

SPATIAL DISTRIBUTION OF SELENIUM AND OTHER INORGANIC CONSTITUENTS IN GROUND WATER UNDERLYING A DRAINED AGRICULTURAL FIELD, WESTERN SAN JOAQUIN VALLEY, CALIFORNIA

By David A. Leighton, S.J. Deverel, *and* Janet K. Macdonald

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 91-4119

REGIONAL AQUIFER-SYSTEM ANALYSIS

Prepared in cooperation with the

SAN JOAQUIN VALLEY DRAINAGE PROGRAM

6439-73

Sacramento, California
1992

U.S. DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., *Secretary*



U.S. GEOLOGICAL SURVEY
Dallas L. Peck, *Director*

Any use of trade, product, or firm names in this publication
is for descriptive purposes only and does not imply
endorsement by the U.S. Government.

For sale by the Books and
Open-File Reports Section,
U.S. Geological Survey
Federal Center, Box 25425
Denver, CO 80225

For additional information write to:
District Chief
U.S. Geological Survey
Federal Building, Room W-2233
2800 Cottage Way
Sacramento, CA 95825

CONTENTS

Abstract	1
Introduction	1
Previous investigations	2
Description of area and agricultural field	2
Study design	3
Well design and construction	3
Sample collection	6
Field methods	7
Laboratory methods	7
Water samples	7
Samples of aquifer solids	7
Data presentation and interpretation	8
Spatial distribution of chemical constituents and isotopes in ground water	8
Selenium, salinity, and isotopes	8
Major ions	14
Other trace elements	14
Temporal variability of constituents in ground water and drainwater	15
Ground water	15
Drainwater	16
Ground-water-flow patterns	20
Physical factors affecting ground-water flow	22
Texture	26
Hydraulic conductivity	26
Distribution of chemical constituents in the solid phase	29
Summary and conclusions	32
References cited	33

FIGURES

1. Map showing location of the drained agricultural field 4
- 2,3. Schematics showing:
 2. Drainage system for the drained agricultural field and location of cluster sites and geohydrologic sections A-A' and B-B' 5
 3. Distribution of selenium concentrations in ground water 9
- 4-6. Graphs showing:
 4. Depth distribution of selenium concentrations in ground water 10
 5. Relation of \log_{10} selenium concentrations and \log_{10} dissolved-solids concentrations for ground-water samples 10
 6. Relation of delta deuterium to delta oxygen-18 for ground-water samples 11
7. Schematic showing distribution of tritium concentrations in ground water 13
8. Graph showing depth distribution of tritium concentrations in ground water 14
9. Trilinear diagram showing relation of major-ion chemistry to ground-water salinity 15

- 10-13. Graphs showing:
- 10. Depth distribution of gypsum saturation indexes 17
 - 11. Depth distribution of selected trace elements 18
 - 12. Selenium and dissolved-solids concentrations and delta oxygen-18 ratio measured over time for the drain sump 20
 - 13. Changes in hydraulic head for wells at sites 7 and 14 21
- 14,15. Geohydrologic sections showing distribution of hydraulic head and generalized directions of ground-water flow superimposed on existing sand layers during periods of high and low hydraulic head:
- 14. Along geohydrologic section A-A' 23
 - 15. Along geohydrologic section B-B' 24
16. Schematic showing areal distribution of hydraulic head 3 meters below land surface and generalized direction of ground-water flow 25
17. Geohydrologic sections showing texture distribution along geohydrologic sections A-A' and B-B' 27
- 18-20. Graphs showing:
- 18. Relation of hydraulic conductivity determined by the methods of Hvorslev (1951) and Cooper and others (1967) in wells with screened intervals opposite coarse- and fine-grained deposits 29
 - 19. Concentrations of total, soluble, and residual selenium and organic carbon in the solid phase 31
 - 20. Relation of percentage of organic carbon to residual selenium concentrations 32

TABLES

- 1. Principal component scores for the solid phase chemical data 30
- 2. Site, well depth, and constituents determined for water samples collected in the drained agricultural field 35
- 3. Field measurements and chemical analysis for major ions, dissolved organic carbon, stable isotopes of hydrogen and oxygen, and tritium 40
- 4. Chemical analysis of dissolved trace elements 48
- 5. Chemical analysis of drilling-core samples 52
- 6. Selenium, dissolved solids, and stable isotope data for wells with multiple samples 68
- 7. Field measurements and chemical analysis of drainwater 71

Conversion Factors

Multiply	By	To obtain
centimeter (cm)	0.3937	inch
hectare (ha)	2.471	acre
kilometer (km)	0.6214	mile
meter (m)	3.281	foot
meter per annum (m/a)	3.281	foot per year
millimeter (mm)	0.03937	inch

Temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$^{\circ}\text{F}=1.8(^{\circ}\text{C})+32.$$

SPATIAL DISTRIBUTION OF SELENIUM AND OTHER INORGANIC CONSTITUENTS IN GROUND WATER UNDERLYING A DRAINED AGRICULTURAL FIELD, WESTERN SAN JOAQUIN VALLEY, CALIFORNIA

By David A. Leighton, S.J. Deverel, and Janet K. Macdonald

Abstract

This report presents the results of a study of the geochemical and hydrologic factors affecting the distribution of selenium and other inorganic constituents in the shallow ground water underlying an artificially drained agricultural field. Ground-water samples collected from observation wells located throughout the field show the highest salinity and selenium concentrations at a depth of 6 to 9 meters. Oxygen- and hydrogen-stable isotope data indicate that this highly saline, selenium-rich ground water was once subject to evapoconcentration near land surface. Subsequent application of less saline irrigation water has displaced this saline, selenium-rich water downward. The distribution of tritium in ground-water samples collected from different depths supports this hypothesis.

During the irrigation season, ground-water flow is primarily downward; during fallow periods, flow is upward. Subsurface sand layers and a regional collector line affect the horizontal flow of ground water. Except during and immediately after irrigation, the drain laterals do not substantially influence flow.

Principal-component analysis of the chemical associations in the solid phase indicates that most of the variation in the chemical composition is accounted for by a felsic component. The elements associated with this component are those associated with alumino silicate and iron and manganese oxides. Soluble selenium represents a small fraction of the total concentration of selenium in the unsaturated and shallow saturated zones. Most of the soluble selenium has been leached from these zones by irrigation. The concentrations of selenium in the solid phase that were not in a soluble form were highest in the unsaturated zone and were significantly correlated with percentage of organic carbon, indicating that a large fraction of the solid phase selenium was associated with organic matter.

INTRODUCTION

High concentrations of selenium in subsurface agricultural drainwater in the western San Joaquin Valley, California, have caused high mortality rates in waterfowl at Kesterson National Wildlife Refuge near Gustine, California (Ohlendorf and others, 1986). Agricultural drainage systems were installed in some low-lying areas of the western San Joaquin Valley to prevent accumulation of soil root-zone salt that adversely affects crop production. These systems generally maintain the water table below about 1.5 m because evaporation of shallow ground water from a water table within 1.5 m of land surface can lead to accumulation of salts in the unsaturated zone and an increase in ground-water salinity. Shallow ground water affects about 100,000 ha of agricultural land in the western San Joaquin Valley (U.S. Bureau of Reclamation, 1984). High concentrations of boron, molybdenum, and arsenic in drainwater and ground water are also of primary environmental concern because of documented or possible adverse effects on water quality, public health, agricultural productivity, and fish and wildlife (San Joaquin Valley Drainage Program, 1990).

The salinity and the concentrations of selenium and other inorganic constituents in the soils and shallow ground water are related to the deposition, geomorphology, and hydrology of the alluvial fans (Deverel and Millard, 1988; Deverel and Gallanthine, 1989). Leaching of naturally occurring salts and associated trace inorganic constituents from soils by irrigation water is the primary factor resulting in the spatially variable concentrations of trace inorganic constituents and dissolved salts in shallow ground

water. Evapotranspiration of shallow ground water in the low-lying areas of the western San Joaquin Valley has led to the accumulation of salts in ground water and soils (Deverel and Gallanthine, 1989). Agricultural drainage systems in some low-lying areas collect this saline ground water. An understanding of the geochemical and hydrologic processes affecting the chemical composition of ground water associated with agricultural drainage systems is required for the development of effective water-management strategies.

This report describes the results of a study of the spatial distribution of selected chemical constituents in shallow ground water (within 15 m of land surface) underlying an artificially drained agricultural field in the western San Joaquin Valley, California. The objectives of this study were: (1) to assess the spatial distribution and temporal variability of salinity, selenium, organic carbon, and other inorganic constituents in ground water and aquifer solids underlying the agricultural field; (2) to identify the geochemical and hydrologic processes that affect the spatial distribution and temporal variability; and (3) to measure the physical properties of the shallow aquifer that will lead to a quantitative assessment of ground-water flow. The approach was to determine the chemical and isotopic composition of ground-water samples collected at depths ranging from 3 to 15 m below land surface in a single agricultural field. The chemical and isotopic composition of the ground water samples was assessed relative to ground-water-flow patterns, the irrigation and drainage history of the field, the chemical composition of the soils and aquifer materials and the temporal variability of the chemical composition of the ground water and drainwater.

This study is part of a comprehensive investigation of the hydrology and geochemistry of the western San Joaquin Valley by the U.S. Geological Survey. The studies are being done in cooperation with San Joaquin Valley Drainage Program and as part of the Regional Aquifer System Analysis Program of the U.S. Geological Survey.

PREVIOUS INVESTIGATIONS

There are few other investigations of the spatial distribution of chemical constituents in shallow ground water associated with agricultural drainage systems. Deverel and Fujii (1988) evaluated the processes affecting the chemistry of shallow ground water associated with agricultural drainage systems in three fields in the northern part of the Panoche Creek

alluvial fan. The highest salinity and selenium concentrations in shallow ground-water samples were associated with isotopic enrichment, and therefore, a result of evapotranspiration from a shallow water table (Deverel and Fujii, 1988). Varying degrees of displacement of this saline, high selenium water toward the drain laterals resulted in different distributions of salinity, selenium, and isotopes measured in the three fields.

Transport of saline ground water in artificially drained agricultural fields in the western San Joaquin Valley has been examined by Pillsbury and others (1965) and Jury (1975a, 1975b). These authors generally agreed that several decades would be required for saline ground water to travel to drain laterals from midway between the laterals, which are typically 50 to 100 m apart. Luthin and others (1969), Ortiz and Luthin (1970), Raats (1978), Mansell and others (1985), and other authors have evaluated conservative solute movement in ground water associated with artificially drained agricultural fields. Although the results presented by these authors are not specifically applicable to the San Joaquin Valley problem, their analyses generally agree with the Jury (1975a, 1975b) approach.

DESCRIPTION OF AREA AND AGRICULTURAL FIELD

California's San Joaquin Valley is a structural trough between the Sierra Nevada on the east and the folded and faulted Coast Ranges on the west. The Sierra Nevada, a fault block that dips southeastward, is composed of igneous and metamorphic rock, mostly of pre-Tertiary age. The Diablo Range of the California Coast Ranges, which borders the study area to the west, consists of an exposed Upper Jurassic and Cretaceous core assemblage of marine origin overlain and juxtaposed with Cretaceous marine and Tertiary marine and continental deposits. The alluvial-fan deposits of the western valley are derived exclusively from Diablo Range rocks (Miller and others, 1971). The basin deposits are derived from the Sierra Nevada and the Diablo Range, but are dominated by Sierra Nevada deposits.

The deposition of the alluvial fans on the westernmost edge of the valley has been described by Bull (1964). At the margins of the alluvial fans, soils are fine grained and often saline (Harradine, 1950). Ground water at the margins of the alluvial fans is saline, and selenium concentrations are high (Deverel and Gallanthine, 1989).

Ground-water flow in the western valley has changed considerably since the development of irrigated agriculture. Under natural conditions, ground-water recharge was primarily from infiltration of water from intermittent streams in the upper parts of the alluvial fans (Belitz and Heimes, 1990). Ground water flowed from southwest to northeast, reflecting the general topographic trend of the area. Discharge from the system was by evapotranspiration and streamflow along the valley trough (Mendenhall and others, 1916; Davis and Poland, 1957). Flowing wells mapped by Mendenhall and others (1916) indicate that artesian conditions prevailed along a broad stretch of the valley trough.

Development of irrigated agriculture began in the late 1800's with ground-water pumping and diversions from the San Joaquin River. Ground-water pumping became the primary source of irrigation water in the 1920's and reached a maximum in the 1950's. During agricultural development, pumping and evapotranspiration by plants became the primary discharge mechanisms. Percolation of irrigation water past crop roots became the primary recharge mechanism. The increase in recharge to the upper part of the hydrologic system and discharge from the lower part of the system resulted in a downward hydraulic gradient over most of the western valley (Belitz and Heimes, 1990).

Ground-water withdrawals until 1952 in the area north of Mendota and until 1967 in the area south of Mendota caused the water table to decline along alluvial-fan margins and in the valley trough. When surface water imported from northern California replaced ground water for irrigation, the water table rose throughout the area. The percentage of the area characterized by a water table within 6 m of land surface has increased substantially since 1952 (Belitz and Heimes, 1990).

The field selected for study is in an area where the water table has risen more than 12.2 m to within 1.8 m of land surface since the early 1950's (Davis and Poland, 1957; U.S. Bureau of Reclamation, written commun., 1984) and evapotranspiration from a shallow water table has caused high ground-water salinity and selenium concentrations (Deverel and Gallanthine, 1989). Figure 1 shows the location of the drained agricultural field. The area of the field is 65 ha and cotton has always been the primary crop.

Using aerial photographs, Bull and Miller (1975) mapped the development of irrigation in the western valley. Clyde Irion (farm manager, oral commun.,

1986) stated that the field had been first irrigated sometime in the 1930's. Water initially pumped for irrigation of this field came primarily from the lower confined aquifer described by Belitz and Heimes (1990). Surface water imported from northern California through the California Aqueduct by the Federal Central Valley Project replaced pumped ground water for irrigation in the field by about 1970.

To lower the water table, a drainage system was installed in this field in 1980. Figure 2 shows the drainage system, cluster sites, and geohydrologic sections *A-A'* and *B-B'*. Drain laterals are constructed of corrugated and perforated plastic pipe buried at depths of 1.9 to 2.1 m. Regional collectors collected drainwater from many farm-drainage systems and transported it to the San Luis Drain until 1986 (fig. 1). Since 1986, drainwater in the regional collector has been mixed with California Aqueduct water and used for irrigation.

STUDY DESIGN

To assess the spatial distribution of chemical constituents in ground water underlying the field, 202 observation wells were installed at 59 cluster sites (fig. 2). Each cluster site consisted of 1 to 5 wells drilled to depths of 3 to 15 m (table 2, at back of report). Samples collected from 86 of these wells were analyzed for various chemical constituents and 66 wells were used to estimate horizontal hydraulic conductivity. Ground-water samples were collected periodically from spring 1986 to summer 1988 to evaluate the spatial and temporal variability of concentrations of chemical constituents. The temporal variability of the chemical constituents was evaluated in relation to temporal changes in drain flow, hydraulic gradients in ground water, and the spatial distribution of chemical constituents. Water levels were measured periodically in all existing observation wells to characterize the shallow ground-water-flow system.

WELL DESIGN AND CONSTRUCTION

Wells at the 32 sites labeled EW, NW, and SE were completed during the summer 1985 (table 2). Two methods were used to complete these wells. At each site, 2.5-cm diameter wells were jetted to depths of 3, 4.5, 6, and 9 m by pumping water at high pressures through the well casing. The casing was inserted into the hole created by the high-pressure stream of water. These wells were used exclusively

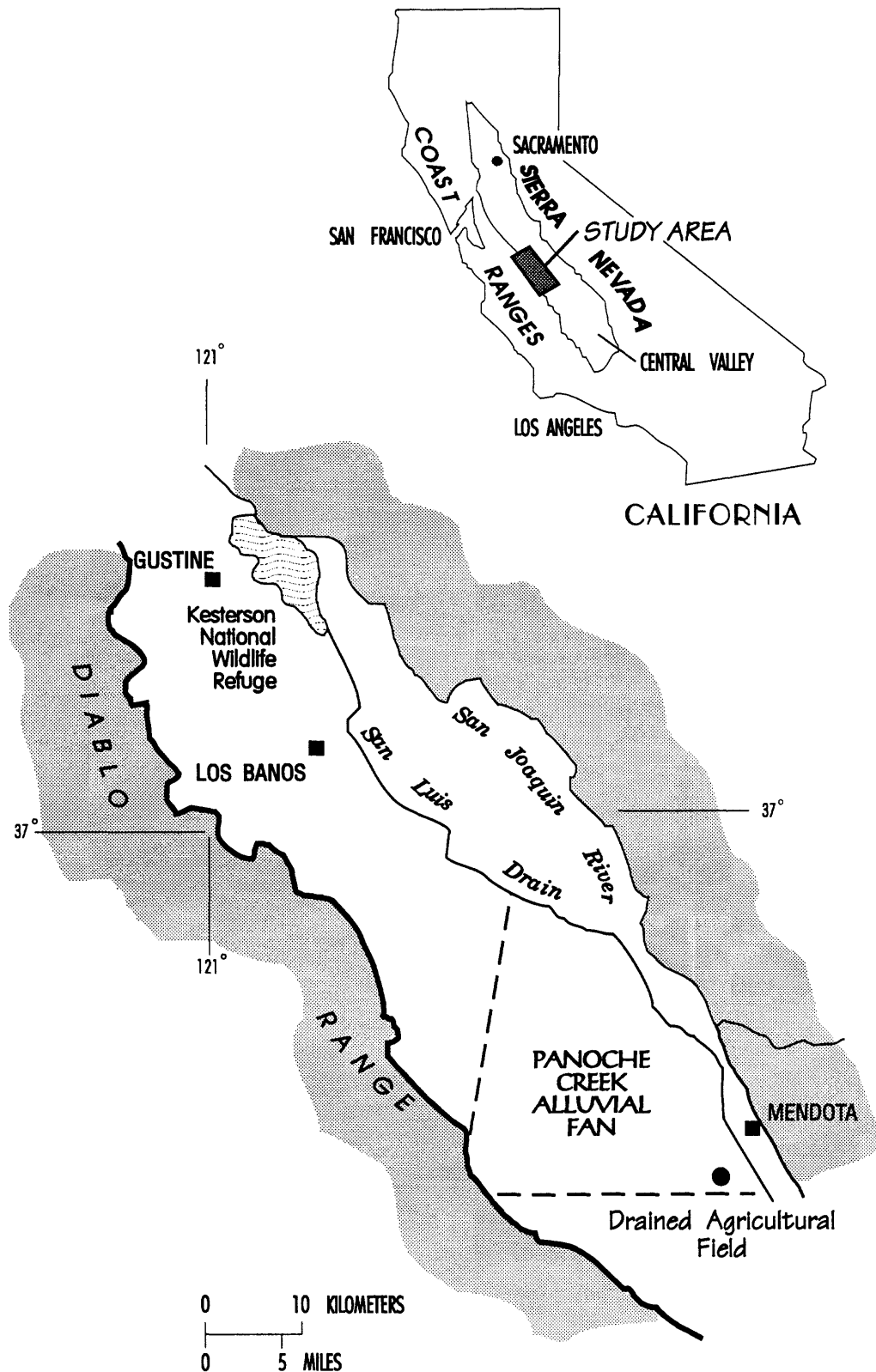


Figure 1. Location of the drained agricultural field.

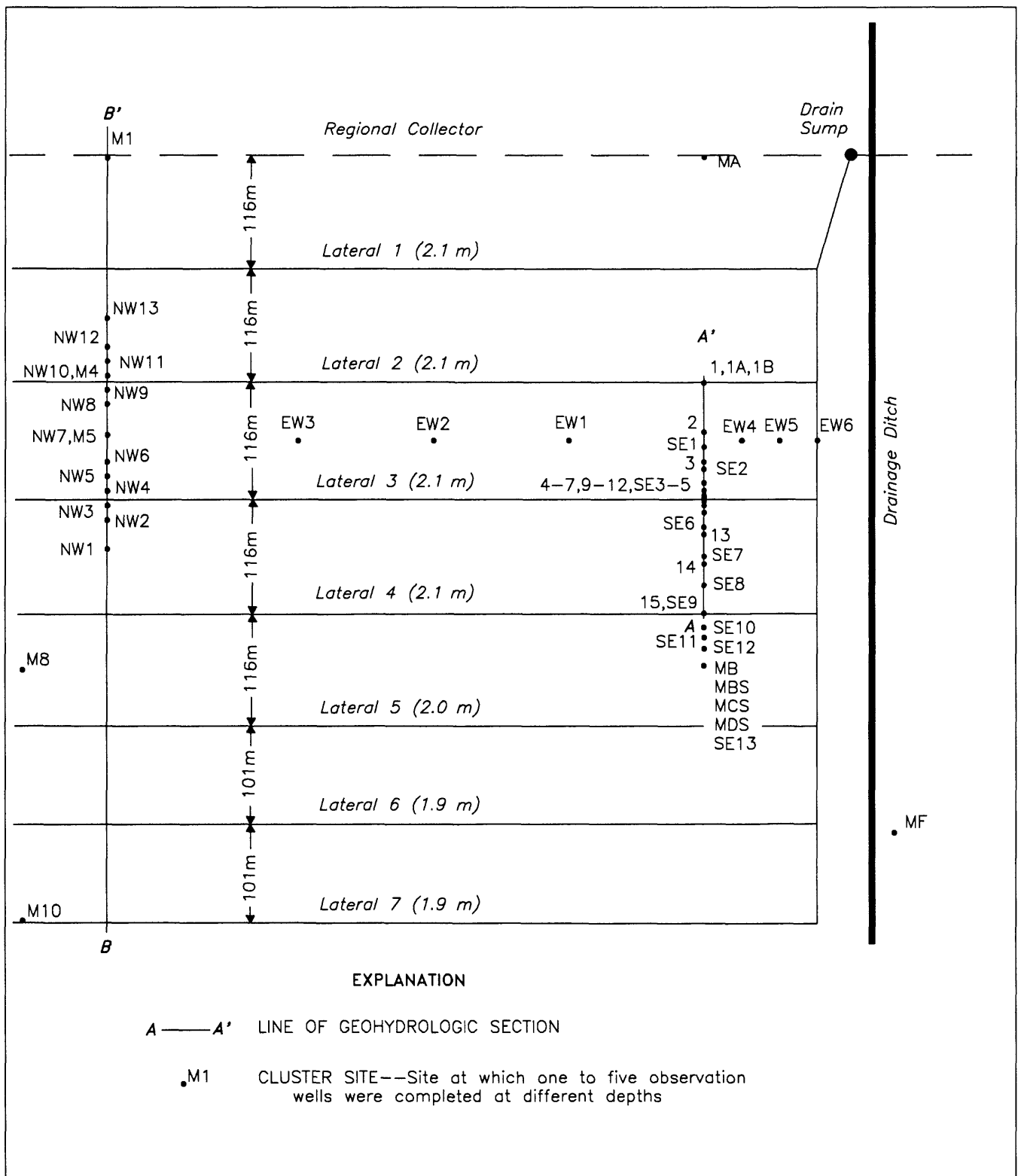


Figure 2. Drainage system for the drained agricultural field and location of cluster sites and geohydrologic sections A-A' and B-B'.

for hydraulic-head measurements. An additional well for sample collection was completed at 16 of these sites using a hand auger. The casing was set at a depth of 4 m with perforations over the bottom 120 cm. Open space around the casing was back-filled with cuttings removed during the augering.

Sites labeled 1 through 15 were drilled in January and February 1986 using a hollow-stem auger. The auger was used to drill to within 1 m of the desired depth. To assure that the perforated section of casing was placed in a relatively undisturbed section of subsurface material, the final 1 m of material was removed using a core tube of the same diameter as the casing. The tube was pushed below the auger bit and the core was removed. The casing then was placed in the borehole and the augers were removed. Wells were completed at depths of 3, 6, 9, and 12 m and the bottom 30 cm of the casing was screened. Each well was sealed to land surface with bentonite grout.

Wells at the M sites were drilled using the hollow-stem auger in spring 1987. At these sites, the casing was screened over the bottom 60 cm, placed in the borehole, and sand packed around the screened interval. Wells were completed at depths of 3, 6, 9, 12, and 15 m and all were sealed to land surface using bentonite grout. Periodically, wells were damaged or destroyed by farming operations in the field. All wells were constructed of polyvinyl chloride (PVC) pipe.

SAMPLE COLLECTION

Most of the water-quality samples were collected with tubing and positive-displacement bladder pumps constructed of Teflon and stainless steel. The submersible, 4.5-cm stainless steel bladder pump operates by allowing water to enter through a one-way valve in the bottom of the pump. Pressurized nitrogen gas is cycled in and out of a Teflon bladder inside the pump casing, displacing the water up the Teflon tubing. Some of the observation wells were sampled using a peristaltic pump to remove water from the well through Teflon tubing and into the sample containers.

