	11.03
Number of Samples	54	54	53	54
Confidence Level (95%) of the Mean	4.24	2.68	0.80	0.57
Coefficient of Variation of the Mean	0.54	0.81	0.96	1.06

Appendix 9.1.2 (cont'd)
Descriptive Statistics for the Log of Soil Water NO_3-N Concentrations with Depth

1994 Samples:

Statistics:	0 - 30 cm	30 - 60 cm	60 - 90 cm	90 - 120 cm
Mean	2.18	1.59	1.14	0.87
Standard Error of the Mean	0.02	0.04	0.04	0.10
Median	2.19	1.68	1.16	0.87
Standard Deviation of the Sample	0.16	0.31	0.32	0.72
Sample Variance	0.02	0.09	0.10	0.52
Kurtosis	1.69	12.52	-0.59	-0.78
Skewness	0.81	-2.69	-0.15	-0.07
Range	0.81	1.99	1.28	2.95
Minimum	1.86	0.02	0.45	-0.76
Maximum	2.67	2.00	1.73	2.19
Number of Samples	54	53	54	54
Confidence Level of the Mean (95%)	0.04	0.08	0.08	0.19
Coefficient of Variation of the Mean	0.07	0.19	0.28	0.83
Kolomogorov-Smirnov Test Statistic	0.104	0.137	0.081	0.132

1995 Samples:

Statistics:	0 - 30 cm	30 - 60 cm	60 - 90 cm	90 - 120 cm
Mean	1.31	0.89	0.32	0.16
Standard Error of the Mean	0.07	0.07	0.06	0.05
Median	1.49	0.99	0.38	0.12
Standard Deviation of the Sample	0.55	0.49	0.41	0.34
Sample Variance	0.30	0.24	0.17	0.12
Kurtosis	12.29	0.33	-0.52	0.22
Skewness	-3.14	-0.85	-0.11	0.70
Range	3.35	2.06	1.76	1.61
Minimum	-1.46	-0.50	-0.64	-0.56
Maximum	1.89	1.55	1.12	1.04
Number of Samples	54	54	53	53
Confidence Level of the Mean (95%)	0.15	0.13	0.11	0.09
Coefficient of Variation of the Mean	0.42	0.55	1.30	2.14
Kolomogorov-Smirnov Test Statistic	0.082	0.123	0.073	0.087

Appendix 9.1.2 (cont'd)

Data for Calculations of the Correlation Between the Log of Soil Water NO_3-N Concentration in 1994 and 1995

	1994 (x)	1995 (y)	1994	1995	1994	1995	1994	1995
	0-30 cm		30-60 cm		60-90 cm		90-120 cm	
	2.16	0.61	1.24	-0.50	1.11	1.12	0.30	0.81
	2.10	1.54		0.77	1.10	0.61	0.18	-0.08
	2.20	1.36	1.37	0.62	1.11	-0.03	1.28	-0.12
	2.28	1.70	1.68	0.72	1.41	-0.28	0.84	0.09
	2.19	1.70	1.58	1.28	1.01	0.38	0.65	-0.17
	2.29	1.89	1.70	1.25	1.11	0.87	0.08	0.38
	1.98	1.23	0.02	0.66	1.17	-0.34	0.64	0.16
	2.27	1.51	1.74	0.65	0.75	0.33	0.13	0.23
	2.16	1.55	1.69	0.28	0.99	0.38	1.82	-0.17
	2.24	1.48	1.75	0.84	1.65	0.55	1.44	0.22
	2.11	1.55	1.85	1.36	1.49	0.68	0.83	-0.20
	2.63	1.29	1.60	1.04	0.80	-0.64	0.50	
	2.21	1.57	1.36	0.62	0.90	0.04	1.71	0.15
	2.26	1.26	1.86	0.57	0.92	0.15	0.87	0.17
	2.05	1.36	1.71	0.43	1.24	0.47	1.81	-0.56
	2.45	1.64	1.98	1.02	1.39	-0.02	2.17	0.18
	2.20	1.63	1.70	0.65	0.66	0.32	1.47	-0.08
	2.26	1.26	1.87	0.24	1.24	0.82	1.87	0.35
	2.07	1.61	1.68	0.29	0.76	-0.17	1.79	-0.21
	2.18	1.65	1.90	1.26	1.44	-0.07	1.28	0.68
	2.05	1.17	1.44	-0.18	0.89	0.04	0.06	-0.36
	2.27	-1.46	1.71	-0.32	0.93	-0.41	0.19	-0.10
	2.12	1.29	1.60	0.08	1.35	-0.15	0.06	-0.24
	2.12	1.80	1.53	1.47	0.62	0.99	1.48	0.67
	2.23	1.66	1.76	1.26	0.88		0.11	0.59
	2.20	1.60	1.51	1.50	0.68	0.46	0.48	0.84
	2.24	1.49	1.69	0.63	1.36	0.76	0.91	0.55
	2.24	1.01	1.90	1.28	1.37	0.19	2.19	0.05
	2.13	1.45	1.83	1.35	1.39	0.71	-0.76	0.78
	2.07	0.08	1.80	1.42	1.51	0.40	0.59	0.01
	2.67	1.51	1.94	1.53	1.22	0.45	1.19	0.03
	2.21	1.53	1.55	0.99	0.75	0.31	-0.02	0.89
	2.20	1.52	1.54	1.33	1.03	-0.22	1.08	1.04
	1.86	1.42	1.34	0.86	1.73	-0.07	0.38	0.09
	2.44	1.66	1.52	1.04	1.37	0.10	1.59	-0.18
	2.20	1.47	1.72	0.54	1.38	0.29	2.09	0.31
	2.14	1.59	1.70	0.99	1.07	0.58	0.20	-0.11
	2.12	1.58	1.58	0.44	1.47	0.69	0.16	0.24
	2.29	1.60	1.35	1.23	1.20	1.12	1.43	0.18
	2.37	0.79	1.52	0.89	1.16	0.43	0.29	0.04
	2.35	1.36	1.96	0.95	1.70	0.43	1.04	0.14
	2.32	1.45	2.00	1.33	1.61	0.12	1.68	0.12
	2.22	1.58	1.42	0.73	1.68	0.39	1.18	-0.04
	1.99	1.45	1.25	1.27	0.89	-0.30	0.39	-0.10
	1.99	1.53	1.29	1.37	1.17	0.94	0.21	0.16
	2.12	1.36	1.70	1.27	1.53	0.61	-0.02	-0.06
	2.09	1.45	1.81	0.68	1.16	0.39	1.34	-0.16
	2.00	0.80	1.56	1.55	0.50	-0.15	1.33	0.20
	2.02	0.80	1.62	1.55	0.99	-0.15	1.10	0.20
	1.92	1.53	1.45	0.28	0.81	0.47	1.30	0.12
	2.08	1.43	1.10	1.28	1.11	0.69	0.27	0.35
	1.97	1.66	1.22	1.37	0.45	0.30	-0.66	-0.08
	2.03	0.60	1.49	1.06	1.28	0.84	1.76	-0.05
	2.35	-0.19	1.75	1.16	1.25	0.28	0.86	0.52
c_{xy}:	-0.02		1.03		1.10		-2.04	
c_{xx}:	-253		-129		-69		-40	
c_{yy}:	-89.66		-42.92		-4.27		-0.96	
r:	-0.00014		0.01375		0.06403		-0.32995	

where the correlation coefficient, $r = c_{xy} / (sqrt(c_{xx}*c_{yy}))$
and c_{xy}=the covariance between x and y
c_{xx}=the variance of x
c_{yy}=the variance of y

Appendix 9.1.3 % Soil Gravimetric Water Content Data

1994 Samples:

Sample Location (m from tile line)	Sample Depth Interval:			
	0-30 cm	30-60 cm	60-90 cm	90-120 cm
38 North	18.66	38.73	21.45	20.29
36.5	17.20	24.95	28.63	18.79
35	20.97	24.80	25.27	20.08
33.5	16.15	24.56	23.35	17.98
32	16.89	25.58	21.00	19.15
30.5	17.43	15.41	26.53	21.11
29	18.26	25.21	21.22	19.85
27.5	16.14	23.05	29.68	20.80
26	16.16	21.65	26.27	16.87
24.5	15.74	22.30	23.15	21.42
23	15.01	20.71	23.62	21.53
21.5	12.36	22.63	30.59	20.86
20	16.46	20.68	17.31	16.77
18.5	23.15	18.27	28.81	20.45
17	15.09	16.81	29.23	15.09
15.5	17.43	20.35	28.96	16.31
14	17.55	22.51	28.19	17.55
12.5	17.33	19.47	30.46	20.15
11	18.36	21.76	26.23	16.90
9.5	18.32	19.13	27.16	20.04
8	17.54	23.97	28.67	20.12
6.5	17.40	21.67	22.39	16.47
5	17.49	23.46	29.98	18.33
3.5	17.41	22.69	30.21	19.65
2	17.65	23.00	31.34	25.20
1	17.72	21.87	29.16	27.68
0.5	17.04	23.08	30.90	20.92
0.5 South	16.04	23.47	25.42	20.08
1	17.28	21.64	23.34	21.13
2	15.75	22.06	28.69	22.29
3.5	13.21	22.65	27.01	22.39
5	16.40	24.83	29.46	21.76
6.5	15.44	21.98	28.94	20.70
8	19.96	24.25	17.96	17.83
9.5	15.30	23.72	23.01	19.49
11	15.14	21.11	24.95	16.22
12.5	16.24	23.59	26.65	21.46
14	15.01	24.02	30.31	17.98
15.5	15.59	21.94	30.09	17.11
17	14.88	21.73	31.71	24.22
18.5	17.82	23.53	28.96	18.37
20	15.97	22.76	30.38	18.30
21.5	14.92	26.15	23.03	20.63
23	18.55	25.76	32.12	20.51
24.5	15.32	26.43	32.78	20.95
26	15.99	25.74	20.06	19.92
27.5	15.93	23.02	23.68	19.20
29	16.47	23.76	25.43	21.97
30.5	15.18	23.07	30.70	22.58
32	14.79	24.22	28.55	27.15
33.5	15.47	26.47	27.50	20.91
35	16.73	23.91	30.37	22.62
36.5	14.90	22.49	26.51	17.35
38	15.65	24.14	24.42	22.64

Appendix 9.1.3 (continued)

1995 Samples:

Sample Location (m from tile line)	**Sample Depth Interval:**			
	0-30 cm	**30-60 cm**	**60-90 cm**	**90-120 cm**
38 North	15.49	23.74	27.91	20.77
36.5	15.88	24.81	25.81	20.26
35	22.40	21.68	29.42	20.68
33.5	16.55	25.20	20.64	20.67
32	17.47	21.26	26.44	19.53
30.5	13.93	24.89	27.38	20.90
29	13.59	20.91	27.89	20.68
27.5	15.39	23.93	29.31	19.67
26	16.18	26.02	27.46	19.18
24.5	15.11	23.15	27.46	17.90
23	14.42	19.37	26.85	26.11
21.5	14.85	18.61	27.89	22.38
20	15.02	18.35	30.99	26.19
18.5	14.56	21.34	25.97	28.45
17	14.67	23.21	28.01	28.22
15.5	15.88	18.42	28.38	16.04
14	16.32	22.85	28.96	23.67
12.5	15.67	25.23	28.68	23.14
11	18.28	26.79	26.01	19.55
9.5	17.08	26.29	28.40	25.97
8	15.71	24.40	29.34	19.30
6.5	16.66	23.00	30.15	25.12
5	17.46	20.98	26.57	23.40
3.5	17.89	23.35	28.10	26.20
2	15.77	25.06	23.46	22.07
1	15.43	21.72	27.77	26.46
0.5	12.68	19.38	28.29	22.65
0.5 South	15.85	19.51	26.06	23.01
1	15.42	19.46	24.93	20.90
2	17.71	20.98	28.83	22.67
3.5	17.42	16.64	27.04	24.44
5	14.97	23.98	28.75	18.96
6.5	14.93	22.98	25.03	17.72
8	13.35	23.83	25.13	19.39
9.5	16.00	23.81	28.39	19.95
11	13.14	27.03	24.02	22.87
12.5	14.28	24.50	31.08	18.47
14	17.52	26.80	28.62	27.63
15.5	16.40	21.84	27.03	19.95
17	14.88	20.75	27.43	26.21
18.5	14.96	24.00	27.84	19.04
20	13.12	19.35	31.05	21.99
21.5	14.66	24.77	27.84	21.19
23	12.73	20.38	31.77	27.31
24.5	14.78	19.54	24.87	24.25
26	12.78	21.38	28.67	24.27
27.5	15.72	25.42	27.81	21.00
29	13.85	15.81	28.93	25.08
30.5	14.19	24.63	28.23	24.27
32	16.29	23.39	30.00	24.32
33.5	16.77	20.95	27.46	23.89
35	14.02	17.14	22.83	23.79
36.5	15.73	24.06	28.23	20.04
38	18.62	23.80	28.31	20.77

Appendix 9.1.4
Descriptive Statistics for % Soil Moisture

1994 Samples:

Statistic	0 - 30 cm	30 - 60 cm	60 - 90 cm	90 - 120 cm
Mean	16.61	23.09	26.89	20.11
Standard Error of the Mean	0.24	0.42	0.50	0.35
Median	16.32	23.03	27.84	20.14
Standard Deviation of the Sample	1.77	3.10	3.71	2.56
Sample Minimum Value	12.36	15.41	17.31	15.09
Sample Maximum Value	23.15	38.73	32.78	27.68
Sample Range	10.80	23.32	15.47	12.59
Number of Samples	54	54	54	54
Confidence Level (95%) of the Mean	0.47	0.83	0.99	0.68
Coefficient of Variation of the Mean	0.11	0.13	0.14	0.13

1995 Samples:

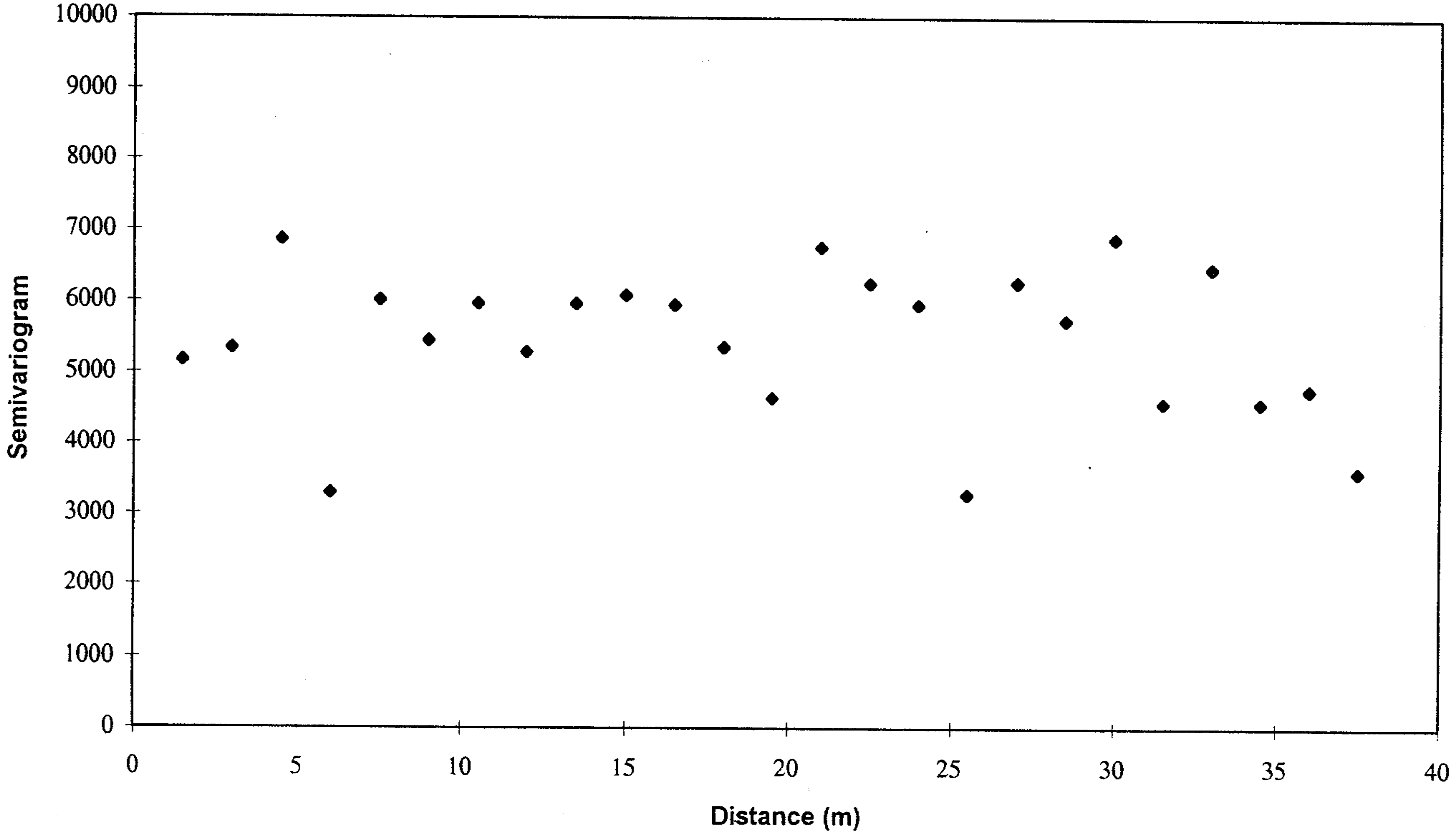
Statistic	0 - 30 cm	30 - 60 cm	60 - 90 cm	90 - 120 cm
Mean	15.56	22.42	27.59	22.38
Standard Error of the Mean	0.24	0.37	0.28	0.40
Median	15.46	23.07	27.89	22.23
Standard Deviation of the Sample	1.74	2.74	2.09	2.97
Sample Minimum Value	12.68	15.81	20.64	16.04
Sample Maximum Value	22.40	27.03	31.77	28.45
Sample Range	9.71	11.21	11.12	12.41
Number of Samples	54	54	54	54
Confidence Level (95%) of the Mean	0.46	0.73	0.56	0.79
Coefficient of Variation of the Mean	0.11	0.12	0.08	0.13

Appendix 9.1.5 Soil Water NO_3-N Variograms

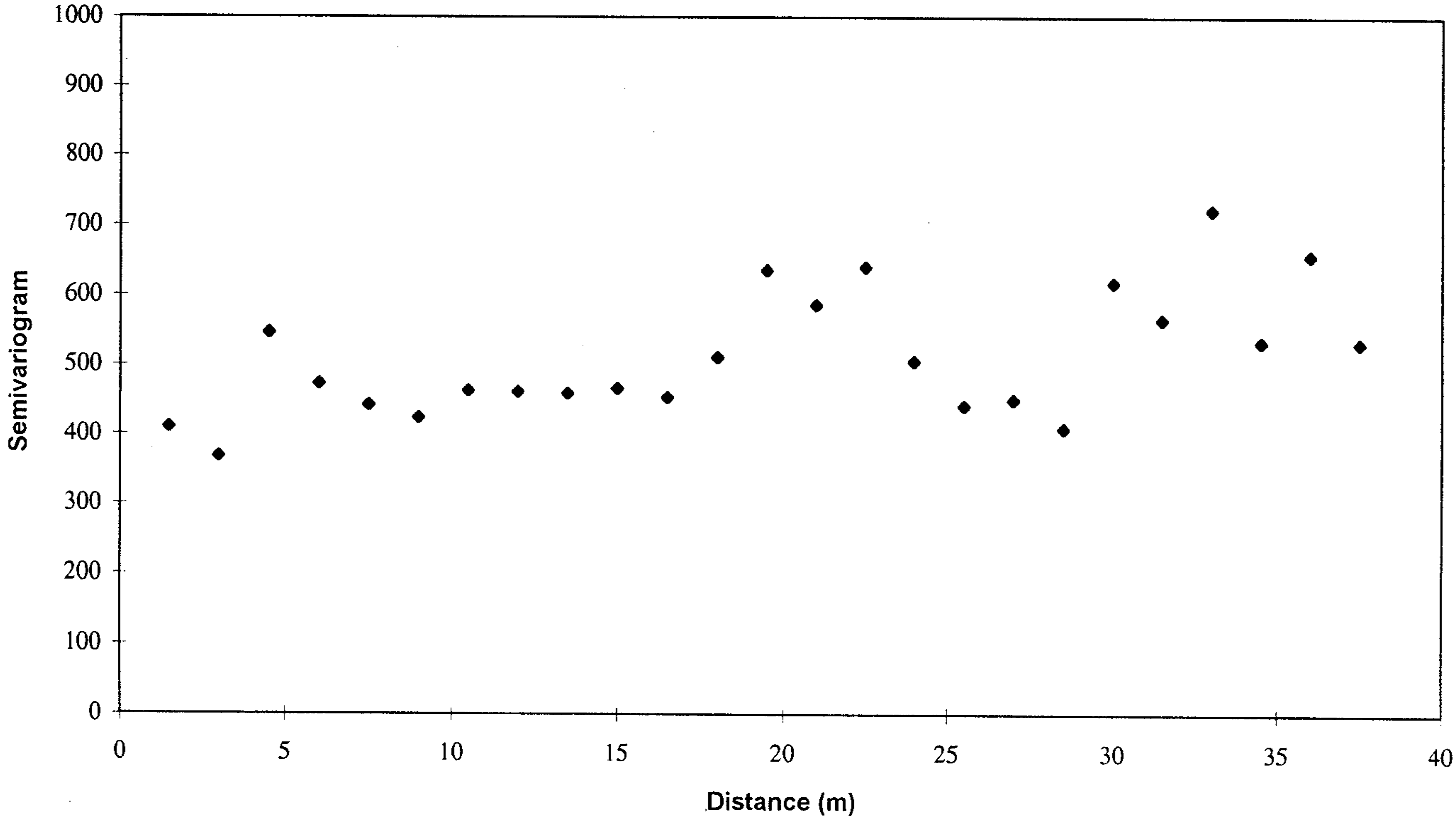
Semivariograms were created for the 1994 and 1995 NO_3-N concentrations in the soil water using the statistical software package GEOPACK Version 1.0 (Yates and Yates, 1990). The variogram is a tool used in geostatistics as a way to characterize the spatial variability of any property of interest. In brief, the variogram satisfies the assumption that the sample mean is constant in space and that the variance is independent of location. The semivariance is the variogram estimator. As the correlation between any combination of observed values at some separation distance (lag) decreases from the point of interest, the semivariogram will increase. This increase can go on indefinitely from the point of origin, or stabilize to a value known as the sill. Discontinuities at the origin (nugget effect) are caused by errors brought about from sampling, analytical, or data analysis. For a complete description of geostatistics and variogram theory as used in hydrogeologic studies, see Greenholtz et al., 1988.

Most of the semivariograms created show a pure nugget effect, i.e. there is no correlation scale associated with the data set. This means that at any given point, the concentration of NO_3-N within the soil water is best described by its mean value.

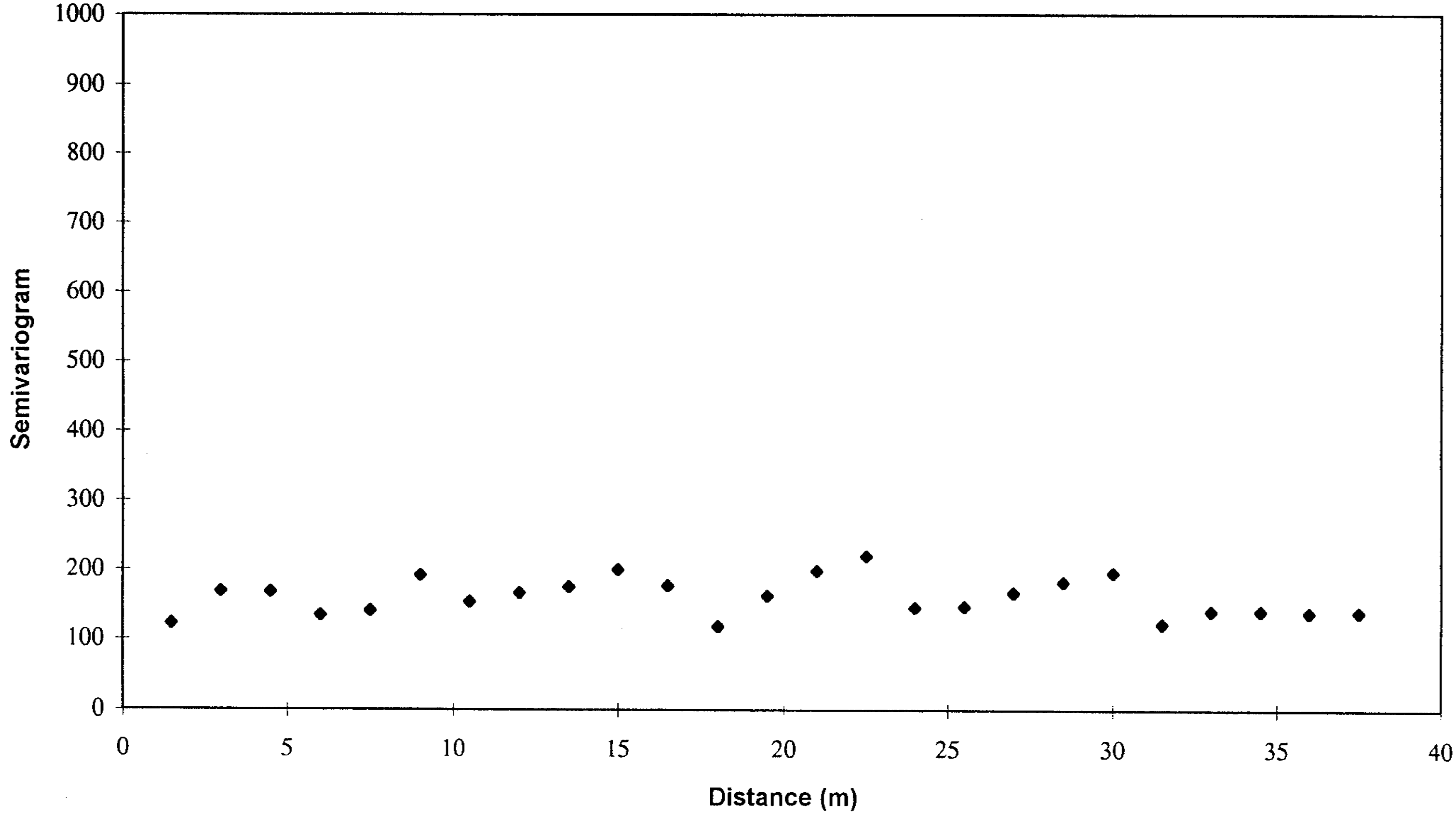
1994 Semivariogram for 0-30 cm Interval



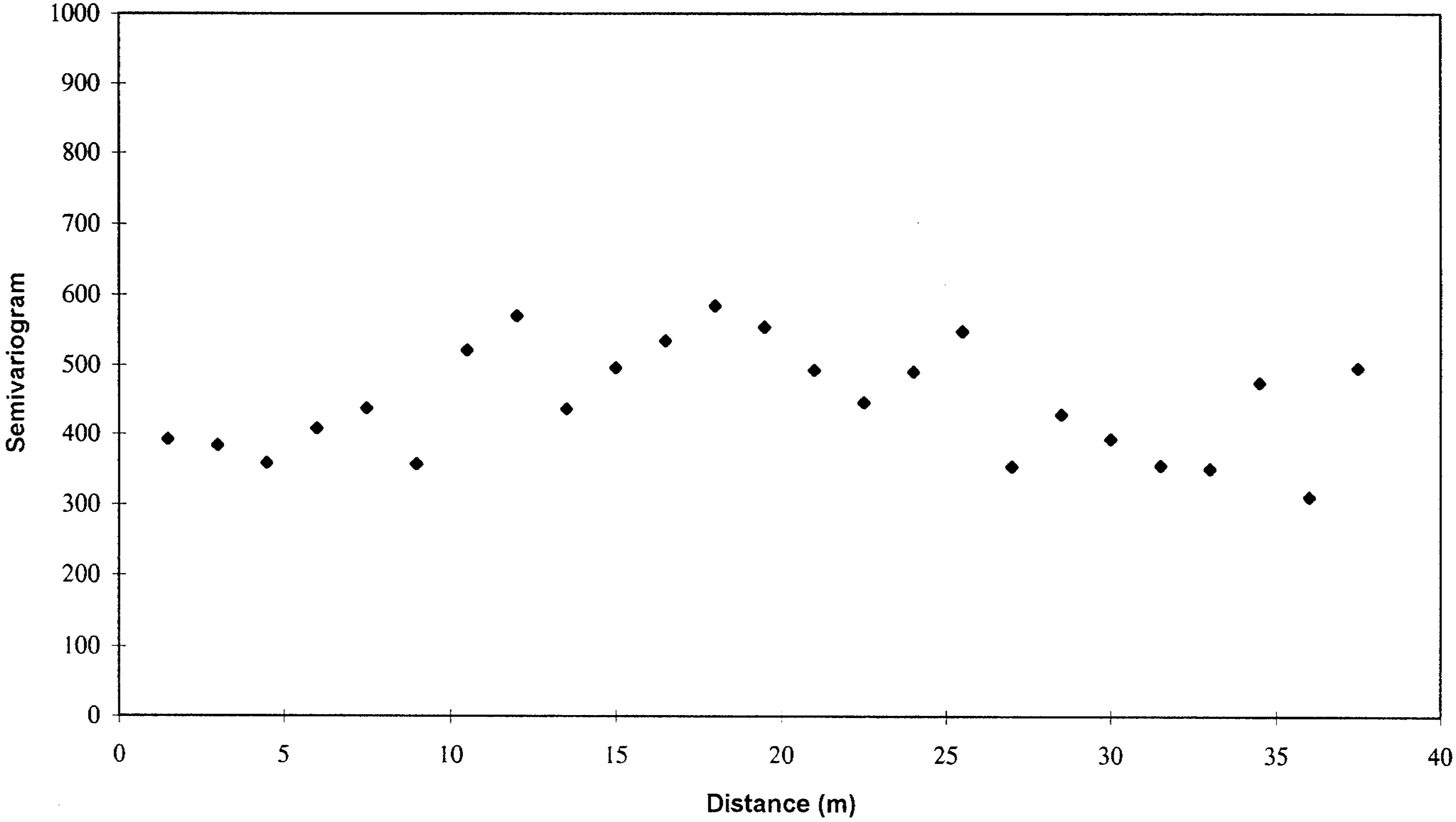
1994 Semivariogram for 30-60 cm Interval

