INFLUENCE OF PREVAILING HYDROGEOLOGIC

CONDITIONS ON VARIATIONS IN SHALLOW

GROUND-WATER QUALITY

By

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CHAPTER I

INTRODUCTION

General Overview

Ground-water monitoring programs established for
compliance with environmental regulations often call for
sampling to take place only one, two, or four times yearly.
Although cost, time, and manpower constraints may make more
frequent sampling impractical, recent research indicates
that ground-water quality can change significantly in a
matter of hours or days. The extent of such variation in
quality depends largely upon the hydrogeologic conditions
that prevail during the time the change takes place. A
routine ground-water recharge event resulting from rainfall
just prior to sampling may, given the right set of
circumstances, dramatically affect ground-water quality.
Consequently, an investigator's conclusions regarding
nature and extent of contamination may be based upon
chemical data from "unrepresentative" ground-water samples.
This type of situation is of particular concern in cases
involving shallow aquifers where the water table lies only
a few feet or meters below land surface. Deeper ground
water is less susceptible to significant short-term
variations in quality.

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Purpose and Scope

The purpose of this study is to describe how prevailing hydrogeologic conditions can affect the magnitude of variations in shallow ground-water quality. Factors to be examined are: 1) depth to ground water, 2) soil-moisture content in the unsaturated zone, 3) water quality in the unsaturated zone, 4) underflow, 5) amount and quality of precipitation, 6) land use, and 7) soil structure.

To meet the research objective, a comprehensive monitoring program was established at a 26,000 sq. ft. field site. The site is a suburban yard in northeast Stillwater, Oklahoma. It overlies a shallow, fine-grained alluvial aquifer which has historically shown significant short-term variations in water quality (Hagen, 1986; Hoyle, 1987; Ross, 1988). Rainfall amounts, fertilizer application rates, ground-water levels, soil-moisture content in the unsaturated zone, and chemical quality of water samples from the unsaturated zone and ground water were measured between March and December 1988 to relate observed variations in ground-water quality to controlling hydrogeologic factors. Supplementing the monitoring program, tracer testing of the unsaturated zone was performed to evaluate chemical transport capabilities of unsaturated soil at the site under both "wet" and "dry" initial soil-moisture conditions. The tests utilized concentrated solutions of conservative tracers and were

designed to simulate precipitation events.

Literature Review

Previous Studies at the Field Site

Work was initiated at the study site by Hagen (1986). He monitored water-level fluctuations and various water-quality parameters in 20 shallow wells from June 1985 through April 1986. Hagen concluded that water-level fluctuations and variations in ground-water quality observed during recharge events are largely controlled by the presence of macropores in the unsaturated zone, particularly after extended periods of hot, dry weather when dessication cracks are observed at the surface.

Recognizing that fluctuations in shallow ground-water quality are largely governed by hydraulic properties of the unsaturated zone, Acre (1989) monitored soil-moisture content at four locations within the study area from September 1985 to April 1986. He also suggested that macropores may provide a means for infiltrating water to move rapidly from the surface to the water table.

Hoyle (1987) observed short-term variations in shallow ground-water quality at the site between April 1986 and February 1987. The fluctuations were attributed to various human activities and geochemical processes.

Ross (1988) was the first investigator to monitor water quality in the unsaturated zone. He obtained water samples from eight suction lysimeters and four monitoring

wells from January through June 1987 and found that the unsaturated zone is more susceptible than the aquifer to short-term variations in water quality.

Variability of Ground-Water Quality

Variations in ground-water quality have received increasing attention in recent years due to heightened awareness of the need for protecting ground-water resources. Studies describing fluctuations in ground-water quality as a result of discharge from specific sources at the surface are quite common in the literature, but researchers seldom have sufficient data to definitively trace these discharges as they migrate through the unsaturated zone to the water table.

Spalding and Exner (1980) described how agricultural practices along the Platte River in Nebraska were responsible for deteriorating the quality of shallow ground water. They pointed out that significant temporal fluctuations in nitrate concentrations occurred downgradient from cultivated fields in response to the periodic initiation and termination of irrigation. Katz and others (1978) related variations in chloride, nitrate, and sulfate concentrations in ground water of a surficial aquifer in Long Island, New York, to temporal fluctuations in input from nonpoint sources such as fertilizers, effluent from septic tanks and cesspools, and storm runoff. Schmidt (1972) cited similar contamination sources to explain the occurrence of high nitrate contents in ground

water of the San Joaquin Valley, California. Nitrate contamination in rural ground-water supplies was studied by Walker (1973). He postulated that concentrated slugs of nitrate-enriched water, derived from agricultural sources such as livestock feedlots and cultivated fields, enter shallow aquifers during late autumn and early spring ground-water recharge periods. These slugs of high-nitrate water migrate through aquifers with relatively little mixing or dilution. Gustafson (1983) utilized aquifer hydraulics to explain the occurrence of elevated nitrate levels in ground water of agricultural areas in Sweden. He pointed out that aquifer recharge zones, where ground water exhibits some downward movement, may be significantly impacted by agricultural pollutants at depths somewhat deeper than the water table.

Rapid ground-water level and quality response to major storms was addressed by Gerhart (1986). He found that storm water reaches the water table below a manured field site in Lancaster County, Pennsylvania within several hours by infiltrating through near-surface fractures and sinkholes. Nitrate concentrations either increase or decrease, depending on the amount of fresh manure on the surface at the time of the storm. Pettyjohn (1976) reported cyclic fluctuations in chloride concentrations due to downward and lateral movement of brines through a shallow aquifer in central Ohio. He concluded that three abandoned brine disposal pits were responsible for salt accumulation in the unsaturated zone, and recharge events intermittently

flushed the salt into the aquifer over a period of several years. Toler and Pollock (1974) were able to document the accumulation of highway deicing salt in the unsaturated zone before chloride concentrations peaked in shallow ground water at a site in northeastern Massachusetts.

Unsaturated Flow and Recharge

The potential for surface-applied pollutants to contaminate ground water depends largely on the hydraulic properties of the unsaturated zone. Lawes and others (1882) were among the first to employ two domains of flow to explain the mechanics of water movement through soil. Researchers now refer to drainage from smaller pores that is influenced by capillary forces as "piston flow", whereas rapid movement of water down open channels such as interfaces between adjacent soil peds is termed "short circuiting" (Thomas and Phillips, 1979; Bouma and others, 1982). Beven and Germann (1982) discussed the importance of these large continuous openings, or "macropores", on water flow in soils. Field infiltration tests were performed on three soils in Kentucky by Thomas and others (1978). They found that preferential flow pathways provided by strong soil structure may allow rain water or irrigation water to move 20 times deeper than expected when piston flow is assumed; thus, ground-water recharge may occur when a soil is below field capacity. Quisenberry and Phillips (1976) also attributed rapid, deep percolation of irrigation water to movement through cracks and channels in soil.

Variability of water-table response to precipitation was discussed by Gillham (1984). He stated that in field situations involving fine-grained geologic materials, the capillary fringe may extend several meters above the water table, and addition of a small amount of infiltrating water to the capillary fringe may result in a large water-table rise. Viswanathan (1984) discussed rapid ground-water recharge due to precipitation in a coastal aquifer near Newcastle, Australia. He found that recharge to the aquifer often occurred on the same day as rainfall, and the amount of recharge observed depended upon the intensity of the precipitation event as well as recent temporal rainfall patterns.

Tracer Testing

Many chemical constituents which occur naturally in soil are relatively abundant and subject to complex chemical transformations; thus, they serve as poor hydrologic tracers. A comprehensive guide to the selection of more effective tracers and their practical use in ground-water investigations was provided by Davis and others (1985).

Much of the work regarding tracer testing of the unsaturated zone has been contributed by soil scientists. Tracer tests performed for the purposes of this research were patterned after procedures described by Warrick and others (1971). They applied 3 inches of chloride solution to a 400 sq. ft. plot on an alluvial soil in the Central

Valley, California. Lysimeters were utilized for collecting solute samples and tensiometers were employed to monitor soil-moisture distributions during infiltration. Germann and others (1984) sprinkled bromide solution on the surface of seven columns of two undisturbed soils to investigate solute and water distributions in soils with macropores. Bouma (1981) also made use of tracers to quantitatively describe preferential flow along soil macropores.

CHAPTER II

SITE DESCRIPTION

Location

The investigated area occupies 26,000 sq. ft. of a suburban neighborhood in northeast Stillwater, Payne County, Oklahoma (Figure 1). The site is bounded by residential streets to the east and north, and private property lines to the west and south. Topographic relief across the site is less than 1 foot; the approximate surface elevation is 886 feet.

Geologic Setting

The site lies on the floodplain of a perennial stream, Boomer Creek, which flows sluggishly from northwest to southeast and passes approximately 1000 feet to the west. Boomer Creek drains several tributaries and small ponds in the area.

Surficial geology at the site consists of 43 feet of late Quaternary alluvial deposits which have filled a steep-walled valley carved into underlying Pennsylvanian rocks of the Oscar Group (Figure 2). The upper 35.5 feet of this valley-fill material exhibits soil characteristics. The modern soil belongs to the Ashport series and extends
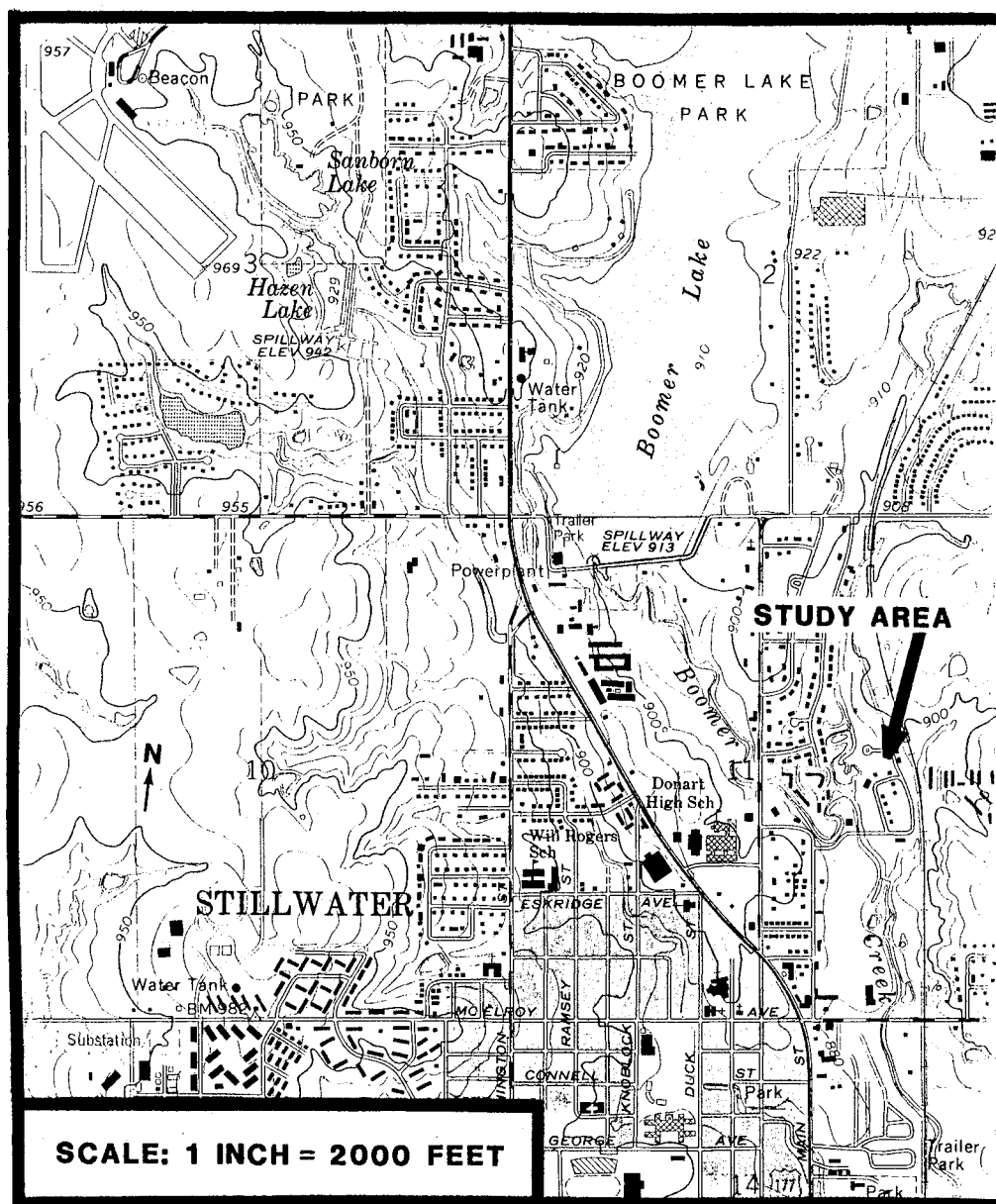
Figure 1. Location of Study Area in Relation to
City of Stillwater (USGS, 1979).

from land surface to a depth of 4 feet (SCS, 1987). An upper buried soil extends from 4 feet to 27.5 feet beneath land surface; organic material from its uppermost horizon has been radiocarbon dated at 1300 +/- 70 years before present. The uppermost horizon of a lower buried soil, which lies between 27.5 and 35.5 feet beneath land surface, has been radiocarbon dated at 10,600 +/- 170 years before present. The 25 individual horizons which comprise these three distinct soil profiles are predominantly silt loam or silty clay loam. A few loam, clay loam, and silty clay horizons are also present. Soil peds and root casts are distinguishable throughout the 35.5-foot zone of soil development. An alluvial lag deposit consisting of gravel grading upward into sand separates the zone of soil development from the underlying shale unit of the Oscar Group. Ross (1988) provided a detailed description of the aforementioned surficial deposits.

The unconsolidated deposits present at the site are underlain by 5000 feet of Paleozoic strata that lie unconformably on granitic basement rock. Sandstones, shales, and limestones of Pennsylvanian age dominate the lithology in the immediate vicinity of the study area (Figure 3). These units generally dip to the west 40 to 50 feet per mile (Shelton and others, 1985).

Climate

Central Oklahoma receives an average of 34 inches of precipitation annually (Pettyjohn and others, 1983).

W

E

Boomer Creek   Study Area

$\mathbf{P}_h$

$\mathbf{P}_{en}$

$\mathbf{P}_{en}$

Q_{al}

$\mathbf{P}_d$

$\mathbf{P}_{fr}$

HORIZONTAL SCALE: 1 INCH=1000 FEET

VERTICAL SCALE: 1 INCH=100 FEET

VERTICAL EXAGGERATION: 10X

Q_{al} Alluvium   Quaternary

$\mathbf{P}_h$ Herington Limestone

$\mathbf{P}_{en}$ Enterprise Shale

$\mathbf{P}_d$ Doyle Shale

$\mathbf{P}_{fr}$ Fort Riley Limestone

Oscar Group   Pennsylvanian
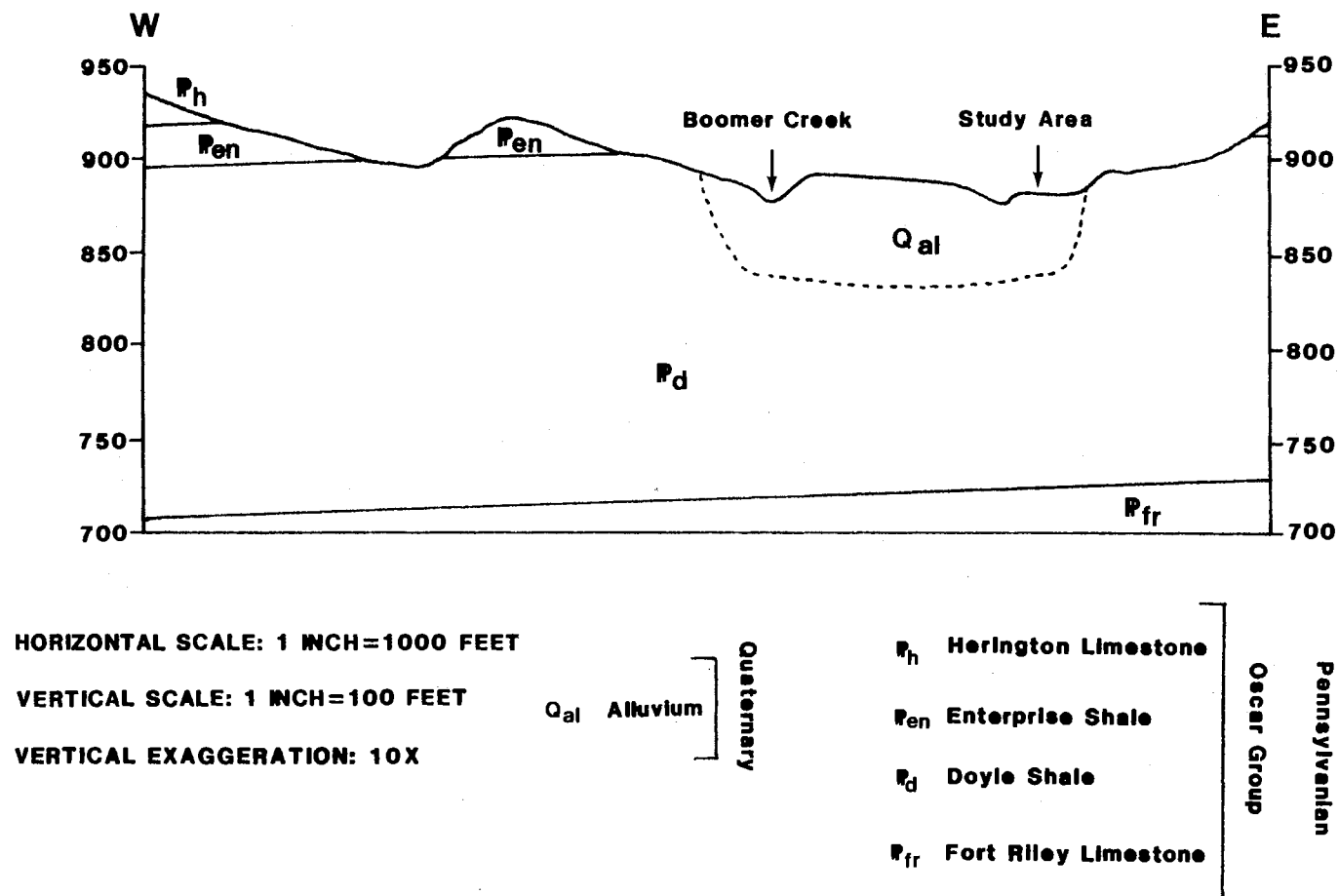
Figure 3. Geologic Cross-Section through Study Area (Hoyle, 1987).

Typically, most of the rain falls in spring and early summer during convective thunderstorms of high intensity and short duration. Cyclonic storm systems bring slow, steady rains to the area during fall and winter. Rainfall at the research area totalled 21.91 inches during the nine month study period, from March 3 to December 3, 1988 (Appendix A).

Evapotranspiration losses in Payne County total about 30 inches per year (Pettyjohn and others, 1983). Most of these losses occur during the dry summer months, when the average temperature is 80 degrees F. In winter the average temperature is 39 degrees F (SCS, 1987). Average annual runoff in north central Oklahoma is 4.5 inches. The effective regional ground-water recharge rate is about 1 inch per year (Pettyjohn and others, 1983).

Monitoring Instrumentation

A total of 41 wells have been installed at 10 locations (A-J) within the study area (Figure 4). Most of the wells are grouped in clusters of two, three, or five. Each well has been assigned a letter and number for identifying its location and depth. All wells have their slotted interval in the unconsolidated surficial deposits described above. Total depths range from 6.6 feet to 40.3 feet (Appendix B). All but three of the wells were completed with PVC casing which was slotted with a hand saw and wrapped with nylon screen. Wells B11, I3, and J1 utilize a stainless steel, perforated pipe well point which
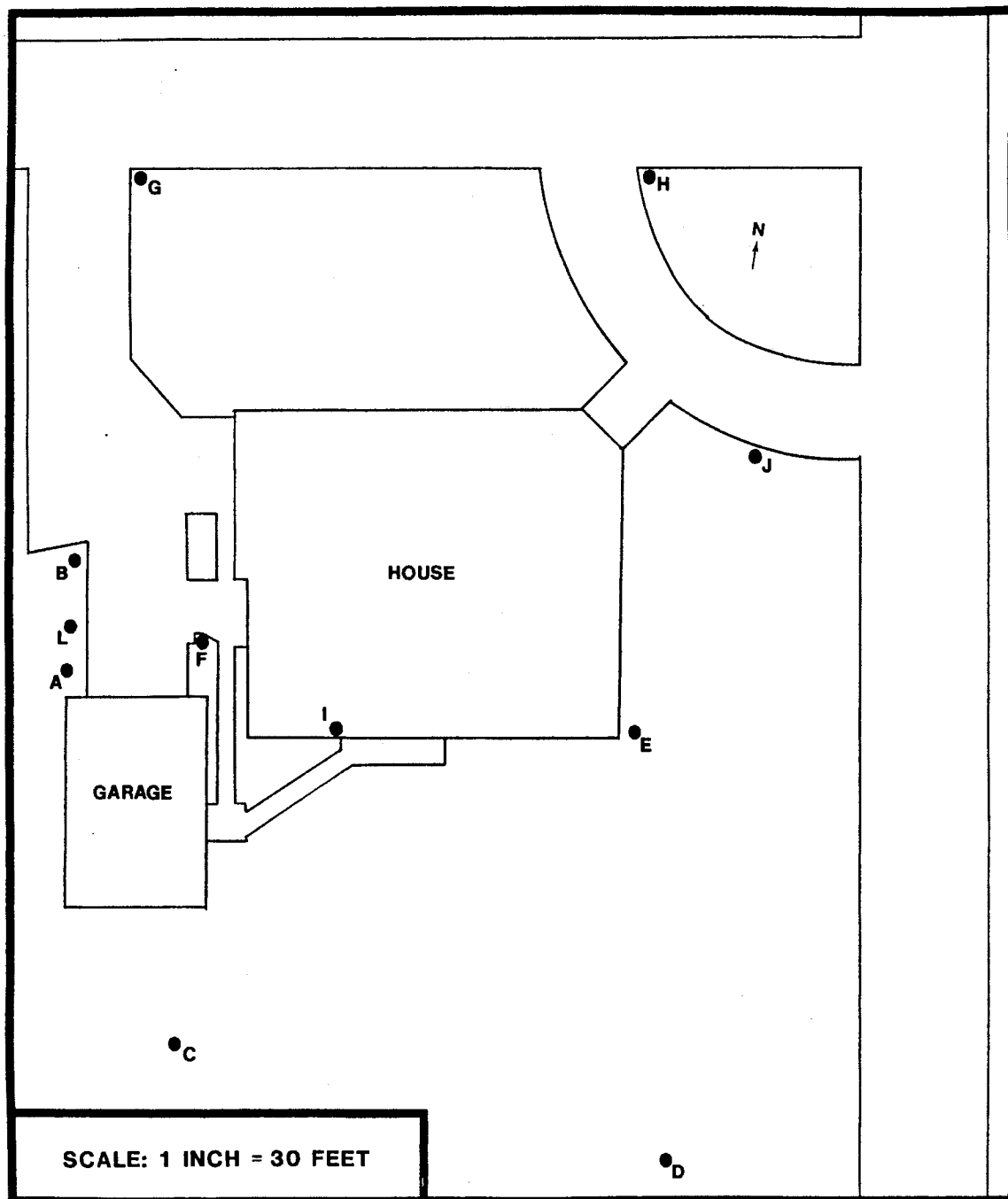
Figure 4. Site Instrumentation Map.

is attached at the lower end of PVC casing. Filter pack, consisting of medium- to coarse-grained sand, generally extends several inches above the slotted interval. A bentonite seal separates the filter pack from overlying native backfill, and the wells are sealed at the surface with a concrete pad.

To sample water migrating through the unsaturated zone, Ross (1988) installed eight soil-water suction lysimeters in holes excavated within an 8 sq. ft. area between the A and B well clusters (Figure 4). The lysimeters, designated L1, L2, L3, L4, L5, L6, L6B, and L7, are installed at depths of 1.5, 2.0, 3.0, 3.6, 5.0, 6.9, 6.7, and 8.0 feet below land surface, respectively. Each lysimeter consists of a porous ceramic cup attached to PVC pipe to form a 500 ml sample collection chamber, which is sealed at the top with a compressional o-ring and plastic cap. A combination of stainless steel and tygon tubing extends from inside the sample collection chamber to above the ground surface, allowing the lysimeters to be pressurized and sampled. Bentonite and native backfill form a seal preventing downward migration of water through the annulus.

In-situ measurements of soil moisture were made at the site with a Troxler Model 3330 depth moisture gauge (soil-moisture neutron probe). A neutron probe access tube is located adjacent to each of five well clusters at the site. At the A, C, D, and E wells, the 1.7-inch diameter aluminum tubes extend to a depth of 7 feet and are open-bottomed.

The tube at the B site extends to a depth of 12 feet and is sealed at the bottom with a rubber ball; thus, ground water cannot seep into the tube and soil-moisture measurements can be made below the water table.

A continuously recording tipping bucket rain gauge has been employed to measure intensity and duration of precipitation events at the study site. Barometric pressure and air temperature are monitored continuously with a barograph and remote reading recording thermometer, respectively.

Land Use

Approximately 7,000 sq. ft., or 27% of the 26,000 sq. ft. study area is covered by concrete driveways, walkways, and one-story buildings; the remainder of the site is covered with Bermuda grass (Figure 4). The buildings do not have basements and are underlain by concrete foundations. The I wells are located in a cut-out portion of the concrete foundation just inside the south wall of the house. One of the drainspouts which drains the roof of the house spills within 5 feet of the E wells. Streets which form the northern and eastern boundaries of the study area are curbed; thus, rain on the streets does not drain into the yard.

Two municipal sewer lines transect the study area. An 8-inch diameter line, buried approximately 5 feet below the surface, runs from east to west across the southern boundary. At the southwest corner of the site, the 8-inch

line empties into a 15-inch line that extends from south to north along the western boundary, approximately 8 feet below the surface.

Fertilizer was applied to the lawn four times during the period of investigation. Nitrogen was the primary ingredient in the fertilizers, but smaller amounts of sulfur, potash, and phosphoric acid were also present. Urea constituted the majority of total nitrogen, which was applied at an average rate of 1.5 lb/1,000 ft^2.

CHAPTER III

MATERIALS AND METHODS

Water-Level and Soil-Moisture Measurements

Water levels were measured 66 times between March 3 and December 3, 1988. Because of fluctuations in the water table, several wells were dry during part of the investigative period. Depth to water, measured to the nearest hundredth of a foot with a chalked steel tape, was subtracted from the altitude of the top of well casing to determine water-table elevation (Appendix C).

Soil-moisture profiles were measured at each of the five neutron probe access tube locations immediately prior to routine sampling of monitoring wells and lysimeters, approximately every 9 days during the study period. Generally, soil moisture at the A site also was recorded once between sampling events. The Troxler Model 3330 depth moisture gauge works on the principle of neutron thermalization. Fast neutrons emitted by a radioactive source in the probe are slowed by hydrogen ions in the soil and soil water adjacent to the access tube. These slowed neutrons are detected, and counts are displayed in direct proportion to the moisture content of the soil (Troxler Manual, 1983). Prior to moisture testing, standard count

measurements were made for 4 minutes with the probe inside the gauge body. Two 30-second neutron counts were made at 0.5-foot increments to a depth of 6.5 feet in the A, C, D, and E tubes and to a depth of 11 feet in the B tube. A simple BASIC computer program was utilized to convert the average of the two neutron count measurements from each depth to soil-moisture content as cm^3 water/cm^3 soil.

Sampling Procedures

Ground-water samples were collected from monitoring wells 29 times during the study period. Tracer testing of the unsaturated zone neccessitated more frequent sampling of the lysimeters. Samples were collected in 500 ml polyethylene bottles that were pre-washed with near-neutral pH laboratory grade detergent and rinsed thoroughly with deionized water.

Monitoring Wells

The 3 and 4 wells of the A, C, D, and E clusters and similarly designed 1 and 2 wells of the G, H, and I clusters were utilized for regular sampling. Samples obtained from these wells are representative of two narrow horizons in the upper part of the aquifer. The shallow sampled well at each cluster has a 2- to 6-inch screened interval approximately 10 feet below land surface. The deeper well is slotted over a 2- to 4-inch interval approximately 14 feet beneath the surface (Appendix B). Low water-table conditions prevented sampling of most of the

10-foot wells from early July to mid-November. To insure that representative samples of the ground water were collected, approximately three well volumes of water were purged from each monitoring well prior to sampling (Barcelona and others, 1985). Water was removed through tygon tubing by a peristaltic pump. Field duplicate samples were obtained from three randomly selected wells each time sampling was conducted.

Lysimeters

A suction of -24 inches mercury was placed on each lysimeter with a 42-liter displacement capacity vacuum pump to induce the flow of water into the sample collection chamber over periods ranging from 1 day to 20 days. Water samples were retrieved with a peristaltic pump and varied in volume from less than 10 ml to 500 ml, depending on the moisture condition of the soil and duration of the collection period. Approximately 100 ml of deionized water was passed through the pump between the sampling of successive lysimeters to prevent cross-contamination of the samples.

When the water table reached its highest level during the investigative period, lysimeters L5, L6, L6B, and L7 collected water from the top of the aquifer rather than from the unsaturated zone. Lysimeters L1, L2, L3, L4, and L5 did not yield samples for various lengths of time during summer and fall due to the dry condition of the shallow soil.

Measurement of Field Parameters

Temperature, pH, electrical conductivity (EC), and bicarbonate (HCO_3-) concentration of each sample were determined in the field due to the "time-sensitive" nature of these parameters (Appendix D). A hand-held digital thermometer, sensitive to 0.1 degrees Celsius, was employed to measure water temperature. Determinations of pH were made with a meter calibrated with pH 4 and pH 7 buffer solutions. Electrical conductivity was measured in micromhos/cm with a temperature compensating electrical conductivity meter. Bicarbonate analyses were performed by titrating an aliquot of each sample with 2N HCl to a pH 4.5 end-point; duplicate measurements were made for every third sample.

Laboratory Analyses

Water samples were transported to the laboratory immediately after field analyses were completed. Each sample was passed through a Gelman 0.2 micrometer membrane filter and refrigerated at 4 degrees C until further analytical tests were performed.

Chloride (Cl-), bromide (Br-), nitrate (NO_3-), and sulfate (SO_4=) concentrations were determined with a Dionex series 2000i/SP liquid ion chromatograph in accordance with EPA Standard Methods 300.0 (EPA, 1984; Appendix D). Field and laboratory duplicate samples, laboratory blank samples, and calibration standards were tested frequently to check

the reliability of the anion determinations. Regular analysis of a five anion standard prepared by personnel of the Dionex Corporation provided additional quality control. Samples collected on April 20 and April 27 were tested for cations by inductively coupled plasma atomic emission spectroscopy (ICP). Ninety-five percent of these lysimeter and well samples had ionic balances between +/- 10% (Appendix E).

CHAPTER IV

UNDERGROUND WATER

Aquifer Characterization

The investigated aquifer occurs in the alluvial deposits which extend to a depth of approximately 43 feet beneath the site. The underlying bedrock is shale. During the period of study, the water table fluctuated from about 3 to 13 feet below land surface. Hence, saturated thickness ranged from 30 to 40 feet. Recharge occurs as a result of the infiltration of precipitation, while lowering of the water table is largely controlled by evapotranspiration. The relation between precipitation and water levels in well A4 is illustrated in Figure 5.

Aquifer tests performed by Hoyle (1987) and Melby (1989) yielded average hydraulic conductivity values for the aquifer ranging from 39 to 96 gpd/ft^2. Considering the fine-grained nature of the deposits, these values seem unusually large, suggesting that preferential movement of ground water through macropores plays an important role in flow through the aquifer. A calculated storativity of 0.01, based on several aquifer tests, indicates that the system is unconfined.

Head differences between wells at individual clusters
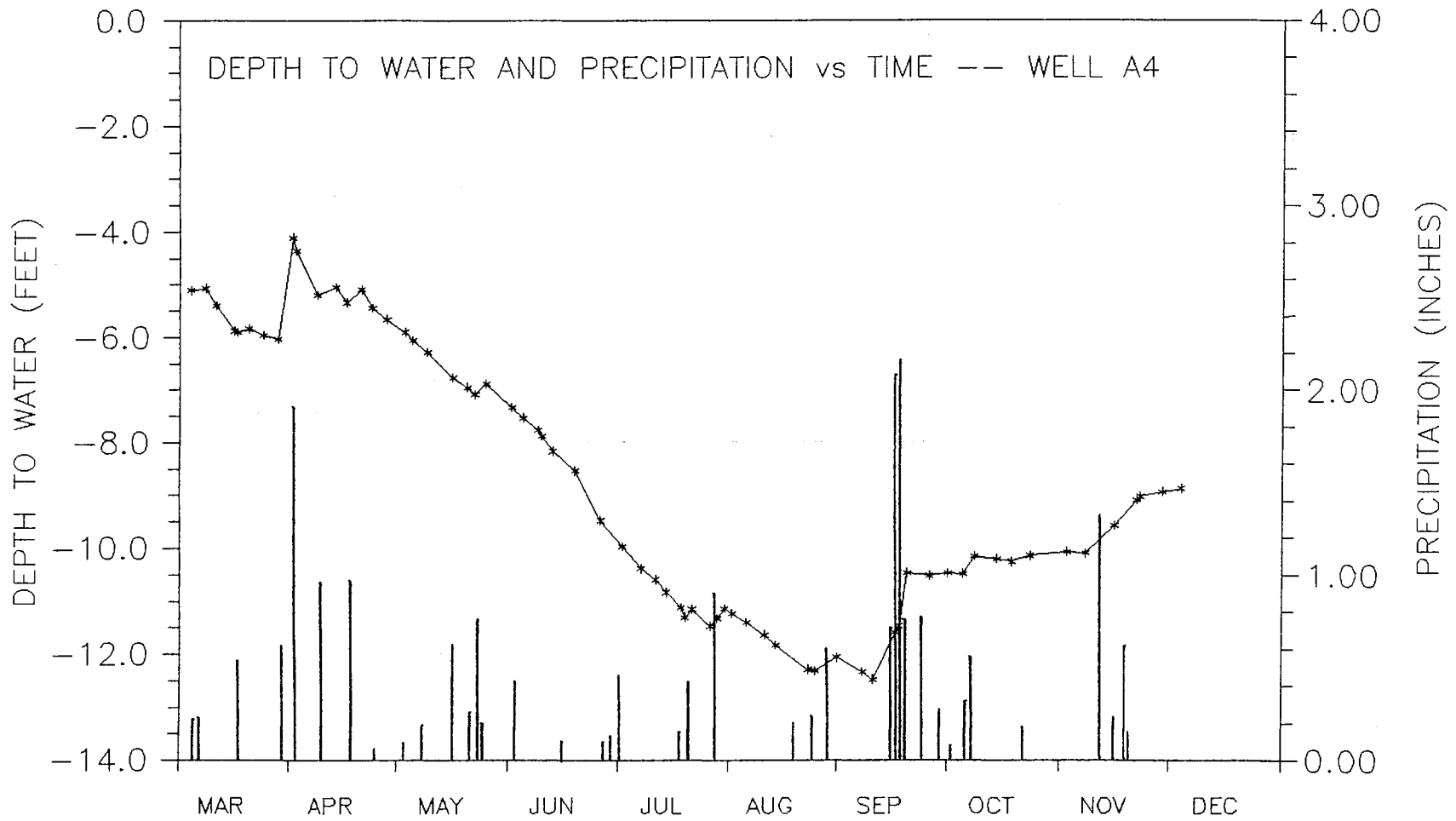
Figure 5. Depth to Ground Water in Well A4 and Precipitation vs Time, 1988.

usually range from 0 to 0.10 feet. However, the heads exhibit no consistent, specific trend with increasing well depth. It is believed that differences between water levels in adjacent wells are related to slight variations in hydraulic conductivity associated with the stratification of the aquifer material.

Direction of ground-water flow is variable and appears to be controlled by the relation between the water table and streamflow in an unnamed tributary of Boomer Creek (Nelson, 1989). The tributary flows from north to south and passes approximately 200 feet to the west before reaching its confluence with Boomer Creek 500 feet southwest of the research area (Figure 1). When high water-table conditions prevail at the site, the investigated aquifer and the unnamed tributary are hydrologically connected. Ground water flows away from the study area to the west-southwest and is discharged into the tributary. As the water table declines below the base of the stream bed, the tributary changes from a gaining stream to a losing stream and ground water beneath the site begins to flow toward the southeast.

The configuration of the water table at various times during the period of investigation is illustrated in Figures 6, 7, and 8. During the high water-table conditions of April, 1988, hydrologic connection between the aquifer and the tributary caused ground water beneath the site to flow west-southwestward under a horizontal hydraulic gradient of 0.009 ft/ft (Figure 6). By September the gradient had shifted to the southeast and decreased to

08 APRIL 1988
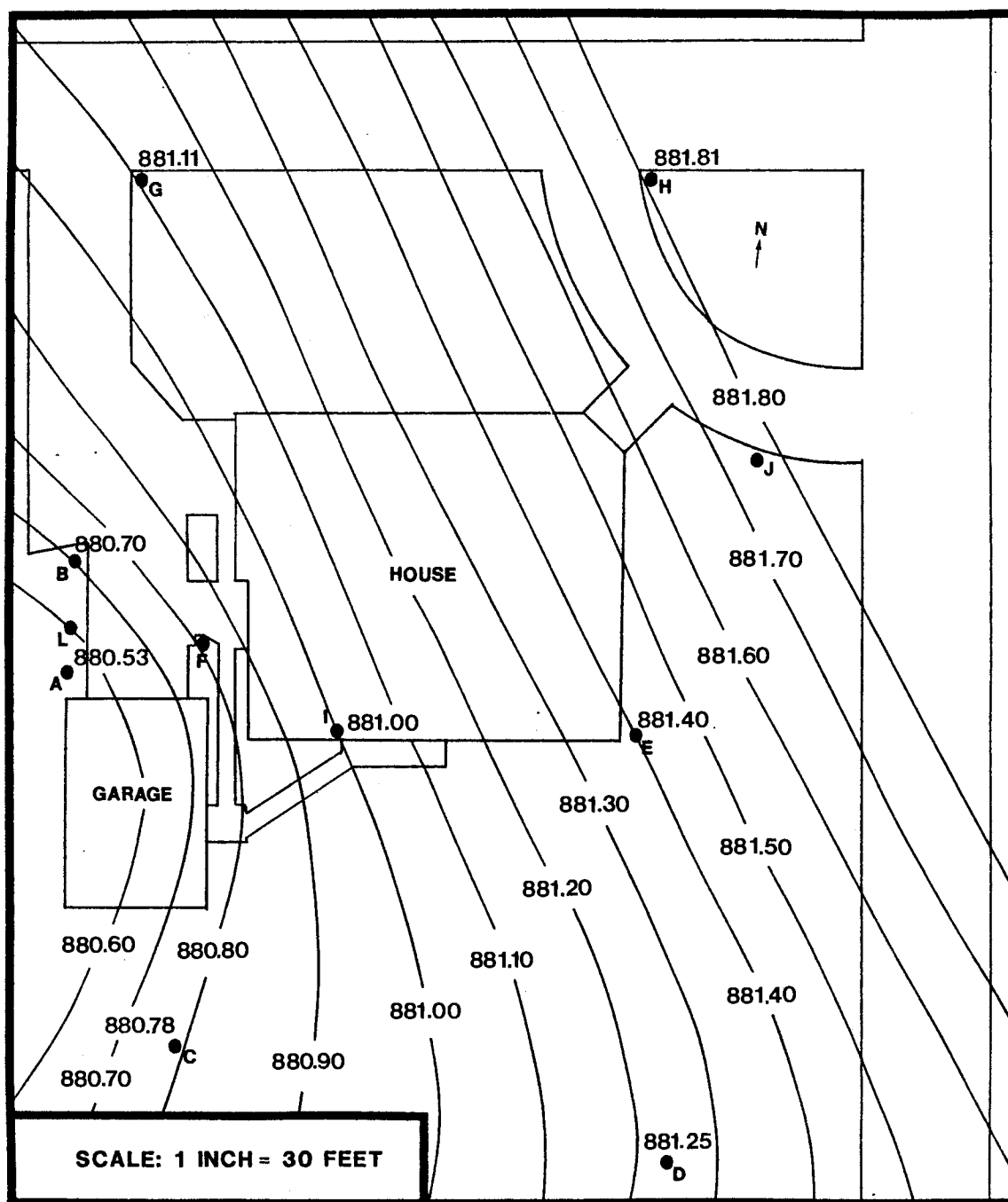
Figure 6. Configuration of the Water Table on April 8, 1988.

10 SEPTEMBER 1988
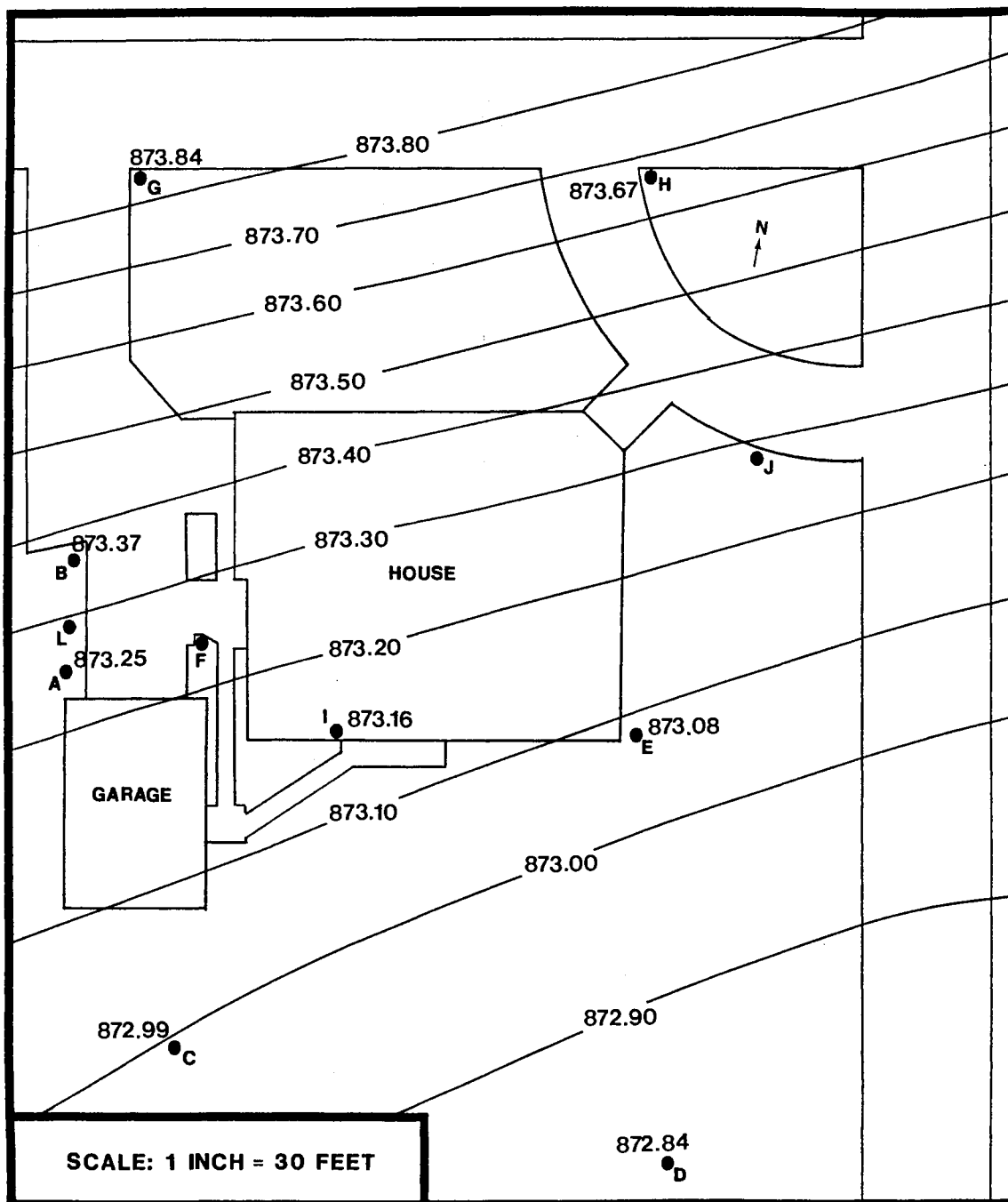
Figure 7. Configuration of the Water Table on September 10, 1988.