Prior to sampling, each well was pumped until the specific conductance of the water did not vary by more than 10 percent for three consecutive well-casing volumes of water. Electrical conductivity meters were standardized with potassium chloride

standards within 2,000 $\mu\text{S}/\text{cm}$ (microsiemen per centimeter at 25 °C) of the well water. Temperature, specific conductance, pH, dissolved oxygen, and oxidation-reduction potential were measured several times at each well prior to sampling. Before each sample was taken, another well-casing volume was pumped.

Before collecting each sample, all sampling apparatus and containers were rinsed three times with the well water. Bicarbonate and carbonate concentrations were determined in the field for each site by incrementally titrating unfiltered samples with dilute sulfuric acid. Portable pH meters and electrodes were calibrated at each well and for each titration with pH buffers maintained at the temperature of the sample water within ± 2 °C. Temperature was measured with mercury thermometers that were checked for accuracy against a standardized laboratory thermometer. The oxidation-reduction potential status of the sample was determined by measuring the platinum electrode redox potential. The platinum electrodes were field checked by placing in pH buffers saturated with Quinhydrone. These solutions have known redox potentials that can be compared to the value obtained from the meter. Dissolved-oxygen meters were calibrated by placing the probe in a chamber saturated with water vapor and adjusting the meter to the dissolved oxygen saturation value for the measured water temperature and ambient atmospheric pressure. The platinum electrode redox potential and dissolved oxygen were determined by placing the respective probes in a flow-through chamber as described by Wood (1981).

Samples for analysis of dissolved constituents were pressure filtered through 0.1-mm membrane filters. Samples for determination of major ions and all trace elements were collected and stored in polyethylene bottles with Teflon-lined caps. All samples were acidified with nitric acid to a pH of less than 2 except those collected for determination of pH, specific conductance, bicarbonate, carbonate, sulfate, chloride, silica, boron, and vanadium, which were untreated. Samples for analysis of oxygen- and hydrogen-stable isotopes and tritium were not filtered and were collected in glass bottles with polyethylene-lined caps so that there was no air space.

Drilling-core samples were collected from the deepest borehole at each site by pushing a core tube ahead of the auger bit for every 1 m of depth. Each core was displaced from the tube in the field and the length and a qualitative description of texture were recorded.

FIELD METHODS

Water levels were measured monthly during the study period in all existing wells using a steel tape. Water-level recorders were installed at sites 2, 7, 14, 15, MCS, and MF to provide a continuous record of water-level changes.

Hydraulic conductivities were estimated by analyzing data from single-well response tests (slug tests) in 66 wells. Fifty-four of the wells were screened in fine-grained deposits and 12 wells were screened in coarse-grained deposits. Fine-grained deposits were defined on the basis of the texture descriptions done during drilling and particle-size analysis. A known volume of water was displaced within the well, and the rate of change in the hydraulic head was measured over time with a pressure transducer connected to a data micrologger. The volume of water was displaced by lowering a length of 2.5-cm PVC pipe filled with sand and sealed with PVC caps at both ends (the slug). The amount of head displaced in the 6- to 15-m wells was about 30 cm when the slug was completely submerged. The 3-m wells required a smaller head displacement of about 15 cm. The water level in the wells remained above the screened interval at all times during the testing. The hydraulic characteristics of the geologic materials surrounding the screen controlled the rate at which the hydraulic head decreased.

LABORATORY METHODS

Water samples.--Major ions and trace elements were analyzed at the U.S. Geological Survey's National Water Quality Laboratory in Arvada, Colorado. Calcium, magnesium, sodium, potassium, silica, aluminum, arsenic, chromium, iron, lithium, manganese, molybdenum, and nickel were determined by atomic absorption spectrometry. Chloride and vanadium were determined by colorimetry. Boron was determined by atomic emission. Sulfate was determined by the turbidimetric procedure. All these methods are described by Fishman and Friedman (1985).

Selenium was determined by hydride generation and atomic absorption spectrometry. The method used for selenium in this study is designed to determine the total concentration of all forms of selenium present in the water sample. A sample is first subjected to an oxidative digestion to release any selenium from the organic fraction. The selenium

released by this digestion, together with the inorganic selenium originally present, is then reduced to the selenite form with stannous chloride and potassium iodide mixture. The selenium hydride is generated by reducing the selenite form with sodium borohydride. The hydride gas is stripped from solution by a stream of nitrogen gas and its concentration determined by atomic absorption spectrometry.

The oxygen-isotopic composition of the water samples was determined with the carbon dioxide equilibration methods (Epstein and Mayeda, 1953). Analysis was done with a 60° sector, 150-mm radius double-collecting isotope ratio mass spectrometer. The results are reported relative to Vienna Standard Mean Ocean Water (V-SMOW):

$$\delta^{18}\text{O} = \frac{(^{18}\text{O}/^{16}\text{O})_{\text{sample}} - (^{18}\text{O}/^{16}\text{O})_{\text{V-SMOW}}}{(^{18}\text{O}/^{16}\text{O})_{\text{V-SMOW}}} \times 1,000. \quad (1)$$

The hydrogen-isotopic compositions were determined by analyzing hydrogen quantitatively extracted from water (Kendall and Coplen, 1985). Hydrogen results are reported relative to V-SMOW in per mil notation. The standard deviation of the laboratory measurements of oxygen- and hydrogen-isotopic composition are 0.10 and 1 per mil, respectively. The oxygen- and hydrogen-isotopic compositions were determined at the Isotope Fractionation Project Laboratory of the U.S. Geological Survey, Reston, Virginia.

Tritium was determined by scintillation counting after electrolytic enrichment (International Atomic Energy Agency, 1976). Tritium concentrations are expressed in tritium units (TU), where 1 TU is equal to 1 tritium atom in 10^{18} hydrogen atoms. All tritium analyses were done by the Environmental Isotope Laboratory at the University of Waterloo, Ontario, Canada.

Samples of aquifer solids.--Samples of aquifer solids collected for chemical analysis during the drilling process were air-dried and ground to a fine powder. The samples were then subjected to the extraction and digestion procedure described by Fujii and others (1988). All constituents except arsenic and selenium were analyzed using inductively coupled plasma optical emission spectrometry (ICPS) (Thornton, 1983).

Samples for the determination of arsenic and selenium concentrations were subjected to the digestion procedure described by Briggs and Crock

(1986). The digested sample then was analyzed by hydride generation followed by atomic absorption spectrometry (Briggs and Crock, 1986).

Total organic carbon was determined as the difference of total carbon (measured by oxidizing the sample in an induction furnace) and total inorganic carbon (measured by treating a sample with acid, heating it, and measuring the amount of carbon dioxide evolved) (Wershaw and others, 1987).

Air-dried and ground core samples also were analyzed to determine percentage of sand, silt, and clay. Analyses were done at the U.S. Geological Survey Sediment Laboratory, Salinas, California, and the University of California Agricultural Extension Laboratory, Davis, California. The fraction of sand, silt, and clay was determined by the sieve-pipet and chemically dispersed analysis method (Guy, 1969). Samples were divided into three grain-size classes: less than 50 percent sand, 51 to 70 percent sand, and greater than 70 percent sand. The textural distribution of the wells in the northwest transect were estimated on the basis of field observations during drilling.

DATA PRESENTATION AND INTERPRETATION

Data for field measurements, major ions, dissolved organic carbon, stable isotopes, and tritium are shown in table 3 (at back of report) and concentrations of dissolved trace elements are shown in table 4 (at back of report).

Differences in chemical compositions of ground water were evaluated using trilinear diagrams (Hem, 1985) and the chemical equilibrium model WATEQF (Plummer and others, 1976). Mineral phases affecting the ground-water chemistry were assessed using mineral saturation indices determined by the WATEQF chemical equilibrium model. The saturation index is equal to the quotient of the ion-activity product and mineral-solubility constant. Negative saturation index values indicate mineral undersaturation and positive values indicate supersaturation. The hydrologic history of selected water samples was assessed from the determination of tritium concentrations and deuterium and oxygen-18 enrichment.

Results of chemical analysis of drilling-core samples collected in the field are shown in table 5 (at back of report). Principal-component analysis

(Johnson and Wichern, 1982) was used to assess chemical associations in the solid phase. Principal-component analysis apportions the total variance of the soil chemical data among several master variables (the principal components). Principal-component scores are calculated for each soil sample and constituent determined in the soil samples. The scores have a mean of 0 and a variance of 1. The elements and the samples are related to the principal components by the value of the scores. The value of the principal-component score is analogous to the correlation between the concentration of the constituent in the sample and the principal component.

SPATIAL DISTRIBUTION OF CHEMICAL CONSTITUENTS AND ISOTOPES IN GROUND WATER

SELENIUM, SALINITY, AND ISOTOPES

The vertical distribution of selenium in the ground water is related to evapoconcentration of solutes in the shallow ground water and the downward displacement of ground water. Figure 3 shows the selenium concentrations in samples collected in the observation wells. For multiple samples, the number reported in figure 3 is the average of all samples collected from the observation well. In general, selenium concentrations are larger in samples collected from wells at cluster sites in the southeast relative to the northwest section of the field. The higher selenium concentrations in observation wells in the southeast are the result of prolonged evapotranspiration from a shallow water table relative to the northeast in the 1970's. The vertical distribution of selenium concentrations reflects the downward displacement of ground water that was near land surface in the 1970's.

Figure 4 shows the depth distribution of selenium concentrations in ground-water samples. The selenium concentrations in samples collected from the 3- and 4-m-deep wells were combined and represented at 3 m in figure 4. Similarly, samples collected in 8.5- and 9-m-deep wells were combined and represented at 9 m. The ground-water samples having the largest selenium concentrations were collected at the 9-m depth. Based on tritium and stable isotope data, ground water at the 9-m depth was near land surface in the late 1960's to early 1970's. The high selenium concentrations in the samples from the 9-m depth and, to a lesser extent, the 6-m depth are the result of

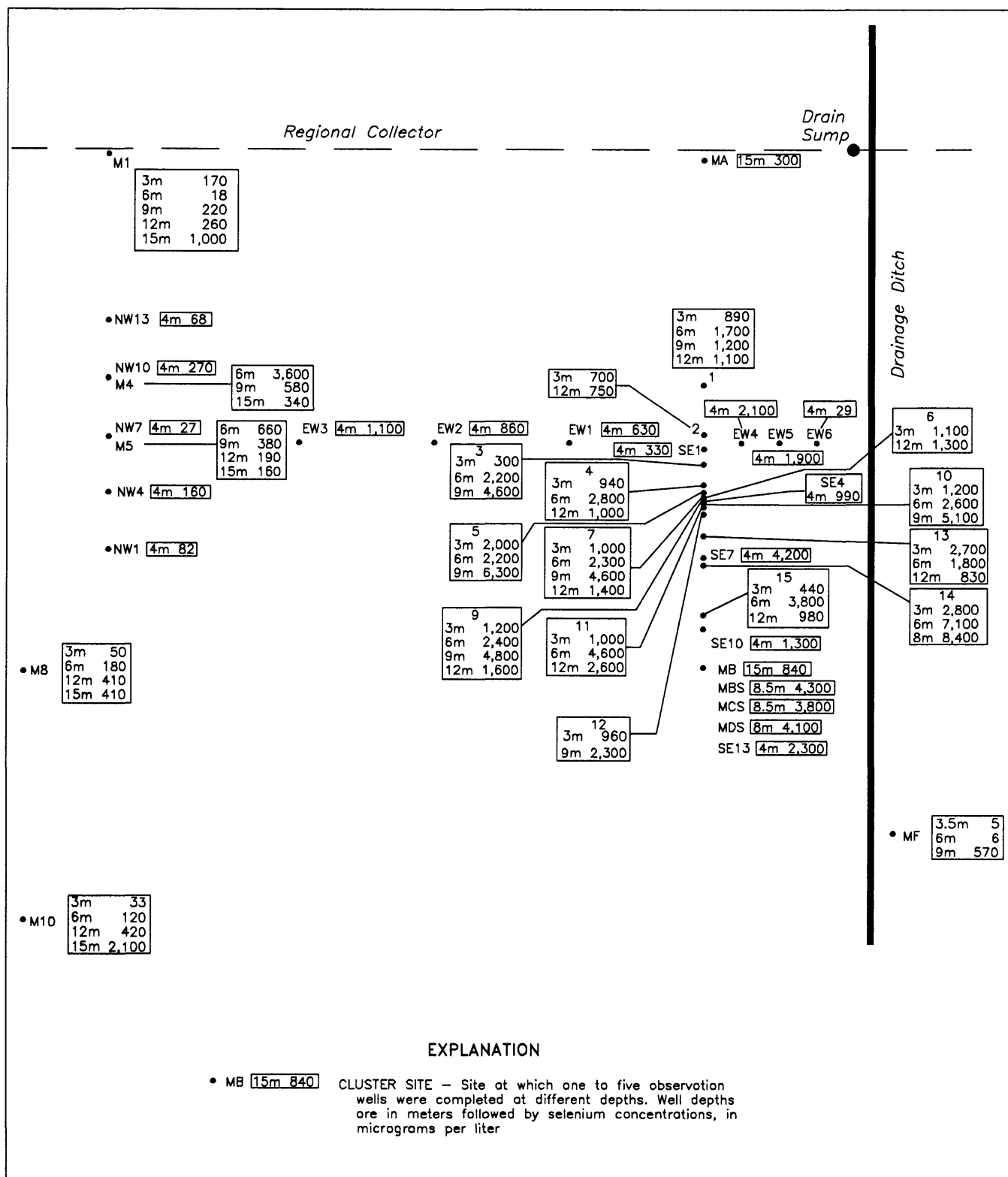
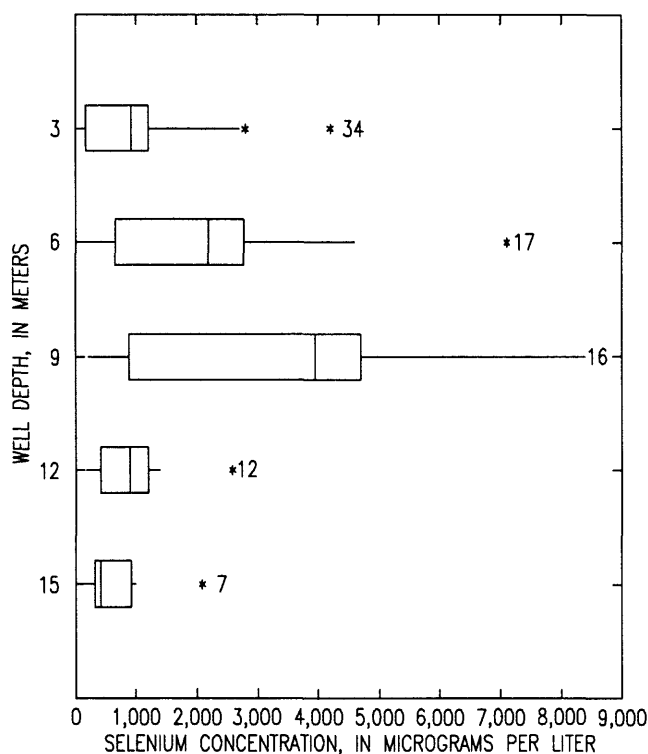
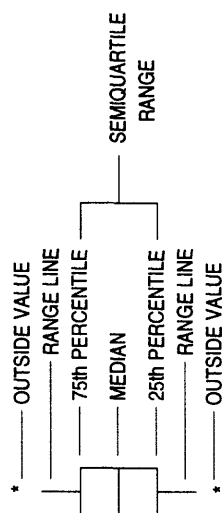


Figure 3. Distribution of selenium concentrations in ground water.



EXPLANATION



Outside values are between 1.5 and 3.0 times the semi-quartile range from the end of the rectangle

Range lines extend a distance equal to 1.5 times the semi-quartile range away from the end of the rectangle or to the limit of the data, whichever is least

7 Number of observations

Figure 4. Depth distribution of selenium concentrations in ground water. Average concentrations were used for wells where multiple samples were collected.

evapotranspiration from a shallow water table. The ground water at the 6- and 9-m depths was displaced by water that infiltrated primarily after 1970. The shallowest ground water at 3 m has lower selenium concentrations because it infiltrated after drainage-system installation in 1980. The lowering of the water table to below 1.5 m after drainage-system installation in 1980 resulted in less evapotranspiration of the shallow water table, resulting in lower selenium concentrations.

Ground-water salinity as determined by the concentration of dissolved solids varies similarly to selenium in ground water and is affected by the same processes. The \log_{10} of dissolved solids and selenium concentrations in ground water are significantly correlated ($r=0.76$, $\alpha=0.01$). Figure 5 shows the relation of the \log_{10} of dissolved solids and the \log_{10} of selenium concentrations.

The stable isotope enrichment in ground-water samples confirm that the highest selenium concentrations and salinity in ground water are the result of evapotranspiration from a shallow water table. Both selenium concentrations ($r=0.93$) and salinity ($r=0.91$) are highly correlated with delta oxygen-18 ($\delta^{18}\text{O}$). Figure 6 shows the relation of delta deuterium (δD) to $\delta^{18}\text{O}$ for the ground-water samples collected in the field. All the samples fall along an evaporative trend line similar to that described by Deverel and Fujii (1988) and Deverel and Gallanthine (1989). Water

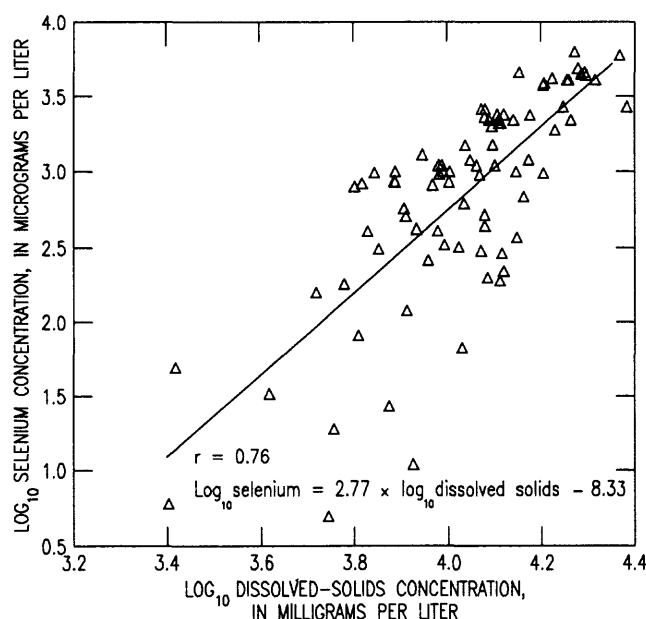


Figure 5. Relation of \log_{10} selenium concentrations and \log_{10} dissolved-solids concentrations for ground-water samples.

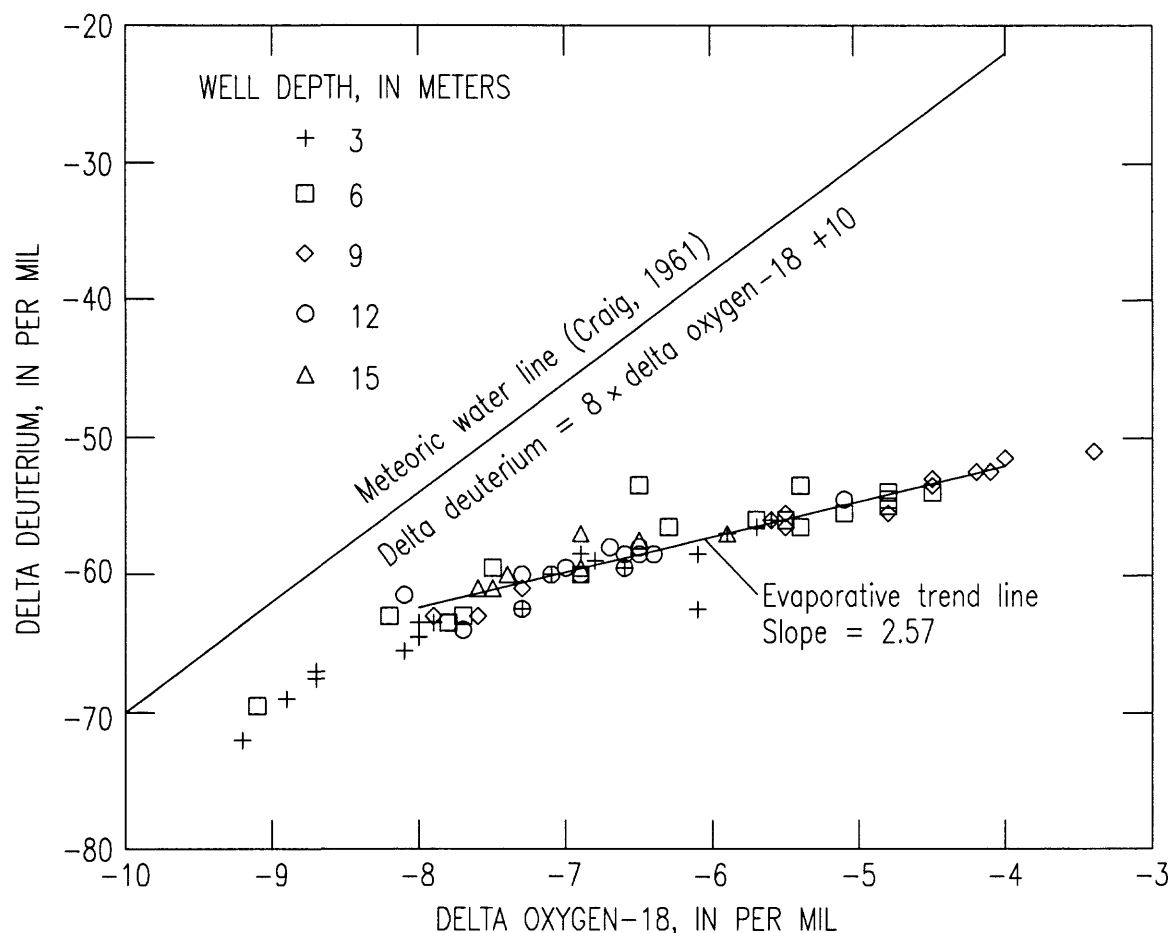


Figure 6. Relation of delta deuterium to delta oxygen-18 for ground-water samples.

samples collected in other arid and semiarid regions also fall along evaporative trend lines (Fontes and Gonfiantini, 1967; Gat, 1971; Zat and Gat, 1975). Samples that show a greater displacement along an evaporative trend line from the meteoric water line have been subject to greater evapotranspiration. The meteoric water line is a relationship established by the isotopic composition of precipitation from samples collected around the world (Craig, 1961). Samples collected at the 6- and 9-m depths have been subject to greater evaporative enrichment of the heavy isotopes than water samples collected at the other depths.

Equilibrium isotopic fractionation results in values that fall on a line with a slope similar to that of the meteoric water line (Craig, 1961) (fig. 6). Evapotranspiration of water from just below land surface is a nonequilibrium fractionation process. Mass transfer of water molecules during evapotranspiration is

controlled by diffusion in the region just above the air/water interface. Transport through this region causes kinetic separation, which results in greater enrichment of the oxygen-18 water species than the deuterium water species. Therefore, the ratio of deuterium/oxygen-18 enrichments is lower than would be expected for equilibrium fractionation processes (International Atomic Energy Agency, 1981).

The highest selenium and salinity concentrations were in samples collected at the 6- and 9-m depths (fig. 4) and are the result of the most evaporative concentration. The samples collected at the 3-m depth generally have isotopic compositions that are close to the meteoric water line and have been subject to less evaporative concentration (fig. 6). This is because of the drainage-system installation in 1980 and subsequent lowering of the water table to a depth from which little or no evapotranspiration occurs.

The points plotted in figure 6 represent an evaporative trend line that is described by the equation:

$$\delta D = 2.70 \times \delta^{18}O - 41.1 (r=0.90). \quad (2)$$

The slope of this line is significantly ($\alpha=0.01$) lower than the evaporative trend slope of 4.28 reported by Deverel and Fujii (1988) for shallow ground water collected beneath agricultural fields in the western valley, north of the study site. Allison (1982) presented evidence that such a low slope is the result of prolonged evaporation from a dry surface. Displacement since the mid-1970's of unsaturated-zone water that has been subject to evapotranspiration from a dry soil surface probably has resulted in the present-day pattern of isotopic enrichment in the shallow ground water (fig. 6).

The slope in equation 2 is dominated by points that represent water samples collected at the 6-m depth and below. The equation of the evaporative trend line for water samples collected at 3 m is:

$$\delta D = 3.21 \times \delta^{18}O - 38.5 (r=0.96). \quad (3)$$

The oxygen-18 value at the intercept of this line with the global meteoric water line is -10.13. This value is close to the median of measured values for data collected by the authors for the past 2 years from the California Aqueduct (-9.55).