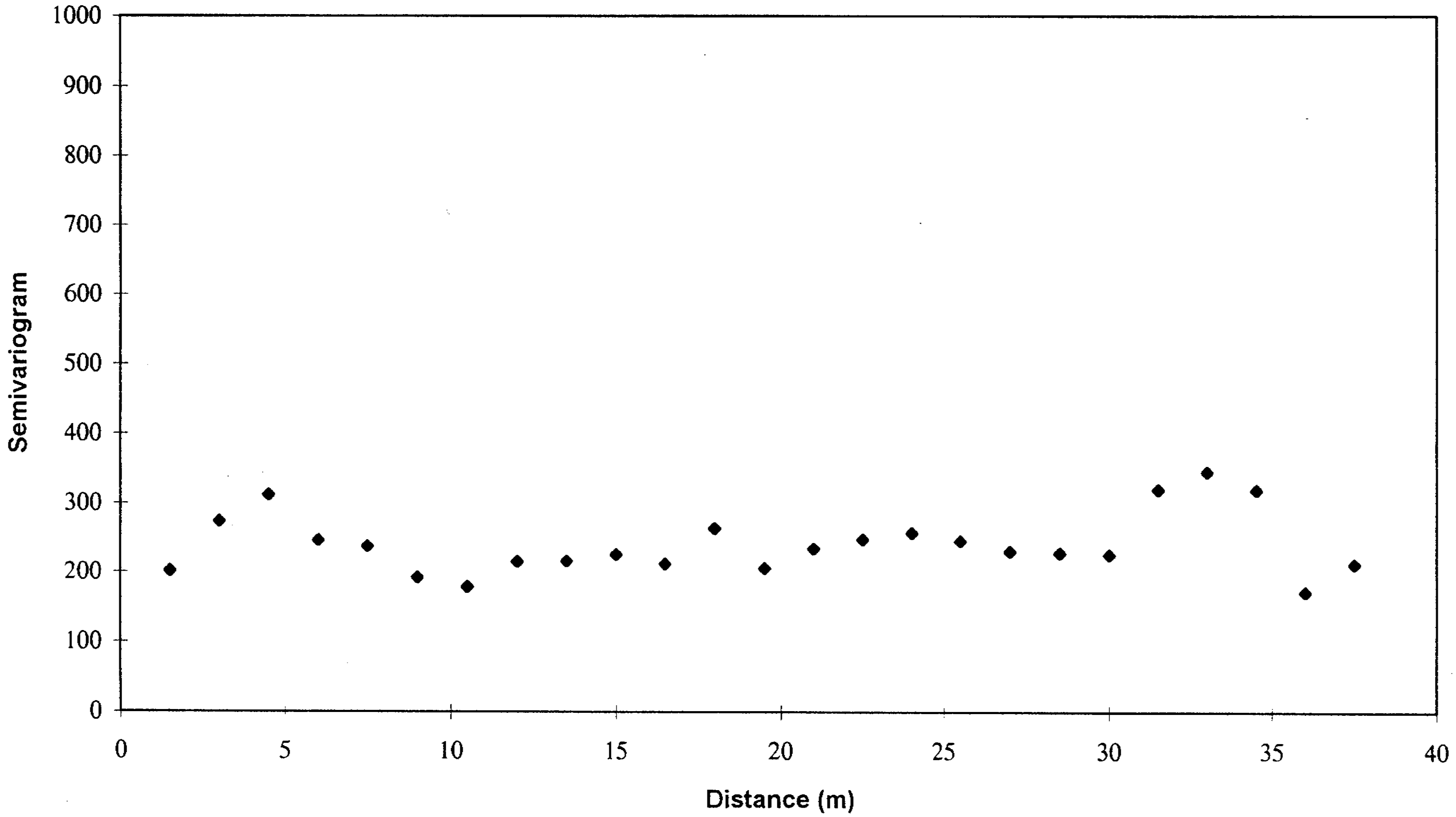


1994 Semivariogram for 60-90 cm Interval

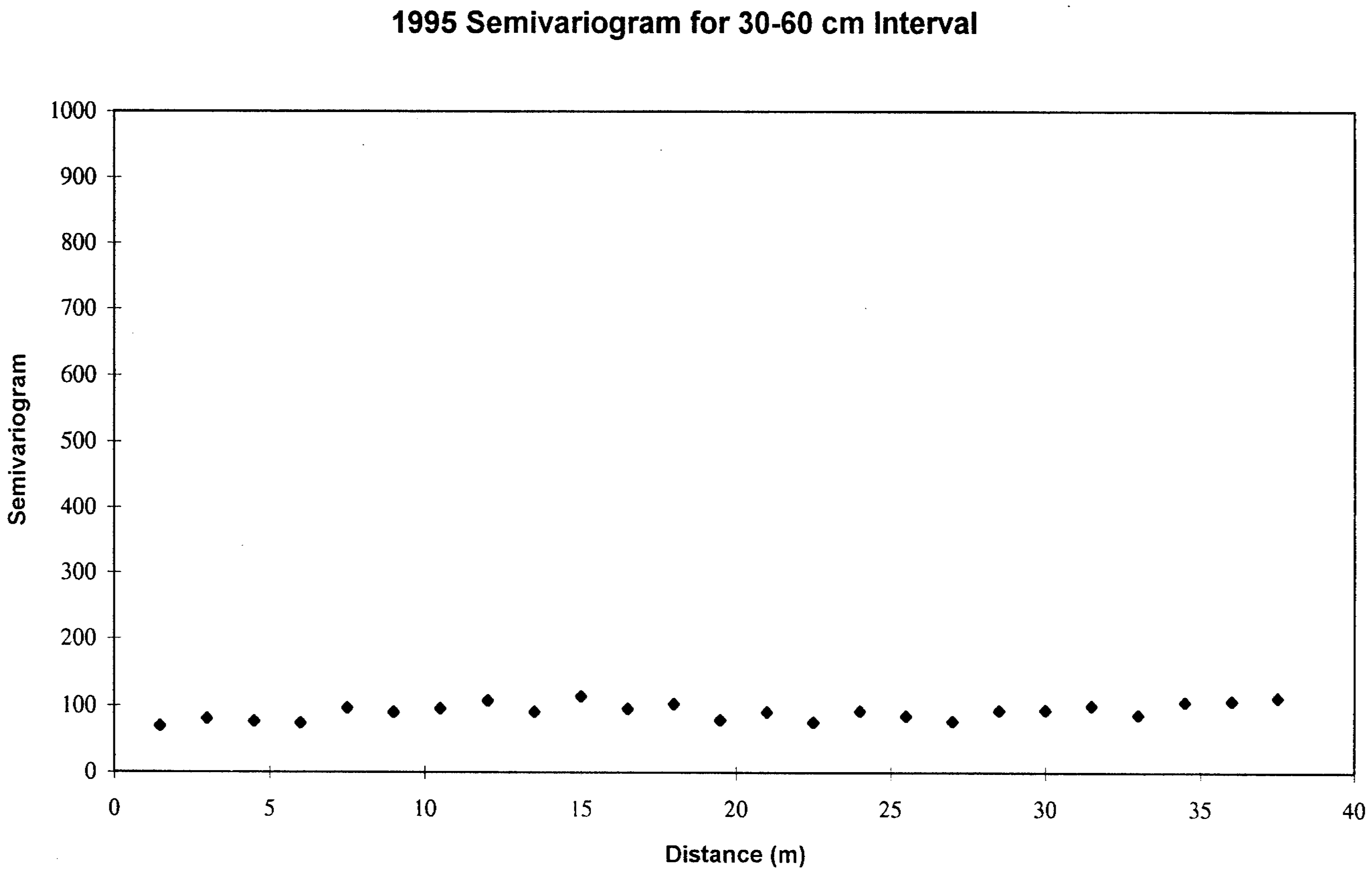


1994 Semivariogram for 90-120 cm Interval

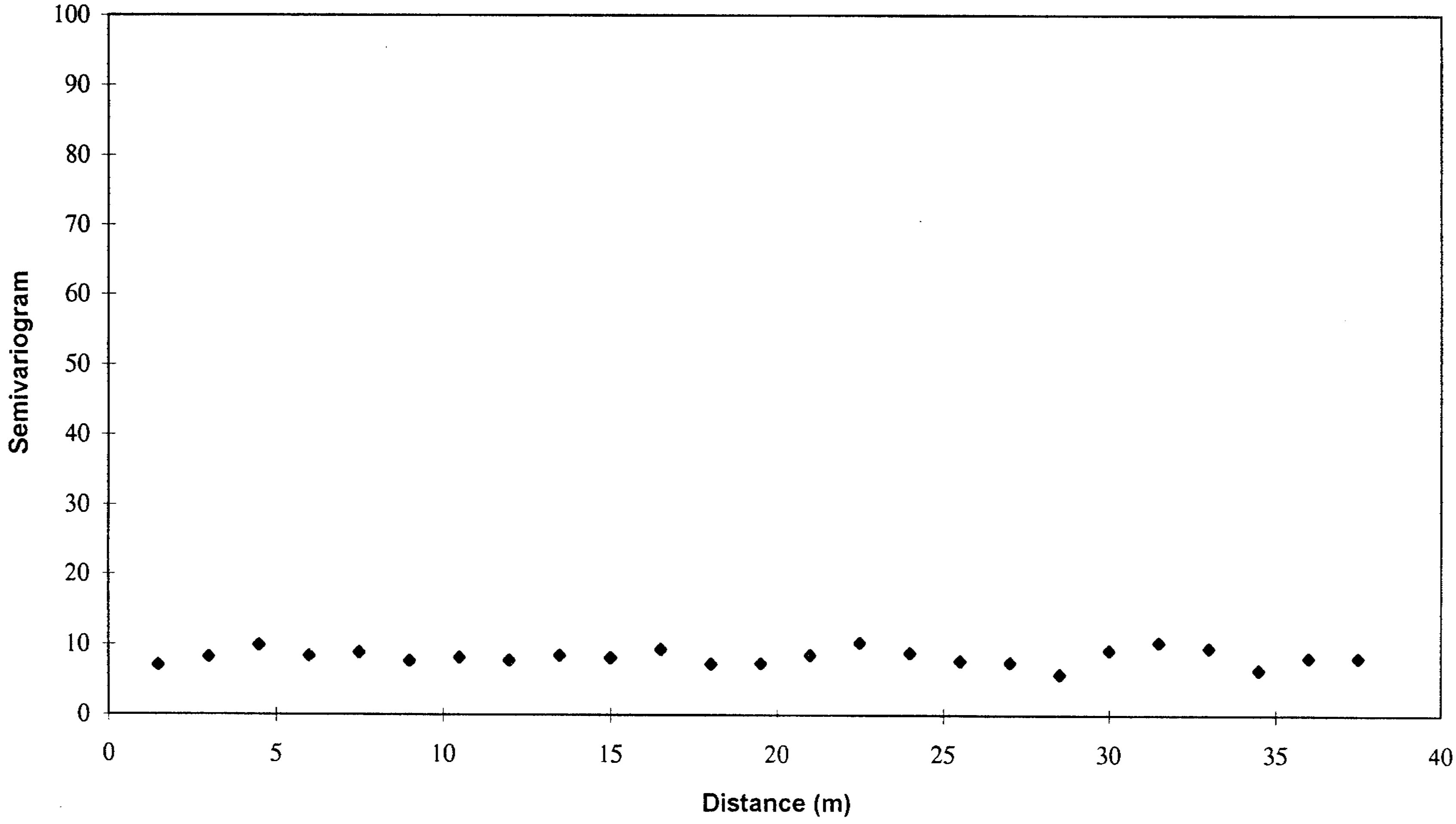




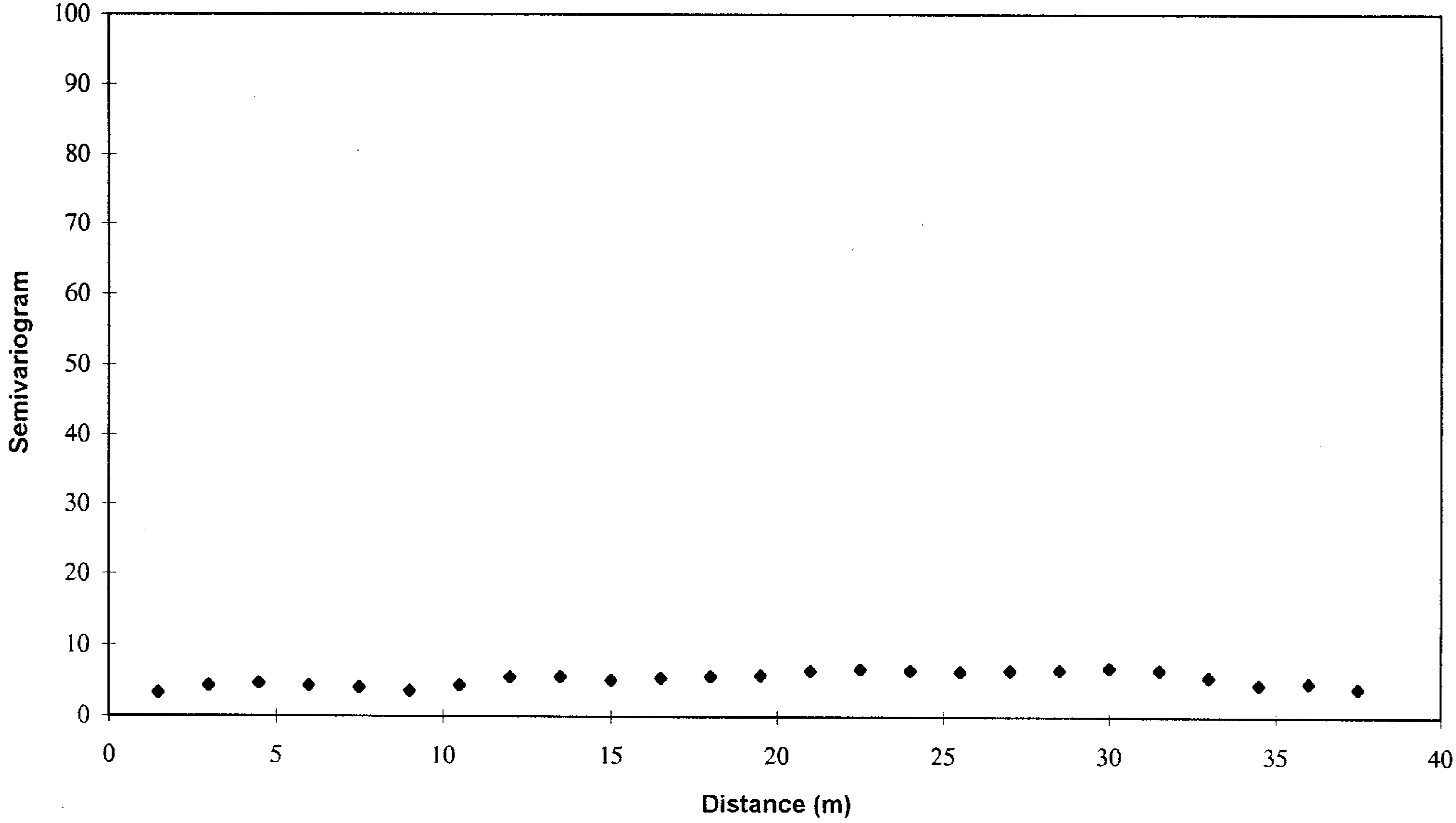
1995 Semivariogram for 0-30 cm Interval


1995 Semivariogram for 30-60 cm Interval
Semivariogram
1000
900
800
700
600
500
400
300
200
100
0
0
5
10
15
20
25
30
35
40
Distance (m)

1995 Semivariogram for 60-90 cm Interval



1995 Semivariogram for 90-120 cm Interval



Appendix 9.2
Applied Irrigation Water NO_3-N Concentration (mg/l) and Electrical Conductivity (umhos/cm)

Irrigation Date	NO_3-N (mg/l)	Electrical Conductivity (umhos/cm)
10-Mar-94	0.91	300
19-May-94	0.35	292
8-Jun-94	0.25	343
27-Jun-94	0.46	437
12-Jul-94	0.33	422
8-Aug-94	0.70	417
21-Sep-94	0.50	410
10-Apr-95	0.46	322
Averages:	**0.50**	**368**

9.3.1 Observation Well Data

9.3.1.1 NO_3-N and Conductivity Data

NO_3-N Concentrations (mg/l)*

well id	x	y	1-Apr-94	10-Apr-94	24-Apr	29-Apr	17-May	25-May	1 6 1994	9 6 1994	1-Jul	19-Jul	19-Aug	11-Sep	24-Sep	8-Oct	23-Oct	8-Nov	15-Nov	MEAN
A1	1583.6	354.8	0.926	2.725	1.370	1.230	0.950	0.900	1.160	2.740	1.860	2.660	1.560	2.770	1.650	0.46	0.547	0.904	0.100	1.44
A2	1558.3	221.6	0.000	0.149	0.200	0.260	0.200	0.210	0.190	0.390	0.030	0.170	0.080		0.010	0.13	0.188	0.048	0.234	0.16
A3	1532.3	96.21	2.438	1.084	0.130	0.160	0.080	0.070	0.000	0.450	0.050	0.080	0.080	1.680	0.070	0.03	0.146	0.051	0.185	0.40
A4	1460.7	377.2				7.000	7.000	7.000	7.000	0.390	0.030	0.060	0.000	0.000	0.490	0.03	0.243	0.654	1.484	2.24
A5	1428.8	119.9	0.000	0.923	6.280	2.460	0.320	0.330	0.350	1.720	3.130	1.280	7.000	0.310	0.310	0.30	0.109	0.023	0.043	1.46
A6	1329	396.8	0.000	0.056	0.210	0.070	0.060	0.090	0.000	0.150	0.030	0.030	0.000	0.000	0.020	0.01	0.129	0.164	0.102	0.07
A7	1314.4	279.3			2.560	2.810	1.370	0.150	0.100	0.560	0.070	0.030	0.000	0.000	0.410	0.04	0.110	0.032	0.125	0.56
A8	1298.7	150.7	3.801	0.176	0.560	0.210	7.540	0.100	0.070	0.300	1.950	0.030	0.020	0.000	0.120	0.03	0.074	0.042	0.017	0.88
A9	1325.6	397.5	0.050	0.065	0.180	0.180	0.070	0.090	0.080	0.040	0.070	0.030	0.000	0.780	0.200	0.24	0.138	0.030	0.033	0.13
A10	1314.9	316.1			0.160	0.090	0.080	0.090	0.000	0.530	0.040	0.000	0.000	0.040	0.040	0.02	0.129	0.026	0.017	0.09
A11	1310.4	278			0.190	0.130	0.060	0.100	0.000	0.220	0.040	0.030	0.000	0.010	0.030	0.01	0.325	0.065	0.085	0.09
A12	1306.2	245.8			0.220	0.110	0.060	0.100	0.000	0.250	0.040	0.020	0.000	0.200	0.070	0.02	0.116	0.012	0.124	0.10
A13	1305.7	242.1			0.190	0.100	0.110	0.110	0.080	0.520	0.050	0.030	0.000	0.000	0.050	0.01	0.000	0.052	0.134	0.10
A14	1301.7	208.8	0.233		0.210	0.160	0.100	0.080	0.000	0.270	0.060	0.030	0.000	0.000	0.050	0.00	0.170	0.113	0.121	0.10
A15	1297.3	173.7			0.210	0.130	0.120	0.080	0.070	2.180	0.000	0.030	0.020	0.000	0.060	0.01	0.000	0.088	0.117	0.21
A16	1294.6	151.6	4.621	0.603	0.110	0.130	0.100	0.090	0.000	0.080	0.140	0.020	7.000		0.050	0.00	0.014			0.93
A17	1208.8	420.9	0.072	0.072	0.270	0.050	0.120	0.160	0.140	0.300	0.060	0.030	0.000	0.020	0.070	0.01	0.030		0.345	0.11
A18	1153.5	183.8	0.221	0.117	0.210	0.090	0.090	0.090	0.000	0.550	0.060	0.000	7.000	0.000	0.050	0.15	0.148	0.047	0.111	0.53
A19	1088.6	436.6	0.027	0.079	0.190	0.050	0.090	0.090	0.080	0.120	0.040	0.030	0.690	0.000	0.050	0.51	0.572	0.072	0.385	0.18
A20	1077.8	365.9			0.310	0.190	0.110	0.090	0.000	0.120	0.030	0.040	0.000		0.050	0.04	0.097	0.062	0.128	0.09
A21	1072.4	328.9			0.420	0.080	0.090	0.070	0.000	0.120		0.090	0.000	0.000	0.060	0.01	0.007	0.007	0.117	0.08
A22	1067.5	296.3			0.170	0.090	0.110	0.080	0.000	0.300	0.320	0.040	0.040	0.030	0.080	0.01	0.023	0.041	0.108	0.10
A23	1066.8	292.2			0.280	0.050	0.120	0.080	0.080	1.450	0.030	0.000	0.040	0.000	0.080	0.01	0.000	0.048	0.036	0.15
A24	1062.3	261.6			0.290	0.140	0.120	0.070	0.000	1.840	0.000	0.000	0.000	0.000	0.130	0.01	0.038	0.062		0.19
A25	1056.7	223.5			0.190	0.050	0.120	0.760	0.090	0.780	0.000	0.050	0.030	0.000	0.090	0.03	0.414	0.158	0.109	0.19
A26	1054.2	207.7	0.140	0.059	0.210	0.080	0.110	0.090	0.070	0.010	0.230	0.050	0.040	0.000	0.090	0.01	0.057		0.153	0.09
A27	1083.2	438.5	0.824	1.454	1.280	1.720	0.580	0.090	0.430	0.140	4.000	0.040	0.000	0.000	0.070	0.05	0.105	0.060	0.033	0.64
A28	1067.9	328.1			0.190	0.120	0.120	0.080	0.080	7.000	0.000	0.000	0.000	0.000	0.080	0.01	0.044	0.102	0.065	0.53
A30				0.086	1.940	0.440	0.000	0.610	0.180	1.490	1.700	0.070	0.000	0.000	0.400	2.76		1.156	6.619	1.16
A32	583.8	526.6	0.181	0.097	0.260	0.090	0.120	0.100	0.000	0.040	0.000	0.040	0.000	0.000	0.090	0.04	0.000	0.050	0.033	0.07
A33	631	287.8	3.102	0.939	0.900	0.050	0.120	0.150	0.140	0.550	0.040	0.040	0.030	0.000	0.100	0.01	0.000	0.027	0.031	0.37
A34	660.2	298.3	1.853	0.047	0.050	0.230	0.110	0.110	0.070	0.170	0.000	0.070	0.000	0.000	0.120	0.01	0.000	0.022	0.036	0.17
MEAN:			1.088	0.514	0.643	0.586	0.636	0.385	0.327	0.805	0.455	0.160	0.738	0.201	0.164	0.16	0.128	0.145	0.374	

* - blank cells indicate that the data is missing

Appendix 9.3.1.1 (continued)

Electrical Conductivity (umhos/cm)*

Well ID	Location:		Sample Date:													
	x	y	17-May	25-May	1-Jun	30-Jun	1-Jul	19-Jul	28-Jul	19-Aug	11-Sep	8-Oct	23-Oct	8-Nov	15-Aug	MEAN:
A1	1583.6	354.8	593	637.5	681.5	698	872	996	717	745	1025	979.5	853.5	810	770	797.85
A2	1558.3	221.6	824	797	673	1072	732	894	441	663	758	755	779	840	749.5	767.50
A3	1532.3	96.21	769.5	742	782.5	1063	834	987	397	843.5	564	888.5	825	866	753	793.46
A4	1460.7	377.2	388	431	614	709	604	585	487	508	958	1056	1152	1159	1021	744.00
A5	1428.8	119.9	619	553	600	1034	550	995	409		1245	1437	1312		1318	915.64
A6	1329	396.8	671	597	746	1667	873	1015	1467	533	876	983	848	942	935	934.85
A7	1314.4	279.3	580	751	818	652	543	698	477	804	732	868	884		993	733.33
A8	1298.7	150.7	667.5	610	600	1033	884	1015	1056	810	826	1033	1122	1308	1148	931.73
A9	1325.6	397.5	861	804	876	816	977	1122	939	656	1036	1006	960		1197	937.50
A10	1314.9	316.1	1628	1140	1131	1133	1038	1183	800	856	946	1994	1081	1669	991.5	1122.35
A11	1310.4	278	1100	854	904	634	769	1392	418	1124	1176	1300	1131	1048	1117	997.46
A12	1306.2	245.8	1026	1026	1211	478	1374	1445	360	1029	1286	1141	1276.5	1506	1284	1110.96
A13	1305.7	242.1	1286	1158	952	618	1256.5	1120	327	1036	1062	1205	1145	1274	998	1033.65
A14	1301.7	208.8	643	599	546	569	834	1051	612	835	1179	2140	1088	1088	1074	942.92
A15	1297.3	173.7	1041	877	866	573	993	943	698	770	912	959	777		606	834.58
A16	1294.6	151.6	784	804	802	658	773	977	1158			784	646			820.67
A17	1208.8	420.9	1131	816	752	1090	1064	1451	857	1060	1188	1520	1210		1205	1112.00
A18	1153.5	183.8	1940	1784	1814	2105	2230	2190	1834		1727	3110	2870	3240	3170	2334.50
A19	1088.6	436.6	648	577	492	561	758	885	1045	739	669	577	620		698	689.08
A20	1077.8	365.9	1375	1222	1190	804	1122	1198	1039	996		1141	1080	1162	1074	1116.92
A21	1072.4	328.9	1427	1227	1443	1145	1779	1930	1205	1489	1488	1663	1455	1669	1596	1501.23
A22	1067.5	296.3	1740	1423.5	1232	1380	1827	1729	1699	1028	1088	1410	1277	1359	1225.5	1416.77
A23	1066.8	292.2	1675	879	889	743	3010	2870	597	1657	1366	1276	1039		923	1410.33
A24	1062.3	261.6	1225	2160	1885	1160	1169	3450	1253	2950	2920	2210	1826	2700	2220	2086.77
A25	1056.7	223.5	1134	859	907	825	435	923	958	1048	777	1160	1100	1107	1169	954.00
A26	1054.2	207.7	660	488	627	591	785	765	670	730	821	962	925		616	720.00
A27	1083.2	438.5	828	414	524	869	1004	777	436	600	758	893	949	1009	984	772.69
A28	1067.9	328.1	1300	695	690	670.5	2040	896	780	1224	932	1456	1419	757	617	1036.65
A30	886.8	478.2	583	663	602	581	1166	765	902	588	736	795		439	789	717.42
A32	583.8	526.6	2410	1641	1839.5	1373	948	2305	1917	2330	2250	2140	1777.5	1735	1780	1880.46
A33	631	287.8	810	811	867	794		848	919	766	771	1505	772	939	818	885.00
A34	660.2	298.3	773	694.5	748			1172.5	867	807.5	838	913	825.5	1008	752	854.45
MEAN:			1035.63	866.52	915.77	906.40	1108.12	1267.89	866.91	1043.75	1097.00	1289.38	1129.84	1288.43	1115.85	

* - blank cells indicate that the data is missing

Appendix 9.3.1.2

Descriptive Statistics for Observation Well NO_3-N Concentrations (mg/l)

1994 Samples:

Statistics:	1-Apr	10-Apr	24-Apr	29-Apr	17-May	25-May	1-Jun	9-Jun	1-Jul	19-Jul	19-Aug	11-Sep	24-Sep	8-Oct	23-Oct	8-Nov	15-Nov
Mean	1.088	0.514	0.343	0.586	0.636	0.385	0.327	0.805	0.455	0.160	0.738	0.201	0.164	0.157	0.13	0.145	0.374
Standard Error of the Mean	0.366	0.176	0.214	0.240	0.312	0.216	0.219	0.234	0.179	0.090	0.365	0.111	0.052	0.087	0.03	0.051	0.221
Standard Deviation of the Sample	1.508	0.726	1.194	1.357	1.764	1.224	1.237	1.324	0.996	0.507	2.067	0.600	0.296	0.491	0.15	0.273	1.209
Sample Variance	2.275	0.527	1.425	1.841	3.110	1.498	1.529	1.753	0.992	0.257	4.274	0.360	0.088	0.241	0.02	0.075	1.461
Sample Minimum Value	0.000	0.047	0.050	0.050	0.000	0.070	0.000	0.010	0.000	0.000	0.000	0.000	0.010	0.002	0.00	0.007	0.017
Sample Maximum Value	4.621	2.725	6.280	7.000	7.540	7.000	7.000	7.000	4.000	2.660	7.000	2.770	1.650	2.755	0.57	1.156	6.619
Number of Samples	17	17	31	32	32	32	32	32	31	32	32	29	32	32	31	29	30
Confidence Level (95%) of the Mean	0.717	0.345	0.420	0.470	0.611	0.424	0.428	0.459	0.351	0.176	0.716	0.218	0.102	0.170	0.05	0.099	0.433

Appendix 9.3.1.2 (CONT'D)

Descriptive Statistics for Observation Well Electrical Conductivity (umhos/cm)

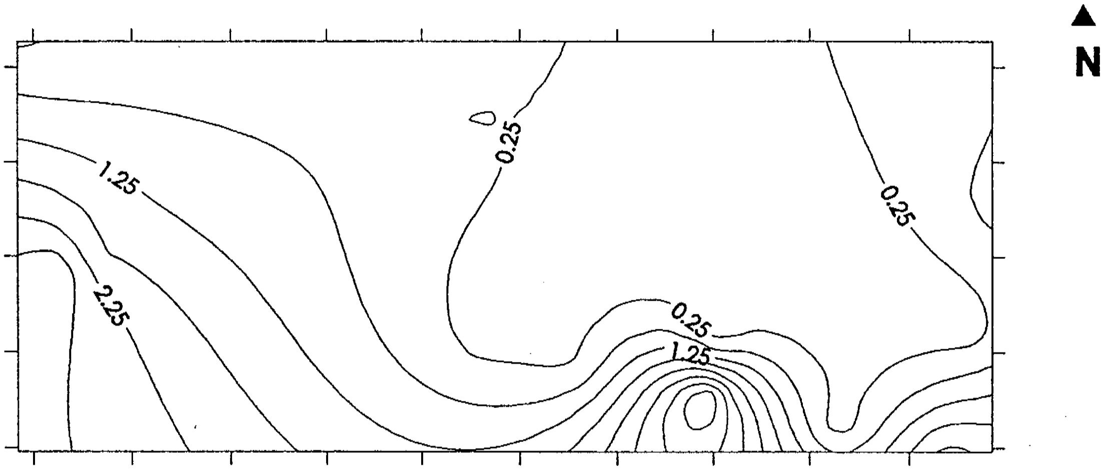
1994 Samples:

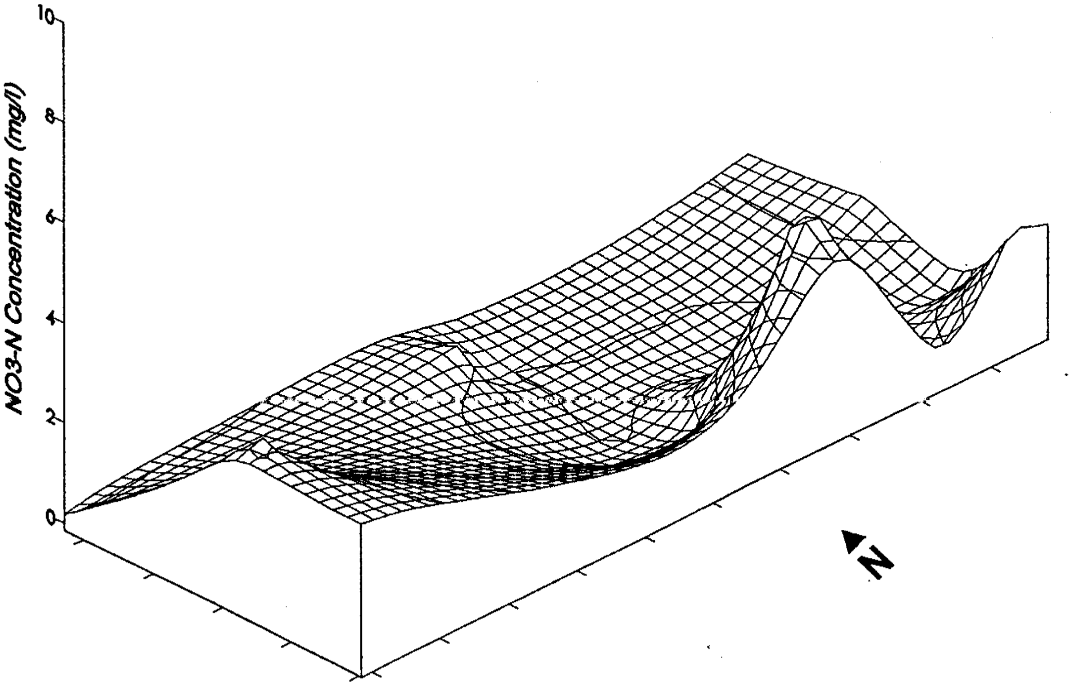
Statistics:	17-May	25-May	1-Jun	30-Jun	1-Jul	19-Jul	28-Jul	19-Aug	11-Sep	8-Oct	23-Oct	8-Nov	15-Nov
Mean	1035.63	866.52	915.77	906.40	1108.12	1267.89	866.91	1007.76	1097.00	1289.38	1129.84	1288.43	1115.85
Standard Error of the Mean	82.25	74.14	66.79	65.33	102.44	114.04	75.38	98.23	89.07	95.32	77.57	129.75	92.75
Standard Deviation of the Sample	465.25	419.39	377.85	363.72	561.10	645.08	426.41	528.96	487.87	539.23	431.89	622.24	516.42
Sample Variance	216459.19	175889.65	142768.00	132292.24	314833.62	416134.00	181829.70	279798.10	238014.14	290773.87	186529.54	387182.08	266692.10
Sample Minimum Value	388.00	140.00	492.00	478.00	435.00	585.00	327.00	508.00	564.00	577.00	620.00	439.00	606.00
Sample Maximum Value	2410.00	2160.00	1885.00	2105.00	3010.00	3450.00	1917.00	2950.00	2920.00	3110.00	2870.00	3240.00	3170.00
Number of Samples	32	32	32	31	30	32	32	29	30	32	31	23	31
Confidence Level (95%) of the Mean	161.20	145.31	130.91	128.04	200.78	223.51	147.74	192.52	174.58	186.83	152.03	254.30	181.79

Appendix 9.3.1.3 NO_3-N Contour Maps and 3-D Surface Plots

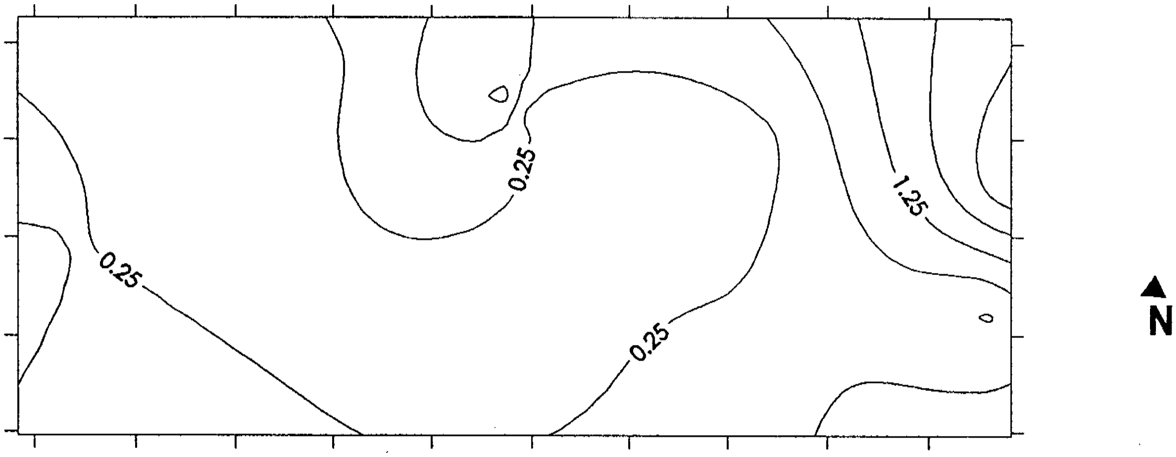
As stated in section 4.3.1.2, the software package Surfer for Windows by Golden Software, Inc. was used to create NO_3-N concentration contour maps from each observation well sampling event at the Las Nutrias Field site in 1994. The following pages contain typical contour maps as well as 3-dimensional surface plots of the data sets. The kriging method was used to interpolate values in between data points. The contour interval used is 0.50 mg/l NO_3-N. The surface plots have been rotated 45 deg counter-clockwise from north to enable the reader to see the data more clearly.