03 DECEMBER 1988

877.48 ●G

877.40

877.30

877.20

877.10

877.27 ●H

N
↑

877.00

876.90

876.80

HOUSE

876.97 ●B

●L

876.86 ●A

●F

GARAGE

876.70

I ● 876.74

876.69 ●E

●J

876.60

876.50

876.55 ●C

SCALE: 1 INCH = 30 FEET

876.42 ●D
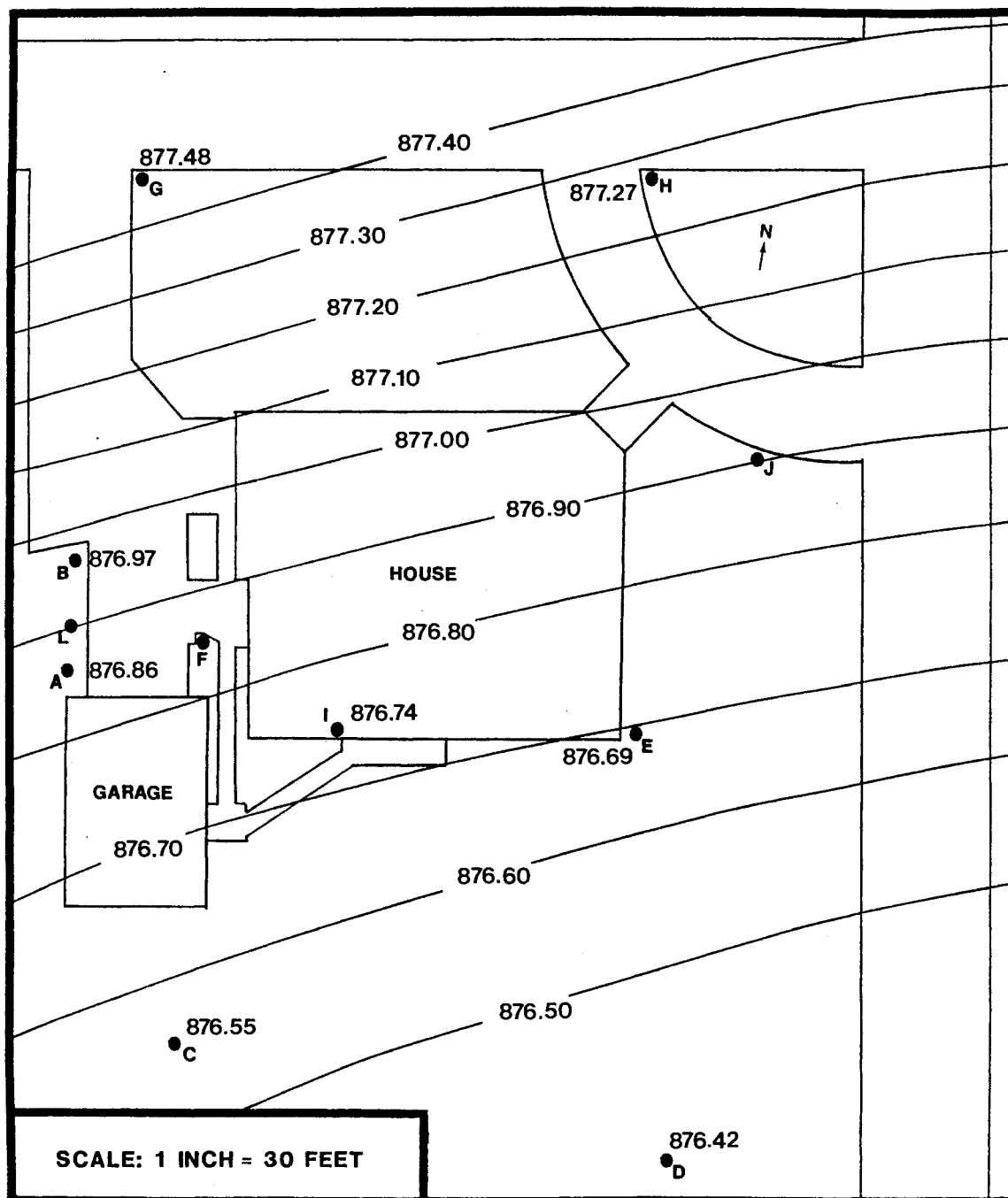
Figure 8. Configuration of the Water Table on December 3, 1988.

0.006 ft/ft as the water table reached its lowest recorded level (Figure 7). Water levels recovered only slightly during autumn; consequently, hydrologic connection between the aquifer and the tributary was not reestablished. In early December ground-water flow remained southeastward under a gradient of 0.006 ft/ft (Figure 8).

Average lateral ground-water velocity ranges from about 0.3 to 1.0 ft/day, depending on the hydraulic conductivity and gradient. Rates of movement were estimated with the following equation:

$$v = K * I / n * (7.48 \text{ gal/ft}^3)$$

where

v = average lateral ground-water velocity (ft/day)

K = hydraulic conductivity (gpd/ft^2)

I = horizontal hydraulic gradient (ft/ft)

n = effective porosity (percent)

A value of 12 percent was used for effective porosity. This estimate is based on typical effective specific yield values calculated for the unsaturated zone when recharge occurs under high antecedent soil-moisture conditions.

The G and H well clusters are situated immediately downgradient from the street that runs along the northern boundary of the site, and the I cluster is located in a room on the downgradient side of the house (Figures 6, 7, and 8). The street and house act as barriers, restricting the infiltration of precipitation. As a result, samples retrieved from the G, H, and I wells are less impacted by

water flushed from the unsaturated zone during recharge events than are samples retrieved from other monitoring wells around the site.

In light of the wide range of calculated ground-water velocities and variable nature of flow direction, it is not an easy matter to accurately predict the amount of time required for ground water to pass underneath the street and house. Assuming a constant north to south flow path, ground water moving through the aquifer at a rate of 0.3 ft/day would require about 73 days to pass underneath the northern street and approximately 183 days to migrate from below the north wall of the house to the I wells. With a velocity of 1.0 ft/day, times of travel under the street and the house would be reduced to 22 days and 55 days, respectively.

Water-Bearing Properties of the
Unsaturated Zone

Thickness of the unsaturated zone varies considerably through time and is tantamount to the existing depth to ground water. Moreover, the amount of water stored in the unsaturated zone is not constant. Soil-moisture levels measured from the neutron probe access tube adjacent to the A well cluster are fairly typical of those recorded at other locations within the study area. The relation between precipitation and fluctuations in soil-moisture content at four depths below the A site is shown in Figure 9. Moisture levels were relatively uniform with depth in the unsaturated zone during the high water-table conditions
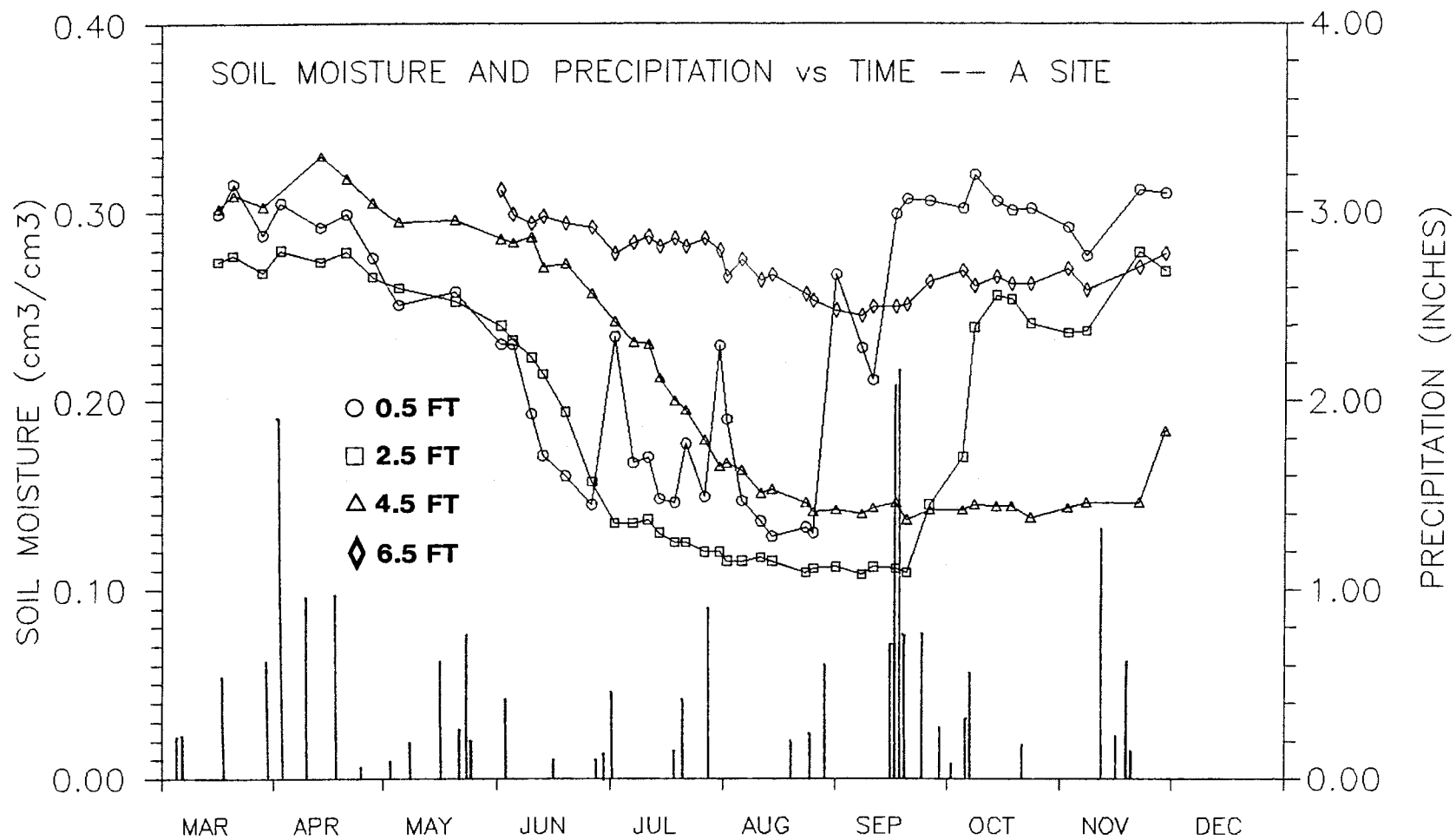
Figure 9. Soil-Moisture Content in Unsaturated Zone at Well Cluster A and Precipitation vs Time, 1988.

which existed early in the monitoring program. The 2.53
inches of rain which fell on the site between March 28 and
April 1 brought ground water to within 4.11 feet of land
surface in well A4. This precipitation event was also
responsible for raising soil-moisture contents in the
unsaturated zone to their highest observed levels during
the investigative period, although the difference between
pre- and post-storm moisture levels was quite small. The
relatively high antecedent moisture levels suggest that the
soil throughout most of the unsaturated zone was at field
capacity prior to the rainfall. Infiltrating rain water
triggered substantial downward drainage from the
unsaturated zone to the aquifer; thus, the overall moisture
condition of the unsaturated soil did not change
substantially.

By June 18, the water table had fallen to 8.53 feet
below land surface in well A4 and moisture levels in the
unsaturated zone began to exhibit greater vertical
variability. Sharp short-term fluctuations in soil-moisture
content at a depth of 0.5 feet beneath the surface from
late June through September can be attributed to wetting by
specific precipitation events and subsequent drying by
evapotranspiration. Moisture levels recorded at depths of
2.5 and 4.5 feet fell steadily during June, July, and
August, as soil at these depths was subject to drying by
evapotranspiration, but was less susceptible than shallower
soil to wetting by summer thundershowers. Since dry soil at
shallower depths "soaked up" most infiltrating rain water

and was quickly redried by evapotranspiration, relatively little infiltrate was able to reach soil at depths of 2.5 and 4.5 feet. Although both depths exhibit similar moisture trends, soil at 2.5 feet was consistently drier than soil at 4.5 feet through the summer months. This reflects greater evapotranspiration losses at 2.5 feet than at 4.5 feet.

Consistently high moisture levels recorded at 6.5 feet suggest that soil at this depth remained at or near saturation throughout the study period. The water level in well A4 reached a recorded low of 12.48 feet beneath the land surface on September 10. At this time, moisture content in the soil 6.5 feet below the A site was approximately 0.25 cm^3/cm^3. Moisture levels taken at deeper depths from the neutron probe access tube adjacent to the B wells were equally high, or higher. This implies that as the water table falls to a depth of over 12 feet below land surface, a zone of nearly saturated soil or the capillary fringe extends some 6 feet above the water table. This "wet" zone separates the relatively dry shallow soil from the aquifer.

Increased rainfall in late summer and autumn brought about significant increases in soil moisture throughout the unsaturated zone. Marked increases in moisture content were first recorded in the shallowest soil, but substantial wetting at greater depths soon followed. The 5.71 inches of rain which fell at the site between September 15 and September 18 resulted in a soil-moisture content increase

of 0.1 cm^3/cm^3 at a depth of 0.5 feet, while moisture levels at 2.5 feet, 4.5 feet, and 6.5 feet were relatively unaffected. Having reached field capacity, the shallow soil began draining at the onset of subsequent precipitation. This drainage created the increase in soil-moisture content observed at 2.5 feet in late September and early October. Moisture levels at 4.5 feet began recovering with rain which fell in mid-November.

<div align="center">

Water-Level and Soil-Moisture Response

to Precipitation

</div>

The two most significant ground-water recharge events documented during the investigative period occurred under considerably different antecedent moisture conditions. Recharge during the "wet" portion of the study occurred when the water table was elevated and soil-moisture content throughout the unsaturated zone was high. During the "dry" portion of the investigation, the water table was comparatively low and soil in the upper part of the unsaturated zone was well below field capacity.

"Wet" Season Recharge

High soil-moisture content and elevated water table at the site during late March, 1988 reflected the influence of recharge to the aquifer by precipitation during late winter and early spring, when the impacts of evapotranspiration on the system were minimal. On March 27, water levels measured in wells around the site ranged from 4.91 to 6.17 feet

below land surface, and soil-moisture content was at or above 0.26 cm^3/cm^3 throughout the unsaturated zone at the A well cluster.

The research area received 0.62 inches of rainfall during the night of March 28 and morning of March 29. This storm was followed by a 1.91-inch rain which fell fairly steadily over a 33-hour period on March 31 and April 1. The average water-level rise in response to the 2.53-inch rain total was 20.3 inches. Therefore, the effective specific yield for this event was 0.125.

During the recharge event, soil-moisture content increased from 0.29 to 0.31 cm^3/cm^3 at a depth of 0.5 feet below the A site. The zone from 1 to 2 feet below the surface remained virtually unaffected by the precipitation, but soil-moisture content increased from 0.27 to 0.28 cm^3/cm^3 at 2.5 feet, from 0.28 to 0.29 cm^3/cm^3 at 3.0 feet, from 0.29 to 0.31 cm^3/cm^3 at 3.5 feet, and from 0.30 to 0.35 cm^3/cm^3 at 4.0 feet. This increase in moisture content in the lower portion of the unsaturated zone reflects upward movement of the capillary fringe associated with the water-table rise.

"Dry" Season Recharge

Only 3.82 inches of rain fell on the site from June 1 through the middle of September. Coupled with the effects of evapotranspiration, this lack of precipitation caused the water table to decline to its lowest recorded level and also brought about significant decreases in soil-moisture

content throughout the upper 6 feet of the unsaturated zone. During this same interval, moisture content in the lower portion of the unsaturated zone remained relatively high. On September 10, measured depths to ground water around the site ranged from 11.33 to 12.97 feet below land surface.

The site received 0.71 inches of rain during the early morning hours of September 15. An additional 2.08 inches of rain fell on September 16. These storms were followed by rains of 0.02 inches on September 17 and 2.90 inches on September 18. The average water-level rise in response to this 5.71-inch precipitation total was 24.1 inches. Thus, the effective specific yield for this ground-water recharge event was 0.237.

Moisture levels increased markedly in the upper 2 feet of the unsaturated zone in response to the mid-September precipitation event. For example, soil-moisture content changed from 0.21 to 0.31 cm^3/cm^3 at a depth of 0.5 feet beneath the A site, and from 0.14 to 0.20 cm^3/cm^3 at a depth of 2.0 feet. Depths between 2.0 and 6.5 feet did not show significant increases in soil-moisture content.

Recharge occurred despite the soil-moisture deficiency through much of the unsaturated zone. This implies that some infiltration water migrates downward via macropores. Undoubtedly, such short circuiting also occurs when the unsaturated zone is at or above field capacity. Moreover, evidence presented later in this report suggests that macropores will allow water to percolate deeper beneath the

surface when the soil is initially very moist.

Discussion

Effective specific yield calculated for the "dry" recharge event was roughly twice as large as the value calculated for the "wet" event. That is, the 2.53 inches of rain which fell at the site during elevated water-table, high soil-moisture conditions produced about the same rise in water levels as did the 5.71-inch rain when the water table was relatively low and the upper portion of the unsaturated zone was well below field capacity. Previous investigators at the research site documented similar water-table responses to precipitation under comparable initial conditions (Hagen, 1986; Hoyle, 1987; Ross, 1988).

Figure 10 shows a generalized diagram of water-table and soil-moisture response to rainfall under "wet" and "dry" antecedent conditions. In this figure, relative moisture levels in the unsaturated zone are identified by different degrees of shading; unshaded areas denote relatively dry soil, while darker areas correspond to higher moisture levels. It appears as though there is always a zone of moist soil separating the land surface from the aquifer. When elevated water-table, high soil-moisture conditions prevail at the site, this zone may extend from land surface to the water table. Rain is immediately available to soil that is already at field capacity; thus, moisture levels in the unsaturated zone increase but slightly, and comparatively large water-table
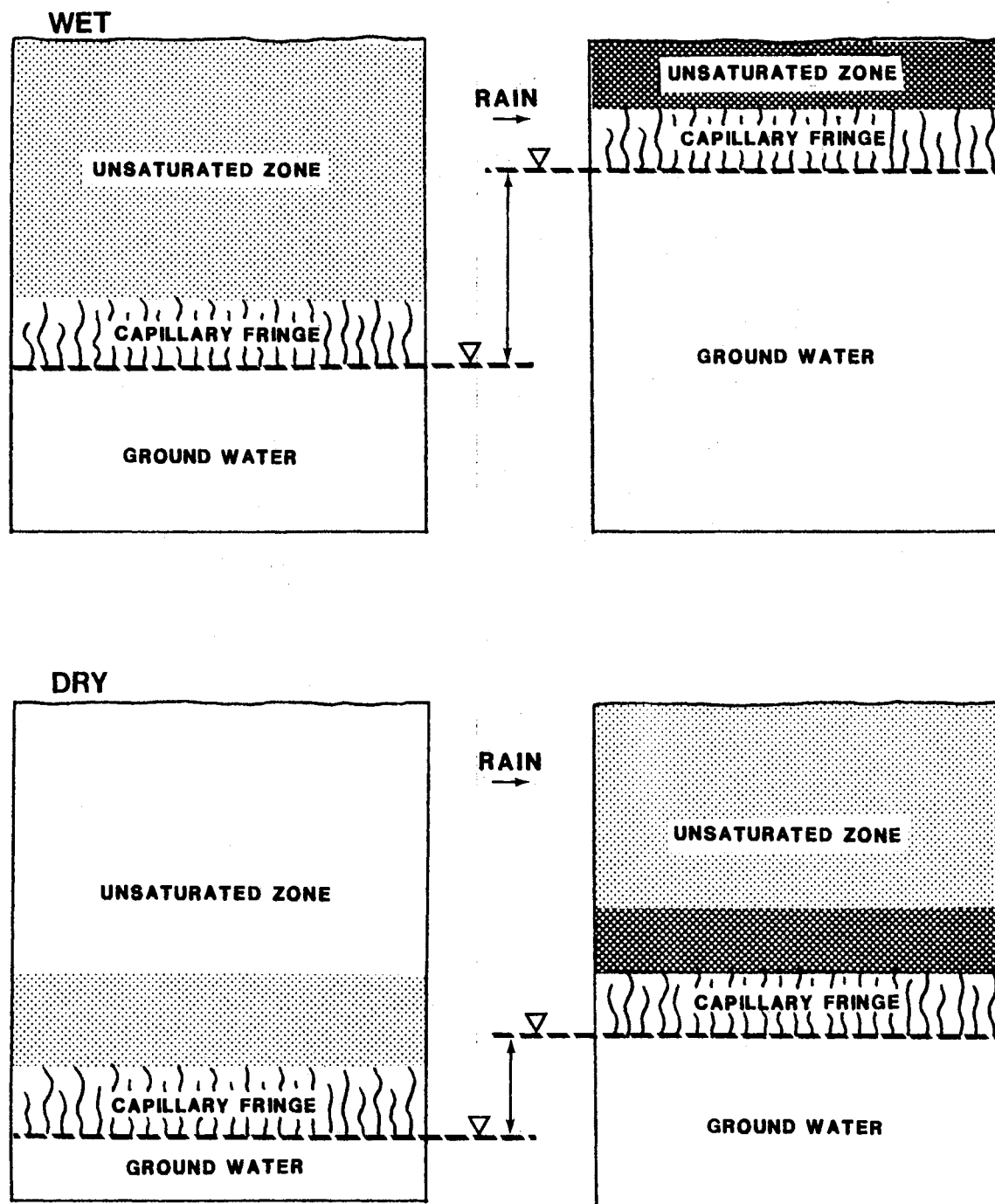
Figure 10. Schematic Presentation of Water-Level and Soil-
Moisture Response to Precipitaion under "Wet"
and "Dry" Antecedent Conditions.

rises occur. When water levels decline to more than 12 feet below land surface, the upper 6 feet of the unsaturated zone exhibits a substantial soil-moisture deficiency, while the lower portion remains moist. Soil in the moisture deficient upper portion of the unsaturated zone absorbs most infiltrating precipitation; therefore, water-table rise in response to rainfall is comparatively small.

CHAPTER V

WATER QUALITY

Precipitation and Surface Ponding

Gaseous and particulate constituents of the atmosphere produced from both natural and man-made sources provide the chemical component of rain water (Gambell and Fisher, 1964). If the infiltration capacity of a soil is exceeded during a storm, ponding may occur. This allows rain water to acquire additional dissolved solids at the soil surface. Chemical composition of rain water and ponded water samples collected at the field site during a summer thundershower are shown in Table I.

TABLE I

CHEMICAL COMPOSITION OF RAIN WATER
AND PONDED WATER

Sample	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	NO3 MG/L	SO4 MG/L
Rain Water	28.6	5.14	27	ND	1.8	4.8	2.5
Ponded Water	26.1	5.92	83	45.8	2.3	13.6	5.6

ND = No data

It should be noted that both of these samples were probably influenced by dry fallout. The dilute character of the precipitation and ponded water suggests that any change in water quality incurred during sample handling could be quite significant; hence, the reported values should not be considered absolute.

Variations of Selected Parameters

As infiltration water migrates downward through the unsaturated zone to the water table and is subsequently flushed through the aquifer, it undergoes considerable change in composition. Fluctuations in water quality can be viewed in two respects: short-term and long-term. For the purposes of this report, short-term variations are defined as those occurring between two successive sampling events, over periods ranging from less than 24 hours to several days. Long-term fluctuations take place over the course of several weeks or months.

Electrical Conductivity

Electrical conductivity in the lysimeters and sampled wells varied from 233 to 1683 umhos/cm during the investigative period (Figure 11a-h). There appears to be no specific trend in electrical conductivity with depth in the lysimeters. Increases in electrical conductivity occurred in all measured samples from the lysimeters in response to the application of tracer solution to the lysimeter plot on May 12, but increases during a similar tracer experiment in
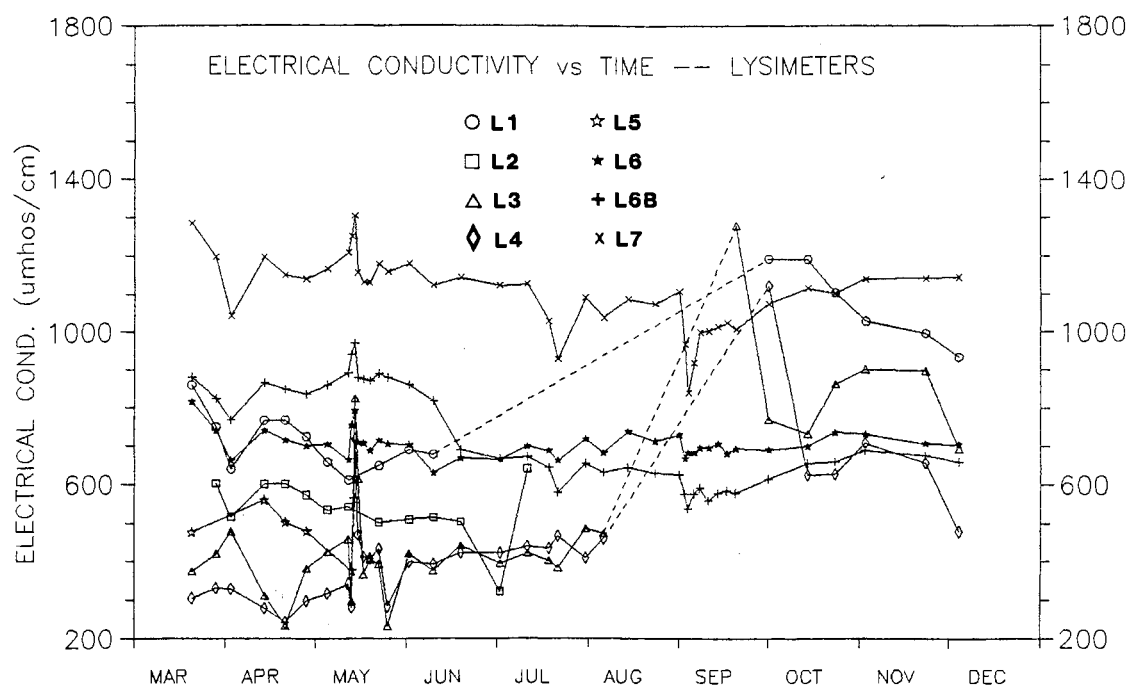
Figure 11a. Electrical Conductivity vs Time, Lysimeters - 1988.
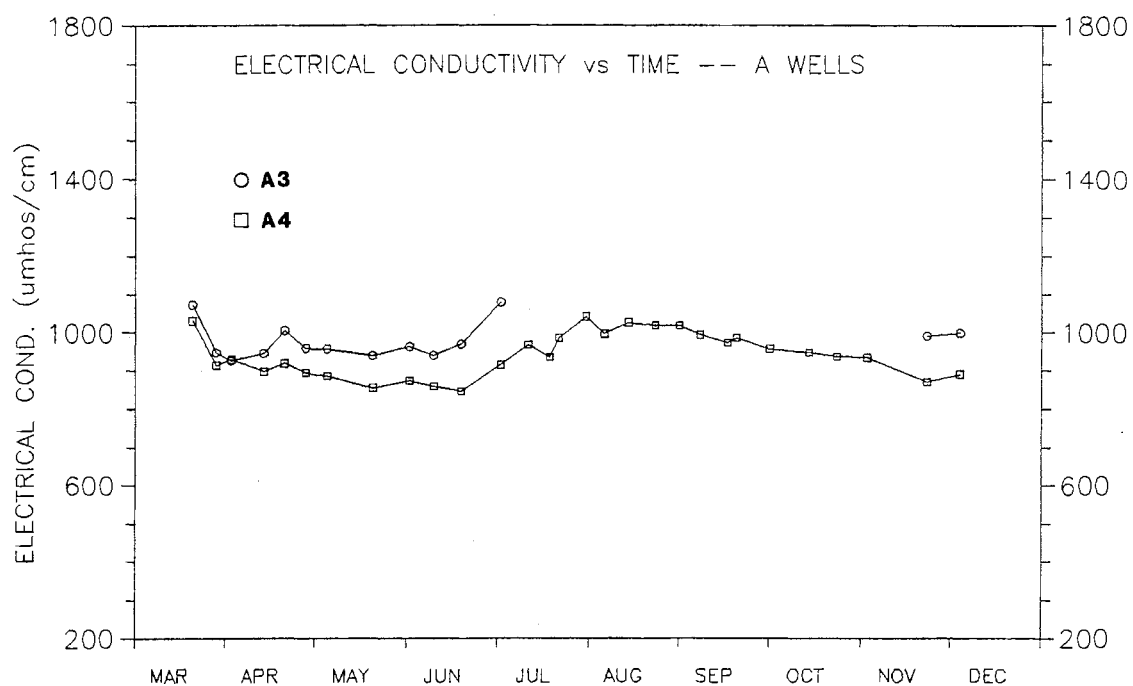
Figure 11b. Electrical Conductivity vs Time, A Wells - 1988.
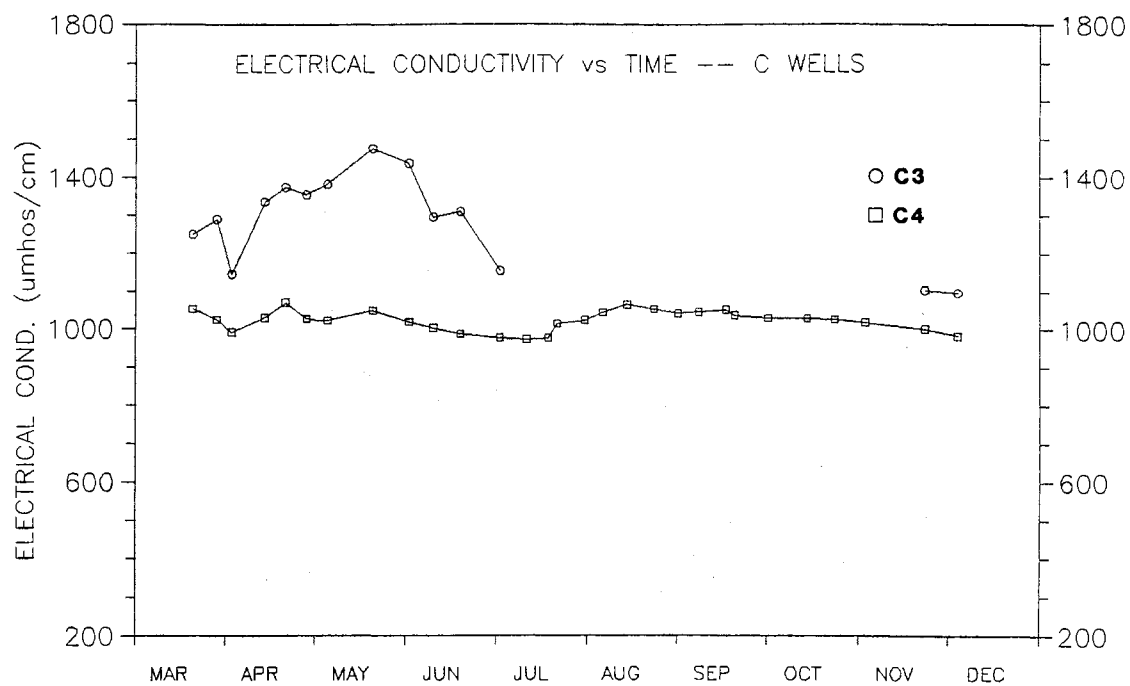
Figure 11c. Electrical Conductivity vs Time, C Wells – 1988.
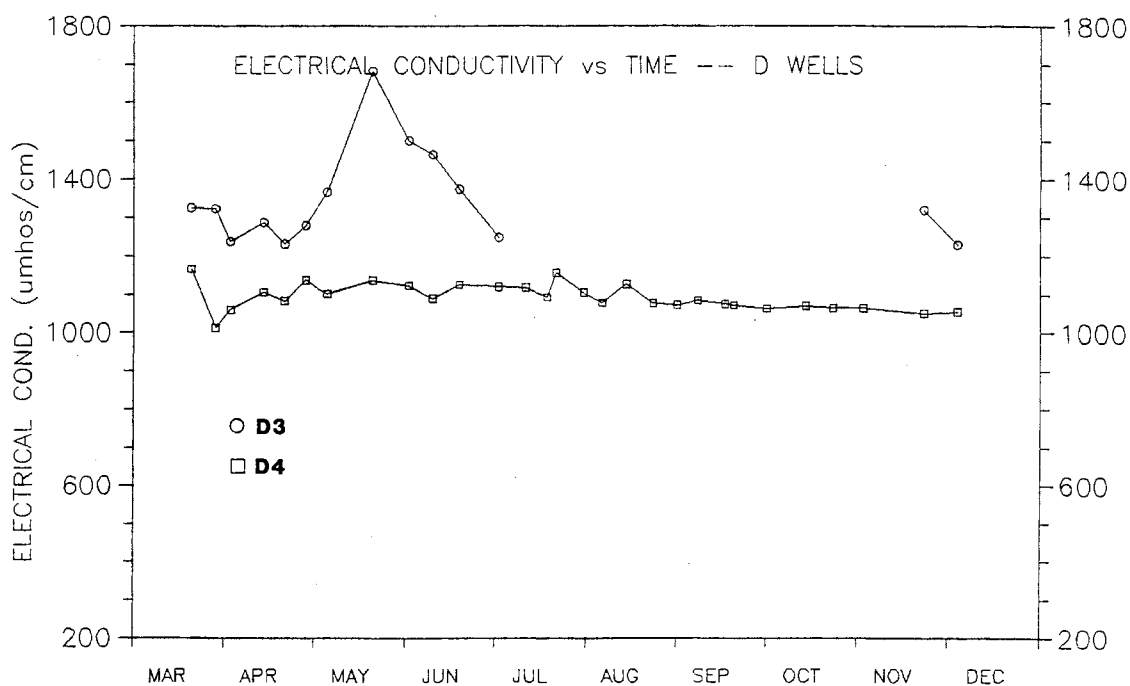
Figure 11d. Electrical Conductivity vs Time, D Wells – 1988.
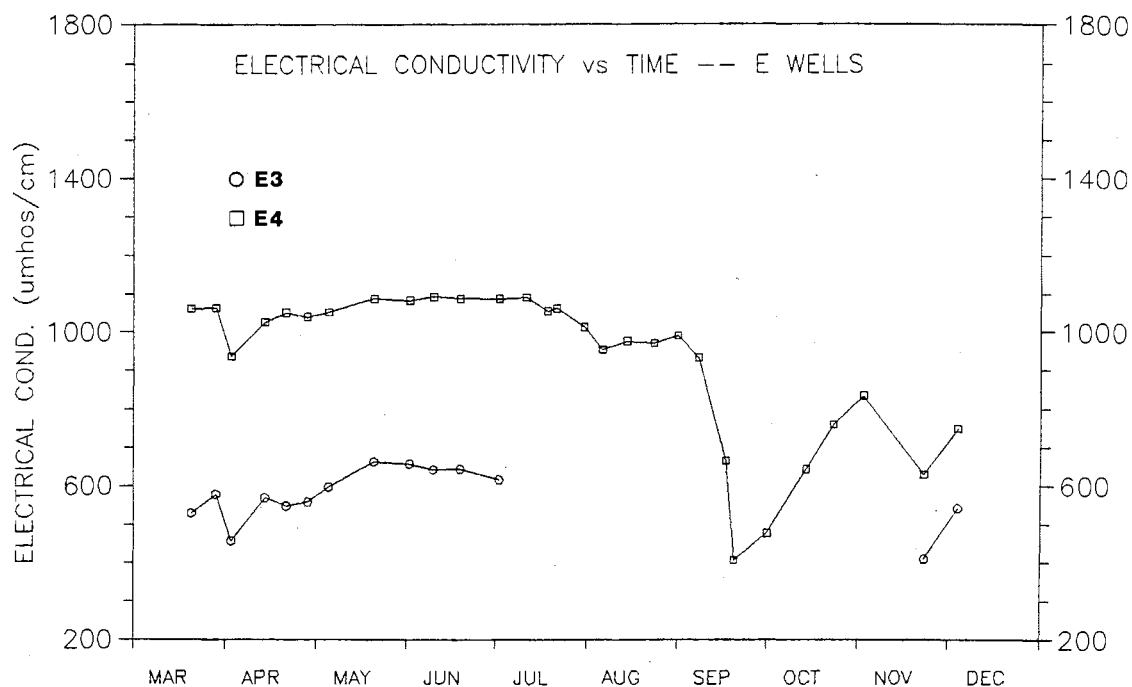
Figure 11e. Electrical Conductivity vs Time, E Wells - 1988.
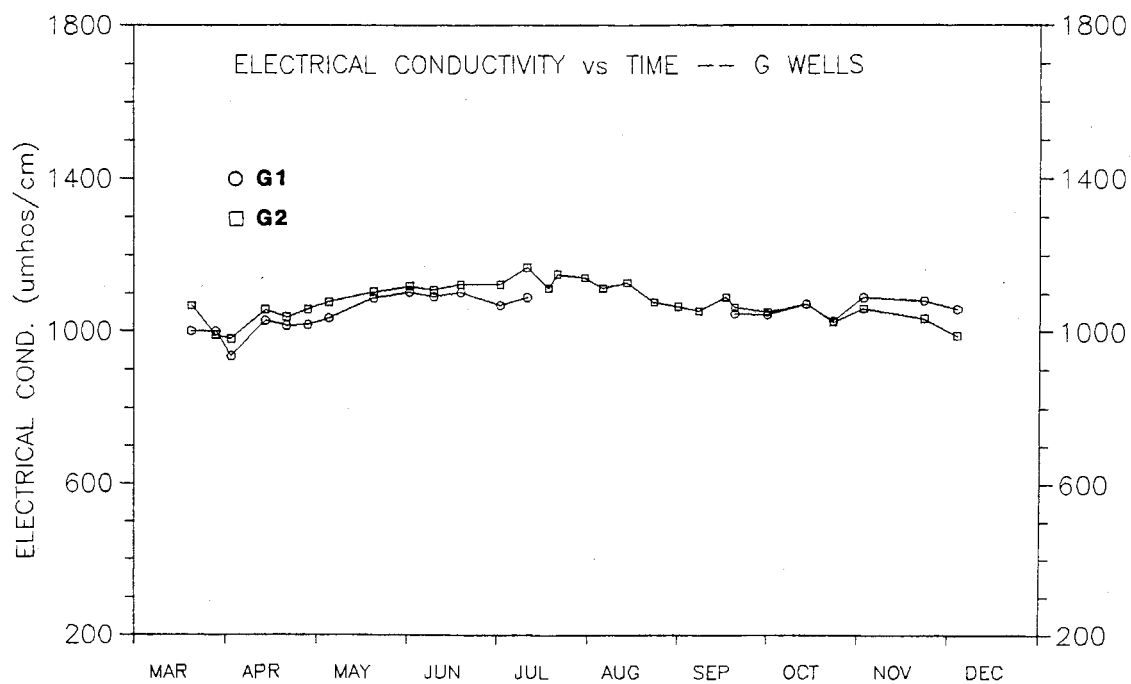
Figure 11f. Electrical Conductivity vs Time, G Wells - 1988.
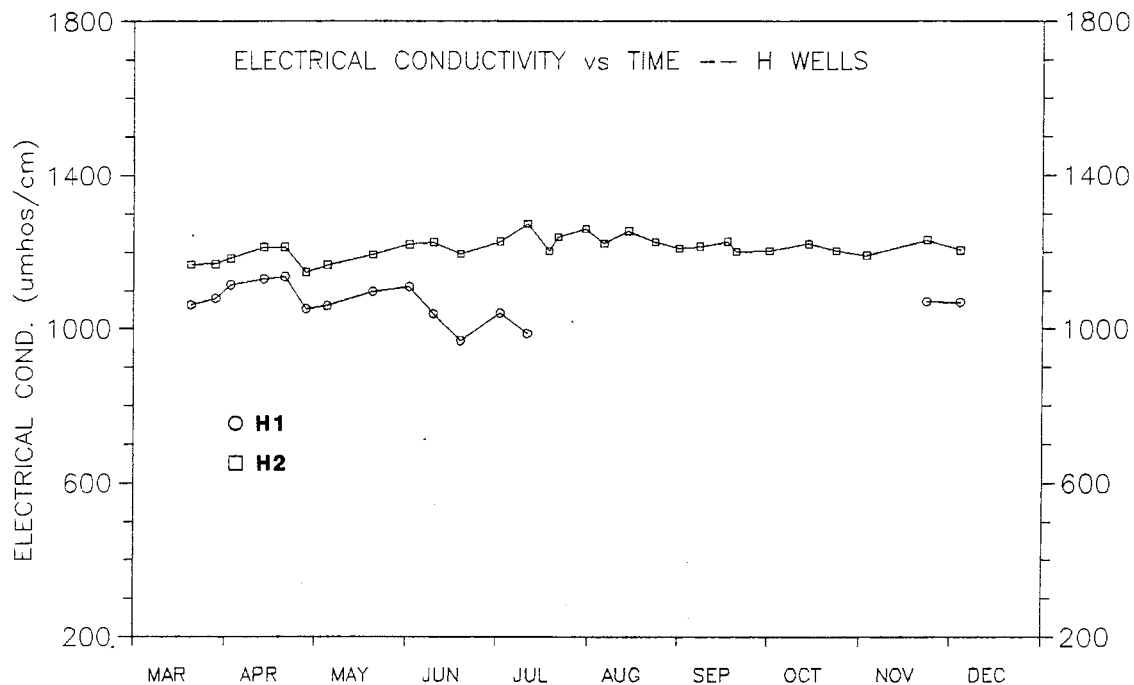
Figure 11g. Electrical Conductivity vs Time, H Wells - 1988.
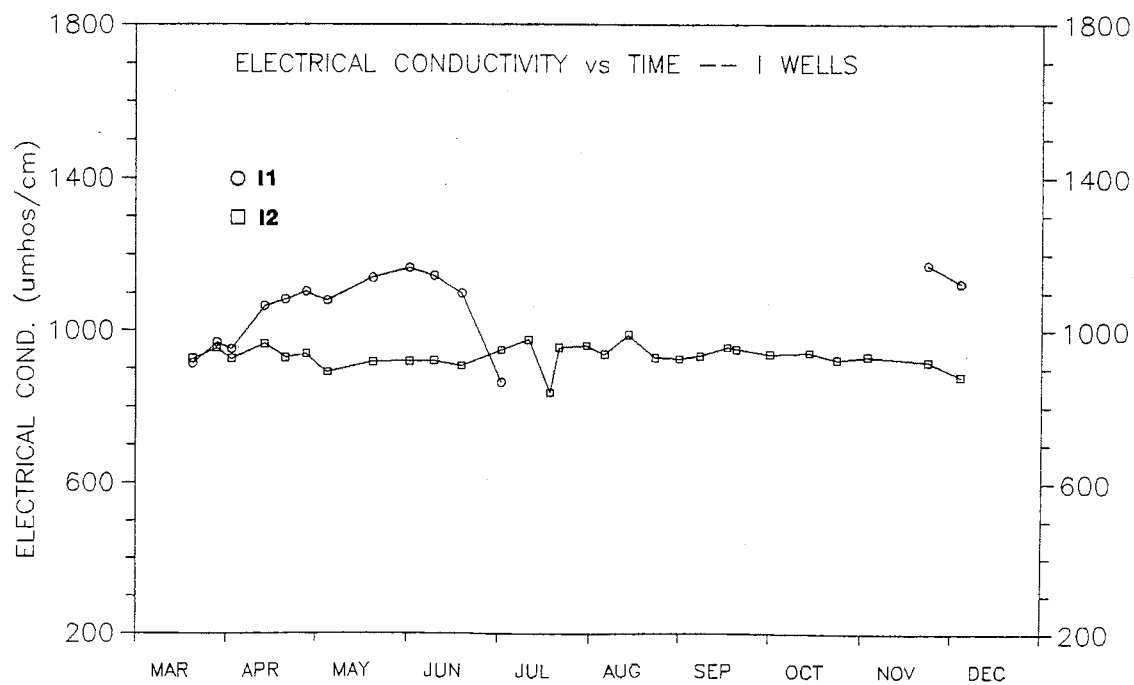
Figure 11h. Electrical Conductivity vs Time, I Wells - 1988.