Equation 2 is significantly different ($\alpha=0.01$) from the equation representing the data from the 6- and 9-m depths,

$$\delta D = 2.37 \times \delta^{18}O - 42.7 (r=0.92). \quad (4)$$

The $\delta^{18}O$ intercept of this line with the local ground water trend line is -7.99, close to the mean of -8.59 for the confined aquifer water used for irrigation prior to 1970 (Davis and Coplen, 1987).

The difference in the slopes between the two groups of data indicates different evaporative processes. The lower slope for the 6- and 9-m data may be the result of prolonged evaporation from a dry surface soil. This may have occurred under saline conditions that inhibited crop growth. In contrast, the conditions under which the water at the 3-m depth infiltrated were less saline, and more plant transpiration may have been the primary mechanism of evaporative losses. This resulted in a different slope and a more depleted isotopic composition (Barnes and Allison, 1983). Samples collected from wells at depths of 12 and 15 m are similar in isotopic composition to the

samples collected at the 3-m depth. The water at these lower depths probably infiltrated 25 to 40 years ago and underwent some isotopic enrichment due to evapotranspiration as it traveled through the unsaturated zone.

Below 9 m, ground water is less isotopically enriched than water at the 6- and 9-m depths, yet the selenium concentrations are high [median=880 $\mu\text{g/L}$ (micrograms per liter)]. The lower isotopic enrichment indicates that selenium in ground water at this depth was the result of leaching of soil salts when the water level was too far from land surface for evaporative enrichment to occur. The tritium data supports this hypothesis.

As a result of nuclear testing, high levels of tritium were introduced into the atmosphere between 1953 and 1969. Water exposed to the atmosphere since 1953 can be expected to have tritium concentrations greater than 5-10 TU (tritium unit) (Freeze and Cherry, 1979). Irrigation water for this field has been imported from northern California by the Federal Central Valley Project since 1970. Figures 7 and 8 show the spatial and depth distribution of tritium in water samples collected from the observation wells. Tritium was detected in all samples collected at the 3-m depth. Samples collected from the 6-m depth had lower tritium concentrations than the 3-m depth and few of the samples from the 9- and 12-m depths had any detectable tritium. The samples collected at the 15-m depths all had less than 1.6 TU except the sample collected from the 15-m well at site M5, which had an average tritium concentration of 18.4 TU (fig. 7). All samples collected at site M5 are high in tritium relative to samples collected from the same depths at other sites in the field.

Water imported from northern California has tritium concentrations of about 10 TU and is now at the 3- and 4-m depths. This water has displaced saline, isotopically enriched water, downward. Because ground water pumped from the deep confined aquifer was used for irrigation until 1970, present-day samples with low tritium concentrations originated from this source and are now at depths greater than 6 m. Ground water at the 6-m depth generally has low tritium concentrations and represents primarily ground water applied prior to 1970. Based on the tritium data, the net downward rate of movement is between 0.25 and 0.75 m/a since 1970. This downward movement has been affected in recent years because of drain installation and by addition of water to storage before 1970. The primary source of recharge here is assumed to be irrigation water and not the sparse rainfall.

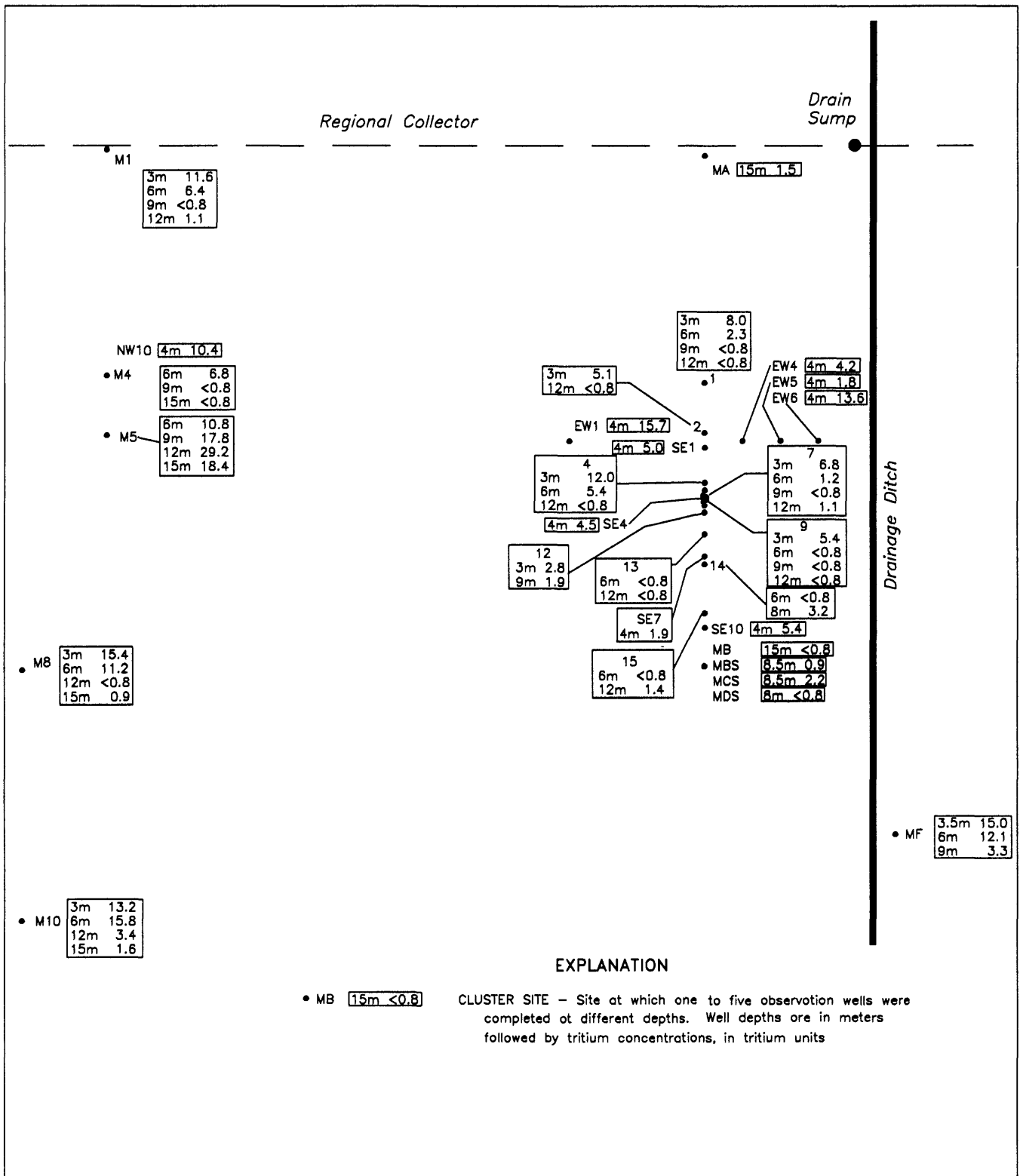
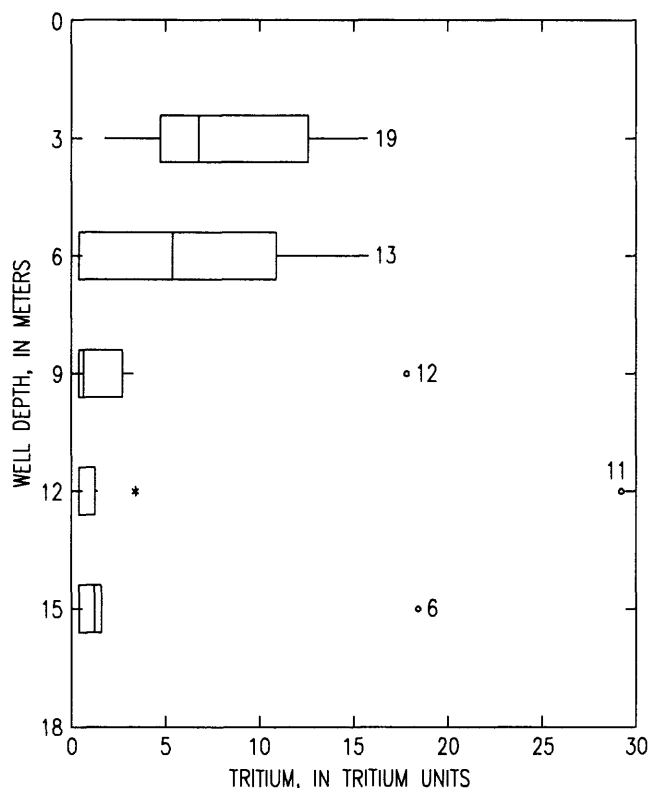
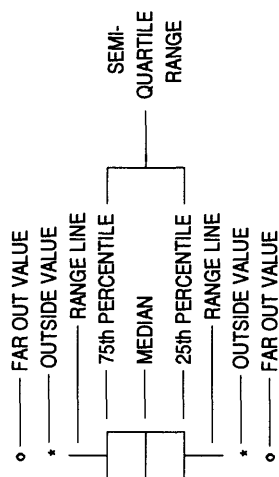


Figure 7. Distribution of tritium concentrations in ground water. Average concentrations shown for wells where multiple samples were collected.



EXPLANATION



Far out values are more than 3.0 times the semi-quartile range from the end of the rectangle

Outside values are between 1.5 and 3.0 times the semi-quartile range from the top or bottom of the rectangle

Range lines extend a distance equal to 1.5 times the semi-quartile range away from the end of the rectangle or to the limit of the data, whichever is least

6 Number of observations

Figure 8. Depth distribution of tritium concentrations in ground water. Average concentrations were used for wells where multiple samples were collected.

MAJOR IONS

Trilinear diagrams (Hem, 1985) (fig. 9) show the relation of major-ion chemistry to ground-water salinity as represented by dissolved-solids concentrations. Sodium and sulfate are the predominant species in the more dilute waters. Although sodium and chloride are the dominant ions in water having the highest salinities. As the salinity increases, the higher concentrations of sulfate result in precipitation of gypsum, causing chloride to become more dominant as the sulfate is removed from solution.

Gypsum and calcite saturation indexes were calculated using WATEQF (Plummer and others, 1976). The median gypsum saturation indexes were highest, and indicate generally supersaturated conditions at the 6- and 9-m depths (fig. 10). The saturation indexes in samples collected from the 3- and 4-m wells were combined and represented at 3 m in figure 4. Similarly, samples collected in 8.5- and 9-m wells were combined and represented at 9 m. These indexes correspond with the samples with the highest salinities. Virtually all samples were supersaturated with respect to calcite. Precipitation of calcite from solution accounts for the relatively low calcium and bicarbonate at all but the lowest salinities.

OTHER TRACE ELEMENTS

For the inorganic trace elements determined, figure 11 shows the ranges of concentrations for selected elements with depth. The concentrations determined in samples collected from the 3- and 4-m wells were combined and represented at 3 m in figure 11. Similarly, samples collected on 8.5- and 9-m wells were combined and represented at 9 m. The \log_{10} of the concentrations of boron ($r=0.883$), iron ($r=0.55$), lithium ($r=0.476$), selenium ($r=0.773$), and vanadium ($r=0.453$) were significantly correlated ($\alpha=0.01$) with the \log_{10} of dissolved solids. This correlation is consistent with data reported by Deverel and Millard (1988), who reported that boron, selenium, and vanadium are likely present as mobile oxyanions in oxidized ground water and are associated with salinity. The distribution of these trace elements reflects the salinity and geologic origin of the valley alluvial deposits. The field is in alluvial-fan material exclusively derived from the California Coast Ranges. Boron, selenium, and vanadium are present in the Coast Ranges source material and thus have similar relations to salinity. Molybdenum seems to be associated with the Sierra Nevada deposits (Deverel and Millard, 1988) and does not show a statistically significant correlation with salinity in this study.

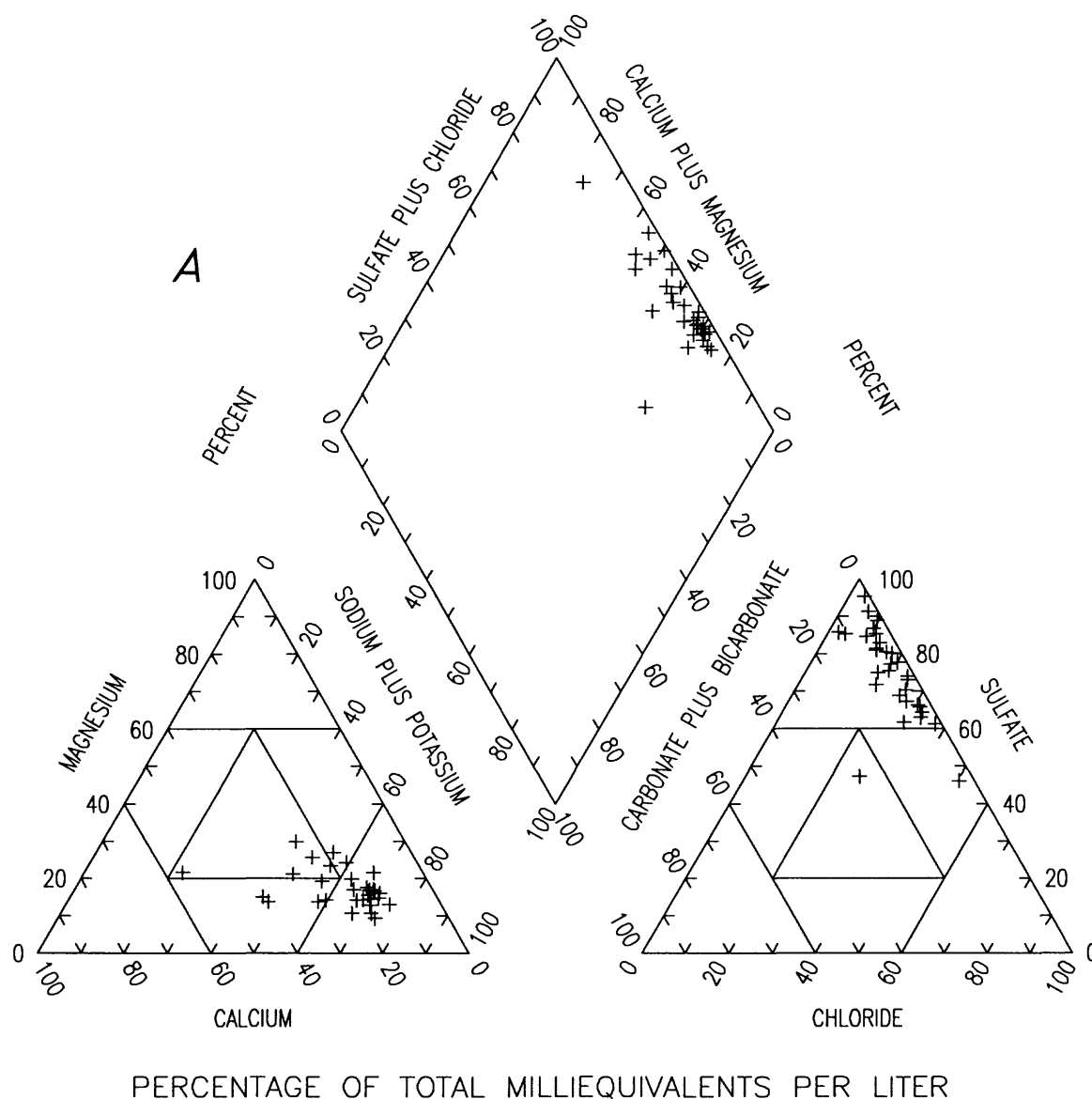


Figure 9. Relation of major-ion chemistry to ground-water salinity. A, Dissolved solids less than 12,000 mg/L. B, Dissolved solids greater than 12,000 mg/L.

TEMPORAL VARIABILITY OF CONSTITUENTS IN GROUND WATER AND DRAINWATER

GROUND WATER

Selected wells were sampled several times during the study period to assess the temporal variability of the ground-water chemistry. Selenium concentrations, dissolved solids, and stable isotope data for wells with multiple samples are shown in table 6 (at back of report). Thirty-seven wells had multiple samples collected more than 2 months apart and were used for this analysis. Although the selenium concentrations

and salinity varied with time, the temporal trend in the data is not statistically significant.

There were 22 wells with multiple analysis of the stable isotopes. Over time, 16 wells became more depleted in deuterium and 14 wells became more depleted in oxygen-18. Multiple samples collected in 14 of 15 wells in the coarse-grained deposits became more depleted in both stable isotopes. This general trend of depletion of the stable isotopes probably is the result of the downward movement of water from the 3- and 4-m depths. This shallow ground water was subject to less evaporative concentration than water at the 6- and 9-m depths.

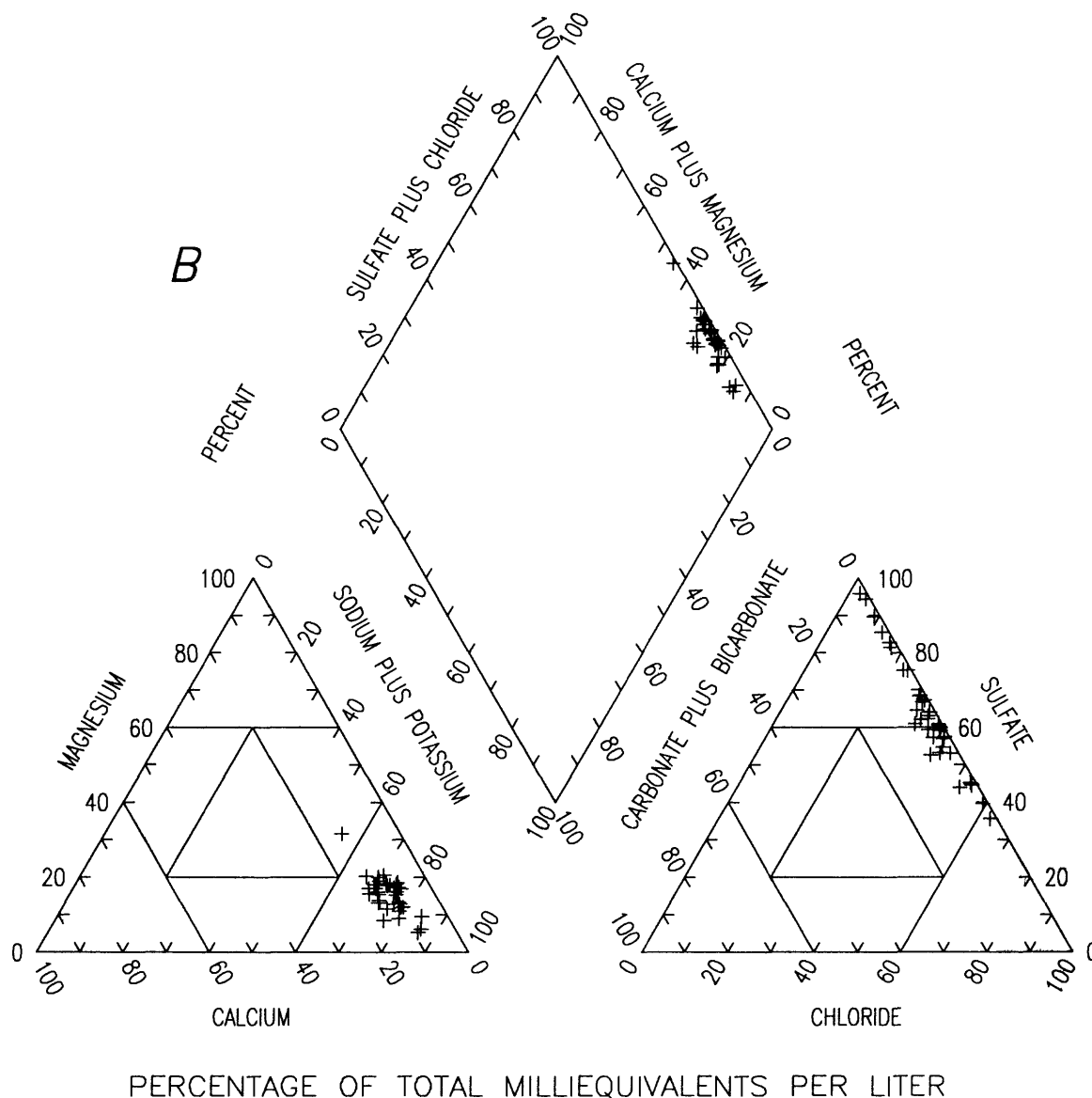


Figure 9. Continued.

DRAINWATER

The drain laterals in the drained agricultural field lead into the field collector line which leads into a drain sump in the northeast corner of the field (fig. 3). Water in the field collector was collected and analyzed periodically. Table 7 (at back of report) contains the results of the analysis of these samples. Figure 12 shows selenium and dissolved-solids concentrations and delta oxygen-18 values for the drainwater plotted over time. Concentrations of these constituents vary substantially, but two peaks are evident. The first peak was in September 1986, and

the second was during November and December 1987 and January and February 1988. These peaks coincide with periods of high ground-water levels that were the result of irrigation.

Increased hydraulic gradients toward the drain laterals result in increased flow into the laterals. As irrigation water is applied to the field, saline ground water is displaced toward the laterals. This displacement results in an increase in the selenium concentrations and salinity of the drainwater. This displaced ground water also is enriched in the stable isotopes, and the drainwater reflects this change in isotopic

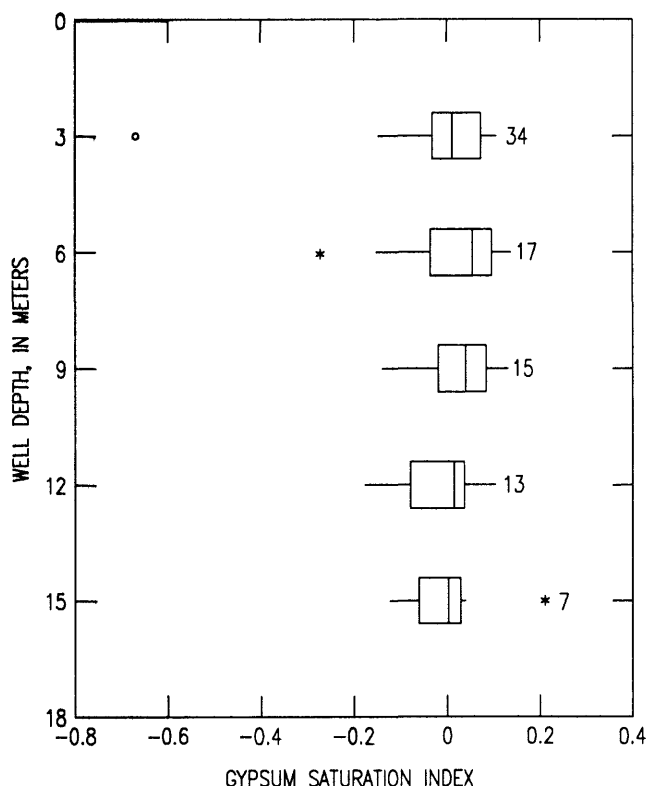


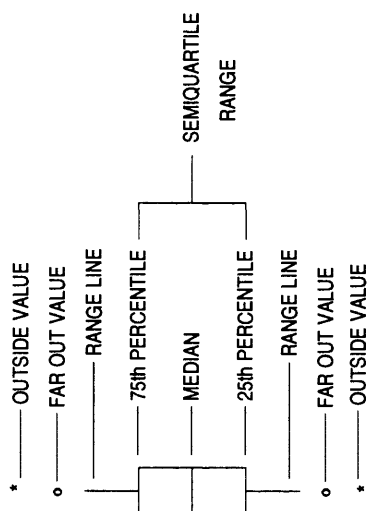
Figure 10. Depth distribution of gypsum saturation indexes. Average concentrations were used for wells where multiple samples were collected.

composition. As hydraulic heads return to preirrigation levels, the amount of water entering the drain laterals decreases. Ground water does not flow into the drain laterals during fallow periods.

Water from the sump is pumped into a drainage ditch that runs along the eastern edge of the field. Excess surface water from this and other nearby fields also is collected in this ditch. Water in the ditch seeps into the field collector. Because of the diluting effect of the less saline, isotopically depleted excess surface irrigation water, the water from this ditch is less saline and isotopically depleted relative to the shallow ground water. The seepage of this ditch water into the field collector causes the water collected at the sump to be less saline and isotopically depleted than would be expected if the sump water consisted of drainwater from the field only.