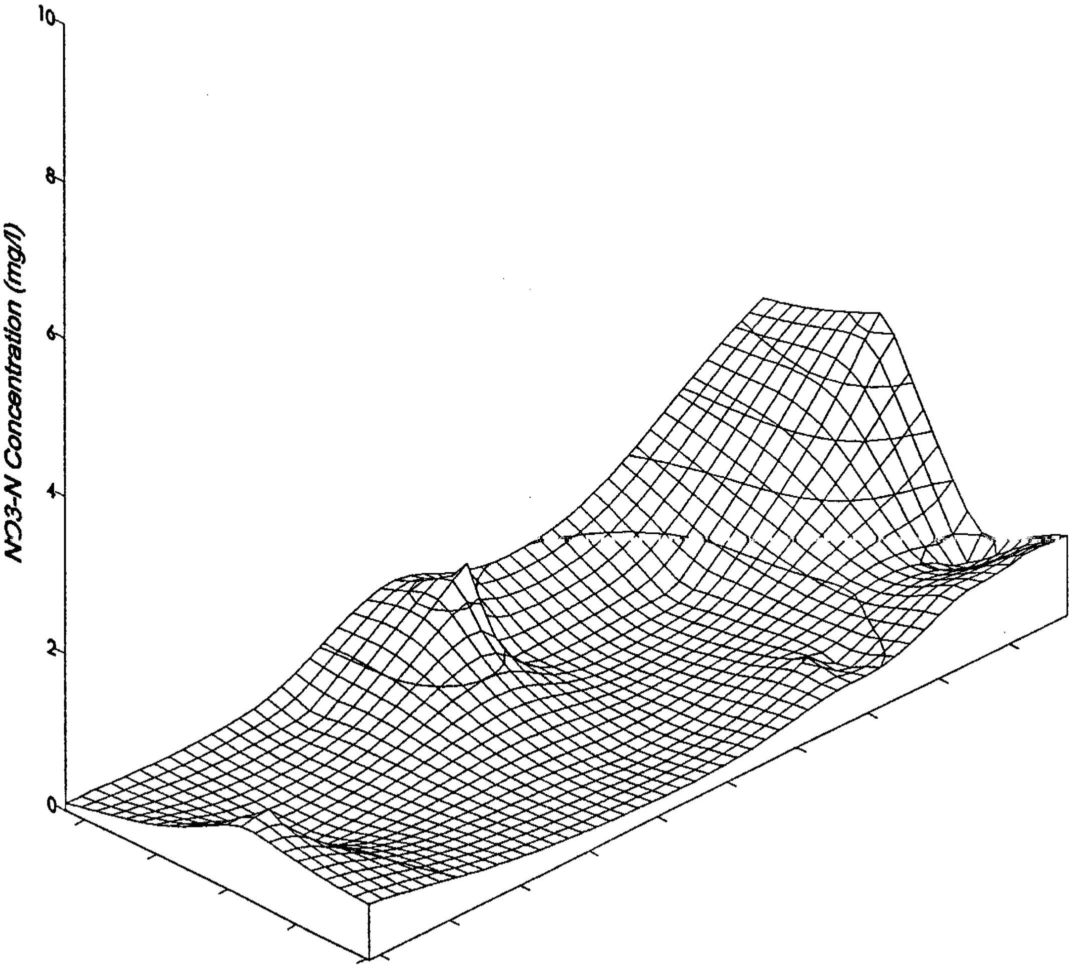
1 April 1994



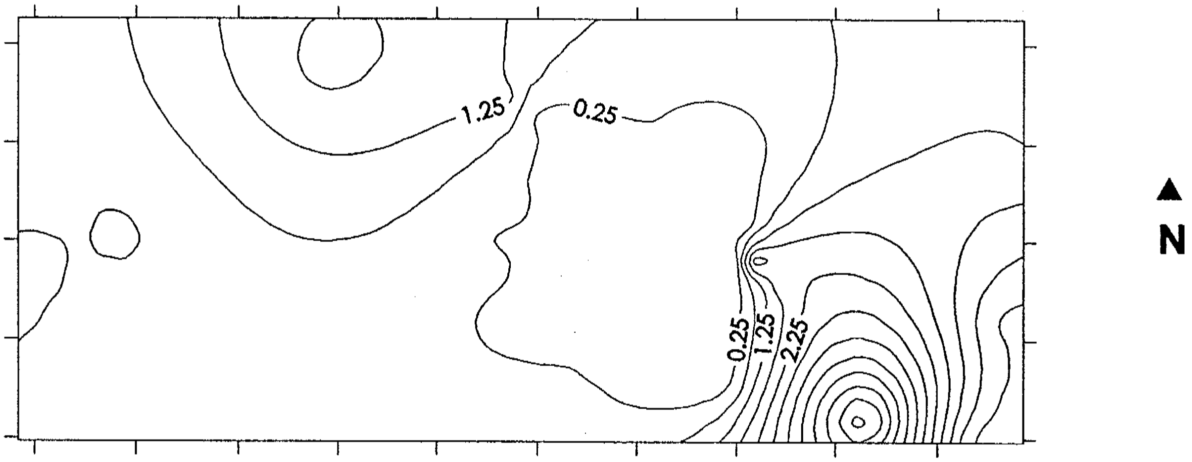


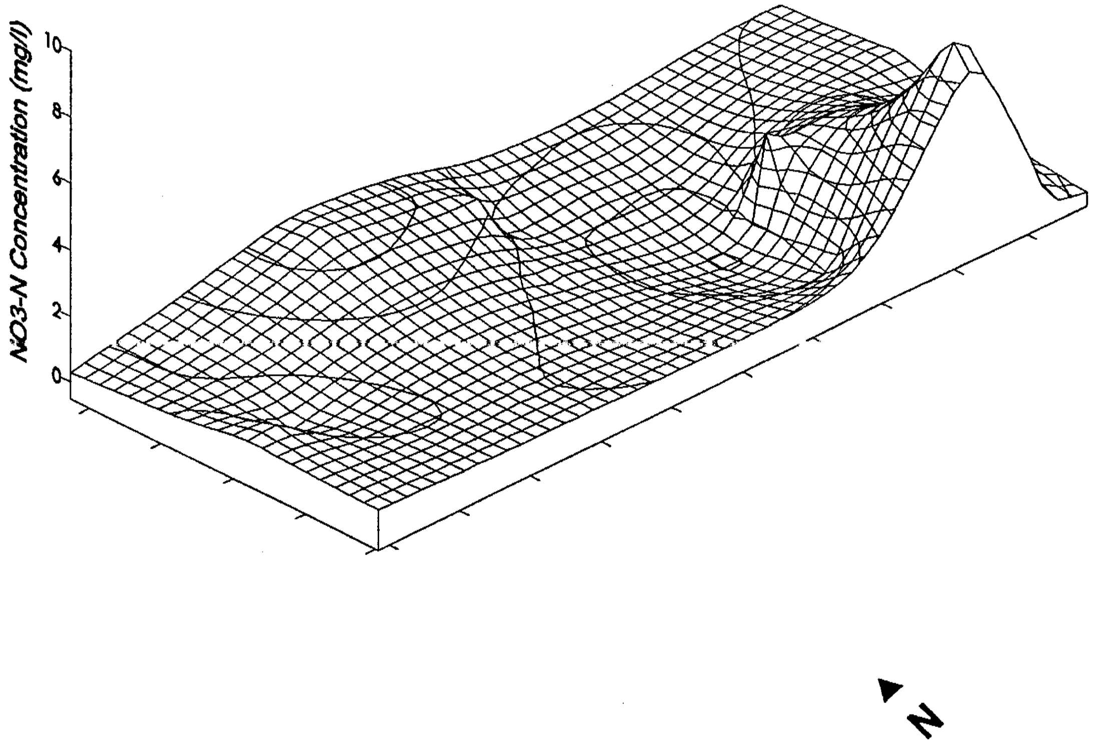
10 April 1994



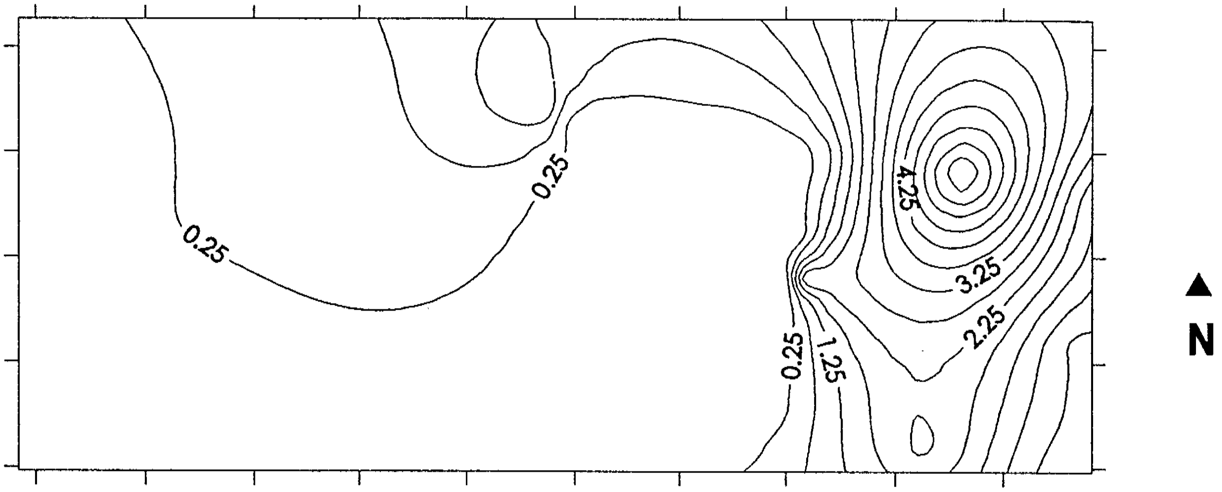


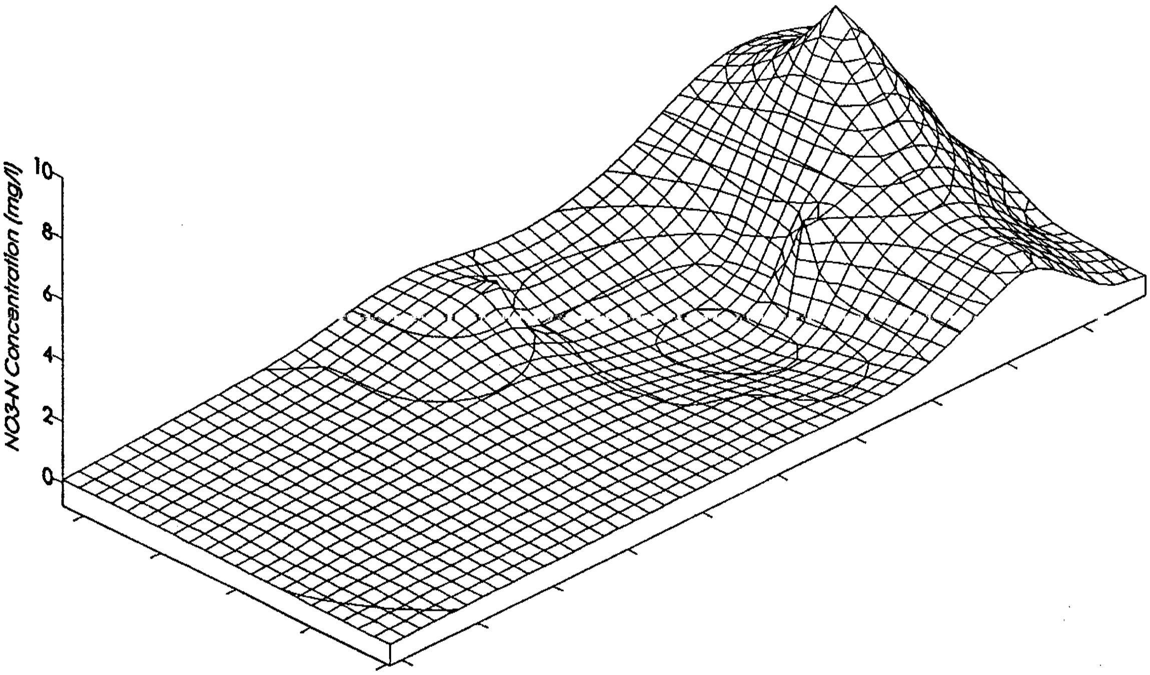
24 April 1994



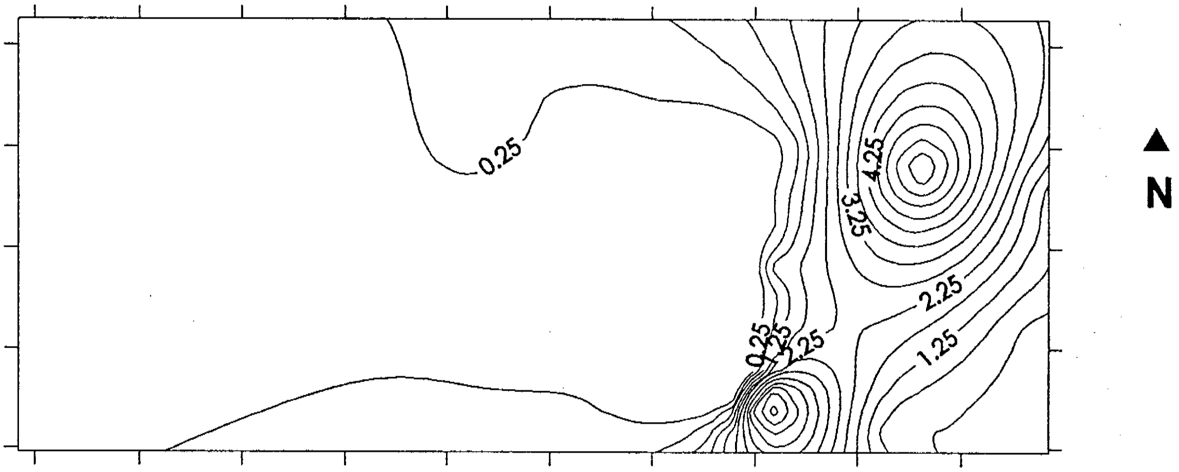


29 April 1994

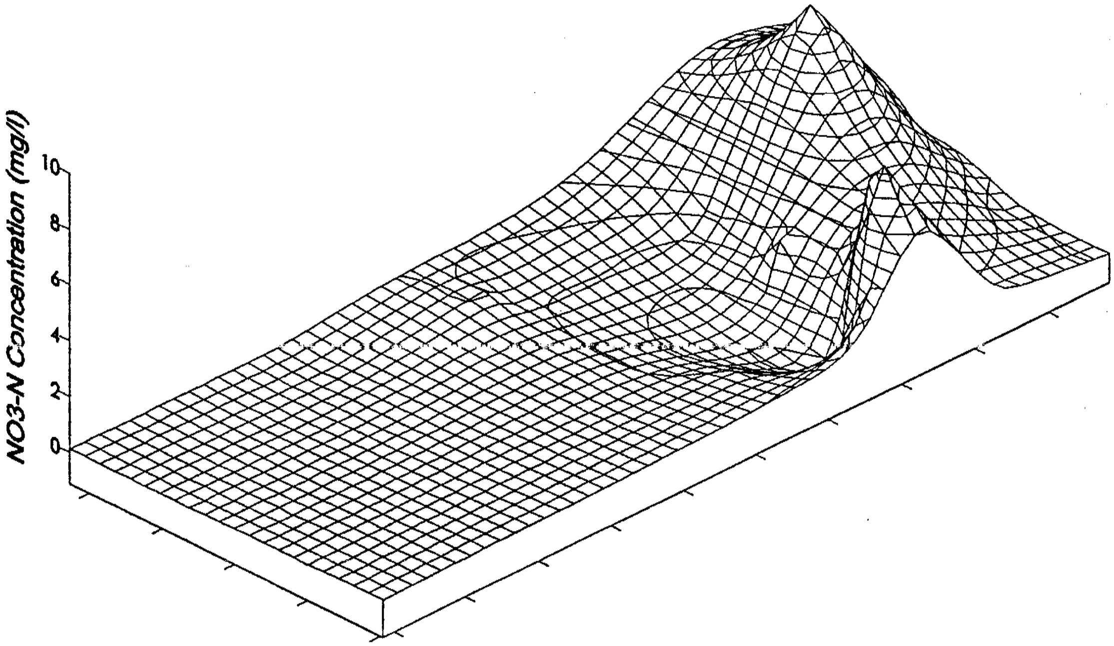




17 May 1994

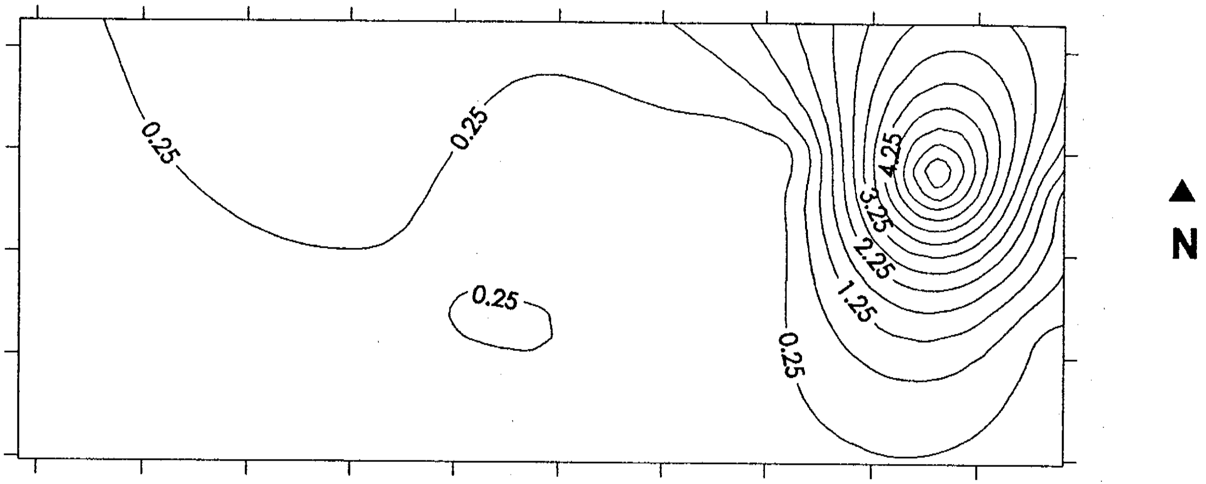


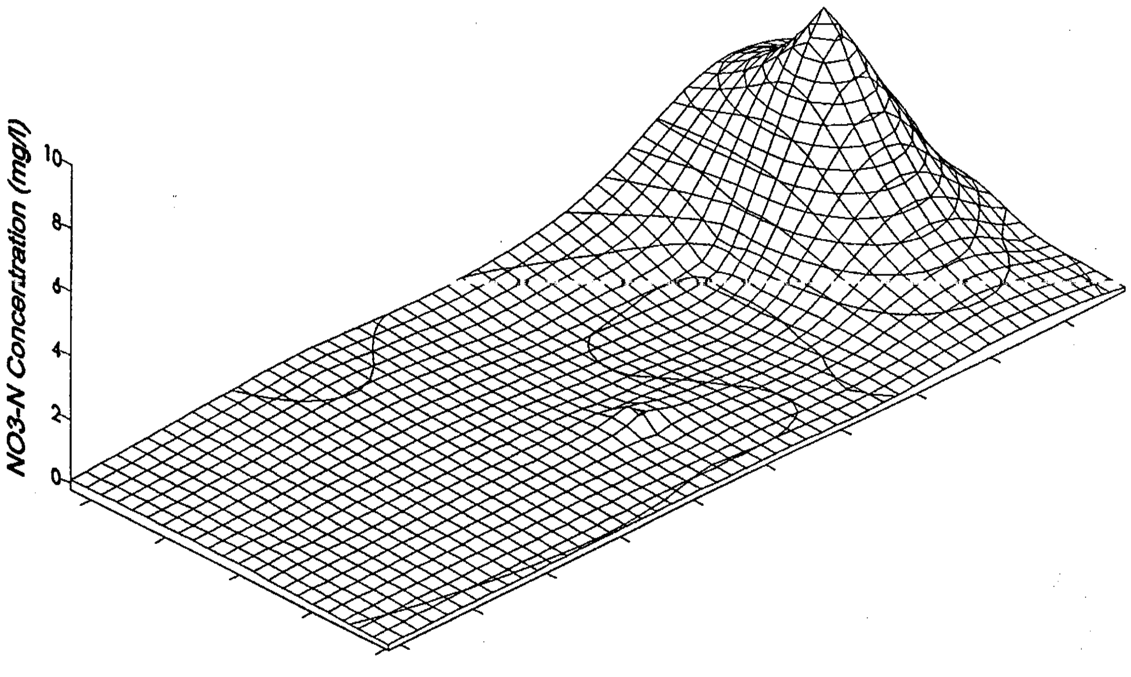
0.25
4.25
3.25
2.25
0.25
1.25
2.25
1.25
N