September were limited to lysimeters L1, L3, and L4. As discussed in a later chapter, tracer solution applied at the surface on September 1 was retained in the relatively dry upper portion of the unsaturated zone.

Electrical conductivity showed vertical stratification at all well sites, and generally, variations at the two sampled wells within a cluster paralleled one another. Values decreased with depth in the ground water at the A, C, D, and I clusters and increased with depth at the E, G, and H clusters. Electrical conductivity remained relatively constant in most monitoring wells throughout the study period; the notable exceptions being wells C3, D3, and E4.

Sharp peaks in electrical conductivity of samples from well D3 and to a lesser extent well C3 between late April and early June reflect increases in chloride concentration. These increases were brought about by the water table declining to a level just below the leaky sewer line which transects the site along its southern boundary, some 5 feet below the surface.

Electrical conductivity in well E4 fell from 933 to 407 umhos/cm between September 7 and September 19. Rainfall at the site totalled 5.71 inches during this period, but the effect of the rain on ground-water quality at the E site was magnified by the presence of a drainspout adjacent to these wells. A considerable volume of water draining from the roof of the house was discharged through the drainspout, effectively increasing the amount of rain this small area received. A decrease in electrical conductivity

of samples from well E4 in response to this precipitation event reflected dilution of ground water with respect to all measured anions. Recovery of electrical conductivity values to near pre-rainfall levels appears to be related to underflow, which transported ground water uninfluenced by such a tremendous volume of rain water into the vicinity of the E wells.

The computer software package MICROSTAT was employed to determine the mean, standard deviation, maximum and minimum values for electrical conductivity and other parameters from samples collected from the monitoring wells throughout the study period (Appendix F). Electrical conductivity values were normally distributed at the 95% confidence level for all regularly sampled wells except C4 and E4.

Bicarbonate

The presence of bicarbonate in water samples extracted from the lysimeters and monitoring wells is controlled by carbon dioxide in the atmosphere and atmospheric gases of the unsaturated zone. As rain water migrates through the unsaturated zone, it becomes enriched in carbon dioxide derived from respiration by plant roots and microbial degradation of organic material, resulting in the formation of carbonic acid. Bicarbonate is produced during the course of dissolution of calcite by carbonic acid (Hem, 1985).

Bicarbonate typically comprises nearly half of the total dissolved solids content in water samples collected

at the field site; thus, temporal variations in bicarbonate imitate trends demonstrated by electrical conductivity at individual lysimeters and monitoring wells (Figure 12a-h). Bicarbonate concentrations recorded during the study period ranged from a minimum of 43 mg/l to a maximum of 913 mg/l.

Concentrations varied considerably with depth in the lysimeters, generally declining in value from L1 to L4 and increasing in value from L5 to L7. Vertical stratification was evident at individual well clusters. Bicarbonate levels generally decreased with depth at the A, C, D, and I well clusters and increased with depth at the E, G, and H sites. Concentrations remained relatively constant in samples collected from most wells throughout the investigative period. The sharp decline in bicarbonate concentration noted in samples collected from well E3 between September 7 and September 19 occurred in response to dilution by infiltration water discharged from the adjacent house drainspout during the 5.71-inch mid-September precipitation event. Bicarbonate concentrations were normally distributed at the 95% confidence level in all monitoring wells except C3, E4, and H1 (Appendix F).

<u>Chloride</u>

Chloride in vadose water and ground water at the research site is derived primarily from natural sources such as ancient evaporites in the soil, and rainfall. Measured concentrations in samples from monitoring wells and lysimeters during the investigative period ranged from
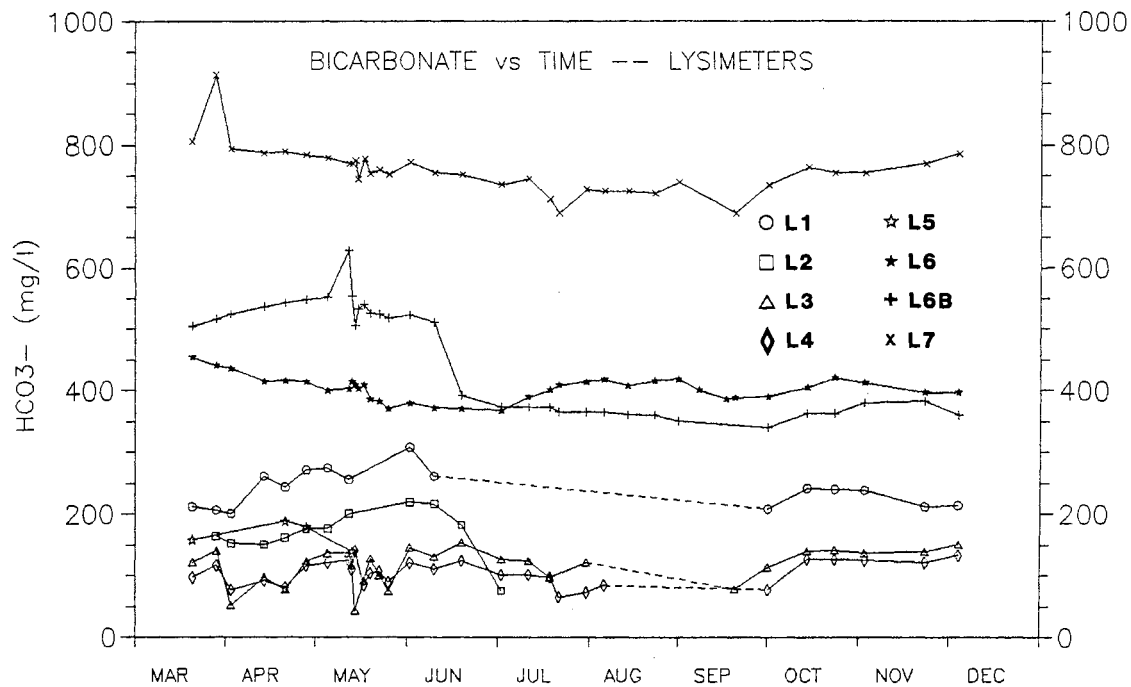
Figure 12a. Bicarbonate Concentrations vs Time,
Lysimeters - 1988.
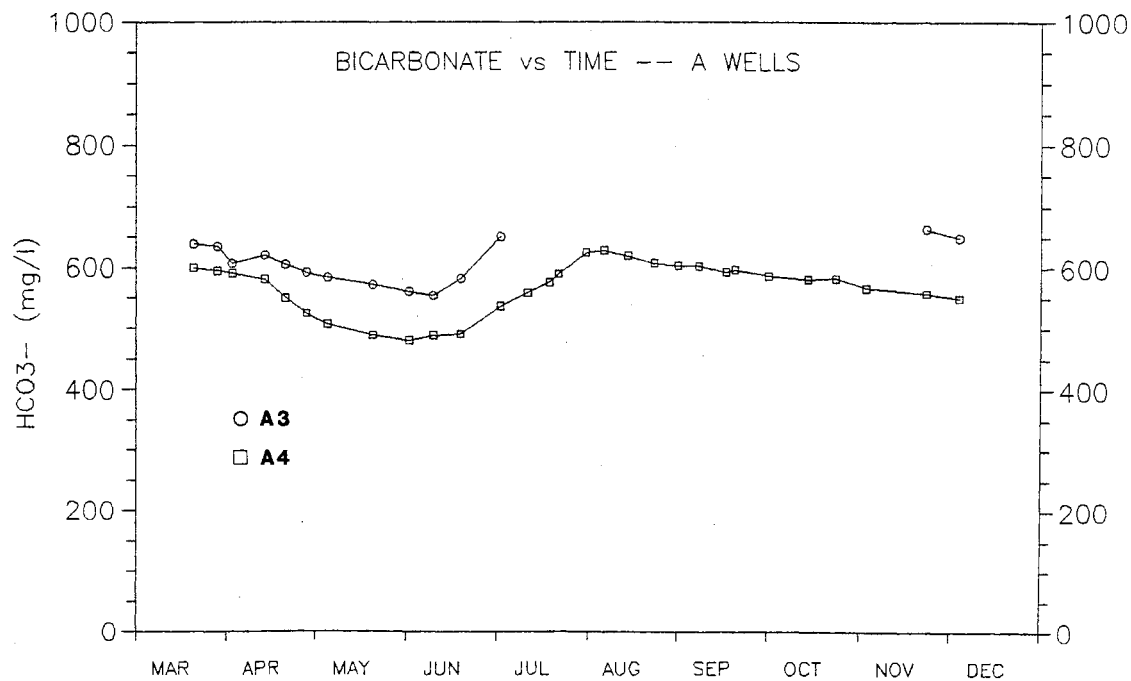
Figure 12b. Bicarbonate Concentrations vs Time, A Wells -
1988.
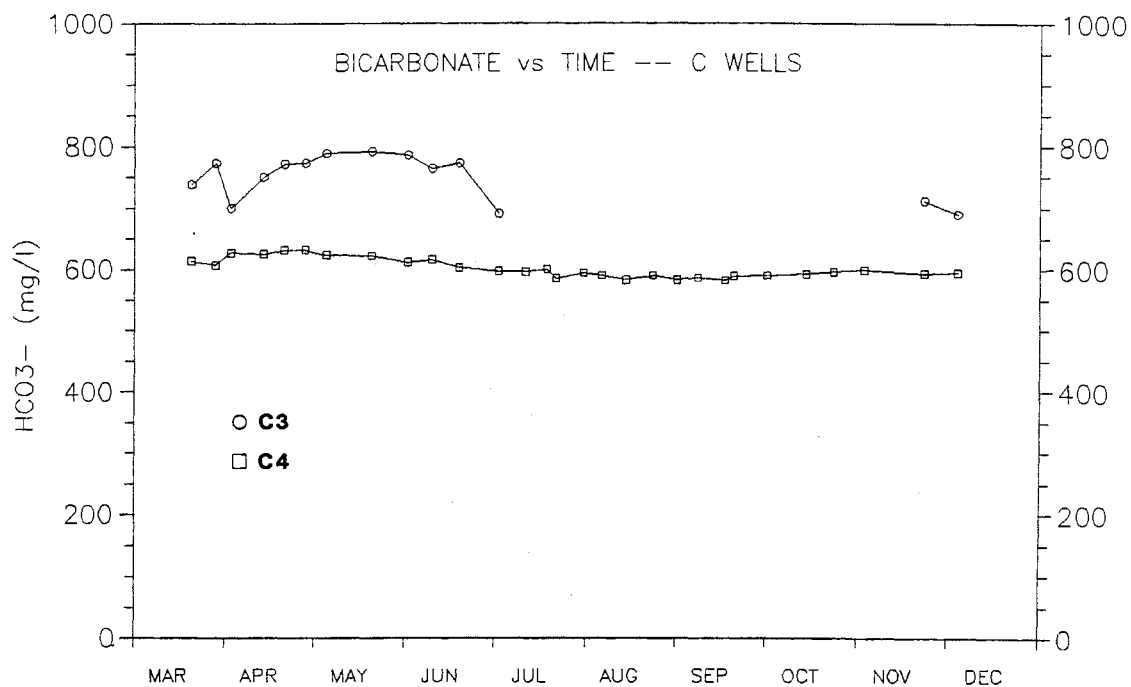
Figure 12c. Bicarbonate Concentrations vs Time, C Wells - 1988.
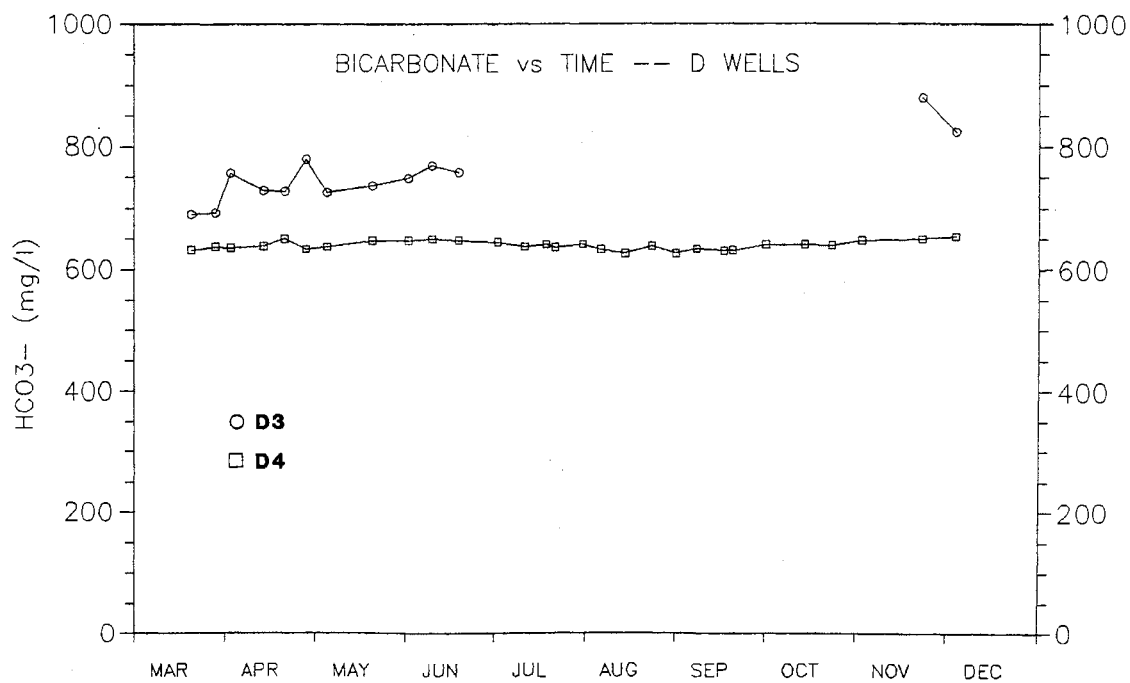
Figure 12d. Bicarbonate Concentrations vs Time, D Wells - 1988
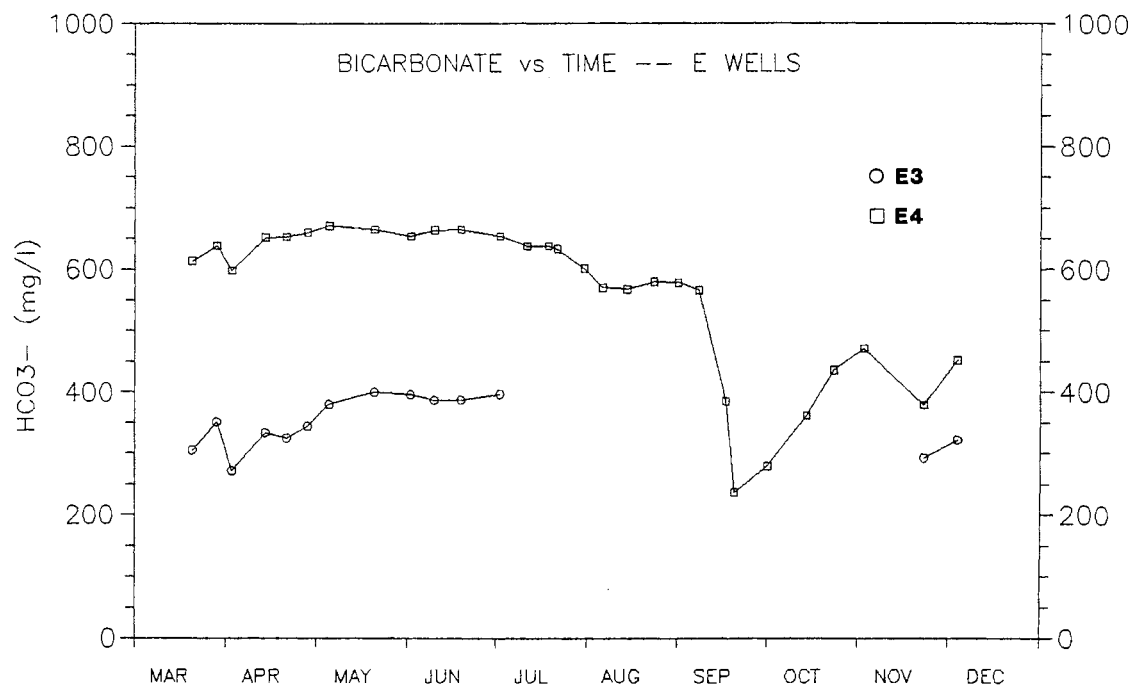
Figure 12e. Bicarbonate Concentrations vs Time, E Wells - 1988.
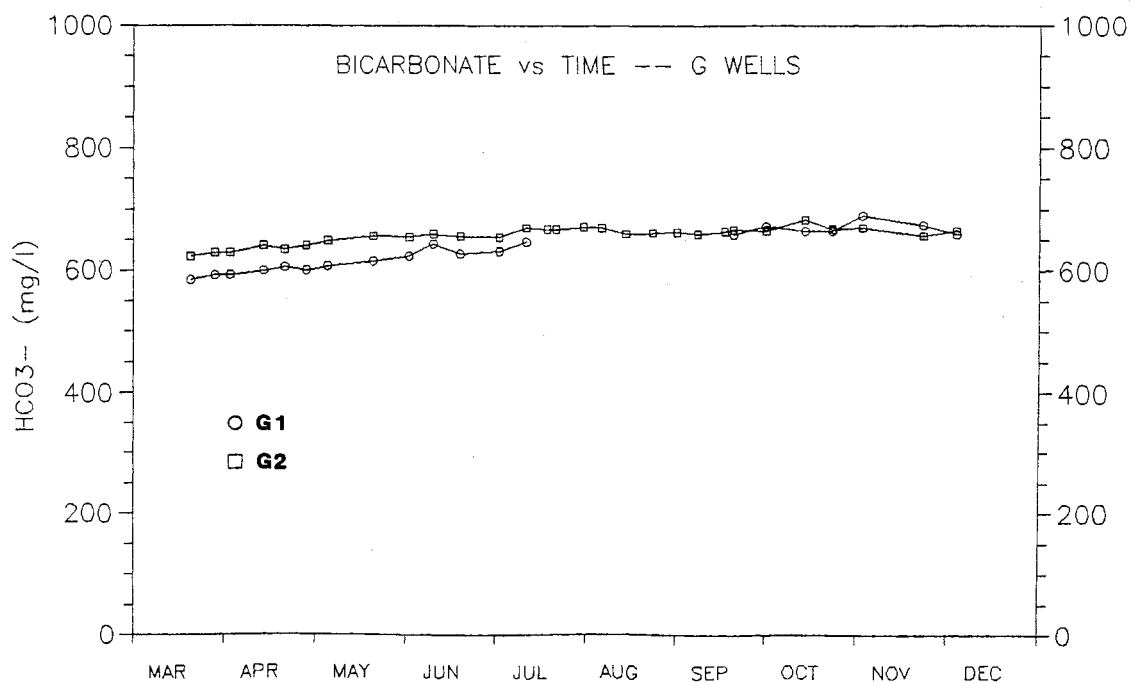
Figure 12f. Bicarbonate Concentrations vs Time, G Wells - 1988.
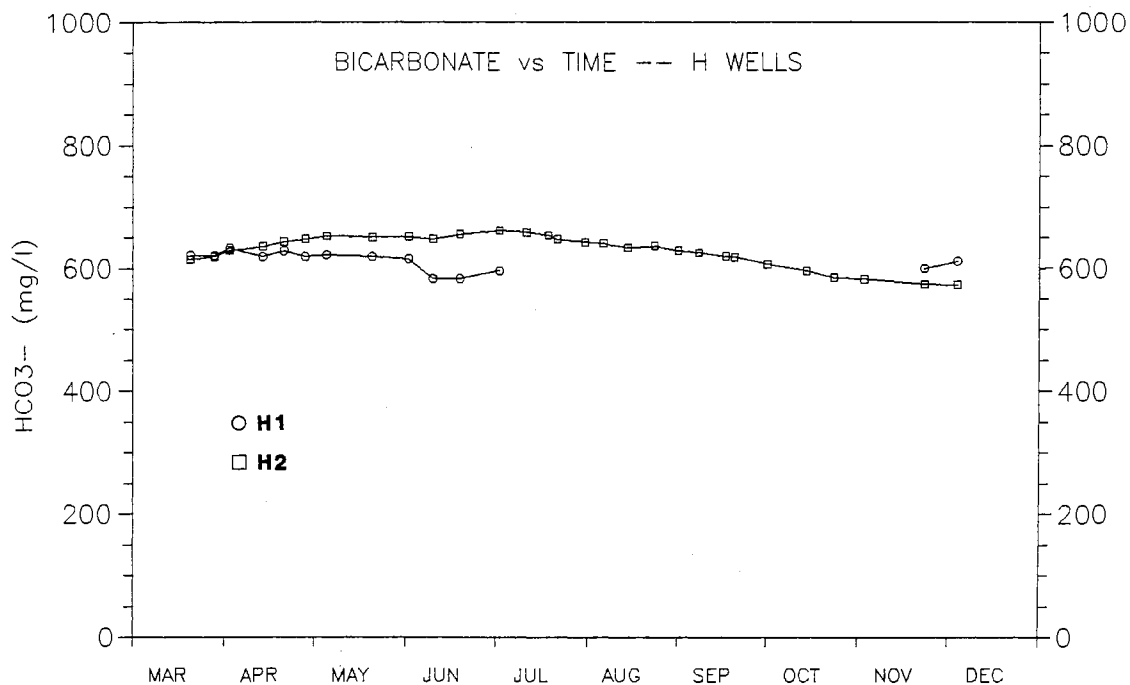
Figure 12g. Bicarbonate Concentrations vs Time, H Wells - 1988.
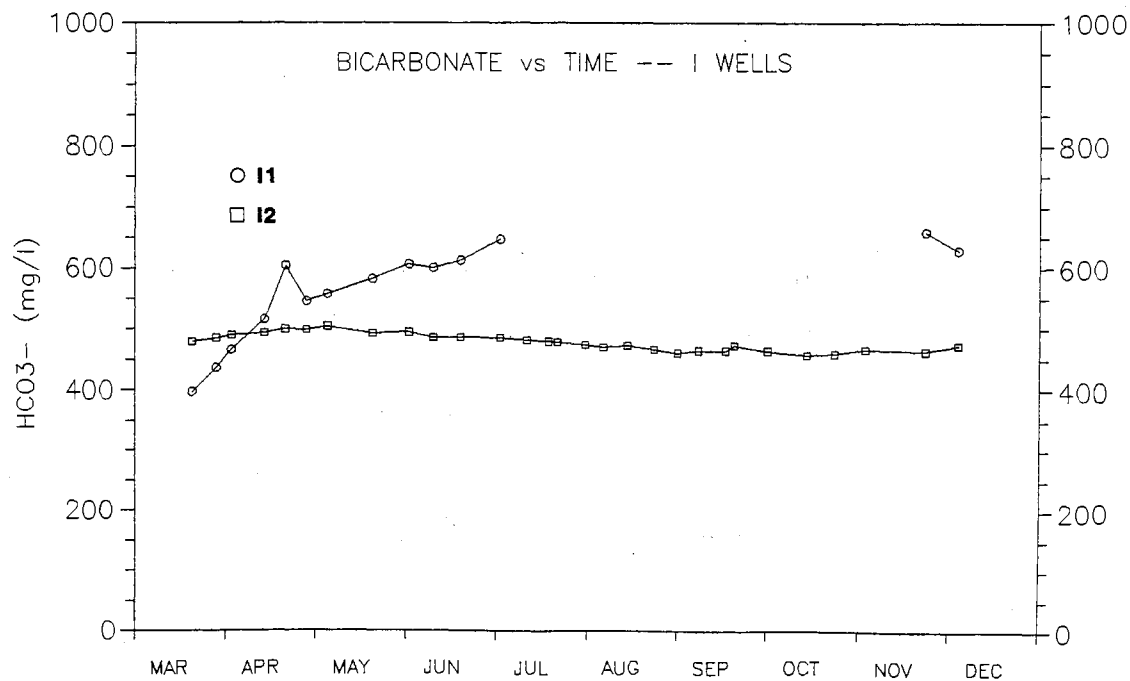
Figure 12h. Bicarbonate Concentrations vs Time, I Wells - 1988.

a minimum of 4.1 mg/l to a maximum of 337.9 mg/l (Figure 13a-h). The maximum chloride level was recorded in lysimeter L3 shortly after a concentrated chloride solution was applied at the surface of the lysimeter plot to begin a tracer experiment on September 1. Until the time of application of the tracer solution, concentrations at individual lysimeters were extremely stable through time. Lysimeters L6, L6B, and L7 were unaffected by the tracer application, as the chloride solution was not able to penetrate to these depths. The chloride concentration spike observed in lysimeter L2 between sampling events of July 1 and July 10 may owe to the surface-spillage of several gallons of ground water bailed from a borehole which was contaminated with raw sewage. The effect of the spill was also noticeable in lysimeters L3 and L4, although increases in chloride concentrations at these depths in the unsaturated zone were less pronounced than increases at the shallower level of lysimeter L2. Chloride concentrations measured in lysimeter samples during the study period exhibited no particular trend with increasing depth.

With a few exceptions, chloride levels in individual monitoring wells remained relatively consistent throughout the investigative period. Chloride showed little vertical variability in the A and G wells, but strong stratification at other regularly sampled well clusters. Concentrations decreased with depth at the C, D, and I clusters, and increased with depth at the E and H sites.

Wells C3, D3, and D4 exhibited considerably large
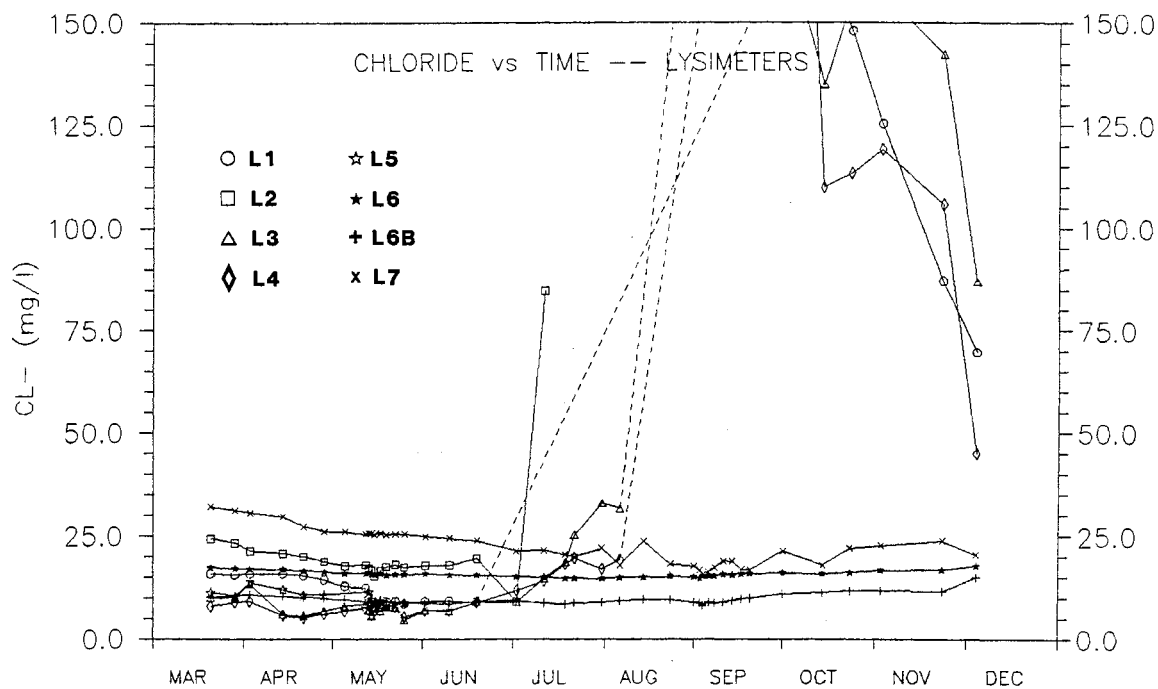
Figure 13a. Chloride Concentrations vs Time, Lysimeters - 1988.
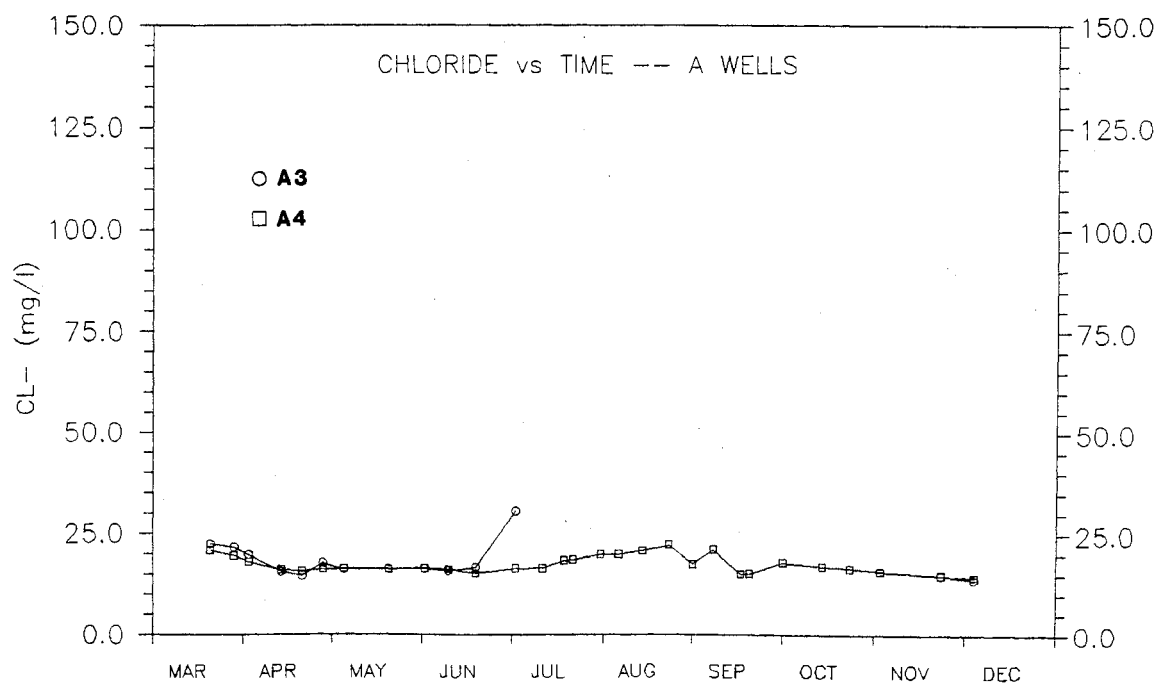
Figure 13b. Chloride Concentrations vs Time, A Wells - 1988.
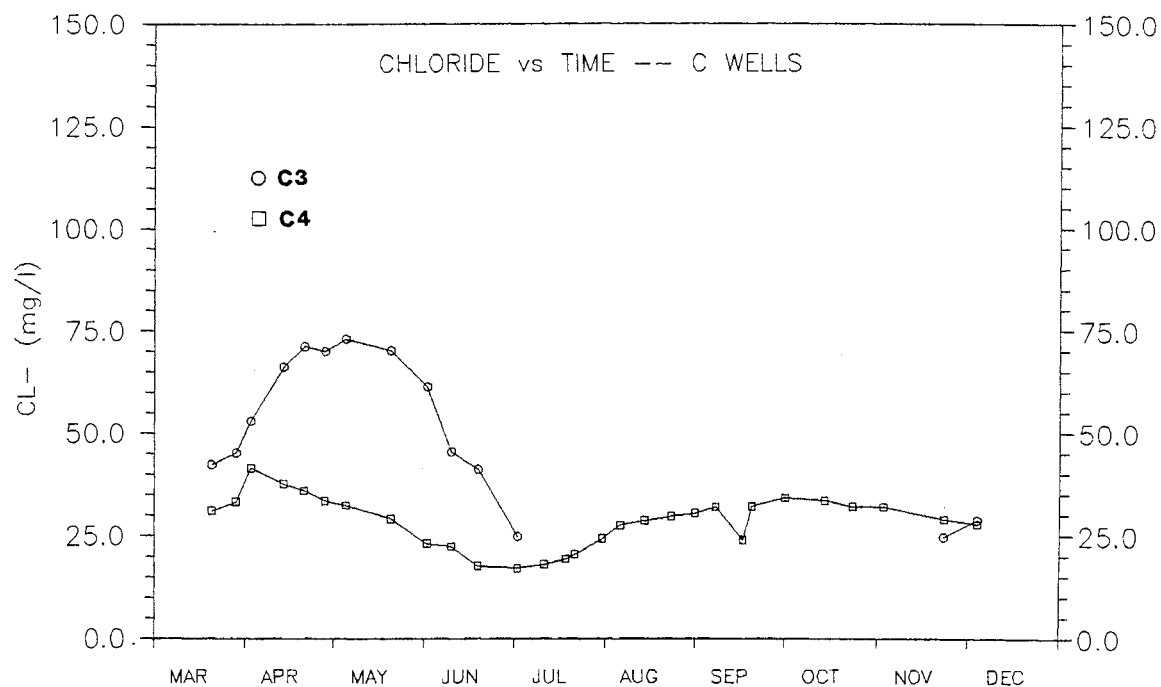
Figure 13c. Chloride Concentrations vs Time, C Wells -
1988.
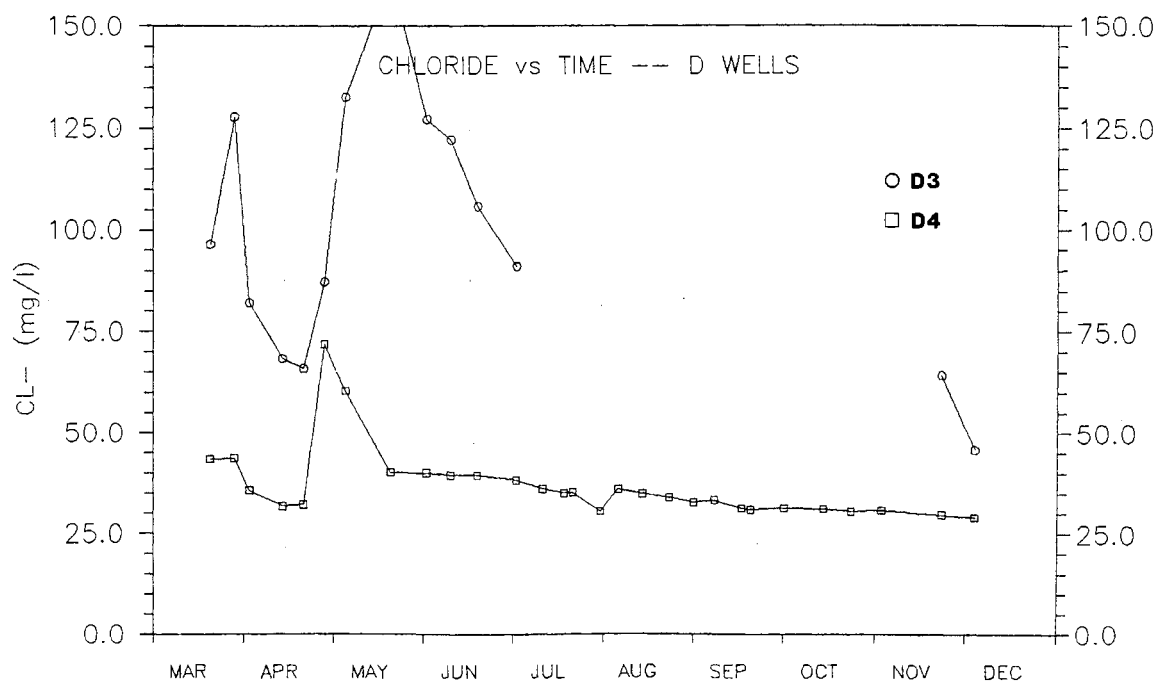
Figure 13d. Chloride Concentrations vs Time, D Wells -
1988.
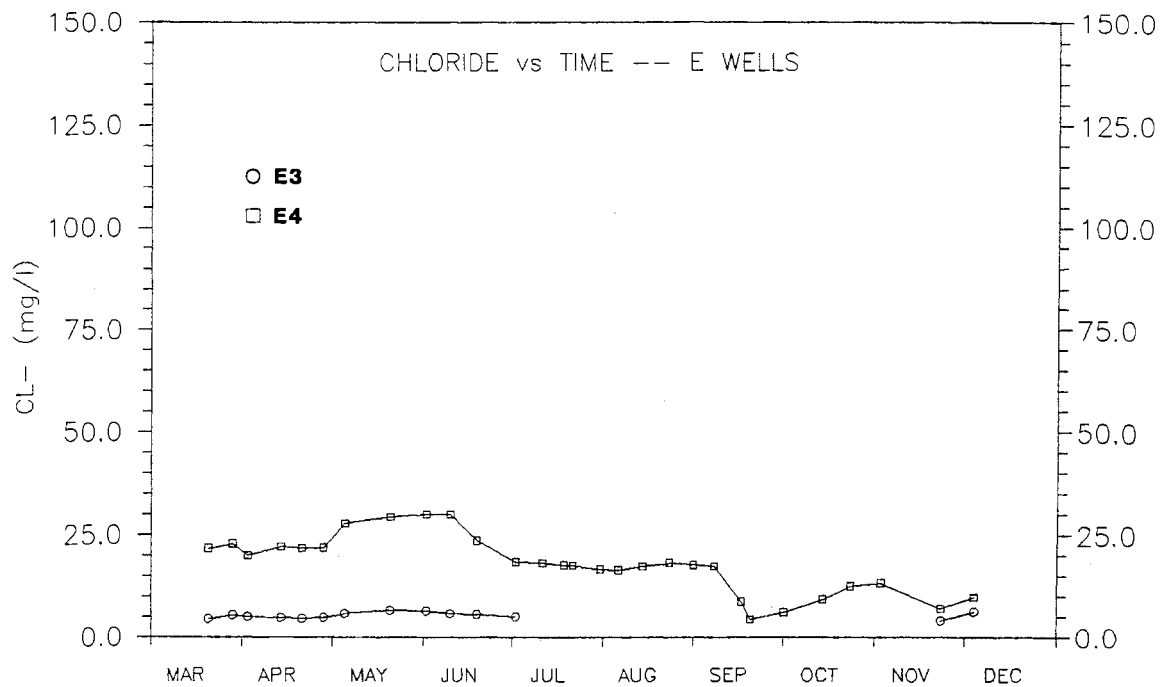
Figure 13e. Chloride Concentrations vs Time, E Wells – 1988.
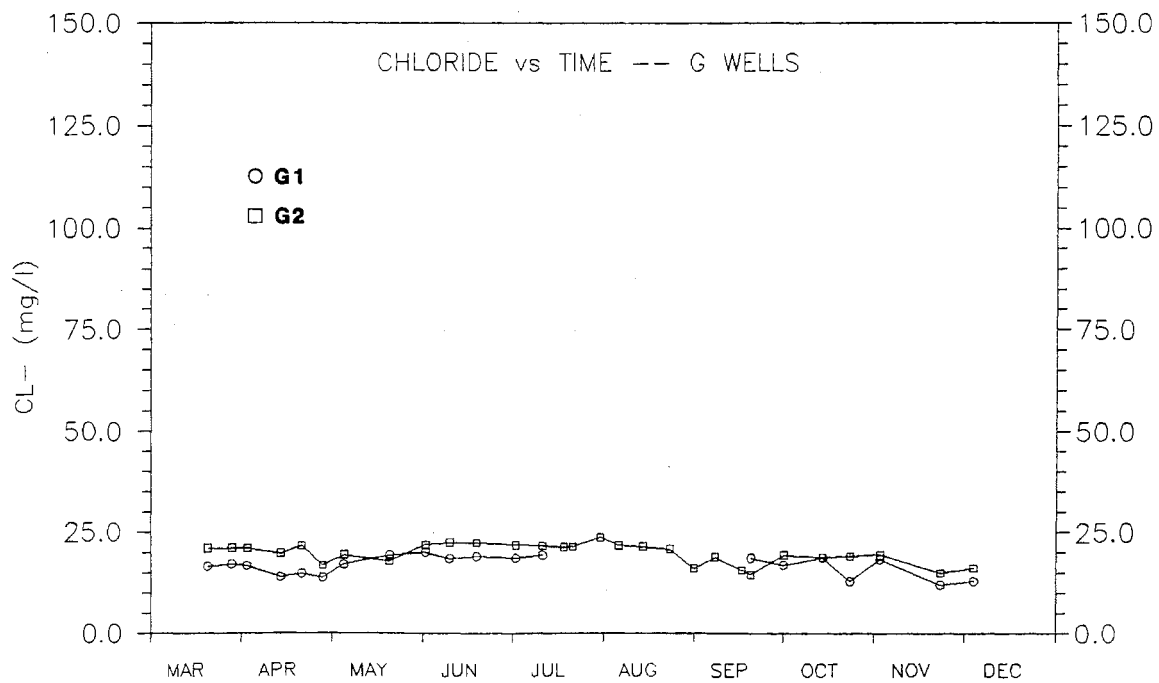
Figure 13f. Chloride Concentrations vs Time, G Wells – 1988.
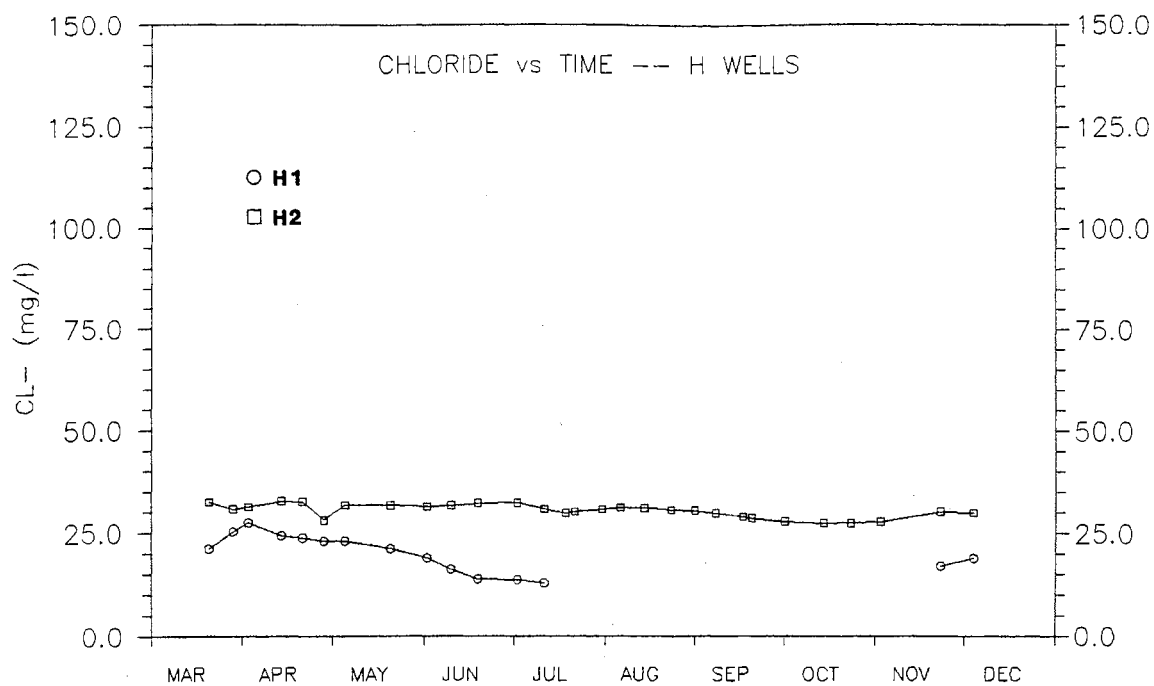
Figure 13g. Chloride Concentrations vs Time, H Wells -
1988.
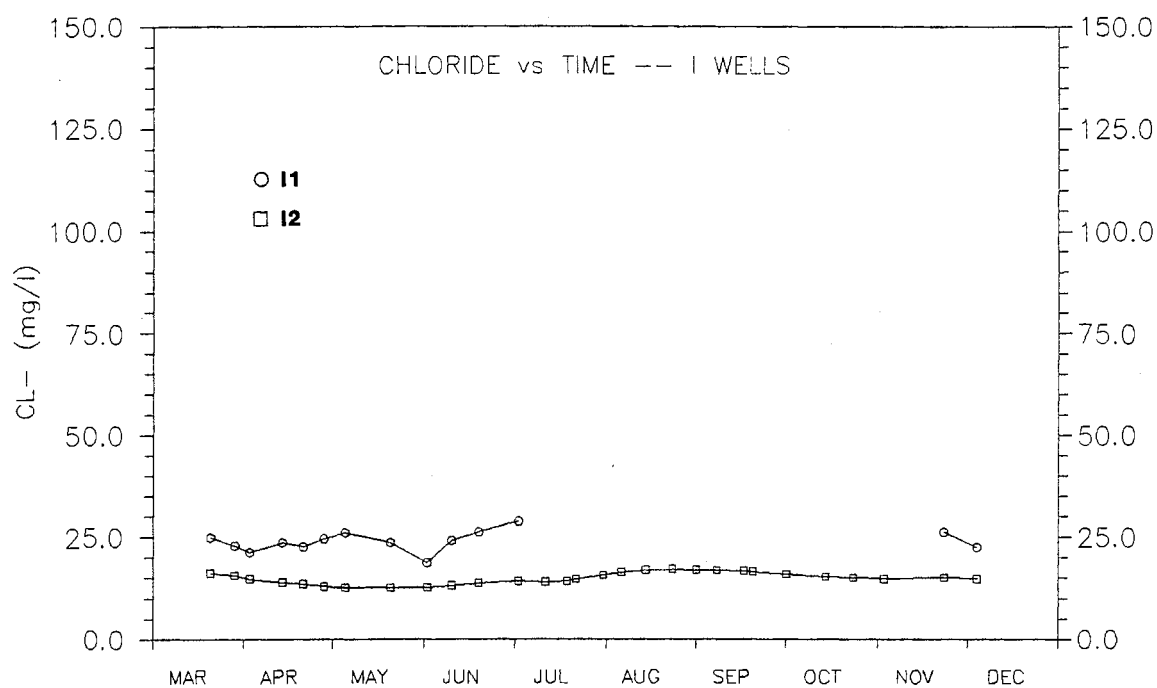
Figure 13h. Chloride Concentrations vs Time, I Wells -
1988.

chloride peaks during late April and early May. Presumably, effluent leaks from a sewer line which crosses the field site near these wells (Hoyle, 1987). On May 19, chloride reached its highest recorded level of 162.7 mg/l in well D3. At this time, depth to ground water in this well was 6.46 feet; thus, the leaking sewer line, buried approximately 5 feet beneath the surface, provided a source of contamination just above the water table. Precipitation events at the field site during late April and May likely flushed this effluent from the lower portion of the unsaturated zone into the aquifer. The declining water table and lack of precipitation during the summer months rendered the aquifer less susceptible to the effects of downward flushing of sewer effluent from the unsaturated zone. Consequently, chloride concentrations in samples from wells C3, D3, and D4 dropped markedly. Measured chloride concentrations were normally distributed at the 95% confidence level in eight of the 14 regularly sampled monitoring wells.