During the nonirrigated seasons, flow in the field collector line is primarily from seepage from the ditch, because the drain laterals collect ground water only during the irrigation season. The increase in the selenium concentrations, salinity and isotopic enrichment of the drainwater during the irrigation events as shown in figure 12 is due to ground-water flow to the drain laterals. This water has higher selenium concentrations, salinity, and greater isotopic enrichment than the water in the ditch. Evaluations of the

EXPLANATION FOR FIGURES 10 AND 11



Outside values are between 1.5 and 3.0 times the semiquartile range from the end of the rectangle

Far out values are more than 3.0 times the semiquartile range from the end of the rectangle

Range lines extend a distance equal to 1.5 times the semiquartile range away from the end of the rectangle or to the limit of the data, whichever is least

7 Number of observations

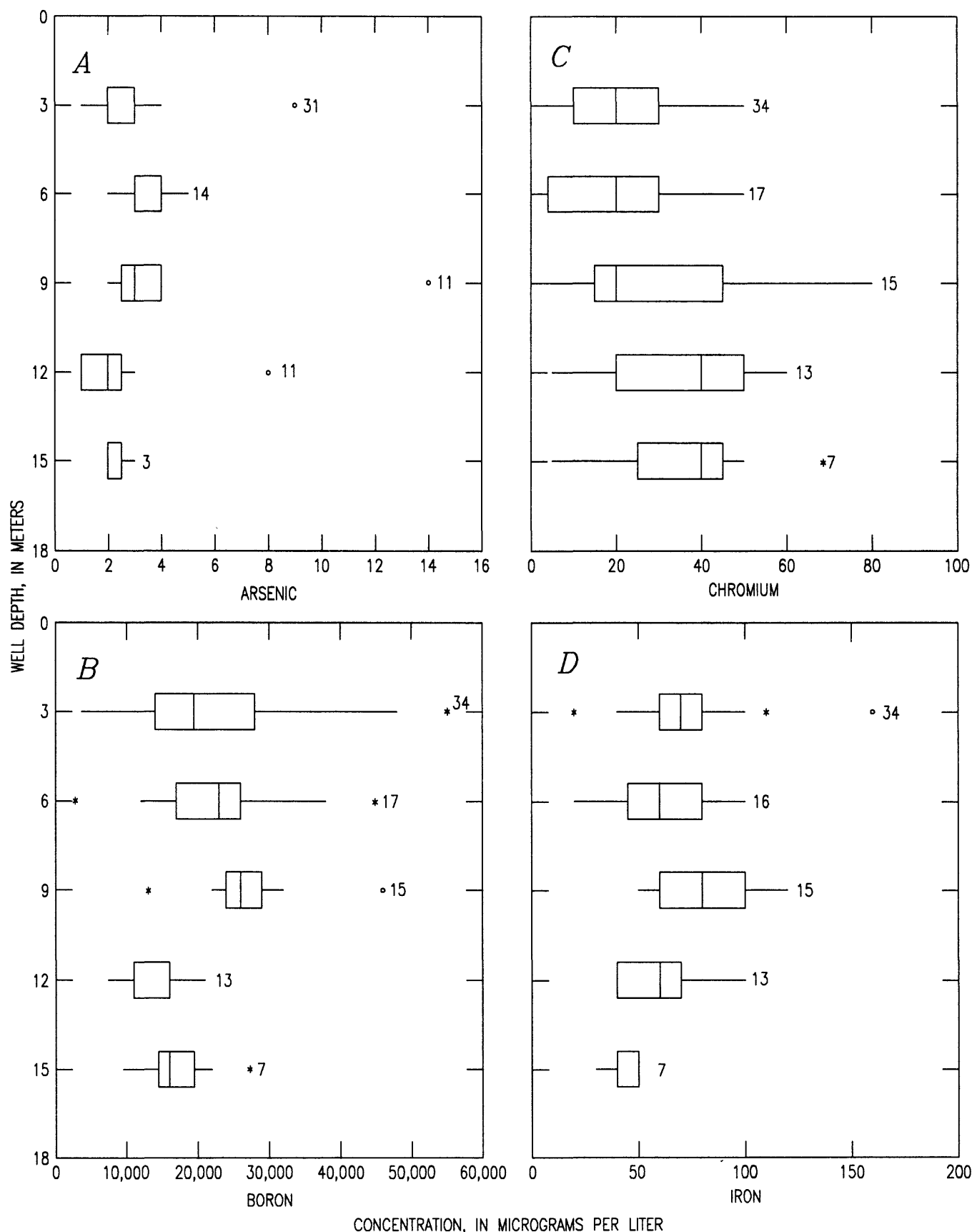


Figure 11. Depth distribution of selected trace elements. Average concentrations were used for wells where multiple samples were collected.

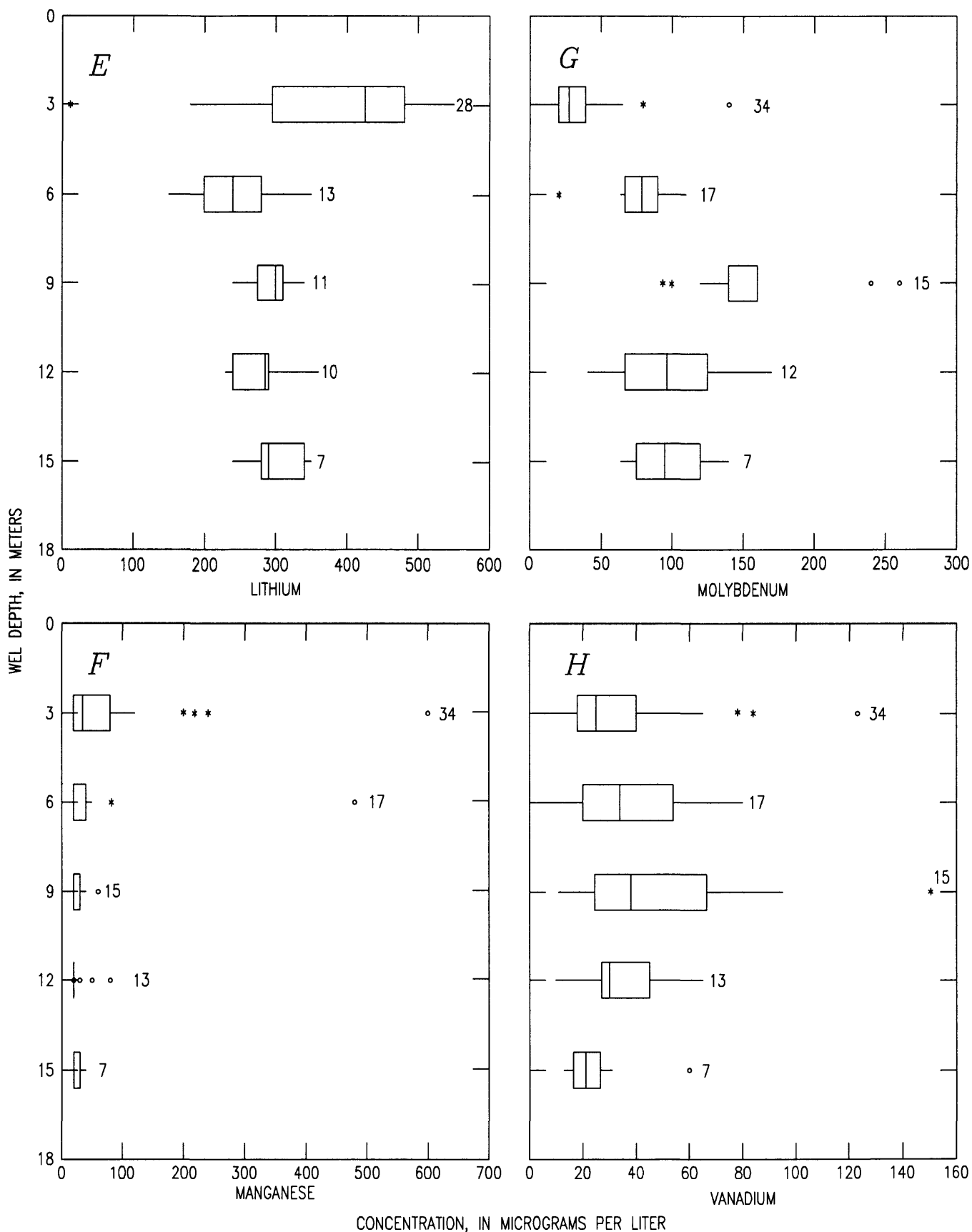


Figure 11.--Continued.

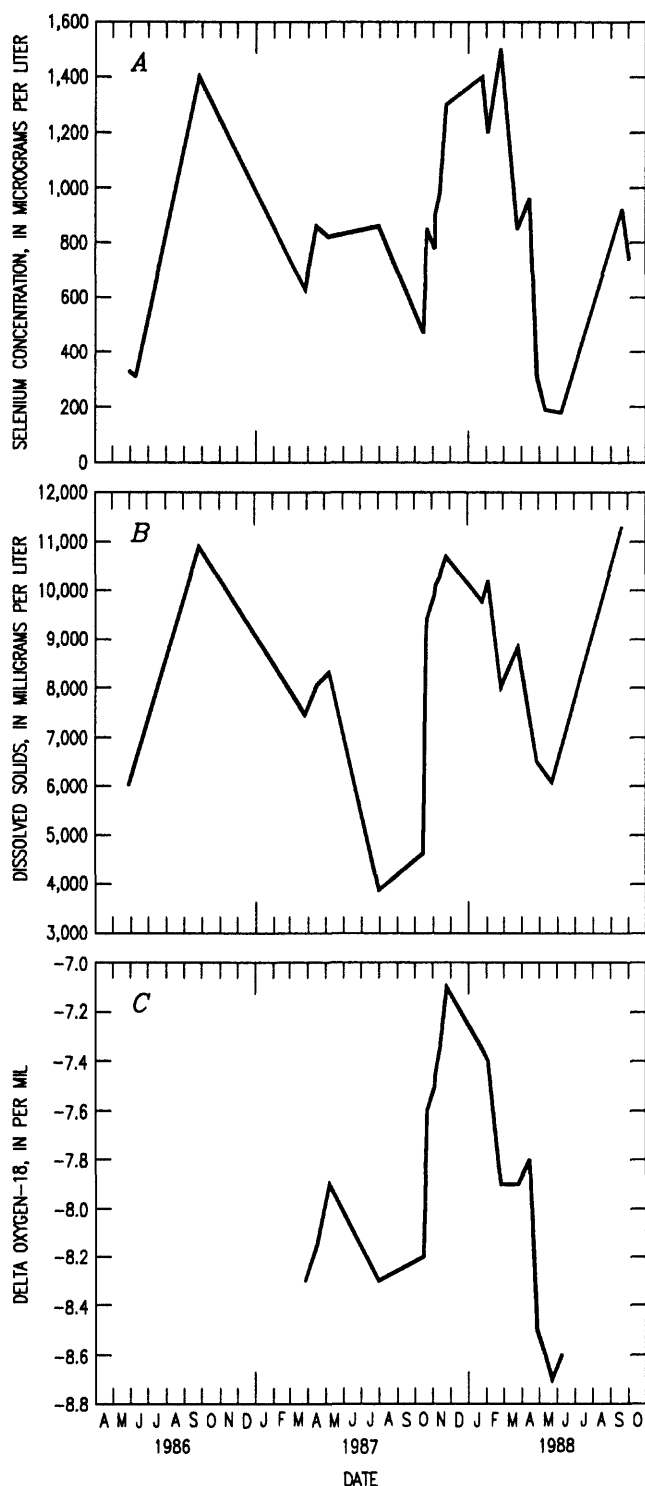


Figure 12. Selenium and dissolved-solids concentrations and delta oxygen-18 ratio measured over time for the drain sump.

ground-water-flow patterns provide further insight into the processes affecting the temporal and spatial variability of the chemical and isotopic composition of ground water and drainwater.

GROUND-WATER-FLOW PATTERNS

Ground-water hydraulic gradients in the field change substantially over time. During the irrigation season, gradients are primarily vertically downward. During fallow periods, gradients are primarily upward. The stratigraphy, notably the presence of subsurface sand lenses and the presence of regional collector drains, substantially influences the direction of ground-water flow.

Hydraulic head was recorded continuously at sites 7 and 14 and is shown in figure 13. For both sites, substantial rises in hydraulic head are the result of irrigation during the summer of 1986 and autumn of 1987. A reversal in gradients is illustrated further by an examination of the distribution of hydraulic heads in the two cross sections in the field.

Figure 14 shows the distribution of hydraulic head superimposed on existing sand layers along geohydrologic section A-A' during periods of high and low hydraulic heads. The hydraulic heads representative of an irrigation period were measured August 11, 1986, and those representative of a nonirrigation period were measured April 9, 1986 (figs. 13 and 14). The means of the head values for sites 6 through 12 were used in the central part of the diagram. Lines of equal hydraulic head and generalized directions of ground-water flow represent a qualitative-flow net (Freeze and Cherry, 1979) and are based on the anisotropy in the fine-grained material. The horizontal and vertical axes were drawn based on the horizontal and vertical conductivities for the fine-grained material reported by Fio and Deverel (1990). As described by Freeze and Cherry (1979), the ratio of x to y axis is proportional to the ratio of the square roots of the hydraulic conductivities in the horizontal and vertical directions.

During irrigation, flow is primarily downward. The sand lens present at sites 13, 14, and 15 seems to influence flow substantially. At site 15, for example, flow is toward the sand layer from above and below. Lower hydraulic heads in the sand lens are probably the result of relatively higher flow in the sand lens.

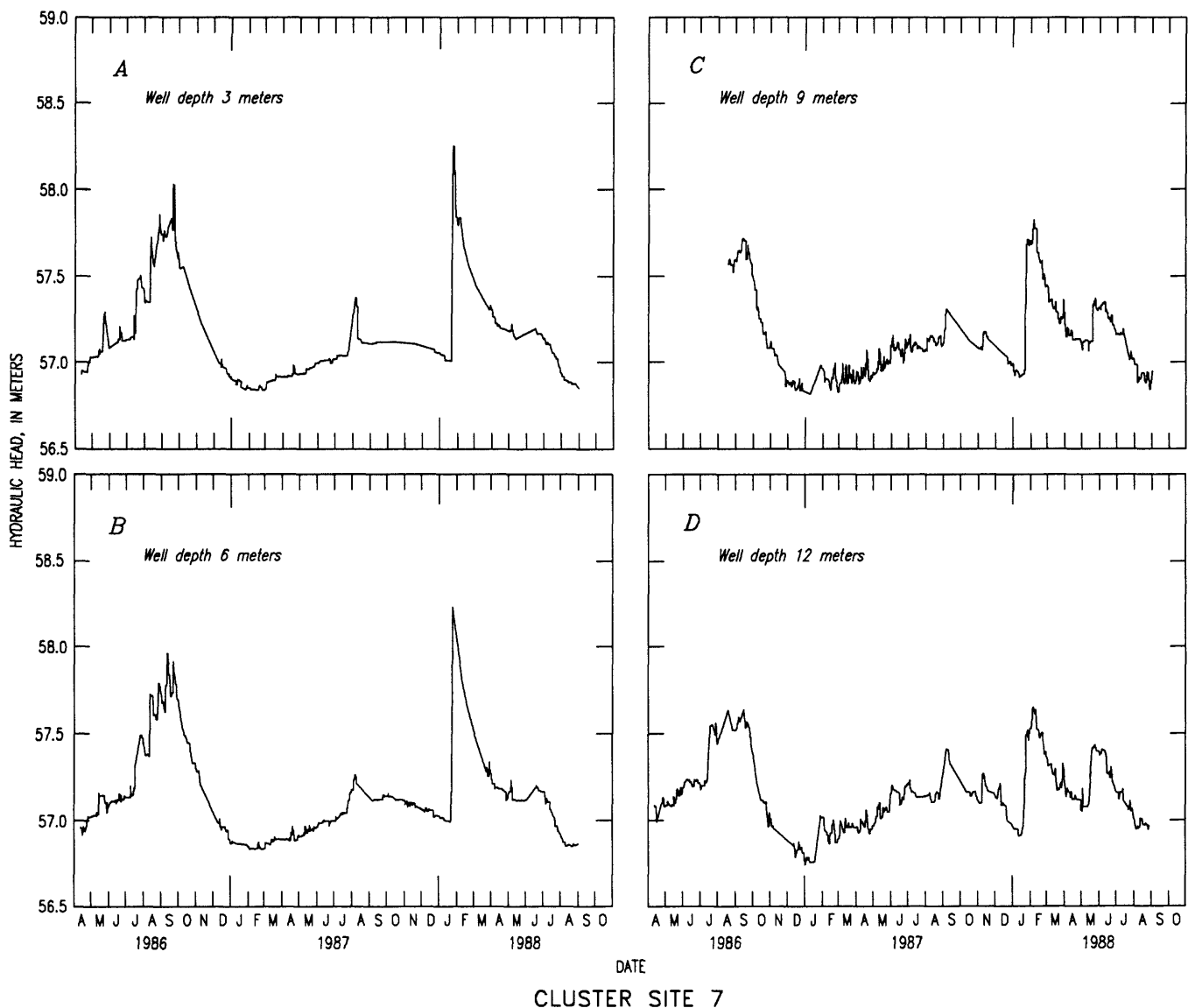


Figure 13. Changes in hydraulic head for wells at sites 7 and 14.

which is influenced by ground-water flow to the regional collector (fig. 2). Except during and immediately after an irrigation event, the drain laterals do not substantially influence ground-water flow.

During nonirrigation periods, the drain laterals do not flow and gradients are primarily upward. The hydraulic gradient at site 15 is changed relative to the irrigated period with flow apparently through the sand layer. In both cases, there is a horizontal gradient within the sand layer from site 15 to 14. Irrigation causes hydraulic heads to increase everywhere in the cross section. Following irrigation, this increase in hydraulic head dissipates rapidly in the sand lens

because of its high hydraulic conductivity and discharge to the collector drain, causing flow into the sand lens from the fine-grained aquifer material below.

Figure 15 shows the distribution of lines of equal hydraulic head and generalized directions of ground-water flow for geohydrologic section *B-B'* during high and low hydraulic head periods. There were no distinct sand layers in geohydrologic section *B-B'*. The texture of the deposits is discussed in the following section. These periods probably corresponded to irrigation periods. Irrigation was done at different times in this area of the field relative to the area

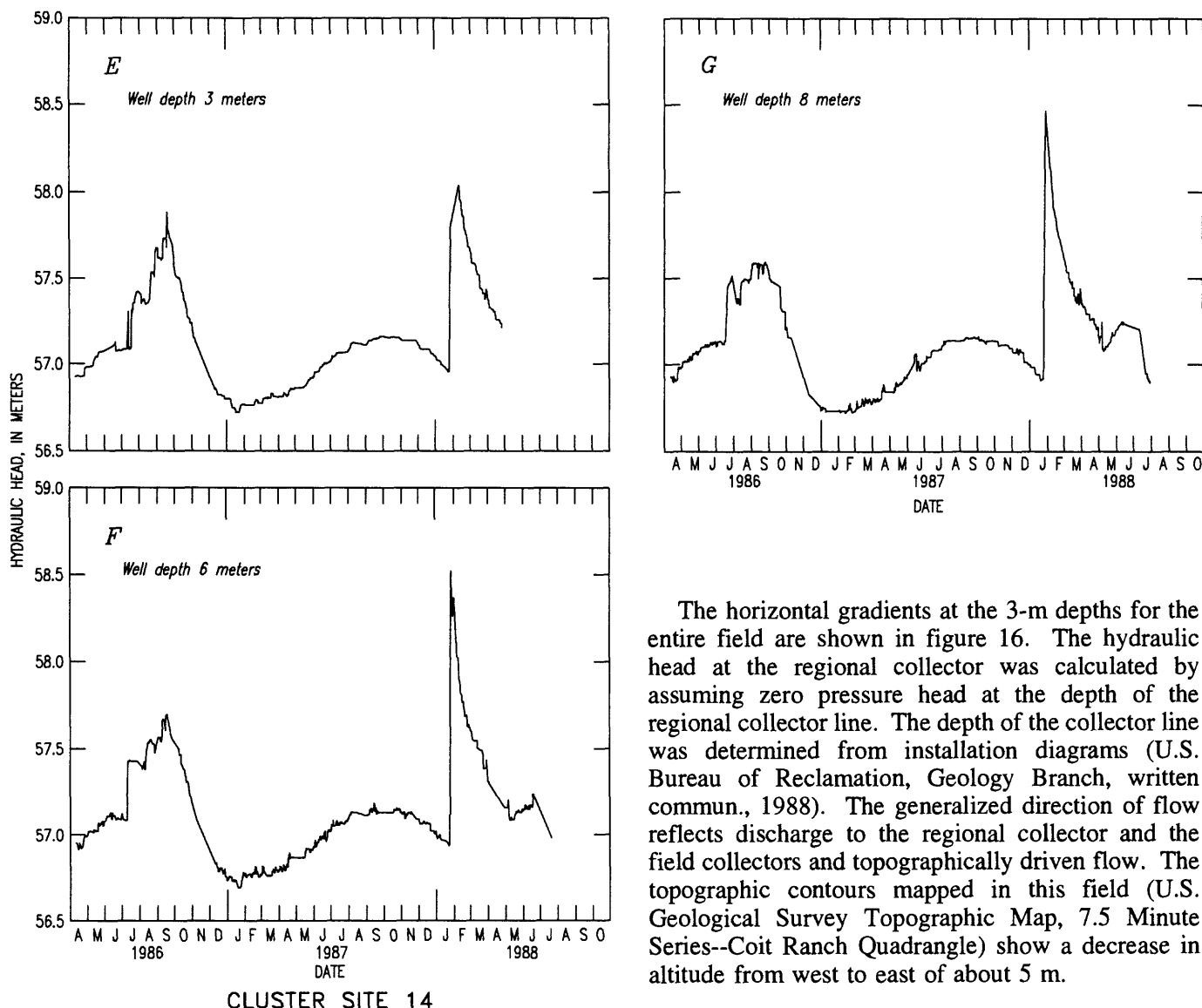


Figure 13. Continued.

encompassing the A-A' section. Hydraulic gradients are similar to those calculated for section A-A'. In contrast to the geohydrologic section A-A', hydraulic gradients were determined adjacent to the regional collector at the 3-, 6-, 9-, 12-, and 15-m depths at the site M1. The hydraulic gradient is always toward the regional collector, which acts as a discharge zone. During the high hydraulic head period, downward flow is greater at all sites relative to the low hydraulic head period. Ground-water flow may also be influenced by regional, topographically driven flow from southwest to northeast.

The horizontal gradients at the 3-m depths for the entire field are shown in figure 16. The hydraulic head at the regional collector was calculated by assuming zero pressure head at the depth of the regional collector line. The depth of the collector line was determined from installation diagrams (U.S. Bureau of Reclamation, Geology Branch, written commun., 1988). The generalized direction of flow reflects discharge to the regional collector and the field collectors and topographically driven flow. The topographic contours mapped in this field (U.S. Geological Survey Topographic Map, 7.5 Minute Series--Coit Ranch Quadrangle) show a decrease in altitude from west to east of about 5 m.

The lines of equal hydraulic head and generalized flow directions provide information about ground-water movement in the field. This information combined with information about hydraulic characteristics and texture can allow a more quantitative assessment of directions and rates of ground-water flow.

PHYSICAL FACTORS AFFECTING GROUND-WATER FLOW

Ground-water-flow patterns described in the previous section are influenced by the texture of the alluvial deposits which in turn influences the hydraulic conductivity.