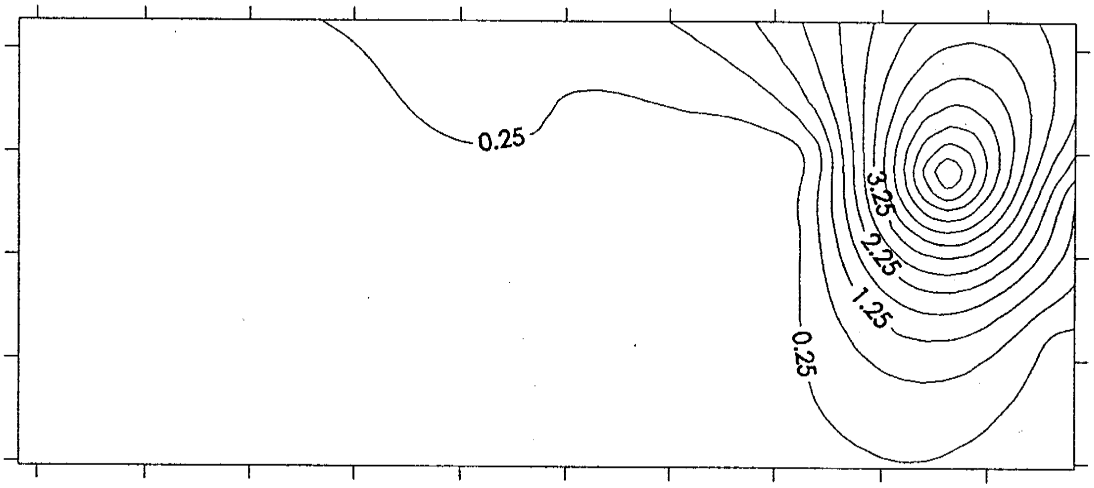
NO3-N Concentration (mg/l)
10
8
6
4
2
0

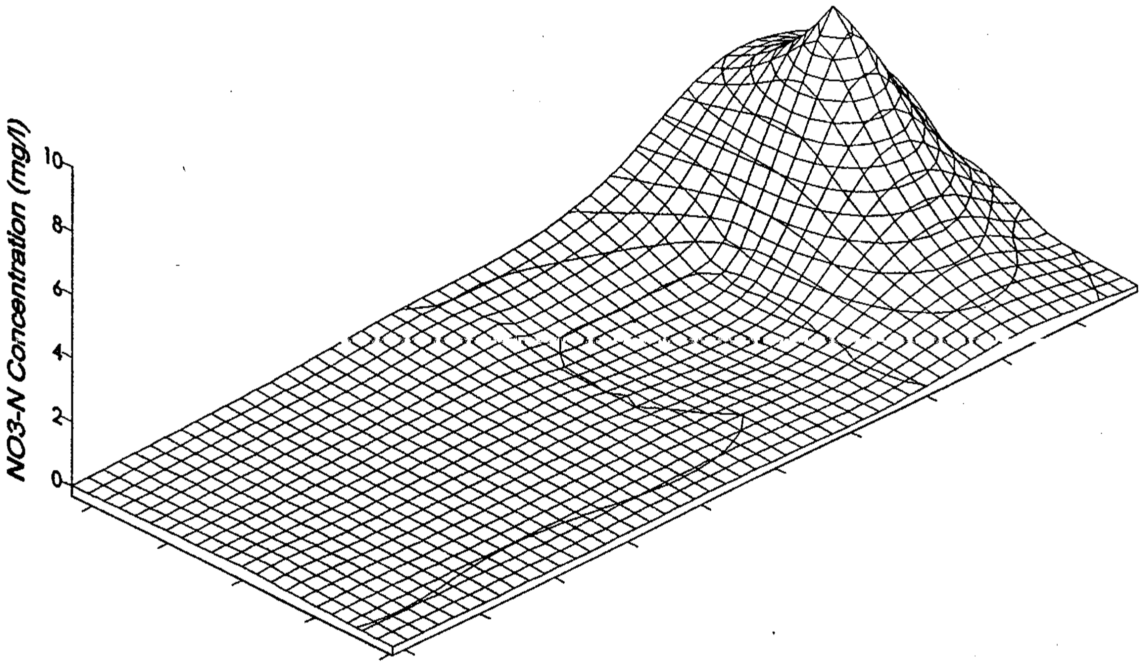
25 May 1994


0.25
0.25
0.25
4.25
3.25
2.25
1.25
0.25
N

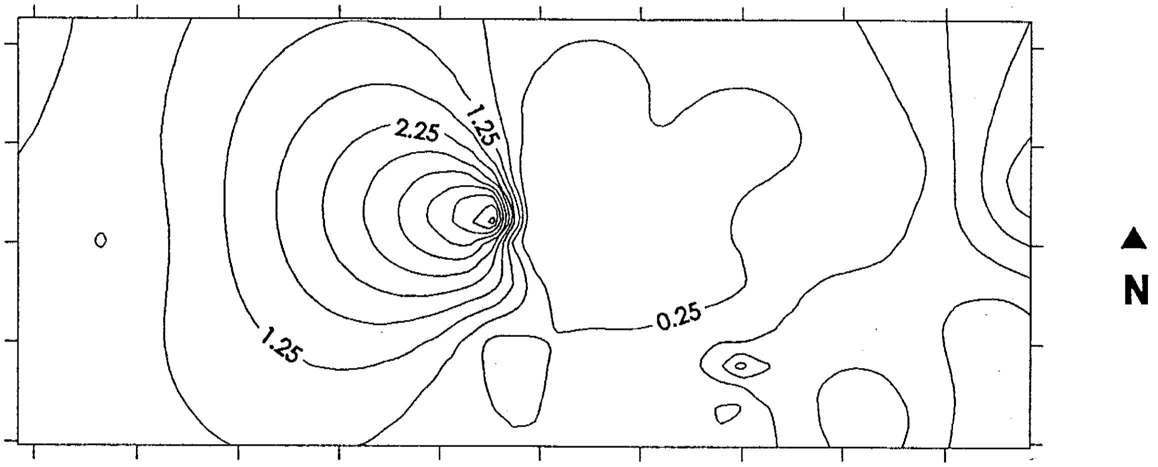

NO3-N Concentration (mg/l)
10
8
6
4
2
0

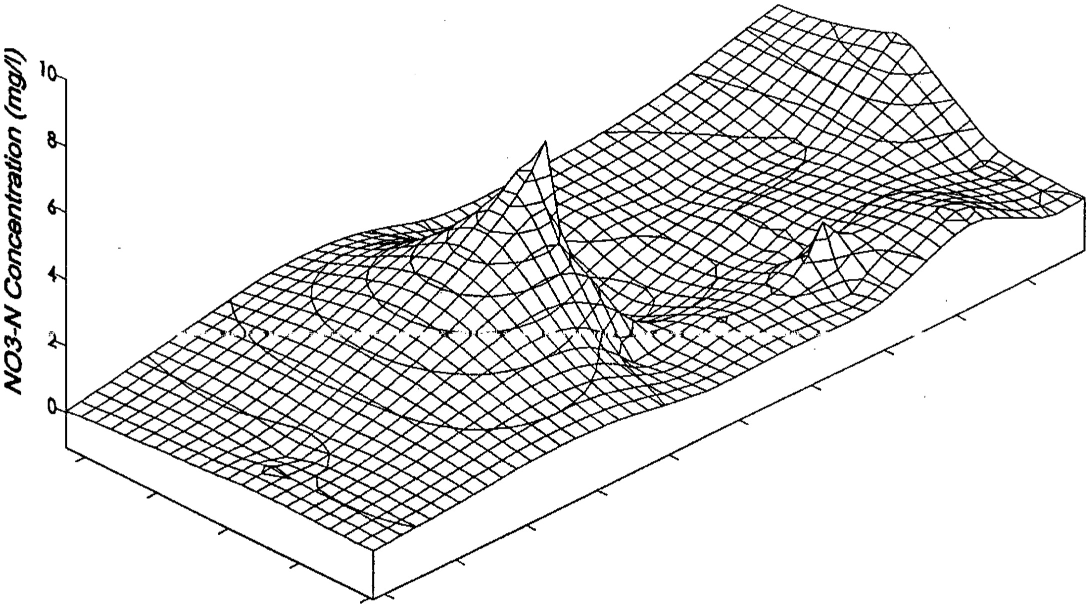
1 June 1994



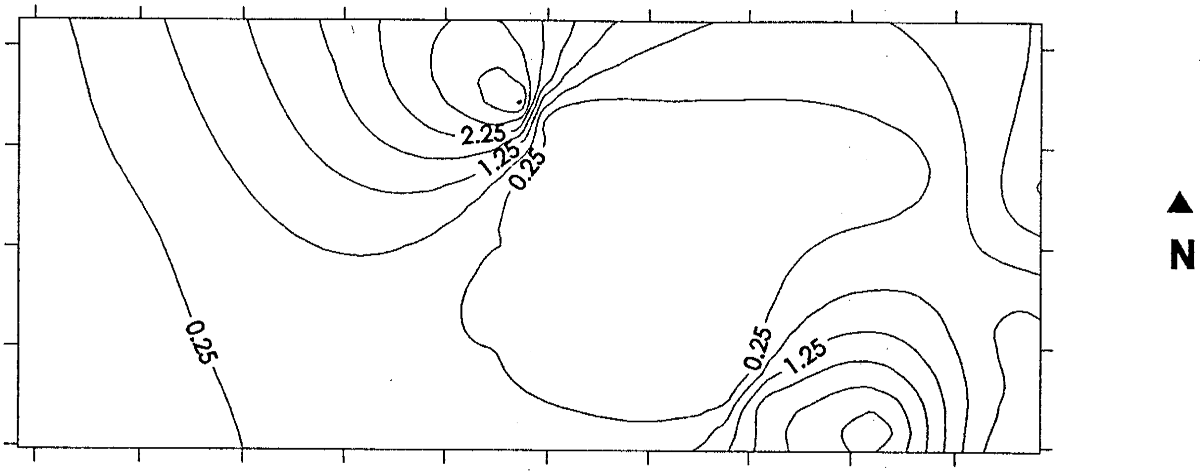


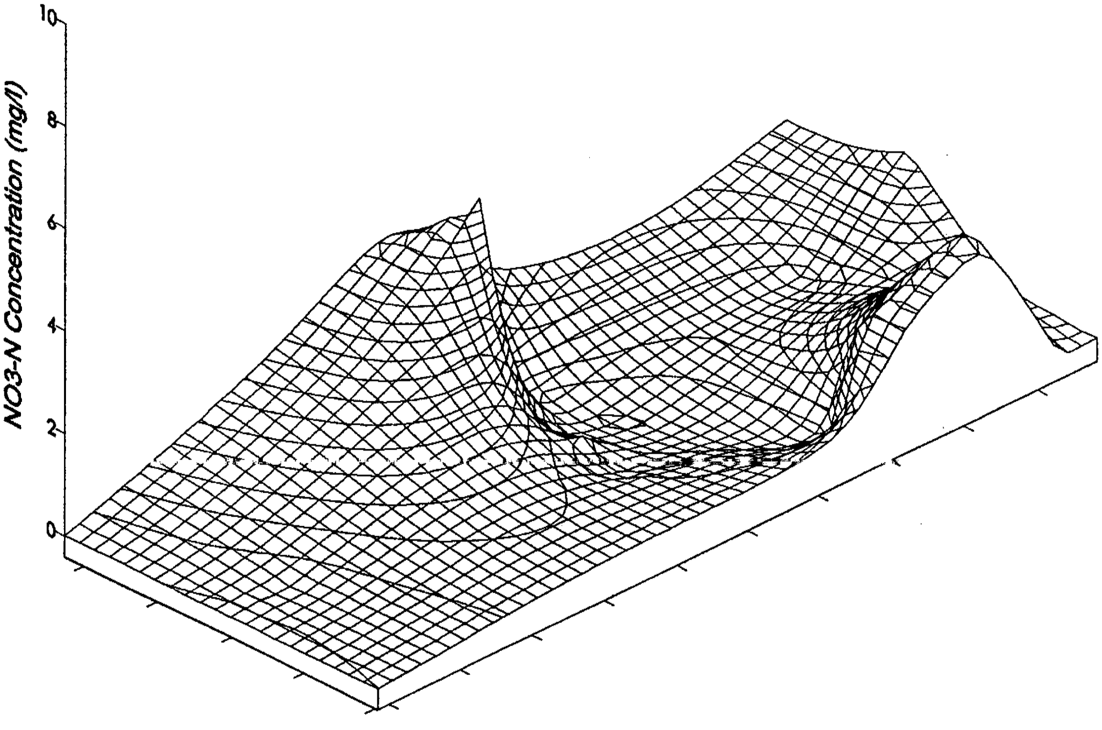
9 June 1994



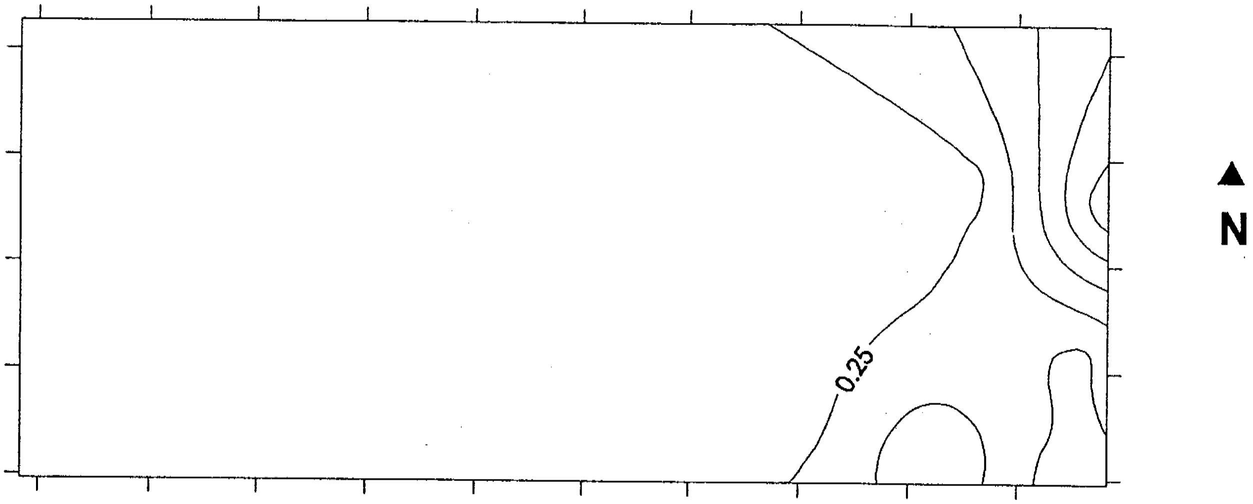


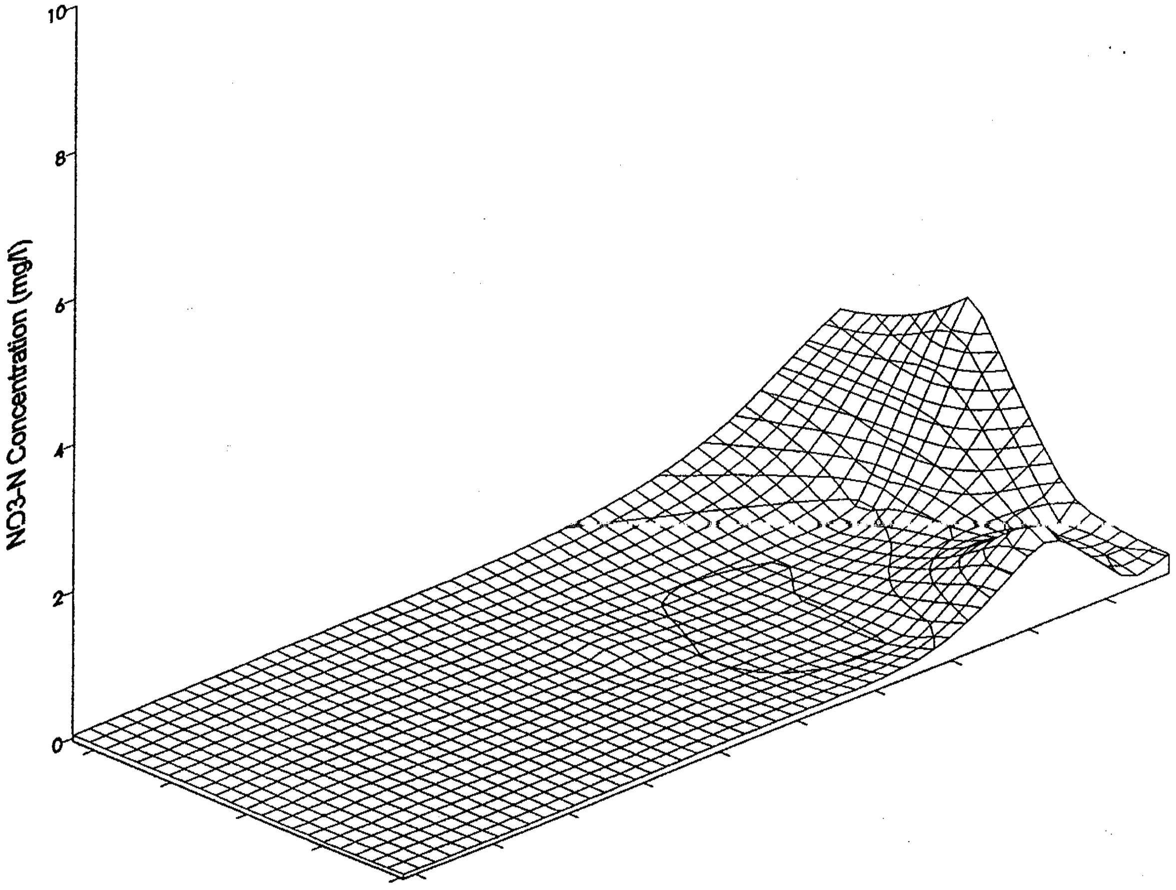
1 July 1994



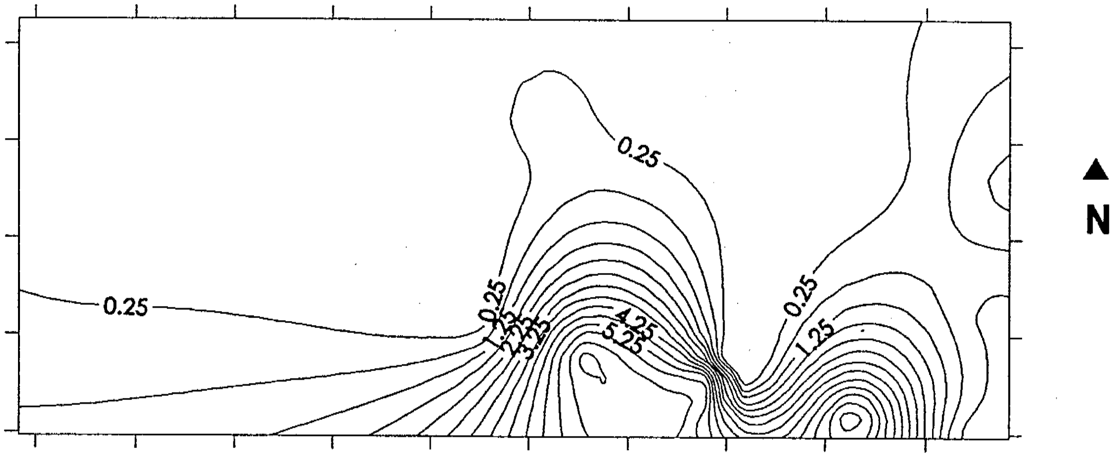


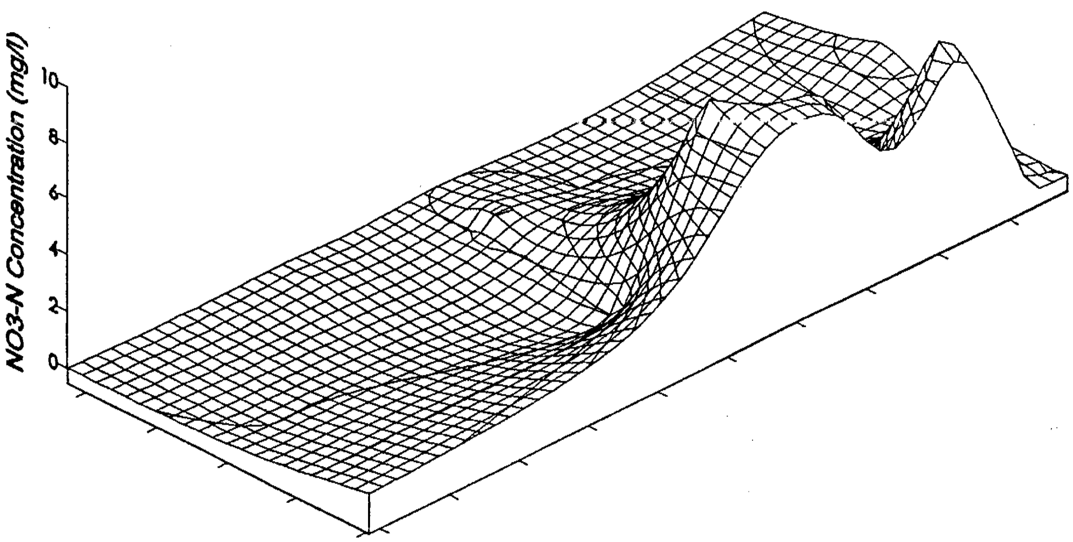
19 July 1994



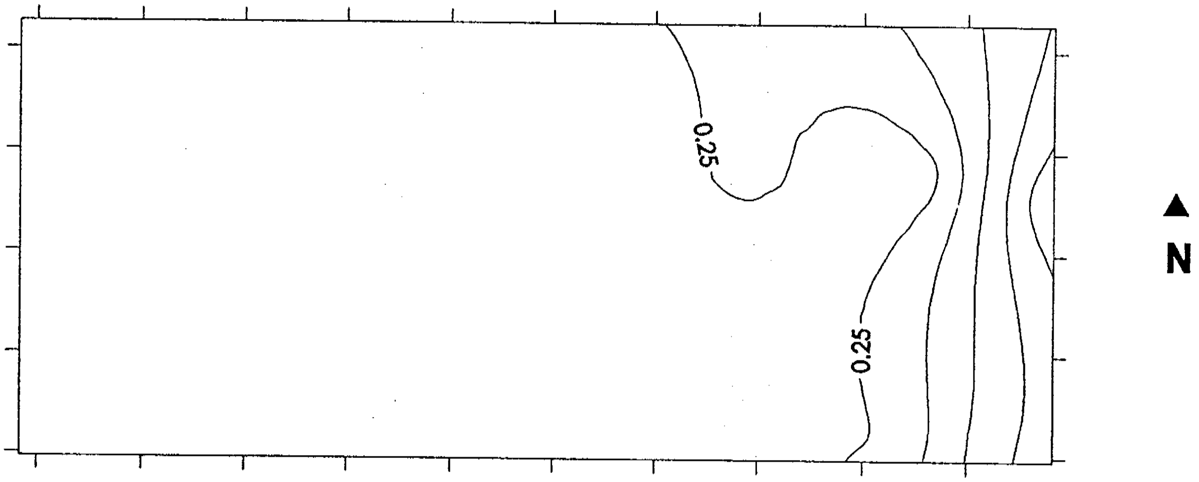


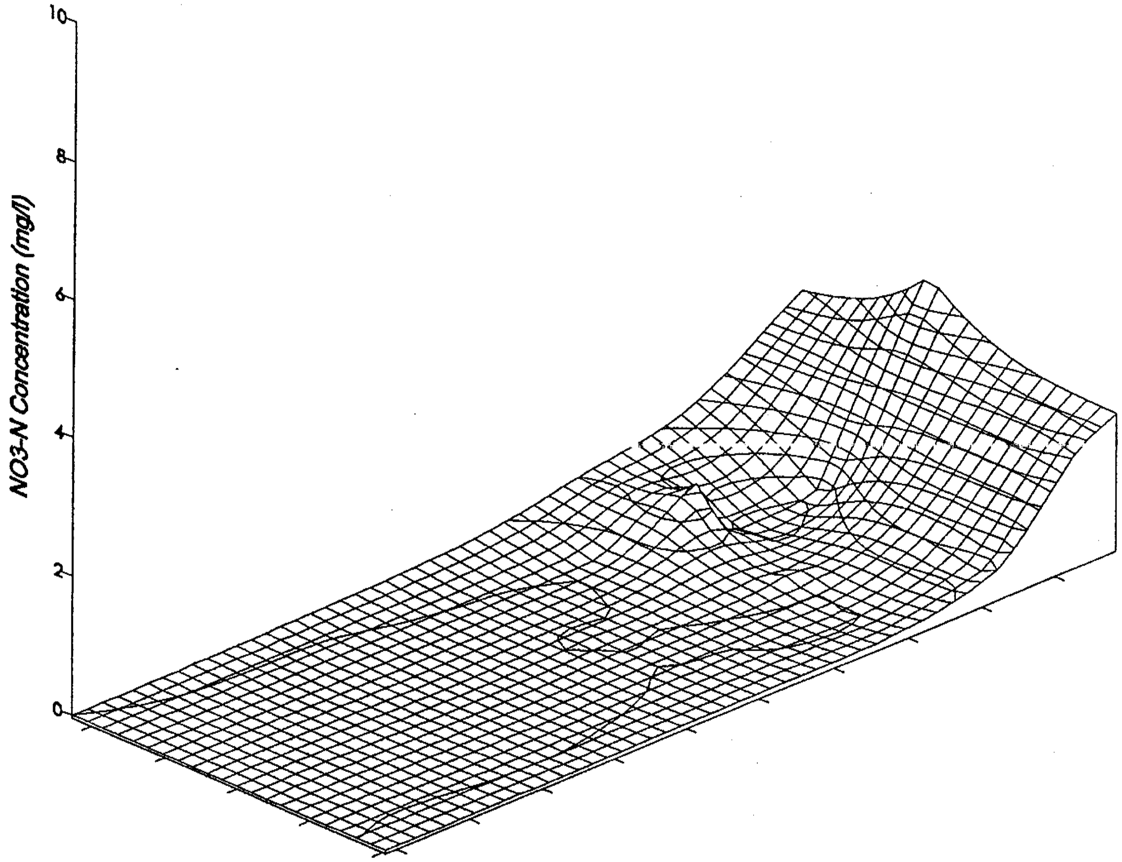
19 August 1994



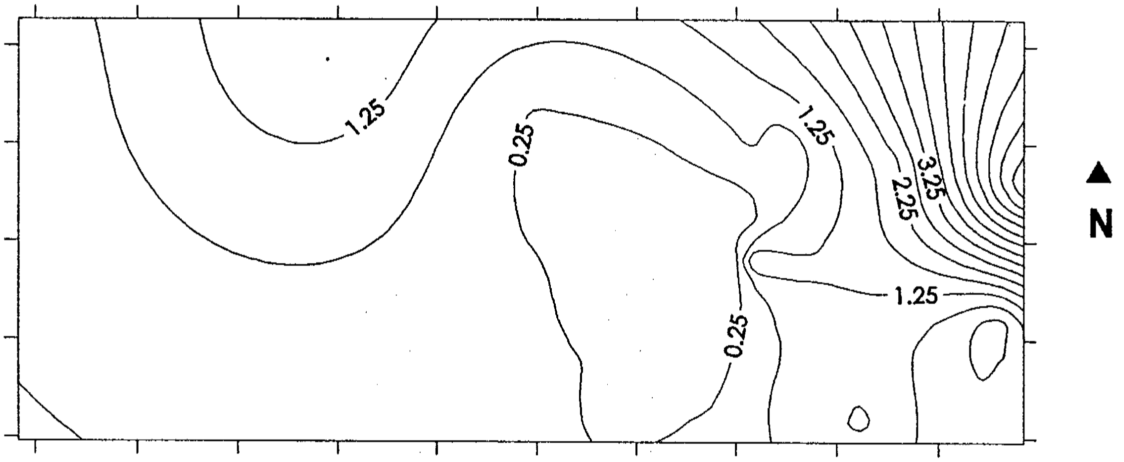


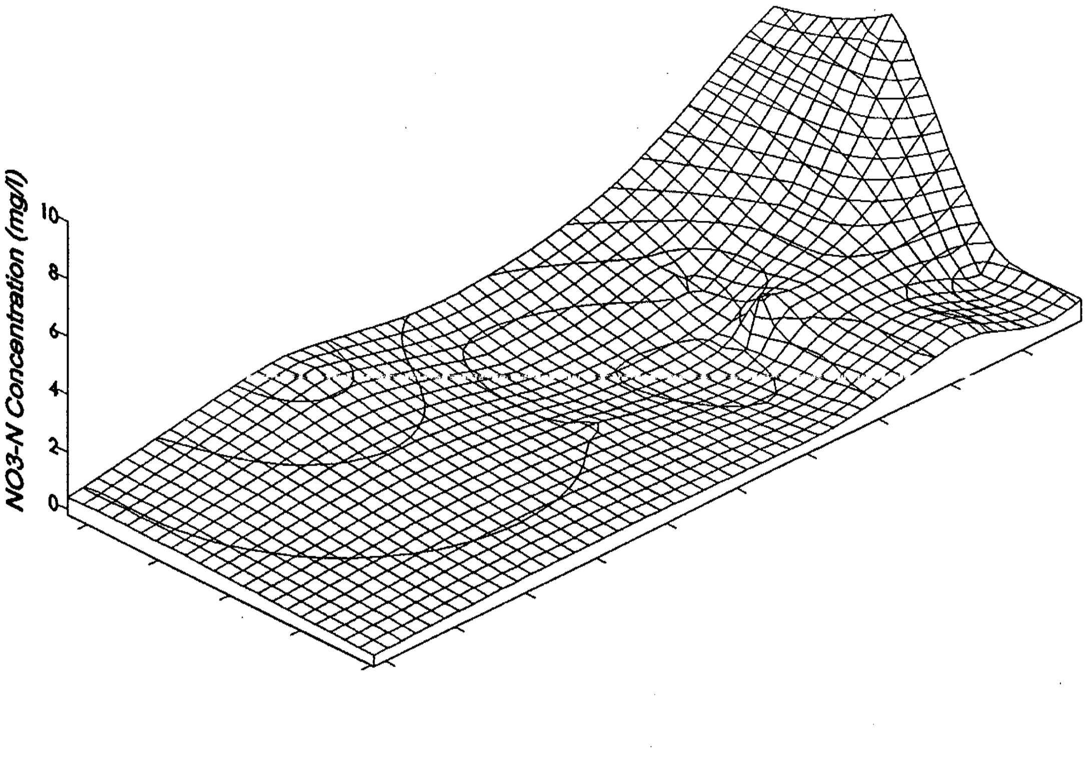
11 September 1994



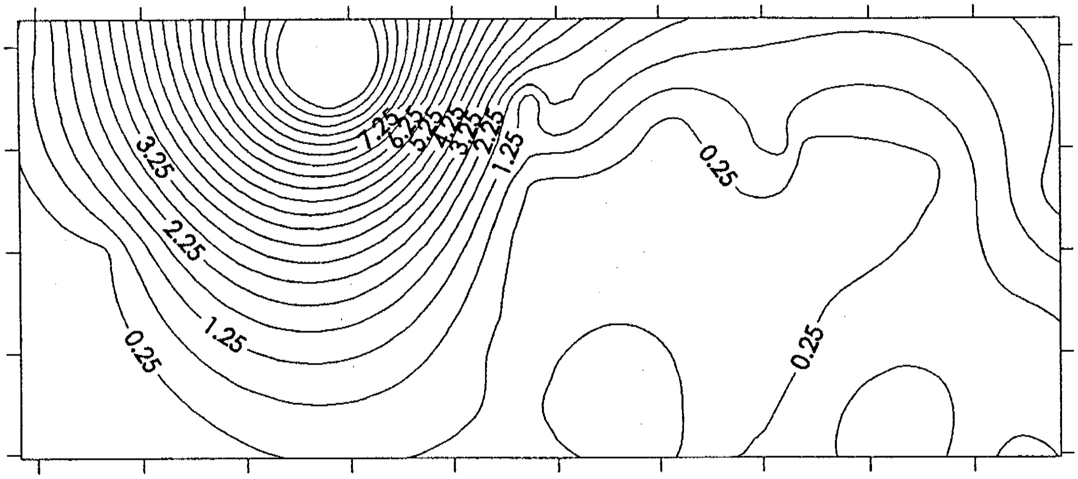


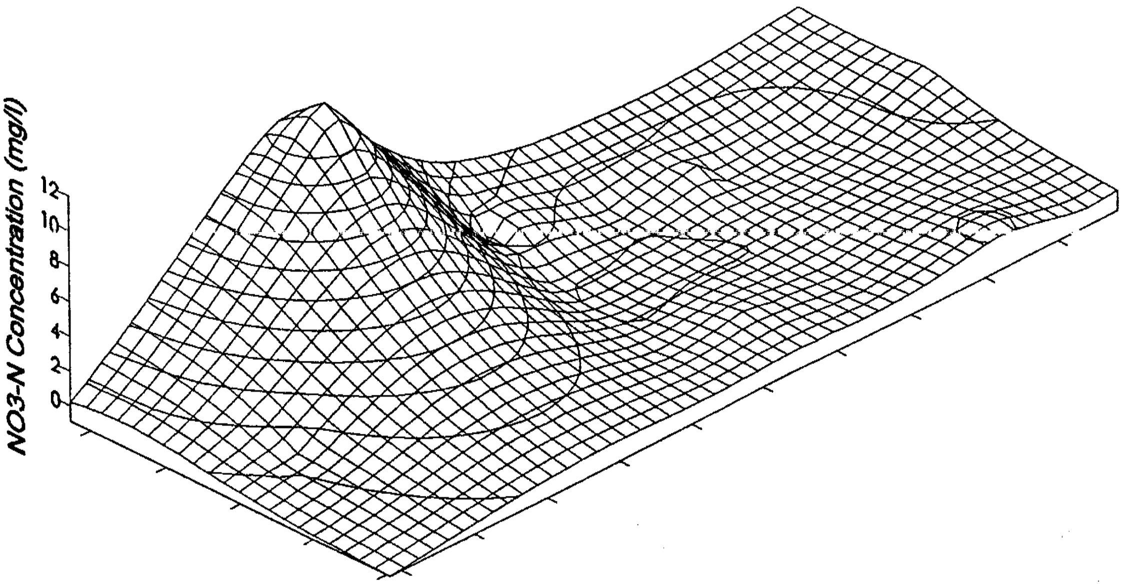
24 September 1994



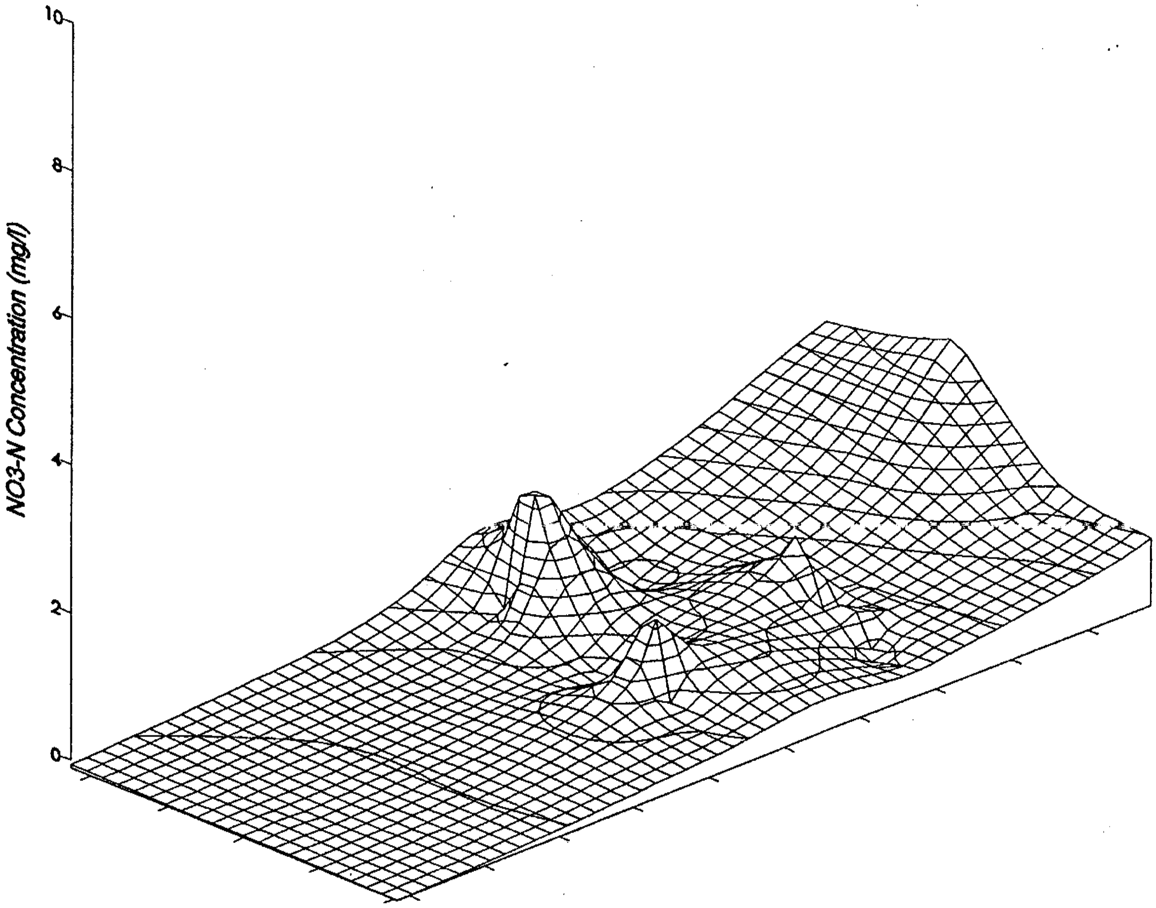


8 October 1994

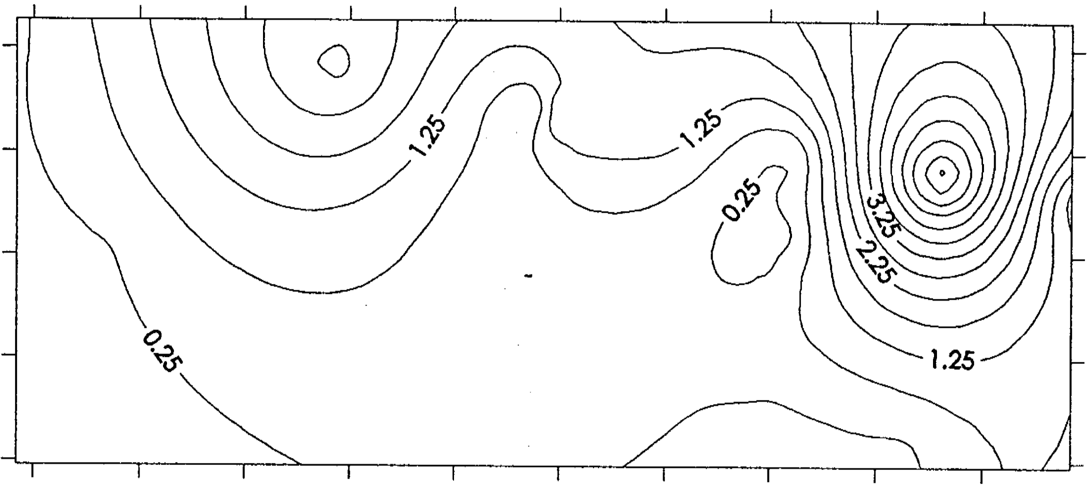


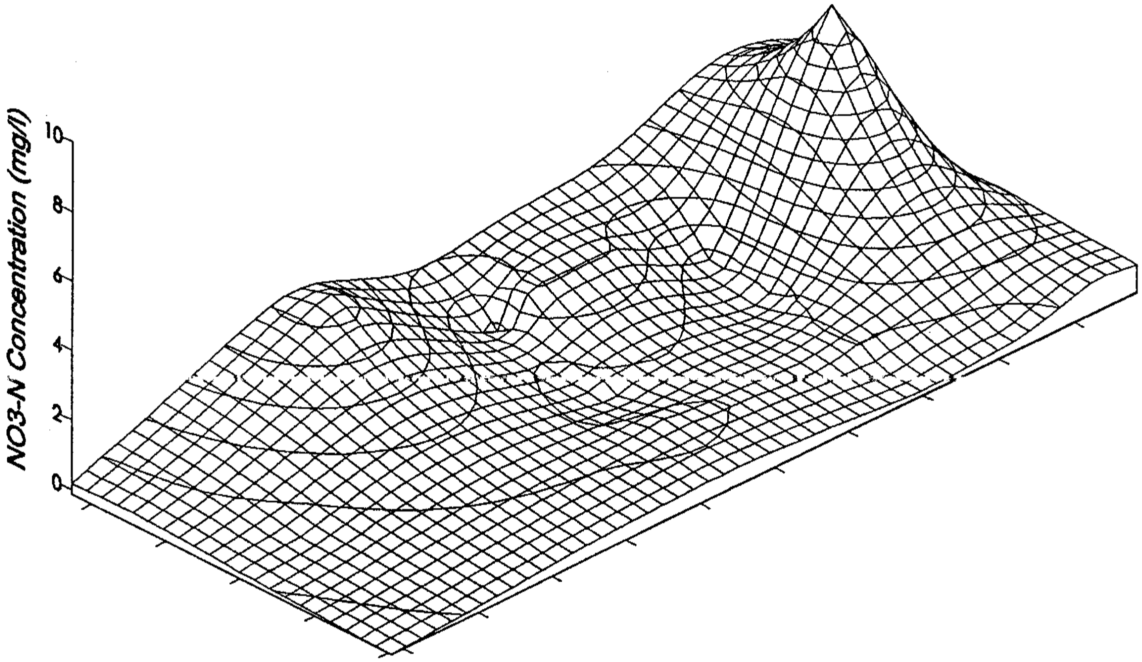


23 October 1994



15 November 1994

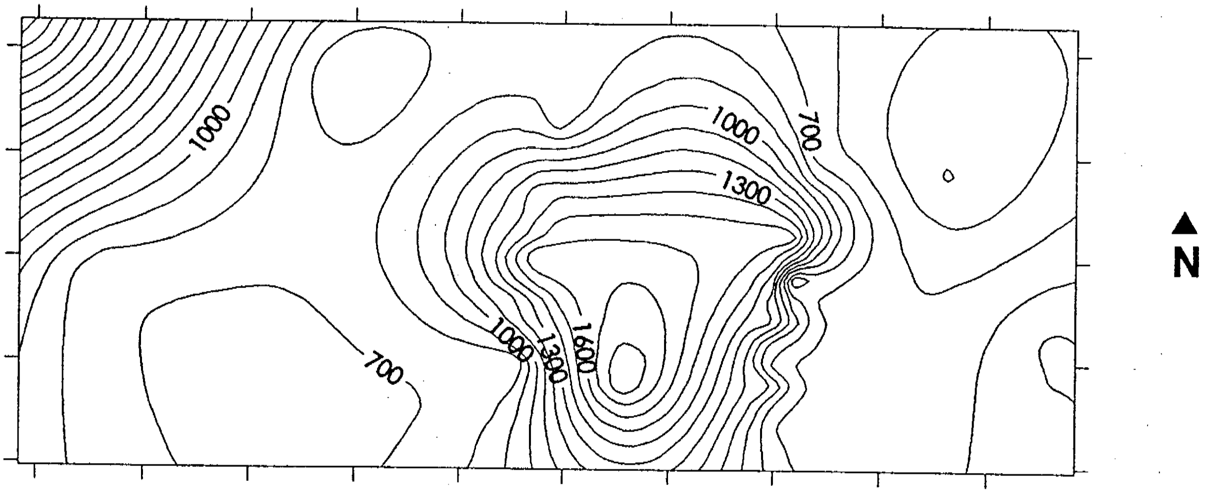


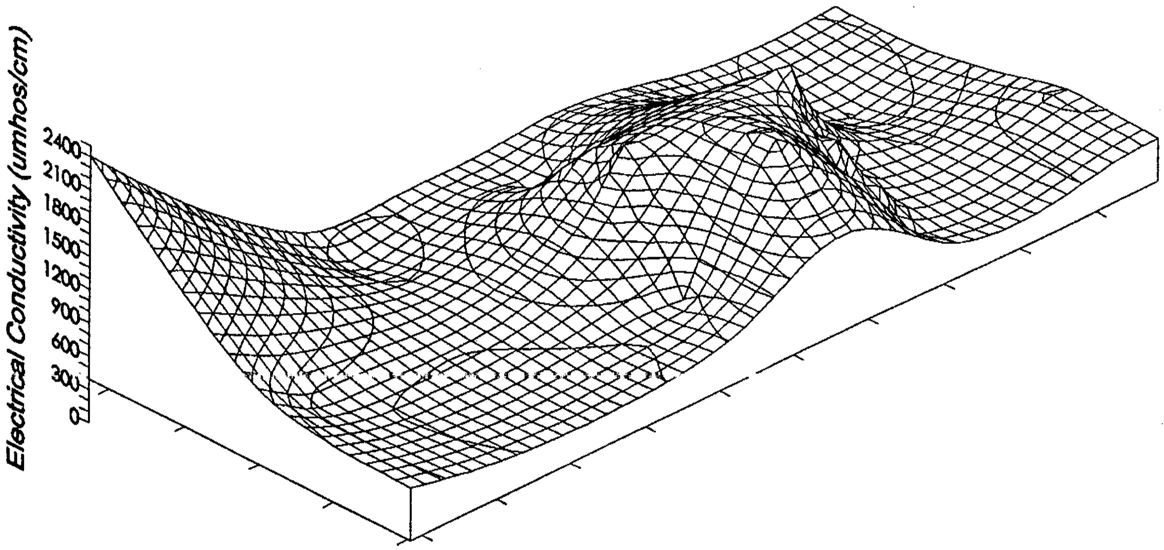


Appendix 9.3.1.4 Electrical Conductivity Contour Maps and 3-Dimensional Surface Plots

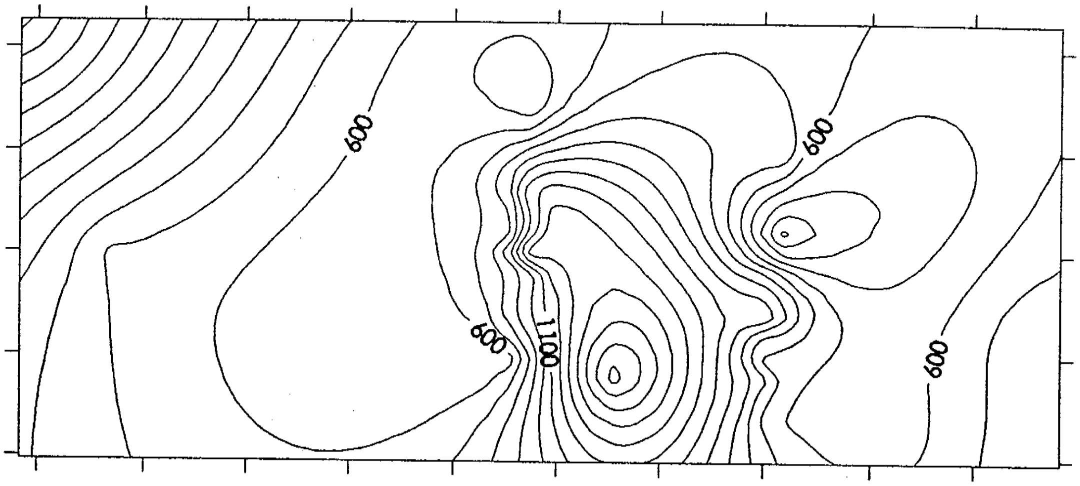
Surfer for Windows by Golden Software, Inc. was also used to create electrical conductivity contour maps and 3-dimensional surface plots for the 1994 observation well sampling events, starting in May 1994. The kriging method was also used for these data sets to interpolate the values in between data points. The contour interval is 100 umhos/cm.