Nitrate

The occurrence of nitrate in samples extracted from the lysimeters and monitoring wells can be principally attributed to the application of nitrogen fertilizers and the decay of vegetative material at land surface. Some portion of nitrate in the shallow ground water beneath the site originates from the surface directly above; however, a substantial quantity is undoubtedly transported through the

unsaturated zone and leached into the aquifer at locations upgradient from the research area. Underflow transports the nitrate-enriched ground water into the the study area from these outside sources.

Measured nitrate concentrations in lysimeters and monitoring wells ranged from a minimum of 3.4 mg/l to a maximum of 121.0 mg/l during the investigative period (Figure 14a-h). Short-term fluctuations were most pronounced in the shallow lysimeters due to the relative proximity of these sample-collection devices to the nitrate source at land surface. Substantial quantities of rain water enriched with nitrogen from fertilizer or decaying plant material can quickly percolate through the upper portion of the unsaturated zone, resulting in rapid increases in nitrate concentration in shallow lysimeters. On the other hand, if little nitrogen is available at the surface, the comparatively pristine infiltration water can quickly dilute shallow lysimeter samples with respect to nitrate. Elevated nitrate concentrations in the shallow lysimeters at the onset of the monitoring program can be attributed to the decomposition of vegetation from the previous growing season and subsequent downward flushing by winter rains and snowmelt. Increases in nitrate levels in lysimeters L1 and L2 between late March and mid-April were probably aided by fertilizer application to the lawn on March 24. Concentrations in L1 and L2 began to drop as the contaminated mass was diluted by more pristine infiltration water during periods of rainfall in late April and May. The
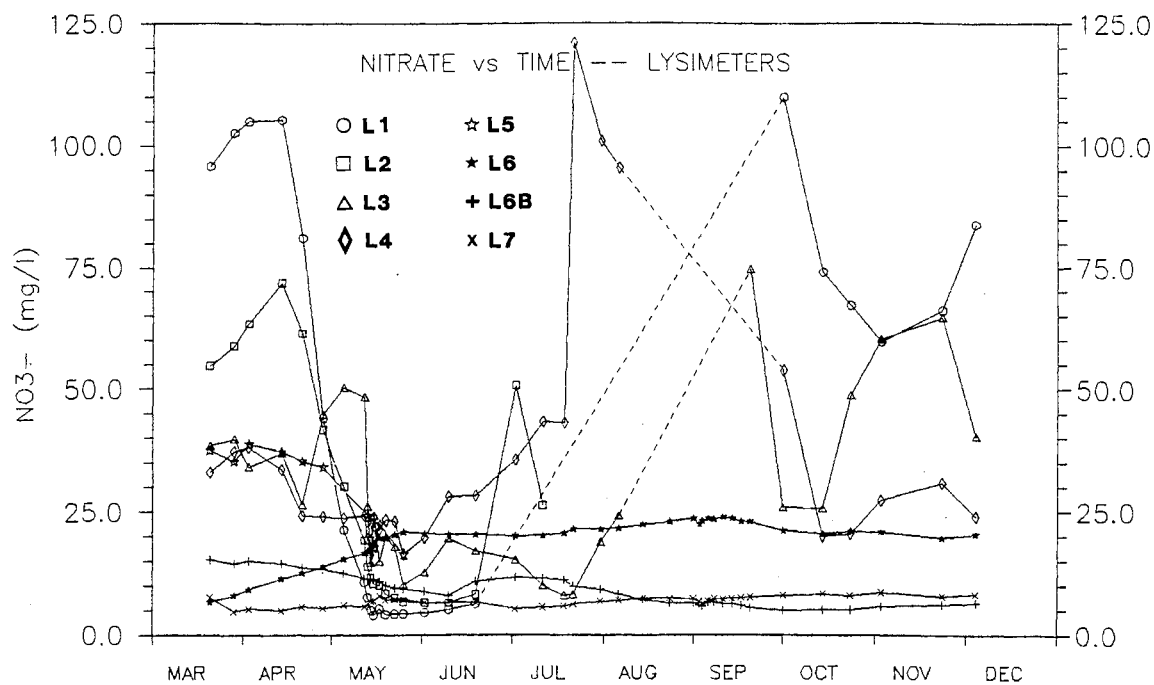
Figure 14a. Nitrate Concentrations vs Time, Lysimeters -
1988.
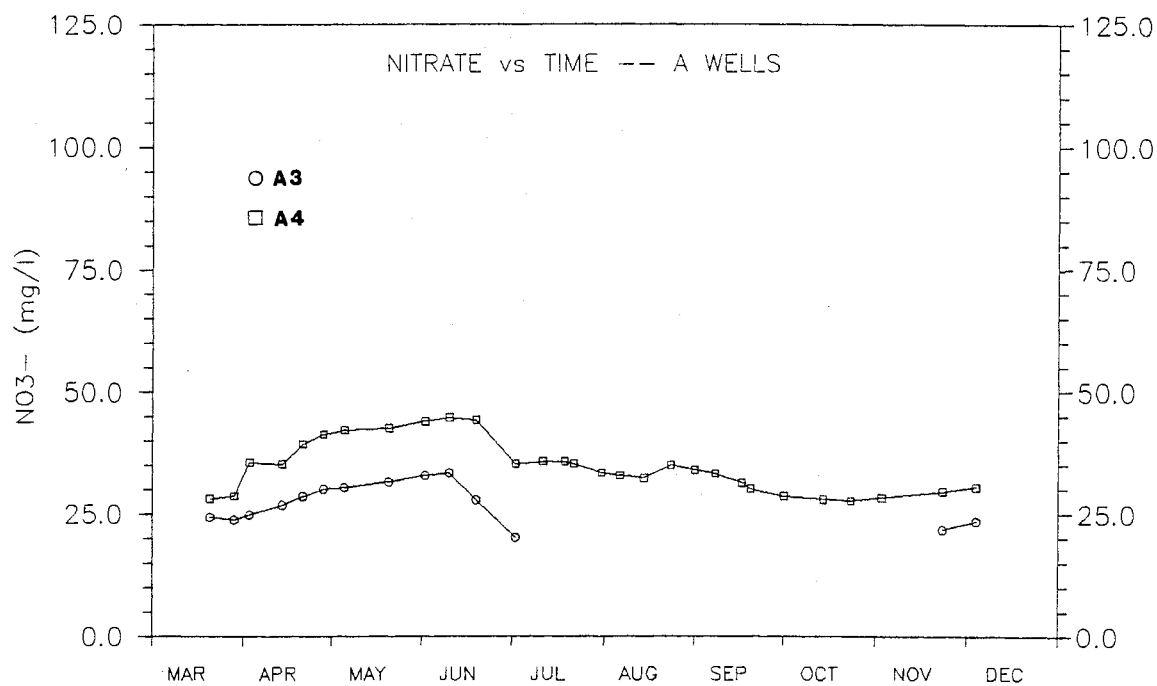
Figure 14b. Nitrate Concentrations vs Time, A Wells - 1988.
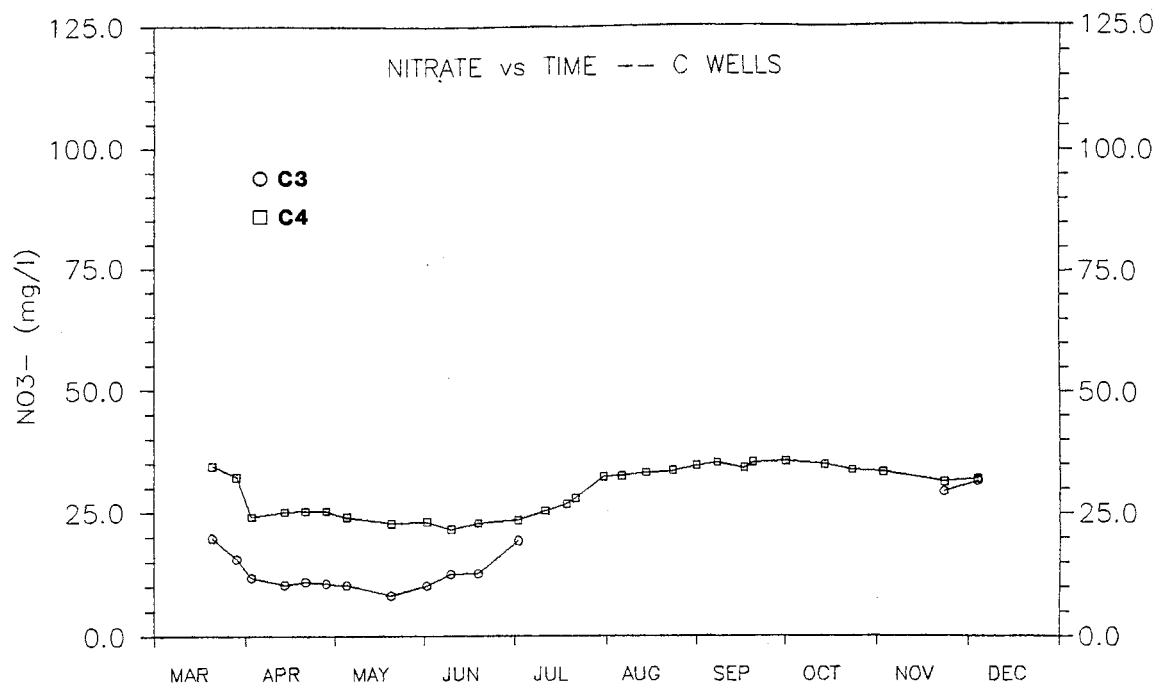
Figure 14c. Nitrate Concentrations vs Time, C Wells - 1988.
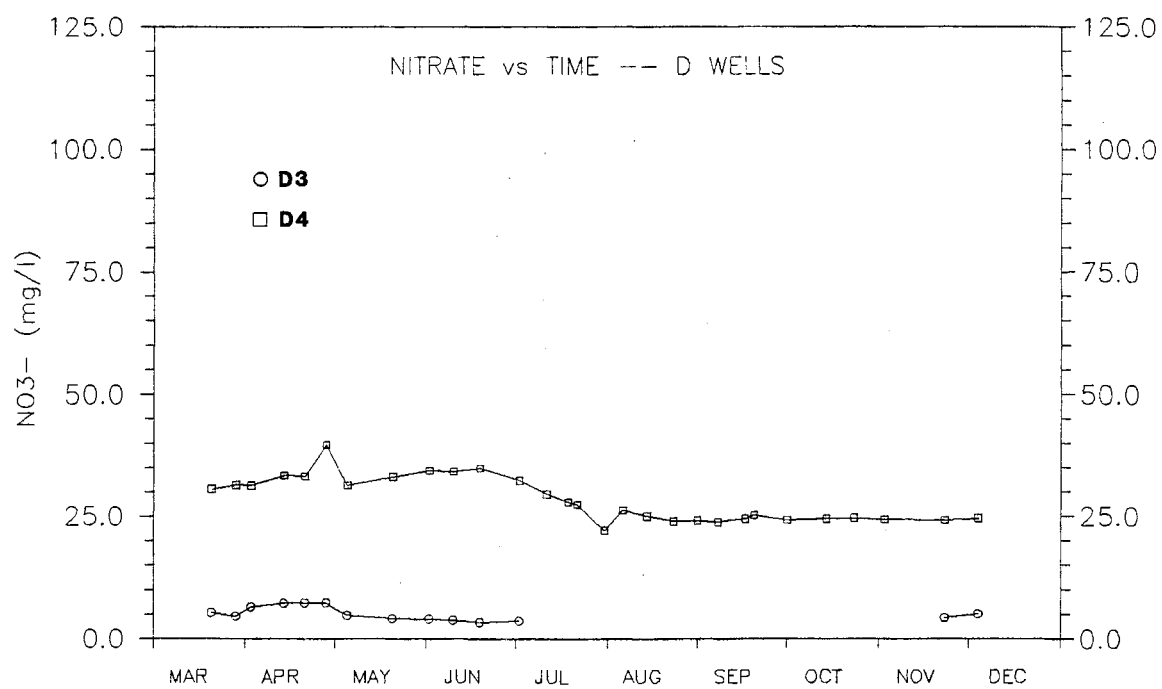
Figure 14d. Nitrate Concentrations vs Time, D Wells - 1988.
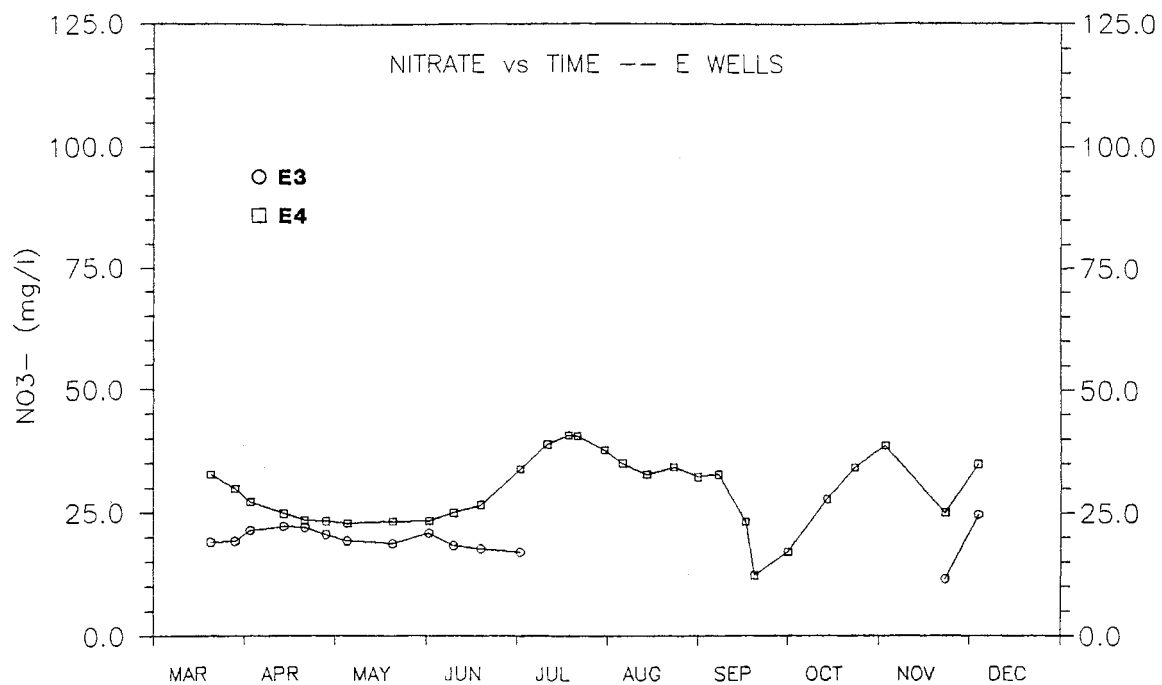
Figure 14e. Nitrate Concentrations vs Time, E Wells - 1988.
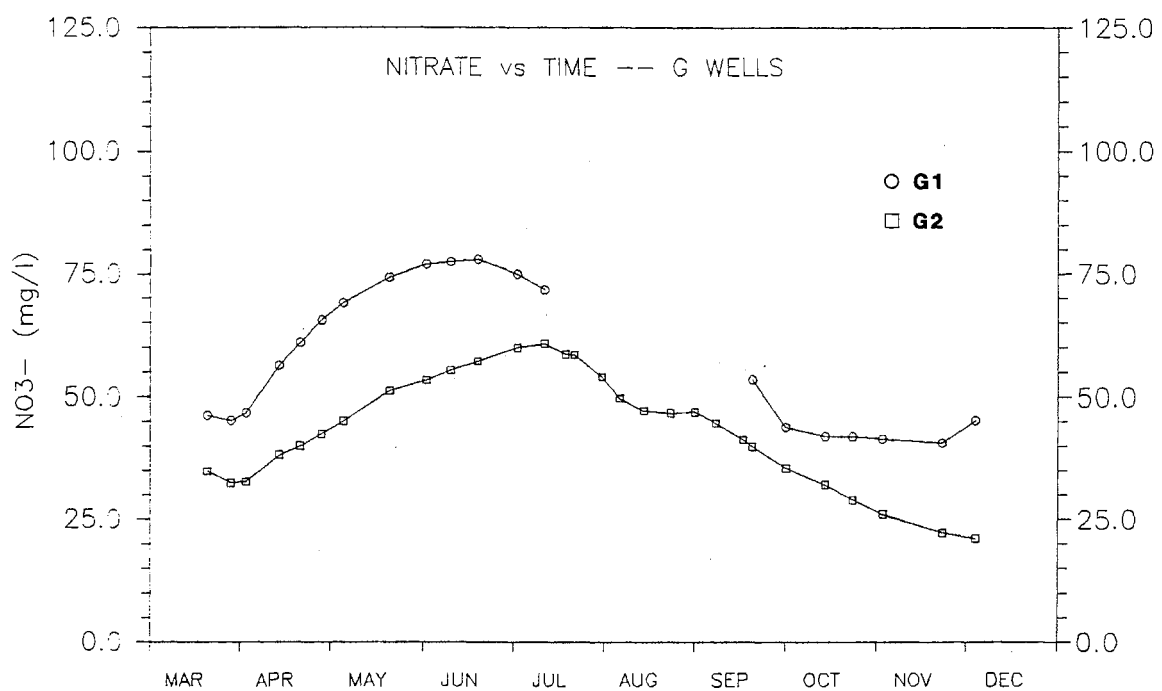
Figure 14f. Nitrate Concentrations vs Time, G Wells - 1988.
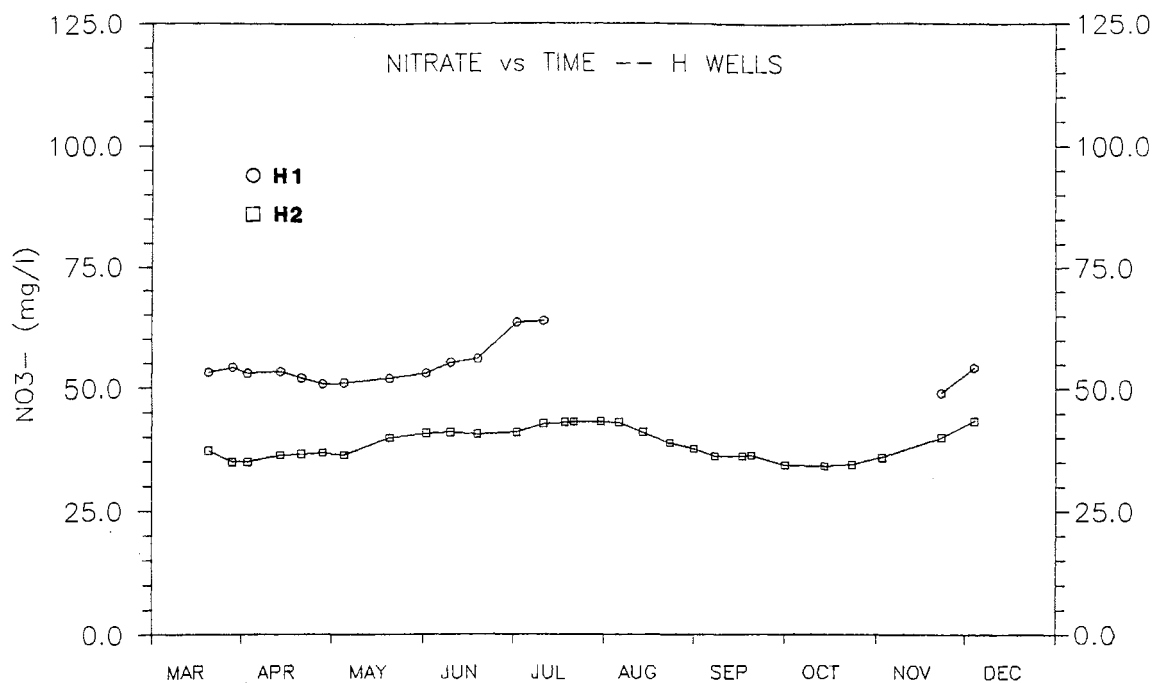
Figure 14g. Nitrate Concentrations vs Time, H Wells - 1988.
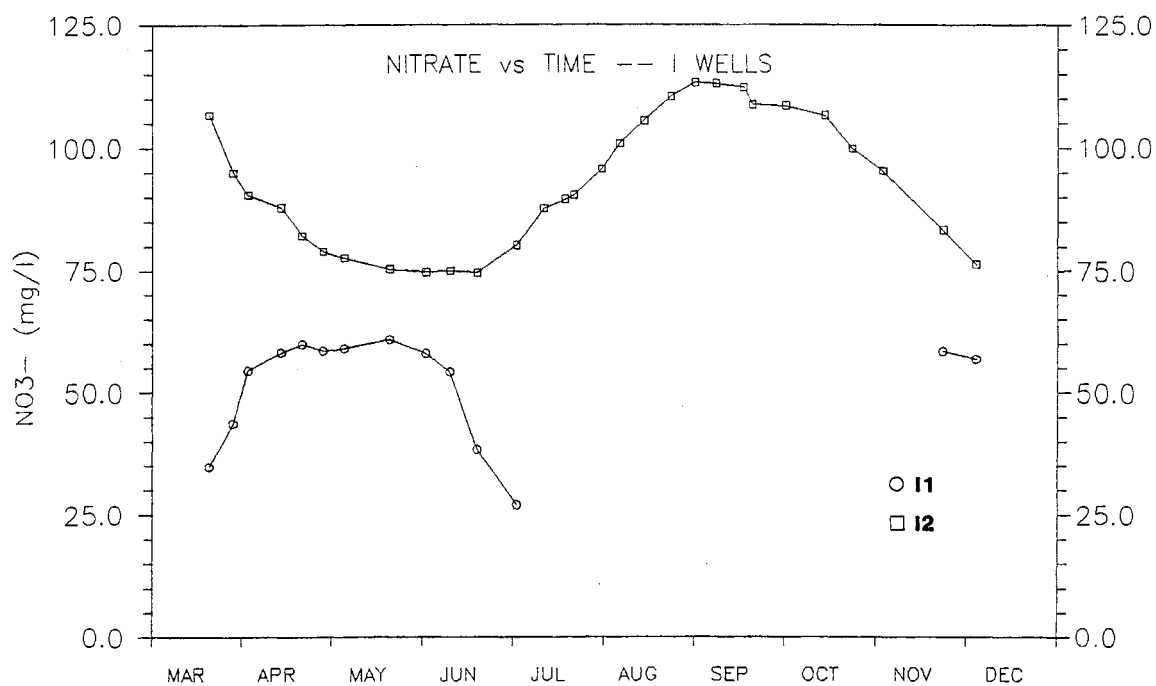
Figure 14h. Nitrate Concentrations vs Time, I Wells - 1988.

tracer solution applied at the surface of the lysimeter plot on May 12 lacked measurable nitrate; thus, dilution with respect to nitrate was noted in samples collected from shallow lysimeters shortly thereafter. The sharp short-term increase in nitrate concentration in lysimeter L4 between sampling events of July 17 and July 20 may be related to fertilizer application on July 16 and subsequent rainfall totalling 0.57 inches on July 17 and July 19.

Nitrate levels in all regularly sampled monitoring wells, as well as lysimeters L5, L6, L6B, and L7, exhibited little short-term response to rainfall following nitrogen fertilizer applications on March 24, May 31, July 16, and September 26. Furthermore, deeper monitoring wells often exhibited greater variation than shallow wells between successive sampling events. Surface influences, such as direct infiltration of nitrate-enriched percolate, would undoubtedly affect the quality of deep lysimeters before shallow wells, and shallow wells prior to deeper wells. Therefore, it appears as though short circuiting of infiltration water from the surface has little impact on nitrate levels in shallow ground water.

Nitrate showed strong stratification at each regularly sampled well cluster within the research area. Concentrations decreased with depth in the ground water at the G and H sites and increased with depth at the A, C, D, E, and I sites. Concentration trends from the two sampled wells in each cluster were generally parallel. Nitrate concentrations were normally distributed at the 95%

confidence level in eight of the 14 regularly sampled monitoring wells (Appendix F).

An examination of the areal distribution of nitrate in sampled wells provides insight to the contribution of underflow in providing a source of pollution to ground water beneath the site. Visual inspection and comparison of the graphs of Figure 14b-h reveals that the G, H, and I wells, which are shielded from the influence of recharge water, consistently exhibited higher nitrate levels than any other sampled wells at the site. Moreover, mean concentrations of nitrate in samples collected from each G, H, and I well were greater than mean nitrate concentrations in samples from any A, C, D, or E well (Appendix F).

A statistical comparison of nitrate levels in the A, C, D, and E wells versus levels in the G, H, and I wells was performed using the Mann-Whitney test. This test utilizes the ranking of observations as a non-parametric method of statistically analyzing observations from unequal group sizes (Snedecor and Cochran, 1967). All observations in both groups are put into a single array, care being taken to label the observations so that their group association can be distinguished. Ranks are then assigned to each observation in the combined array. The smaller sum of ranks, T or T', is compared to a critical T value estimated from a formula provided by White (1952) for the desired level of significance. Values of T or T' smaller than the critical T value cause rejection of the null hypothesis.

In this case, the null hypothesis stated: there was no significant difference between nitrate levels in wells shielded from the effects of recharge water and those not shielded from the effects of recharge water. In other words, differences in nitrate concentrations between the two groups of wells were merely due to fluctuations within the same population. Nitrate concentrations in each of the 136 samples collected from the G, H, and I wells (N1 = 136) were compared to nitrate concentrations in each of the 172 samples collected from the A, C, D, and E wells (N2 = 172) to test this null hypothesis. A summary of results of the Mann-Whitney test is shown in Table II.

TABLE II

SUMMARY OF MANN-WHITNEY TEST RESULTS

Sample Size	Sum of Ranks	Critical Value at P = .01
N1 = 136 -- G, H, I Wells	T = 31,543	
N2 = 172 -- A, C, D, E Wells	T'= 10,481	T = 19,010

The smaller sum of ranks, T', was less than the calculated critical value of T at the 1% critical level; thus, the null hypothesis was rejected and it was concluded

that nitrate concentrations were significantly higher in wells shielded from the influences of recharge water than in wells not shielded from the influences of recharge water. These results suggest that: 1) infiltrate from the upgradient neighborhood lawns provides most of the nitrate to the shallow ground water beneath the research site, or 2) nitrate present in the unsaturated zone beneath the lawn cover has little opportunity to be removed other than through the annual rise and fall of the water table.

Sulfate

Two principal sources of sulfate in water samples from the unsaturated zone and aquifer beneath the site are the dissolution of sulfur bearing minerals in the soil and fertilizer applications at the surface. Sulfate levels in samples collected from lysimeters and monitoring wells ranged from 13.7 to 180.1 mg/l (Figure 15a-h).

Sulfate concentrations exhibited no specific trend with depth in the lysimeters; however, concentrations in lysimeters L1 and L2 were consistently higher than concentrations in other lysimeters. Significant short-term variations in quality with respect to sulfate were limited to the five shallowest lysimeters. Lysimeters L1 through L5 showed the effects of dilution shortly after application of sulfate-poor tracer solution to the surface on May 12, while sulfate levels in lysimeters L3, L4, and L5 appeared to be significantly affected by fertilizer application on March 24 and subsequent precipitation. Deeper lysimeters
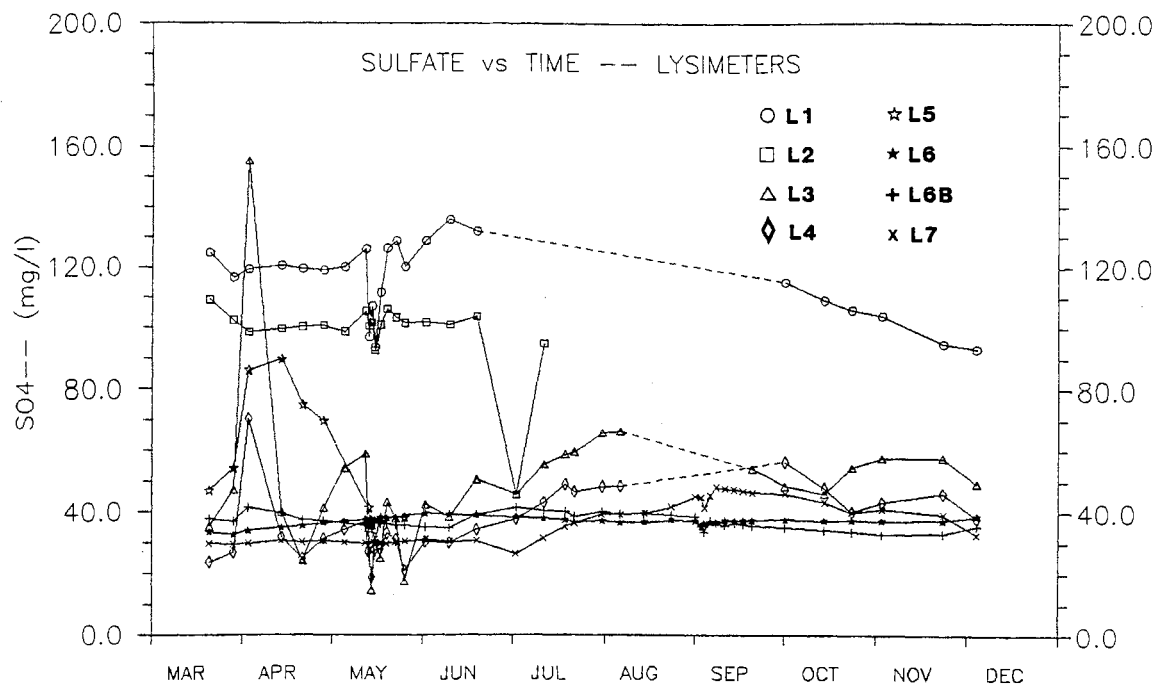
Figure 15a. Sulfate Concentrations vs Time, Lysimeters - 1988.
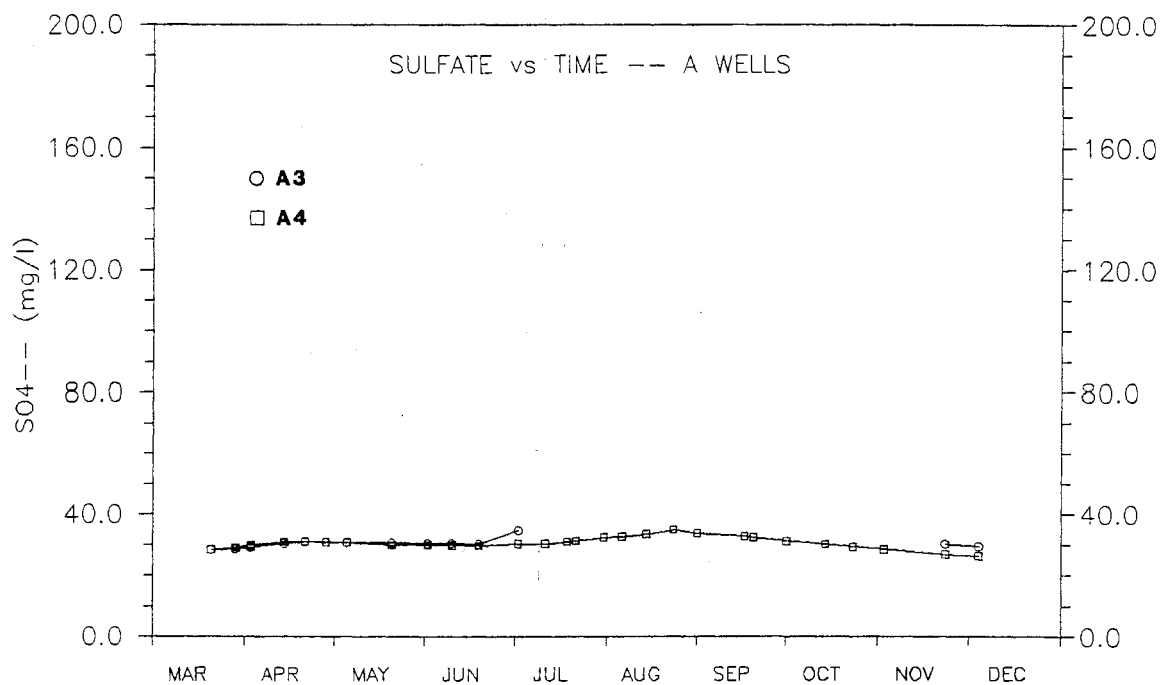
Figure 15b. Sulfate Concentrations vs Time, A Wells - 1988.
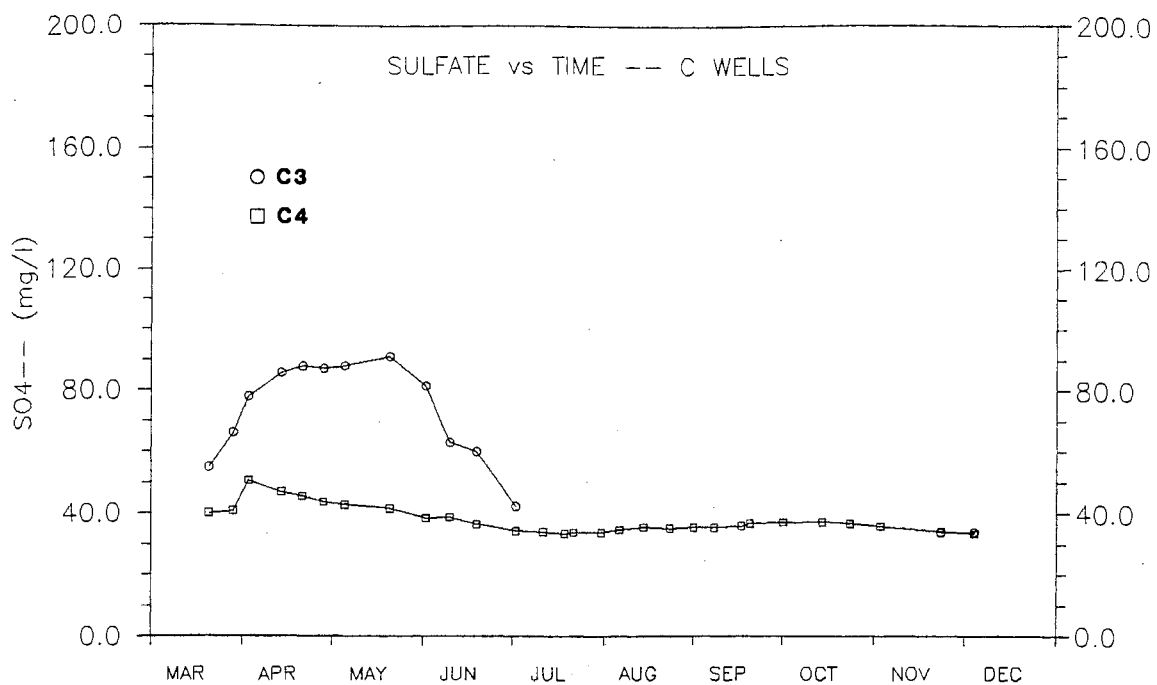
Figure 15c. Sulfate Concentrations vs Time, C Wells - 1988.
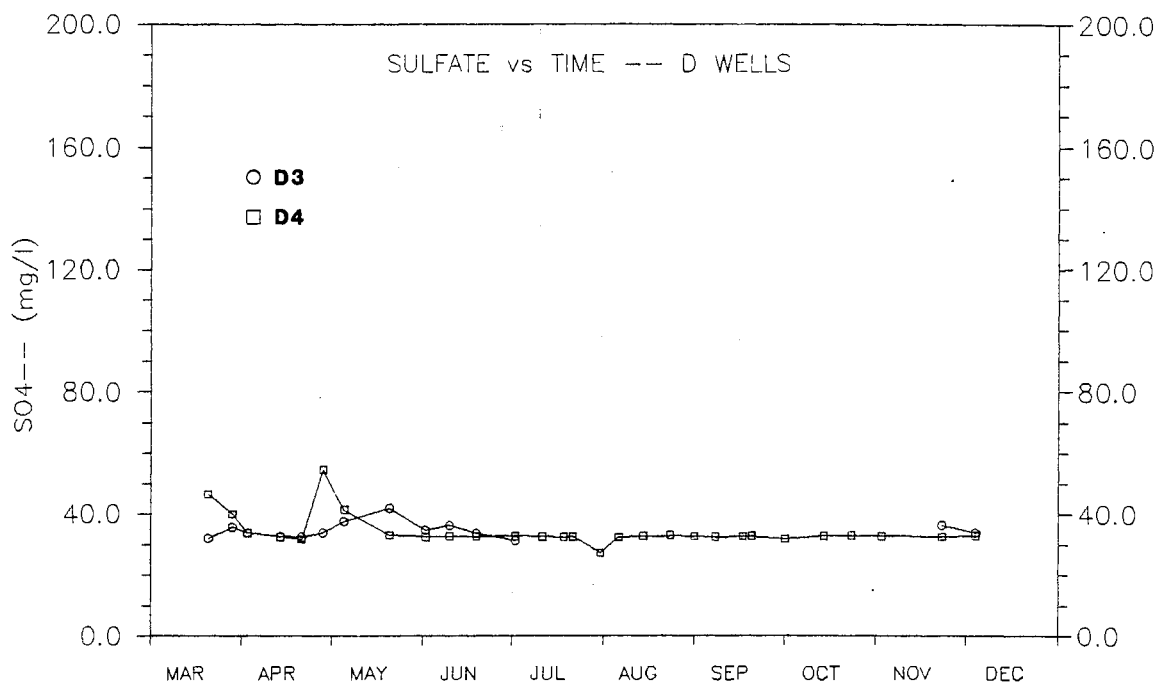
Figure 15d. Sulfate Concentrations vs Time, D Wells - 1988.
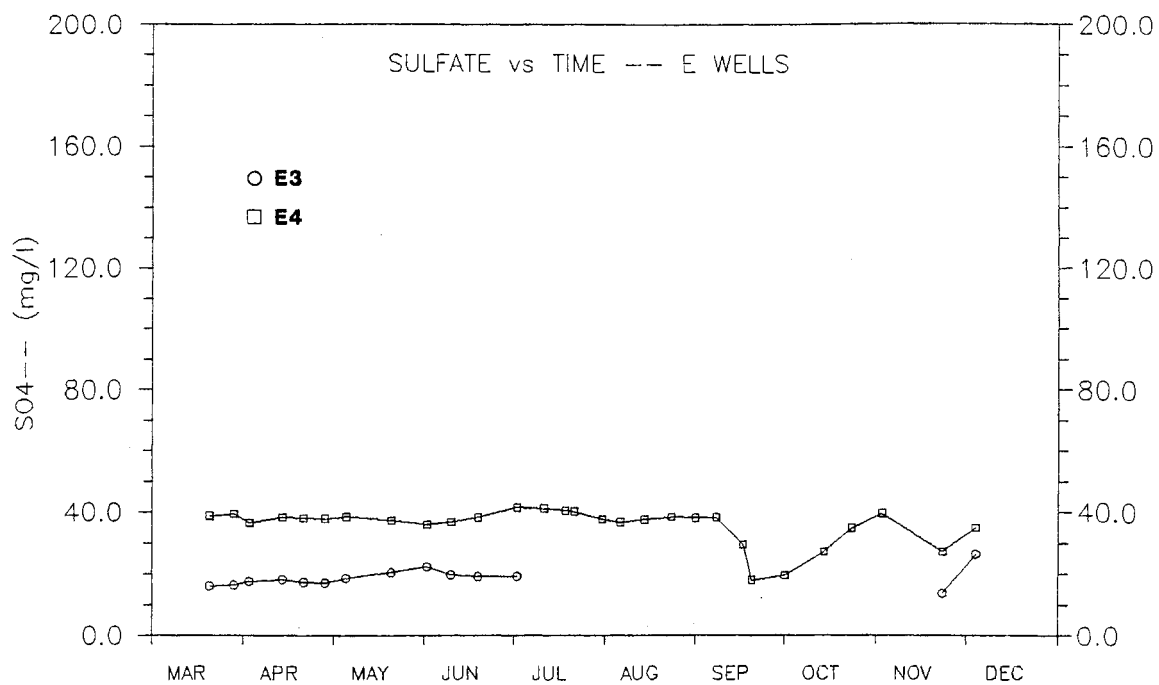
Figure 15e. Sulfate Concentrations vs Time, E Wells - 1988.
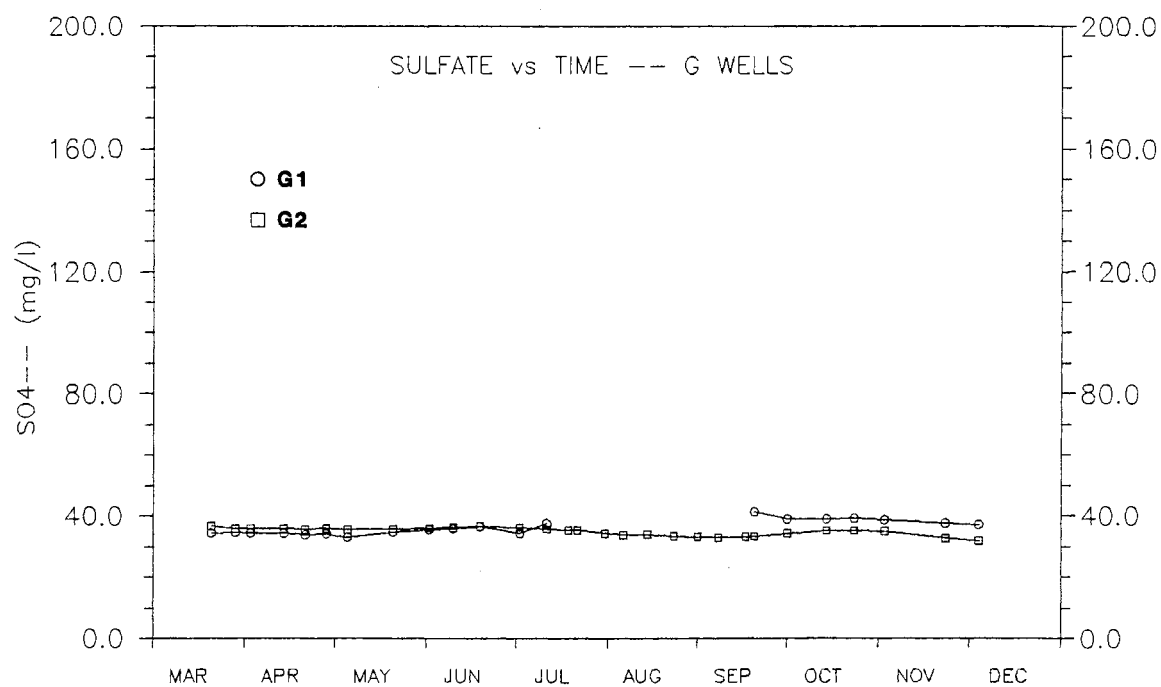
Figure 15f. Sulfate Concentrations vs Time, G Wells - 1988.
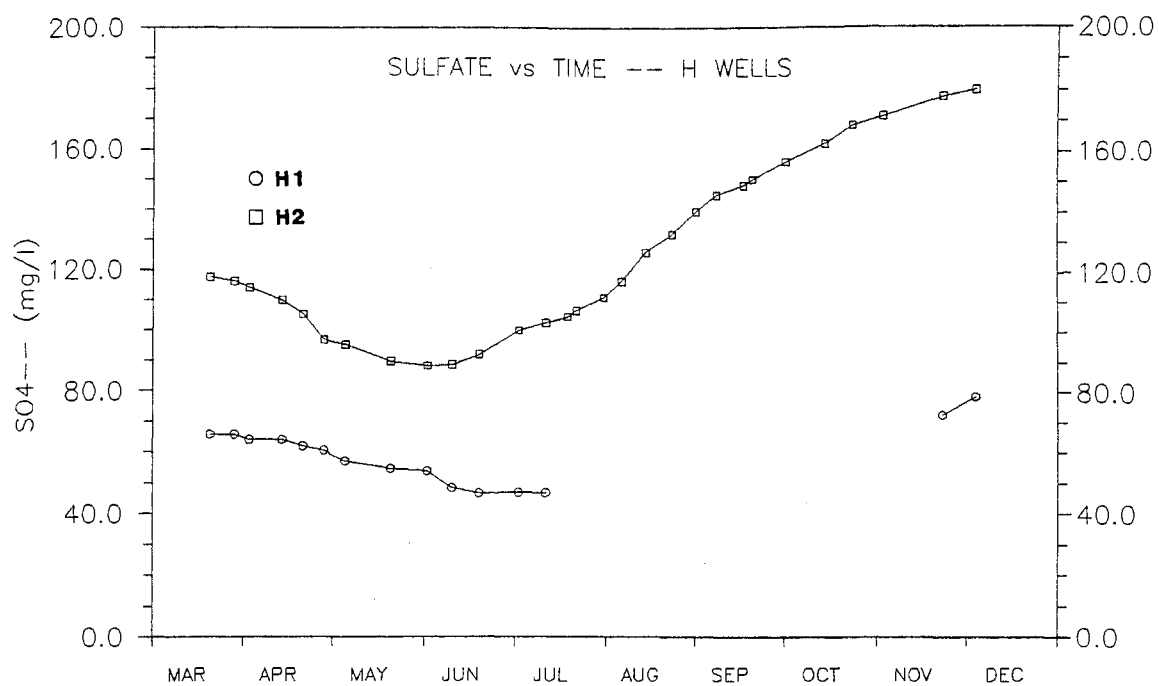
Figure 15g. Sulfate Concentrations vs Time, H Wells - 1988.
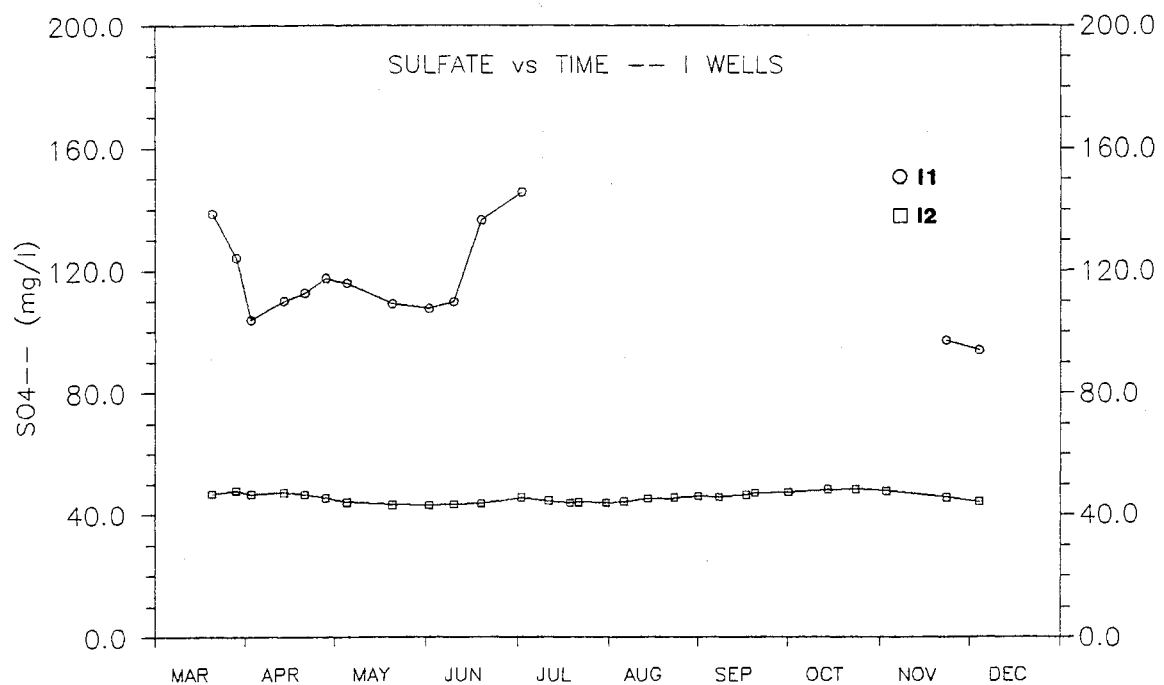