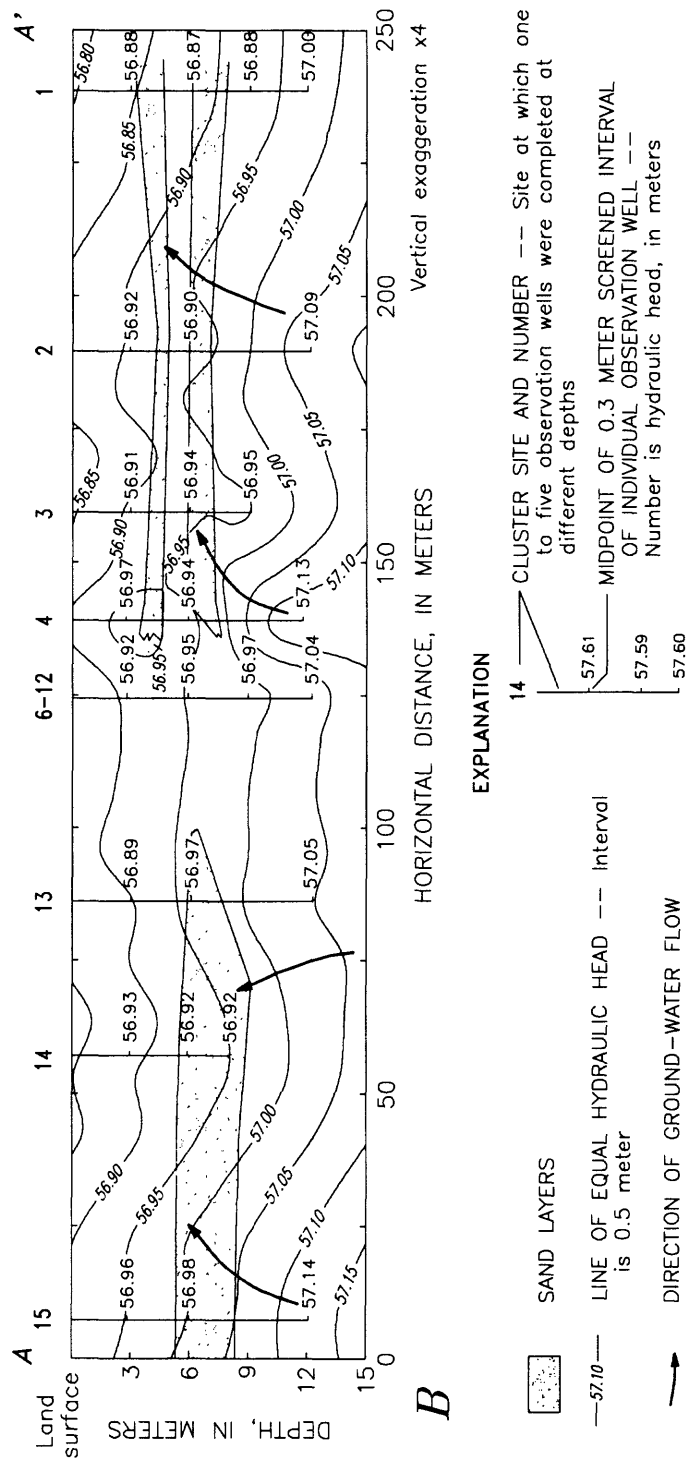
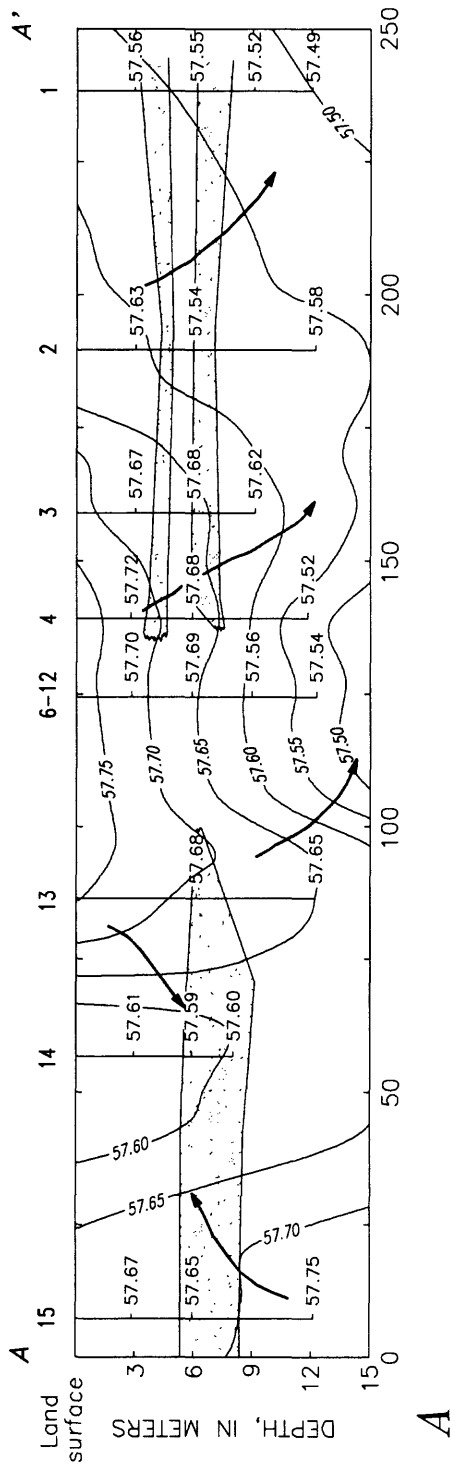


Figure 14. Distribution of hydraulic head and generalized directions of ground-water flow superimposed on existing sand layers along geohydrologic section A-A' during periods of high and low hydraulic head. A. High hydraulic head, August 11, 1986. B. Low hydraulic head, April 9, 1986.

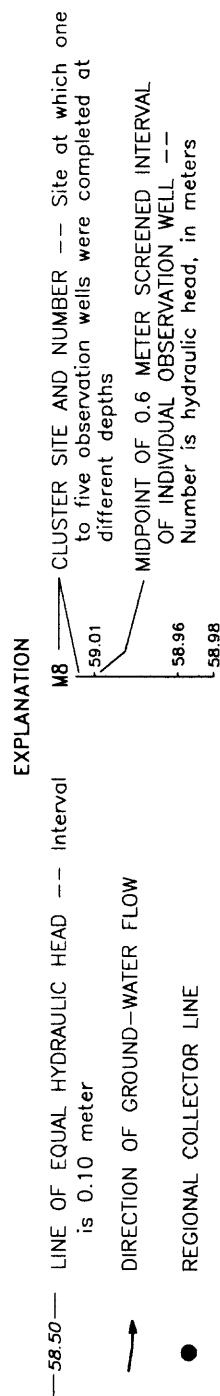
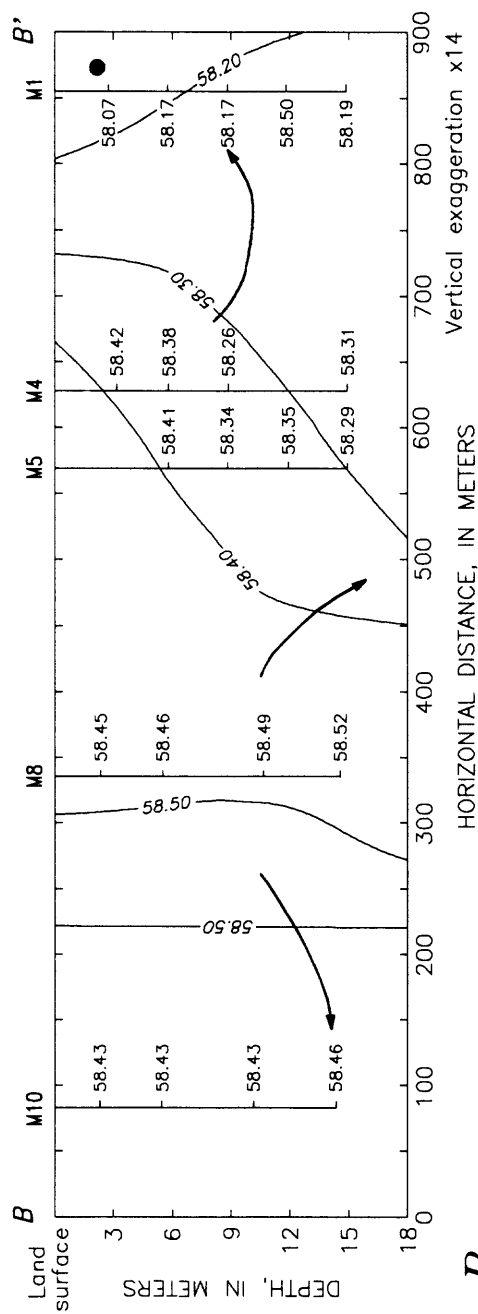
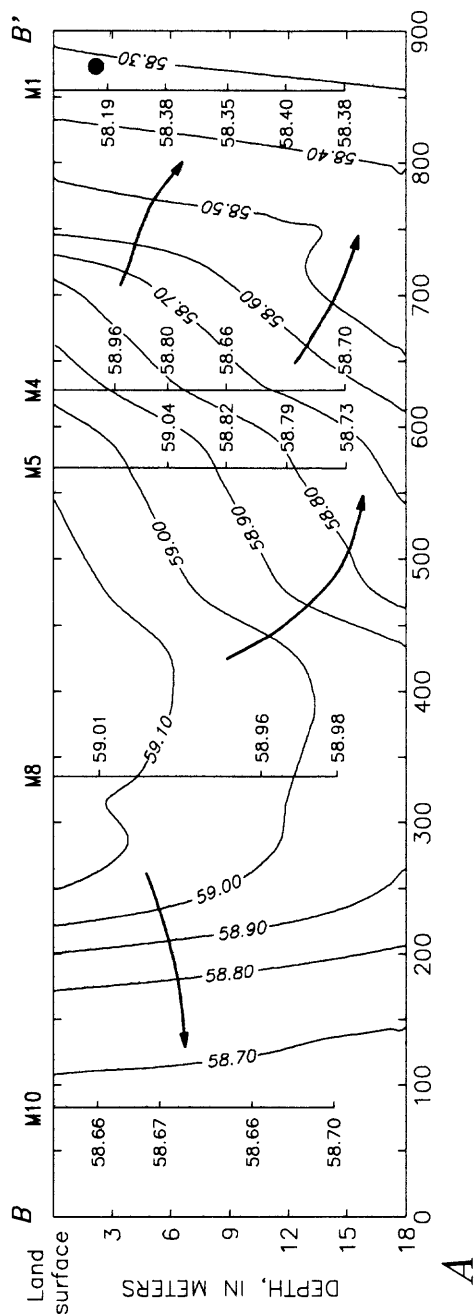
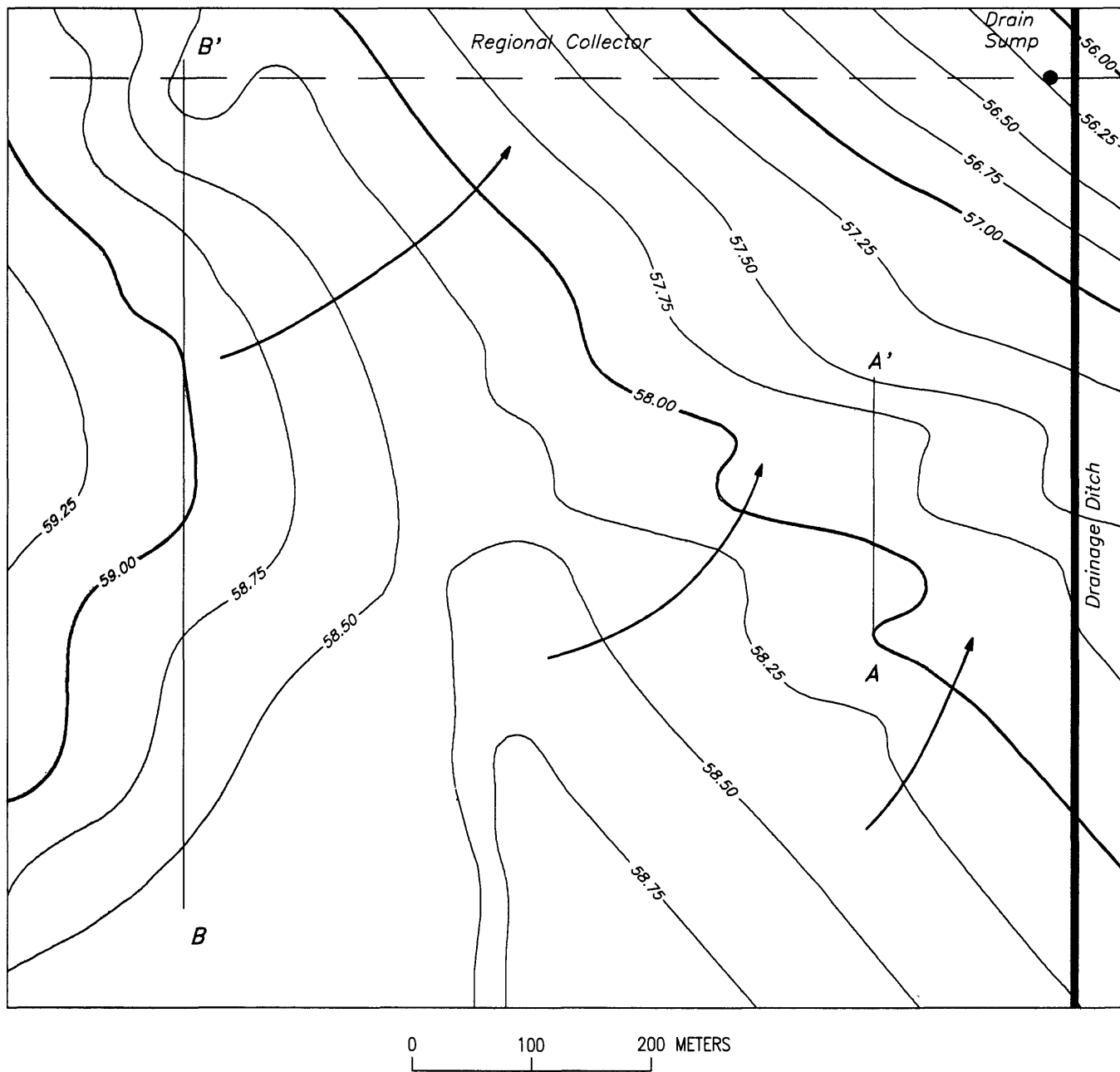


Figure 15. Distribution of hydraulic head and generalized directions of ground-water flow superimposed on existing sand layers along geohydrologic section B-B' during periods of high and low hydraulic head. A. High hydraulic head, November 5, 1981. B. Low hydraulic head, September 23, 1987.



EXPLANATION

- $B-B'$ LINE OF GEOHYDROLOGIC SECTION
- 58.00 LINE OF EQUAL HYDRAULIC HEAD -- Interval is 0.25 meter
- \rightarrow GENERALIZED DIRECTION OF GROUND-WATER FLOW

Figure 16. Areal distribution of hydraulic head 3 meters below land surface and generalized direction of ground-water flow.

TEXTURE

The texture distribution in the samples of aquifer material collected from this field indicate that the grain size of geologic deposits in this field generally become more coarse with increasing depth. This texture distribution is in agreement with information presented by Laudon and Belitz (1991) who studied the texture of near-surface alluvial deposits in the central San Joaquin Valley. Figure 17 shows the texture distribution of geohydrologic sections A-A' and B-B'. Geohydrologic section A-A' shows that the top 6 m are predominately fine grained in the southeast part of the field. Geohydrologic section B-B' indicates that the top 6 m of the deposits in the northwest part of the field are more coarse grained than the shallow deposits in the southeast part of the field.

The texture difference between the two areas of the field may be the reason for the higher salinity of the ground-water samples collected from the wells along geohydrologic section A-A' compared with those along geohydrologic section B-B'. The finer grained deposits in the southeast part of the field may have restricted infiltration and downward movement of water to a greater degree than in the northwest part of the field, causing greater evapoconcentration of the shallow ground water. This is consistent with the observation made by Clyde Irion (farm manager, oral commun., 1986) that the water table was within 0.6 m of land surface, and the soil was more saline in the southeast part of the field in the mid-1970's. From grain-size analyses, the wells were divided into coarse- or fine-grained groups according to the texture of the deposits adjacent to the well screen. Coarse-grained materials are those containing greater than 70 percent sand.

HYDRAULIC CONDUCTIVITY

Two methods were used to determine hydraulic conductivities. The method of analysis described by Hvorslev (1951) assumes a homogeneous, isotropic, spatially infinite medium; an incompressible medium and constant specific gravity of water; and wells with small screened intervals. Flow to the well screen is assumed to be spherical and isotropic. The Cooper method (Cooper and others, 1967) also assumes a

homogeneous, isotropic, and spatially infinite medium, but in contrast with the first technique the medium is confined, both water and medium are assumed compressible, and the well is screened over the entire thickness of the aquifer. Flow to the well is assumed to be horizontal.

Analysis by the Hvorslev method uses regression analysis to calculate the transmissivity of the aquifer at the screened interval by the equation:

$$T = (-1 - b)/m, \quad (5)$$

where

T is the transmissivity,

b is the y-intercept, (hydraulic head at time = 0) and

m is the slope of the regression line between hydraulic head and time.

The hydraulic conductivity was calculated by dividing the transmissivity by the length of the well screen. Data analysis using this method results in values for spherical, isotropic flows.

Values of hydraulic conductivities calculated by the Cooper method apply to water moving horizontally to and from the well. The Cooper method assumes that the length of the well screen is equal to the thickness of the aquifer.

The relation of the logs of hydraulic conductivity determined by the Hvorslev and Cooper methods for wells screened in the fine-grained and coarse-grained material are shown in figure 18. The hydraulic conductivities determined by the two methods are highly correlated; $r^2=0.74$ for the fine-grained wells and $r^2=0.87$ for the coarse-grained wells. The median horizontal hydraulic conductivity values of the coarse-grained material are 565 and 1,983 m/a for the Hvorslev and Cooper methods, respectively. The values for the fine-grained deposits are 195 and 671 m/a, respectively. There is considerable variability in the fine-grained and coarse-grained deposits, but the medians are significantly different ($\alpha=0.05$), as determined by the Mann-Whitney test (Hollander and Wolfe, 1973). There is a significant but weak correlation between percent sand and the log hydraulic conductivity ($r^2=0.25$). Large horizontal hydraulic conductivity values in wells screened in fine-grained material probably are due to coarse-grained lenses.

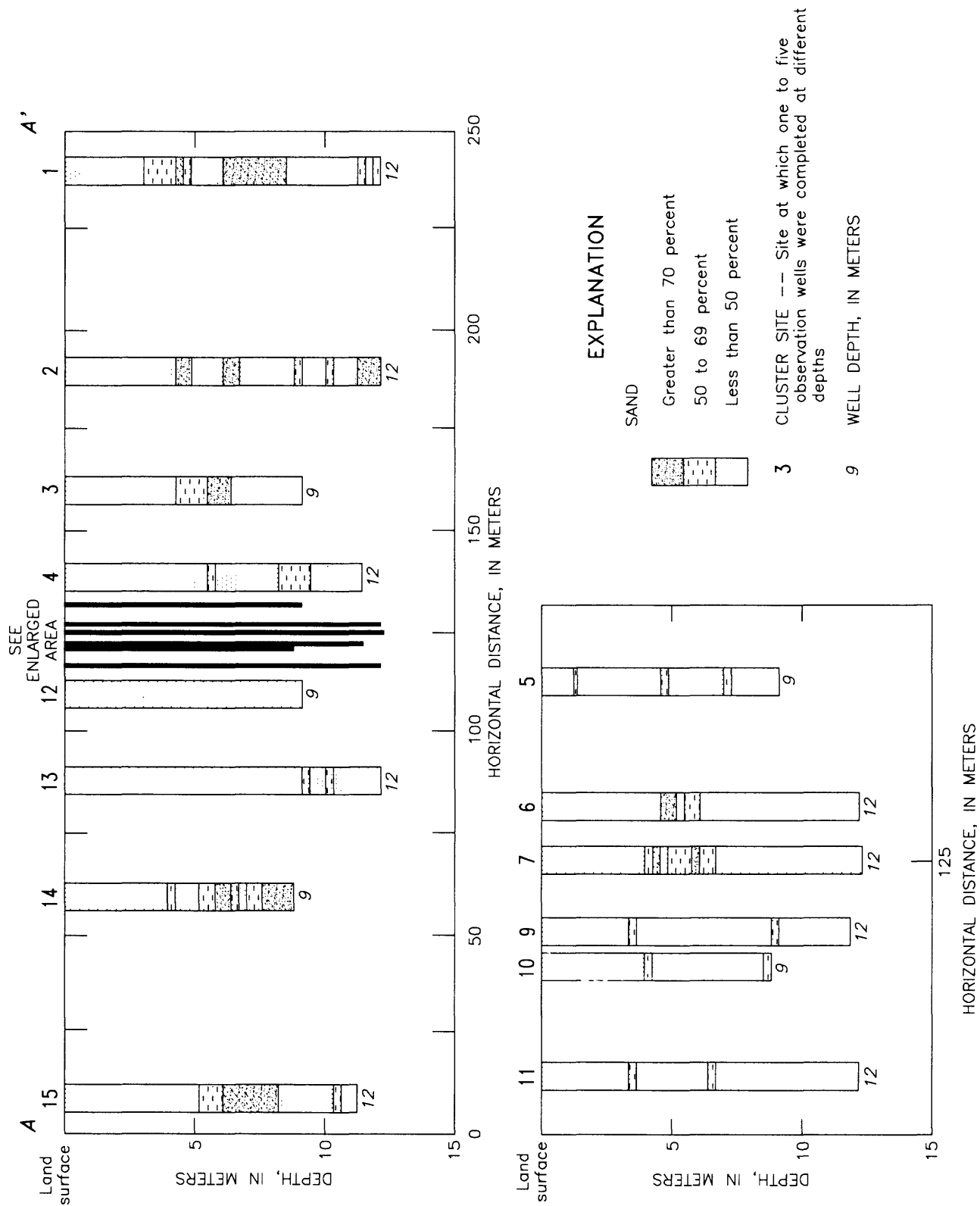
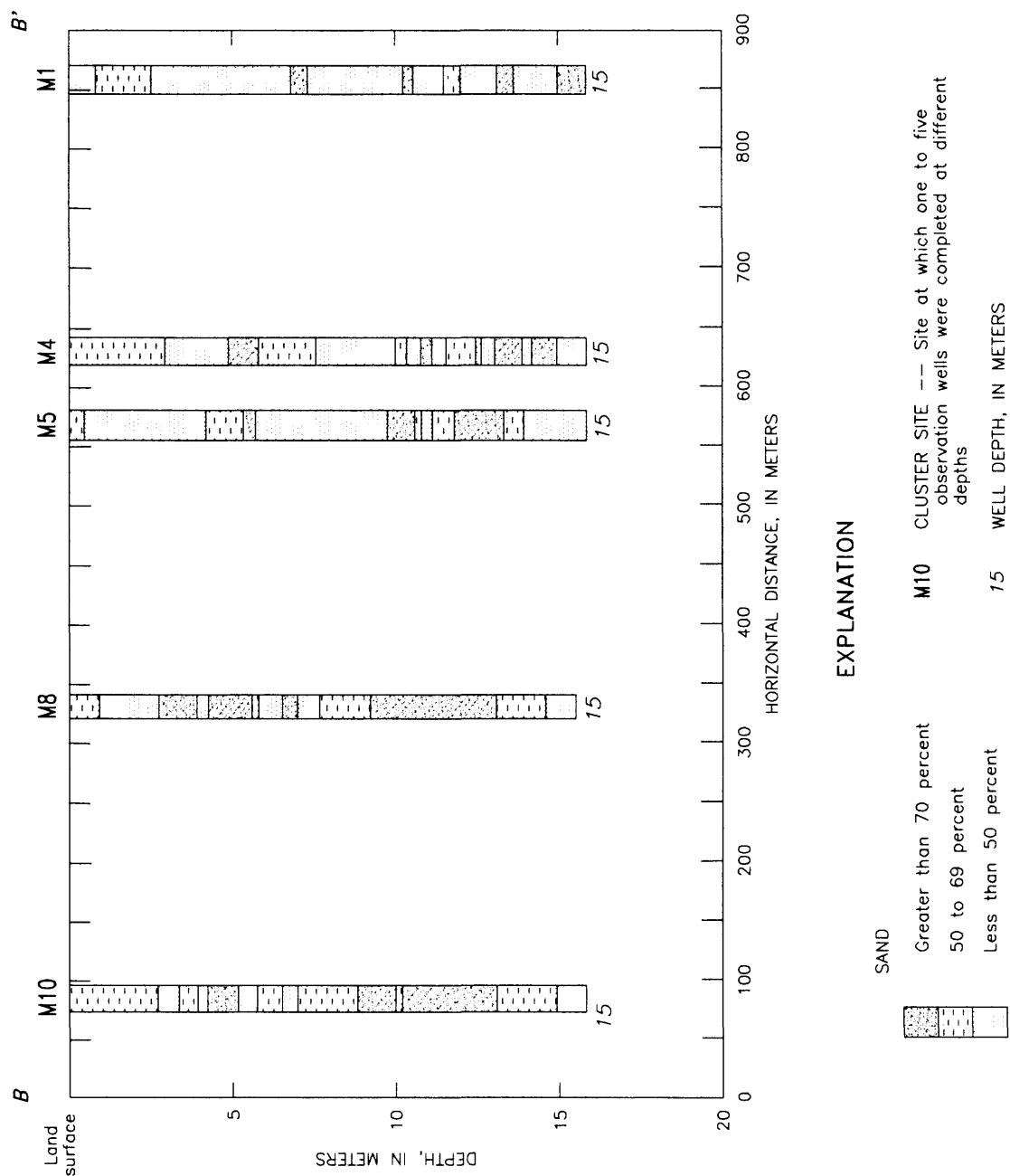


Figure 17. Texture distribution along geohydrologic sections A-A' and B-B'.