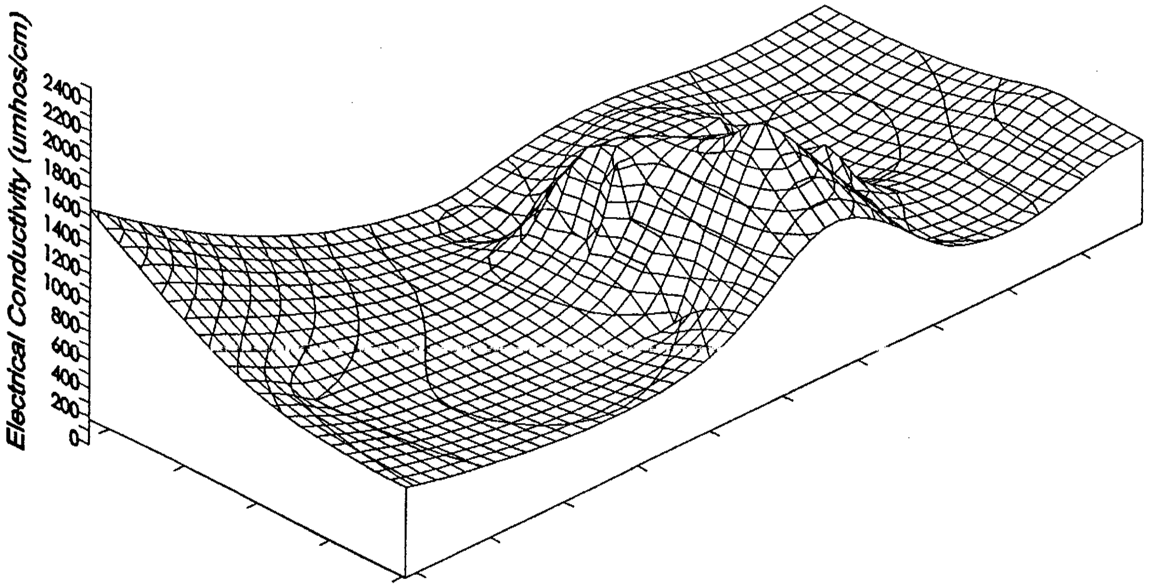
17 May 1994


1000
1000
700
1300
700
1000
1300
1600
N

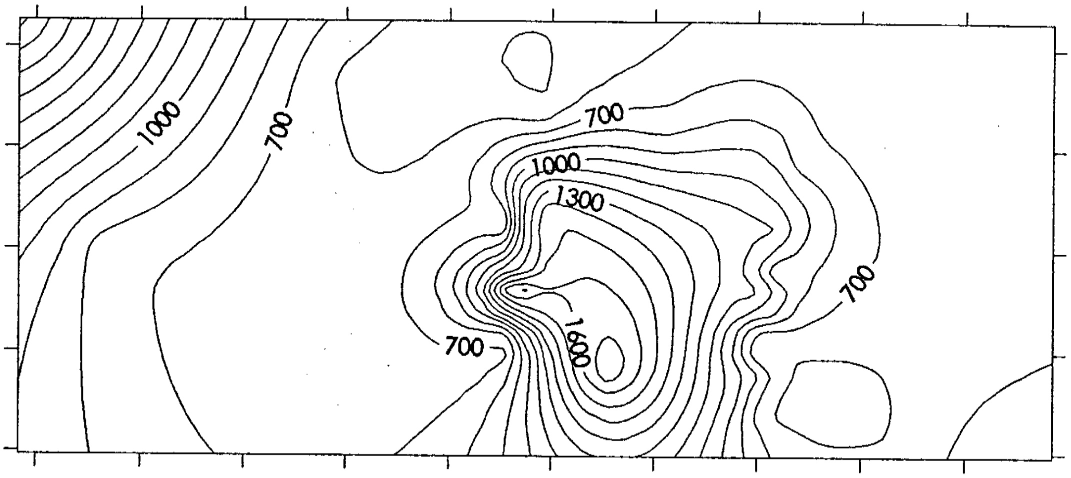

Electrical Conductivity (umhos/cm)
2400
2100
1800
1500
1200
900
600
300
0

25 May 1994

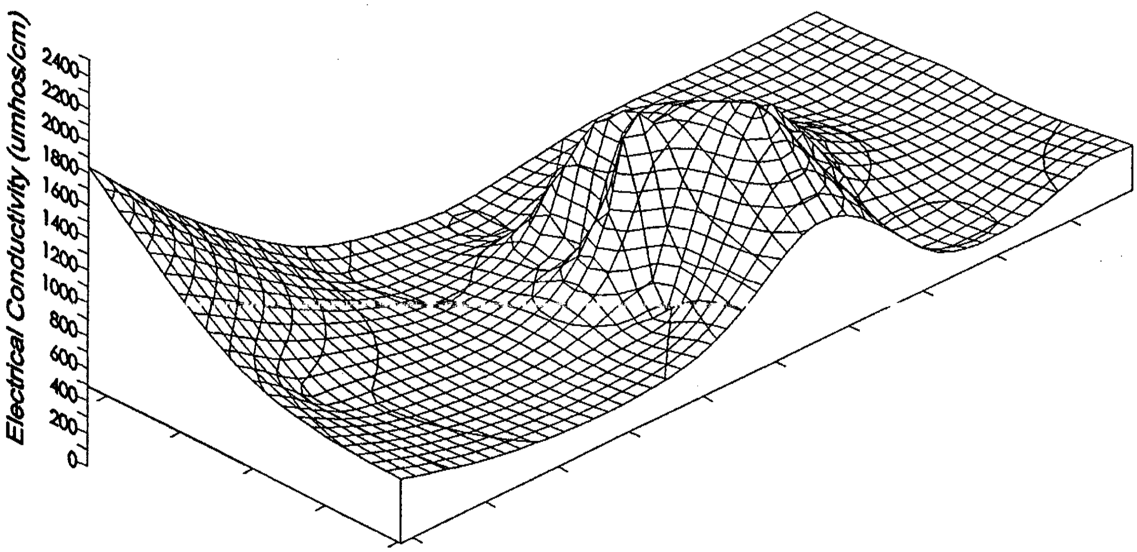

600
600
600
600
1100
600


Electrical Conductivity (umhos/cm)
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0

1 June 1994

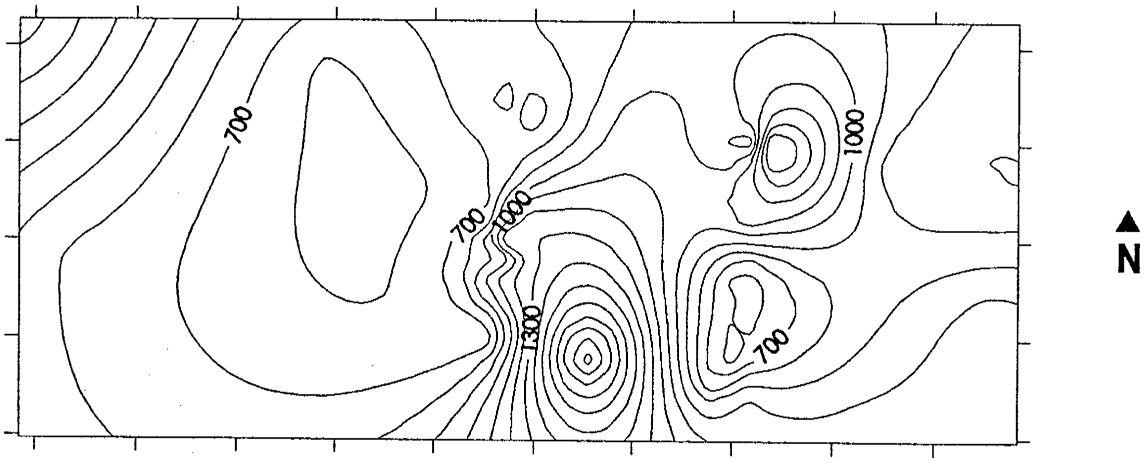


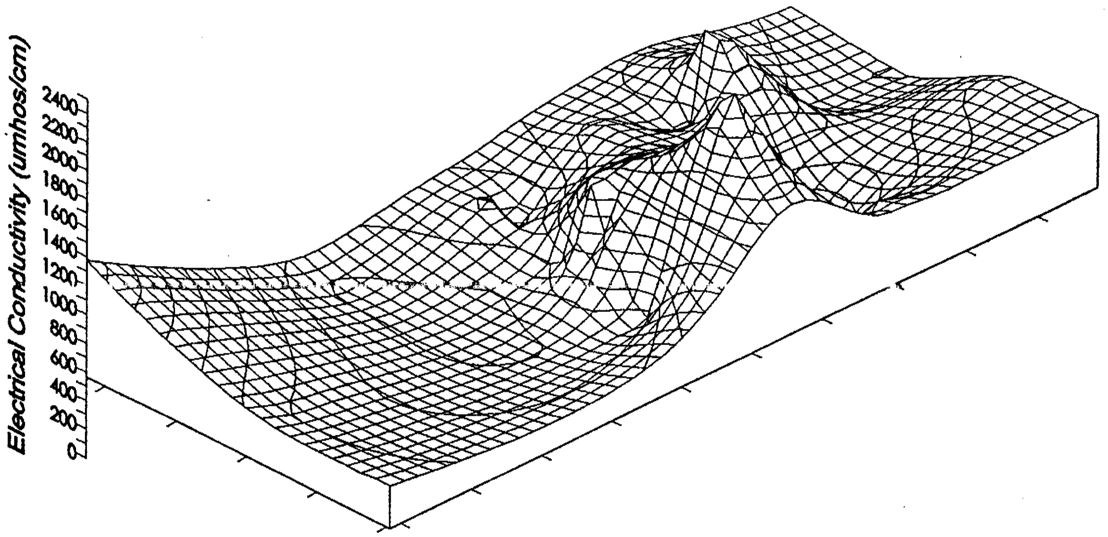
1000
700
700
1000
1300
700
700
1600



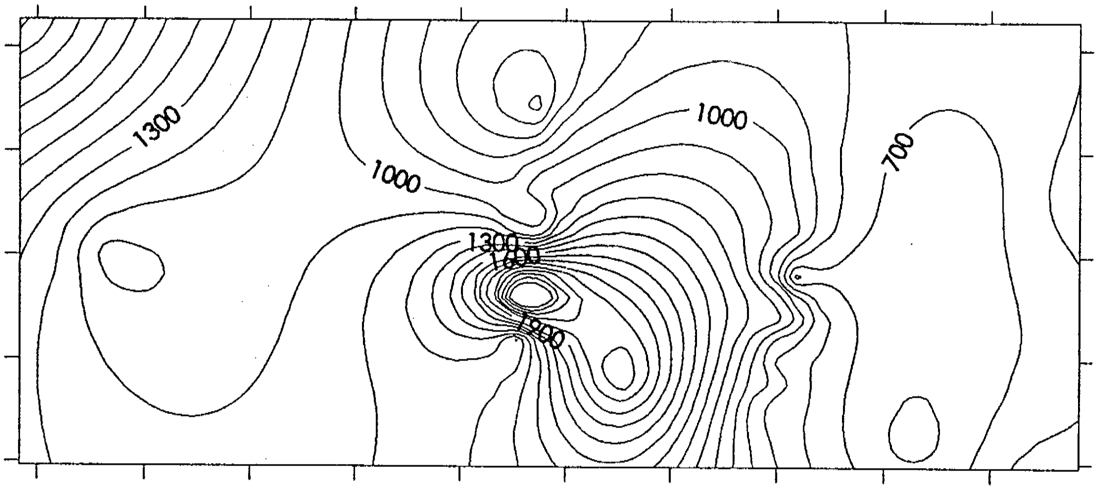
Electrical Conductivity (umhos/cm)
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0

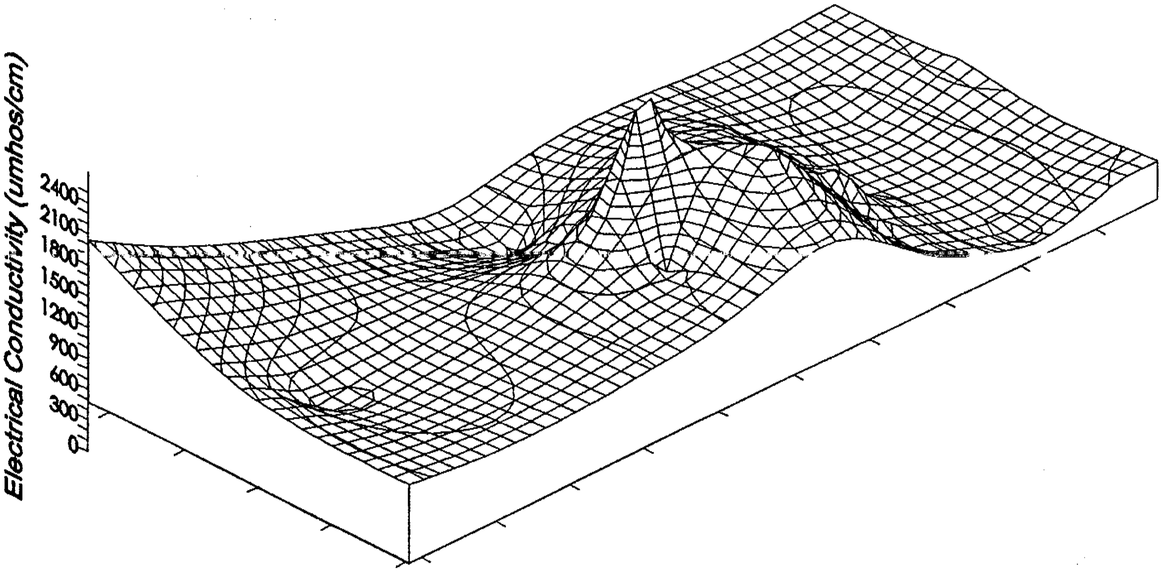
9 June 1994


700
700
1000
1300
1000
700
N

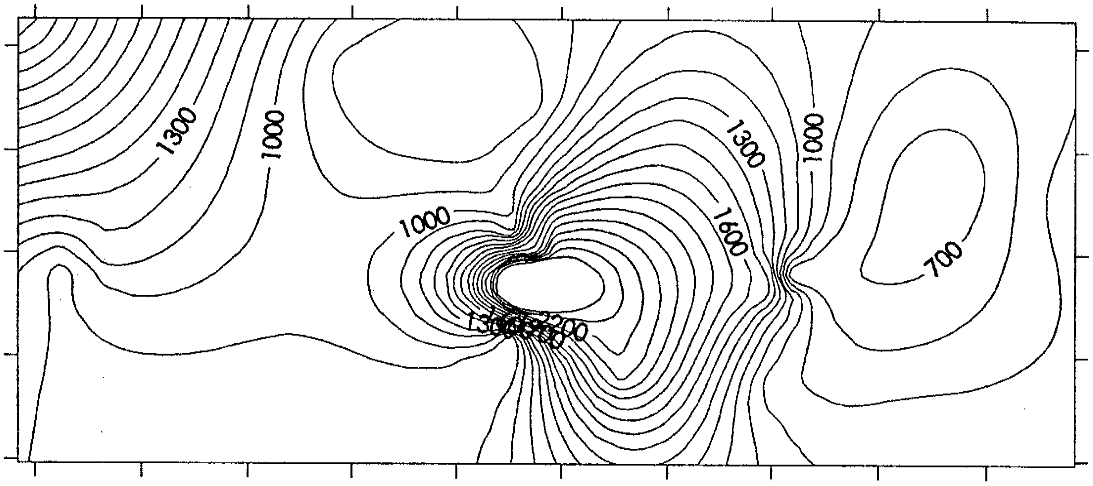

Electrical Conductivity (umhos/cm)
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0

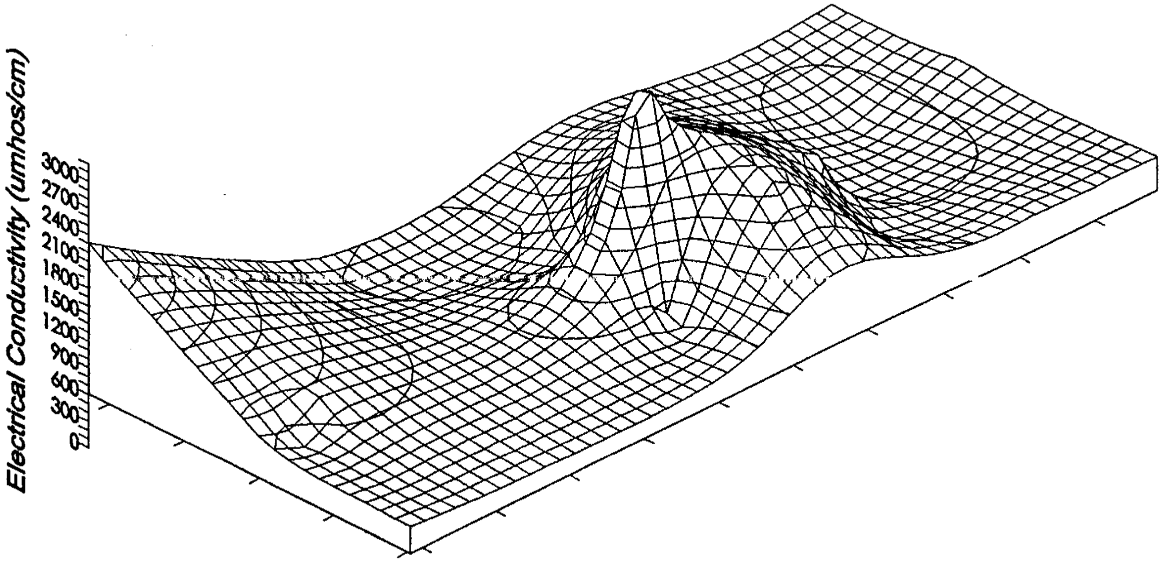
1 July 1994


1300
1000
1000
700
1300
1600
1900

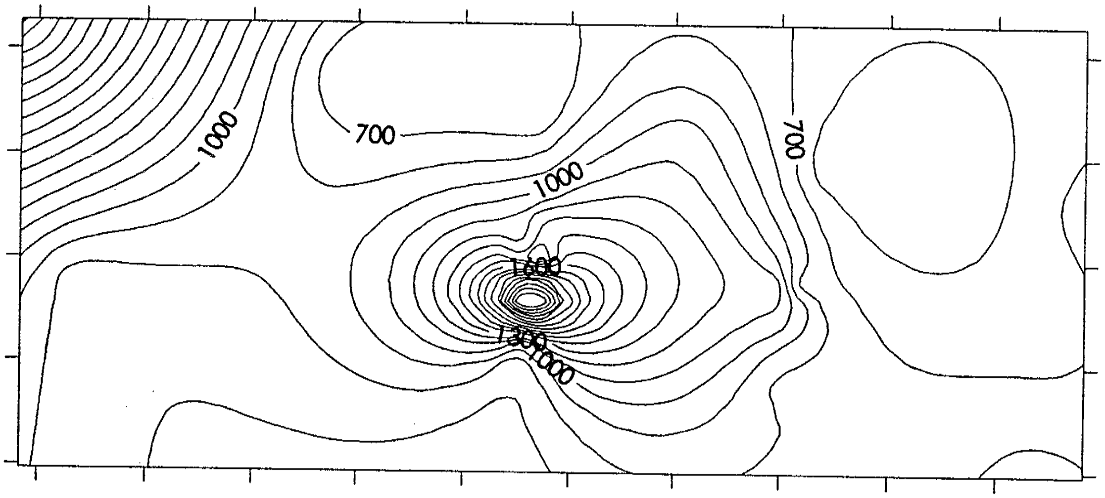

Electrical Conductivity (umhos/cm)
2400
2100
1800
1500
1200
900
600
300
0

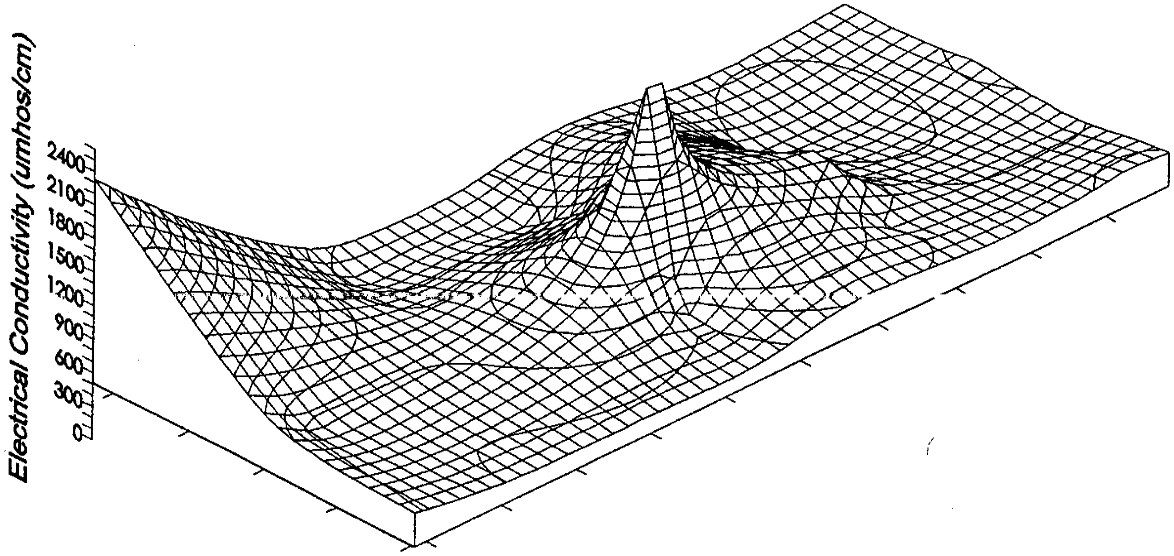
19 July 1994


1300
1000
1000
1300
1000
1600
700
1300
2200

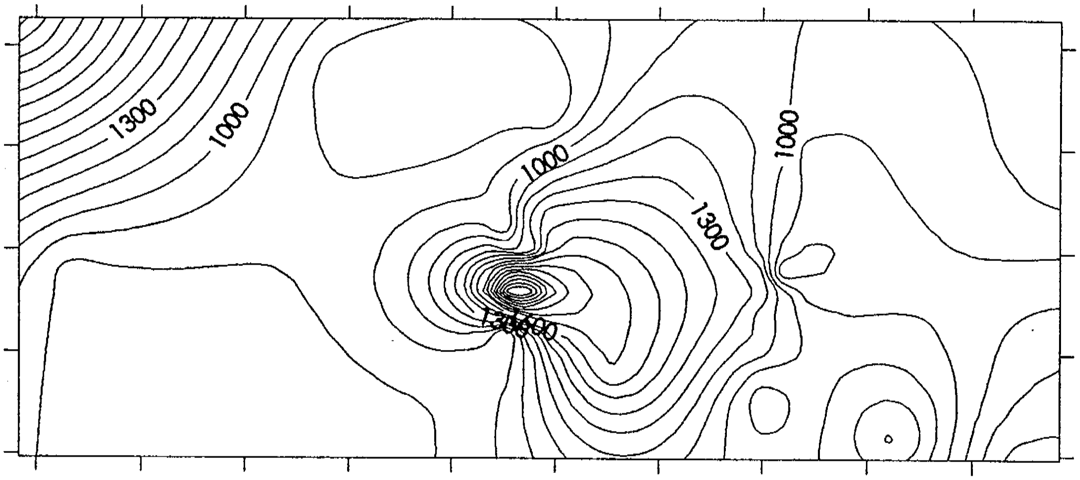

Electrical Conductivity (umhos/cm)
3000
2700
2400
2100
1800
1500
1200
900
600
300
0