Figure 15h. Sulfate Concentrations vs Time, I Wells - 1988.

exhibited little short-term variability with respect to sulfate during the monitoring period.

Sulfate concentrations in most sampled wells remained relatively constant throughout the investigative period. Concentrations decreased with depth in ground water at the C and I clusters, and increased with depth at the E and H clusters. No trends with depth can be established for the A, D, and G wells. Fluctuations were relatively parallel at the two sampled depths of the A, D, E, G, and H clusters. Sulfate concentrations were normally distributed at the 95% confidence interval in all regularly sampled monitoring wells except C3, C4, D4, and E4 (Appendix F).

Discussion

Water quality with respect to specific chemical constituents was relatively consistent through time at most sampling points during the period of study. A few significant short-term variations in quality were documented throughout the narrow unsaturated zone during high water-table conditions and in the upper part of the unsaturated zone during low water-table conditions. These changes appear to be intimately related to surface phenomena such as application of fertilizer and subsequent short circuiting of infiltration water. Naturally occurring water soluble materials measured regularly during this study do not generally move rapidly from the surface to the water table in quantities sufficient to significantly alter ground-water quality, as evidenced by the relative

stability of quality in deep lysimeters and most monitoring wells through time. Dramatic short-term variations in ground-water quality occur only in the vicinity of discharge from specific sources such as the leaking sewer line and house drainspout.

An obvious concern of any investigator examining short-term variability of ground-water quality is the time interval between sampling events during the investigative period. Are samples being collected often enough to "catch" rapid changes in quality as a result of recharge events? What kind of sampling schedule must be used to adequately establish a monitoring program which insures that all significant changes will be documented? Clearly, continuous sampling is not feasible. The chemical nature of samples obtained from monitoring wells represent ground-water quality at one instant in time. By contrast, lysimeters sample water over a period of time. Shallow lysimeters at the research site did show several incidences of sharp variability in quality, providing evidence that lysimeters will give good indications of short-term variations on a sampling schedule such as established for this study. Since the deep lysimeters did not show significant short-term variability in quality, it is apparent that there is little potential for large quantities of infiltrating water and water-soluble materials to move rapidly from the surface to the water table.

CHAPTER VI

TRACER TESTING OF THE UNSATURATED ZONE

Experimental Procedures

Ionic constituents measured in water samples during this investigation are relatively abundant in the hydrologic system. Most of the water-soluble materials are also subject to a series of complex chemical transformations during downward migration through the unsaturated zone and subsequent flushing through the aquifer. Consequently, in order to understand the hydraulic properties of the unsaturated zone at the site, tracer tests utilizing solutions of conservative, biologically non-reactive tracers with concentrations far above background levels were performed under different antecedent water-level and soil-moisture conditions. Bromide solution was applied at the soil surface to initiate a "wet" test on May 12, when the water table was relatively shallow and soil-moisture content throughout the unsaturated zone was high. Following 3 months of relatively hot, dry weather, chloride solution was applied to start a "dry" test on September 1. At this time the water table was relatively deep and the upper portion of the unsaturated zone was well below field capacity.

The 6-foot by 8-foot experimental plot was bounded by a 4-inch wide strip of aluminum flashing buried on-edge in the ground to a depth of approximately 1 inch. Within the plot were the eight lysimeters used for regular monitoring during the investigative period, the 11-foot deep neutron probe access tube, and nine tensiometers (Figure 16). The shallowest eight tensiometers were installed at depths corresponding to lysimeter depths, while the additional tensiometer was installed at a depth of 9 feet below land surface. The tensiometers failed to perform satisfactorily during both tests.

Solutions for each test were prepared by adding a known weight of oven-dried laboratory-grade salt to each of three 30-gallon storage tanks filled with distilled water. Potassium bromide (KBr) was utilized as solute for the "wet" test, while calcium chloride ($CaCl_2$) was employed for the "dry" test. Application of the 90 gallons of tracer solution to the 6-foot by 8-foot experimental plot simulated a 3-inch precipitation event.

Concentrations of bromide measured in water samples collected during the regular monitoring program were generally less than the detectable limit of approximately 1.0 mg/l (Appendix D). This, coupled with its non-reactive chemical nature, made bromide a suitable tracer for the first test. Application of bromide solution to the soil on May 12 neccessitated the use of a different tracer for the test initiated on September 1. Chloride was chosen because of its non-reactive nature and relative vertical and
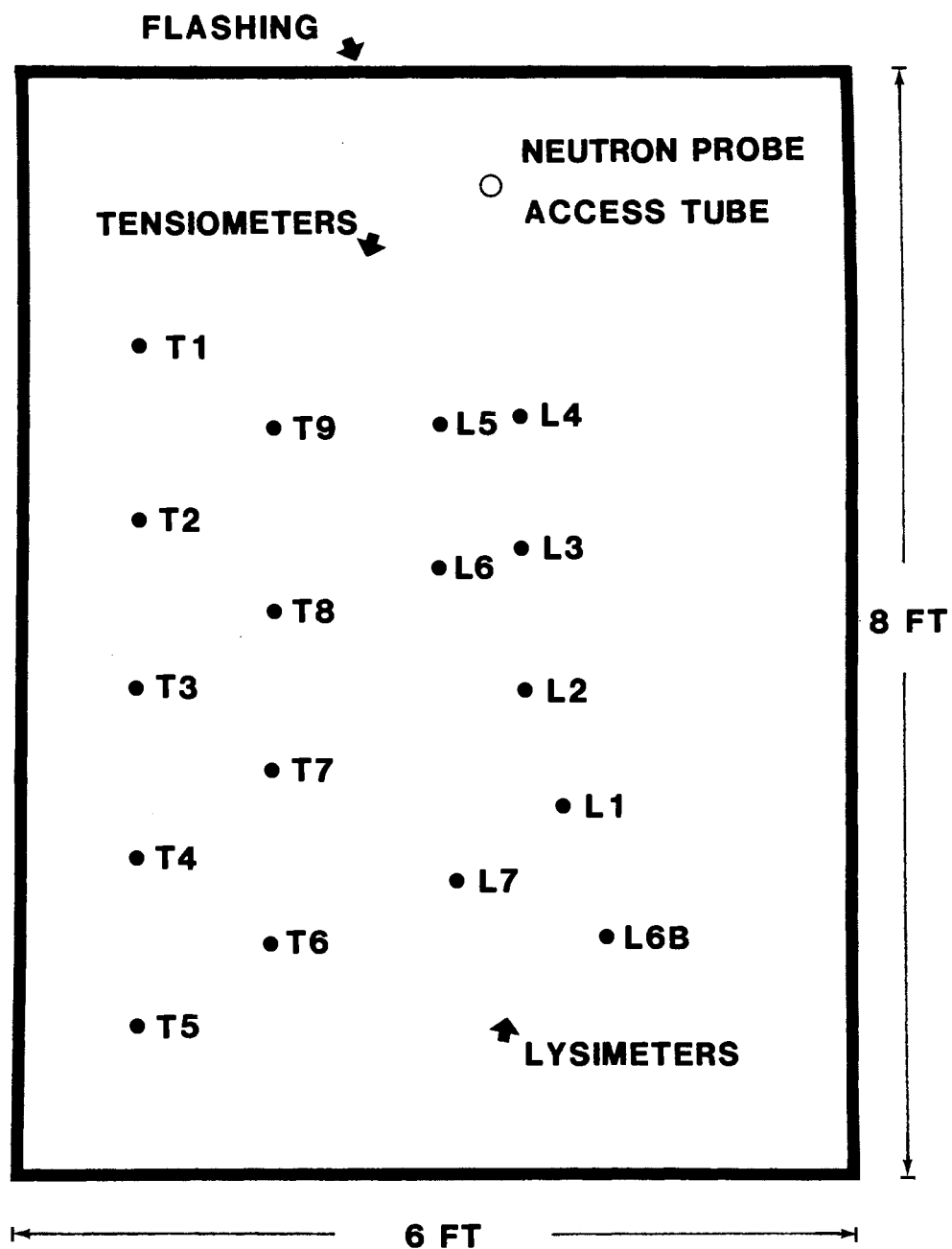
Figure 16. Sketch Map of Tracer Test Site.

temporal uniformity throughout the unsaturated zone during the monitoring program. Average bromide concentration of solution samples taken from each of the three storage tanks just prior to the onset of the "wet" test was 503 mg/l. Chloride concentrations in samples of the "dry" test solution averaged 518 mg/l.

Solutions were applied to the experimental plot in a manner comparable to trickle irrigation techniques. Over a 3-hour period, solution was removed from the storage tanks through tygon tubing intake lines, passed through a peristaltic pump, and discharged through very small perforations set at 3-inch intervals along each of four parallel-lying sections of close-ended tygon tubing which extended across the plot. Surface ponding was evident throughout most of the 3-hour application period of both tests, but the aluminum flashing prevented surface runoff away from the plot.

Soil-moisture measurements were taken at 6-inch depth increments immediately prior to the onset of each test, and at 1 hour, 2 hours, 4 hours, 8 hours, 1 day, and 2 days following the initiation of tracer application. Moisture content was recorded less frequently during the succeeding days. Lysimeters were also sampled immediately prior to the tests, as well as at 1 day, 2 days, 4 days, 6 days, 9 days, and 12 days following application, and less frequently thereafter.

In order to check the validity of tracer distribution in the lysimeters, three 2-inch diameter, 8-foot long soil

cores were extracted from the experimental plot 1 day after application of chloride tracer solution. Each core was cut into 24 sections, each 4 inches long. A saturated paste procedure was then employed to extract water-soluble constituents from each soil sample (SCS, 1972). This method involves saturating each core plug with deionized water, allowing the water to dissolve water-soluble constituents in the soil, and removing the mineralized water by applying gas pressure to the wet soil sample. Water samples obtained in this manner were analyzed for bromide and chloride by ion chromatography.

Distribution of Soil Moisture

Initial moisture profiles for each test are shown in Figure 17. Moisture levels were significantly higher throughout the measured profile immediately prior to the "wet" test than they were just before the "dry" test. Depth to water in well A4, which is immediately adjacent to the tracer plot, was 6.56 feet below land surface at the start of the "wet" test. Due to time constraints, soil-moisture measurements were made only to a depth of 8.0 feet, or just below the water table, during the early stages of this tracer experiment. Since depth to water in well A4 was 12.02 feet at the onset of the "dry" test, the moisture profile was characterized to a depth of 11.0 feet, the full length of the neutron probe access tube. It is interesting to note that moisture levels ranged rather widely with depth at the onset of the "dry" test. Soil-moisture content

INITIAL MOISTURE PROFILES
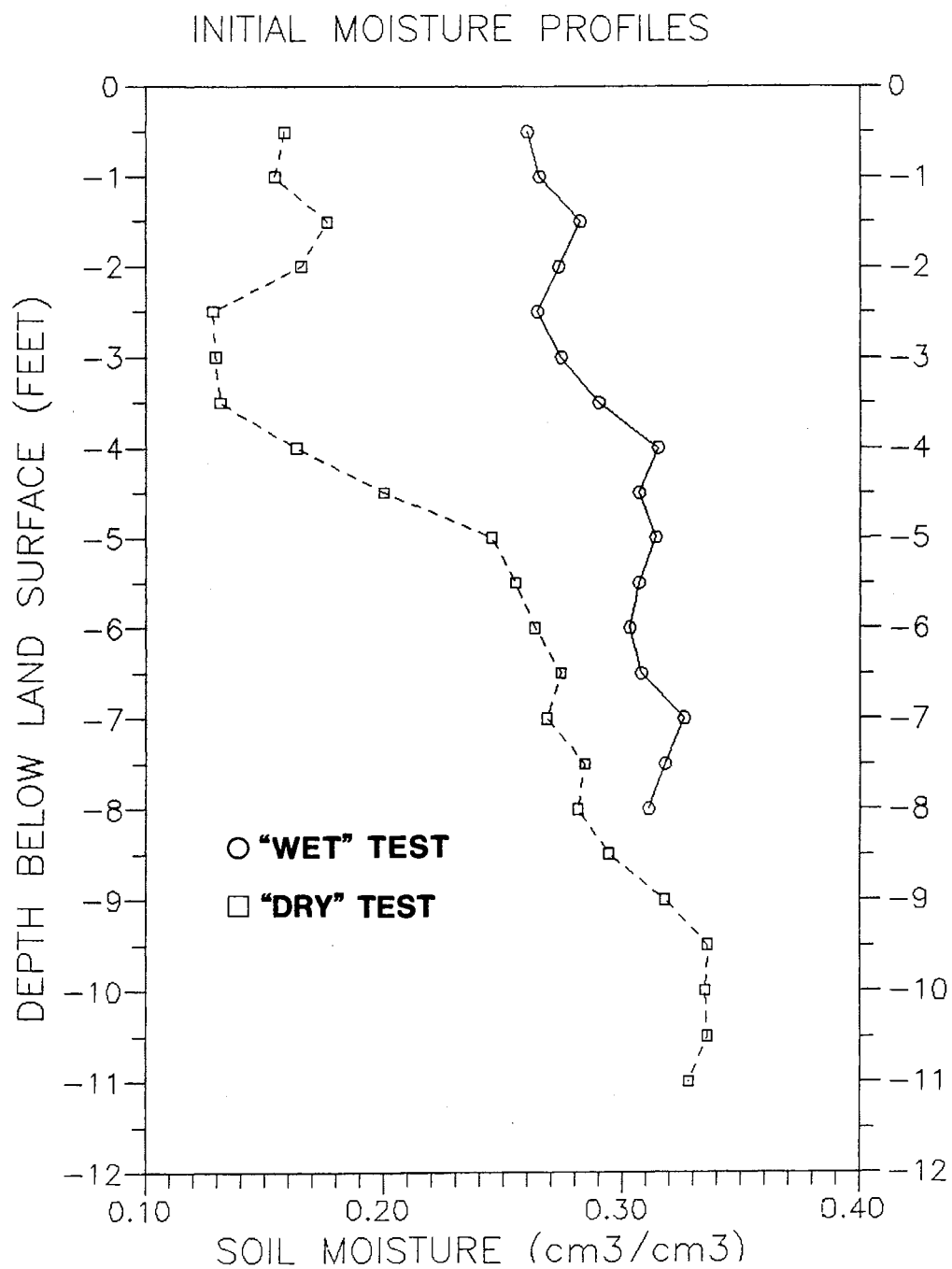
Figure 17. Initial Profiles of Soil Moisture.

increased from 0.13 to 0.25 cm^3/cm^3 between depths of 3.5 and 5.0 feet.

Significant wetting of the upper 2.0 feet of the "wet" profile and upper 2.5 feet of the "dry" profile occurred within 1 hour after the initiation of tracer application (Figure 18). Moisture increases at these depths in such short timespans indicates that short circuiting through macropores may be an important domain of unsaturated flow. After 4 hours, moisture contents from 1.5 to 4.0 feet in the "wet" profile had dropped somewhat, as tracer application had ceased and solution which had been flowing through open channels and cracks moved into the soil matrix. Movement of solution into the soil matrix triggered downward displacement by piston flow. Moisture levels decreased because not only was solution no longer available to the open channels in the absence of application at the surface, but also as the solution moved into the soil matrix it simply replaced moisture which was initially present. Moisture contents in the upper 1 foot of the "wet" profile and the upper 2.5 feet of the "dry" profile showed increases throughout the first 4 hours of infiltration, as solution moving into the soil matrix from the macropores at these depths did not trigger any downward drainage. These soils never reached field capacity and thus simply held all water absorbed. Greater increases in the upper portion of the "dry" profile reflect lower initial moisture contents, and thus greater absorbtion capacity than the upper portion of the "wet" profile.
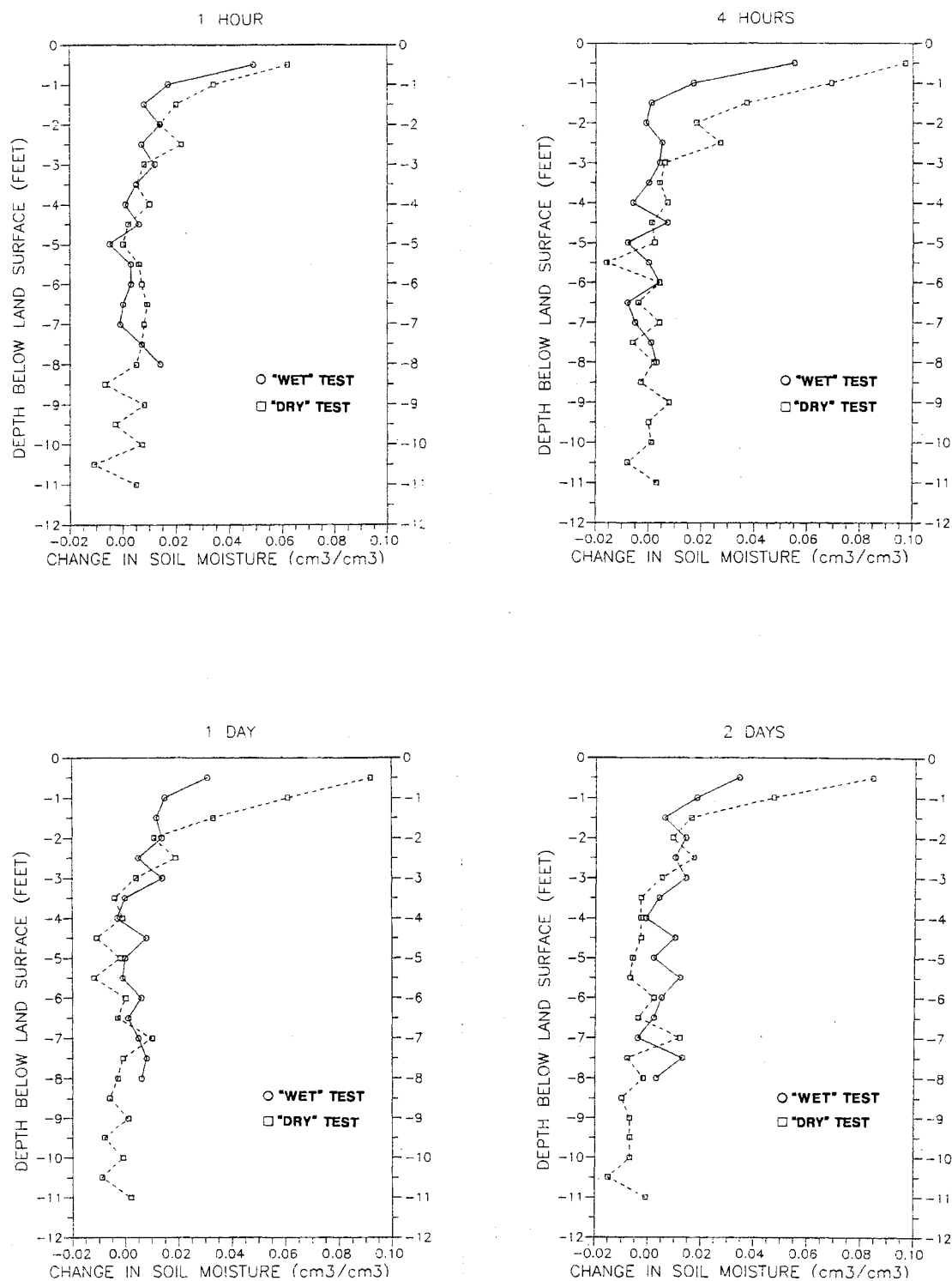
Figure 18. Profiles of Changes in Soil Moisture - 1 Hour,
4 Hours, 1 Day, and 2 Days after Onset of
Tracer Application.

Changes in moisture levels at most depths in both profiles between 4 hours and 2 days following initiation of tracer application reflect the impacts of redistribution of soil moisture and evapotranspiration. Slight error in neutron probe measurements undoubtedly also accounts for some of the documented moisture fluctuations.

Distribution of Solute

Depth distributions of bromide at selected times in the 3 months following application to the soil surface during "wet" initial conditions are shown in Table III. The heterogeneous bromide distribution which had developed within 1 day after application included the presence of tracer in lysimeters L6B and L7. This implies that short circuiting may allow infiltrating water to move 8.0 feet downward from the surface to the aquifer in 1 day when high soil-moisture, elevated water-table conditions prevail at the research site. However, comparison of bromide concentration in the original suface-applied solution with concentations noted in lysimeters L6B and L7 after 1 day suggests that the amount of water reaching the water table quickly is a very small percentage of the total applied volume. Meandering vertical macropores may explain the sudden occurrence of bromide at lower depths without previous corresponding increases at layers above those depths, such as between lysimeters L1 and L2, and between lysimeters L6 and L7, 1 day following tracer application. The effects of piston flow began to be seen in lysimeter L1

TABLE III

DISTRIBUTION OF BROMIDE IN LYSIMETERS
DURING "WET" TRACER TEST

Bromide concentrations in mg/l

Time Since Tracer Application	L1 1.5 Ft	L2 2.0 Ft	L3 3.0 Ft	L4 3.6 Ft	L5 5.0 Ft	L6 6.9 Ft	L6B 6.7 Ft	L7 8.0 Ft
Initial	* 5/12	* 5/12	* 5/12	* 5/12	* 5/12	* 5/12	* 5/12	* 5/12
1 Day	*	5.2	408.9	318.4	118.1	*	39.0	1.6
2 Days	*	*	228.6	154.5	115.2	*	12.1	*
4 Days	2.8	1.7	98.5	119.9	117.2	*	15.0	*
6 Days	6.0	*	91.2	108.9	63.6	*	21.0	*
9 Days	11.3	1.4	64.4	102.9	57.6	*	23.3	*
12 Days	17.8	1.5	25.6	40.3	62.1	*	26.3	*
19 Days	26.1	2.5	58.2	80.3	44.5	*	27.7	*
28 Days	32.6	3.6	45.8	69.2	DRY	*	24.7	*
37 Days	29.0	4.5	63.2	83.6	DRY	1.5	16.6	*
50 Days	DRY	9.0	54.2	73.2	DRY	1.6	18.5	*
59 Days	DRY	10.4	55.4	68.8	DRY	1.9	21.9	*
66 Days	DRY	DRY	56.1	69.9	DRY	2.2	24.5	*
69 Days	DRY	DRY	54.9	35.9	DRY	2.4	24.8	1.5
78 Days	DRY	DRY	52.7	34.6	DRY	2.7	27.2	1.5
85 Days	DRY	DRY	47.1	44.3	DRY	3.0	28.5	1.6
93 Days	DRY	DRY	DRY	DRY	DRY	3.3	29.4	1.5

* = Concentration below detectable limit
DRY = Dry lysimeter -- no sample

after 4 days, as some tracer solution reached the sample collection chamber 1.5 feet below land surface. Bromide levels continued to rise in lysimeter L1 over the next 33 days as the center of mass of the tracer slug was slowly displaced downward by infiltrating precipitation.

Tracer concentrations peaked in lysimeters L2, L3, L4, L5, and L6B just 1 day after application at the surface on May 12. However, concentrations in these lysimeters also dropped rather dramatically over the next several days as tracer solution moving from macropores into the soil matrix was diluted by mixing with initially present soil-matrix water. Some infiltrating water from the 0.62-inch rain event of May 15 undoubtedly flowed through the same macropore network as the tracer solution, and thus also may have served to dilute these lysimeter samples with respect to bromide. Concentrations of bromide began to rise again in lysimeter L2 after Day 6. This may be attributable to moisture losses at this depth due to evapotranspiration. Changes in bromide concentration in the lysimeters between 1 day and 28 days after application at the surface are shown in the schematic sketch of Figure 19.

Bromide concentrations remained below the detectable limit of 1.0 mg/l in lysimeter L6 through Day 37, and then began a slow but steady climb. Because bromide appeared in the lysimeters immediately above and below this depth just 1 day after the onset of the test, it is hypothesized that macropores in the vicinity of the sample collection chamber of lysimeter L6 contained tracer solution shortly after
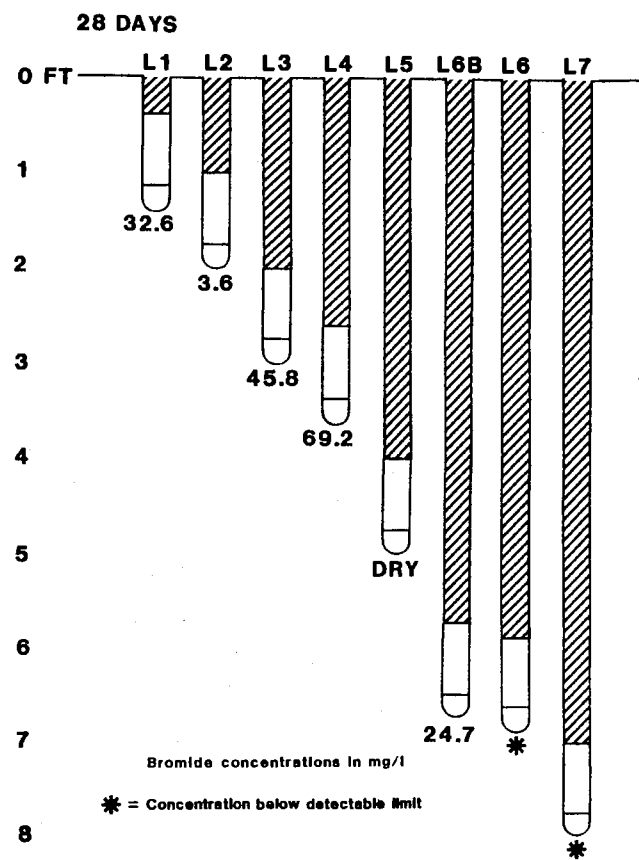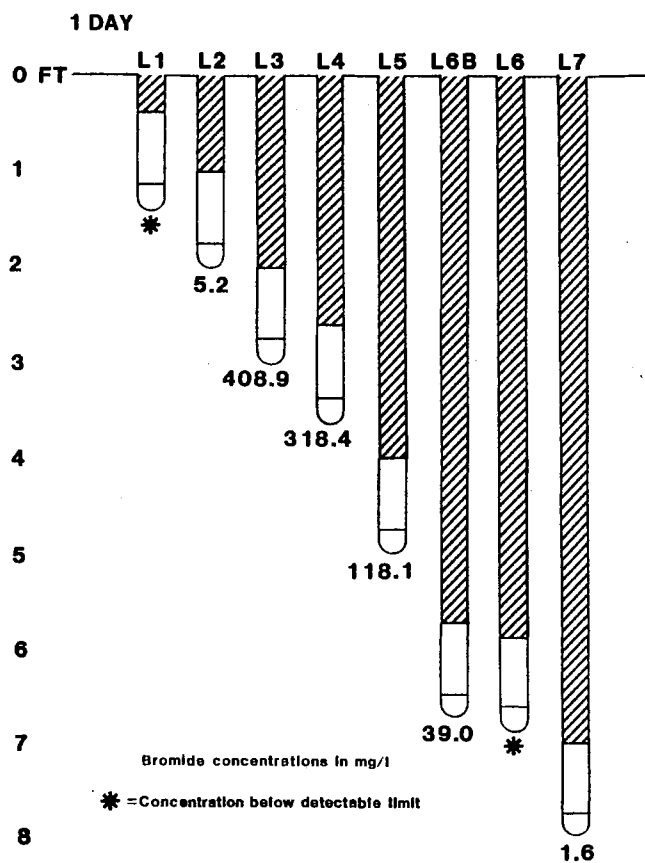
Figure 19. Schematic Diagram Showing Distribution of Bromide in Lysimeters - 1 Day and 28 Days after Onset of "Wet" Tracer Test.

application at the surface. However, this lysimeter was able to recover applied solute only after the tracer solution had drained from macropores into adjacent soil matrix and then slowly migrated closer to the sample collection chamber.

Concentrations of bromide in the lysimeters remained above background levels through the end of the regular monitoring period on December 3, 1988. This indicates that while some small portion of water may move through the unsaturated zone in 1 day or less, the bulk of infiltrating water, even when "wet" antecedent soil-moisture conditions prevail at the site, may be held in the unsaturated zone for periods exceeding 7 months.

The depth distribution of chloride at selected times during the 3 months following application of the tracer solution to the soil to initiate the "dry" test on September 1 is shown in Table IV. The dry condition of the shallow soil prevented the sampling of lysimeters L1 through L5 immediately prior to the onset of the test and for various lengths of time after the tracer was applied. Lysimeters L2 and L5 were not sampled at any time during this second tracer experiment.

One day after tracer application, chloride concentrations in lysimeters L6, L6B, and L7 were below levels measured the day prior to initiation of the test. This implies that tracer failed to reach any of these lysimeters during the first day after application. Chloride concentrations in these lysimeters remained below or only

TABLE IV

DISTRIBUTION OF CHLORIDE IN LYSIMETERS
DURING "DRY" TRACER TEST

Chloride concentrations in mg/l

Time Since Tracer Application	L1 1.5 Ft	L2 2.0 Ft	L3 3.0 Ft	L4 3.6 Ft	L5 5.0 Ft	L6 6.9 Ft	L6B 6.7 Ft	L7 8.0 Ft
Initial	9.1 6/18	84.8 7/10	31.8 8/05	19.2 8/05	8.9 5/24	15.1 8/30	9.1 8/30	17.7 8/30
1 Day	DRY	DRY	DRY	DRY	DRY	14.8	8.9	16.7
2 Days	DRY	DRY	DRY	DRY	DRY	15.4	8.2	15.8
4 Days	DRY	DRY	DRY	DRY	DRY	15.4	9.0	16.4
6 Days	DRY	DRY	DRY	DRY	DRY	15.4	8.9	17.4
9 Days	DRY	DRY	DRY	DRY	DRY	15.7	9.0	19.0
12 Days	DRY	DRY	DRY	DRY	DRY	15.6	9.5	18.9
15 Days	DRY	DRY	DRY	DRY	DRY	15.8	9.8	16.9
18 Days	DRY	DRY	337.9	DRY	DRY	15.9	10.0	16.8
29 Days	169.3	DRY	169.8	299.7	DRY	16.1	11.1	21.4
42 Days	165.5	DRY	134.9	109.9	DRY	15.9	11.4	18.0
51 Days	148.0	DRY	156.3	113.4	DRY	16.2	11.8	22.1
62 Days	125.4	DRY	157.4	119.2	DRY	16.7	11.8	22.7
82 Days	87.2	DRY	142.2	105.8	DRY	16.8	11.7	23.9
93 Days	69.8	DRY	87.1	45.0	DRY	17.8	15.1	20.5

DRY = Dry lysimeter -- no sample

slightly above initial levels through Day 18. Slow increases in chloride concentration observed in these three lysimeters beginning on Day 29 were probably the result of piston flow of naturally present chloride moving downward toward the water table, rather than drainage of tracer solution from macropores into the soil matrix. Evidence for this is provided by the lack of data suggesting rapid percolation of tracer solution to the vicinity of the sample collection chamber of any of these lysimeters.

Lysimeter L3 did not yield a water sample until 18 days after application of tracer at the surface. This initial post-application sample was more concentrated with respect to chloride than any sample subsequently collected from lysimeter L3. Similarly, lysimeters L1 and L4 showed peak chloride levels in initial post-application samples, which were retrieved 29 days following the onset of the test. It is suspected that the tracer solution reached these three lysimeters within 1 day of application at the surface through a macropore system similar to that documented during the "wet" test. Low moisture content in the shallow soil at the onset of the "dry" test caused a loss of suction in these lysimeters; consequently, after moving some 3.6 feet downward to the region of lysimeter L4 in 1 day via open cracks and channels, the tracer solution was not able to move into the sample collection chamber of any of these lysimeters. Instead, the solution drained into adjacent soil matrix, where it remained relatively concentrated with respect to chloride because of low

antecedent moisture levels in the soil matrix. The autumn
rainfall, which allowed lysimeters L1, L3, and L4 to begin
to be sampled, also served to dilute samples retrieved from
these lysimeters. The distribution of chloride in the
lysimeters at 1 day and 29 days after application of the
tracer solution at the surface is shown in the schematic
sketch of Figure 20.

The distribution of chloride and bromide in the three
8-foot cores obtained from the tracer plot 1 day following
the onset of the "dry" tracer test is shown in Table V. It
should be noted that tracer concentrations obtained by the
saturated paste method should only be compared to
concentrations in lysimeter samples in a cursory manner.
Like the chemical data from lysimeter samples, the depth
distribution trend of solute in the core samples seems to
indicate that some preferential downward movement occurred
during each tracer experiment. Core 1 probably intercepted
the region around a preferred channel of vertical movement,
as evidenced by the presence of bromide at near-surface
depths as well as throughout the lower half of the core,
but absence of bromide at depth intervals in between. Most
of the chloride tracer solution appears to have been
absorbed by the shallow soil of this core; however, a spike
of 42.1 mg/l was recorded in the water sample obtained from
the 28- to 32-inch depth interval, indicating that some
preferential movement did take place to this depth. Core 2
and Core 3 exhibit the effects of piston flow, as both
bromide and chloride were held in the near-surface soil of
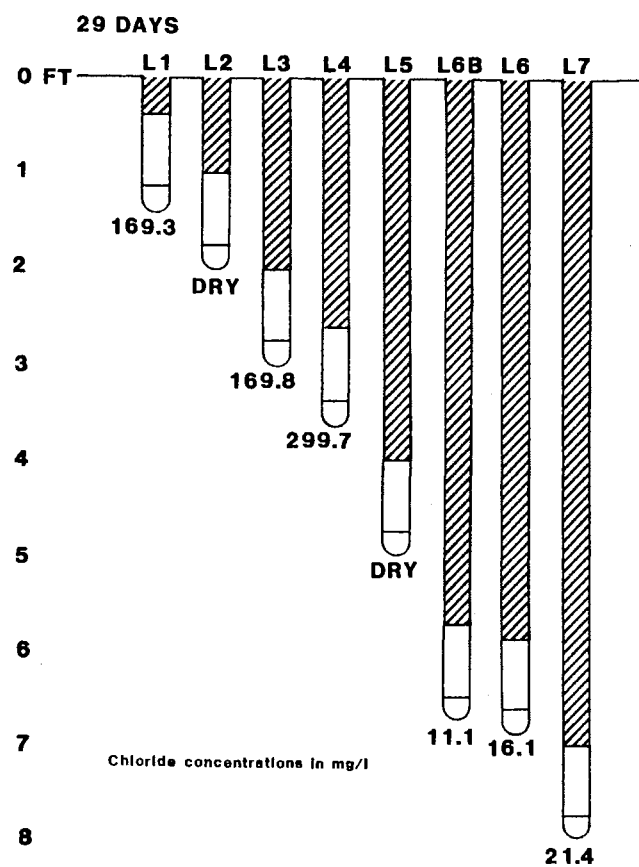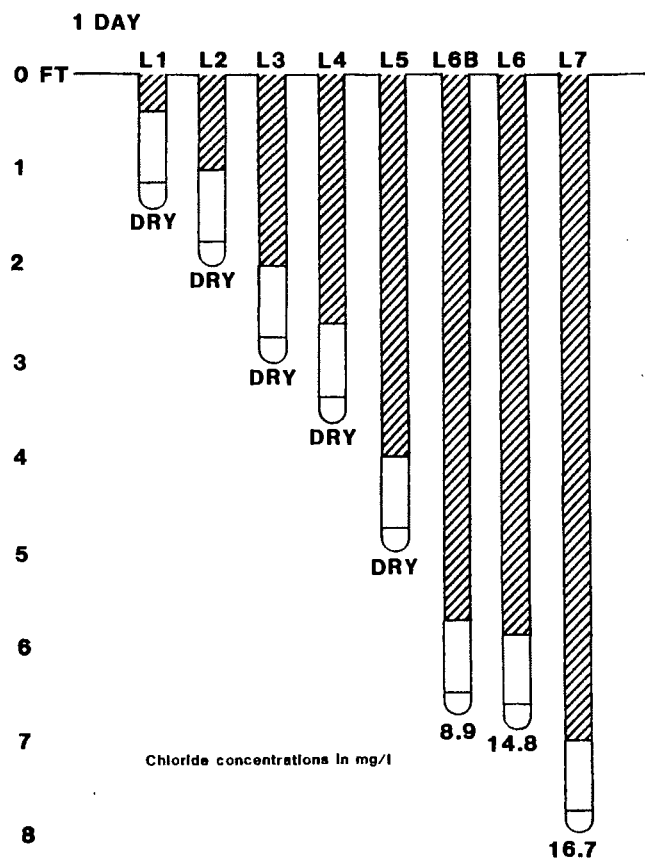
Figure 20. Schematic Diagram Showing Distribution of Chloride in Lysimeters - 1 Day and 29 Days after Onset of "Dry" Tracer Test.