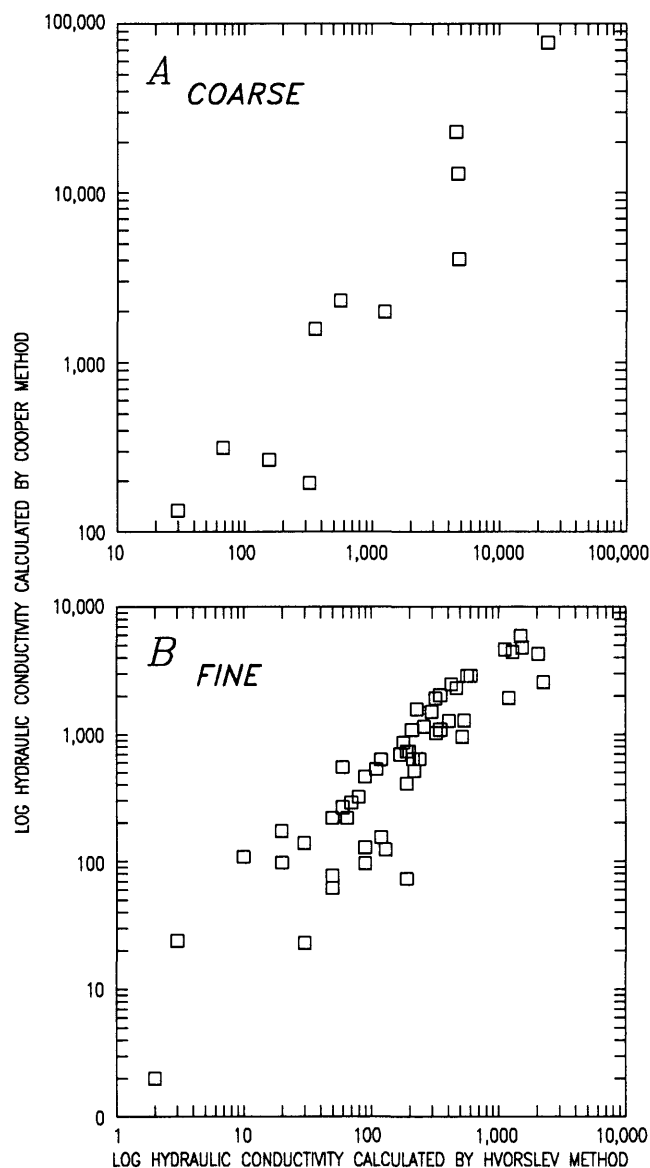


Figure 18. Relation of hydraulic conductivity determined by the methods of Hvorslev (1951) and Cooper and others (1967) in wells with screened intervals opposite coarse- and fine-grained deposits.

The median horizontal hydraulic conductivity determined by the Cooper method is about 3.5 times larger than the hydraulic conductivity determined by the Hvorslev method for the coarse-grained and fine-grained wells. Using the approach described by Prudic (1982), the anisotropy of the deposits can be roughly estimated from the results of the two methods. For both fine-grained and coarse-grained materials, horizontal hydraulic conductivity is about

12 times the vertical conductivity. The method described by Prudic (1982) may not be directly applicable to the deposits in this field because of the layering demonstrated by the results of this study. Prudic applied the method to glacial till that generally showed less anisotropy. However, the analysis does provide an initial estimate of the anisotropy.

DISTRIBUTION OF CHEMICAL CONSTITUENTS IN THE SOLID PHASE

Concentrations of constituents were evaluated in the solid phase to gain information about the factors affecting the mobility and distribution of constituents, notably selenium, in the ground water and solid phase. Because of the large number of constituents and samples, principle-component analyses was used to examine interrelations among constituents. Table 1 shows the principal component scores for the solid phase chemical data. Eighty percent of the variance in the solid phase chemical data can be accounted for by four principal components. The constituents associated with these four principal components are similar to those reported by Tidball and others (1986) and will be denoted similarly. The first principal component accounts for most of the variance and is denoted as a felsic component. The elements associated with this component are those associated with aluminosilicate and iron and manganese oxides, for example, iron, manganese, aluminum, copper, titanium, and others (table 1).

The second principal component is denoted as serpentinitic (Tidball and others, 1986) because of the large association with chromium, cobalt, magnesium, and nickel. The soils in this area are derived partly from a serpentine outcrop in the California Coast Ranges to the west. Samples by Tidball and others (1986) in the area of this field had large principal-component scores for this principal component. Principal-component scores for residual selenium and organic carbon are negative for this principal component meaning that neither of these constituents would be expected in high concentrations in a sample where the second principal component score was high.

The third principal component is denoted as a salinity principal component and it is associated with the dissolved solids. Total selenium also is highly correlated with this principal component indicating that there is some association of dissolved solids in the saturation extract and the total amount of selenium

Table 1. Principal component scores for the solid phase chemical data

(Samples were collected during drilling at observation well sites)

Constituent	Principal component			
	Felsic	Serpen- tinitic	Salin- ity	Car- bonate
Aluminum	0.963	-0.135	-0.057	-0.146
Arsenic . . . . .	.655	-.012	.380	.393
Barium	-.623	-.455	-.074	.259
Calcium . . . . .	.563	.282	.463	.127
Cerium . . . . .	.934	-.111	-.056	-.102
Chromium . . . . .	.280	.596	-.291	.501
Cobalt . . . . .	.731	.538	-.176	.276
Copper . . . . .	.948	-.035	.007	-.045
Iron . . . . .	.987	.050	-.069	-.051
Lanthanum . . . . .	.941	-.127	-.095	-.163
Lead . . . . .	.255	-.585	.033	.302
Lithium . . . . .	.971	-.119	.015	-.078
Magnesium . . . . .	.441	.789	-.190	.272
Manganese . . . . .	.817	.373	-.115	-.013
Neodymium . . . . .	.940	-.054	.009	-.130
Nickel . . . . .	.064	.807	-.261	.452
Phosphorous . . . . .	.806	.108	-.206	.032
Potassium	-.795	-.264	-.151	-.238
Scandium . . . . .	.972	.037	-.102	-.080
Total selenium . . . . .	.306	-.006	.804	.024
Soluble selenium . . . . .	.149	.585	.486	-.271
Residual selenium . . . . .	.176	-.665	.349	.330
Sodium	-.646	.229	.405	.122
Strontium . . . . .	.000	.407	.509	-.288
Thorium . . . . .	.897	-.238	.001	-.074
Titanium . . . . .	.978	.026	.019	-.082
Vanadium . . . . .	.977	-.066	-.058	-.062
Yttrium . . . . .	.937	.029	.021	-.067
Zinc . . . . .	.949	-.181	-.022	-.082
Total carbon . . . . .	.448	-.604	.150	.411
Organic carbon . . . . .	.330	-.694	.002	.184
Inorganic carbon . . . . .	.439	-.126	.351	.622
Specific conductance	-.083	.413	.677	-.133
Percentage of total variance	52.0	14.3	7.8	5.9

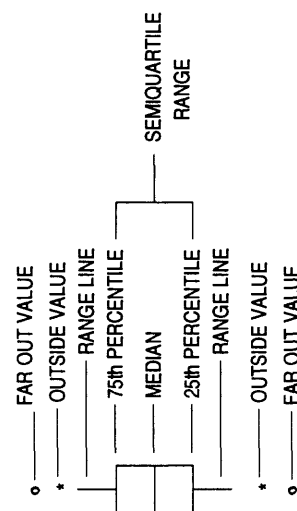
in the soil. The fourth principal component is denoted as a carbonate component because of the high scores for inorganic carbon. Chromium is moderately associated with this principal component.

Soluble selenium generally represents a small fraction of the total concentration of selenium in the solid phase in the unsaturated and shallow saturated zone. This is illustrated by the depth distributions of the total, soluble, and residual selenium shown in figure 19. In contrast, soluble selenium represents most of the total selenium in the saturated zone between 6 and 9 m where selenium concentrations in ground water are high (fig. 4). These data are consistent with the hypothesis set forth by Fujii and others (1988). They stated that most soluble selenium had been leached from the unsaturated zone during decades of irrigation.

The concentrations of selenium in the solid phase not in a soluble form (residual selenium) generally are highest in the unsaturated and shallow saturated zone and decrease with depth (fig. 19). The percentage of organic carbon in the solid phase follows a similar pattern (fig. 19) and is significantly correlated ($r=0.69$, $\alpha=0.01$) with residual selenium.

The relation of the percentage of organic carbon to residual selenium is shown in figure 20. For concentrations of residual selenium less than about

EXPLANATION FOR FIGURE 19



Far out values are more than 3.0 times the semiquartile range from the end of the rectangle

Outside values are between 1.5 and 3.0 times the semiquartile range from the end of the rectangle

Range lines extend a distance equal to 1.5 times the semiquartile range away from the end of the rectangle or to the limit of the data, whichever is least

6 Number of observations

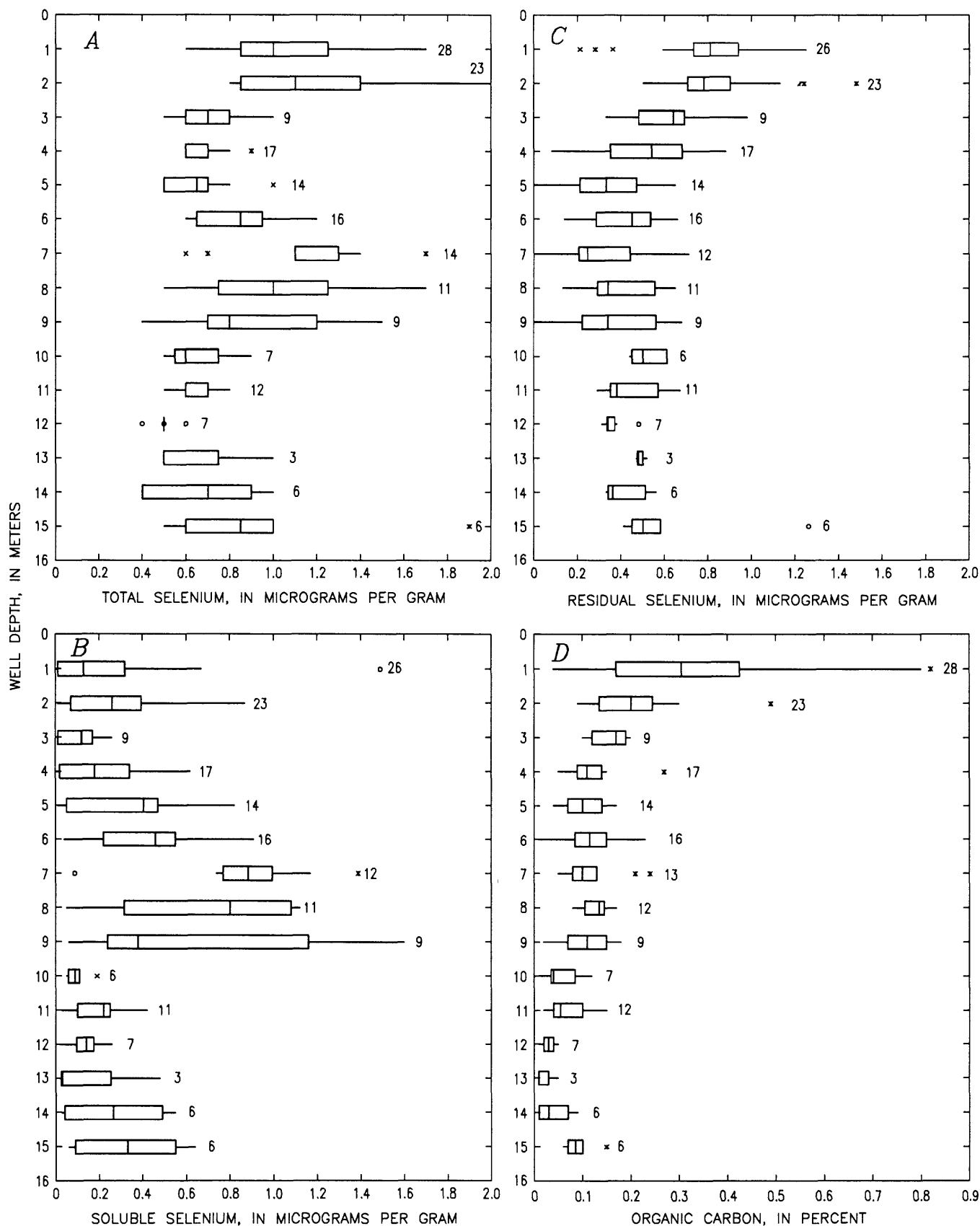


Figure 19. Concentrations of total, soluble, and residual selenium and organic carbon in the solid phase.

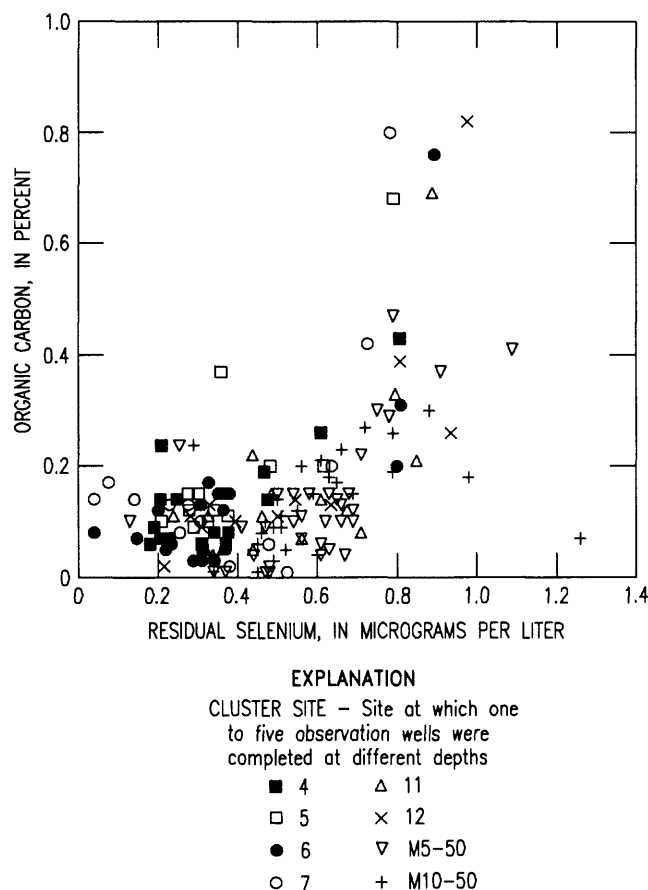


Figure 20. Relation of percentage of organic carbon to residual selenium concentrations.

0.6 µg/L and organic carbon less than about 0.2 percent, residual selenium and organic carbon vary independently of one another. These low concentrations and percentages are representative of samples collected at depths greater than 3 m of land surface. High residual selenium concentrations are associated with organic carbon present near land surface. This is consistent with information presented by Doner and Lipton (1990). These authors presented data that indicate that a large fraction of solid phase selenium in western San Joaquin Valley soils is associated with organic matter.

Evidence suggests that soluble inorganic selenium was incorporated into organic matter over geologic time in the valley soils. Doner and others (1989) present evidence that this organic matter is being oxidized over time since the beginning of irrigation. By comparing archived soil samples collected in the 1940's and soil samples collected at the same sites in 1985, these authors found that organic carbon decreased, on the average in every soil series

collected except one at the 15-cm depth. As these soils are cultivated and irrigated, organic matter that has accumulated over geologic time apparently is solubilized and oxidized. Selenium associated with this organic matter can be mobilized as this process occurs.

SUMMARY AND CONCLUSIONS

The results of the study illustrate the processes affecting the spatial and temporal distribution of salinity, selenium, and other inorganic constituents in an artificially drained agricultural field. Evapoconcentration of shallow ground water and ground-water flow are the primary processes affecting these distributions.

The highest selenium concentrations and salinities in ground water are the result of evapotranspiration from a shallow water table. This is evidenced by the high correlation of salinity, selenium, and enrichment in deuterium and oxygen-18.

During this study, the ground water with the highest selenium concentrations was at 6 to 9 m below land surface. Stable-isotope and tritium data support the hypothesis that this ground water was near land surface at some time in the past and has been displaced downward by less saline ground water since at least 1970. The ground water at depths less than 6 m is less saline and has lower selenium concentrations because it was near land surface after drainage-system installation. Concentrations of other mobile constituents such as boron, lithium, and vanadium are also significantly correlated with ground-water salinity.

Analysis of samples of soils and aquifer materials provided information about the factors affecting selenium mobility. The concentration of soluble selenium in the solid phase was lowest in the unsaturated zone and shallow saturated zone, indicating that it had been leached by irrigation. The concentrations of the residual selenium in the soil and aquifer-material samples were significantly correlated with organic carbon, indicating that the mobility of selenium in the solid phase was influenced by the mobilization of organic carbon.

Analysis of hydraulic gradients provide information about directions of ground-water flow. During the irrigation season, gradients are primarily downward.

Sand lenses influence ground-water flow by conducting ground water more rapidly than adjacent fine-grained layers. This results in upward and downward flow into the sand lenses during nonirrigated periods. Regional collector drains substantially influence near-surface ground-water flow. Drain laterals and drain-collector lines influence flow to a lesser extent.

REFERENCES CITED

- Allison, G.E., 1982, The relationship between ^{18}O and deuterium in water in sand columns undergoing evaporation: *Journal of Hydrology*, v. 55, p. 163-169.
- Barnes, C.J., and Allison, G.B., 1983, The distribution of deuterium and ^{18}O in dry soils. 1. Theory: *Journal of Hydrology*, v. 60, p. 141-156.
- Belitz, Kenneth, and Heimes, F.J., 1990, Character and evolution of the ground-water flow system in the central part of the western San Joaquin Valley, California: U.S. Geological Survey Water-Supply Paper 2348, 28 p.
- Briggs, P.H., and Crock, J.G., 1986, Automated determination of total selenium in rocks, soils, and plants: U.S. Geological Survey Open-File Report 86-40, 20 p.
- Bull, W.B., 1964, Geomorphology of segmented alluvial fans in western Fresno County, California: U.S. Geological Survey Professional Paper 352-E., p. 89-129.
- Bull, W.B., and Miller, R.E., 1975, Land subsidence due to ground-water withdrawal in the Los Banos-Kettleman City area, California. Part 1. Changes in the hydrologic environment conducive to subsidence: U.S. Geological Survey Professional Paper 437-E, 71 p.
- Cooper, H.H., Jr., Bredehoeft, J.D., and Papadopoulos, I.S., 1967, Response of a finite-diameter well to an instantaneous charge of water: *Water Resources Research*, v. 3, no. 1, p. 263-269.
- Craig, H., 1961, Isotopic variation in meteoric waters: *Science*, v. 133, p. 1833.
- Davis, G.H., and Coplen, T.B., 1987, Stable isotopic composition of groundwater of central California as an indicator of mid-pleistocene tectonic evolution: *Isotope Techniques in Water Resources Development*, International Atomic Energy Agency, Proceedings, p. 225-239.
- Davis, G.H., and Poland, J.F., 1957, Ground-water conditions in the Mendota-Huron area, Fresno and Kings Counties, California: U.S. Geological Survey Water-Supply Paper 1360-G, p. 409-588.
- Deverel, S.J., and Fujii, Roger, 1988, Processes affecting the distribution of selenium in shallow groundwater of agricultural areas, western San Joaquin Valley, California: *Water Resources Research*, v. 24, no. 4, p. 516-524.
- Deverel, S.J., and Gallanthine, S.K., 1989, Relation of salinity and selenium in shallow groundwater to hydrologic and geochemical processes, western San Joaquin Valley, California: *Journal of Hydrology*, v. 109, p. 125-149.
- Deverel, S.J., and Millard, S.P., 1988, Distribution and mobility of selenium and other trace elements in shallow groundwater of the western San Joaquin Valley, California: *Environmental Science and Technology*, v. 22, no. 6, p. 697-702.
- Doner, H.E., Amundson, R.G., and Lilieholm, B., 1989, A comparison of Se and As concentrations in soils of the western San Joaquin Valley, California, 1946-1985: *Arid Soil Research Rehabilitation*, v. 3, p. 315-325.
- Doner, H.E., and Lipton, D.S., 1990, Soil organic matter interactions with selenium in K.K. Tanji, and others (eds.), 1989-90 Technical Progress Report, UC Salinity/Drainage Task Force: Davis, University of California, Division of Agriculture and Natural Resources, 156 p.
- Epstein, S., and Mayeda, T., 1953, Variation of the O-18 content of waters from natural sources: *Geochimica et Cosmochimica Acta*, v. 4, p. 213-224.
- Fishman, M.J., and Friedman, L.C., eds., 1985, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 5, Chapter A1, 709 p.
- Fio, J.L., and Deverel, S.J., 1990, Ground-water flow and solute movement to drain laterals, western San Joaquin Valley, California. II. Quantitative hydrologic assessment: U.S. Geological Survey Open-File Report 90-137, 15 p.
- Fontes, J.C., and Gonfiantini, R., 1967, Isotopic composition of two Saharan basins: *Earth and Planetary Science Letters*, v. 3, p. 258-266.
- Freeze, R.A., and Cherry, J.A., 1979, *Groundwater*: Englewood Cliffs, New Jersey, Prentice-Hall, 604 p.
- Fujii, Roger, Deverel, S.J., and Hatfield, D.B., 1988, Distribution of selenium in soils of agricultural fields, western San Joaquin Valley, California: *Soil Science Society of America Journal*, v. 52, no. 5, p. 1274-1283.
- Gat, J.R., 1971, Comments on the stable isotope method in regional groundwater investigations: *Water Resources Research*, v. 7, no. 4, p. 980-993.
- Guy, H.P., 1969, Laboratory theory and methods for sediment analysis: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 5, Chapter C1, 58 p.
- Harradine, F.F., 1950, *Soils of western Fresno County*: Berkeley, University of California Press, 86 p.
- Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 2254, 264 p.
- Hollander, M., and Wolfe, D.A., 1973, *Nonparametric statistical methods*: New York, John Wiley, 503 p.
- Hvorslev, J.M., 1951, Time lag and soil permeability in ground-water observations: U.S. Army Corps of Engineers, Waterways Express Station, Vicksburg, Mississippi, Bulletin 36, 50 p.
- International Atomic Energy Agency, 1976, Proceedings and technique critique of tritium enrichment by electrolysis: International Atomic Energy Agency Technical Note, No. 19.

- International Atomic Energy Agency, 1981, Stable isotope hydrology: deuterium and oxygen-18 in the water cycle: International Atomic Energy Agency Technical Reports, Series No. 210, 335 p.
- Johnson, R.A., and Wichern, D.W., 1982, Applied multivariate statistical analysis: Englewood Cliffs, New Jersey, Prentice-Hall.
- Jury, W.A., 1975a, Solute travel-time estimates for tile drained fields. I. Theory: Soil Science Society of America, v. 39, p. 1020-1024.
- _____, 1975b, Solute travel-time estimates for tile drained fields. II. Experimental: Soil Science Society of America, v. 39, p. 1024-1028.
- Kendall, Carol, and Coplen, T.B., 1985, Multisample conversion of water to hydrogen by zinc for stable isotope determination: Analytical Chemistry, v. 57, no. 7, p. 1437-1440.
- Laudon, Julie, and Belitz, Kenneth, 1991, Texture and depositional history of late Pleistocene-Holocene alluvium in the central part of the western San Joaquin Valley, California: Bulletin of the Association of Engineering Geologists, v. 28, no. 1, p. 73-88.
- Luthin, J.N., Fernandez, P., Maslov, B., Woerner, J., and Robinson, F., 1969, Displacement front under ponded leaching: American Society of Civil Engineers, Journal of the Irrigation Drainage Division, v. 95, p. 117-125.
- Mansell, R.S., McKenna, P.J., and Hall, M.E., 1985, Solute discharge during steady water drainage from a sand tank: Soil Science Society of America, v. 49, p. 556-562.
- Mendenhall, W.C., Dole, R.B., and Stabler, Herman, 1916, Ground water in San Joaquin Valley, California: U.S. Geological Survey Water-Supply Paper 398, 310 p.
- Miller, R.E., Green, J.H., and Davis, G.H., 1971, Geology of the compacting deposits in the Los Banos-Kettleman City subsidence area, California: U.S. Geological Survey Professional Paper 497-E, 46 p.
- Ohlendorf, H.M., Hothem, R.L., Bunck, C.M., Aldrich, T.W., and Moore, J.F., 1986, Relationships between selenium concentration and avian reproduction: North American Wildlife and Natural Resources Conference, 51st, Reno, Nevada, Transactions, 1986, p. 330-442.
- Ortiz, J., and Luthin, J.N., 1970, Movement of salts in ponded anisotropic soils: American Society of Civil Engineers, Journal of the Irrigation Drainage Division, v. 96, p. 256-264.
- Pillsbury, A.F., Johnston, W.R., Ittihadieh, F., and Daum, R.M., 1965, Salinity of tile drainage effluent: Water Resources Research, v. 1, no. 4, p. 531-535.
- Plummer, L.N., Jones, B.F., and Truesdell, A.H., 1976, WATEQF-A FORTRAN IV version of WATEQ, a computer program for calculating chemical equilibrium of natural waters: U.S. Geological Survey Water-Resources Investigations Report 76-13, 66 p.
- Prudic, D.E., 1982, Hydraulic conductivity of a fine-grained till, Cattaraugus County, New York: Ground Water, v. 20, no. 2, p. 194-204.
- Raats, P.A.C., 1978, Convective transport of solutes by steady flows, II, Specific flow problems: Agricultural Water Management, v. 1, p. 219-232.
- San Joaquin Valley Drainage Program, 1990, A management plan for agricultural subsurface drainage and related problems on the westside San Joaquin Valley, Final Report of the San Joaquin Valley Drainage Program, 183 p.
- Thornton, Iain, ed., 1983, Applied environmental geochemistry: New York, Academic Press, 501 p.
- Tidball, R.R., Grundy, W.D., and Sawatzky, D.L., 1986, Kriging techniques applied to element distribution in soils of the San Joaquin Valley, California: HAZTECH International Conference, Denver, Colorado, August 13-15, 1986, Proceedings, p. 992-1009.
- U.S. Bureau of Reclamation, 1984, Kesterson Reservoir and waterfowl: Information Bulletin 1, 10 p.
- Wershaw, R.L., Fishman, M.J., Grabbe, R.R. and Lowe, L.E., eds., 1987, Methods for the determination of organic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 5, Chapter A3, 80 p.
- Wood, W.W., 1981, Guidelines for collection and field analysis of ground-water samples for selected unstable constituents: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 1, Chapter D2, 24 p.
- Zat, I., and Gat, J.R., 1975, Saline waters and residual brines in the Shiraz-Sarvistan Basin, Iran: Chemical Geology, v. 16, p. 179-188.