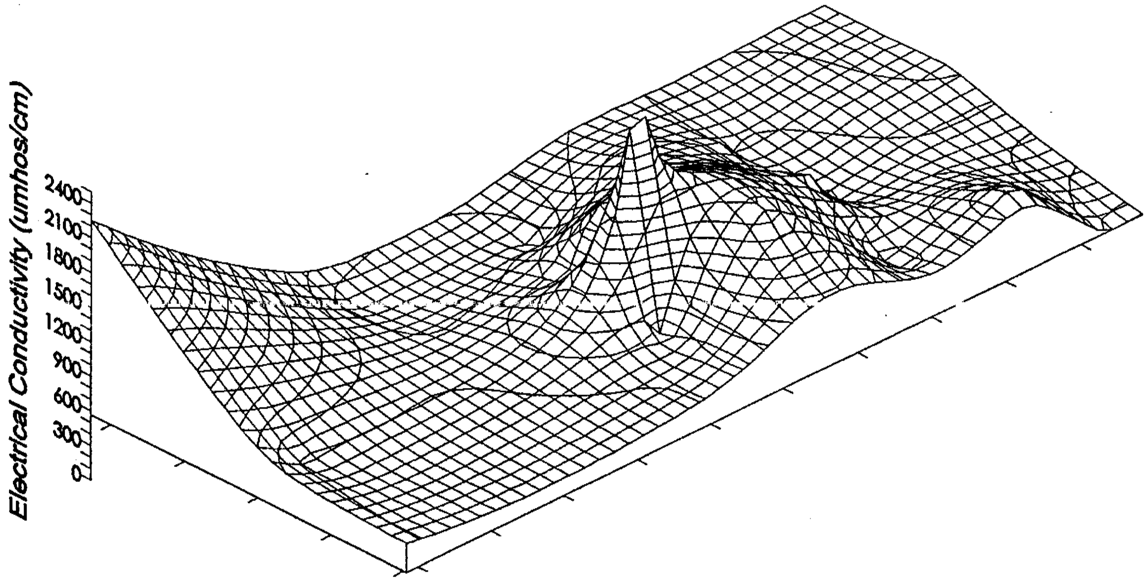
19 August 1994



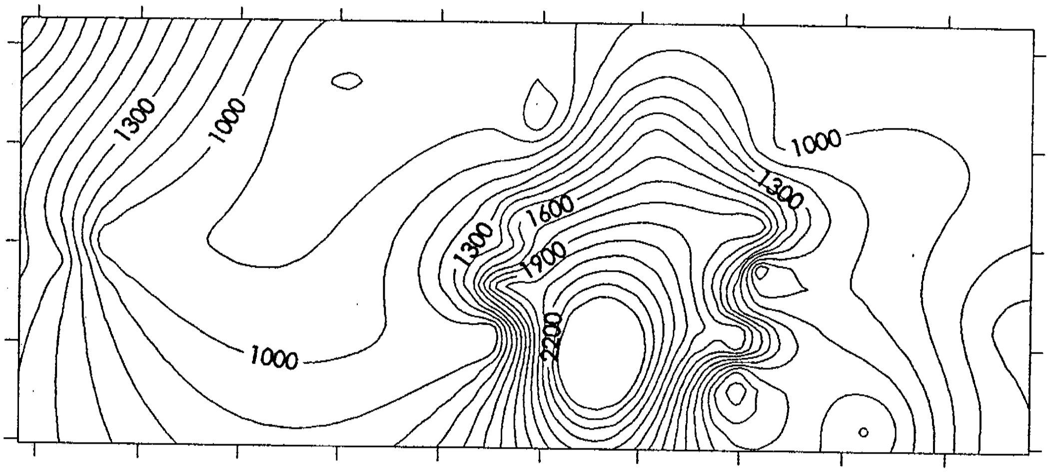


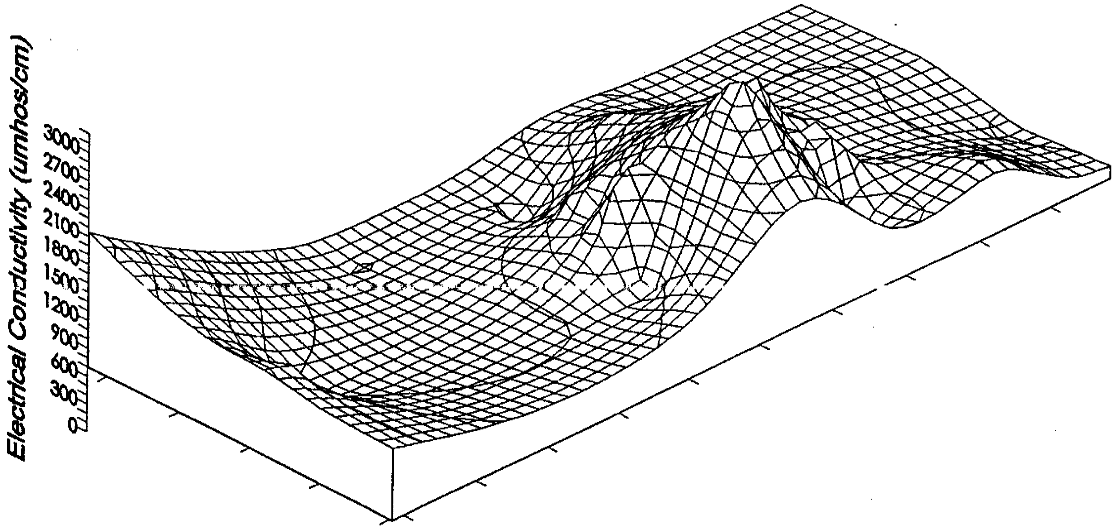
11 September 1994



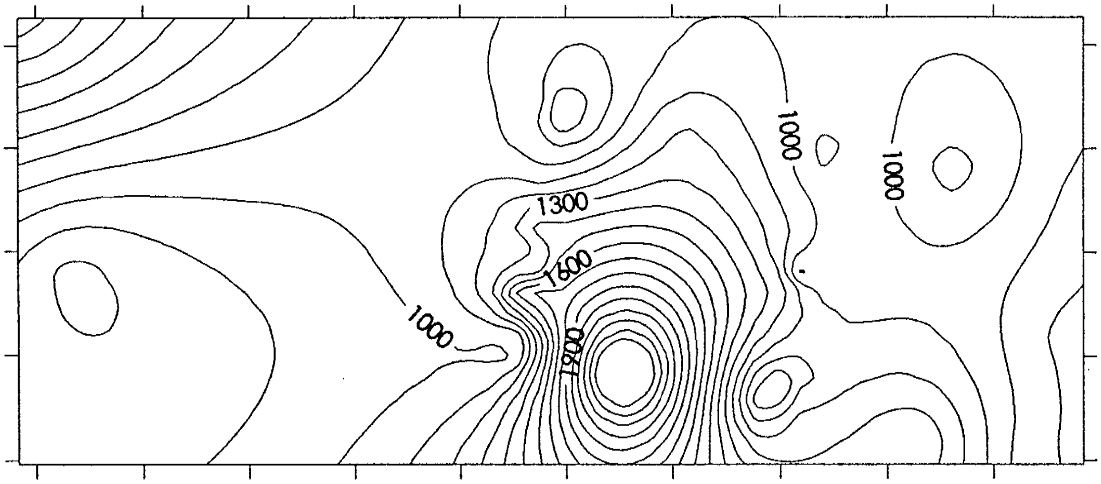


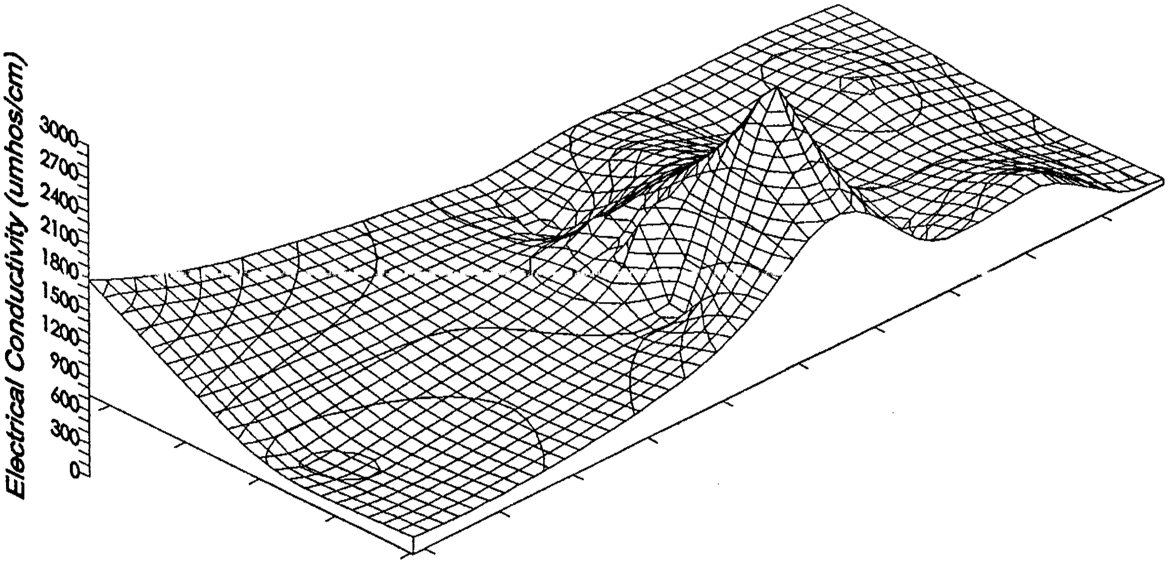
8 October 1994



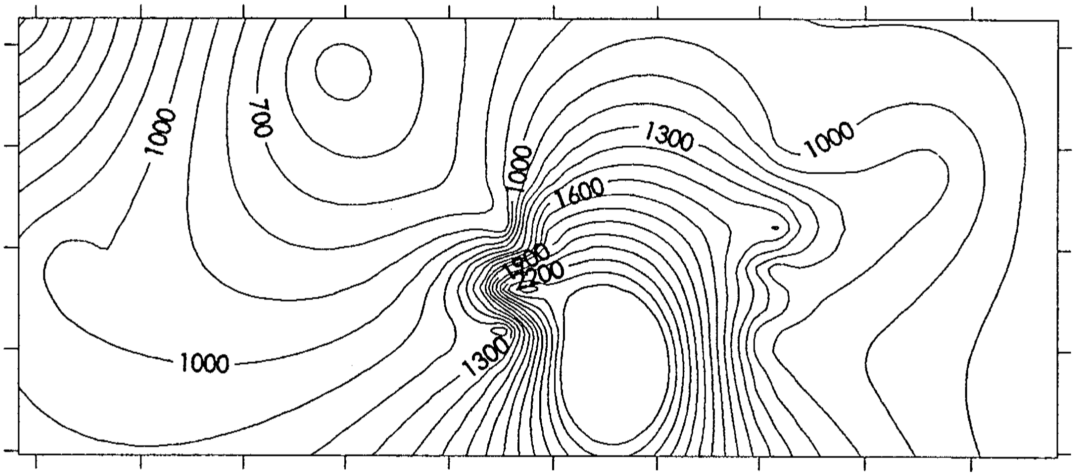


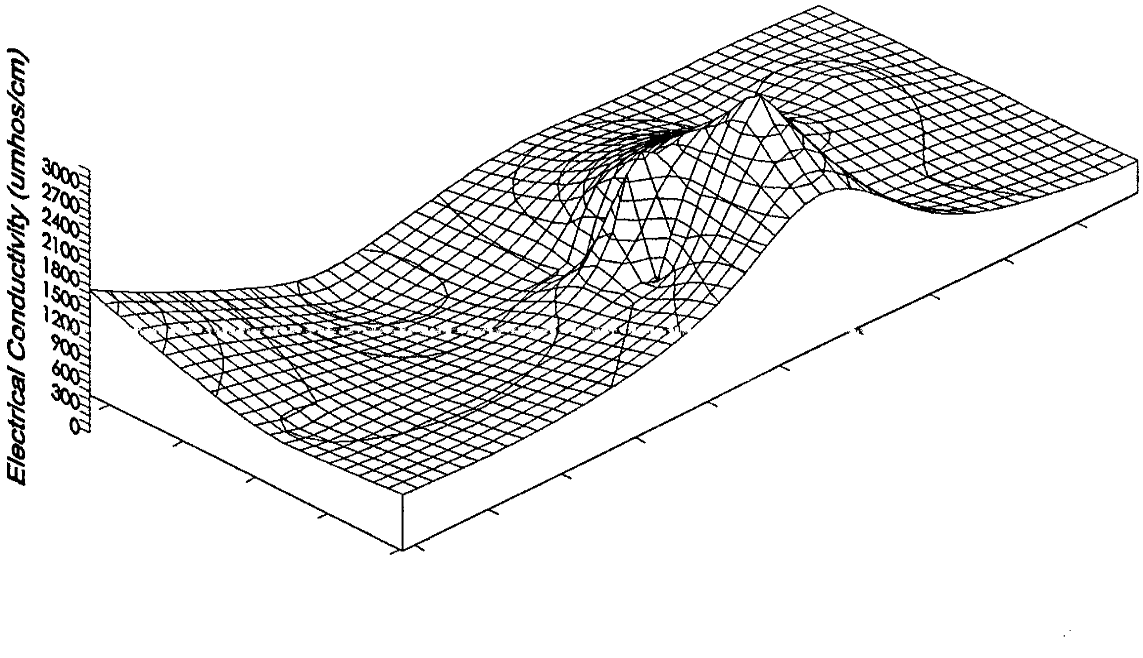
23 October 1994



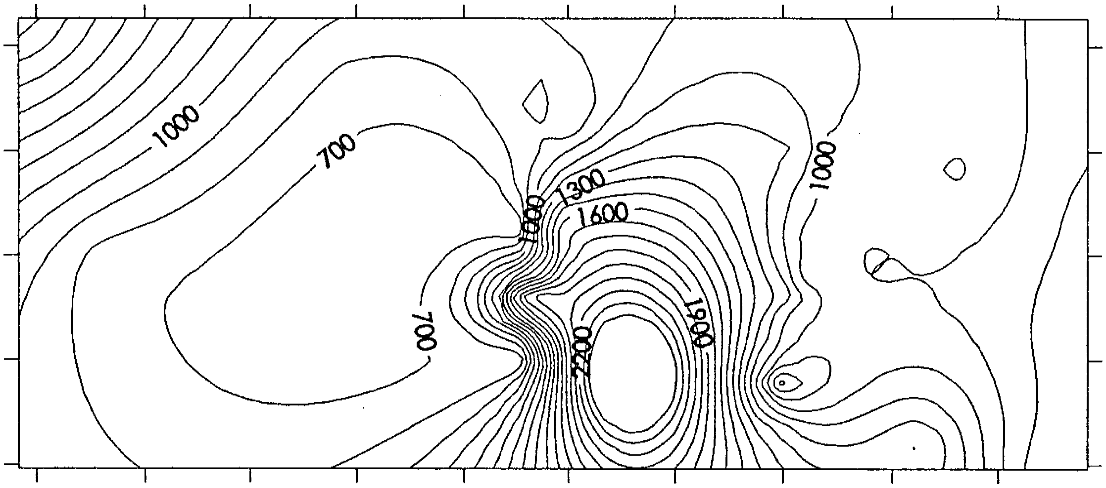


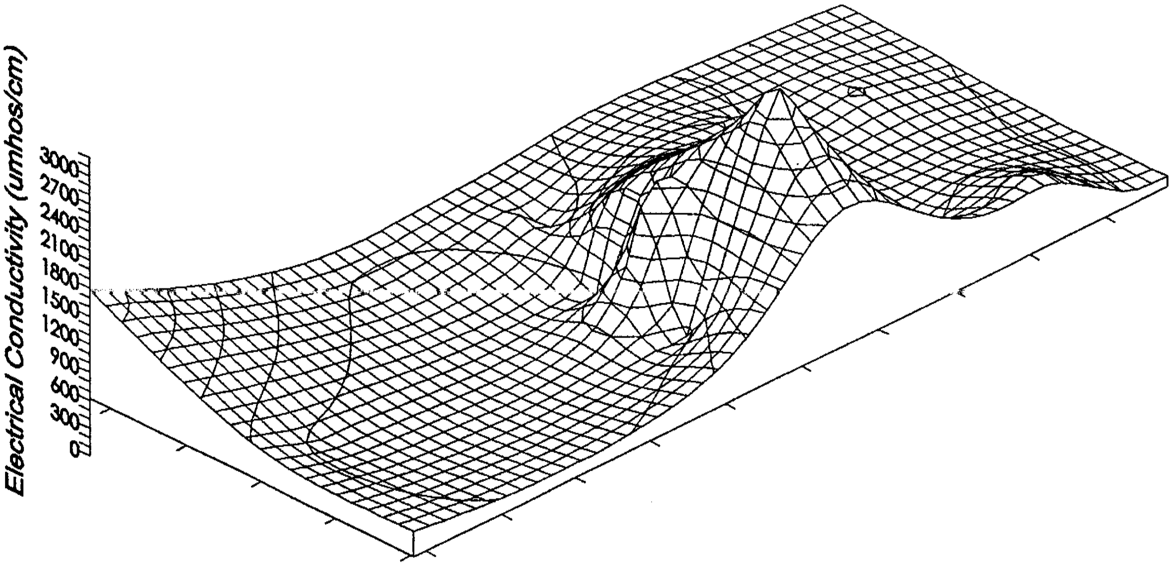
8 November 1994





15 November 1994



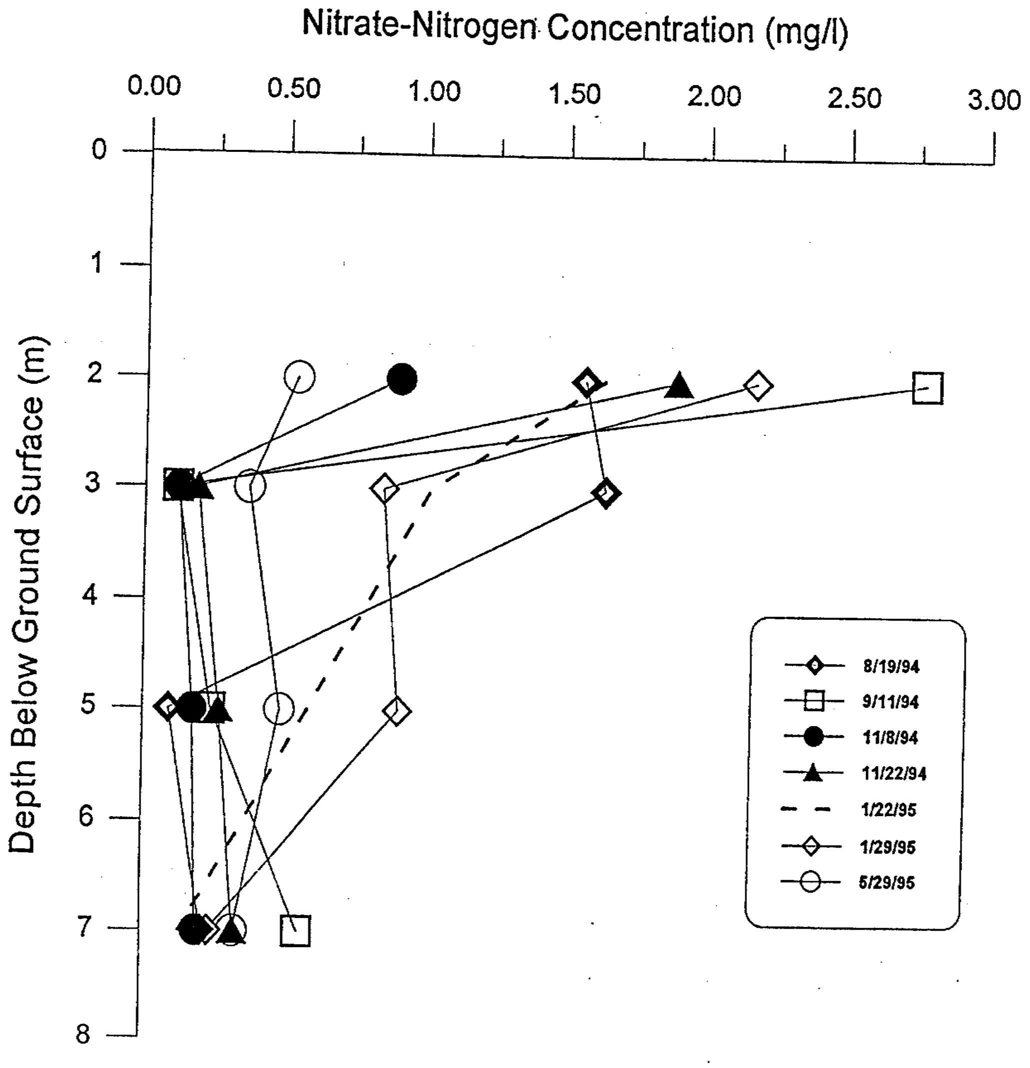


Appendix 9.3.2 Piezometer Nest Data

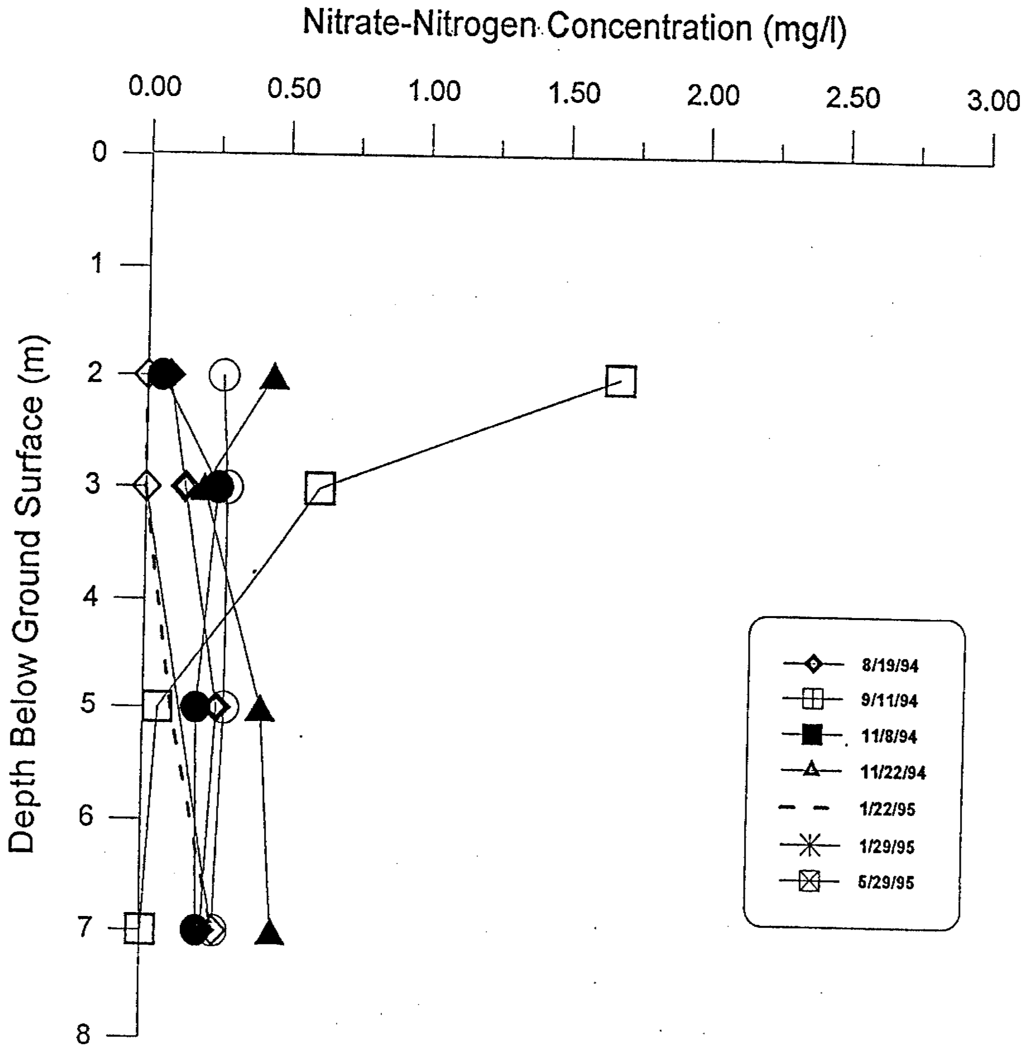
Appendix 9.3.2.1 Piezometer Nest NO_3-N Concentration (mg/l)

well id	depth (m below ground surface)		19-Aug-94	11-Sep-94	8-Nov-94	22-Nov-94	22-Jan-95	29-Jan-95	29-Ma
A1	2		1.56	2.77	0.90	1.89	1.63	2.17	0.5
B1	3		1.64	0.12	0.12	0.19	1.02	0.85	0.3
C1	5		0.09	0.24	0.18	0.27	0.59	0.91	0.4
E1	7		0.22	0.56	0.20	0.33	0.14	0.24	0.3
			19-Aug-94	11-Sep-94	8-Nov-94	22-Nov-94	22-Jan-95	29-Jan-95	29-Ma
A3	2		0.08	1.68	0.05	0.45	0.00	0.00	0.2
B3	3		0.14	0.62	0.26	0.21	0.00	0.00	0.2
C3	5		0.26	0.05	0.19	0.42	0.10		0.2
E3	7		0.22	0.00	0.20	0.47	0.26	0.26	0.2
		3-Aug-94			8-Nov-94	22-Nov-94	22-Jan-95	29-Jan-95	29-May
A11	2	0.00			0.07	0.24	0.02	0.14	0.21
B11	3	0.05			0.25	0.27	0.00	0.09	0.35
C11	5	0.08			0.30	0.50	0.18		2.2
E11	7	0.05			0.15	0.42	0.51	0.71	0.1
		3-Aug-94			8-Nov-94	22-Nov-94	22-Jan-95	29-Jan-95	29-May
A14	2	0.00			0.11	0.28	0.00	0.08	0.21
B14	3	0.00			0.02	0.31	0.00	0.05	0.37
E14	7	0.03			0.36	0.51	0.37	0.08	0.29
		3-Aug-94			8-Nov-94	22-Nov-94	22-Jan-95	29-Jan-95	29-May
A21	2	0.00			0.01	0.18	0.00	0.04	0.23
B21	3	0.04			0.07	0.21	0.00	0.07	0.33
C21	5	0.00			0.07	0.34	0.10	0.24	0.26
E21	7	0.00			0.05	0.19	0.04	0.05	0.26
		3-Aug-94			8-Nov-94	22-Nov-94	22-Jan-95	29-Jan-95	29-May-
A24	2	0.00			0.06		0.08	0.18	0.24
B24	3	0.00			0.04	0.18	0.00	0.03	0.28
C24	5	0.00			0.30	0.20	0.15	0.23	0.36
E24	7	0.00			0.38	0.82	0.31	0.29	0.38
			19-Aug-94	11-Sep-94	8-Nov-94	22-Nov-94	22-Jan-95	29-Jan-95	29-May-
A32	2		0.00	0.00	0.05	0.19	0.00		
B32	3		0.05	0.02	0.05	0.24	0.02	0.08	0.32
C32	5		0.06	0.01	0.06	0.51	0.38	0.39	0.36
E32	7		0.05	0.00	0.11	0.32	0.36	0.79	0.47
			19-Aug-94	11-Sep-94	8-Nov-94	22-Nov-94	22-Jan-95	29-Jan-95	29-May-
A34	2		0.00	0.00	0.02	0.19	0.00	0.02	0.21
B34	3		0.14	0.01	0.07		0.12	0.11	0.31
C34	5		0.28	0.07	0.12	0.32	0.10	0.11	0.27
E34	7		0.02	0.00	0.17	0.60	0.18	0.12	0.20

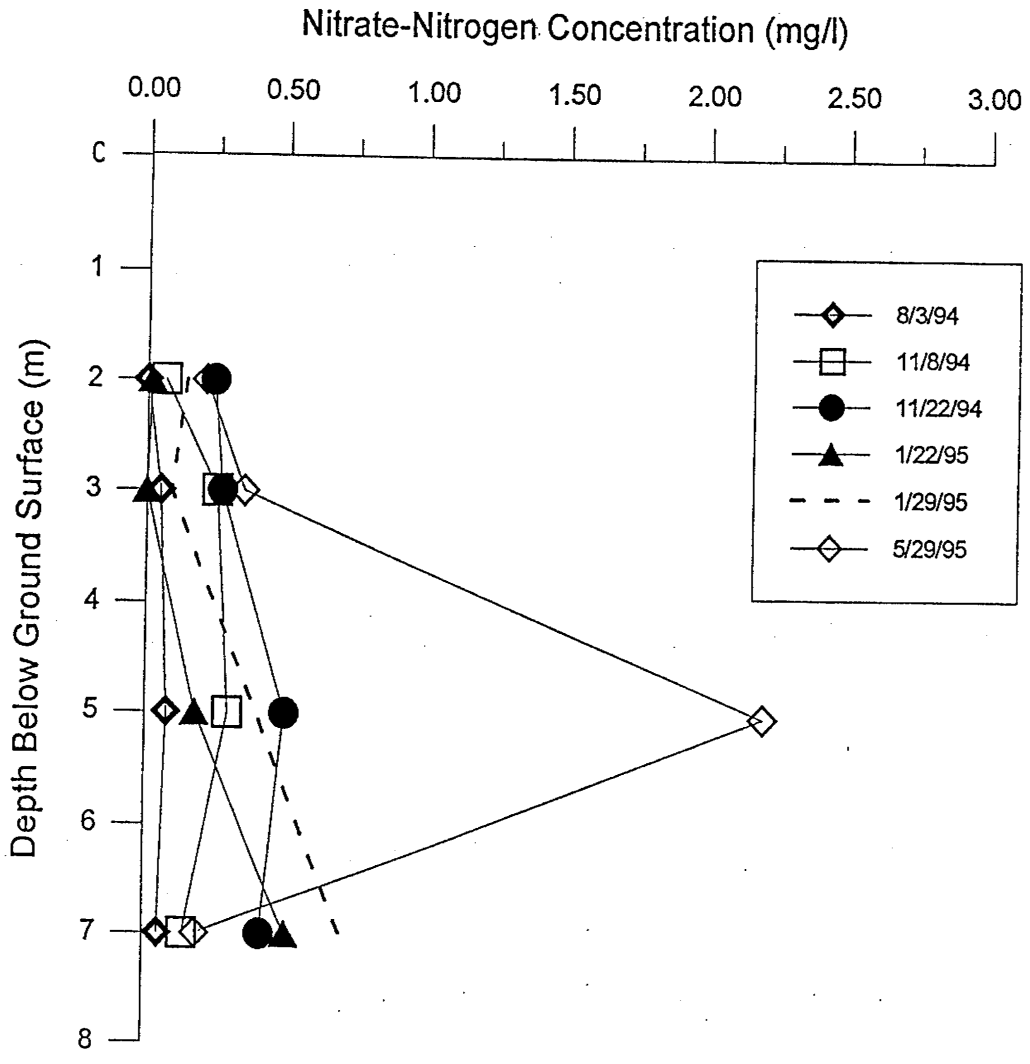
Nitrate-Nitrogen Concentrations in Piezometer Nest 1



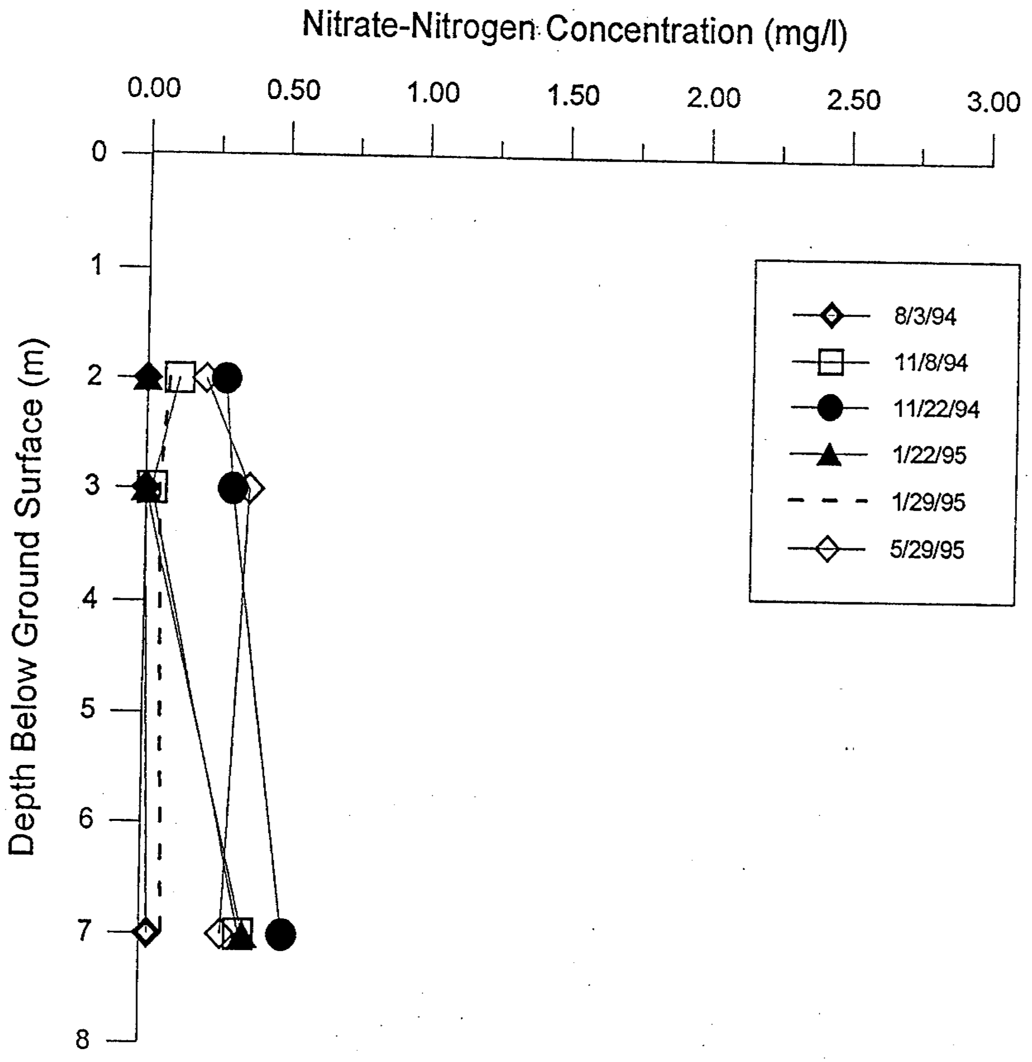
Nitrate-Nitrogen Concentrations in Piezometer Nest 3



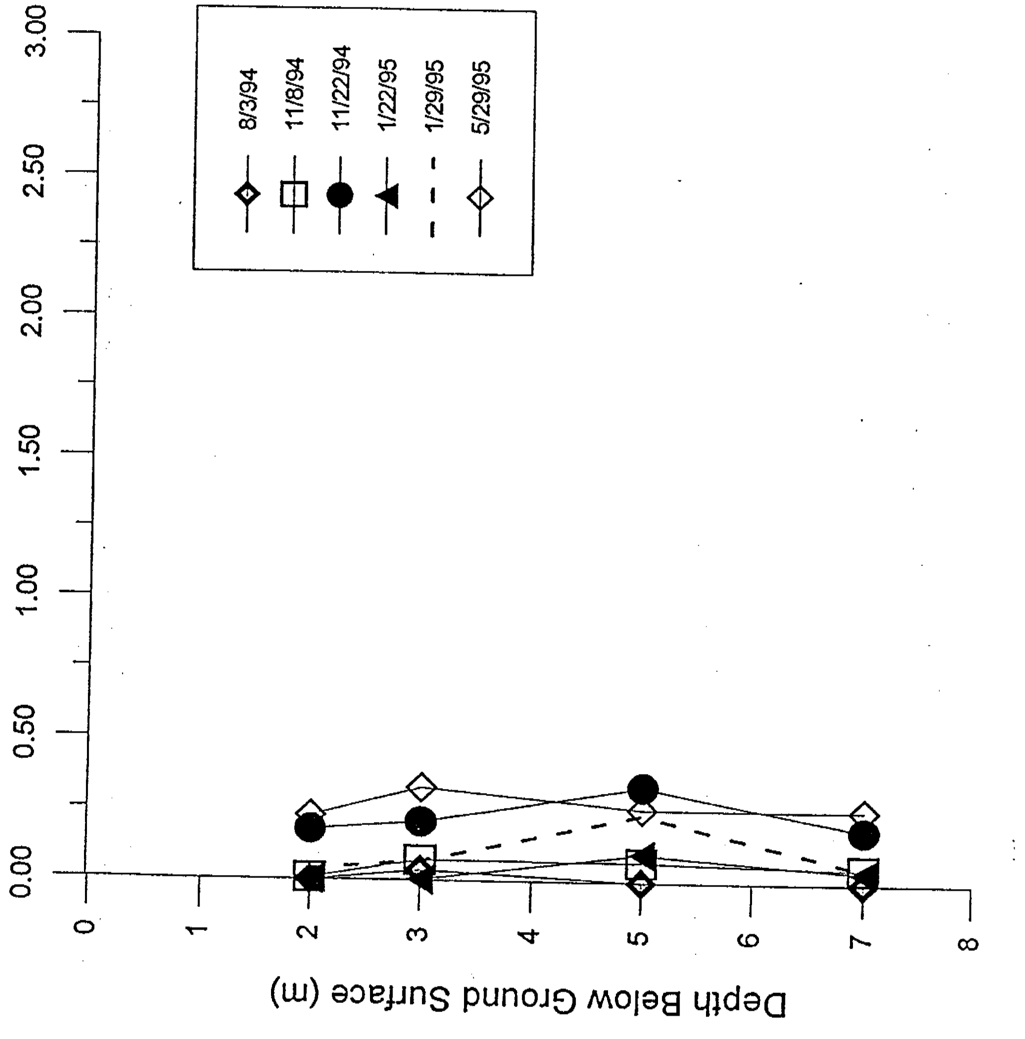
Nitrate-Nitrogen Concentrations in Piezometer Nest 11

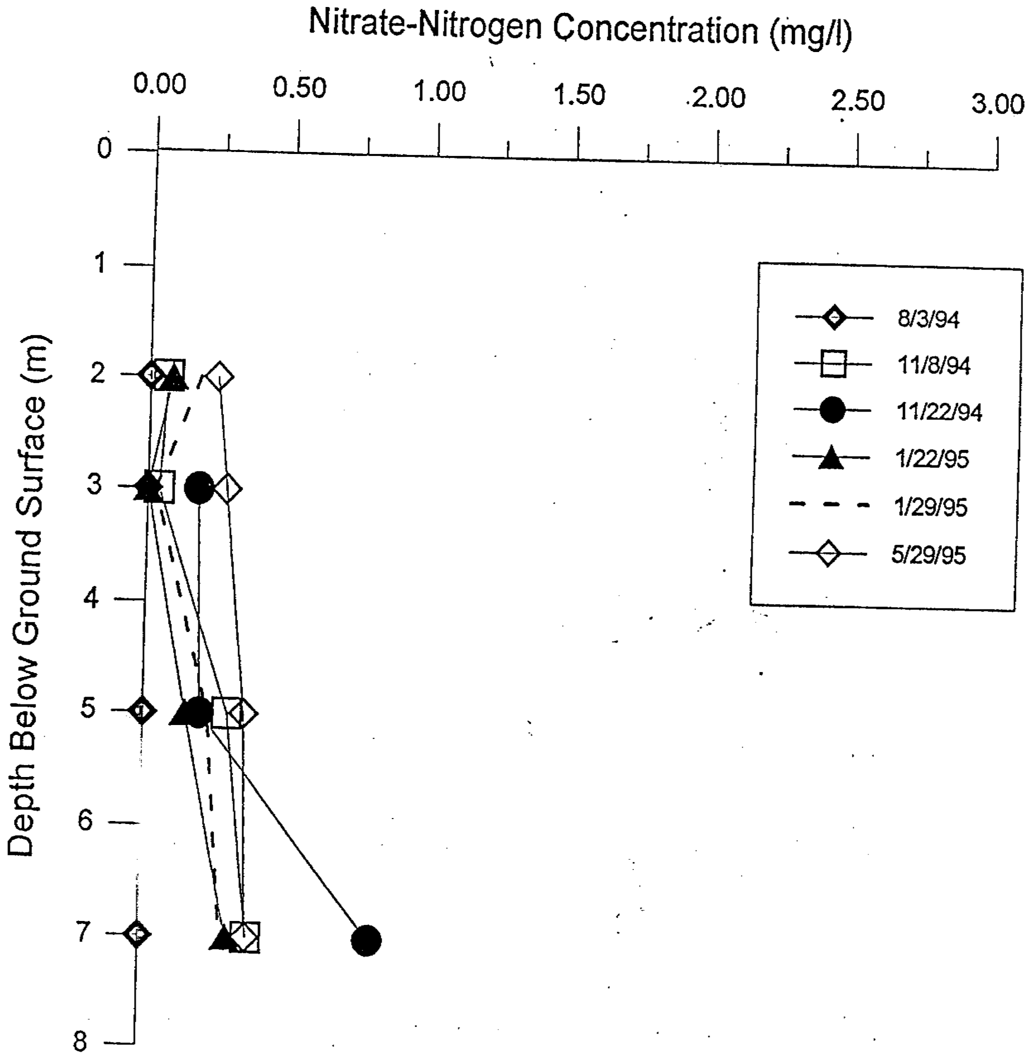


Nitrate-Nitrogen Concentrations in Piezometer Nest 14



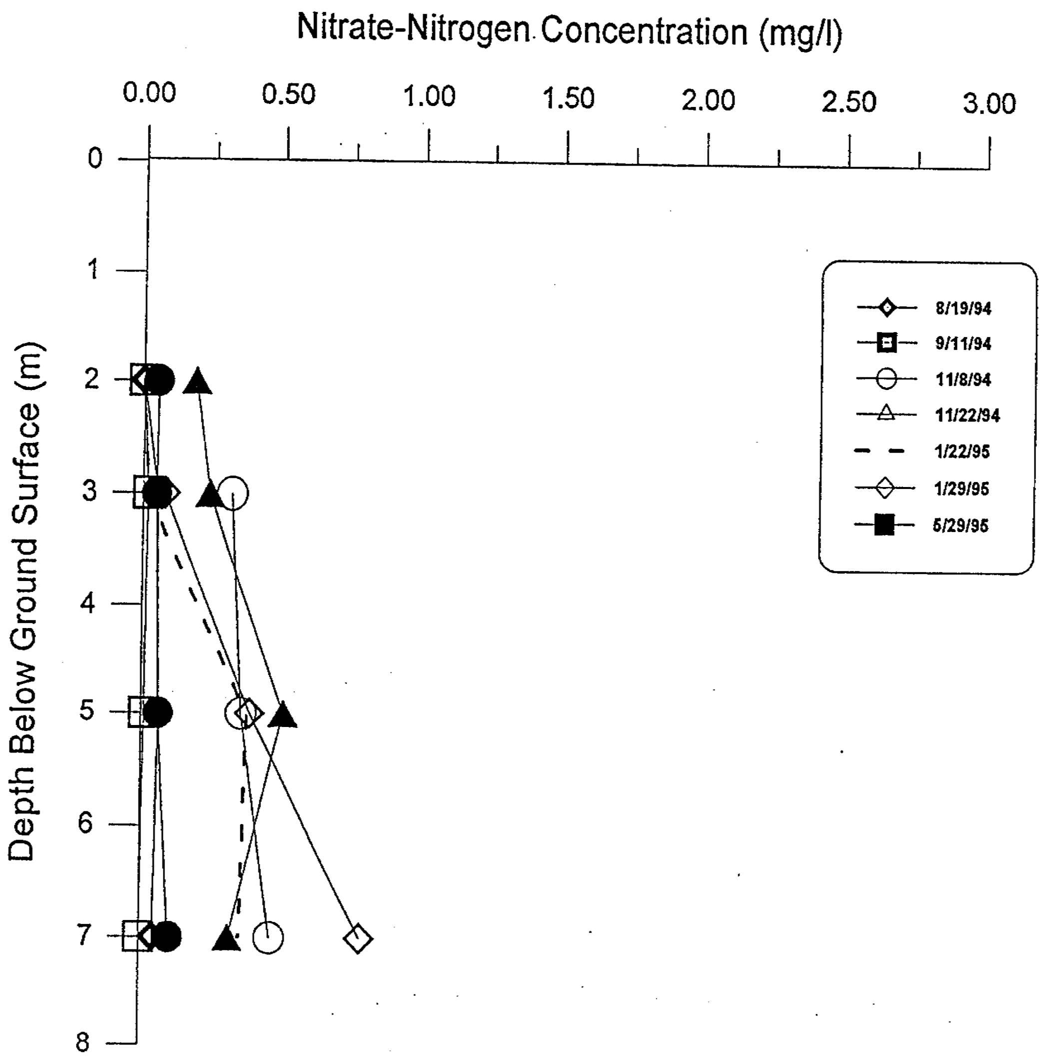
Nitrate-Nitrogen Concentrations in Piezometer Nest 21