TABLE V

BROMIDE AND CHLORIDE CONCENTRATIONS IN WATER
SAMPLES EXTRACTED FROM SOIL CORES

Depth	Core 1		Core 2		Core 3	
INCHES	BR (MG/L)	CL (MG/L)	BR (MG/L)	CL (MG/L)	BR (MG/L)	CL (MG/L)
0 - 4	45.1	191.9	34.3	215.2	12.2	228.1
4 - 8	48.2	94.8	50.2	56.6	17.9	194.0
8 - 12	9.7	13.5	9.0	13.4	13.8	128.0
12 - 16	*	10.0	2.6	9.7	22.7	101.2
16 - 20	1.5	10.7	*	10.1	21.8	52.5
20 - 24	*	10.2	*	12.1	12.9	22.8
24 - 28	10.1	17.0	*	12.9	24.1	14.1
28 - 32	4.9	42.1	*	12.8	12.7	13.1
32 - 36	1.7	16.1	*	14.4	4.0	12.7
36 - 40	*	11.7	1.5	12.9	1.8	15.9
40 - 44	*	11.7	1.5	17.6	*	17.5
44 - 48	*	12.6	*	22.9	*	19.2
48 - 52	28.1	13.5	*	19.7	*	12.1
52 - 56	28.1	9.7	*	23.5	*	11.4
56 - 60	18.9	9.4	*	20.8	*	12.7
60 - 64	14.0	10.8	*	15.1	*	13.3
64 - 68	11.9	9.6	*	13.0	*	15.4
68 - 72	11.8	15.0	*	16.9	*	17.3
72 - 76	14.8	10.0	*	13.3	*	17.3
76 - 80	12.6	8.8	*	10.8	*	19.1
80 - 84	10.2	8.7	*	11.8	*	19.7
84 - 88	6.7	7.8	*	10.4	*	19.9
88 - 92	5.7	13.4	*	11.6	*	16.8
92 - 96	4.8	14.8	*	10.8	1.6	20.5

* = Concentration below detectable limit

each of these cores.

Discussion

Differences in moisture and solute distribution following similar application procedures under different initial moisture conditions can be explained with the aid of the schematic sketch of Figure 21. When the soil is initially very moist, there is displacement of initially present soil-matrix water as well as rapid movement of tracer solution along the macropores. Therefore, peaks in solute concentration occur without corresponding increases in soil-moisture content, as the tracer solution simply "replaces" moisture which was initially present. When antecedent moisture levels throughout the unsaturated zone are high, the water table is generally in a relatively high position. This, in conjunction with the rapid transport capabilities of the moist soil, allows tracer solution to reach the water table within hours after application at the surface, although data obtained during this experiment suggest that when compared to the initial concentration at the surface, the concentration of solution reaching the ground water will be relatively small.

When antecedent soil-moisture is low, there is still preferential vertical movement along soil macropores and associated lateral infiltration, but short circuiting is not as pronounced as when the soil is initially wet. Since the soil is relatively dry, there is little or no downward displacement of water from the upper part of the
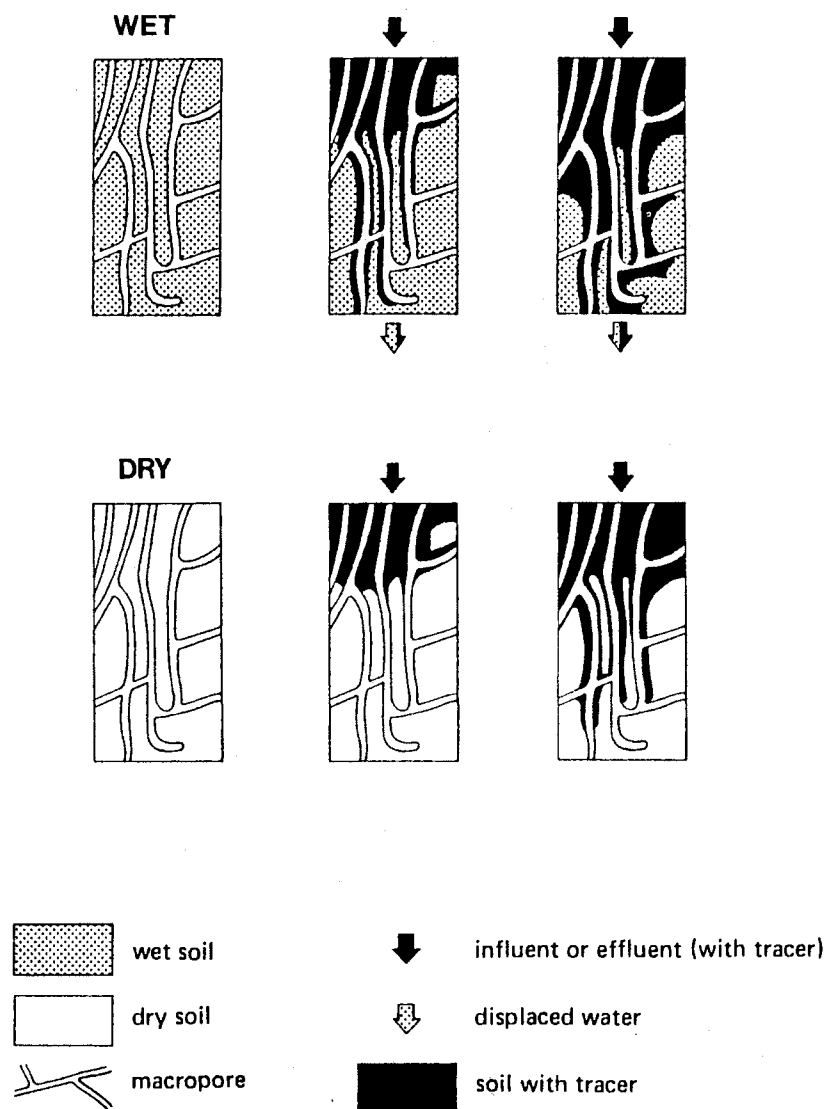
Figure 21. Schematic Diagram Showing the
Effects of Macropores on Water
and Solute Movement through
"Wet" and "Dry" Unsaturated
Soil (Bouma, 1981).

unsaturated zone. The upper soil acts as a dry sponge, "soaking up" most of the tracer solution. This gives rise to large increases in tracer concentrations and moisture levels in water samples obtained from the near-surface soil, but solute does not reach the lower portion of the profile. Simply put, after absorption by the upper soil, there is less tracer solution available to move deeper into the profile. In the field situation described here, "dry" soil-moisture conditions are generally associated with a relatively low water table; thus, the tracer solution also has further to migrate before reaching the ground water. Consequently, the potential for rapid movement of tracer solution to the water table is minimized (Bouma, 1981).

Vertical movement of water through the unsaturated zone appears to occur under two distinct regimes: short circuiting and piston flow. Although large spikes in tracer concentrations may appear at different depths in the unsaturated zone after a very short time, it appears as though the bulk of infiltrating solution is held in the unsaturated zone for a period of several months or longer, as both bromide and chloride concentrations remained well above background levels in most lysimeters through the end of the monitoring program.

CHAPTER VII

CONCLUSIONS

Deep lysimeters and most monitoring wells at the research site exhibited minimal short-term variability in water quality. This suggests that large quantities of rain water and regularly measured ionic constituents do not move rapidly from the surface to the water table. Although tracer experiments demonstrated that small percentages of rain water and surface-applied contaminants may quickly migrate to ground water by direct infiltration when the soil is initially very moist and the water table is high, temporal changes in shallow ground-water quality are probably more heavily influenced by other processes. These processes include flushing of water and solutes from the lower part of the unsaturated zone into the aquifer, underflow phenomena, soil-water interactions, microbial activity, and changes in redox potential.

Water-level response to precipitation is most pronounced when elevated water-table, high soil-moisture conditions prevail at the study site. Addition of a small volume of water to the very moist unsaturated zone is all that is neccessary to trigger a significant water-table rise. While the bulk of infiltrating rain water and

surface-applied contaminant can be held in the unsaturated zone for weeks or months, a small fraction may reach the shallow water table within hours after the onset of precipitation. Root casts and interfaces between adjacent soil peds provide conduits for this short circuiting. The relative magnitude of the documented short-term variation in ground-water quality will depend on both the amount of contaminant available at the surface and the pre-existing contaminant level in the aquifer. Generally, ionic species measured regularly during this study are relatively abundant in the ground water; hence, either a highly contaminated or extremely pristine mass of infiltration water would have to reach the sampled intervals in the aquifer in order for measured concentrations to change significantly. If pre-existing contaminant level is very low, the small percentage of surface pollutant which reaches the ground water may cause a significantly large change in concentration. For example, bromide concentration increased from less than 1 mg/l to 1.6 mg/l in lysimeter L7 during the 24-hour period immediately following application of tracer solution to the "wet" soil profile. This increase in concentration represents at least a 60% change in quality with respect to bromide due to downward migration from land surface to ground water at a rate of 8 ft/day. Conversely, a 0.6 mg/l change in bicarbonate, chloride, nitrate, or sulfate concentration between sampling events would hardly be considered significant for ground-water samples collected from most monitoring wells at the site.

After extended periods of hot, dry weather, the water table below the field site is relatively low and the upper part of the unsaturated zone is well below field capacity. Recharge to the aquifer despite the moisture deficiency, spikes in concentrations of several ionic species in shallow lysimeters, and rapid increases in moisture content following application of tracer solution to the "dry" soil provide evidence for short circuiting of infiltrating precipitation and water soluble materials through the upper portion of the unsaturated zone under these prevailing conditions. However, the combination of dry soil at the surface and the greater depth to the water table renders the aquifer less susceptible to rapid contamination from surface-applied pollutants than when the water table is comparatively shallow and soil-moisture levels are high. Not only does the contaminated mass have further to travel to reach the aquifer, but its ability to percolate is impeded by the "soaking up" effect of dry soil at the surface. Moreover, since less infiltrating water is available to the deeper, wetter portion of the unsaturated zone, water-table response to precipitation is comparatively small.

It is evident from the data presented in this study that hydrogeologic conditions, and thus potential for ground-water contamination, can change considerably over a period of several months. A knowledge of prevailing conditions is critical to understanding the mechanisms by which changes in ground-water quality occur. In this study,

ionic constituents were measured in concentrations of milligrams per liter. The significance of short-term variations resulting from direct infiltration of highly contaminated water would undoubtedly be greater for constituents normally measured at a scale of micrograms per liter. The magnitude of such short-term fluctuations could be larger than the actual long-term changes in concentration. In turn, chemical quality of samples collected quarterly, semi-annually, or annually for compliance with environmental regulations might not provide an accurate basis for characterizing true nature and extent of ground-water contamination.

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APPENDIXES

APPENDIX A

PRECIPITATION

DATE	PRECIPITATION (INCHES)	MONTHLY TOTAL (INCHES)	DATE	PRECIPITATION (INCHES)	MONTHLY TOTAL (INCHES)
04 MAR 88	.22		18 AUG 88	.20	
05 MAR 88	.23		23 AUG 88	.24	
16 MAR 88	.01		27 AUG 88	.04	
17 MAR 88	.53		28 AUG 88	.56	1.04
28 MAR 88	.46				
29 MAR 88	.16				
31 MAR 88	.85	2.46	03 SEP 88	.01	
			15 SEP 88	.71	
			16 SEP 88	2.08	
01 APR 88	1.06		17 SEP 88	.02	
09 APR 88	.96		18 SEP 88	2.90	
17 APR 88	.97		23 SEP 88	.77	
18 APR 88	.04		28 SEP 88	.26	
24 APR 88	.03		29 SEP 88	.01	6.76
25 APR 88	.03				
29 APR 88	.02	3.11	01 OCT 88	.08	
			05 OCT 88	.14	
02 MAY 88	.09		06 OCT 88	.34	
07 MAY 88	.19		07 OCT 88	.40	
15 MAY 88	.62		15 OCT 88	.05	
20 MAY 88	.26		16 OCT 88	.01	
21 MAY 88	.04		20 OCT 88	.18	1.20
22 MAY 88	.76				
23 MAY 88	.20				
31 MAY 88	.04	2.20	11 NOV 88	1.32	
			15 NOV 88	.23	
			18 NOV 88	.31	
01 JUN 88	.04		19 NOV 88	.42	
02 JUN 88	.42		20 NOV 88	.07	
15 JUN 88	.10		26 NOV 88	.02	2.37
26 JUN 88	.10				
27 JUN 88	.01				
28 JUN 88	.13				
30 JUN 88	.46	1.26			
17 JUL 88	.15				
19 JUL 88	.42				
26 JUL 88	.81				
27 JUL 88	.13	1.51			

APPENDIX B

WELL SPECIFICATIONS

WELL SPECIFICATIONS MEASURED IN FEET FROM CONCRETE PAD

WELL	TOTAL DEPTH	SCREENED INTERVAL	DIAMETER
A1	8.5	8.0-8.2	2 INCHES
A2	9.2	8.7-8.9	2 INCHES
A3	10.3	9.9-10.1	2 INCHES
A4	13.8	13.3-13.6	2 INCHES
A5	14.0	7.0-14.0	2 INCHES
B1	6.6	6.1-6.4	.75 INCH
B2	9.3	8.8-9.1	2 INCHES
B3	11.0	10.5-10.8	2 INCHES
B4	13.2	12.7-13.0	2 INCHES
B5	13.4	4.4-13.2	6 INCHES
B6	11.3	11.0-11.2	.5 INCH
B7	13.9	13.6-13.8	.5 INCH
B8	18.7	18.4-18.6	.5 INCH
B9	21.2	20.9-21.1	.5 INCH
B10	25.7	25.4-25.6	.5 INCH
B11	40.3	38.4-40.0	1.25 INCHES
C1	8.3	7.9-8.1	2 INCHES
C2	9.2	8.9-9.1	2 INCHES
C3	10.6	9.9-10.4	2 INCHES
C4	14.6	14.2-14.4	2 INCHES
C5	14.0	7.0-14.0	2 INCHES
D1	8.2	8.0-8.2	2 INCHES
D2	9.3	9.0-9.2	2 INCHES
D3	10.8	9.9-10.4	2 INCHES
D4	14.2	13.6-13.9	2 INCHES
D5	14.0	7.0-14.0	2 INCHES
E1	8.7	8.3-8.5	2 INCHES
E2	9.7	9.3-9.5	2 INCHES
E3	10.5	10.1-10.3	2 INCHES
E4	14.1	13.6-13.9	2 INCHES
E5	14.0	7.0-14.0	2 INCHES
F1	40.0	10.0-40.0	4 INCHES
F2	40.0	10.0-40.0	2 INCHES
G1	10.3	9.7-10.1	1 INCH
G2	14.0	13.5-13.8	1 INCH
H1	10.2	9.6-10.0	1 INCH
H2	13.9	13.4-13.7	1 INCH
I1	11.0	10.4-10.8	1 INCH
I2	14.5	14.0-14.3	1 INCH
I3	14.9	10.0-14.4	2 INCHES
J1	13.5	11.6-13.2	1.25 INCHES

Note: Concrete pad of J1 well is approximately .75 feet below ground surface. A, C, D, and E well specifications from Hagen (1986).

APPENDIX C

WATER LEVEL DATA

ELEVATION OF THE WATER TABLE (FEET)

1988

WELL	03 MAR	07 MAR	10 MAR	15 MAR	16 MAR	19 MAR	23 MAR	27 MAR	01 APR
A1	880.53	880.65	880.32	879.82	879.76	879.86	879.74	879.67	881.51
A2	880.59	880.64	880.31	879.83	879.80	879.86	879.74	879.66	881.58
A3	880.60	880.61	880.30	879.82	879.80	879.86	879.74	879.66	881.57
A4	880.62	880.65	880.33	879.85	879.82	879.89	879.77	879.69	881.62
A5	880.59	880.61	880.29	879.82	879.79	879.86	879.74	879.65	881.57
B1	880.07	880.70	880.45	879.97	879.91	879.99	879.87	879.78	881.17
B2	880.72	880.76	880.43	879.93	879.91	879.98	879.85	879.76	881.76
B3	880.48	880.78	880.44	879.93	879.92	880.01	879.87	879.77	881.51
B4	880.71	880.79	880.45	879.96	879.95	880.01	879.88	879.78	881.78
B5	880.73	880.81	880.49	880.00	879.95	880.03	879.91	879.82	881.84
B6	880.76	880.80	880.48	880.00	879.96	880.03	879.91	879.83	881.86
B7	880.75	880.79	880.48	880.00	879.97	880.04	879.90	879.84	881.86
B8	880.71	880.81	880.49	880.01	879.97	880.04	879.92	879.85	881.85
B9	880.74	880.77	880.46	879.98	879.96	880.03	879.90	879.82	881.84
B10	880.72	880.75	880.44	879.97	879.92	880.00	879.88	879.79	881.82
C1	881.18	880.85	880.51	880.00	879.99	880.07	879.95	879.87	882.03
C2	880.98	880.83	880.51	880.05	880.01	880.09	879.98	879.89	881.96
C3	880.94	880.79	880.49	880.02	879.99	880.08	879.95	879.86	881.95
C4	880.76	880.77	880.49	880.02	879.98	880.09	879.95	879.87	881.91
C5	880.66	880.78	880.48	880.03	879.99	880.08	879.94	879.86	881.95
D1	880.39	881.03	880.86	880.41	880.39	880.51	880.39	880.29	881.87
D2	880.34	881.03	880.86	880.43	880.41	880.50	880.40	880.30	881.79
D3	880.39	881.03	880.85	880.39	880.33	880.50	880.39	880.30	881.79
D4	880.57	881.03	880.82	880.39	880.38	880.48	880.36	880.27	882.08
D5	880.59	881.05	880.86	880.41	880.38	880.50	880.37	880.29	881.93
E1	880.81	881.24	880.99	880.52	880.50	880.58	880.46	880.36	882.18
E2	880.92	881.23	880.98	880.44	880.49	880.58	880.45	880.36	882.07
E3	880.77	881.22	880.99	880.54	880.45	880.57	880.45	880.36	882.10
E4	880.71	881.22	880.97	880.52	880.49	880.55	880.46	880.37	882.08
E5	880.77	881.22	880.99	880.54	880.51	880.60	880.47	880.39	882.09
F1	880.67	880.83	880.55	880.07	880.03	880.08	879.98	879.90	881.82
F2	880.70	880.85	880.55	880.07	880.04	880.10	879.99	879.91	881.84
G1	880.95	881.16	880.90	880.39	880.35	880.38	880.27	880.24	881.93
G2	880.97	881.16	880.87	880.38	880.34	880.38	880.25	880.15	881.98
H1	880.61	881.46	881.32	880.92	880.87	880.89	880.77	880.66	881.98
H2	880.70	881.48	881.36	880.90	880.85	880.87	880.75	880.64	882.11
I1	880.75	880.99	880.75	880.24	880.21	880.29	880.16	880.08	881.85
I2	880.77	880.98	880.69	880.25	880.18	880.27	880.14	880.06	881.91
I3	880.68	880.95	880.65	880.19	880.15	880.23	880.11	880.02	881.90
J1	ND	ND	881.17	880.75	880.69	880.74	880.63	880.53	882.12

ND = No data

ELEVATION OF THE WATER TABLE (FEET)

1988

WELL	02 APR	08 APR	13 APR	16 APR	20 APR	23 APR	27 APR	02 MAY	04 MAY
A1	881.35	880.51	880.65	880.37	880.61	880.26	880.04	879.81	879.65
A2	881.34	880.50	880.64	880.35	880.60	880.24	880.04	879.80	879.64
A3	881.34	880.49	880.66	880.36	880.59	880.26	880.04	879.80	879.66
A4	881.37	880.53	880.68	880.39	880.64	880.29	880.07	879.83	879.67
A5	881.31	880.54	880.62	880.34	880.57	880.24	880.02	879.78	879.64
B1	881.58	880.69	880.84	880.53	880.81	880.42	880.18	879.95	879.79
B2	881.51	880.65	880.80	880.51	880.76	880.40	880.17	879.93	879.77
B3	881.55	880.68	880.83	880.53	880.78	880.42	880.20	879.95	879.79
B4	881.52	880.70	880.84	880.53	880.74	880.44	880.21	879.95	879.79
B5	881.55	880.71	880.85	880.56	880.82	880.45	880.23	879.98	879.82
B6	881.54	880.70	880.85	880.55	880.80	880.45	880.22	879.97	879.82
B7	881.54	880.69	880.84	880.54	880.81	880.45	880.23	879.98	879.82
B8	881.57	880.71	880.84	880.57	880.80	880.43	880.24	879.97	879.84
B9	881.52	880.68	880.84	880.53	880.79	880.43	880.21	879.96	879.81
B10	881.51	880.66	880.82	880.51	880.76	880.41	880.19	879.93	879.77
C1	881.75	880.77	880.95	880.65	880.90	880.54	880.32	880.03	879.86
C2	881.63	880.79	880.95	880.66	880.92	880.56	880.33	880.05	879.88
C3	881.61	880.78	880.94	880.64	880.89	880.54	880.31	880.03	879.87
C4	881.57	880.78	880.95	880.65	880.89	880.54	880.30	880.03	879.86
C5	881.59	880.77	880.94	880.65	880.90	880.54	880.31	880.03	879.86
D1	881.83	881.26	881.41	881.13	881.36	881.02	880.78	880.49	880.32
D2	881.82	881.26	881.40	881.15	881.36	881.02	880.79	880.50	880.33
D3	881.85	881.26	881.43	881.14	881.37	881.02	880.79	880.49	880.32
D4	881.88	881.25	881.43	881.14	881.38	881.00	880.77	880.46	880.28
D5	881.88	881.26	881.42	881.12	881.38	881.01	880.78	880.48	880.30
E1	882.07	881.40	881.57	881.25	881.53	881.15	880.90	880.60	880.42
E2	882.07	881.39	881.55	881.25	881.51	881.14	880.90	880.58	880.40
E3	882.07	881.39	881.55	881.25	881.52	881.14	880.90	880.58	880.41
E4	882.06	881.40	881.56	881.25	881.51	881.13	880.89	880.58	880.40
E5	882.07	881.40	881.57	881.27	881.52	881.16	880.90	880.60	880.42
F1	881.61	880.81	880.95	880.67	880.91	880.56	880.33	880.06	879.90
F2	881.61	880.81	880.96	880.67	880.92	880.56	880.34	880.07	879.90
G1	881.91	881.12	881.25	880.95	881.17	880.84	880.62	880.34	880.17
G2	881.89	881.11	881.22	880.95	881.16	880.84	880.60	880.33	880.16
H1	882.24	881.80	881.99	881.69	881.89	881.57	881.29	880.98	880.78
H2	882.29	881.81	881.93	881.66	881.87	881.54	881.26	880.96	880.76
I1	881.80	881.02	881.18	880.90	881.14	880.78	880.54	880.26	880.07
I2	881.76	881.00	881.16	880.85	881.10	880.75	880.52	880.23	880.07
I3	881.75	880.96	881.13	880.83	881.08	880.71	880.50	880.20	880.04
J1	882.19	881.61	881.77	881.47	881.72	881.36	881.11	880.79	880.61

ELEVATION OF THE WATER TABLE (FEET)

1988

WELL	08 MAY	15 MAY	19 MAY	21 MAY	24 MAY	31 MAY	04 JUN	08 JUN	09 JUN
A1	879.43	878.94	878.75	878.63	878.82	878.39	878.17	ND	ND
A2	879.42	878.93	878.75	878.63	878.82	878.38	878.17	877.94	877.83
A3	879.43	878.93	878.76	878.64	878.83	878.39	878.19	877.97	877.87
A4	879.45	878.96	878.78	878.65	878.85	878.40	878.20	877.97	877.86
A5	879.41	878.92	878.75	878.62	878.82	878.38	878.19	877.96	877.85
B1	879.71	ND	DRY	DRY	ND	DRY	DRY	DRY	DRY
B2	879.56	879.06	878.87	878.76	ND	878.50	878.30	878.10	877.95
B3	879.58	879.08	878.88	878.78	ND	878.51	878.32	878.11	877.97
B4	879.58	879.08	878.89	878.77	ND	878.51	878.31	878.09	877.96
B5	879.61	879.10	878.91	878.80	ND	878.54	878.34	878.12	878.00
B6	879.58	879.10	878.91	878.79	ND	878.53	878.34	878.11	877.99
B7	879.59	879.10	878.90	878.80	ND	878.54	878.35	878.11	878.00
B8	879.59	879.10	878.91	878.80	ND	878.53	878.36	878.10	877.99
B9	879.58	879.09	878.89	878.78	ND	878.53	878.32	878.08	877.97
B10	879.55	879.05	878.87	878.75	ND	878.49	878.30	878.06	877.94
C1	879.61	879.02	878.79	878.66	ND	878.33	878.09	877.79	ND
C2	879.63	879.04	878.81	878.69	ND	878.35	878.12	877.82	877.72
C3	879.60	879.01	878.79	878.65	ND	878.33	878.09	877.80	877.69
C4	879.60	879.01	878.79	878.66	ND	878.34	878.11	877.81	877.70
C5	879.59	879.01	878.78	878.66	ND	878.33	878.10	877.81	877.70
D1	880.03	879.40	879.10	878.94	ND	878.56	878.29	878.00	877.84
D2	880.05	879.41	879.12	878.96	ND	878.58	878.30	878.03	877.87
D3	880.04	879.40	879.11	878.94	ND	878.58	878.30	878.02	877.86
D4	879.99	879.35	879.07	878.91	ND	878.55	878.27	877.97	877.83
D5	880.01	879.36	879.09	878.92	ND	878.57	878.29	877.99	877.85
E1	880.15	879.55	879.28	879.11	ND	878.76	878.51	878.25	878.09
E2	880.14	879.54	879.27	879.10	ND	878.76	878.50	878.24	878.09
E3	880.14	879.54	879.27	879.10	ND	878.76	878.51	878.24	878.09
E4	880.15	879.54	879.27	879.10	ND	878.75	878.50	878.24	878.08
E5	880.15	879.55	879.27	879.11	ND	878.77	878.52	878.26	878.10
F1	879.67	879.13	878.93	878.80	ND	878.52	878.31	878.05	877.93
F2	879.66	879.14	878.94	878.80	ND	878.53	878.32	878.07	877.94
G1	879.98	879.49	879.30	879.19	ND	878.93	878.77	878.55	878.43
G2	879.97	879.49	879.29	879.18	ND	878.92	878.76	878.55	878.42
H1	880.56	880.02	879.73	879.58	ND	879.22	879.01	878.78	878.62
H2	880.54	880.00	879.71	879.56	ND	879.20	878.99	878.75	878.59
I1	879.83	879.27	879.05	878.90	ND	878.60	878.36	878.11	877.98
I2	879.80	879.25	879.04	878.88	ND	878.58	878.35	878.10	877.96
I3	879.78	879.23	878.99	878.86	ND	878.55	878.32	878.07	877.94
J1	880.35	879.76	879.47	879.31	ND	878.96	878.72	878.46	878.31

ND = No data
DRY = Dry well

ELEVATION OF THE WATER TABLE (FEET)

1988

WELL	12 JUN	18 JUN	25 JUN	01 JUL	06 JUL	10 JUL	13 JUL	17 JUL	18 JUL
A1	ND	ND	DRY	DRY	DRY	DRY	DRY	DRY	DRY
A2	877.54	877.17	DRY	DRY	DRY	DRY	DRY	DRY	DRY
A3	877.57	877.20	876.27	ND	ND	DRY	DRY	DRY	DRY
A4	877.57	877.20	876.26	875.77	875.35	875.14	874.90	874.61	874.43
A5	877.56	877.19	876.26	875.78	875.36	875.15	874.91	874.63	874.44
B1	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	ND
B2	877.69	877.26	DRY	DRY	DRY	DRY	DRY	DRY	ND
B3	877.71	877.28	876.41	875.91	875.47	875.29	ND	ND	ND
B4	877.69	877.29	876.38	875.89	ND	ND	875.05	874.74	ND
B5	877.71	877.32	876.42	875.92	875.51	875.30	875.07	874.76	ND
B6	877.72	877.31	876.38	875.93	875.53	875.32	875.08	ND	ND
B7	877.71	877.32	876.40	875.92	875.53	875.30	875.06	874.76	ND
B8	877.72	877.32	876.39	875.93	875.54	875.31	875.07	874.76	ND
B9	877.69	877.30	876.36	875.91	875.51	875.27	875.03	874.72	ND
B10	877.67	877.27	876.34	875.89	875.50	875.26	ND	ND	ND
C1	ND	DRY	DRY	DRY	DRY	DRY	DRY	DRY	ND
C2	877.39	876.99	DRY	DRY	DRY	DRY	DRY	DRY	ND
C3	877.37	876.97	875.92	875.44	ND	ND	DRY	DRY	ND
C4	877.39	876.98	875.94	875.47	875.01	874.80	874.57	874.31	ND
C5	877.38	876.98	875.94	875.46	875.02	874.81	874.56	874.30	ND
D1	ND	DRY	DRY	DRY	DRY	DRY	DRY	DRY	ND
D2	877.53	877.03	DRY	DRY	DRY	DRY	DRY	DRY	ND
D3	877.53	877.04	876.00	875.46	ND	ND	DRY	DRY	ND
D4	877.49	877.03	875.98	875.46	875.02	874.79	874.56	874.25	ND
D5	877.51	877.05	876.00	875.47	875.05	874.81	874.58	874.27	ND
E1	877.80	ND	DRY	DRY	DRY	DRY	DRY	DRY	ND
E2	877.79	877.30	ND	DRY	DRY	DRY	DRY	DRY	ND
E3	877.81	877.32	876.35	875.79	ND	DRY	DRY	DRY	ND
E4	877.79	877.30	876.34	875.78	875.39	875.14	874.91	874.56	ND
E5	877.81	877.31	876.34	875.81	875.41	875.16	874.93	874.59	ND
F1	877.64	877.24	876.30	875.80	875.39	875.17	874.93	874.63	ND
F2	877.66	877.25	876.31	875.81	875.40	875.18	874.94	874.64	ND
G1	878.22	877.80	877.00	876.50	876.18	875.93	875.64	875.29	ND
G2	878.22	877.79	876.98	876.50	876.19	875.92	875.67	875.31	ND
H1	878.42	877.90	877.07	876.56	876.21	875.88	ND	DRY	ND
H2	878.39	877.88	877.05	876.50	876.19	875.88	875.63	875.25	ND
I1	877.69	877.25	876.28	875.76	ND	ND	DRY	DRY	ND
I2	877.66	877.22	876.27	875.75	875.34	875.12	874.88	874.56	ND
I3	877.65	877.21	876.24	875.73	875.33	875.10	874.86	874.54	ND
J1	878.04	877.55	876.63	876.07	875.70	875.44	875.19	874.83	ND

ND = No data
DRY = Dry well

ELEVATION OF THE WATER TABLE (FEET)

1988

WELL	20 JUL	25 JUL	27 JUL	29 JUL	01 AUG	05 AUG	10 AUG	13 AUG	22 AUG
A1	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
A2	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
A3	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
A4	874.58	874.26	874.40	874.59	874.50	874.33	874.09	873.90	873.44
A5	874.59	874.28	874.41	874.61	874.51	874.35	874.10	873.90	873.45
B1	DRY	DRY	ND	DRY	DRY	DRY	DRY	DRY	DRY
B2	DRY	DRY	ND	DRY	DRY	DRY	DRY	DRY	DRY
B3	DRY	DRY	ND	DRY	DRY	DRY	DRY	DRY	DRY
B4	874.69	874.40	ND	874.73	874.65	874.48	874.23	874.02	873.58
B5	874.71	874.44	ND	874.76	874.69	874.52	874.26	874.08	873.65
B6	ND	ND	ND	ND	ND	ND	DRY	DRY	DRY
B7	874.70	874.41	ND	874.74	874.66	874.46	874.25	874.05	873.57
B8	874.72	874.42	ND	874.75	874.67	874.46	874.27	874.07	873.59
B9	874.68	874.37	ND	874.70	874.61	874.42	874.21	874.02	873.53
B10	ND	ND	ND	ND	874.57	874.43	874.22	874.05	873.57
B11	ND	ND	ND	ND	ND	ND	ND	ND	873.59
C1	DRY	DRY	ND	DRY	DRY	DRY	DRY	DRY	DRY
C2	DRY	DRY	ND	DRY	DRY	DRY	DRY	DRY	DRY
C3	DRY	DRY	ND	DRY	DRY	DRY	DRY	DRY	DRY
C4	874.30	873.92	ND	874.19	874.07	873.93	873.72	873.53	873.13
C5	874.29	873.94	ND	874.20	874.07	873.93	873.70	873.53	873.13
D1	DRY	DRY	ND	DRY	DRY	DRY	DRY	DRY	DRY
D2	DRY	DRY	ND	DRY	DRY	DRY	DRY	DRY	DRY
D3	DRY	DRY	ND	DRY	DRY	DRY	DRY	DRY	DRY
D4	874.19	873.86	ND	874.04	873.89	873.75	873.53	873.40	872.99
D5	874.21	873.88	ND	874.06	873.91	873.77	873.56	873.42	873.01
E1	DRY	DRY	ND	DRY	DRY	DRY	DRY	DRY	DRY
E2	DRY	DRY	ND	DRY	DRY	DRY	DRY	DRY	DRY
E3	DRY	DRY	ND	DRY	DRY	DRY	DRY	DRY	DRY
E4	874.47	874.19	ND	874.38	874.27	874.13	873.90	873.74	873.28
E5	874.50	874.21	ND	874.40	874.29	874.14	873.92	873.76	873.31
F1	874.59	874.28	ND	874.58	874.48	874.32	874.07	873.88	873.43
F2	874.59	874.29	ND	874.58	874.48	874.32	874.08	873.89	873.44
G1	ND	ND	ND	875.32	875.29	ND	ND	DRY	DRY
G2	875.23	875.00	ND	875.34	875.32	875.15	874.89	874.69	874.13
H1	DRY	DRY	ND	DRY	DRY	DRY	DRY	DRY	DRY
H2	875.11	874.90	ND	875.08	875.04	874.89	874.68	874.52	873.95
I1	DRY	DRY	ND	DRY	DRY	ND	ND	DRY	DRY
I2	874.52	874.20	ND	874.46	874.35	874.20	ND	873.79	873.34
I3	874.50	874.18	ND	874.45	874.34	874.19	ND	873.78	873.33
J1	874.71	874.46	ND	874.64	874.56	874.41	874.19	874.03	873.54

ND = No data
DRY = Dry well

ELEVATION OF THE WATER TABLE (FEET)

1988

WELL	24 AUG	30 AUG	07 SEP	10 SEP	16 SEP	17 SEP	19 SEP	25 SEP	30 SEP
A1	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
A2	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
A3	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
A4	873.41	873.67	873.40	873.25	874.14	874.26	875.27	875.22	875.26
A5	873.42	873.69	873.42	873.26	874.16	874.28	875.27	875.23	875.28
B1	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
B2	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
B3	DRY	DRY	DRY	DRY	DRY	DRY	876.06	875.47	875.45
B4	873.55	873.76	873.52	873.37	874.27	874.38	875.60	875.39	875.40
B5	873.61	873.71	873.61	873.45	874.12	874.34	875.61	875.46	875.44
B6	DRY	DRY	DRY	DRY	DRY	ND	875.58	875.45	875.47
B7	873.54	873.80	873.52	873.37	874.34	874.43	875.52	875.42	875.45
B8	873.55	873.81	873.53	873.38	874.36	874.45	875.52	875.43	875.46
B9	873.49	873.76	873.47	873.33	874.31	874.40	875.49	875.39	875.43
B10	873.54	873.79	873.50	873.35	874.34	874.42	875.48	875.39	875.43
B11	873.56	873.79	873.53	873.37	874.28	874.42	875.72	875.42	875.44
C1	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
C2	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
C3	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	ND
C4	873.12	873.36	873.12	872.99	873.71	873.84	874.78	874.78	874.85
C5	873.12	873.36	873.12	872.98	873.71	873.84	874.71	874.77	874.83
D1	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
D2	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
D3	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
D4	872.97	873.14	872.96	872.84	873.41	873.55	874.45	874.56	874.62
D5	873.00	873.18	872.98	872.86	873.42	873.57	874.46	874.57	874.63
E1	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
E2	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
E3	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
E4	873.25	873.41	873.21	873.08	873.77	873.86	874.95	874.94	874.98
E5	873.27	873.44	873.24	873.11	873.79	873.90	874.98	874.98	875.01
F1	873.41	873.64	873.39	873.25	874.10	874.20	875.24	875.20	875.23
F2	873.41	873.64	873.40	873.25	874.11	874.20	875.24	875.20	875.24
G1	DRY	DRY	DRY	DRY	ND	ND	876.13	876.20	876.08
G2	874.05	874.25	874.03	873.84	874.95	874.99	876.30	876.15	876.11
H1	DRY	DRY	DRY	DRY	DRY	DRY	ND	ND	ND
H2	873.89	874.03	873.82	873.67	874.41	874.51	875.90	875.79	875.77
I1	DRY	DRY	DRY	DRY	DRY	DRY	DRY	ND	ND
I2	873.32	873.53	873.27	873.16	873.94	874.04	874.99	ND	875.07
I3	873.31	873.53	873.27	873.16	873.94	874.03	874.98	ND	875.06
J1	873.49	873.63	873.43	873.30	873.99	874.11	875.28	875.25	875.27

ND = No data
DRY = Dry well

ELEVATION OF THE WATER TABLE (FEET)

1988

WELL	04 OCT	07 OCT	13 OCT	17 OCT	22 OCT	02 NOV	07 NOV	15 NOV	21 NOV
A1	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
A2	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	ND
A3	DRY	875.50	875.49	875.49	875.56	875.66	875.61	876.13	876.62
A4	875.25	875.58	875.53	875.48	875.59	875.66	875.63	876.16	876.65
A5	875.26	875.59	875.54	875.48	875.60	875.68	875.63	876.17	876.66
B1	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
B2	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	ND
B3	875.45	875.59	875.74	875.70	875.70	875.77	875.76	876.22	876.84
B4	875.41	875.71	875.69	875.65	875.71	875.80	875.77	876.26	876.78
B5	875.46	875.77	875.74	875.70	875.74	875.82	875.81	876.26	876.83
B6	875.45	875.69	875.75	875.69	875.73	875.84	875.77	876.27	876.59
B7	875.43	875.75	875.72	875.65	875.76	875.83	875.76	876.30	876.79
B8	875.45	875.75	875.72	875.66	875.75	875.84	875.77	876.31	876.83
B9	875.41	875.78	875.69	875.62	875.74	875.80	875.73	876.28	876.74
B10	875.40	875.76	875.69	875.62	875.73	875.79	875.74	876.27	876.78
B11	875.43	875.67	875.71	875.66	875.76	875.83	875.77	876.30	876.82
C1	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
C2	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
C3	ND	ND	ND	ND	ND	875.21	875.21	875.67	876.13
C4	874.84	875.10	875.10	875.04	875.21	875.31	875.28	875.82	876.23
C5	874.83	875.14	875.09	875.03	875.19	875.30	875.26	875.80	876.27
D1	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
D2	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
D3	DRY	ND	ND	ND	ND	ND	ND	875.43	875.88
D4	874.62	874.90	874.93	874.89	875.00	875.13	875.09	875.62	876.14
D5	874.63	874.91	874.95	874.90	875.00	875.13	875.09	875.62	876.14
E1	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
E2	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	ND
E3	DRY	DRY	ND	ND	ND	ND	ND	875.92	877.01
E4	874.98	875.21	875.30	875.25	875.32	875.43	875.38	875.91	876.47
E5	875.00	875.32	875.32	875.27	875.36	875.46	875.40	875.94	876.58
F1	875.21	875.58	875.51	875.45	875.56	875.64	875.59	876.12	876.62
F2	875.22	875.58	875.51	875.45	875.56	875.64	875.59	876.14	876.63
G1	876.08	876.29	876.38	876.32	876.37	876.40	876.29	876.83	877.26
G2	876.08	876.38	876.38	876.31	876.35	876.40	876.29	876.82	877.32
H1	ND	875.98	876.08	876.05	876.08	876.01	876.03	876.52	876.79
H2	875.76	876.00	876.08	876.03	876.07	876.12	876.01	876.52	876.99
I1	ND	ND	ND	ND	ND	875.53	ND	ND	ND
I2	ND	875.40	875.36	875.32	875.44	875.50	ND	ND	ND
I3	ND	875.40	875.37	875.32	875.45	875.50	ND	ND	ND
J1	875.26	875.54	875.58	ND	875.59	875.67	875.60	876.12	876.65

ND = No data
DRY = Dry well

ELEVATION OF THE WATER TABLE (FEET)

1988

WELL	22 NOV	28 NOV	03 DEC
A1	DRY	DRY	DRY
A2	ND	ND	ND
A3	876.63	876.71	876.85
A4	876.71	876.80	876.86
A5	876.72	876.81	876.86
B1	DRY	DRY	DRY
B2	ND	ND	ND
B3	876.91	876.88	876.96
B4	876.85	876.88	876.97
B5	876.89	876.89	877.01
B6	876.75	877.06	877.01
B7	876.84	877.05	877.00
B8	876.88	876.97	877.01
B9	876.85	876.95	876.98
B10	876.84	876.93	876.97
B11	876.87	876.95	876.99
C1	DRY	DRY	DRY
C2	DRY	ND	ND
C3	876.14	876.37	876.46
C4	876.30	876.50	876.55
C5	876.33	876.49	876.54
D1	DRY	DRY	DRY
D2	DRY	DRY	ND
D3	875.91	876.18	876.31
D4	876.19	876.37	876.42
D5	876.20	876.37	876.42
E1	DRY	DRY	DRY
E2	876.65	876.74	876.70
E3	876.80	876.83	876.70
E4	876.49	876.64	876.69
E5	876.53	876.68	876.72
F1	876.69	876.80	876.84
F2	876.69	876.81	876.85
G1	877.29	877.46	877.49
G2	877.38	877.46	877.48
H1	876.85	876.92	877.28
H2	877.08	877.25	877.27
I1	876.61	876.72	876.77
I2	876.62	876.72	876.74
I3	876.63	876.71	876.75
J1	876.71	876.87	876.90

ND = No data
DRY = Dry well

APPENDIX D

WATER QUALITY DATA

19 MARCH 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1	8.4	6.47	859	212	15.9	*	95.8	124.7
L2					24.4	*	54.8	109.1
L3	11.1	6.49	375	122	10.0	*	38.5	35.2
L4	10.2	6.01	306	97	8.0	*	33.1	23.6
L5	12.0	6.15	477	159	11.4	*	37.6	46.9
L6	12.9	6.44	815	454	17.4	*	6.8	33.4
L6B	12.2	6.54	879	505	10.3	*	15.4	37.6
L7	13.9	6.62	1284	805	32.1	*	7.7	29.6
A1	12.5	6.68	1040	647	20.5	1.7	17.4	34.3
A2	13.3	6.69	1094	639	23.2	*	24.2	31.2
A3	14.2	6.74	1072	639	22.4	*	24.4	28.3
A4	15.7	6.76	1030	600	20.9	*	28.1	28.4
A5	15.6	6.81	1039	607	22.2	*	28.2	28.1
B6	14.1	7.13	1238		13.5	*	5.0	35.8
B7	15.3	6.93	1270	757	16.5	*	7.1	69.3
B8	17.3	6.91	1462	798	23.0	*	6.5	172.8
B9	14.5	6.86	960	560	19.3	*	23.0	32.4
B10	18.0	6.99	902	545	19.0	*	17.8	26.1
C1	13.0	6.96	1508	826	66.4	*	9.1	113.8
C2	13.4	6.91	1445	841	51.9	*	9.8	88.8
C3	13.8	6.87	1250	738	42.4	*	19.8	55.1
C4	15.0	6.85	1052	613	31.1	*	34.5	40.2
C5	14.6	6.92	1174	665	44.6	*	26.0	57.7
D1	11.8	7.17	1557	639	144.3	1.8	8.6	64.7
D2	12.4	6.98	1425	772	65.8	*	4.4	48.7
D3	13.5	6.94	1326	690	96.5	*	5.4	32.1
D4	14.4	7.04	1165	632	43.5	*	30.6	46.5
D5	14.3	7.07	1102	642	32.7	*	26.8	33.0
E1	16.5	6.98	597	374	4.3	*	19.9	17.5
E2	17.2	6.97	595	375	4.7	*	19.1	16.6
E3	13.7	7.09	529	305	4.5	*	19.0	16.1
E4	14.5	6.88	1061	613	21.7	*	32.7	38.8
E5	14.0	6.90	734	435	7.1	*	21.3	21.7
G1	15.7	6.86	1001	584	16.7	*	46.3	34.5
G2	17.2	6.89	1067	623	21.1	*	34.9	36.8
H1	19.5	7.02	1063	621	21.2	*	53.2	65.7
H2	18.8	7.15	1167	614	32.6	*	37.3	117.6
I1	16.5	6.99	914	397	24.8	*	34.8	138.5
I2	17.8	6.83	927	479	16.1	*	106.6	46.7
I3	17.0	7.09	825	424	15.9	*	67.7	49.6
J1	18.8	6.95	1026	665	16.1	*	35.1	33.8