Table 2. Site, well depth, and constituents determined for water samples collected in the drained agricultural field

[Cluster site: Site at which one to five observation wells were installed at different depths. Site identification No.: Unique number for each well based on the latitude and longitude of the site. First six digits are latitude, next seven digits are longitude, and final two digits are a sequence number to uniquely identify each well. Well depth: Depth, in meters below land surface, of each observation well completed at cluster site. Type of analyses: xx, data available; --, no data]

Cluster site	Site identification No.	Well depth	Type of analyses			
			Major ions	Trace elements	Stable isotopes	Tritium
EW1	363906120243601	3	--	--	--	--
		4	xx	xx	xx	xx
		4.5	--	--	--	--
		6	--	--	--	--
EW2	363906120243602	3	--	--	--	--
		4	xx	xx	xx	--
		4.5	--	--	--	--
		6	--	--	--	--
EW3	363906120243603	3	--	--	--	--
		4	xx	xx	xx	--
		4.5	--	--	--	--
		6	--	--	--	--
EW4	363906120243604	4	xx	xx	--	xx
EW5	363906120243605	4	xx	xx	--	xx
EW6	363906120243606	4	xx	xx	--	xx
MA	363915120242002	15	xx	xx	xx	xx
MB	363902120242559	15	xx	xx	xx	xx
MBS	363902120242561	4.5	--	--	--	--
		8.5	xx	xx	xx	xx
		9	--	--	--	--
MCS	363902120242564	4.5	--	--	--	--
		8.5	xx	xx	xx	xx
		9	--	--	--	--
MDS	363902120242567	4.5	--	--	--	--
		8	xx	xx	xx	xx
		8.5	--	--	--	--
MF	363902120242571	3.5	xx	xx	xx	xx
	363902120242570	6	xx	xx	xx	xx
	363902120242569	9	xx	xx	xx	xx
M1	363906120244618	3	xx	xx	xx	xx
	363906120244617	6	xx	xx	xx	xx
	363906120244616	9	xx	xx	xx	xx
	363906120244615	12	xx	xx	xx	xx
	363906120244614	15	xx	xx	xx	--
M4	363906120244621	6	xx	xx	xx	xx
	363906120244620	9	xx	xx	xx	xx
	363906120244619	15	xx	xx	xx	xx

Table 2. Site, well depth, and constituents determined for water samples collected in the drained agricultural field--*Continued*

Cluster site	Site identification No.	Well depth	Type of analyses			
			Major ions	Trace elements	Stable isotopes	Tritium
M5	363906120244626	3	--	--	--	--
	363906120244625	6	xx	xx	xx	xx
	363906120244624	9	xx	xx	xx	xx
	363906120244623	12	xx	xx	xx	xx
	363906120244622	15	xx	xx	xx	xx
M8	363906120244630	3	xx	xx	xx	xx
	363906120244629	6	xx	xx	xx	xx
	363906120244628	12	xx	xx	xx	xx
	363906120244627	15	xx	xx	xx	xx
M10	363906120244634	3	xx	xx	xx	xx
	363906120244633	6	xx	xx	xx	xx
	363906120244632	12	xx	xx	xx	xx
	363906120244631	15	xx	xx	xx	xx
NW1	363906120244601	3	--	--	--	--
		4	xx	xx	xx	--
		4.5	--	--	--	--
		6	--	--	--	--
		9	--	--	--	--
NW2	--	3	--	--	--	--
		4.5	--	--	--	--
		6	--	--	--	--
		9	--	--	--	--
NW3	--	3	--	--	--	--
		4.5	--	--	--	--
		6	--	--	--	--
NW4	363906120244604	3	--	--	--	--
		4	xx	xx	xx	--
		4.5	--	--	--	--
		6	--	--	--	--
		9	--	--	--	--
NW5	--	3	--	--	--	--
		4.5	--	--	--	--
		6	--	--	--	--
NW6	--	3	--	--	--	--
		4.5	--	--	--	--
		6	--	--	--	--
		9	--	--	--	--
NW7	363906120244607	3	--	--	--	--
		4	xx	xx	xx	--
		4.5	--	--	--	--
		6	--	--	--	--
		9	--	--	--	--

Table 2. Site, well depth, and constituents determined for water samples collected in the drained agricultural field--*Continued*

Cluster site	Site identification No.	Well depth	Type of analyses			
			Major ions	Trace elements	Stable isotopes	Tritium
NW8	--	3	--	--	--	--
		4.5	--	--	--	--
		6	--	--	--	--
		9	--	--	--	--
NW9	--	3	--	--	--	--
		4.5	--	--	--	--
		6	--	--	--	--
NW10	363906120244610	3	--	--	--	--
		4	xx	xx	xx	xx
		4.5	--	--	--	--
		6	--	--	--	--
		9	--	--	--	--
NW11	--	3	--	--	--	--
		4.5	--	--	--	--
		6	--	--	--	--
NW12	--	3	--	--	--	--
		4.5	--	--	--	--
		6	--	--	--	--
		9	--	--	--	--
NW13	363906120244613	3	--	--	--	--
		4	xx	xx	xx	--
		4.5	--	--	--	--
		6	--	--	--	--
		9	--	--	--	--
SE1	363902120242501	3	--	--	--	--
		4	xx	xx	xx	xx
		4.5	--	--	--	--
		6	--	--	--	--
		9	--	--	--	--
SE2	--	3	--	--	--	--
		4.5	--	--	--	--
		6	--	--	--	--
SE3	--	3	--	--	--	--
		4.5	--	--	--	--
		6	--	--	--	--
SE4	363902120242504	3	--	--	--	--
		4	xx	xx	xx	xx
		4.5	--	--	--	--
		6	--	--	--	--
		9	--	--	--	--
SE5	--	3	--	--	--	--
		4.5	--	--	--	--
		6	--	--	--	--

Table 2. Site, well depth, and constituents determined for water samples collected in the drained agricultural field--*Continued*

Cluster site	Site identification No.	Well depth	Type of analyses			
			Major ions	Trace elements	Stable isotopes	Tritium
SE6	--	3	--	--	--	--
		4.5	--	--	--	--
		6	--	--	--	--
		9	--	--	--	--
SE7	363902120242507	3	--	--	--	--
		4	xx	xx	xx	xx
		4.5	--	--	--	--
		6	--	--	--	--
		9	--	--	--	--
SE8	--	3	--	--	--	--
		4.5	--	--	--	--
		6	--	--	--	--
		8.5	--	--	--	--
SE9	--	3	--	--	--	--
		4.5	--	--	--	--
		6	--	--	--	--
SE10	363902120242510	3	--	--	--	--
		4	xx	xx	xx	xx
		4.5	--	--	--	--
		6	--	--	--	--
		9	--	--	--	--
SE11	--	3	--	--	--	--
		4.5	--	--	--	--
		6	--	--	--	--
SE12	--	3	--	--	--	--
		4.5	--	--	--	--
		6	--	--	--	--
		9	--	--	--	--
SE13	363902120242513	3	--	--	--	--
		4	xx	xx	xx	--
		4.5	--	--	--	--
		6	--	--	--	--
		9	--	--	--	--
1	363902120242514	3	xx	xx	xx	xx
	363902120242515	6	xx	xx	xx	xx
	363902120242516	9	xx	xx	xx	xx
	363902120242517	12	xx	xx	xx	xx
1A	--	3	--	--	--	--
1B	--	3	--	--	--	--
2	363902120242518	3	xx	xx	xx	xx
	363902120242519	6	--	--	--	--
	363902120242520	12	xx	xx	xx	xx

Table 2. Site, well depth, and constituents determined for water samples collected in the drained agricultural field--*Continued*

Cluster site	Site identification No.	Well depth	Type of analyses			
			Major ions	Trace elements	Stable isotopes	Tritium
3	363902120242521	3	xx	xx	--	--
	363902120242522	6	xx	xx	xx	--
	363902120242523	9	xx	xx	xx	--
4	363902120242524	3	xx	xx	--	xx
	363902120242525	6	xx	xx	xx	xx
	363902120242526	12	xx	xx	xx	xx
5	363902120242527	3	xx	xx	--	--
	363902120242528	6	xx	xx	xx	--
	363902120242529	9	xx	xx	xx	--
6	363902120242530	3	xx	xx	--	--
	363902120242531	6	--	--	--	--
	363902120242532	12	xx	xx	xx	--
7	363902120242533	3	xx	xx	--	xx
	363902120242534	6	xx	xx	xx	xx
	363902120242535	9	xx	xx	xx	xx
	363902120242536	12	xx	xx	xx	xx
9	363902120242537	3	xx	xx	--	xx
	363902120242538	6	xx	xx	xx	xx
	363902120242539	9	xx	xx	xx	xx
	363902120242540	12	xx	xx	xx	xx
10	363902120242541	3	xx	xx	--	--
	363902120242542	6	xx	xx	xx	--
	363902120242543	9	xx	xx	xx	--
11	363902120242544	3	xx	xx	--	--
	363902120242545	6	xx	xx	--	--
	363902120242546	12	xx	xx	xx	--
12	363902120242547	3	xx	xx	--	xx
	363902120242548	6	--	--	--	--
	363902120242549	9	xx	xx	--	xx
13	363902120242550	3	xx	xx	--	--
	363902120242551	6	xx	xx	xx	xx
	363902120242552	12	xx	xx	xx	xx
14	363902120242553	3	xx	xx	--	--
	363902120242554	6	xx	xx	xx	xx
	363902120242555	8	xx	xx	xx	xx
15	363902120242556	3	xx	xx	--	--
	363902120242557	6	xx	xx	xx	xx
	363902120242558	12	xx	xx	xx	xx

Table 3. Field measurements and chemical analysis for major ions, dissolved organic carbon, stable

[Cluster site: Site at which one to five observation wells were installed at different depths. Well depth: Depth, in meters
mV, millivolt; °C, degrees Celsius; mg/L, microgram per liter; TU, tritium unit; <, actual value is less than value shown]

Cluster site	Well depth	Date	Specific conductance (µS/cm)	pH (standard units)	Oxidation reduction potential (mV)	Temperature, water (°C)	Oxygen, dissolved (mg/L)		
								Calcium, dissolved	Magnesium, dissolved
EW1	4	2-04-86	--	7.02	--	16.0	0.2	--	270
		7-17-86	9,700	7.20	354	22.5	.5	440	260
		7-30-86	9,000	7.30	386	24.0	.1	440	260
EW2	4	2-04-86	11,300	7.45	--	16.0	.2	450	200
EW3	4	2-04-86	10,700	7.20	215	17.0	.5	490	160
EW4	4	7-17-86	20,700	7.30	--	20.0	3.3	490	370
		7-30-86	17,300	7.40	390	23.0	4.2	500	310
EW5	4	7-17-86	20,400	7.20	381	22.0	2.6	360	170
		7-30-86	19,100	7.10	233	22.5	1.2	430	440
EW6	4	7-17-86	5,920	7.50	446	22.0	.8	360	170
		7-30-86	5,850	7.50	391	21.0	.4	410	190
MA	15	6-30-87	9,240	7.60	372	20.0	6.0	530	350
MB	15	3-31-87	7,500	7.54	354	23.0	3.2	490	350
MBS	8.5	4-01-87	22,400	7.55	331	22.5	.3	480	350
		9-01-88	22,900	7.54	--	19.5	1.8	580	730
MCS	8.5	4-01-87	21,800	7.62	355	20.0	.3	540	610
MDS	8	4-01-87	23,400	7.59	370	19.5	1.2	530	610
MF	3.5	10-22-87	5,850	7.27	403	23.5	.2	370	130
	6	10-22-87	3,360	7.51	209	21.0	.2	470	110
	9	10-22-87	9,470	7.58	218	20.0	1.0	370	260
M1	3	6-11-87	9,900	7.50	320	21.5	3.2	440	260
		7-20-88	10,100	7.38	331	20.5	1.9	170	290
	6	6-11-87	8,440	7.90	291	22.0	.1	360	310
		7-20-88	9,730	7.75	290	24.5	.2	290	280
	9	6-11-87	13,000	7.80	297	22.0	.1	360	430
	12	7-01-87	14,700	7.80	344	22.0	.1	520	350
	15	6-11-87	9,500	7.50	235	26.0	3.0	490	440
M4	6	6-10-87	19,000	7.80	391	23.0	4.3	410	430
		7-22-88	19,800	7.72	410	25.5	4.2	460	540
	9	6-10-87	16,200	7.90	365	24.0	.2	370	540
		7-20-88	17,900	7.84	268	23.5	.2	390	444
	15	6-10-87	8,930	7.60	422	24.5	2.8	460	410
		7-20-88	11,700	7.53	281	27.0	.5	420	470
M5	6	6-09-87	9,930	7.90	293	20.0	.2	450	250
		7-21-88	10,400	7.74	380	27.0	.1	300	230
	9	6-09-87	12,600	8.00	278	21.0	.1	410	230
		7-21-88	14,500	7.89	350	21.0	.1	140	400

isotopes of hydrogen and oxygen, and tritium

below land surface, of each observation well completed at cluster site. --, no data. $\mu\text{S/cm}$, microseimen per centimeter

Major ions, in milligrams per liter						Carbon, organic, dissolved (as C)	$^2\text{H}/^1\text{H}$ stable isotope ratio (per mil)	$^{18}\text{O}/^{16}\text{O}$ stable isotope ratio (per mil)	Tritium, in water molecules (TU)
Sodium, dissolved	Potassium, dissolved	Bicarbonate, whole water	Sulfate, dissolved	Chloride, dissolved	Silica, dissolved				
1,400	1.4	442	3,900	--	76	8.0	58.5	6.9	--
1,700	2.1	--	4,000	1,200	74	11	--	--	--
2,300	1.6	464	4,000	1,100	78	9.2	--	--	15.7
1,800	2.9	356	6,400	760	88	6.0	-59.0	-6.8	--
2,400	4.2	341	5,300	950	48	7.0	-59.5	-6.6	--
4,600	13	693	8,900	3,200	38	21	--	--	--
2,800	8.1	518	7,300	2,400	39	17	--	--	4.2
4,500	4.2	636	7,700	3,500	53	22	--	--	--
3,600	3.6	454	7,400	3,500	53	21	--	--	1.8
940	3.2	611	3,500	72	48	7.0	--	--	--
1,700	2.9	177	3,600	97	48	4.9	--	--	13.6
1,300	1.8	122	9,300	140	32	1.6	-57.0	-6.9	1.5
990	2.2	136	3,700	840	50	1.8	-60.0	-7.4	<.8
3,900	3.4	213	6,200	4,900	33	14	-56.0	-5.6	1.0
5,000	3.6	230	6,800	4,800	35	15	-55.0	-5.0	<.8
4,000	3.6	217	5,900	4,700	34	13	-55.5	-5.5	2.2
4,500	3.9	243	6,800	5,400	34	16	-54.5	-5.1	<.8
970	2.7	355	3,600	66	59	--	-72.0	-9.2	15.0
220	0.9	218	1,400	50	59	--	-69.5	-9.1	12.1
1,900	2.9	164	4,700	600	54	4.3	-63.0	-7.6	3.3
2,200	2.6	437	5,100	590	62	9.1	-67.5	-8.7	12.2
2,000	1.8	386	4,900	520	63	7.4	-66.0	-8.7	11.1
2,000	2.6	170	5,300	180	34	5.0	-63.0	-8.2	5.5
1,900	2.4	161	5,500	260	34	9.2	-67.0	-8.3	7.3
3,300	2.0	174	8,700	150	34	4.4	-61.0	-7.3	<.8
3,300	1.7	182	3,700	1,000	44	4.0	-60.0	-7.1	1.1
1,700	2.0	132	4,800	1,000	46	--	-57.5	-6.5	--
5,100	9.0	294	9,800	1,900	26	11	-56.5	-6.3	6.8
5,300	5.0	280	11,000	1,800	24	8.8	-57.5	-6.4	--
4,200	2.8	171	6,700	910	26	4.7	--	--	<.8
3,900	3.0	163	10,000	690	26	3.8	-61.5	-7.4	.9
1,900	1.7	199	6,500	300	53	2.8	-61.0	-7.5	.9
2,300	1.9	186	6,900	370	52	2.5	-62.5	-7.6	<.8
2,300	3.1	182	5,200	840	42	5.6	-59.5	-7.5	11.0
2,000	2.5	175	4,600	750	42	4.1	-62.0	-7.5	10.7
2,400	1.5	116	8,500	290	28	3.7	-63.0	-7.9	15.9
3,400	2.3	115	8,600	380	28	3.3	-62.5	-7.7	19.6

Table 3. Field measurements and chemical analysis for major ions, dissolved organic carbon, stable

Cluster site	Well depth	Date	Specific conductance ($\mu\text{S}/\text{cm}$)	pH (standard units)	Oxidation reduction potential (mV)	Temperature, water ($^{\circ}\text{C}$)	Oxygen, dissolved (mg/L)		
								Calcium, dissolved	Magnesium, dissolved
M5	12	7-01-87	7,480	8.00	336	22.0	4.0	360	570
		7-21-88	7,410	7.73	381	27.0	.4	450	280
	15	6-09-87	7,960	7.60	273	23.0	1.0	470	220
		7-21-88	10,500	7.75	389	20.0	.3	250	390
M8	3	10-20-87	3,380	7.00	350	21.5	2.1	180	53
	6	10-20-87	6,090	7.60	313	21.0	.5	510	150
	12	10-20-87	7,020	7.40	333	20.0	1.2	410	160
	15	10-20-87	8,900	7.74	326	21.5	6.2	300	340
M10	3	10-21-87	4,680	7.36	390	23.0	.3	480	100
	6	10-21-87	8,880	7.99	369	19.5	.3	370	170
	12	10-21-87	10,100	7.98	370	20.0	.5	340	220
	15	10-21-87	14,800	7.90	377	19.5	.3	350	380
NW1	4	2-04-86	7,250	7.37	--	16.5	.8	500	210
NW4	4	2-04-86	25,800	7.23	191	15.0	2.3	580	130
NW7	4	2-03-86	13,400	7.22	326	16.0	1.9	460	150
NW10	4	1-31-86	23,800	7.55	319	16.0	.4	410	230
		7-22-88	7,480	7.26	366	21.0	.2	460	210
NW13	4	2-04-86	14,600	7.42	--	16.0	2.5	520	290
SE1	4	2-05-86	--	7.05	363	16.5	1.3	540	330
		5-23-86	15,400	7.08	393	18.5	.6	540	410
		7-16-86	15,900	7.20	417	23.0	.2	510	410
		7-29-86	15,500	7.10	465	24.0	.2	480	390
SE4	4	2-05-86	--	7.06	239	17.0	2.4	510	270
		5-22-86	9,580	7.45	299	19.0	2.3	480	280
		7-15-86	11,700	7.50	347	24.0	.2	430	300
		7-29-86	11,800	7.40	369	20.5	.8	440	300
SE7	4	2-05-86	--	7.35	269	18.0	.6	500	390
		5-21-86	26,100	7.29	292	20.5	.3	500	550
		7-16-86	26,500	7.40	322	24.0	.5	460	540
		7-29-86	24,800	7.40	389	27.0	.6	480	550
SE10	4	2-05-86	17,300	7.50	169	16.0	2.6	500	310
		5-21-86	12,900	7.39	158	21.0	1.2	440	290
		7-31-86	12,600	7.50	354	23.5	.7	400	270
		9-01-88	14,500	7.33	--	23.0	.4	260	370
SE13	4	2-05-86	--	7.08	282	17.0	.8	680	300
		5-21-86	15,800	7.17	242	18.0	.8	700	340

isotopes of hydrogen and oxygen, and tritium--*Continued*

Major ions, in milligrams per liter						Carbon, organic, dissolved (as C)	² H/ ¹ H stable isotope ratio (per mil)	¹⁸ O/ ¹⁶ O stable isotope ratio (per mil)	Tritium, in water molecules (TU)
Sodium, dissolved	Potassium, dissolved	Bicarbonate, whole water	Sulfate, dissolved	Chloride, dissolved	Silica, dissolved				
1,200	1.3	98	1,500	190	33	2.8	-61.5	-8.1	31.9
1,200	1.3	112	3,800	460	34	2.5	-64.0	-8.1	26.5
3,700	2.2	134	7,100	460	43	3.3	-61.0	-7.6	11.6
2,100	1.1	98	6,100	380	36	2.5	--	--	25.1
630	5.8	563	800	330	59	--	-69.0	-9.0	15.4
1,200	5.8	280	3,200	600	50	--	-63.5	-7.9	11.2
1,400	2.4	162	4,000	560	46	--	-64.0	-7.7	<.8
2,000	2.3	118	6,200	500	32	--	-59.5	-7.0	.9
640	4.2	376	2,100	390	63	--	-67.0	-8.7	13.2
1,800	3.5	239	5,100	430	43	--	-63.0	-7.8	15.8
2,000	3.3	188	5,200	580	38	--	-62.5	-7.4	3.4
3,300	3.4	173	6,500	2,100	34	--	-57.0	-5.9	1.6
910	4.7	331	4,000	480	45	6.0	-65.5	-8.1	--
730	4.2	397	2,900	480	60	4.8	-64.5	-8.0	--
1,200	3.4	424	4,800	390	68	4.1	-63.5	-8.0	--
2,500	3.5	--	9,600	870	72	7.4	-60.0	-7.1	--
1,300	3.2	356	3,300	620	71	6.1	-66.5	-8.6	10.4
2,100	1.6	625	5,600	1,500	70	13	-63.5	-7.9	--
2,700	2.1	606	5,800	2,800	74	18	-56.0	-5.6	--
3,200	2.3	672	5,400	2,800	74	20	--	--	--
3,200	3.2	830	5,100	2,900	76	25	--	--	--
2,400	2.9	633	5,700	3,000	76	22	--	--	5.0
2,100	2.1	220	5,700	1,600	64	7.3	-57.0	-5.9	--
1,900	2.0	281	5,400	970	63	6.3	--	--	--
2,300	2.0	290	5,000	1,700	61	8.1	--	--	--
3,500	2.2	217	5,500	1,700	68	7.8	--	--	4.5
5,400	4.1	403	9,800	4,600	56	15	-56.5	-5.7	--
5,800	3.9	402	9,000	5,100	54	21	--	--	--
2,200	4.2	384	9,000	5,600	53	17	--	--	--
4,900	4.2	385	8,800	5,500	53	15	--	--	1.9
3,200	3.0	434	7,000	2,900	66	18	-58.5	-6.1	--
2,700	2.5	369	6,600	1,100	64	13	--	--	--
2,100	3.1	349	6,700	990	70	53	--	--	--
3,400	2.4	358	6,600	1,500	69	10	-61.5	-7.0	5.4
2,900	3.6	437	4,700	3,000	46	24	-62.5	-6.1	--
3,100	3.4	408	4,100	3,300	46	21	--	--	--

Table 3. Field measurements and chemical analysis for major ions, dissolved organic carbon, stable