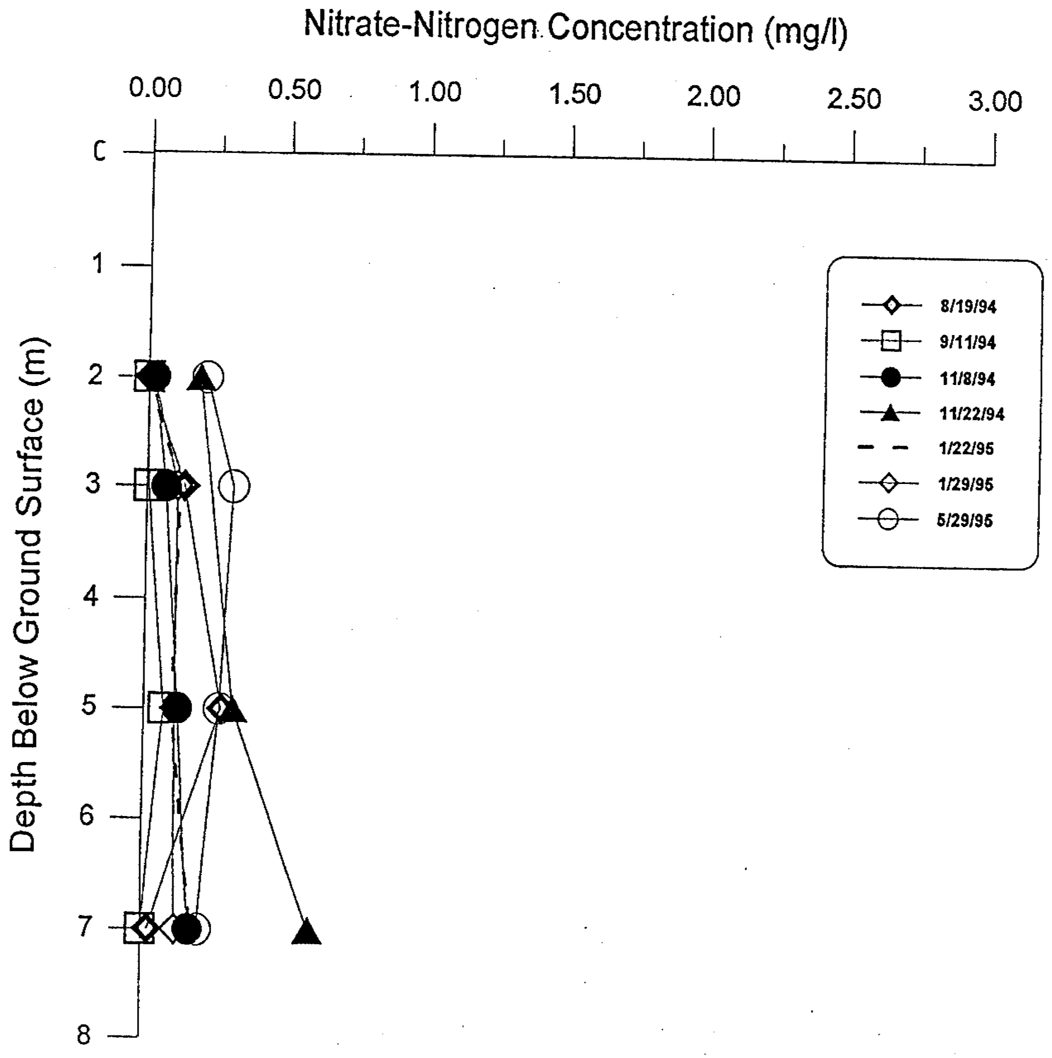


Nitrate-Nitrogen Concentrations in Piezometer Nest 24

Nitrate-Nitrogen Concentrations in Piezometer Nest 32



Nitrate-Nitrogen Concentrations in Piezometer Nest 34



Appendix 9.4 Tile Drain Data

9.4.1 Up- and Downgradient (East and West, respectively) Manholes and Riverside Drain Groundwater Chemistry Data

DATE	DAYS SINCE PROJECT BEGAN	DOWNGRADIENT (WEST) MANHOLE:			UPGRADIENT (EAST) MANHOLE:			RIVERSIDE DRAIN:		
		NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)
1-Apr-93	289.00	1.24		1220	3.63		1090			
20-Apr-93	308.00	0.10		1100	0.12		1250			
24-Jun-93	373.00	0.18		1550	0.36		1180			
1-Jul-93	380.00	0.36		1400	1.06		1250			
6-Jul-93	385.00	0.00		1100	1.08					
8-Jul-93	387.00	2.14		1000	1.40		1090			
13-Jul-93	392.00	0.74		1150	0.93		1120			
16-Jul-93	395.00	0.65		1400	0.86		1300			
20-Jul-93	399.00	0.72		1310	1.06		1180			
23-Jul-93	402.00	0.52		1250	0.84		1190			
14-Sep-93	455.00	0.36		1350	0.63		1200			
20-Sep-93	461.00			1100			1220			
30-Sep-93	471.00	0.45		1400	0.47		1300			
16-Oct-93	487.00	0.45		1000	0.45		950			
31-Oct-93	502.00	0.32		1000	0.43		1000			
4-Nov-93	506.00	0.32		1300	0.34		1200			
7-Nov-93	509.00	0.32		1300	0.32		1200			
13-Nov-93	515.00	0.27		1100	0.27		1000			
17-Nov-93	519.00	0.29		1150	0.29		1000			
21-Nov-93	523.00	0.29		1100	0.43		1000			
24-Nov-93	526.00	0.32		1350	0.43		1150			
1-Dec-93	533.00	0.34		1300	0.43		1100			
20-Dec-93	552.00	0.23		1350	0.40		1100			
2-Jan-94	565.00	0.43			0.65			6.85		
7-Jan-94	570.00	0.23		1650	0.38		1150	5.5		1000
11-Jan-94	574.00	0.27		1620	0.38		1120	4.94		910
18-Jan-94	581.00	0.27		1300	0.25		930	5.09		750
25-Jan-94	588.00	0.50		1400	0.25		1000	7.33		800
1-Feb-94	595.00	0.20		1200	0.09		980	5.62		700
10-Feb-94	603.00	0.30		1590	0.40		980	4.56		938
17-Feb-94	610.00	0.12		1660	0.27		1180	3.82		938
26-Feb-94	619.00	0.28		1695	0.32		1230			
8-Mar-94	629.00	0.17		1540	0.33		1100	3.88		890
9-Mar-94	630.00	0.19		1550	0.27		1165			
11-Mar-94	632.00	8.32			9.22			7.25		
16-Mar-94	637.00	0.56		800	0.54		750	4.85		500
18-Mar-94	639.00	0.40		850	0.31		900	4.65		700
22-Mar-94	643.00	0.51			0.60			7.8		
25-Mar-94	646.00	0.47		1255	0.51		1095	6.4		1025
29-Mar-94	650.00							4.33		
1-Apr-94	653.00							6.89		
5-Apr-94	657.00	0.37		1255	0.43		1095	5.88		1000
9-Apr-94	661.00	0.52		1375	0.55		1400	6.23		950
12-Apr-94	664.00	0.43		1400	0.46		1320	5.88		900
17-Apr-94	669.00	0.27		1475	0.31		1325	5.27		950
19-Apr-94	671.00	0.26		1275	0.22		1050	4.96		950
24-Apr-94	676.00							5.57		708
30-Apr-94	682.00	0.11		1120	0.09		870	5.25		
1-May-94	683.00	0.10		1035	0.05		975			
2-May-94	684.00	0.10		1030	0.05		970			
3-May-94	685.00	0.12		1070	0.08		975			
4-May-94	686.00	0.12		1085	0.09		925			
5-May-94	687.00				0.09		890			
6-May-94	688.00				0.09		920			
7-May-94	689.00				0.60		950			
8-May-94	690.00				0.11		1030			
9-May-94	691.00				0.10		1005			
10-May-94	692.00				0.06		940			
11-May-94	693.00				0.08		945			
15-May-94	697.00	0.14		1050	0.18		948			
17-May-94	699.00	0.14		893			993			
19-May-94	701.00	0.15			0.16			4.19		738
	701.08	0.14			0.16					
	701.17	5.77			0.14					
	701.25	5.36			0.14					
	701.33	5.60		985	0.14		906			
	701.42	5.74		1147	2.57		878			
	701.50			936	6.41		993			

DATE	DAYS SINCE PROJECT BEGAN	DOWNGRADIENT (WEST) MANHOLE:			UPGRADIENT (EAST) MANHOLE:			RIVERSIDE DRAIN:		
		NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)
	701.58			914	8.14		1028			
	701.67			882	7.59		1087			
	701.75			888	8.05		973			
	701.83				7.94		887			
	701.92				7.40		680			
20-May-94	702.50				7.61		651			
	702.58				6.85		642			
	702.67				7.50		788			
	702.75				8.04		761			
	702.83				9.14		765			
	702.92				7.82		781			
	702.99				8.33		774			
21-May-94	703.08				8.52		815			
	703.17				8.36		839			
	703.25				7.52		843			
	703.33				8.30					
	703.42				8.71					
25-May-94	707.00	0.38		896	0.51		825	4.36		708
29-May-94	711.00	0.30		1069	0.17		979			
30-May-94	712.00			1058	0.02		972			
31-May-94	713.00	0.12		1082	0.03		946			
1-Jun-94	714.00	0.12		1144	0.03		955			
2-Jun-94	715.00	0.09		1094	0.03		937			
3-Jun-94	716.00	0.07		1113	0.03		934			
4-Jun-94	717.00	0.10		1132	0.03		966			
5-Jun-94	718.00			1074	0.04		985			
6-Jun-94	719.00	0.09		1084	0.03		991			
7-Jun-94	720.00	0.08		1169	0.04		1010			
8-Jun-94	721.33	0.19		1335	0.04		1223	9.84		904
	721.42	1.98		1287	0.03		1216			
	721.50	4.67		1243	0.03		1213			
	721.58	3.89		1261	0.03		1236			
	721.67	2.81		1333	0.03		1197			
	721.75	4.44		1259	2.75		1056			
	721.83			1112						
	721.92	9.84		1095						
9-Jun-94	722.00	12.05		891			937			
	722.08	11.75		941			905			
	722.17	11.08		902			891			
	722.25	11.30		949			873			
	722.33	10.42		920	10.06		901			
	722.42	10.71		941	10.61		925			
	722.50	10.82		1012	10.40		931			
	722.58	9.80		1115	11.01		1008			
	722.67	9.80		1243	10.03		888			
	722.75	9.18		1340	10.92		904			
	722.83	8.95		1091	9.58		948			
	722.92	6.82			10.44					
	722.99				10.81					
10-Jun-94	723.08			1004	10.77		908			
	723.17	8.12		1170	10.43		1137			
12-Jun-94	725.50	9.41		1316	9.48		1200			
	725.67	8.27								
	725.83	7.39								
13-Jun-94	726.00	6.39								
	726.17	4.93								
	726.33	3.86			5.04					
	726.50	2.90			3.90					
	726.67	2.22			2.99					
	726.83	1.66			2.32					
14-Jun-94	727.00	1.36			1.79					
	727.17	1.09			1.39					
	727.33	0.91			1.16					
23-Jun-94	736.00				1.01					
	736.67	0.29								
	736.83	0.45								
24-Jun-94	737.00	0.24						5.00		
	737.17	0.23								
	737.33	0.18								
	737.50	0.25								
	737.67	0.27								
	737.83	0.19								
25-Jun-94	738.00	0.22		1367						
	738.17	0.21		1349						

	DAYS SINCE	DOWNGRADIENT (WEST) MANHOLE:			UPGRADIENT (EAST) MANHOLE:			RIVERSIDE DRAIN:		
DATE	PROJECT BEGAN	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)
	738.33	0.23		1354						
	738.50	0.21		1381						
	738.83	0.19		1357						
26-Jun-94	739.00	0.18		1343						
	739.17	0.18		1313						
	739.33	0.16		1336						
	739.50	0.10		1320						
	739.67	0.12		1321						
	739.83	0.19		1320						
27-Jun-94	740.00	0.22		1254						
	740.17	0.16		1275						
	740.33	0.22		1348						
	740.50	0.08		1386						
	740.83	0.11		1390						
28-Jun-94	741.00	0.12		1020						
	741.17	0.14								
	741.33	0.15		1028						
	741.50	0.13		1028						
	741.67	10.17		1030						
	741.83	11.85		1030						
29-Jun-94	742.00	12.26		964						
	742.17	12.61		948						
	742.33	12.71		921						
	742.50	12.51		936						
	742.67	11.43		929						
	742.83	9.57		875						
30-Jun-94	743.00	9.74								
	743.17	11.21		960						
	743.33	12.16		930						
	743.50	9.88		950						
	743.67	8.17		960						
	743.83	7.09								
1-Jul-94	744.00	5.99		974						
	744.17	5.08		1014						
	744.33	3.83		919			945			
	744.50	2.75								
	744.67				1.79					
	744.83				0.75					
3-Jul-94	746.00			937	0.52					
4-Jul-94	747.00			957	0.32					
5-Jul-94	748.00			966	0.23					
6-Jul-94	749.00			975	0.14					
7-Jul-94	750.00			1002	0.16					
8-Jul-94	751.00			993	0.07					
9-Jul-94	752.00			982	0.01			10.00		
10-Jul-94	753.00			967	0.06					
11-Jul-94	754.00			979	0.01					
12-Jul-95	755.00			1041	0.11					
13-Jul-94	756.00	10.82		1077						
14-Jul-94	757.00	7.53		1150						
15-Jul-94	758.00	10.03		1083						
16-Jul-94	759.00	5.13		1191						
17-Jul-94	760.00	1.40		1286						
18-Jul-94	761.00	0.48		1310						
19 Jul 94	762.00	0.24		1279	0.27		1193			
20-Jul-94	763.00	0.06								
21-Jul-94	764.00	0.00								
22-Jul-94	765.00	0.03								
23-Jul-94	766.00	0.01						8.00		
24-Jul-94	767.00	0.04								
25-Jul-94	768.00	8.03								
26-Jul-94	769.00	7.64								
28-Jul-94	771.00	2.72								
	771.50	1.53		1303						
29-Jul-94	772.00	0.75		1352			1201			
	772.50	0.38		1269	0.48					
30-Jul-94	773.00	0.22			0.22		1200			
	773.50	0.12			0.14					
31-Jul-94	774.00	0.09			0.13		1190			
	774.50	0.09			0.10					
1-Aug-94	775.00	0.10			0.12					
	775.50	0.10			0.12					
2-Aug-94	776.00	0.11			0.11					
	776.50	0.12			0.09					

	DAYS SINCE	DOWNGRADIENT (WEST) MANHOLE:			UPGRADIENT (EAST) MANHOLE:			RIVERSIDE DRAIN:		
DATE	PROJECT BEGAN	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)
3-Aug-94	777.21				0.11					
	777.62	0.13			0.14					
4-Aug-94	778.12	0.11			0.20					
	778.62	0.15			0.20					
5-Aug-94	779.12	0.15			0.15					
	779.63	0.14			0.19					
6-Aug-94	780.13	0.14			0.19					
	780.63	0.15			0.18					
7-Aug-94	781.12	0.14			0.20			3.5		
	781.62	0.14			0.18					
10-Aug-94	784.54	0.20			0.20					
	784.70	0.23			0.20					
	784.87	0.22			0.23					
11-Aug-94	785.04	0.22			0.23					
	785.20	0.24			0.23					
	785.37	0.24			0.23					
	785.54	0.25			0.24					
	785.70	0.24								
	785.87	0.23								
12-Aug-94	786.04	0.23			0.17					
	786.20	0.23			0.15					
	786.37	0.23								
	786.49	0.46			0.18					
	786.74	0.56			0.12					
13-Aug-94	787.00	0.47			0.17					
	787.25	0.43			0.17					
	787.50	0.44			0.13					
	787.75	0.42			0.14					
14-Aug-94	788.00	0.41			0.13					
	788.25	0.41			0.02					
	788.50	0.42			0.14					
	788.75	0.41			0.14					
15-Aug-94	789.00	0.12			0.08					
	789.25	0.16		1070	0.09		1140			
	789.73	0.16		1455	0.16		1150			
16-Aug-94	790.23	0.16		1304	0.16		1152			
	790.73	0.14		1403	0.18		1133			
17-Aug-94	791.23	0.14		1306	0.14		1146			
	791.73	0.13		1443	0.15		1125			
18-Aug-94	792.23	0.13		1337	0.14		1097			
	792.73	0.15		1432	0.14		1150			
19-Aug-94	793.23	0.13		913	0.12		820			
20-Aug-94	794.00			913			884			
21-Aug-94	795.00			882			942			
22-Aug-94	796.00			901			927	3.2		
23-Aug-94	797.00			950			897			
24-Aug-94	798.00			926			932			
25-Aug-94	799.00			942			963			
26-Aug-94	800.00			904			980			
27-Aug-94	801.00			962			1001	2.5		
28-Aug-94	802.00			999			1028			
29-Aug-94	803.00			946			1016			
30-Aug-94	804.00	0.18		951	0.43		1027			
31-Aug-94	805.00	0.04		1047	0.35		934			
1-Sep-94	806.00	0.08		1238	0.39		907			
2-Sep-94	807.00	0.12		1396	0.29		903			
3-Sep-94	808.00	0.11		1327	0.35		906			
4-Sep-94	809.00	0.11		1340	0.32		916			
5-Sep-94	810.00	0.11		1414	0.25		878			
6-Sep-94	811.00	0.11		1408	0.31		941			
7-Sep-94	812.00	0.63		1448	0.44		948			
8-Sep-94	813.00	0.37		1363	0.22		956			
9-Sep-94	814.00			1355			945			
10-Sep-94	815.00			987						
11-Sep-94	816.00	0.15		1021						
12-Sep-94	817.00	0.05		1041			917	4.22		924
13-Sep-94	818.00	0.03		1498			1091			
14-Sep-94	819.00	0.02		1540			1137			
15-Sep-94	820.00	0.02		1603			1165			
16-Sep-94	821.00	0.01		1758			1160			
17-Sep-94	822.00	0.01		1778			1093			
18-Sep-94	823.00	0.02		1709			1125			
19-Sep-94	824.00	0.02		1690			1184			
20-Sep-94	825.00	0.09		1624			1207			

DATE	DAYS SINCE PROJECT BEGAN	DOWNGRADIENT (WEST) MANHOLE:			UPGRADIENT (EAST) MANHOLE:			RIVERSIDE DRAIN:		
		NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)
21-Sep-94	826.00	0.00		1649			1227	5.02		785
22-Sep-94	827.00	0.17		1774	0.17		1289			
23-Sep-94	828.00	0.22		1540	0.25		1026			
24-Sep-94	829.00	0.22		1046			920			
25-Sep-94	830.00	0.17		1081						
26-Sep-94	831.00	0.10		998						
27-Sep-94	832.00	0.17		1442						
28-Sep-94	833.50	0.21		1727				5.08		838
	833.67	0.19								
	833.83	0.10								
29-Sep-94	834.00	0.10								
	834.17	0.11								
	834.33	0.11								
	834.50	0.12		1908						
	834.67	0.12		1335						
	834.83	0.12		1314						
30-Sep-94	835.00	0.25		1355						
	835.17	0.22		1360						
	835.33	0.23		1338						
	835.50			1341						
	835.67			1319						
	835.83			1311						
1-Oct-94	836.00			1490						
	836.16			1616						
	836.32			1620						
2-Oct-94	837.00				0.02			4.43		892
3-Oct-94	838.56			2080			956			
	838.81			2050						
4-Oct-94	839.06			1955						
	839.31			1908						
	839.56			1962						
	839.81			1882						
6-Oct-94	841.00	0.31		2630						
7-Oct-94	842.00	0.44		2620						
8-Oct-94	843.00	0.27		1897						
9-Oct-94	844.00	0.27		1631			1090			
10-Oct-94	845.00	0.22		1620						
11-Oct-94	846.00	0.22		1579						
12-Oct-94	847.00	0.21		1503						
13-Oct-94	848.00	0.21		1494						
14-Oct-94	849.00	0.35		1426						
15-Oct-94	850.00	0.25		1504						
16-Oct-94	851.00	0.25		1496	0.31					
17-Oct-94	852.00	0.18		1488						
18-Oct-94	853.00	0.22		1684				3.77		817
27-Oct-94	862.00	4.48		1530	3.68		900			
28-Oct-94	863.00			1489	3.30			5.1		802
8-Nov-94	874.00							3.83		939
15-Nov-94	881.00							3.79		860
18-Nov-94	884.00	0.25		1615	0.37					
20-Nov-94	886.00							4.07		940
22-Nov-94	888.00							4.1		997
25-Nov-94	891.00	0.23		1214	0.24		1229			
4-Dec-94	900.00							4.11		
14-Dec-94	910.00	0.09		1106	0.05		1199	3.82		886
17-Dec-94	913.00							3.77		901
3-Jan-95	930.00			1344	0.00		1018	3.47		
22-Jan-95	949.00	0.04						2.175		
23-Jan-95	950.00			1702			1055	2.18		
27-Jan-95	954.00	0.04						3.03		
28-Jan-95	955.00			1715			1066			
29-Jan-95	956.00							3.28		
30-Jan-95	957.00			1683			1181			
3-Feb-95	959.00	0.04								
7-Feb-95	964.00	0.04								
10-Feb-95	967.00	0.04			0.02					386
11-Feb-95	968.00	0.03		1330	0.01		908	2.66		731
13-Feb-95	970.00			1415			996			
16-Feb-95	973.00	0.03			0.01			4.01		781
18-Feb-95	975.00			1429			902			
9-Mar-95	994.00				0.07		838	3.79	45.19	718
14-Mar-95	999.64	0.03								
	999.72	0.04								
	999.80	0.08								

DATE	DAYS SINCE PROJECT BEGAN	DOWNGRADIENT (WEST) MANHOLE: NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)	UPGRADIENT (EAST) MANHOLE: NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)	RIVERSIDE DRAIN: NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)
	999.88	0.06								
	999.97	0.00								
15-Mar-95	1000.05	0.05								
	1000.13	0.05								
	1000.22	0.08								
	1000.30	0.08								
	1000.38	0.05								
	1000.47	0.05								
	1000.55	0.11								
	1000.64	0.44								
	1000.71	0.04								
	1000.80	0.08	92.06							
	1000.88	0.06								
	1000.97	0.00								
16-Mar-95	1001.05	0.05		1310				1.54		847
	1001.13	0.05		1310						
	1001.22	0.08		1330						
	1001.30	0.08		1320						
	1001.38	0.05		1280						
	1001.47	0.05		1290						
	1001.54	0.11								
	1001.63	0.44								
	1001.71	0.28	93.47							
	1001.79	0.27	92.06							
17-Mar-94	1002.04	0.26	90.52							
	1002.12	0.26	89.80							
	1002.39	0.28	89.97							
17-Mar-95	1002.54	0.29	86.32	1572						
	1002.62			1522						
	1002.71			1319						
	1002.79	0.01		1278						
	1002.88	0.01		1029						
	1002.96			1038						
18-Mar-95	1003.04	0.04		937			1019	3.16	40.62	781
	1003.13	0.01	72.76	998						
	1003.21	0.01		1099						
	1003.29	0.08		1072						
	1003.64	0.11								
20-Mar-95	1005.63	0.16		1073			852	2.98	42.98	748
	1005.79	0.18		916						
	1005.96	0.16		935						
21-Mar-95	1006.13	0.13		915						
	1006.29	0.14		788						
	1006.46	0.12		985						
	1006.63	0.12		932						
	1006.79	0.13		935						
	1006.93	0.07		1034						
22-Mar-95	1007.13	0.10		953				2.78		
	1007.29	0.11		870						
	1007.46	0.06		930						
	1007.71	0.12		993						
23-Mar-95	1008.71	0.10		970						
24-Mar-95	1009.71	0.06		1019						
25-Mar-95	1010.71	0.03		989						
26-Mar-95	1011.71	0.03		998			1002			
27-Mar-95	1012.71	0.02		1008						
28-Mar-95	1013.71	0.02		1045						
29-Mar-95	1014.71	0.02		978						
30-Mar-95	1015.71	0.02		1019						
31-Mar-95	1016.71	0.02		981						
1-Apr-95	1017.71	0.02		1012						
2-Apr-95	1018.00						905	2.8		777
3-Apr-95	1019.52	0.41	57.35		0.47	48.29				
4-Apr-95	1020.52	0.39	54.76							
5-Apr-95	1021.50			923						
6-Apr-95	1022.52	0.35	46.64							
7-Apr-95	1023.56			1172	0.25		914	2.77		805
9-Apr-95	1025.00				0.24	49.25	1022	2.65	45.73	899
	1025.48	0.24		1065						
	1025.56	0.26		1086						
	1025.65	0.24		1070						
	1025.73	0.22		1021						
	1025.81	0.23		1079						
	1025.90	0.23		1100						

DATE	DAYS SINCE PROJECT BEGAN	DOWNGRADIENT (WEST) MANHOLE:			UPGRADIENT (EAST) MANHOLE:			RIVERSIDE DRAIN:		
		NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)
	1025.98	0.25		1111						
10-Apr-95	1026.31			935	0.20		950	2.51		788
	1026.42	0.17								
	1026.50	0.15								
	1026.58	0.12								
	1026.67	0.11								
	1026.75	0.07								
	1026.83	0.05								
	1026.92	0.04								
11-Apr-95	1027.08	0.28	93.06							
	1027.17	0.28	96.10							
	1027.40	0.02	98.50							
	1027.48	0.03	95.89							
	1027.56	0.03	86.12							
	1027.65	0.03	83.10							
	1027.73	0.03	81.75							
	1027.81	0.04	77.24							
	1027.90	0.04	73.65							
	1027.98	0.04	74.18							
12-Apr-95	1028.54	0.03	64.88							
	1028.71	0.04	60.66	1085						
	1028.88	0.05	56.65	1042						
	1029.04	0.05	62.29							
	1029.21	0.08	59.42							
	1029.38	0.11	60.05							
	1029.54	0.06								
	1029.71	0.06	58.37							
	1029.88	0.06	59.20							
13-Apr-95	1030.04	0.07	55.31	988						
	1030.21	0.07	53.44							
	1030.38	0.07	52.60							
	1030.87			951						
14-Apr-95	1031.04			947						
20-Apr-95	1037.38	0.12			0.10	49.32	1054	2.69	43.3	867
21-Apr-95	1038.38	0.11		1072	0.09		903			
23-Apr-95	1040.38	0.10		1074	0.09		933			
24-Apr-95	1041.00	0.10		1062						
25-Apr-95	1042.00	0.10		1109						
26-Apr-95	1043.67	0.36	52.90	1088						
	1043.80	0.38	54.68	1080						
	1043.92	0.34	71.09	1315						
27-Apr-95	1044.05	0.02		1284			1046	3.37	35.53	665
	1044.17			1537						
	1044.29	0.32	100.66	1775		49.82				
	1044.42	0.34	54.54							
	1044.50	0.32	89.87	1612	0.18		911			
	1044.63	0.29	74.50	1603						
	1044.75	0.26	70.35	1630						
	1044.88	0.27	70.80	1563						
28-Apr-95	1045.00	0.27	73.87	1584				2.64	44.51	770
	1045.13	0.28	73.50	1084						
	1045.38	0.39	57.64	1065	0.05		877			
	1045.46	0.40								
	1045.54	0.39								
	1045.63	0.38	57.52							
	1045.71	0.38	56.20							
	1045.79	0.39	56.61							
	1045.87	0.40	56.85							
	1045.96	0.39	56.62							
	1046.04	0.39	56.08							
	1046.12	0.39	56.50							
	1046.21	0.39	55.80							
	1046.29	0.40	56.68							
30-Apr-95	1047.44	0.04								
	1047.69	0.04								
	1047.81	0.04								
	1047.94	0.05	57.31	1050						
1-May-95	1048.06	0.08								
	1048.19	0.39	55.70	1178						
	1048.44	0.39	54.51	1029						
	1048.69	0.39	54.08	1023						
	1048.94	0.40	53.66	1033						
2-May-95	1049.19	0.39	53.93	1031						
	1049.44	0.38	53.62	1035						

DATE	DAYS SINCE PROJECT BEGAN	DOWNGRADIENT (WEST) MANHOLE:			UPGRADIENT (EAST) MANHOLE:			RIVERSIDE DRAIN:		
		NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)
	1049.69	0.38	53.69	1051						
	1049.94	0.37	53.81	1037						
3-May-95	1050.19	0.37	54.92					2.56		739
	1050.44	0.35	54.04							
	1050.69	0.34	54.46	986			894			
	1050.70	0.39	56.17	938	0.15					
4-May-95	1051.70	0.36	57.37	961						
11-May-95	1058.39	0.34	60.39	950	0.11		933	2.46	43.63	762
12-May-95	1059.40	0.35	56.02	994						
13-May-95	1060.40	0.33	55.72	984						
14-May-95	1061.40	0.32	55.21	980						
15-May-95	1062.40	0.30	54.78	985			974		37.19	763
	1062.65	0.37	53.97	928		43.95				
	1062.73	0.36	55.07	907						
	1062.81	0.34	60.48	950						
	1062.90	0.34	75.26	1090						
	1062.98	0.35	89.21	1360						
16-May-95	1063.06	0.34	94.42	1493			1014			
	1063.15	0.34	99.26	1562						
	1063.23	0.33	100.02	1656						
	1063.31	0.33	101.65	1685						
	1063.40	0.32	101.08	1687						
	1063.48	0.32	100.90	1739						
	1063.56	0.31	93.15	1775						
	1063.65	0.31	91.02	1861		43.70				
	1063.73	0.30	89.02	1818						
	1063.81	0.30	88.94	1664						
	1063.90	0.29	86.04	1646						
	1063.98	0.29	82.07	1554						
17-May-95	1064.06	0.29	79.91	1482			1011		39.33	755
	1064.15	0.29	78.62	1471						
	1064.23	0.29	77.22	1442						
	1064.31	0.30	76.87	1419						
	1064.50	0.28	76.02	1424	0.34	44.59				
	1064.58	0.28	77.57	1455						
	1064.67	0.28	77.98							
	1064.75	0.08	23.48							
	1064.84	0.08	23.18							
	1064.92	0.08	23.33							
18-May-95	1065.09	0.08	22.94				909			693
	1065.17	0.08	22.33							
	1065.25	0.08	22.48							
	1065.34	0.08	22.29							
	1065.42	0.01	10.20							
	1065.50	0.01	10.15							
	1065.63	0.01	10.11	1147	0.29	7.53				
	1065.71	0.01	9.86	1155						
	1065.79	0.01	9.76	1125						
	1065.88	0.01	9.71	1122						
	1065.96	0.01	9.38	1093						
19-May-95	1066.00			1103						
	1066.04	0.01	9.28	1077						
	1066.21	0.01	9.79	1048						
	1066.29		9.73	1037						
	1066.37		10.85	1033						
	1066.46		9.69	1030						
	1066.54			1045	0.28	8.04	921	0.26	8.27	735
	1066.62	0.01	9.69	1157						
	1066.87	0.01	9.65	1054						
20-May-95	1067.12	0.01	9.61	978						
	1067.37	0.01	9.45	958						
	1067.62			958						
	1067.87			982						
21-May-95	1068.12			970						
	1068.37	0.01	10.41	958						
	1068.62	0.01	10.49	969						
	1068.87	0.01	10.56	989						
22-May-95	1069.12		10.43	991					8.53	738
	1069.37		9.77	1002						
25-May-95	1072.00		9.75					0.26	8.4	744
26-May-95	1073.00				0.01	9.58	867			
27-May-95	1074.00		10.25	919	0.01	9.54	916	0.26	8.39	738
28-May-95	1075.00			988			868			
29-May-95	1076.00			993			901			