* = Concentration below detectable limit

27 MARCH 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1	18.7	6.46	751	207	15.7	*	102.6	116.5
L2	17.2	6.09	604	165	23.4	*	58.8	102.3
L3	17.1	5.88	421	141	10.2	*	39.8	47.2
L4	16.6	5.77	333	117	9.0	*	37.2	26.7
L5	20.6				10.6	*	35.3	54.2
L6	17.3	6.36	740	441	17.1	*	8.1	32.5
L6B	16.6	6.49	824	516	10.6	*	14.5	36.9
L7	17.1	6.53	1198	913	31.2	*	4.8	29.4
A3	19.9	6.59	948	635	21.7	*	23.9	28.6
A4	21.2	6.56	914	595	19.6	*	28.7	29.1
C3	16.6	6.81	1290	773	45.2	*	15.7	66.3
C4	17.6	6.77	1024	607	33.3	*	32.3	41.0
D3	18.9	6.94	1323	693	127.8	1.6	4.7	35.7
D4	20.5	6.96	1013	637	43.7	*	31.5	40.1
E3	15.8	7.06	578	351	5.5	*	19.2	16.5
E4	16.6	6.99	1063	638	22.9	*	29.9	39.5
G1	17.3	6.63	1000	592	17.3	*	45.3	34.8
G2	20.0	6.76	991	629	21.1	*	32.5	36.0
H1	18.8	7.00	1080	621	25.4	*	54.3	65.8
H2	19.6	7.08	1169	619	30.9	*	35.0	116.3
I1	16.3	6.80	970	436	22.9	*	43.7	124.2
I2	17.6	6.69	955	485	15.6	*	94.9	47.8

02 APRIL 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1	18.3	6.61	641	201	15.8	*	104.9	119.2
L2	18.6	6.41	517	153	21.4	*	63.4	98.5
L3	19.2	6.24	479	52	13.4	*	34.1	155.1
L4	19.3	6.17	331	78	9.3	*	38.1	70.3
L5					13.9	*	38.8	86.0
L6	19.8	6.62	662	436	17.0	*	9.3	33.8
L6B	19.5	6.74	769	525	10.9	*	15.0	41.5
L7	20.3	6.81	1042	794	30.6	*	5.3	29.7
A3	18.4	6.81	926	607	19.8	*	24.9	29.2
A4	18.7	6.89	930	591	18.0	*	35.6	29.8
C3	17.6	6.87	1145	700	53.1	*	11.9	78.1
C4	18.2	6.88	991	627	41.6	*	24.2	50.8
D3	14.6	7.00	1238	757	82.2	*	6.6	33.9
D4	15.3	7.12	1060	636	35.7	*	31.3	33.8
E3	15.5	7.24	457	272	5.0	*	21.4	17.6
E4	16.2	7.16	937	598	20.0	*	27.2	36.6
G1	17.6	6.81	936	593	16.8	*	46.8	34.5
G2	18.4	6.93	981	629	21.0	*	32.7	36.0
H1	14.1	6.92	1115	633	27.6	*	53.0	64.0
H2	15.2	7.05	1184	629	31.4	*	35.0	114.2
I1	15.4	6.91	952	466	21.2	*	54.5	103.8
I2	17.0	6.85	927	490	14.7	*	90.4	46.6

* = Concentration below detectable limit

13 APRIL 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1	16.1	6.55	767	262	15.9	*	105.3	120.5
L2	15.3	6.28	601	151	20.8	*	71.8	99.6
L3	14.7	6.08	311	98	6.0	*	36.9	39.9
L4	14.8	6.02	280	92	5.8	*	33.6	31.7
L5	14.4	6.56	561		12.1	*	37.2	89.7
L6	14.4	6.65	740	415	16.9	*	11.4	35.0
L6B	14.3	6.72	865	537	10.5	*	14.5	39.6
L7	14.7	6.73	1198	787	29.7	*	5.0	30.6
A3	18.6	6.83	945	621	15.6	*	26.8	30.4
A4	19.1	6.93	898	581	16.1	*	35.3	31.0
C3	16.5	6.88	1336	750	66.3	*	10.4	85.9
C4	17.1	6.87	1030	625	37.7	*	25.2	47.1
D3	13.8	7.02	1287	729	68.5	*	7.3	32.8
D4	14.4	7.14	1106	639	31.8	*	33.4	32.5
E3	15.0	7.27	569	334	4.8	*	22.2	18.3
E4	16.1	7.12	1027	652	22.2	*	24.8	38.5
G1	15.1	6.97	1028	600	14.0	*	56.4	34.4
G2	16.0	7.01	1057	641	19.9	*	38.3	36.0
H1	15.2	7.18	1130	619	24.5	*	53.4	64.1
H2	15.9	7.26	1213	636	32.9	*	36.4	110.1
I1	16.5	6.86	1066	516	23.6	*	58.2	110.1
I2	16.8	6.80	966	494	13.9	*	87.8	47.2

20 APRIL 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1	17.9	6.57	767	244	15.5	*	81.1	119.3
L2	17.6	6.30	601	162	20.0	*	61.4	100.3
L3	18.1	5.88	234	78	5.6	*	26.5	24.1
L4	17.6	5.83	242	82	5.3	*	24.2	24.9
L5	18.3	6.28	502	189	10.8	*	35.3	74.8
L6	17.6	6.44	714	416	16.6	*	12.6	35.4
L6B	18.0	6.64	847	543	10.3	*	13.7	37.4
L7	17.6	6.63	1150	789	27.4	*	5.8	30.2
A3	17.3	6.70	1005	606	14.7	*	28.6	31.1
A4	17.7	6.72	919	551	15.8	*	39.4	31.0
C3	15.4	6.75	1375	772	71.2	*	11.0	88.0
C4	16.1	6.75	1070	632	36.1	*	25.4	45.7
D3	16.0	6.90	1231	728	66.0	*	7.4	32.5
D4	16.5	6.99	1083	651	32.2	*	33.2	31.8
E3	16.3	7.05	548	325	4.6	*	22.1	17.5
E4	16.9	6.97	1051	653	21.8	*	23.5	38.2
G1	18.4	6.81	1015	606	14.9	*	61.1	33.9
G2	19.1	6.88	1038	635	21.6	*	40.1	35.7
H1	17.2	7.03	1136	629	23.9	*	52.1	62.0
H2	18.0	7.12	1213	644	32.7	*	36.6	105.4
I1	16.5	6.69	1083	604	22.6	*	59.9	112.7
I2	18.1	6.63	930	500	13.5	*	82.1	46.5

* = Concentration below detectable limit

27 APRIL 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1	17.4	6.81	724	272	14.5	*	44.0	118.7
L2	17.3	6.45	573	177	18.8	*	41.6	100.6
L3	17.4	6.07	382	124	6.9	*	44.8	41.2
L4	17.2	6.07	299	116	6.2	*	24.1	31.3
L5	16.4	6.43	479	180	10.8	*	34.1	69.6
L6	17.4	6.63	700	415	16.4	*	13.9	36.4
L6B	17.4	6.72	834	549	10.0	*	13.3	37.1
L7	17.5	6.78	1140	784	26.2	*	5.5	30.6
A3	17.2	6.78	959	593	17.8	*	30.1	30.9
A4	17.1	6.85	894	526	16.3	*	41.4	30.8
C3	16.6	6.76	1355	773	70.1	*	10.7	87.2
C4	16.9	6.76	1027	632	33.6	*	25.4	43.8
D3	15.0	6.85	1279	780	87.3	*	7.4	33.9
D4	15.5	6.98	1137	634	72.0	*	39.7	54.6
E3	17.1	7.08	558	344	4.8	*	20.6	17.2
E4	17.2	6.99	1040	660	21.9	*	23.3	38.0
G1	15.9	6.87	1017	601	13.9	*	65.5	34.2
G2	16.3	6.92	1058	641	16.8	*	42.5	36.0
H1	18.1	7.12	1052	619	23.0	*	50.9	60.6
H2	18.5	7.13	1147	648	28.2	*	36.9	97.1
I1	16.9	6.70	1103	546	24.6	*	58.6	117.4
I2	17.1	6.72	940	499	13.0	*	78.9	45.3

04 MAY 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1	17.9	7.00	657	275	12.9	*	21.3	119.8
L2	17.7	6.31	534	177	17.8	*	30.1	98.6
L3	17.7	6.05	424	137	8.1	*	50.3	54.1
L4	17.6	6.00	318	121	6.9	*	23.7	34.3
L6	16.7	6.63	704	400	16.0	*	15.5	36.9
L6B	16.6	6.70	859	552	9.6	*	12.6	36.4
L7	16.8	6.77	1166	779	26.1	*	6.1	30.1
A3	16.1	6.81	957	584	16.3	*	30.4	30.8
A4	16.4	6.86	886	508	16.4	*	42.2	30.7
C3	15.2	6.72	1382	789	73.1	*	10.3	88.1
C4	15.5	6.72	1022	624	32.5	*	24.1	42.9
D3	17.5	6.93	1367	726	132.6	1.7	4.8	37.7
D4	17.6	7.01	1101	638	60.5	*	31.4	41.5
E3	16.7	7.12	598	380	5.8	*	19.3	18.7
E4	16.6	7.00	1052	671	27.8	*	22.9	38.6
G1	16.3	6.90	1035	608	17.2	*	69.1	33.2
G2	16.6	6.94	1077	649	19.5	*	45.1	35.7
H1	17.4	7.10	1060	622	23.1	*	51.1	57.2
H2	17.5	7.19	1166	653	31.9	*	36.4	95.5
I1	18.8	6.62	1080	558	26.0	*	59.1	115.9
I2	19.0	6.62	892	505	12.6	*	77.6	44.0

* = Concentration below detectable limit

11 MAY 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1	24.8	7.29	611	256	12.5	*	10.7	125.7
L2	23.5	6.50	542	201	18.0	*	19.2	105.3
L3	21.8	5.96	458	137	8.6	*	48.3	58.7
L4	21.7	5.92	342	125	7.6	*	24.2	36.8
L6	19.1	6.57	662	403	16.0	*	16.6	37.4
L6B	18.9	6.54	889	629	9.3	*	11.6	35.6
L7	18.9	6.64	1209	770	25.5	*	5.8	29.7

12 MAY 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1					10.4	*	7.7	96.8
L2					17.1	*	13.9	100.4
L3	25.4	6.53	297	116	7.1	*	26.1	34.5
L4	24.9	6.59	281	110	7.3	*	19.5	27.1
L5	24.6	7.04	376	140	11.6	*	24.3	41.2
L6	22.1	7.01	752	415	16.1	*	17.2	36.9
L6B	19.2	6.48	940	554	9.1	*	11.4	35.0
L7	20.6	7.08	1252	769	25.8	*	6.3	29.1

13 MAY 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1					9.2	*	5.1	106.9
L2					16.8	5.2	11.7	101.5
L3	21.3	5.78	821	43	5.7	408.9	14.7	14.6
L4	20.4	5.83	716	140	6.0	318.4	16.3	18.7
L5	21.0	6.72	563		9.8	118.1	22.9	35.8
L6	19.2	6.68	791	409	15.8	*	18.2	37.5
L6B	18.3	6.46	970	506	8.8	39.0	11.3	34.2
L7	18.5	6.68	1306	775	25.8	1.6	6.9	29.9

14 MAY 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1					8.1	*	4.1	93.5
L2					15.2	*	10.4	92.4
L3	25.0	6.36	613		7.4	228.6	24.2	32.0
L4	24.6	6.32	469		7.1	154.5	20.0	27.4
L5					8.5	115.2	17.6	29.9
L6	21.8	6.60	707	403	15.6	*	18.5	37.2
L6B	21.2	6.54	877	532	9.1	12.1	11.4	36.1
L7	21.2	6.71	1156	744	25.4	*	7.0	29.4

* = Concentration below detectable limit

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16 MAY 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1					8.6	2.8	5.3	111.4
L2					16.5	1.7	10.0	100.8
L3	22.8	6.01	366	92	6.9	98.5	14.9	24.9
L4	22.0	5.91	412	84	8.0	119.9	21.4	27.9
L5					9.4	117.2	22.4	38.0
L6	19.2	6.47	706	409	15.9	*	19.6	38.2
L6B	19.2	6.36	872	540	9.2	15.0	10.9	36.0
L7	18.8	6.60	1130	778	25.8	*	7.9	30.0

18 MAY 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1					9.2	6.0	4.2	126.0
L2					17.6	*	8.4	106.0
L3	28.3	6.55	404	128	7.8	91.2	19.9	43.1
L4	27.0	6.35	408	104	8.5	108.9	23.3	33.0
L5						63.6		
L6	22.4	6.63	686	386	15.6	*	19.7	37.8
L6B	21.5	6.55	868	526	9.3	21.0	10.1	36.0
L7	21.3	6.75	1129	754	25.4	*	7.2	29.6

19 MAY 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
A3	17.6	6.75	939	572	16.4	*	31.5	30.6
A4	18.3	6.82	854	490	16.2	*	42.6	29.9
C3	16.1	6.81	1475	792	70.3	*	8.2	91.0
C4	16.2	6.81	1048	622	29.2	*	22.8	41.6
D3	16.9	6.90	1683	737	162.7	1.9	4.2	42.0
D4	16.3	6.99	1136	648	40.3	*	33.1	33.1
E3	17.2	7.14	664	400	6.6	*	18.7	20.5
E4	17.3	6.95	1088	665	29.5	*	23.2	37.4
G1	18.7	6.85	1088	616	19.5	*	74.3	34.8
G2	18.2	6.85	1104	657	18.0	*	51.2	35.8
H1	19.0	7.10	1098	619	21.2	*	52.0	54.8
H2	18.6	7.14	1193	651	31.8	*	39.9	90.1
I1	19.3	6.75	1139	583	23.6	*	60.9	109.1
I2	19.5	6.68	919	494	12.6	*	75.3	43.2

* = Concentration below detectable limit

21 MAY 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1	25.1		648		9.3	11.3	4.3	128.4
L2	25.0		502		18.1	1.4	7.6	103.2
L3	23.3	6.01	394	101	7.6	64.4	17.9	37.8
L4	22.5	5.99	433	107	8.1	102.9	23.1	30.9
L5						57.6		
L6	19.5	6.44	713	383	15.7	*	20.3	38.2
L6B	19.5	6.42	887	524	9.1	23.3	9.6	35.5
L7	18.6	6.61	1179	760	25.6	*	7.3	30.2

24 MAY 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1					8.6	17.8	4.3	119.8
L2					17.4	1.5	6.8	101.3
L3	23.4	5.98	233	75	4.7	25.6	10.2	17.4
L4	23.2	5.95	284	90	5.5	40.3	16.4	20.8
L5					8.9	62.1	16.4	38.2
L6	20.2	6.54	704	371	15.7	*	20.8	38.6
L6B	20.3	6.53	877	518	9.0	26.3	9.3	35.4
L7	19.4	6.68	1157	752	25.5	*	7.3	30.3

31 MAY 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1	25.8	6.89	690	308	9.2	26.1	4.6	128.5
L2	25.8	6.54	509	220	17.9	2.5	6.6	101.6
L3	23.8	6.12	420	146	7.0	58.2	12.7	42.4
L4	23.2	6.04	398	121	7.1	80.3	19.7	30.3
L5						44.5		
L6	20.6	6.55	701	380	15.9	*	20.5	39.4
L6B	20.3	6.68	859	523	8.9	27.7	8.9	35.0
L7	19.7	6.67	1179	772	25.0	*	6.6	31.0
A3	19.3	6.61	962	561	16.4	*	32.8	30.4
A4	20.0	6.76	873	481	16.6	*	44.0	29.9
C3	16.5	6.82	1436	786	61.5	*	10.2	81.4
C4	16.3	6.81	1018	612	23.1	*	23.1	38.5
D3	18.5	7.12	1501	749	127.2	1.7	4.1	34.7
D4	16.6	7.00	1123	648	40.1	*	34.4	32.5
E3	18.2	6.99	658	396	6.5	*	20.9	22.4
E4	17.9	6.92	1083	654	30.1	*	23.4	36.1
G1	19.9	6.80	1103	624	20.3	*	77.0	35.6
G2	19.3	6.86	1119	655	22.0	*	53.4	36.1
H1	19.9	7.08	1110	616	19.0	*	53.1	53.9
H2	19.1	7.11	1220	652	31.4	*	40.8	88.7
I1	19.5	6.90	1165	607	18.7	*	58.0	107.5
I2	18.7	6.84	921	496	12.6	*	74.7	43.0

* = Concentration below detectable limit

09 JUNE 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1	25.1	6.77	677	262	9.3	32.6	5.2	135.5
L2	24.9	6.58	514	217	17.9	3.6	6.5	100.9
L3	25.8	6.07	375	131	6.8	45.8	19.6	38.3
L4	23.0	5.97	392	111	7.1	69.2	28.1	29.9
L6	23.2	6.52	629	372	15.6	*	20.3	39.1
L6B	21.7	6.55	815	511	8.7	24.7	8.1	34.8
L7	20.6	6.52	1121	755	24.5	*	6.7	30.3
A3	17.9	6.81	939	554	15.8	*	33.4	30.5
A4	17.8	6.89	858	489	16.2	*	44.8	29.8
C3	16.0	6.85	1294	764	45.5	*	12.5	62.9
C4	16.1	6.84	1002	616	22.4	*	21.6	38.7
D3	17.8	7.09	1464	769	122.2	1.7	3.9	36.2
D4	17.1	7.01	1089	650	39.6	*	34.2	32.7
E3	18.2	7.22	642	387	5.8	*	18.3	19.7
E4	17.6	6.91	1092	664	30.1	*	25.0	36.9
G1	21.5	6.62	1092	644	18.7	*	77.4	35.8
G2	20.2	6.71	1109	660	22.5	*	55.4	36.2
H1	21.0	6.92	1039	583	16.2	*	55.3	48.5
H2	19.4	7.08	1226	648	31.7	*	41.0	89.0
I1	20.9	6.73	1145	601	24.1	*	54.2	109.7
I2	19.1	6.58	923	487	13.1	*	74.9	43.3

18 JUNE 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1					9.1	29.0	6.4	131.7
L2	30.7	6.63	503	183	19.6	4.5	8.3	103.6
L3	28.2	5.90	442	154	9.0	63.2	17.0	50.4
L4	27.1	5.76	422	124	8.9	83.6	28.2	34.1
L6	23.7	6.39	668	371	15.5	1.5	20.3	38.8
L6B	23.6	6.34	689	392	9.3	16.6	10.9	39.1
L7	22.5	6.52	1142	752	23.9	*	6.7	30.5
A3	20.9	6.69	969	582	16.7	*	27.9	30.2
A4	22.7	6.87	845	491	15.2	*	44.3	29.6
C3	18.4	6.71	1308	773	41.2	*	12.7	60.1
C4	18.2	6.70	986	603	17.7	*	22.9	36.5
D3	24.1	7.18	1374	758	105.8	1.6	3.4	33.6
D4	18.8	6.87	1125	648	39.6	*	34.9	32.7
E3	21.6	7.10	644	387	5.7	*	17.7	19.1
E4	21.4	6.85	1088	665	23.8	*	26.6	38.4
G1	22.4	6.64	1104	627	19.2	*	77.9	36.6
G2	21.0	6.72	1124	656	22.4	*	57.2	36.7
H1	24.0	6.98	970	583	13.9	*	56.0	46.7
H2	22.4	7.03	1195	656	32.3	*	40.6	92.2
I1	25.4	7.13	1099	613	26.2	*	38.4	136.3
I2	21.8	6.65	909	487	13.7	*	74.5	43.5

* = Concentration below detectable limit

01 JULY 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L2	26.9	6.09	323	76	9.1	9.0	50.6	45.4
L3	26.5	6.09	395	127	9.0	54.2	15.3	45.7
L4	26.2	5.96	422	102	11.9	73.2	35.5	37.6
L6	22.9	6.39	664	368	15.2	1.6	20.1	38.3
L6B	23.1	6.20	666	374	9.4	18.5	11.7	41.3
L7	21.8	6.61	1121	736	21.4	*	5.3	26.3
A3	20.2	7.00	1078	651	30.7	*	20.2	34.7
A4	19.3	6.83	915	537	16.5	*	35.3	30.3
A5	19.1	6.62	951	545	17.1	*	44.5	32.1
B6	23.2	7.47	1076		12.3	*	4.7	30.2
B7	21.2	6.89	1195	764	15.6	*	4.4	48.6
B8	21.7	6.79	1479		20.5	*	3.4	152.5
B9	20.0	6.74	1024	609	21.0	*	30.4	42.9
B10	19.7	6.71	990	592	21.2	*	29.6	27.7
C3	18.4	7.24	1152	691	24.8	*	19.3	42.4
C4	16.7	6.73	976	597	17.2	*	23.5	34.4
C5	16.7	6.73	994	613	18.1	*	23.0	37.6
D3	20.3	8.15	1249		91.2	*	3.7	31.3
D4	18.0	6.96	1120	645	38.4	*	32.3	32.8
D5	16.7	6.97	1118	650	37.8	*	30.0	33.0
E3	19.6	7.54	616	397	5.1	*	17.0	19.2
E4	17.9	6.98	1087	654	18.5	*	33.9	41.6
E5	17.9	6.91	1017	619	15.8	*	37.2	38.1
G1	22.4	6.96	1069	632	18.8	*	74.9	34.4
G2	21.1	6.85	1124	655	22.0	*	60.0	36.3
H1	21.1	7.26	1042	596	13.7	*	63.6	46.9
H2	20.3	7.03	1228	662	32.4	*	41.0	100.1
I1	23.5	7.56	865	647	28.8	*	27.0	145.6
I2	19.9	6.53	950	486	14.2	*	80.2	45.5
I3	19.1	6.68	960	497	14.0	*	80.5	45.5
J1	19.3	6.94	1061	654	11.9	*	46.4	31.9

* = Concentration below detectable limit

10 JULY 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L2	27.8	6.76	641		84.8	10.4	26.3	94.8
L3	27.5	6.36	422	124	14.8	55.4	10.0	55.3
L4	27.1	5.91	440	102	14.3	68.8	43.2	43.1
L6	24.0	6.32	699	390	15.1	1.9	20.2	37.9
L6B	24.1	6.29	673	374	8.9	21.9	11.6	40.3
L7	22.8	6.56	1125	745	21.6	*	5.7	31.5
A4	20.3	6.73	967	559	16.6	*	35.8	30.3
C4	17.6	6.66	972	596	18.1	*	25.4	34.0
D4	18.1	6.83	1117	638	36.2	*	29.5	32.5
E4	20.1	6.79	1091	638	18.2	*	39.0	41.2
G1	22.8	7.09	1090	647	19.6	*	71.7	37.6
G2	20.3	6.75	1169	670	21.8	*	60.8	35.8
H1	24.0	7.59	988		12.9	*	63.9	46.8
H2	20.4	7.01	1274	659	30.8	*	42.8	102.7
I2	19.8	6.61	977	482	13.9	*	87.6	44.4

17 JULY 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L3	31.3	6.91	403	98	18.6	56.1	8.1	58.6
L4	30.0	6.28	436	98	18.3	69.9	43.0	48.8
L6	26.5	6.39	688	401	14.8	2.2	20.7	37.3
L6B	26.8	6.62	644	374	8.7	24.5	11.2	40.0
L7	25.9	6.74	1028	712	20.5	*	5.9	35.3
A4	23.7	6.66	935	576	18.5	*	35.8	31.0
C4	20.0	6.80	976	600	19.4	*	26.8	33.5
D4	19.8	7.00	1093	642	35.2	*	27.9	32.4
E4	22.1	6.99	1055	638	17.7	*	40.9	40.5
G2	22.5	6.87	1114	668	21.5	*	58.7	35.4
H2	22.7	7.09	1204	654	29.9	*	43.1	104.6
I2	24.7	6.65	839	480	14.2	*	89.5	43.8

20 JULY 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L3	34.0		384		25.3	54.9	8.3	59.4
L4	32.1	5.89	468	66	19.6	35.9	121.0	46.4
L6	28.8	6.44	662	409	14.8	2.4	21.5	36.6
L6B	29.8	6.39	581	366	8.8	24.8	9.8	38.5
L7	29.2	6.88	927	690	20.0	1.5	6.3	36.3
A4	22.5	6.75	985	590	18.7	*	35.3	31.3
C4	18.3	6.70	1014	585	20.5	*	28.0	33.9
D4	18.1	6.87	1156	637	35.3	*	27.4	32.5
E4	20.7	6.96	1062	633	17.6	*	40.7	40.2
G2	21.9	6.58	1151	668	21.6	*	58.6	35.4
H2	22.5	6.98	1240	648	30.2	*	43.2	106.7
I2	20.9	6.62	957	479	14.6	*	90.3	44.0

* = Concentration below detectable limit

29 JULY 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L3	28.4	6.11	486	122	33.1	52.7	19.0	65.7
L4	27.9	5.78	410	73	17.1	34.6	100.9	48.2
L6	25.3	6.33	718	415	14.7	2.7	21.5	37.1
L6B	25.4	6.26	654	366	9.0	27.2	9.4	40.0
L7	24.3	6.56	1089	728	22.1	1.5	6.9	39.2
A4	21.5	6.72	1040	625	20.1	*	33.4	32.4
C4	18.6	6.84	1023	594	24.3	*	32.3	33.8
D4	18.8	6.99	1104	642	30.7	*	22.1	27.3
E4	20.6	6.99	1013	601	16.7	*	37.9	37.7
G2	22.3	6.71	1142	672	24.0	*	54.1	34.4
H2	22.3	7.02	1261	643	30.8	*	43.3	111.1
I2	21.2	6.68	963	475	15.6	*	95.6	43.8

05 AUGUST 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L3	31.3	6.36	474		31.8	47.1	24.2	66.2
L4	31.1	5.96	460	85	19.2	44.3	95.4	48.3
L6	28.4	6.26	682	418	15.0	3.0	21.7	36.6
L6B	27.5	6.29	631	366	9.4	28.5	8.3	39.2
L7	26.4	6.54	1037	725	18.0	1.6	7.1	39.2
A4	23.5	6.71	996	629	20.1	*	32.9	32.7
C4	19.2	6.77	1044	590	27.6	*	32.5	34.7
D4	21.0	6.92	1078	633	36.2	*	26.2	32.3
E4	22.2	6.95	954	571	16.5	*	35.1	36.7
G2	23.0	6.77	1114	671	22.0	*	49.7	33.8
H2	23.0	7.06	1223	641	31.3	*	43.1	116.6
I2	21.9	6.58	940	471	16.3	*	100.8	44.2

13 AUGUST 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L6	26.5	6.38	737	408	15.0	3.3	22.4	36.7
L6B	26.9	6.32	644	362	9.6	29.4	7.2	39.4
L7	25.9	6.72	1085	725	23.8	1.5	7.5	39.6
A4	22.7	6.79	1025	620	21.0	*	32.3	33.5
C4	18.5	6.71	1064	583	28.7	*	33.2	35.5
D4	20.1	6.94	1126	627	35.0	*	25.0	32.7
E4	22.4	6.99	976	568	17.4	*	32.9	37.6
G2	22.8	6.85	1129	661	21.7	*	47.2	34.0
H2	23.1	7.10	1256	634	31.2	*	41.1	126.2
I2	22.4	6.67	991	474	16.9	*	105.4	45.1

* = Concentration below detectable limit

22 AUGUST 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L6	28.3	6.20	712	416	15.3	3.6	23.0	37.5
L6B	28.5	6.41	630	360	9.6	30.8	6.6	39.0
L7	27.4	6.63	1072	722	18.3	1.6	7.5	41.8
A4	23.6	6.80	1018	608	22.5	*	35.0	35.0
C4	20.4	6.73	1052	590	29.8	*	33.6	35.1
D4	21.1	6.98	1077	639	34.0	*	24.0	32.9
E4	23.7	7.15	971	580	18.3	*	34.4	38.5
G2	25.4	6.79	1078	662	21.1	*	46.8	33.5
H2	24.1	7.02	1227	637	30.7	*	38.9	132.3
I2	23.0	6.77	932	467	17.1	*	110.4	45.5

30 AUGUST 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L6	25.7	6.61	728	419	15.1	3.3	23.7	37.0
L6B	25.5	6.80	625	351	9.1	32.2	6.6	38.5
L7	24.6	6.95	1105	740	17.7	1.7	7.4	44.9
A4	21.5	6.96	1018	604	17.8	*	34.0	33.7
C4	18.9	6.82	1041	583	30.5	*	34.6	35.4
D4	20.2	7.02	1072	627	32.8	*	24.1	32.6
E4	21.1	7.16	990	579	17.8	*	32.3	38.1
G2	24.1	6.74	1066	663	16.3	*	47.0	33.2
H2	24.4	7.07	1210	629	30.5	*	37.7	139.8
I2	22.3	6.83	928	461	16.9	*	113.2	45.9

02 SEPTEMBER 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L6	25.8	6.60	667		14.8	3.0	22.4	35.1
L6B	25.5		576		8.9	28.9	6.1	35.2
L7	25.0		965		16.7	1.7	6.8	44.8

03 SEPTEMBER 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L6	27.2		683		15.4	3.1	23.1	36.3
L6B	26.6		537		8.2	27.7	5.8	33.4
L7	26.1		837		15.8	1.7	6.3	41.2

05 SEPTEMBER 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L6	27.1		681		15.4	3.3	23.6	36.8
L6B	27.7		577		9.0	31.7	6.7	37.0
L7	27.5		916		16.4	1.7	6.9	45.4

* = Concentration below detectable limit

07 SEPTEMBER 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L6	26.5	6.53	695	401	15.4	3.4	23.5	36.7
L6B	26.5		590		8.9	32.3	6.7	36.7
L7	26.0		998		17.4	1.6	7.4	48.1
A4	23.4	6.87	994	603	21.3	*	33.2	34.0
C4	19.7	6.72	1045	586	32.0	*	35.2	35.4
D4	20.1	.6.86	1084	634	33.3	*	23.8	32.4
E4	23.3	7.39	933	567	17.4	*	32.8	38.3
G2	24.9	6.71	1054	660	19.1	*	44.7	33.0
H2	25.1	7.06	1215	626	29.9	*	36.2	145.4
I2	22.5	6.76	936	465	16.8	*	113.0	45.7

10 SEPTEMBER 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L6	27.0		695		15.7	3.0	23.9	37.2
L6B	27.4		558		9.0	30.8	6.4	35.4
L7	27.2		1001		19.0	1.7	7.3	47.6

13 SEPTEMBER 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L6	27.1		706		15.6	3.5	23.6	37.0
L6B	28.1		579		9.5	32.3	6.4	36.2
L7	27.5		1012		18.9	1.7	7.5	47.3

16 SEPTEMBER 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L6	26.2	6.50	680	387	15.8	3.0	23.0	37.2
L6B	25.9		585		9.8	32.7	6.1	36.1
L7	25.4		1023		16.9	1.7	7.6	46.9
A4	23.1	6.83	973	593	15.2	*	31.3	32.8
C4	19.9	6.70	1051	582	23.9	*	34.1	35.9
D4	20.3	6.89	1075	631	31.3	*	24.5	32.6
E4	22.6	7.18	666	385	8.7	*	23.2	29.4
G2	24.9	6.66	1091	664	15.8	*	41.4	33.2
H2	24.6	6.93	1228	620	29.0	*	36.2	148.6
I2	22.4	6.77	958	465	16.7	*	112.2	46.4

* = Concentration below detectable limit

19 SEPTEMBER 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L3	25.0	5.88	1278	79	337.9	42.7	74.7	54.1
L6	24.5	6.44	693	389	15.9	3.0	22.9	37.4
L6B	24.0	6.59	579		10.0	32.3	5.6	35.5
L7	23.7	6.82	1006	690	16.8	1.7	7.7	46.4
A4	22.1	6.78	986	597	15.3	*	30.1	32.4
C4	19.0	6.72	1036	589	32.2	*	35.3	36.8
D4	19.0	6.87	1071	632	31.0	*	25.2	32.7
E4	20.8	7.06	407	237	4.4	*	12.3	18.0
G1	24.4	7.00	1048	659	18.9	*	53.5	41.3
G2	23.3	6.77	1064	667	14.8	*	40.0	33.4
H2	23.7	7.06	1202	619	28.7	*	36.4	150.6
I2	21.2	6.66	953	474	16.5	*	108.7	47.0

30 SEPTEMBER 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1	22.1	6.26	1192	209	169.3	61.8	110.0	115.1
L3	24.1	6.01	768	114	169.8	20.5	25.9	48.5
L4	24.4	5.87	1121	78	299.7	45.3	53.8	56.5
L6	24.9	6.56	690	391	16.1	3.0	21.2	37.6
L6B	24.5	6.58	614	340	11.1	33.1	5.0	35.0
L7	23.8	6.78	1073	735	21.4	1.8	8.1	46.0
A4	21.8	6.85	957	587	18.1	*	28.6	31.2
C4	19.7	6.79	1029	590	34.3	*	35.5	37.1
D4	19.6	6.93	1063	641	31.4	*	24.2	31.8
E4	21.4	7.17	477	280	6.1	*	17.0	19.5
G1	24.2	7.01	1046	673	17.1	*	43.9	38.9
G2	23.7	6.87	1052	665	19.5	*	35.5	34.3
H2	23.7	7.13	1204	607	27.9	*	34.4	156.5
I2	22.1	6.86	940	465	15.8	*	108.5	47.3

13 OCTOBER 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1	15.5	6.15	1192	242	165.5	48.0	74.1	109.2
L3	18.6	5.82	732	140	134.9	20.5	25.7	45.9
L4	19.6	5.84	626	127	109.9	13.9	20.0	47.9
L6	22.7	6.48	700	405	15.9	3.3	20.5	37.2
L6B	22.0	6.52	654	363	11.4	32.9	5.2	34.2
L7	22.7	6.74	1115	764	18.0	2.0	8.4	43.3
A4	20.1	6.88	948	581	17.1	*	28.0	30.2
C4	19.3	6.68	1029	592	33.6	*	34.8	37.3
D4	19.1	6.95	1070	641	31.3	*	24.5	32.8
E4	19.8	7.08	644	362	9.3	*	27.8	27.2
G1	20.8	7.07	1074	665	18.8	*	42.0	39.0
G2	21.6	6.94	1074	683	19.0	*	32.1	35.3
H2	22.6	7.21	1222	596	27.5	*	34.2	162.5
I2	21.7	6.79	943	458	15.2	*	106.5	48.2

* = Concentration below detectable limit

22 OCTOBER 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1	17.4	6.32	1103	241	148.0	36.2	67.2	106.1
L3	19.5	5.95	862	142	156.3	29.1	48.8	54.5
L4	20.2	5.97	628	127	113.4	15.2	20.6	40.0
L6	22.3	6.46	736	421	16.2	3.2	21.1	37.3
L6B	21.7	6.53	660	363	11.8	33.1	5.2	33.7
L7	22.3	6.76	1101	755	22.1	2.0	8.1	39.9
A4	21.8	6.89	937	583	16.6	*	27.7	29.3
C4	19.5	6.76	1027	596	32.1	*	33.7	36.8
D4	19.5	6.95	1064	640	30.6	*	24.6	32.9
E4	21.4	6.99	760	436	12.5	*	34.2	34.8
G1	24.9	7.51	1029	665	13.0	*	42.0	39.2
G2	24.3	6.96	1025	668	19.2	*	29.0	35.3
H2	23.6	7.16	1204	585	27.6	*	34.5	168.4
I2	22.1	6.81	925	460	15.0	*	99.8	48.3

02 NOVEMBER 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1	14.3	6.28	1028	239	125.4	29.1	59.8	104.2
L3	16.7	5.85	901	137	157.4	31.5	60.3	57.7
L4	17.6	5.87	708	125	119.2	18.6	27.4	43.2
L6	20.2	6.46	731	413	16.7	3.3	20.9	37.2
L6B	19.6	6.54	690	380	11.8	32.6	5.9	32.9
L7	20.5	6.79	1139	755	22.7	1.9	8.7	41.1
A4	20.1	6.86	934	567	15.8	1.4	28.3	28.5
C4	18.7	6.71	1019	599	32.0	*	33.3	35.8
D4	18.3	7.00	1064	648	30.8	*	24.4	32.8
E4	19.7	6.96	835	471	13.3	*	38.7	39.6
G1	22.3	6.98	1090	690	18.5	*	41.6	38.7
G2	22.4	6.89	1061	670	19.6	*	26.1	35.1
H2	22.8	7.12	1192	583	27.9	*	36.0	171.5
I2	21.0	6.72	933	467	14.8	*	95.3	47.7

* = Concentration below detectable limit

22 NOVEMBER 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1	7.1	6.21	997	212	87.2	20.8	66.2	95.0
L3	11.2	5.86	898	139	142.2	30.0	64.8	57.8
L4	12.6	5.85	657	121	105.8	16.2	30.9	46.1
L6	16.2	6.39	707	397	16.8	3.7	19.7	37.3
L6B	16.5	6.43	676	383	11.7	32.4	6.2	33.0
L7	17.6	6.69	1141	770	23.9	1.9	7.9	39.3
A3	17.5	6.77	991	664	14.9	*	21.8	30.2
A4	18.2	6.92	871	558	14.9	1.6	29.6	26.8
C3	15.2	6.90	1104	712	24.7	*	29.4	33.8
C4	17.9	6.87	1002	593	29.0	*	31.3	34.1
D3	14.9	7.28	1320	879	64.2	*	4.3	36.4
D4	17.7	7.05	1051	650	29.7	*	24.2	32.6
E3	17.6	7.43	411	293	4.1	*	11.6	13.7
E4	18.7	7.11	629	379	7.0	*	25.1	27.2
G1	19.7	6.93	1081	674	12.1	*	40.7	37.6
G2	21.7	6.95	1034	657	15.0	*	22.3	32.8
H1	19.6	7.24	1072	600	17.1	*	49.2	72.7
H2	21.4	7.15	1232	574	30.3	*	40.1	177.9
I1	19.7	7.22	1171	659	26.2	*	58.5	97.2
I2	20.4	6.98	919	464	15.0	*	83.3	45.6

* = Concentration below detectable limit

03 DECEMBER 1988

SAMPLE	TEMP DEG C	PH	EC UMHOS/CM	HCO3 MG/L	CL MG/L	BR MG/L	NO3 MG/L	SO4 MG/L
L1	7.5	6.40	935	214	69.8	16.5	83.9	93.5
L3	10.5	6.02	695	151	87.1	16.9	40.4	49.5
L4	11.6	5.99	479	133	45.0	7.7	24.1	38.1
L6	15.6	6.37	705	397	17.8	4.7	20.4	38.8
L6B	15.7	6.37	659	360	15.1	36.4	6.6	35.4
L7	17.1	6.68	1144	786	20.5	2.1	8.3	32.8
A3	17.4	6.76	998	649	13.8	*	23.5	29.5
A4	18.3	6.88	891	550	14.4	1.5	30.5	26.3
A5	18.5	6.93	882	531	15.1	*	31.9	24.1
B6	14.9	7.16	1341		12.4	*	*	22.4
B7	19.1	6.95	1186	834	15.9	*	4.5	20.1
B8	17.9	6.92	1256	784	16.7	*	5.4	110.6
B9	19.3	6.86	864	531	15.1	*	26.1	21.7
B10	20.0	6.97	793	502	15.8	*	19.3	18.4
B11	15.3	7.76	848	538	38.0	*	*	18.0
C3	15.4	6.90	1097	690	28.9	*	31.6	34.0
C4	17.4	6.88	983	595	27.8	*	32.0	33.4
C5	18.1	6.90	964	593	27.3	*	31.5	34.1
D3	14.6	7.65	1230	824	45.8	*	5.0	33.9
D4	17.1	7.01	1055	654	29.0	*	24.6	32.9
D5	17.3	7.10	1048	656	30.5	*	23.2	32.4
E3	18.1	6.93	541	322	6.3	*	24.7	26.4
E4	18.4	6.99	749	452	9.8	*	35.0	35.0
E5	19.2	7.07	751	452	9.2	*	31.3	34.2
G1	21.0	6.95	1059	659	13.0	*	45.3	37.2
G2	22.6	6.98	989	665	16.2	*	21.1	31.9
H1	21.1	7.16	1070	612	19.0	*	54.4	78.8
H2	22.4	7.20	1205	573	30.1	*	43.5	180.1
I1	20.6	7.26	1124	629	22.5	*	56.9	93.9
I2	21.2	6.82	880	474	14.8	*	76.3	44.2
I3	20.3	6.85	901	500	14.2	*	69.6	43.7
J1	20.2	7.11	1077	675	18.4	*	38.0	40.4

* = Concentration below detectable limit

APPENDIX E

IONIC BALANCES

```
DATE: 4/20/88   DESIGNATION:   L1
TEMPERATURE: 17.9 DEGREES C
pH:  6.57
CONDUCTIVITY:  767
TDS:  635 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0005
SiO2   15.6 mg/l
```

ION	mg/l	mmole/l	meq/l	% C&A	% TOTAL
Ca	79.400	1.981	3.962	47.922	24.019
Mg	21.900	0.901	1.802	21.792	10.922
Na	56.600	2.463	2.463	29.791	14.931
K	1.600	0.041	0.041	0.495	0.248
TOTAL CATIONS			8.268		
HCO3	244.000	3.999	3.999	48.599	24.241
Cl	15.500	0.437	0.437	5.314	2.651
NO3	81.100	1.308	1.308	15.898	7.930
SO4	119.300	1.242	2.484	30.188	15.058
TOTAL ANIONS			8.228		

```
CATION-ANION BALANCE (C-A)/(C+A) * 100 =   0.24
```

```
DATE: 4/20/88   DESIGNATION:   L2
TEMPERATURE: 17.6 DEGREES C
pH:  6.3
CONDUCTIVITY:  601
TDS:  479.9 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0004
SiO2   16.7 mg/l
```

ION	mg/l	mmole/l	meq/l	% C&A	% TOTAL
Ca	73.100	1.824	3.648	55.651	28.382
Mg	23.600	0.971	1.942	29.622	15.107
Na	21.300	0.927	0.927	14.141	7.212
K	1.500	0.038	0.038	0.585	0.298
TOTAL CATIONS			6.555		
HCO3	162.000	2.655	2.655	42.157	20.657
Cl	20.000	0.564	0.564	8.959	4.390
NO3	61.400	0.990	0.990	15.725	7.705
SO4	100.300	1.044	2.088	33.160	16.248
TOTAL ANIONS			6.298		

```
CATION-ANION BALANCE (C-A)/(C+A) * 100 =   2.00
```

```
DATE: 4/20/88   DESIGNATION:   L3
TEMPERATURE: 18.1 DEGREES C
pH:  5.88
CONDUCTIVITY:  234
TDS:  194.4 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0002
SiO2   7.3 mg/l
```

ION	mg/l	mmole/l	meq/l	% C&A	% TOTAL
Ca	21.200	0.529	1.058	39.200	20.890
Mg	7.900	0.325	0.650	24.084	12.834
Na	21.300	0.927	0.927	34.346	18.303
K	2.500	0.064	0.064	2.369	1.263
TOTAL CATIONS			2.699		
HCO3	78.000	1.278	1.278	54.040	25.242
Cl	5.600	0.158	0.158	6.678	3.119
NO3	26.500	0.427	0.427	18.069	8.440
SO4	24.100	0.251	0.502	21.213	9.908
TOTAL ANIONS			2.365		

```
CATION-ANION BALANCE (C-A)/(C+A) * 100 =   6.58
```

```
DATE: 4/20/88   DESIGNATION:   L4
TEMPERATURE: 17.6 DEGREES C
pH:  5.83
CONDUCTIVITY:  242
TDS:  208.2 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0002
SiO2   11.1 mg/l
```