	DAYS SINCE	DOWNGRADIENT (WEST) MANHOLE:			UPGRADIENT (EAST) MANHOLE:			RIVERSIDE DRAIN:		
DATE	PROJECT BEGAN	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)
1-Jun-95	1079.00			1218						
2-Jun-95	1080.00			1205			1058			839
3-Jun-95	1081.00			1181			1058			
4-Jun-95	1082.00						1051			
5-Jun-95	1083.50						1061			886
	1083.58						1053			
	1083.67						1042			
	1083.75						1017			
	1083.83						1040			
	1083.92						1044			
6-Jun-95	1084.00						1052			891
	1084.08						1060			
	1084.17						1062			
	1084.25						1080			
	1084.33						1071			
	1084.42						1070			
	1084.50						1070			
	1084.58						1088			
	1084.67						1038			
	1084.75						1084			
	1084.83						1148			
	1084.92						1208			
7-Jun-95	1085.00						1174			804
	1085.08						1166			
	1085.17						1148			
	1085.25						1088			
	1085.33						1073			
	1082.42						1063			
	1085.50						979			
	1085.67						1007			
	1085.83						1008			
8-Jun-95	1086.00						925			
	1086.17						1003			
	1086.33						937			
	1086.50						1021			
	1086.65			1215			980			
	1086.81			1185			1042			
	1086.98			1155			1040			
9-Jun-95	1087.00									750
	1087.15			1163						
	1087.30			1177						
	1087.48			1201			1035			
	1087.56			1138			947			
12-Jun-95	1090.56			1125			948			
15-Jun-95	1093.54			1176			967			
	1093.63			1190			960			
	1093.67									758
18-Jun-95	1096.63			1145			962			
19-Jun-95	1097.00									850
	1097.50			995			950			
	1097.58			1014			958			
	1097.67			1014			926			
	1097.75			1075			965			
	1097.83			1105			956			
	1097.92			1147			956			
20-Jun-95	1098.00			1243			949			
	1098.08			1230			958			
	1098.17			1224			962			
	1098.25			1241			963			
	1098.33			1247			969			
	1098.42			1253			997			
	1098.50			1522			1176			
	1098.58			1872			1165			
	1098.67			1763			1291			
	1098.75			1472						
	1098.83			1843			1236			
	1098.92			1680			1278			
21-Jun-95	1099.00			1672			1237			
	1099.08			1663			1191			
	1099.17			1702			1180			
	1099.25			1719			1007			
	1099.33			1671			1189			
	1099.42			1685			1318			
	1099.50			1640			1020			

DATE	DAYS SINCE PROJECT BEGAN	DOWNGRADIENT (WEST) MANHOLE:			UPGRADIENT (EAST) MANHOLE:			RIVERSIDE DRAIN:		
		NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)
	1099.67			1145			948			
	1099.83			1349			782			
22-Jun-95	1100.00			1002			916			
	1100.17			1146			904			
	1100.33			929			814			
	1100.50			1059			913			
	1100.67			1024			917			
	1100.83			1037			553			
23-Jun-95	1101.00			1017						
	1101.00			957			920			
	1101.17			1050			914			
	1101.33			1058			902			
	1101.50						907			
26-Jun-95	1104.00			974						
	1104.50						879			
29-Jun-95	1107.00			1062						
	1107.50						874			
2-Jul-95	1110.00			1207						
	1110.50						892			
5-Jul-95	1113.00			1027						
	1113.50						897			
8-Jul-95	1116.00			1008						
	1116.50						923			
10-Jul-95	1118.00									1006
	1118.50			1151			1003			
	1118.58			1022			964			
	1118.67			977			967			
	1118.75			980			962			
	1118.83			1054			947			
	1118.92			1174			955			
11-Jul-95	1119.00			1248						899
	1119.08			1354			1102			
	1119.17			1399			1117			
	1119.25			1446			1098			
	1119.33			1423			1050			
	1119.42			1424			1120			
	1119.50						1028			
	1119.54			1374			1091			
	1119.63			1397			963			
	1119.71			1390			983			
	1119.79			1361			969			
	1119.88			1356			958			
	1119.96			1361			924			
12-Jul-95	1120.04			1224			900			
	1120.13			1196			913			
	1120.21			1118			904			
	1120.29			1079			903			
	1120.38			1098			893			
	1120.46			1103			918			
	1120.54			1113			956			873
	1120.71			1058			929			
	1120.88			1025			910			
13-Jul-95	1121.04			988			932			
	1121.21			1025			923			
	1121.38			1034			937			
	1121.54			1039			926			
	1121.71			1035			959			
	1121.88			1059			946			
14-Jul-95	1122.04			1051			976	818		
	1122.21			1057			972			
	1122.38			1063			996			
	1122.54			1077			950			
	1122.79			1052			940			
15-Jul-95	1123.04			1032			939			
	1123.29			1002			949			
	1123.54			1046			971			
	1123.79			1020			954			
16-Jul-95	1123.04			1036			956			
	1123.29			1046			953			
	1123.54			1100			958			
	1123.79			1086			970			
17-Jul-95	1124.04			1133			996			
	1124.29			1124			998			817
	1125.58			1279			1004			

	DAYS SINCE	DOWNGRADIENT (WEST) MANHOLE:			UPGRADIENT (EAST) MANHOLE:			RIVERSIDE DRAIN:		
DATE	PROJECT BEGAN	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)	NO_3-N (MG/L)	CL (MG/L)	COND (UMHOS/CM)
20-Jul-95	1128.58			928			845			
23-Jul-95	1131.58			1095			1016			
26-Jul-95	1134.58			1431			1070			
28-Jul-95	1136.31			1261			1059			758
	1136.40			1003			1052			1022
	1136.56			1325			1209			
	1136.65			1242			1174			
	1136.73			1220			1172			
	1136.81			1250			1174			
	1136.90			1327			1181			
	1136.98			1375			1175			
29-Jul-95	1137.06			1382			1177			
	1137.15			1388			1170			
	1137.23			1376			1178			
	1137.31			1362			1183			
	1137.40			1381			1195			
	1137.48			1344			1191			
	1137.63			1088			1027			
	1137.71			1095			1007			
	1137.79			1080			990			
	1137.88			1101			983			
	1137.96			1073			1002			
30-Jul-95	1138.04			1023			989			
	1138.13			1089			997			
	1138.21			1089			976			
	1138.29			1063			994			
	1138.38			1053			979			
	1138.46			906			1009			
	1138.54			1109			1016			
30-Jul-95	1138.73			1067			973			934
	1138.90			1025			956			
31-Jul-95	1139.06			1010			944			
	1139.23			999			943			
	1139.40			1000			942			
	1139.56			982			926			
	1139.73			967			940			
	1139.90			966			912			
1-Aug-95	1140.06			939						927
	1140.23			995						
	1140.40			871						
	1140.56			1031						
	1140.73			1085						
	1140.98			1040						
2-Aug-95	1141.23			1055						
	1141.48			1036						
	1141.73			1044						
	1141.98			1058						
3-Aug-95	1142.23			1051						
	1142.48			1057			1225			
	1142.73			1079						
	1142.98			1095						
4-Aug-95	1143.23			1103						972
	1143.48						1238			

Appendix 9.5.1
Calculation of Volumetric Water Content from Bulk Density Information

Sample Location	Sample Depth	Soil Type	Bulk Density	1994 grav. water cont.	1995 grav. water cont.	1994 vol. water cont.	1995 vol. water c
0.5 North	0-30	SiCL	1.3	0.17	0.13	0.22	0.16
	30-60	SiCL	1.30	0.23	0.19	0.30	0.25
	60-90	SiL	1.40	0.31	0.28	0.43	0.40
	90-120	FS	1.55	0.21	0.23	0.32	0.35
1.0	0-30	SiCL	1.28	0.18	0.28	0.23	0.36
	30-60	SiCL	1.28	0.22	0.26	0.28	0.34
	60-90	SiL	1.40	0.29	0.16	0.41	0.22
	90-120	FS	1.55	0.28	0.25	0.43	0.39
2.0	0-30	SiCL	1.27	0.18	0.23	0.22	0.30
	30-60	SiCL	1.27	0.23	0.22	0.29	0.28
	60-90	SiL	1.40	0.31	0.18	0.44	0.25
	90-120	FS	1.55	0.25	0.23	0.39	0.36
3.5	0-30	SiCL	1.3	0.17	0.26	0.23	0.34
	30-60	SiCL	1.30	0.23	0.17	0.29	0.23
	60-90	SiL	1.40	0.30	0.21	0.42	0.29
	90-120	FS	1.55	0.20	0.27	0.30	0.41
5.0	0-30	SiCL	1.26	0.17	0.17	0.22	0.21
	30-60	SiCL	1.26	0.23	0.23	0.30	0.29
	60-90	SiL	1.40	0.30	0.30	0.42	0.42
	90-120	FS	1.55	0.18	0.25	0.28	0.39
6.5	0-30	SiCL	1.22	0.17	0.24	0.21	0.30
	30-60	SiCL	1.22	0.22	0.29	0.26	0.36
	60-90	SiL	1.40	0.22	0.19	0.31	0.27
	90-120	FS	1.55	0.16	0.17	0.26	0.26
8.0	0-30	SiCL	1.25	0.18	0.28	0.22	0.36
	30-60	SiCL	1.25	0.24	0.26	0.30	0.32
	60-90	SiL	1.40	0.29	0.18	0.40	0.26
	90-120	FS	1.55	0.20	0.27	0.31	0.42
9.5	0-30	SiCL	1.27	0.18	0.20	0.23	0.25
	30-60	SiCL	1.27	0.19	0.16	0.24	0.20
	60-90	SiL	1.40	0.27	0.25	0.38	0.35
	90-120	FS	1.55	0.20	0.29	0.31	0.44
11.0	0-30	SiCL	1.31	0.18	0.16	0.24	0.21
	30-60	SiCL	1.31	0.22	0.23	0.29	0.30
	60-90	SiC	1.20	0.26	0.29	0.31	0.35
	90-120	SiC	1.20	0.17	0.24	0.20	0.28
		SiL	1.40	0.17	0.24	0.24	0.33
		FS	1.55	0.17	0.24	0.26	0.37
12.5	0-30	SiCL	1.26	0.17	0.18	0.22	0.23
	30-60	SiCL	1.26	0.19	0.28	0.25	0.36
	60-90	SiC	1.20	0.30	0.16	0.37	0.19
	90-120	SiC	1.20	0.20	0.15	0.24	0.18
		SiL	1.40	0.20	0.15	0.28	0.21
		FS	1.55	0.20	0.15	0.31	0.23
14.0	0-30	SiCL	1.3	0.18	0.28	0.23	0.36
	30-60	SiCL	1.30	0.23	0.28	0.29	0.37
	60-90	SiC	1.20	0.28	0.15	0.34	0.17
	90-120	SiC	1.20	0.18	0.21	0.21	0.26
		SiL	1.40	0.18	0.21	0.25	0.30
		FS	1.55	0.18	0.21	0.27	0.33
15.5	0-30	SiCL	1.32	0.17	0.28	0.23	0.38

Appendix 9.5.1
Calculation of Volumetric Water Content from Bulk Density Information

Sample Location	Sample Depth	Soil Type	Bulk Density	1994 grav. water cont.	1995 grav. water cont.	1994 vol. water cont.	1995 vol. water
	30-60	SiCL	1.32	0.20	0.15	0.27	0.20
	60-90	SiC	1.20	0.29	0.18	0.35	0.22
	90-120	SiC	1.20	0.16	0.31	0.20	0.37
		SiL	1.40	0.16	0.31	0.23	0.43
		FS	1.55	0.16	0.31	0.25	0.48
17.0	0-30	SiCL	1.27	0.15	0.15	0.19	0.19
	30-60	SiCL	1.27	0.17	0.19	0.21	0.24
	60-90	SiC	1.20	0.29	0.28	0.35	0.33
	90-120	SiC	1.20	0.15	0.22	0.18	0.27
		SiL	1.40	0.15	0.22	0.21	0.31
		FS	1.55	0.15	0.22	0.23	0.35
18.5	0-30	SiCL	1.28	0.23	0.19	0.30	0.25
	30-60	SiCL	1.28	0.18	0.27	0.23	0.34
	60-90	SiC	1.20	0.29	0.26	0.35	0.31
	90-120	SiC	1.20	0.20	0.15	0.25	0.18
		SiL	1.40	0.20	0.15	0.29	0.21
		FS	1.55	0.20	0.15	0.32	0.23
20.0	0-30	SiCL	1.38	0.16	0.27	0.23	0.38
	30-60	SiCL	1.38	0.21	0.18	0.29	0.25
	60-90	SiC	1.20	0.17	0.16	0.21	0.19
	90-120	SiC	1.20	0.17	0.26	0.20	0.31
		SiL	1.40	0.17	0.26	0.23	0.36
		FS	1.55	0.17	0.26	0.26	0.40
21.5	0-30	SiCL	1.34	0.12	0.19	0.17	0.26
	30-60	SiCL	1.34	0.23	0.15	0.30	0.21
	60-90	SiC	1.20	0.31	0.24	0.37	0.29
	90-120	SiC	1.20	0.21	0.29	0.25	0.35
		SiL	1.40	0.21	0.29	0.29	0.41
		FS	1.55	0.21	0.29	0.32	0.45
23.0	0-30	SiCL	1.31	0.15	0.14	0.20	0.18
	30-60	SiCL	1.31	0.21	0.21	0.27	0.27
	60-90	SiC	1.20	0.24	0.28	0.28	0.33
	90-120	SiC	1.20	0.22	0.21	0.26	0.25
		SiL	1.40	0.22	0.21	0.30	0.29
		FS	1.55	0.22	0.21	0.33	0.32
24.5	0-30	SiCL	1.31	0.16	0.25	0.21	0.33
	30-60	SiCL	1.31	0.22	0.27	0.29	0.36
	60-90	SiC	1.20	0.23	0.21	0.28	0.25
	90-120	SiC	1.20	0.21	0.17	0.26	0.21
		SiL	1.40	0.21	0.17	0.30	0.24
		FS	1.55	0.21	0.17	0.33	0.27
26.0	0-30	SiCL	1.3	0.16	0.26	0.21	0.34
	30-60	SiCL	1.30	0.22	0.20	0.28	0.25
	60-90	SiC	1.20	0.26	0.17	0.32	0.20
	90-120	SiC	1.20	0.17	0.25	0.20	0.30
		SiL	1.40	0.17	0.25	0.24	0.35
		FS	1.55	0.17	0.25	0.26	0.39
27.5	0-30	SiCL	1.22	0.16	0.21	0.20	0.25
	30-60	SiCL	1.22	0.23	0.22	0.28	0.27
	60-90	SiC	1.20	0.30	0.22	0.36	0.26
	90-120	SiC	1.20	0.21	0.29	0.25	0.35

Appendix 9.5.1
Calculation of Volumetric Water Content from Bulk Density Information

Sample Location	Sample Depth	Soil Type	Bulk Density	1994 grav. water cont.	1995 grav. water cont.	1994 vol. water cont.	1995 vol. water c
		SiL	1.40	0.21	0.29	0.29	0.41
		FS	1.55	0.21	0.29	0.32	0.46
29.0	0-30	SiCL	1.33	0.18	0.16	0.24	0.21
	30-60	SiCL	1.33	0.25	0.25	0.34	0.33
	60-90	SiC	1.20	0.21	0.26	0.25	0.31
	90-120	SiC	1.20	0.20	0.20	0.24	0.24
		SiL	1.40	0.20	0.20	0.28	0.28
		FS	1.55	0.20	0.20	0.31	0.31
30.5	0-30	SiCL	1.33	0.17	0.24	0.23	0.32
	30-60	SiC	1.22	0.15	0.28	0.19	0.34
	60-90	FS	1.55	0.27	0.21	0.41	0.32
	90-120	FS	1.55	0.21	0.21	0.33	0.33
32.0	0-30	SiCL	1.24	0.17	0.17	0.21	0.21
	30-60	SiC	1.22	0.26	0.21	0.31	0.26
	60-90	FS	1.55	0.21	0.26	0.33	0.40
	90-120	FS	1.55	0.19	0.20	0.30	0.31
33.5	0-30	SiCL	1.25	0.16	0.17	0.20	0.21
	30-60	SiC	1.22	0.25	0.25	0.30	0.31
	60-90	FS	1.55	0.23	0.21	0.36	0.33
	90-120	FS	1.55	0.18	0.21	0.28	0.33
35.0	0-30	SiCL	1.23	0.21	0.22	0.26	0.27
	30-60	SiC	1.22	0.25	0.22	0.30	0.27
	60-90	FS	1.55	0.25	0.29	0.39	0.45
	90-120	FS	1.55	0.20	0.21	0.31	0.33
36.5	0-30	SiCL	1.21	0.17	0.16	0.21	0.19
	30-60	SiC	1.22	0.25	0.25	0.30	0.31
	60-90	FS	1.55	0.29	0.26	0.44	0.40
	90-120	FS	1.55	0.19	0.20	0.29	0.31
38.0	0-30	SiCL	1.32	0.19	0.15	0.25	0.20
	30-60	SiC	1.22	0.39	0.24	0.47	0.29
	60-90	FS	1.55	0.21	0.28	0.33	0.43
	90-120	FS	1.55	0.20	0.21	0.31	0.33
0.5 South	0-30	SiCL	1.32	0.16	0.16	0.21	0.21
	30-60	SiCL	1.32	0.23	0.20	0.31	0.26
	60-90	SiL	1.40	0.25	0.26	0.36	0.36
	90-120	FS	1.55	0.20	0.23	0.31	0.36
1.0	0-30	SiCL	1.34	0.17	0.25	0.23	0.33
	30-60	SiCL	1.34	0.22	0.21	0.29	0.28
	60-90	SiL	1.40	0.23	0.18	0.33	0.25
	90-120	FS	1.55	0.21	0.21	0.33	0.33
2.0	0-30	SiCL	1.32	0.16	0.29	0.21	0.38
	30-60	SiCL	1.32	0.22	0.23	0.29	0.30
	60-90	SiL	1.40	0.29	0.17	0.40	0.24
	90-120	FS	1.55	0.22	0.17	0.35	0.26
3.5	0-30	SiCL	1.3	0.13	0.24	0.17	0.32
	30-60	SiCL	1.30	0.23	0.15	0.29	0.19
	60-90	SiL	1.40	0.27	0.24	0.38	0.34
	90-120	FS	1.55	0.22	0.29	0.35	0.45
5.0	0-30	SiCL	1.27	0.16	0.15	0.21	0.19
	30-60	SiCL	1.27	0.25	0.23	0.32	0.29
	60-90	SiL	1.40	0.29	0.25	0.41	0.35

Appendix 9.5.1
Calculation of Volumetric Water Content from Bulk Density Information

Sample Location	Sample Depth	Soil Type	Bulk Density	1994 grav. water cont.	1995 grav. water cont.	1994 vol. water cont.	1995 vol. water c
	90-120	FS	1.55	0.22	0.18	0.34	0.27
6.5	0-30	SiCL	1.42	0.15	0.24	0.22	0.34
	30-60	SiCL	1.42	0.22	0.25	0.31	0.36
	60-90	SiL	1.40	0.29	0.19	0.41	0.27
	90-120	FS	1.55	0.21	0.16	0.32	0.25
8.0	0-30	SiCL	1.34	0.20	0.28	0.27	0.38
	30-60	SiCL	1.34	0.24	0.20	0.32	0.27
	60-90	SiL	1.40	0.18	0.13	0.25	0.18
	90-120	FS	1.55	0.18	0.27	0.28	0.42
9.5	0-30	SiCL	1.35	0.15	0.23	0.21	0.31
	30-60	SiCL	1.35	0.24	0.14	0.32	0.19
	60-90	SiL	1.40	0.23	0.24	0.32	0.34
	90-120	FS	1.55	0.19	0.31	0.30	0.48
11.0	0-30	SiCL	1.23	0.15	0.18	0.19	0.22
	30-60	SiCL	1.23	0.21	0.27	0.26	0.33
	60-90	SiCL	1.23	0.25	0.29	0.31	0.35
		SiL	1.40	0.25	0.29	0.35	0.40
	90-120	SiL	1.40	0.16	0.28	0.23	0.39
		FS	1.55	0.16	0.28	0.25	0.43
12.5	0-30	SiCL	1.22	0.16	0.22	0.20	0.27
	30-60	SiCL	1.22	0.24	0.27	0.29	0.33
	60-90	SiCL	1.22	0.27	0.20	0.33	0.24
		SiL	1.40	0.27	0.20	0.37	0.28
	90-120	SiL	1.40	0.21	0.15	0.30	0.21
		FS	1.55	0.21	0.15	0.33	0.23
14.0	0-30	SiCL	1.39	0.15	0.27	0.21	0.38
	30-60	SiCL	1.39	0.24	0.26	0.33	0.36
	60-90	SiCL	1.39	0.30	0.15	0.42	0.21
		SiL	1.40	0.30	0.15	0.42	0.21
	90-120	SiL	1.40	0.18	0.24	0.25	0.34
		FS	1.55	0.18	0.24	0.28	0.37
15.5	0-30	SiCL	1.33	0.16	0.19	0.21	0.25
	30-60	SiCL	1.33	0.22	0.13	0.29	0.17
	60-90	SiCL	1.33	0.30	0.19	0.40	0.26
		SiL	1.40	0.30	0.19	0.42	0.27
	90-120	SiL	1.40	0.17	0.31	0.24	0.43
		FS	1.55	0.17	0.31	0.27	0.48
17.0	0-30	SiCL	1.27	0.15	0.15	0.19	0.19
	30-60	SiCL	1.27	0.22	0.25	0.28	0.31
	60-90	SiCL	1.27	0.32	0.28	0.40	0.35
		SiL	1.40	0.32	0.28	0.44	0.39
	90-120	SiL	1.40	0.24	0.21	0.34	0.30
		FS	1.55	0.24	0.21	0.38	0.33
18.5	0-30	SiCL	1.37	0.18	0.20	0.24	0.28
	30-60	SiCL	1.37	0.24	0.32	0.32	0.44
	60-90	SiCL	1.37	0.29	0.27	0.40	0.37
		SiL	1.40	0.29	0.27	0.41	0.38
	90-120	SiL	1.40	0.18	0.15	0.26	0.21
		FS	1.55	0.18	0.15	0.28	0.23
20.0	0-30	SiCL	1.32	0.16	0.25	0.21	0.33
	30-60	SiCL	1.32	0.23	0.24	0.30	0.32

Appendix 9.5.1
Calculation of Volumetric Water Content from Bulk Density Information

Sample Location	Sample Depth	Soil Type	Bulk Density	1994 grav. water cont.	1995 grav. water cont.	1994 vol. water cont.	1995 vol. water c
	60-90	SiCL	1.32	0.30	0.13	0.40	0.17
		SiL	1.40	0.30	0.13	0.43	0.18
	90-120	SiL	1.40	0.18	0.21	0.26	0.30
		FS	1.55	0.18	0.21	0.28	0.33
21.5	0-30	SiCL	1.28	0.15	0.24	0.19	0.31
	30-60	SiCL	1.28	0.26	0.16	0.33	0.20
	60-90	SiCL	1.28	0.23	0.25	0.29	0.33
		SiL	1.40	0.23	0.25	0.32	0.36
	90-120	SiL	1.40	0.21	0.28	0.29	0.39
		FS	1.55	0.21	0.28	0.32	0.43
23.0	0-30	SiCL	1.23	0.19	0.14	0.23	0.17
	30-60	SiCL	1.23	0.26	0.16	0.32	0.19
	60-90	SiCL	1.23	0.32	0.29	0.40	0.36
		SiL	1.40	0.32	0.29	0.45	0.41
	90-120	SiL	1.40	0.21	0.25	0.29	0.35
		FS	1.55	0.21	0.25	0.32	0.39
24.5	0-30	SiCL	1.33	0.15	0.25	0.20	0.33
	30-60	SiCL	1.33	0.26	0.28	0.35	0.38
	60-90	SiCL	1.33	0.33	0.24	0.44	0.32
		SiL	1.40	0.33	0.24	0.46	0.34
	90-120	SiL	1.40	0.21	0.16	0.29	0.23
		FS	1.55	0.21	0.16	0.32	0.25
26.0	0-30	SiCL	1.33	0.16	0.30	0.21	0.40
	30-60	SiCL	1.33	0.26	0.24	0.34	0.32
	60-90	SiCL	1.33	0.20	0.17	0.27	0.22
		SiL	1.40	0.20	0.17	0.28	0.23
	90-120	SiL	1.40	0.20	0.21	0.28	0.29
		FS	1.55	0.20	0.21	0.31	0.32
27.5	0-30	SiCL	1.19	0.16	0.24	0.19	0.28
	30-60	SiCL	1.19	0.23	0.14	0.27	0.17
	60-90	SiCL	1.19	0.24	0.17	0.28	0.20
		SiL	1.40	0.24	0.17	0.33	0.24
	90-120	SiL	1.40	0.19	0.23	0.27	0.32
		FS	1.55	0.19	0.23	0.30	0.35
29.0	0-30	SiCL	1.26	0.16	0.16	0.21	0.20
	30-60	SiCL	1.26	0.24	0.24	0.30	0.30
	60-90	SiCL	1.26	0.25	0.28	0.32	0.36
		SiL	1.40	0.25	0.28	0.36	0.40
	90-120	SiL	1.40	0.22	0.20	0.31	0.28
		FS	1.55	0.22	0.20	0.34	0.31
30.5	0-30	SiCL	1.37	0.15	0.24	0.21	0.33
	30-60	SiCL	1.37	0.23	0.28	0.32	0.39
	60-90	SiCL	1.37	0.31	0.21	0.42	0.28
	90-120	FS	1.55	0.23	0.24	0.35	0.37
		SiL	1.40	0.23	0.24	0.32	0.34
32.0	0-30	SiCL	1.31	0.15	0.16	0.19	0.21
	30-60	SiCL	1.31	0.24	0.23	0.32	0.30
	60-90	SiCL	1.31	0.29	0.30	0.37	0.39
	90-120	FS	1.55	0.27	0.24	0.42	0.37
		SiL	1.40	0.27	0.24	0.38	0.34
33.5	0-30	SiCL	1.24	0.15	0.17	0.19	0.21

Appendix 9.5.1
Calculation of Volumetric Water Content from Bulk Density Information

Sample Location	Sample Depth	Soil Type	Bulk Density	1994 grav. water cont.	1995 grav. water cont.	1994 vol. water cont.	1995 vol. water
	30-60	SiCL	1.24	0.26	0.21	0.33	0.26
	60-90	SiCL	1.24	0.27	0.27	0.34	0.33
	90-120	FS	1.55	0.21	0.24	0.32	0.37
		SiL	1.40	0.21	0.24	0.29	0.34
35.0	0-30	SiCL	1.21	0.17	0.14	0.20	0.17
	30-60	SiCL	1.21	0.24	0.17	0.29	0.21
	60-90	SiCL	1.21	0.30	0.23	0.37	0.28
	90-120	FS	1.55	0.23	0.24	0.35	0.37
		SiL	1.40	0.23	0.24	0.32	0.34
36.5	0-30	SiCL	1.24	0.15	0.16	0.18	0.20
	30-60	SiCL	1.24	0.22	0.24	0.28	0.30
	60-90	SiCL	1.24	0.27	0.28	0.33	0.35
	90-120	FS	1.55	0.17	0.20	0.27	0.31
		SiL	1.40	0.17	0.20	0.24	0.28
38.0	0-30	SiCL	1.19	0.16	0.19	0.19	0.23
	30-60	SiCL	1.19	0.24	0.24	0.29	0.29
	60-90	SiCL	1.19	0.24	0.28	0.29	0.33
	90-120	FS	1.55	0.23	0.21	0.35	0.33
		SiL	1.40	0.23	0.21	0.32	0.29

Appendix 9.5 (cont'd)

Appendix 9.5.2 Calculations Related to the Determination of the Mass of NO_3-N in the Soil Profile

To calculate the mass of NO_3-N in the soil profile, soil water NO_3-N concentration data and volumetric soil water content estimates were multiplied together with the appropriate conversion factors. For each 30-cm-sampled interval, the measured mean sample values were assumed to represent the conditions of the entire center bench.

	1994:				1995:			
Sample Interval (cm below ground surface)	**vol. water cont. (cm^3/cm^3)**	**NO_3-N conc. (mg/l)**	**Mass NO_3-N (lbs/acre)**	**Mass NO_3-N (kg/ha)**	**vol. water cont. (cm^3/cm^3)**	**NO_3-N conc. (mg/l)**	**Mass NO_3-N (lbs/acre)**	**Mass NO_3-N (kg/ha)**
0 - 30	0.22	163.75	96.44	108.09	0.23	29.29	18.00	20.18
30 - 60	0.3	45.28	36.38	40.78	0.29	12.42	9.44	10.58
60 - 90	0.36	17.74	17.13	19.20	0.35	3.11	2.94	3.30
90 - 120	0.18	23.14	11.13	12.48	0.2	2.01	1.06	1.19
Total Mass NO3-N in soil profile (lbs/acre):	-	-	**161.08**	**180.55**	-	-	**31.44**	**35.24**

Appendix 9.6 Calculations relating to the center bench water distributions and the NO3-N mass lost for the center bench

Appendix 9.6.1 Water Distributions

Applied Irrigation Water:

Since the circular weirs were not installed in the irrigation canal for the entire 1994 irrigation season, all the available data from 1994 and 1995 were used to determine the mean amount of water applied to the center bench per irrigation. This was then multiplied by the 8 irrigations in 1994 to the center bench to determine the total amount of applied irrigation water. Refer to Table 3.

Precipitation:

The total precipitation added to the field was measured from 8 March 1994 to 24 September 1995. Since some of the 1994 data is missing or was not recorded, portions of the 1995 data were used to estimate the total amount of precipitation the field received in 1994. Refer to Tables 4 and 7.

Evapotranspiration (ET):

The ET was measured in two ways. WRRI technical report # 191(Mapel and Sammis, 1985) consists of measured and modeled ET rates calculated for sorghum grass in New Mexico and are based on crop yield. Information was obtained from the landowner on the yield of sorghum and the matching ET value from the WRRI report was used. The second way that the ET was calculated was from daily P_{ET} rates obtained from 1994 weather data from the USDA Los Lunas Plant Science Center in Los Lunas, New Mexico:

	Mean P_{ET}	
Month (1994)	**mm**	**in**
January	74.4	2.93
February	84	3.31
March	136.4	5.37
April	183	7.20
May	207.7	8.18
June	273	10.75
July	266.6	10.50
August	229.4	9.03
September	171	6.73
October	120.9	4.76
November	72	2.83
December	58.9	2.32

Appendix 9.6.1 (CONT'D)

These values were then adjusted in two ways to calculate the actual ET. If a crop cover is absent, the calculated flux due to capillary rise from CAPSEV was used together with the precipitation data, as the precipitation is not of a great enough magnitude to infiltrate downward into the soil profile. A summary of the CAPSEV output is found on the following page. If a crop cover was present, the PET was multiplied by a crop coefficient obtained from Doorenbos, 1979. These crop coefficients change as the crops develop and mature:

	P_{ET}			Cap Rise		Precipitation		ET	
Month	mm	in	Kcrop	mm	in	mm	in	mm	in
January	74.4	2.93	-	2.5	0.10	11.3	0.44	13.8	0.54
February	84.0	3.31	-	2.2	0.09	2.6	0.10	4.8	0.19
March	136.4	5.37	-	2.5	0.10	16.9	0.67	19.4	0.76
April	183.0	7.20	-	2.4	0.09	12.4	0.49	14.8	0.58
May	207.7	8.18	0.4					83.1	3.27
June	273.0	10.75	0.4					109.2	4.30
July	266.6	10.50	0.7					193.3	7.61
August	229.4	9.03	-	2.5	0.10	75.2	2.96	77.7	3.06
September	171.0	6.73	-	2.4	0.09	53.6	2.11	56.0	2.20
October	120.9	4.76	0.4					48.4	1.90
November	72.0	2.83	0.7					52.2	2.06
December	58.9	2.32	0.7					42.7	1.68
							total ET:	**715.3**	**28.16**

Tile Drain Discharge:

The volumetric flow rates as measured from the flow measurement system in the downgradient (west) manhole were integrated over time to obtain a total volume passed in a given time period. Since the water was seen to stagnate around the drains shortly after an irrigation, the flow rates seen in between irrigations after the perterbation had ceased was used as an estimate of what the tile flow should have been at these time intervals. See Figure 25 and Section 4.4.1.

Calculation of Recharge Using Electrical Conductivity Values:

The recharge to the shallow groundwater system can be calculated using the ratio of the electrical concuctivity in the applied water to the electrical conductivity in the tile drain. Multiplying this ratio by the amount of applied water gives an estimate of the groundwater recharge. The electrical conductivity in the precipitation was estimated to be approximately 10 umhos/cm

Appendix 9.6.1 (CONT'D)

(Jan Hendrickx, Prof. of Hydrology, New Mexico Tech, pers. comm. 1995). The mean electrical conductivity in the irrigation water was 368 umhos/cm (Section 4.2). The electrical conductivity of the tile drain discharge in 1994 ranges from approximately 900 to 1200 umhos/cm. The recharge calculations therefore show that:

$R = (P + I) * EC_{P+I} / EC_D$ where:

R = recharge to the shallow groundwater system
P = precipitation
I = irrigation
EC_{P+I} = electrical conductivity in the applied water (umhos/cm)
EC_D = electrical conductivity in the tile drain line (umhos/cm)

= 210 - 280 mm 8.27 - 11.02 in

with a mean recharge of 245 mm (9.65 in).

Appendix 9.6.2 Mass NO_3-N lost due to recharge

NO_3-N loss to the center bench tile drains:

Since the 1995 flow data was used with the 1994 water chemistry data, a range in the flow response was used with the most complete concentration data set, from the 27 June 1994 irrigation event. Average concentrations in between irrigation events was multiplied with the average flow rates in between irrigations to obtain a mass lost in between irrigations.

Average NO_3-N concentration in the downgradient (west) manhole tile drain line in between irrigations: 0.05 - 0.23 kg; 0.1 - 0.5 lbs

Multiply by the average flow rates from the intervals between the start of the irrigation season and the last irrigation to the center bench: 0.52 - 2.59 kg; 1.14 - 5.71 lbs.

From the average flow response to an irrigation:

NO_3-N loss per irrigation per tile drain line: 0.14 - 0.41 kg; 0.3 - 0.9 lbs.
Multiply by the four drains and the eight irrigations: 5.08 - 13.54 kg; 11.2 - 29.84 lbs.

Therefore, the total mass loss through the tile drain line is the addition of the mass lost as a result of the irrigations as well as in between irrigations: 5.60 - 16.13 kg; 12.34 - 35.55 lbs.