ION	mg/l	mmole/l	meq/l	% C&A	% TOTAL
Ca	26.700	0.666	1.332	43.165	24.274
Mg	8.200	0.337	0.675	21.856	12.291
Na	23.400	1.018	1.018	32.990	18.552
K	2.400	0.061	0.061	1.989	1.118
TOTAL CATIONS			3.087		
HCO3	82.000	1.344	1.344	55.944	24.483
Cl	5.300	0.150	0.150	6.224	2.724
NO3	24.200	0.390	0.390	16.249	7.111
SO4	24.900	0.259	0.518	21.582	9.445
TOTAL ANIONS			2.402		

```
CATION-ANION BALANCE (C-A)/(C+A) * 100 =  12.47
```

```
DATE: 4/20/88    DESIGNATION:   L5
TEMPERATURE:  18.3 DEGREES C
pH:  6.28
CONDUCTIVITY:  502
TDS:  444.4 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0004
SiO2   16.2 mg/l
ION          mg/l    mmole/l meq/l  % C&A   % TOTAL
----         ------  ------- -----  ------  -------
Ca           60.600  1.512   3.024  48.944  25.830
Mg           17.300  0.712   1.423  23.037  12.157
Na           38.900  1.693   1.693  27.398  14.459
K             1.500  0.038   0.038   0.621   0.328
TOTAL CATIONS                6.178

HCO3        189.000  3.097   3.097  56.023  26.457
Cl           10.800  0.305   0.305   5.510   2.602
NO3          35.300  0.569   0.569  10.298   4.863
SO4          74.800  0.779   1.557  28.169  13.303
TOTAL ANIONS                 5.529

CATION-ANION BALANCE (C-A)/(C+A) * 100 =   5.55
```

```
DATE: 4/20/88    DESIGNATION:   L6
TEMPERATURE:  17.6 DEGREES C
pH:  6.44
CONDUCTIVITY:  714
TDS:  651.6 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0005
SiO2   14.6 mg/l
ION          mg/l    mmole/l meq/l  % C&A   % TOTAL
----         ------  ------- -----  ------  -------
Ca          112.900  2.817   5.634  65.390  33.451
Mg           28.700  1.181   2.361  27.406  14.020
Na           13.500  0.587   0.587   6.819   3.488
K             1.300  0.033   0.033   0.386   0.197
TOTAL CATIONS                8.616

HCO3        416.000  6.817   6.817  82.877  40.480
Cl           16.600  0.468   0.468   5.693   2.780
NO3          12.600  0.203   0.203   2.471   1.207
SO4          35.400  0.369   0.737   8.960   4.376
TOTAL ANIONS                 8.226

CATION-ANION BALANCE (C-A)/(C+A) * 100 =   2.31
```

```
DATE: 4/20/88    DESIGNATION:   L6B
TEMPERATURE:  18 DEGREES C
pH:  6.64
CONDUCTIVITY:  847
TDS:  811.2 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0007
SiO2   14 mg/l
ION          mg/l    mmole/l meq/l  % C&A   % TOTAL
----         ------  ------- -----  ------  -------
Ca          143.800  3.588   7.176  68.115  34.626
Mg           32.300  1.329   2.657  25.225  12.823
Na           15.300  0.666   0.666   6.320   3.213
K             1.400  0.036   0.036   0.340   0.173
TOTAL CATIONS               10.535

HCO3        543.000  8.899   8.899  87.337  42.940
Cl           10.300  0.291   0.291   2.852   1.402
NO3          13.700  0.221   0.221   2.169   1.066
SO4          37.400  0.389   0.779   7.642   3.757
TOTAL ANIONS                10.189

CATION-ANION BALANCE (C-A)/(C+A) * 100 =   1.67
```

```
DATE: 4/20/88    DESIGNATION:   L7
TEMPERATURE:  17.6 DEGREES C
pH:  6.63
CONDUCTIVITY:  1150
TDS:  1125.4 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0009
SiO2   17.2 mg/l
ION          mg/l     mmole/l  meq/l   % C&A   % TOTAL
----         ------   -------  -----   ------  -------
Ca          165.500   4.129    8.258   56.324  28.391
Mg           64.500   2.653    5.306   36.191  18.243
Na           24.400   1.062    1.062    7.242   3.650
K             1.400   0.036    0.036    0.244   0.123
TOTAL CATIONS                 14.663

HCO3        789.000  12.930   12.930   89.635  44.452
Cl           27.400   0.773    0.773    5.358   2.657
NO3           5.800   0.094    0.094    0.648   0.322
SO4          30.200   0.314    0.629    4.359   2.162
TOTAL ANIONS                 14.425

CATION-ANION BALANCE (C-A)/(C+A) * 100 =   0.82
```

```
DATE: 4/20/88    DESIGNATION:   A3
TEMPERATURE:  17.3 DEGREES C
pH:   6.7
CONDUCTIVITY:  1005
TDS:  888.3999 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0007
SiO2   10.1 mg/l
```

ION	mg/l	mmole/l	meq/l	% C&A	% TOTAL
Ca	113.600	2.834	5.669	50.693	25.042
Mg	47.800	1.966	3.933	35.167	17.372
Na	36.100	1.571	1.571	14.048	6.940
K	0.400	0.010	0.010	0.091	0.045
TOTAL CATIONS			11.182		
HCO3	606.000	9.931	9.931	86.700	43.871
Cl	14.700	0.415	0.415	3.620	1.832
NO3	28.600	0.461	0.461	4.027	2.038
SO4	31.100	0.324	0.648	5.653	2.860
TOTAL ANIONS			11.455		

```
CATION-ANION BALANCE (C-A)/(C+A) * 100 = -1.20
```

```
DATE: 4/20/88    DESIGNATION:   A4
TEMPERATURE:  17.7 DEGREES C
pH:   6.72
CONDUCTIVITY:  919
TDS:  835.6001 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0007
SiO2   10.9 mg/l
```

ION	mg/l	mmole/l	meq/l	% C&A	% TOTAL
Ca	99.600	2.485	4.970	47.124	23.330
Mg	45.200	1.859	3.719	35.258	17.456
Na	42.700	1.858	1.858	17.618	8.722
K	0.000	0.000	0.000	0.000	0.000
TOTAL CATIONS			10.547		
HCO3	551.000	9.030	9.030	83.948	42.387
Cl	15.800	0.446	0.446	4.144	2.092
NO3	39.400	0.635	0.635	5.908	2.983
SO4	31.000	0.323	0.645	6.000	3.030
TOTAL ANIONS			10.756		

```
CATION-ANION BALANCE (C-A)/(C+A) * 100 =  -0.98
```

```
DATE: 4/20/88    DESIGNATION:   C3
TEMPERATURE:  15.4 DEGREES C
pH:   6.75
CONDUCTIVITY:  1375
TDS:  1236 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0010
SiO2   9.7 mg/l
```

ION	mg/l	mmole/l	meq/l	% C&A	% TOTAL
Ca	98.000	2.445	4.890	31.393	15.165
Mg	66.800	2.748	5.496	35.280	17.042
Na	119.300	5.191	5.191	33.327	16.099
K	0.000	0.000	0.000	0.000	0.000
TOTAL CATIONS			15.577		
HCO3	772.000	12.652	12.652	75.896	39.233
Cl	71.200	2.008	2.008	12.049	6.228
NO3	11.000	0.177	0.177	1.064	0.550
SO4	88.000	0.916	1.832	10.991	5.682
TOTAL ANIONS			16.670		

```
CATION-ANION BALANCE (C-A)/(C+A) * 100 = -3.39
```

```
DATE: 4/20/88    DESIGNATION:   C4
TEMPERATURE:  16.1 DEGREES C
pH:   6.75
CONDUCTIVITY:  1070
TDS:  970.2 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0008
SiO2   10.6 mg/l
```

ION	mg/l	mmole/l	meq/l	% C&A	% TOTAL
Ca	100.900	2.517	5.035	40.575	20.023
Mg	56.600	2.328	4.657	37.526	18.518
Na	61.800	2.689	2.689	21.672	10.695
K	1.100	0.028	0.028	0.227	0.112
TOTAL CATIONS			12.409		
HCO3	632.000	10.357	10.357	81.318	41.189
Cl	36.100	1.018	1.018	7.995	4.050
NO3	25.400	0.410	0.410	3.216	1.629
SO4	45.700	0.476	0.951	7.470	3.784
TOTAL ANIONS			12.737		

```
CATION-ANION BALANCE (C-A)/(C+A) * 100 =  -1.30
```

```
DATE: 4/20/88   DESIGNATION:  D3
TEMPERATURE: 16 DEGREES C
pH:  6.9
CONDUCTIVITY:  1231
TDS: 1104.1 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0009
SiO2   9.399999 mg/l
```

ION	mg/l	mmole/l	meq/l	% C&A	% TOTAL
Ca	99.300	2.478	4.955	35.247	17.297
Mg	54.100	2.225	4.451	31.660	15.537
Na	106.200	4.621	4.621	32.874	16.133
K	1.200	0.031	0.031	0.218	0.107
TOTAL CATIONS			14.058		
HCO3	728.000	11.931	11.931	81.781	41.648
Cl	66.000	1.862	1.862	12.762	6.499
NO3	7.400	0.119	0.119	0.818	0.417
SO4	32.500	0.338	0.677	4.638	2.362
TOTAL ANIONS			14.588		

CATION-ANION BALANCE (C-A)/(C+A) * 100 = -1.85

```
DATE: 4/20/88   DESIGNATION:  D4
TEMPERATURE: 16.5 DEGREES C
pH:  6.99
CONDUCTIVITY:  1083
TDS: 988.4 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0008
SiO2   9.5 mg/l
```

ION	mg/l	mmole/l	meq/l	% C&A	% TOTAL
Ca	75.900	1.894	3.787	31.259	15.216
Mg	41.700	1.715	3.431	28.314	13.783
Na	111.800	4.865	4.865	40.153	19.546
K	1.300	0.033	0.033	0.274	0.134
TOTAL CATIONS			12.116		
HCO3	651.000	10.669	10.669	83.515	42.861
Cl	32.200	0.908	0.908	7.110	3.649
NO3	33.200	0.535	0.535	4.192	2.151
SO4	31.800	0.331	0.662	5.183	2.660
TOTAL ANIONS			12.775		

CATION-ANION BALANCE (C-A)/(C+A) * 100 = -2.64

```
DATE: 4/20/88   DESIGNATION:  E3
TEMPERATURE: 16.3 DEGREES C
pH:  7.05
CONDUCTIVITY:  548
TDS: 491.2 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0004
SiO2   11.4 mg/l
```

ION	mg/l	mmole/l	meq/l	% C&A	% TOTAL
Ca	64.900	1.619	3.239	50.714	25.779
Mg	30.500	1.255	2.509	39.294	19.974
Na	13.900	0.605	0.605	9.472	4.815
K	1.300	0.033	0.033	0.521	0.265
TOTAL CATIONS			6.386		
HCO3	325.000	5.326	5.326	86.229	42.397
Cl	4.600	0.130	0.130	2.101	1.033
NO3	22.100	0.356	0.356	5.771	2.837
SO4	17.500	0.182	0.364	5.899	2.900
TOTAL ANIONS			6.177		

CATION-ANION BALANCE (C-A)/(C+A) * 100 = 1.67

```
DATE: 4/20/88   DESIGNATION:  E4
TEMPERATURE: 16.9 DEGREES C
pH:  6.97
CONDUCTIVITY:  1051
TDS: 958.8001 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0008
SiO2   13.9 mg/l
```

ION	mg/l	mmole/l	meq/l	% C&A	% TOTAL
Ca	81.900	2.043	4.087	33.468	16.545
Mg	68.100	2.801	5.603	45.882	22.681
Na	57.300	2.493	2.493	20.420	10.094
K	1.100	0.028	0.028	0.230	0.114
TOTAL CATIONS			12.211		
HCO3	653.000	10.701	10.701	85.675	43.322
Cl	21.800	0.615	0.615	4.923	2.489
NO3	23.500	0.379	0.379	3.035	1.534
SO4	38.200	0.398	0.795	6.367	3.220
TOTAL ANIONS			12.491		

CATION-ANION BALANCE (C-A)/(C+A) * 100 = -1.13

```
DATE: 4/20/88    DESIGNATION:   G1
TEMPERATURE:  18.4 DEGREES C
pH:   6.81
CONDUCTIVITY:   1015
TDS:  943.0001 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0008
SiO2   13.7 mg/l
ION          mg/l     mmole/l meq/l  % C&A   % TOTAL
----        ------   ------- -----  ------  -------
Ca          100.200   2.500   5.000  41.988  20.876
Mg           51.700   2.127   4.253  35.718  17.759
Na           60.300   2.624   2.624  22.036  10.956
K             1.200   0.031   0.031   0.258   0.128
TOTAL CATIONS              11.908

HCO3        606.000   9.931   9.931  82.466  41.465
Cl           14.900   0.420   0.420   3.490   1.755
NO3          61.100   0.985   0.985   8.183   4.115
SO4          33.900   0.353   0.706   5.861   2.947
TOTAL ANIONS              12.043

CATION-ANION BALANCE (C-A)/(C+A) * 100 =  -0.56
```

```
DATE: 4/20/88    DESIGNATION:   G2
TEMPERATURE:  19.1 DEGREES C
pH:   6.88
CONDUCTIVITY:   1038
TDS:  967.8 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0008
SiO2   12.2 mg/l
ION          mg/l     mmole/l meq/l  % C&A   % TOTAL
----        ------   ------- -----  ------  -------
Ca           95.900   2.393   4.785  38.871  19.361
Mg           51.800   2.131   4.262  34.616  17.242
Na           74.300   3.233   3.233  26.263  13.081
K             1.200   0.031   0.031   0.249   0.124
TOTAL CATIONS              12.311

HCO3        635.000  10.406  10.406  83.884  42.103
Cl           21.600   0.609   0.609   4.911   2.465
NO3          40.100   0.647   0.647   5.213   2.617
SO4          35.700   0.372   0.743   5.991   3.007
TOTAL ANIONS              12.406

CATION-ANION BALANCE (C-A)/(C+A) * 100 =  -0.38
```

```
DATE: 4/20/88    DESIGNATION:   H1
TEMPERATURE:  17.2 DEGREES C
pH:   7.03
CONDUCTIVITY:   1136
TDS:  1018.1 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0008
SiO2   11.4 mg/l
ION          mg/l     mmole/l meq/l  % C&A   % TOTAL
----        ------   ------- -----  ------  -------
Ca          102.300   2.552   5.105  39.646  19.642
Mg           46.800   1.925   3.850  29.902  14.815
Na           89.400   3.890   3.890  30.214  14.969
K             1.200   0.031   0.031   0.238   0.118
TOTAL CATIONS              12.876

HCO3        629.000  10.308  10.308  78.607  39.662
Cl           23.900   0.674   0.674   5.141   2.594
NO3          52.100   0.840   0.840   6.408   3.233
SO4          62.000   0.645   1.291   9.844   4.967
TOTAL ANIONS              13.113

CATION-ANION BALANCE (C-A)/(C+A) * 100 =  -0.91
```

```
DATE: 4/20/88    DESIGNATION:   H2
TEMPERATURE:  18 DEGREES C
pH:   7.12
CONDUCTIVITY:   1213
TDS:  1074.1 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0009
SiO2   11.5 mg/l
ION          mg/l     mmole/l meq/l  % C&A   % TOTAL
----        ------   ------- -----  ------  -------
Ca           62.500   1.559   3.119  23.976  11.437
Mg           52.000   2.139   4.278  32.888  15.688
Na          128.300   5.583   5.583  42.920  20.474
K             1.100   0.028   0.028   0.216   0.103
TOTAL CATIONS              13.008

HCO3        644.000  10.554  10.554  74.005  38.703
Cl           32.700   0.922   0.922   6.468   3.383
NO3          36.600   0.590   0.590   4.139   2.165
SO4         105.400   1.097   2.194  15.388   8.047
TOTAL ANIONS              14.261

CATION-ANION BALANCE (C-A)/(C+A) * 100 =  -4.60
```

```
DATE: 4/20/88    DESIGNATION:    I1
TEMPERATURE: 16.5 DEGREES C
pH:   6.69
CONDUCTIVITY:  1083
TDS:  1025.8 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0008
SiO2   11.6 mg/l
ION           mg/l    mmole/l meq/l  % C&A   % TOTAL
----          ------  ------- -----  ------  -------
Ca            112.200 2.799   5.599  44.582  21.202
Mg            65.400  2.690   5.381  42.844  20.375
Na            34.700  1.510   1.510  12.024  5.718
K             2.700   0.069   0.069  0.550   0.261
TOTAL CATIONS                 12.558

HCO3          604.000 9.898   9.898  71.476  37.484
Cl            22.600  0.638   0.638  4.604   2.414
NO3           59.900  0.966   0.966  6.976   3.659
SO4           112.700 1.173   2.346  16.944  8.886
TOTAL ANIONS                  13.848

CATION-ANION BALANCE (C-A)/(C+A) * 100 =  -4.89
```

```
DATE: 4/20/88    DESIGNATION:    I2
TEMPERATURE: 18.1 DEGREES C
pH:   6.63
CONDUCTIVITY:   930
TDS:  844.4999 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0007
SiO2   17.6 mg/l
ION           mg/l    mmole/l meq/l  % C&A   % TOTAL
----          ------  ------- -----  ------  -------
Ca            82.200  2.051   4.102  38.348  19.022
Mg            55.600  2.287   4.574  42.765  21.213
Na            45.600  1.984   1.984  18.552  9.202
K             1.400   0.036   0.036  0.335   0.166
TOTAL CATIONS                 10.696

HCO3          500.000 8.194   8.194  75.402  38.000
Cl            13.500  0.381   0.381  3.504   1.766
NO3           82.100  1.324   1.324  12.185  6.141
SO4           46.500  0.484   0.968  8.909   4.490
TOTAL ANIONS                  10.867

CATION-ANION BALANCE (C-A)/(C+A) * 100 =  -0.79
```

```
DATE: 4/27/88    DESIGNATION:    L1
TEMPERATURE: 17.4 DEGREES C
pH:   6.81
CONDUCTIVITY:   724
TDS:  629.9 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0005
SiO2   15.5 mg/l
ION           mg/l    mmole/l meq/l  % C&A   % TOTAL
----          ------  ------- -----  ------  -------
Ca            82.200  2.051   4.102  48.165  24.764
Mg            21.400  0.880   1.761  20.674  10.629
Na            60.100  2.615   2.615  30.710  15.789
K             1.500   0.038   0.038  0.450   0.232
TOTAL CATIONS                 8.516

HCO3          272.000 4.458   4.458  55.390  26.912
Cl            14.500  0.409   0.409  5.083   2.469
NO3           44.000  0.710   0.710  8.818   4.285
SO4           118.700 1.236   2.471  30.709  14.920
TOTAL ANIONS                  8.048

CATION-ANION BALANCE (C-A)/(C+A) * 100 =   2.83
```

```
DATE: 4/27/88    DESIGNATION:    L2
TEMPERATURE: 17.3 DEGREES C
pH:   6.45
CONDUCTIVITY:   573
TDS:  450.6 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0004
SiO2   11.7 mg/l
ION           mg/l    mmole/l meq/l  % C&A   % TOTAL
----          ------  ------- -----  ------  -------
Ca            55.900  1.395   2.789  50.130  23.718
Mg            22.000  0.905   1.810  32.528  15.390
Na            21.000  0.914   0.914  16.423  7.770
K             2.000   0.051   0.051  0.919   0.435
TOTAL CATIONS                 5.564

HCO3          177.000 2.901   2.901  46.812  24.664
Cl            18.800  0.530   0.530  8.558   4.509
NO3           41.600  0.671   0.671  10.828  5.705
SO4           100.600 1.047   2.095  33.802  17.809
TOTAL ANIONS                  6.197

CATION-ANION BALANCE (C-A)/(C+A) * 100 =  -5.37
```

```
DATE: 4/27/88   DESIGNATION:   L3
TEMPERATURE:  17.4 DEGREES C
pH:   6.07
CONDUCTIVITY:  382
TDS:  308.8 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0003
SiO2   8.5 mg/l
```

ION	mg/l	mmole/l	meq/l	% C&A	% TOTAL
Ca	39.500	0.986	1.971	45.235	24.142
Mg	13.300	0.547	1.094	25.111	13.402
Na	28.400	1.236	1.236	28.362	15.137
K	2.200	0.056	0.056	1.291	0.689
TOTAL CATIONS			4.357		
HCO3	124.000	2.032	2.032	53.377	24.890
Cl	6.900	0.195	0.195	5.113	2.384
NO3	44.800	0.723	0.723	18.980	8.850
SO4	41.200	0.429	0.858	22.531	10.506
TOTAL ANIONS			3.807		

```
CATION-ANION BALANCE (C-A)/(C+A) * 100 =  6.74
```

```
DATE: 4/27/88   DESIGNATION:   L4
TEMPERATURE:  17.2 DEGREES C
pH:   6.07
CONDUCTIVITY:  299
TDS:  266.9 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0002
SiO2   11.2 mg/l
```

ION	mg/l	mmole/l	meq/l	% C&A	% TOTAL
Ca	38.000	0.948	1.896	47.327	26.621
Mg	10.400	0.428	0.856	21.355	12.012
Na	27.600	1.201	1.201	29.977	16.862
K	2.100	0.054	0.054	1.341	0.754
TOTAL CATIONS			4.007		
HCO3	116.000	1.901	1.901	61.002	26.689
Cl	6.200	0.175	0.175	5.612	2.455
NO3	24.100	0.389	0.389	12.473	5.457
SO4	31.300	0.326	0.652	20.912	9.149
TOTAL ANIONS			3.116		

```
CATION-ANION BALANCE (C-A)/(C+A) * 100 =  12.50
```

```
DATE: 4/27/88   DESIGNATION:   L5
TEMPERATURE:  16.4 DEGREES C
pH:   6.43
CONDUCTIVITY:  479
TDS:  423.4 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0004
SiO2   16.7 mg/l
```

ION	mg/l	mmole/l	meq/l	% C&A	% TOTAL
Ca	53.100	1.325	2.650	44.911	23.757
Mg	18.200	0.749	1.497	25.379	13.425
Na	39.400	1.715	1.715	29.060	15.372
K	1.500	0.038	0.038	0.650	0.344
TOTAL CATIONS			5.900		
HCO3	180.000	2.950	2.950	56.149	26.448
Cl	10.800	0.305	0.305	5.799	2.731
NO3	34.100	0.550	0.550	10.469	4.931
SO4	69.600	0.725	1.449	27.583	12.992
TOTAL ANIONS			5.254		

```
CATION-ANION BALANCE (C-A)/(C+A) * 100 =  5.79
```

```
DATE: 4/27/88   DESIGNATION:   L6
TEMPERATURE:  17.4 DEGREES C
pH:   6.63
CONDUCTIVITY:  700
TDS:  663.1001 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0006
SiO2   14.3 mg/l
```

ION	mg/l	mmole/l	meq/l	% C&A	% TOTAL
Ca	123.500	3.081	6.163	67.303	35.413
Mg	28.900	1.189	2.378	25.966	13.663
Na	13.400	0.583	0.583	6.368	3.351
K	1.300	0.033	0.033	0.363	0.191
TOTAL CATIONS			9.157		
HCO3	415.000	6.801	6.801	82.480	39.081
Cl	16.400	0.463	0.463	5.610	2.658
NO3	13.900	0.224	0.224	2.719	1.288
SO4	36.400	0.379	0.758	9.191	4.355
TOTAL ANIONS			8.246		

```
CATION-ANION BALANCE (C-A)/(C+A) * 100 =  5.23
```

```
DATE: 4/27/88    DESIGNATION:   L6B
TEMPERATURE: 17.4 DEGREES C
pH:  6.72
CONDUCTIVITY:   834
TDS: 838.7 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0007
SiO2   13.8 mg/l
ION          mg/l    mmole/l  meq/l   % C&A    % TOTAL
----         ------  -------  -----   ------   -------
Ca           166.000  4.142   8.283   70.794   37.709
Mg            33.200  1.366   2.731   23.344   12.434
Na            15.000  0.653   0.653    5.579    2.971
K              1.300  0.033   0.033    0.284    0.151
TOTAL CATIONS                11.701

HCO3         549.000  8.997   8.997   87.639   40.957
Cl            10.000  0.282   0.282    2.748    1.284
NO3           13.300  0.215   0.215    2.090    0.977
SO4           37.100  0.386   0.772    7.524    3.516
TOTAL ANIONS                 10.266

CATION-ANION BALANCE (C-A)/(C+A) * 100 =  6.53
```

```
DATE: 4/27/88    DESIGNATION:   L7
TEMPERATURE: 17.5 DEGREES C
pH:  6.78
CONDUCTIVITY:   1140
TDS: 1146.3 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0010
SiO2   17.5 mg/l
ION          mg/l    mmole/l  meq/l   % C&A    % TOTAL
----         ------  -------  -----   ------   -------
Ca           192.800  4.810   9.621   60.033   31.711
Mg            65.200  2.682   5.364   33.471   17.680
Na            23.100  1.005   1.005    6.273    3.313
K              1.400  0.036   0.036    0.223    0.118
TOTAL CATIONS                16.026

HCO3         784.000 12.848  12.848   89.765   42.349
Cl            26.200  0.739   0.739    5.164    2.436
NO3            5.500  0.089   0.089    0.620    0.292
SO4           30.600  0.319   0.637    4.451    2.100
TOTAL ANIONS                 14.313

CATION-ANION BALANCE (C-A)/(C+A) * 100 =  5.65
```

```
DATE: 4/27/88    DESIGNATION:   A3
TEMPERATURE: 17.2 DEGREES C
pH:  6.78
CONDUCTIVITY:   959
TDS: 887.3999 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0007
SiO2   12.6 mg/l
ION          mg/l    mmole/l  meq/l   % C&A    % TOTAL
----         ------  -------  -----   ------   -------
Ca           116.500  2.907   5.813   50.775   25.499
Mg            48.900  2.012   4.023   35.138   17.646
Na            36.300  1.580   1.580   13.797    6.929
K              1.300  0.033   0.033    0.290    0.146
TOTAL CATIONS                11.449

HCO3         593.000  9.718   9.718   85.629   42.626
Cl            17.800  0.502   0.502    4.424    2.202
NO3           30.100  0.485   0.485    4.278    2.129
SO4           30.900  0.322   0.643    5.669    2.822
TOTAL ANIONS                 11.349

CATION-ANION BALANCE (C-A)/(C+A) * 100 =  0.44
```

```
DATE: 4/27/88    DESIGNATION:   A4
TEMPERATURE: 17.1 DEGREES C
pH:  6.85
CONDUCTIVITY:   894
TDS: 812 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0007
SiO2   13 mg/l
ION          mg/l    mmole/l  meq/l   % C&A    % TOTAL
----         ------  -------  -----   ------   -------
Ca            97.100  2.423   4.845   46.929   23.392
Mg            43.900  1.806   3.612   34.981   17.436
Na            42.100  1.832   1.832   17.744    8.844
K              1.400  0.036   0.036    0.347    0.173
TOTAL CATIONS                10.325

HCO3         526.000  8.620   8.620   82.974   41.615
Cl            16.300  0.460   0.460    4.426    2.220
NO3           41.400  0.668   0.668    6.427    3.224
SO4           30.800  0.321   0.641    6.173    3.096
TOTAL ANIONS                 10.389

CATION-ANION BALANCE (C-A)/(C+A) * 100 =  -0.31
```

```
DATE: 4/27/88   DESIGNATION:   C3
TEMPERATURE: 16.6 DEGREES C
pH:  6.76
CONDUCTIVITY:  1355
TDS:  1235.7 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0010
SiO2   12.1 mg/l
ION           mg/l    mmole/l meq/l  % C&A   % TOTAL
----          ------  ------- -----  ------  -------
Ca            99.700   2.488   4.975  32.154  15.496
Mg            66.100   2.719   5.438  35.147  16.938
Na           115.500   5.026   5.026  32.484  15.655
K              1.300   0.033   0.033   0.215   0.104
TOTAL CATIONS                 15.472

HCO3         773.000  12.668  12.668  76.159  39.457
Cl            70.100   1.977   1.977  11.888   6.159
NO3           10.700   0.173   0.173   1.038   0.538
SO4           87.200   0.908   1.816  10.915   5.655
TOTAL ANIONS                 16.634

CATION-ANION BALANCE (C-A)/(C+A) * 100 = -3.62
```

```
DATE: 4/27/88   DESIGNATION:   C4
TEMPERATURE: 16.9 DEGREES C
pH:  6.76
CONDUCTIVITY:  1027
TDS:  966 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0008
SiO2   11.7 mg/l
ION           mg/l    mmole/l meq/l  % C&A   % TOTAL
----          ------  ------- -----  ------  -------
Ca           103.400   2.580   5.160  41.926  20.694
Mg            54.700   2.250   4.500  36.567  18.049
Na            60.000   2.611   2.611  21.216  10.472
K              1.400   0.036   0.036   0.291   0.144
TOTAL CATIONS                 12.307

HCO3         632.000  10.357  10.357  82.027  41.540
Cl            33.600   0.948   0.948   7.506   3.801
NO3           25.400   0.410   0.410   3.245   1.643
SO4           43.800   0.456   0.912   7.222   3.657
TOTAL ANIONS                 12.627

CATION-ANION BALANCE (C-A)/(C+A) * 100 = -1.28
```

```
DATE: 4/27/88   DESIGNATION:   D3
TEMPERATURE: 15 DEGREES C
pH:  6.85
CONDUCTIVITY:  1279
TDS:  1188.8 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0009
SiO2   10.3 mg/l
ION           mg/l    mmole/l meq/l  % C&A   % TOTAL
----          ------  ------- -----  ------  -------
Ca           103.900   2.592   5.185  35.854  16.982
Mg            53.600   2.205   4.410  30.495  14.443
Na           111.000   4.830   4.830  33.403  15.821
K              1.400   0.036   0.036   0.248   0.117
TOTAL CATIONS                 14.460

HCO3         780.000  12.783  12.783  79.541  41.868
Cl            87.300   2.463   2.463  15.324   8.066
NO3            7.400   0.119   0.119   0.743   0.391
SO4           33.900   0.353   0.706   4.392   2.312
TOTAL ANIONS                 16.070

CATION-ANION BALANCE (C-A)/(C+A) * 100 =  -5.27
```

```
DATE: 4/27/88   DESIGNATION:   D4
TEMPERATURE: 15.5 DEGREES C
pH:  6.98
CONDUCTIVITY:  1137
TDS:  1061.8 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0008
SiO2   11.1 mg/l
ION           mg/l    mmole/l meq/l  % C&A   % TOTAL
----          ------  ------- -----  ------  -------
Ca            95.100   2.373   4.746  36.230  17.385
Mg            41.800   1.719   3.439  26.254  12.598
Na           112.100   4.878   4.878  37.242  17.871
K              1.400   0.036   0.036   0.273   0.131
TOTAL CATIONS                 13.098

HCO3         634.000  10.390  10.390  73.179  38.064
Cl            72.000   2.031   2.031  14.305   7.441
NO3           39.700   0.640   0.640   4.510   2.346
SO4           54.600   0.568   1.137   8.007   4.165
TOTAL ANIONS                 14.198

CATION-ANION BALANCE (C-A)/(C+A) * 100 = -4.03
```

```
DATE: 4/27/88   DESIGNATION:   E3
TEMPERATURE:  17.1 DEGREES C
pH:   7.08
CONDUCTIVITY:  558
TDS:  522.4001 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0004
SiO2   13.1 mg/l
ION           mg/l    mmole/l  meq/l  % C&A   % TOTAL
----          ------  -------  -----  ------  -------
Ca            78.500  1.959    3.917  55.792  29.050
Mg            31.200  1.283    2.567  36.559  19.036
Na            11.400  0.496    0.496  7.066   3.679
K             1.600   0.041    0.041  0.583   0.303
TOTAL CATIONS                  7.021

HCO3          344.000 5.637    5.637  87.224  41.808
Cl            4.800   0.135    0.135  2.095   1.004
NO3           20.600  0.332    0.332  5.141   2.464
SO4           17.200  0.179    0.358  5.541   2.656
TOTAL ANIONS                   6.463

CATION-ANION BALANCE (C-A)/(C+A) * 100 =   4.14
```

```
DATE: 4/27/88   DESIGNATION:   E4
TEMPERATURE:  17.2 DEGREES C
pH:   6.99
CONDUCTIVITY:  1040
TDS:  975.6 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0008
SiO2   15.6 mg/l
ION           mg/l    mmole/l  meq/l  % C&A   % TOTAL
----          ------  -------  -----  ------  -------
Ca            87.100  2.173    4.346  34.456  17.237
Mg            68.300  2.810    5.619  44.547  22.285
Na            60.100  2.615    2.615  20.734  10.372
K             1.300   0.033    0.033  0.264   0.132
TOTAL CATIONS                  12.614

HCO3          660.000 10.816   10.816 85.836  42.896
Cl            21.900  0.618    0.618  4.903   2.450
NO3           23.300  0.376    0.376  2.982   1.490
SO4           38.000  0.396    0.791  6.279   3.138
TOTAL ANIONS                   12.601

CATION-ANION BALANCE (C-A)/(C+A) * 100 =   0.05
```

```
DATE: 4/27/88   DESIGNATION:   G1
TEMPERATURE:  15.9 DEGREES C
pH:   6.87
CONDUCTIVITY:  1017
TDS:  949.7 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0008
SiO2   15.6 mg/l
ION           mg/l    mmole/l  meq/l  % C&A   % TOTAL
----          ------  -------  -----  ------  -------
Ca            104.900 2.617    5.235  42.811  21.597
Mg            52.400  2.155    4.311  35.258  17.787
Na            60.800  2.646    2.646  21.639  10.916
K             1.400   0.036    0.036  0.293   0.148
TOTAL CATIONS                  12.227

HCO3          601.000 9.849    9.849  82.010  40.637
Cl            13.900  0.392    0.392  3.265   1.618
NO3           65.500  1.056    1.056  8.797   4.359
SO4           34.200  0.356    0.712  5.929   2.938
TOTAL ANIONS                   12.010

CATION-ANION BALANCE (C-A)/(C+A) * 100 =   0.90
```

```
DATE: 4/27/88   DESIGNATION:   G2
TEMPERATURE:  16.3 DEGREES C
pH:   6.92
CONDUCTIVITY:  1058
TDS:  972.3 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0008
SiO2   13.2 mg/l
ION           mg/l    mmole/l  meq/l  % C&A   % TOTAL
----          ------  -------  -----  ------  -------
Ca            93.800  2.340    4.681  38.019  18.931
Mg            52.700  2.168    4.336  35.216  17.535
Na            74.900  3.259    3.259  26.474  13.182
K             1.400   0.036    0.036  0.291   0.145
TOTAL CATIONS                  12.311

HCO3          641.000 10.505   10.505 84.622  42.486
Cl            16.800  0.474    0.474  3.818   1.917
NO3           42.500  0.685    0.685  5.522   2.772
SO4           36.000  0.375    0.750  6.038   3.031
TOTAL ANIONS                   12.414

CATION-ANION BALANCE (C-A)/(C+A) * 100 =  -0.41
```

```
DATE: 4/27/88   DESIGNATION:   H1
TEMPERATURE: 18.1 DEGREES C
pH:  7.12
CONDUCTIVITY:  1052
TDS: 1002.6 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0008
SiO2   12.5 mg/l
ION           mg/l      mmole/l  meq/I   % C&A    % TOTAL
----          ------    -------  -----   ------   -------
Ca            101.100   2.522    5.045   39.788   19.741
Mg            45.500    1.872    3.743   29.522   14.648
Na            88.600    3.856    3.856   30.407   15.087
K             1.400     0.036    0.036   0.282    0.140
TOTAL CATIONS                    12.680

HCO3          619.000   10.144   10.144  78.786   39.695
Cl            23.000    0.649    0.649   5.039    2.539
NO3           50.900    0.821    0.821   6.376    3.213
SO4           60.600    0.631    1.262   9.799    4.937
TOTAL ANIONS                     12.876

CATION-ANION BALANCE (C-A)/(C+A) * 100 = -0.77
```

```
DATE: 4/27/88   DESIGNATION:   H2
TEMPERATURE: 18.5 DEGREES C
pH:  7.13
CONDUCTIVITY:  1147
TDS: 1062.4 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0008
SiO2   11 mg/l
ION           mg/l      mmole/l  meq/I   % C&A    % TOTAL
----          ------    -------  -----   ------   -------
Ca            59.900    1.495    2.989   23.375   11.145
Mg            49.900    2.053    4.105   32.105   15.307
Na            130.000   5.657    5.657   44.240   21.094
K             1.400     0.036    0.036   0.280    0.134
TOTAL CATIONS                    12.787

HCO3          648.000   10.619   10.619  75.682   39.597
Cl            28.200    0.795    0.795   5.669    2.966
NO3           36.900    0.595    0.595   4.242    2.219
SO4           97.100    1.011    2.022   14.408   7.538
TOTAL ANIONS                     14.032

CATION-ANION BALANCE (C-A)/(C+A) * 100 = -4.64
```

```
DATE: 4/27/88   DESIGNATION:   I1
TEMPERATURE: 16.9 DEGREES C
pH:  6.7
CONDUCTIVITY:  1103
TDS: 981.7 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0008
SiO2   10.7 mg/l
ION           mg/l      mmole/l  meq/I   % C&A    % TOTAL
----          ------    -------  -----   ------   -------
Ca            118.300   2.952    5.903   45.045   22.586
Mg            67.900    2.793    5.586   42.626   21.373
Na            35.600    1.549    1.549   11.821   5.927
K             2.600     0.066    0.066   0.507    0.254
TOTAL CATIONS                    13.105

HCO3          546.000   8.948    8.948   68.665   34.235
Cl            24.600    0.694    0.694   5.325    2.655
NO3           58.600    0.945    0.945   7.253    3.616
SO4           117.400   1.222    2.444   18.757   9.352
TOTAL ANIONS                     13.031

CATION-ANION BALANCE (C-A)/(C+A) * 100 =  0.28
```

```
DATE: 4/27/88   DESIGNATION:   I2
TEMPERATURE: 17.1 DEGREES C
pH:  6.72
CONDUCTIVITY:  940
TDS: 843.8 mg/l (by summation)
CALCULATED DENSITY (gm/cm3): 1.0007
SiO2   16.8 mg/l
ION           mg/l      mmole/l  meq/I   % C&A    % TOTAL
----          ------    -------  -----   ------   -------
Ca            88.100    2.198    4.396   39.900   20.186
Mg            56.200    2.312    4.624   41.963   21.230
Na            45.100    1.963    1.963   17.812   9.012
K             1.400     0.036    0.036   0.325    0.164
TOTAL CATIONS                    11.018

HCO3          499.000   8.178    8.178   76.000   37.550
Cl            13.000    0.367    0.367   3.408    1.684
NO3           78.900    1.273    1.273   11.827   5.843
SO4           45.300    0.472    0.943   8.765    4.331
TOTAL ANIONS                     10.760

CATION-ANION BALANCE (C-A)/(C+A) * 100 =  1.19
```

APPENDIX F

DESCRIPTIVE STATISTICS

DESCRIPTIVE STATISTICS FOR
ELECTRICAL CONDUCTIVITY

WELL	NUMBER OF SAMPLES	MEAN	MINIMUM	MAXIMUM	STANDARD DEVIATION	NORMAL AT 95%
			(UMHOS/CM)			
A3	14	978	926	1078	47	YES
A4	29	941	845	1040	58	YES
C3	14	1286	1097	1475	121	YES
C4	29	1023	972	1070	27	P = 1.1E-02
D3	14	1348	1230	1683	127	YES
D4	29	1092	1013	1165	35	YES
E3	14	572	411	664	74	YES
E4	29	927	407	1092	196	P = 5.2E-04
G1	20	1050	936	1104	43	YES
G2	29	1078	981	1169	48	YES
H1	15	1068	970	1136	47	YES
H2	29	1211	1147	1274	29	YES
I1	14	1063	865	1171	98	YES
I2	29	934	839	991	30	YES

DESCRIPTIVE STATISTICS FOR
BICARBONATE

WELL	NUMBER OF SAMPLES	MEAN	MINIMUM	MAXIMUM	STANDARD DEVIATION	NORMAL AT 95%
			—————(MG/L)—————			
A3	14	608	554	664	36	YES
A4	29	568	481	629	43	YES
C3	14	750	690	792	37	P = 3.1E-02
C4	29	602	582	632	16	YES
D3	13	755	690	879	51	YES
D4	29	640	627	654	7	YES
E3	14	349	272	400	43	YES
E4	29	557	237	671	125	P = 3.2E-04
G1	20	633	584	690	32	YES
G2	29	657	623	683	15	YES
H1	14	612	583	633	16	P = 2.0E-02
H2	29	629	573	662	26	YES
I1	14	562	397	659	80	YES
I2	29	479	458	505	13	YES

DESCRIPTIVE STATISTICS FOR
CHLORIDE

WELL	NUMBER OF SAMPLES	MEAN	MINIMUM (MG/L)	MAXIMUM	STANDARD DEVIATION	NORMAL AT 95%
A3	14	18.1	13.8	30.7	4.4	P = 4.9E-02
A4	29	17.5	14.4	22.5	2.2	P = 8.7E-03
C3	14	51.3	24.7	73.1	17.7	P = 4.9E-02
C4	29	28.7	17.2	41.6	6.3	YES
D3	14	98.6	45.8	162.7	32.7	YES
D4	29	36.9	29.0	72.0	9.2	P = 2.2E-03
E3	14	5.4	4.1	6.6	.8	YES
E4	29	17.9	4.4	30.1	7.0	YES
G1	20	16.9	12.1	20.3	2.5	P = 1.8E-02
G2	29	19.9	14.8	24.0	2.5	P = 2.7E-03
H1	15	20.1	12.9	27.6	4.6	YES
H2	29	30.5	27.5	32.9	1.6	YES
I1	14	24.0	18.7	28.8	2.5	YES
I2	29	14.9	12.6	17.1	1.4	YES

DESCRIPTIVE STATISTICS FOR
NITRATE

WELL	NUMBER OF SAMPLES	MEAN	MINIMUM (MG/L)	MAXIMUM	STANDARD DEVIATION	NORMAL AT 95%
A3	14	27.2	20.2	33.4	4.2	YES
A4	29	34.6	27.7	44.8	5.4	P = 4.1E-02
C3	14	15.3	8.2	31.6	7.3	P = 4.8E-03
C4	29	29.5	21.6	35.5	4.9	P = 8.7E-03
D3	14	5.2	3.4	7.4	1.4	YES
D4	29	28.5	22.1	39.7	4.6	P = 9.3E-05
E3	14	19.5	11.6	24.7	3.1	YES
E4	29	29.5	12.3	40.9	7.2	YES
G1	20	57.6	40.7	77.9	14.4	P = 1.2E-03
G2	29	43.4	21.1	60.8	11.5	YES
H1	15	54.4	49.2	63.9	4.2	YES
H2	29	38.7	34.2	43.5	3.1	YES
I1	14	51.6	27.0	60.9	11.0	P = 2.0E-02
I2	29	92.9	74.5	113.2	13.5	YES

DESCRIPTIVE STATISTICS FOR
SULFATE

WELL	NUMBER OF SAMPLES	MEAN	MINIMUM —(MG/L)—	MAXIMUM	STANDARD DEVIATION	NORMAL AT 95%
A3	14	30.4	28.3	34.7	1.5	YES
A4	29	30.7	26.3	35.0	2.0	YES
C3	14	68.2	33.8	91.0	20.6	P = 3.1E-02
C4	29	37.9	33.4	50.8	4.5	P = 1.7E-02
D3	14	34.8	31.3	42.0	2.7	YES
D4	29	34.3	27.3	54.6	5.2	P = 4.5E-07
E3	14	18.8	13.7	26.4	3.0	YES
E4	29	35.8	18.0	41.6	5.9	P = 9.5E-06
G1	20	36.3	33.2	41.3	2.3	YES
G2	29	34.9	31.9	36.8	1.3	YES
H1	15	59.2	46.7	78.8	9.8	YES
H2	29	124.8	88.7	180.1	29.1	YES
I1	14	115.8	93.9	145.6	15.3	YES
I2	29	45.5	43.0	48.3	1.6	YES

VITA\

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