Cluster site	Well depth	Date	Specific conductance ($\mu\text{S}/\text{cm}$)	pH (standard units)	Oxidation reduction potential (mV)	Temperature, water ($^{\circ}\text{C}$)	Oxygen, dissolved (mg/L)	Calcium, dissolved	Magnesium, dissolved
1	3	7-30-86	12,500	7.50	386	27.0	0.7	420	320
		8-12-86	13,800	7.60	360	22.0	.5	410	310
		8-30-88	11,100	7.14	--	25.5	.5	330	300
	6	3-05-86	17,600	7.46	401	23.0	2.9	--	270
		8-30-88	16,400	7.45	--	22.0	3.2	210	410
	9	3-05-86	18,800	7.69	455	21.0	2.7	410	370
	12	3-05-86	12,300	7.76	353	19.5	4.8	460	330
2	3	5-23-86	18,500	7.21	391	20.5	4.6	620	470
		7-30-86	17,700	7.10	372	23.0	.6	510	440
		9-01-88	16,200	7.11	--	28.5	1.5	620	390
	12	2-28-86	6,970	7.48	384	18.0	2.3	580	330
		9-01-88	7,360	7.62	--	28.5	2.9	520	360
3	3	7-31-86	12,000	7.20	361	22.0	1.0	440	320
		8-12-86	12,000	7.30	397	24.0	.8	420	310
	6	2-06-86	15,200	7.64	340	15.5	1.6	460	330
	9	2-06-86	27,200	7.55	335	14.5	1.6	430	480
4	3	5-22-86	12,800	7.47	316	21.0	5.8	460	290
		7-16-86	13,400	7.00	370	22.0	.7	440	300
		7-29-86	13,400	7.10	390	23.0	.8	450	310
		8-12-86	14,100	7.20	369	22.0	1.1	440	300
	6	2-06-86	23,200	7.64	288	18.0	.8	410	320
		7-16-86	17,900	7.60	368	24.0	.8	460	450
		7-29-86	17,000	7.60	259	22.5	.5	460	420
		2-06-86	10,200	8.20	425	--	2.3	410	250
	12	7-16-86	9,830	7.50	375	20.0	1.9	380	300
		7-29-86	9,600	7.70	386	24.0	2.4	380	300
5	3	8-11-86	14,900	7.70	346	20.5	.4	470	360
	6	2-06-86	14,900	7.62	361	17.0	.9	510	320
	9	2-06-86	23,000	7.61	370	15.5	.9	480	490
6	3	8-13-86	14,300	7.30	376	25.0	1.0	460	330
	12	2-07-86	10,700	7.48	295	17.0	.7	470	270
7	3	5-22-86	11,300	7.40	289	23.0	1.9	460	290
		7-15-86	11,700	7.30	392	23.0	.4	400	280
		7-28-86	13,000	7.40	352	23.0	.6	440	300
		8-12-86	12,400	7.50	340	24.0	.3	410	290
		8-30-88	12,400	7.19	--	20.0	1.0	520	340
	6	3-06-86	17,300	7.54	444	18.5	1.7	560	250
		7-15-86	14,600	7.80	379	22.0	.4	470	310
		7-29-86	16,500	7.90	353	19.0	.3	450	300
		8-30-88	15,400	7.40	--	24.0	.5	480	330
		2-11-86	23,100	7.68	289	17.0	.5	480	450
	9	7-15-86	20,400	7.70	407	24.5	.1	420	610
		7-29-86	22,800	7.70	168	19.0	.2	430	610
		8-30-88	22,200	7.54	--	28.0	1.7	560	640

isotopes of hydrogen and oxygen, and tritium--*Continued*

Major ions, in milligrams per liter						Carbon, organic, dissolved (as C)	² H/ ¹ H stable isotope ratio (per mil)	¹⁸ O/ ¹⁶ O stable isotope ratio (per mil)	Tritium, in water molecules (TU)
Sodium, dissolved	Potassium, dissolved	Bicarbonate, whole water	Sulfate, dissolved	Chloride, dissolved	Silica, dissolved				
2,700	3.2	309	5,700	2,000	52	14	--	--	10.1
2,700	3.6	403	5,200	1,900	50	14	--	--	--
2,200	2.6	300	5,200	940	54	8.0	-65.0	-7.7	6.0
3,000	4.7	288	8,200	--	41	--	-54.0	-4.8	2.9
3,700	4.2	220	7,700	1,900	38	7.2	-55.0	-5.2	1.7
2,700	2.7	180	9,800	1,400	32	6.2	-56.5	-5.5	<.8
1,900	1.5	123	4,900	1,800	27	3.5	-58.5	-6.4	<.8
3,800	2.9	684	5,200	4,400	78	30	--	--	--
3,200	3.4	660	5,200	4,500	82	28	--	--	6.5
4,200	2.6	582	5,300	1,200	73	27	-56.0	-5.8	3.7
720	1.3	147	3,400	1,100	41	--	-58.0	-6.7	<.8
880	1.7	99	3,100	1,000	41	2.2	-59.5	-6.9	<.8
80	3.0	637	4,900	1,700	57	67	--	--	--
2,400	3.5	841	4,800	1,700	55	12	--	--	--
2,500	4.0	222	7,600	1,700	38	8.0	-53.5	-5.4	--
3,700	4.1	161	12,000	2,800	30	13	-51.5	-4.0	--
2,600	5.0	586	6,100	1,600	64	11	--	--	--
2,700	6.3	701	5,900	1,600	33	12	--	--	--
1,400	5.9	596	6,000	1,800	35	11	--	--	12.0
4,000	6.7	799	6,100	2,000	63	10	--	--	--
3,300	4.5	221	7,500	2,900	35	0.6	-53.5	-6.5	--
3,700	4.8	146	7,500	3,000	33	12	--	--	--
2,600	4.2	170	6,800	2,700	34	11	--	--	5.4
1,500	1.8	116	4,800	1,100	30	1.5	-58.0	-6.5	--
1,800	2.1	203	3,900	1,100	30	3.4	--	--	--
2,400	1.7	108	4,200	1,200	30	2.5	--	--	<.8
3,000	4.4	252	5,900	2,400	32	8.2	--	--	--
2,700	4.0	195	6,300	2,200	37	9.0	-56.5	-5.4	--
4,600	4.4	146	8,700	4,200	30	8.0	-52.5	-4.2	--
2,900	9.5	751	5,800	2,300	56	11	--	--	--
1,700	1.7	126	5,100	1,100	28	1.8	-59.5	-6.6	--
2,300	3.4	344	5,800	1,400	72	8.7	--	--	--
2,500	3.3	414	5,700	1,400	38	9.6	--	--	--
1,800	3.7	360	5,200	1,400	78	5.7	--	--	7.8
2,400	4.5	505	5,500	1,500	80	8.6	--	--	--
2,400	6.2	368	4,800	2,000	77	10	-59.5	-6.7	5.7
2,900	3.9	190	6,500	2,500	37	11	-55.5	-5.1	--
3,500	3.7	229	6,100	2,800	35	14	--	--	--
2,200	3.9	191	5,900	2,900	35	12	--	--	<.8
3,300	3.4	196	6,400	2,500	36	6.9	-55.5	-5.3	1.6
4,500	3.8	158	11,000	3,800	33	--	-53.0	-4.5	--
5,200	3.5	166	9,000	4,300	32	9.2	--	--	--
2,000	3.7	145	9,000	4,200	32	8.3	--	--	<.8
4,800	3.7	152	8,200	3,700	32	7.0	-52.5	-4.7	<.8

Table 3. Field measurements and chemical analysis for major ions, dissolved organic carbon, stable

Cluster site	Well depth	Date	Specific conductance (μS/cm)	pH (standard units)	Oxidation reduction potential (mV)	Temperature, water (°C)	Oxygen, dissolved (mg/L)	Calcium, dissolved	Magnesium, dissolved
7	12	2-11-86	12,200	7.71	350	18.0	0.8	470	270
		7-15-86	10,400	8.00	337	22.0	.3	400	290
		7-28-86	11,900	7.90	338	21.0	.6	410	300
		8-30-88	14,700	8.71	--	20.0	.7	560	390
9	3	7-15-86	12,900	7.60	354	32.0	1.8	410	300
		7-28-86	13,300	7.30	177	24.0	.8	450	340
		8-13-86	13,500	7.40	304	23.5	.6	460	340
	6	3-06-86	15,700	7.75	167	21.0	.7	560	230
		7-16-86	15,800	7.80	327	24.0	1.2	480	260
		7-28-86	16,100	7.90	340	24.0	.5	500	270
	9	2-11-86	17,100	7.71	315	17.0	2.6	470	450
		7-16-86	21,700	7.80	388	19.5	.2	410	580
		7-28-86	21,100	7.90	364	23.0	.2	420	590
	12	2-28-86	13,700	7.62	301	17.5	.7	490	320
		7-15-86	15,400	7.60	420	29.0	.5	410	400
		7-29-86	13,900	7.70	357	20.0	.9	420	410
10	3	8-13-86	13,200	7.20	260	22.0	1.4	450	290
	6	2-26-86	14,000	7.77	346	20.0	.4	570	210
	9	2-25-86	20,900	7.79	343	19.5	.4	470	400
		2-26-86	20,800	7.77	366	18.0	.3	470	410
11	3	8-13-86	16,400	7.20	265	22.5	.8	430	270
	6	2-26-86	17,200	7.75	377	21.0	.2	600	200
	12	2-26-86	15,400	7.82	373	19.5	.7	530	270
12	3	7-16-86	18,300	7.20	427	22.0	.9	410	330
		7-29-86	17,700	7.20	375	24.0	.6	430	350
		8-13-86	17,900	7.20	279	23.5	.8	480	370
	9	7-17-86	14,900	8.80	--	23.0	--	340	120
		7-31-86	22,400	8.60	--	24.5	--	400	440
13	3	8-14-86	27,100	7.30	257	22.5	.7	430	410
	6	3-06-86	19,600	7.56	378	19.5	1.8	540	330
		4-02-87	11,600	7.57	328	19.0	2.6	480	330
	12	2-27-86	8,130	7.56	415	20.0	5.6	490	290
		4-02-87	8,930	7.38	344	19.5	4.7	480	420
14	3	7-30-86	23,300	7.30	207	24.0	.5	410	340
		8-14-86	22,000	7.30	268	21.5	.4	480	370
	6	3-06-86	30,500	7.37	365	19.5	.8	620	640
		4-02-87	36,200	7.25	178	19.5	.4	620	780
	8	2-27-86	32,100	7.43	424	20.5	.5	590	650
		4-02-87	38,500	7.32	412	19.5	.4	550	880
15	3	8-14-87	31,200	7.50	--	25.0	--	390	260
	6	3-06-86	20,800	7.50	173	19.0	2.4	540	560
		8-31-88	23,000	7.43	--	20.5	1.5	600	830
	12	2-27-86	5,510	7.45	399	20.0	7.0	560	330
		8-31-88	5,950	7.62	--	20.5	6.1	550	370

isotopes of hydrogen and oxygen, and tritium--*Continued*

Major ions, in milligrams per liter						Carbon, organic, dissolved (as C)	² H/ ¹ H stable isotope ratio (per mil)	¹⁸ O/ ¹⁶ O stable isotope ratio (per mil)	Tritium, in water molecules (TU)
Sodium, dissolved	Potassium, dissolved	Bicarbonate, whole water	Sulfate, dissolved	Chloride, dissolved	Silica, dissolved				
1,900	1.8	160	5,400	1,400	24	--	-58.5	-6.5	--
2,100	1.4	164	5,000	1,300	25	3.0	--	--	--
2,600	1.7	130	5,000	1,300	24	3.4	--	--	<0.8
3,000	2.2	142	5,400	2,100	27	5.3	-57.0	-5.9	1.4
2,500	3.7	417	5,800	1,300	74	10	--	--	--
2,900	3.8	273	5,800	1,900	74	10	--	--	5.4
2,700	4.8	299	5,100	1,900	76	8.7	--	--	--
2,900	4.1	182	5,600	2,600	31	12	-54.5	-4.8	--
3,200	3.8	189	5,600	3,000	29	11	--	--	--
2,300	3.7	182	5,600	3,000	30	10	--	--	<.8
4,500	3.9	215	9,500	3,900	31	--	-53.5	-4.5	--
4,800	3.8	134	9,100	4,200	31	9.1	--	--	--
4,600	3.6	--	9,000	4,000	30	7.7	--	--	<.8
2,400	2.3	178	6,500	1,900	23	--	-58.5	-6.6	--
2,900	2.0	149	6,600	2,000	23	13.5	--	--	--
5,800	2.1	133	6,700	2,000	22	4.2	--	--	<.8
2,700	5.5	423	5,200	2,000	74	9.6	--	--	--
2,700	3.9	176	5,600	2,500	30	--	-55.0	-4.8	--
4,400	3.6	168	10,000	3,500	30	--	-55.5	-4.8	--
3,900	3.8	168	10,000	3,700	31	--	--	--	--
3,700	3.7	575	5,600	3,300	80	15	--	--	--
3,400	4.6	160	6,400	3,400	28	--	--	--	--
3,100	4.0	158	33,000	2,400	25	--	-54.5	-5.1	--
4,100	4.6	578	7,000	3,500	66	26	--	--	--
2,600	4.5	635	6,700	3,200	70	23	--	--	2.8
4,200	5.0	751	6,900	3,300	74	20	--	--	--
3,700	12	309	6,000	2,500	13	12	--	--	--
2,700	3.9	141	9,600	3,000	26	13	--	--	1.9
6,900	7.3	947	11,000	4,400	53	28	--	--	--
3,300	4.3	180	8,000	2,600	30	6.7	-56.0	-5.5	--
2,200	2.0	140	5,100	1,500	55	3.0	-60.0	-6.9	<.8
1,300	1.2	211	4,700	890	44	--	-59.5	-7.0	--
1,400	0.70	132	4,200	1,000	44	1.4	-60.0	-7.3	<.8
3,900	4.7	524	7,900	4,500	55	28	--	--	--
5,300	5.2	691	7,700	4,300	56	24	--	--	--
5,800	6.9	358	8,100	7,500	41	19	-54.0	-4.5	--
6,300	6.1	376	7,000	8,200	41	26	-55.0	-4.6	<.8
7,000	5.8	420	11,000	8,300	35	--	-51.0	-3.4	--
6,700	4.9	312	8,500	8,400	35	19	-52.5	-4.1	3.2
2,800	3.8	383	7,400	720	42	10	--	--	--
3,900	4.0	200	7,700	3,800	35	--	-56.0	-5.7	--
4,400	3.6	188	7,100	4,200	32	11	-57.5	-5.7	<.8
1,000	1.2	150	3,700	1,200	36	--	-60.0	-6.9	--
1,200	1.1	102	3,600	1,200	38	2.2	-61.0	-6.9	1.4

Table 4. Chemical analysis of dissolved trace elements

[Cluster site: Site at which one to five observation wells were installed at different depths. Well depth: Depth, in meters below land surface, of each observation well completed at cluster site. Concentrations of trace elements in micrograms per liter. --, no data; <, actual value is less than value shown]

Cluster site	Well depth	Date	Aluminum	Arsenic	Boron	Chromium	Iron	Lithium	Manganese	Molybdenum	Nickel	Selenium	Vanadium
EW1	4	2-04-86	20	2	10,000	20	70	--	30	24	8	1,000	38
		7-17-86	20	2	11,000	30	60	470	20	25	--	510	<20
		7-30-86	20	2	11,000	30	40	500	30	17	--	390	<20
EW2	4	2-04-86	30	2	18,000	10	80	--	200	36	35	860	30
EW3	4	2-04-86	20	2	15,000	10	70	--	30	48	20	1,100	40
EW4	4	7-17-86	10	2	30,000	30	90	460	40	16	--	2,200	<40
		7-30-86	10	2	24,000	30	60	410	30	10	--	2,000	<30
EW5	4	7-17-86	10	2	37,000	20	90	480	30	57	--	1,900	<40
		7-30-86	<10	2	36,000	20	50	500	40	38	--	1,800	<40
EW6	4	7-17-86	20	2	5,700	<10	50	210	40	150	--	19	7
		7-30-86	<10	2	11,000	20	20	220	120	140	--	39	5
MA	15	6-30-87	10	2	27,000	50	40	330	20	74	1	300	17
MB	15	3-31-87	<10	--	9,500	30	30	290	40	64	1	840	<60
MBS	9	4-01-87	10	--	29,000	20	60	280	30	130	7	3,900	<60
		9-01-88	20	--	29,000	30	60	320	30	78	7	4,600	93
MCS	9	4-01-87	20	--	29,000	20	80	290	30	140	--	3,800	<60
MDS	8	4-01-87	<10	--	32,000	20	60	300	30	160	8	4,100	<60
MF	3.5	10-22-87	20	--	5,900	3	40	280	220	79	10	5	10
	6	10-22-87	<10	--	1,900	2	20	150	480	99	6	6	5
	9	10-22-87	<10	--	13,000	40	50	240	20	120	9	570	18
M1	3	6-11-87	10	4	15,000	<1	40	280	20	31	5	310	16
		7-20-88	<10	--	12,000	9	40	320	30	30	8	27	20
	6	6-11-87	10	4	16,000	<1	50	190	20	83	<1	11	10
		7-20-88	20	--	14,000	8	50	180	30	76	3	25	11
	9	6-11-87	<10	4	27,000	<1	60	250	20	150	3	220	11
	12	7-01-87	20	3	11,000	5	70	360	20	170	1	260	45
	15	6-11-87	20	2	15,000	40	50	350	<10	130	6	1,000	21
M4	6	6-10-87	10	5	39,000	<1	70	190	70	74	5	4,100	28
		7-22-88	20	--	37,000	6	80	220	80	100	5	3,100	80
	9	6-10-87	10	4	28,000	8	60	330	20	120	1	190	22
		7-20-88	20	--	25,000	20	70	300	30	160	397	970	33
	15	6-10-87	10	3	17,000	20	30	350	30	72	1	330	13
		7-20-88	20	--	17,000	20	50	350	30	80	2	340	20
M5	6	6-09-87	10	4	16,000	5	50	200	20	67	1	820	35
		7-21-88	20	--	13,000	10	40	200	40	64	4	500	33
	9	6-09-87	<10	3	24,000	<1	60	360	20	110	<1	520	16
		7-21-88	10	--	22,000	20	60	250	20	160	2	240	25
	12	7-01-87	<10	2	12,000	<1	50	230	20	87	2	200	18
		7-21-88	<10	--	11,000	20	40	230	20	76	4	170	17
	15	6-09-87	<10	--	17,000	<1	60	260	20	140	<1	200	23
		7-21-88	10	--	15,000	10	40	300	20	150	3	110	20

Table 4. Chemical analysis of dissolved trace elements--*Continued*

Cluster site	Well depth	Date	Aluminum	Arsenic	Boron	Chromium	Iron	Lithium	Manganese	Molybdenum	Nickel	Selenium	Vanadium
M8	3	10-20-87	<10	--	3,700	50	20	180	90	20	9	50	12
	6	10-20-87	10	--	12,000	30	30	310	50	21	10	180	13
	12	10-20-87	20	--	11,000	30	40	240	20	41	<1	410	10
	15	10-20-87	<10	--	14,000	90	40	280	30	110	6	410	13
M10	3	10-21-87	20	--	5,200	4	20	11	90	11	2	33	12
	6	10-21-87	20	--	17,000	4	30	240	30	67	8	120	15
	12	10-21-87	30	--	16,000	20	40	240	20	83	<1	420	18
	15	10-21-87	20	--	22,000	40	50	300	30	95	<1	2,100	31
NW1	4	2-04-86	10	1	10,000	<1	40	--	50	28	8	82	18
NW4	4	2-04-86	30	2	8,500	10	60	--	120	21	6	160	16
NW7	4	2-03-86	<10	2	8,700	4	60	--	20	18	1	27	14
NW10	4	1-31-86	20	4	29,000	<1	70	--	20	42	4	370	28
		7-22-88	10	--	9,500	20	40	250	20	18	3	160	22
NW13	4	2-04-86	20	2	25,000	<1	50	--	80	62	15	68	42
SE1	4	2-05-86	90	3	30,000	4	240	--	240	30	24	330	80
		5-23-86	20	3	30,000	8	80	480	270	29	22	320	60
		7-16-86	10	3	31,000	20	50	490	210	25	--	290	90
		7-29-86	20	3	31,000	30	80	500	220	34	--	370	<30
SE4	4	2-05-86	40	2	16,000	10	90	--	20	38	13	1,300	56
		5-22-86	10	3	13,000	20	60	280	20	26	6	540	29
		7-15-86	<10	3	17,000	20	50	300	20	40	--	1,000	<20
		7-29-86	20	3	17,000	30	60	290	20	51	--	1,100	<20
SE7	4	2-05-86	20	3	37,000	1	70	--	30	160	8	4,400	65
		5-21-86	<10	3	37,000	2	100	410	30	110	6	3,900	150
		7-16-86	<10	3	39,000	20	80	420	30	140	--	4,400	<60
		7-29-86	<10	3	37,000	30	90	430	30	130	--	4,100	<60
SE10	4	2-05-86	20	2	35,000	5	80	--	30	24	7	3,000	85
		5-21-86	30	2	22,000	5	60	390	20	24	5	630	41
		7-31-86	20	4	20,000	150	80	400	20	30	--	620	<10
		9-01-88	10	--	24,000	<1	40	380	10	30	4	990	12
SE13	4	2-05-86	20	1	29,000	6	70	--	30	10	11	2,000	82
		5-21-86	140	1	28,000	4	260	480	40	11	15	2,600	75
1	3	7-30-86	20	2	24,000	40	100	330	20	24	--	1,100	<20
		8-12-86	10	2	24,000	30	70	340	20	24	--	1,100	10
		8-30-88	20	--	14,000	10	50	280	30	19	4	480	35
	6	3-05-86	20	2	26,000	20	80	--	30	72	6	2,200	56
		8-30-88	10	--	23,000	40	30	240	50	76	6	1,200	13
		3-05-86	20	3	24,000	50	70	--	20	240	1	1,200	34
	12	3-05-86	20	1	16,000	50	50	--	30	1,500	2	1,100	52
2	3	5-23-86	20	2	32,000	20	100	560	40	12	13	430	110
		7-30-86	20	2	35,000	40	80	590	50	14	--	690	<50
		9-01-88	20	--	39,000	30	70	490	140	14	17	970	210

Table 4. Chemical analysis of dissolved trace elements--*Continued*

Cluster site	Well depth	Date	Aluminum	Arsenic	Boron	Chromium	Iron	Lithium	Manganese	Molybdenum	Nickel	Selenium	Vanadium
2	12	2-28-86	10	1	7,400	30	80	--	40	77	1	800	28
		9-01-88	20	--	7,300	50	40	290	10	62	4	700	26
3	3	7-31-86	40	4	22,000	10	80	530	600	56	--	280	<20
		8-12-86	20	3	22,000	10	70	520	610	53	--	320	<20
	6	2-06-86	30	3	23,000	50	80	--	20	82	3	2,200	42
	9	2-06-86	30	4	31,000	20	100	--	30	160	4	4,600	21
4	3	5-22-86	20	5	16,000	20	70	470	50	26	9	860	--
		7-16-86	230	5	17,000	40	50	490	30	22	--	950	<20
		7-29-86	10	3	18,000	30	70	490	30	26	--	960	<20
		8-12-86	30	3	20,000	30	110	420	30	25	--	1,000	<20
	6	2-06-86	20	3	26,000	20	70	--	20	110	1	3,000	77
		7-16-86	10	3	26,000	--	40	290	20	100	--	2,900	<30
		7-29-86	10	3	25,000	50	80	280	30	100	--	2,400	<30
		7-29-86	10	3	25,000	50	80	280	30	100	--	2,400	<30
	12	2-06-86	30	2	11,000	40	80	--	20	100	<1	1,100	44
		7-16-86	<10	2	11,000	50	50	290	20	120	--	860	<20
		7-29-86	20	2	11,000	50	70	290	20	120	--	1,100	<20
		7-29-86	20	2	11,000	50	70	290	20	120	--	1,100	<20
5	3	8-11-86	20	3	21,000	40	80	210	20	65	--	2,000	<25
	6	2-06-86	630	4	21,000	20	1,200	--	40	64	1	2,200	58
	9	2-06-86	20	2	27,000	40	100	--	30	160	2	6,300	150
6	3	8-13-86	20	9	19,000	20	70	450	100	20	--	1,100	<25
	12	2-07-86	50	1	11,000	30	100	--	50	52	1	1,300	44
7	3	5-22-86	10	3	14,000	7	70	410	20	14	5	890	20
		7-15-86	20	3	16,000	20	60	430	20	12	--	1,100	<20
		7-28-86	10	3	16,000	10	60	440	20	16	--	970	20
		8-12-86	20	3	18,000	20	70	390	40	17	--	960	<15
		8-30-88	20	--	14,000	7	20	480	140	12	7	1,100	23
	6	3-06-86	10	3	22,000	20	70	--	20	80	1	2,500	17
		7-15-86	20	3	23,000	30	70	260	20	55	--	2,500	<30
		7-29-86	10	3	23,000	60	70	270	20	70	--	2,300	<30
		8-30-88	20	--	21,000	20	7	280	1	62	2	1,700	26
		8-30-88	20	--	21,000	20	7	280	1	62	2	1,700	26
	9	2-11-86	20	3	26,000	40	80	--	20	150	<1	5,500	51
		7-15-86	20	3	25,000	50	90	360	20	150	--	4,400	<50
		7-29-86	10	3	25,000	50	80	350	20	150	--	4,400	<50
		8-30-88	30	--	22,000	60	80	300	30	120	2	4,000	61
	12	2-11-86	20	<1	13,000	30	60	--	20	110	4	1,500	51
		7-15-86	<10	21	13,000	60	40	290	20	130	--	1,200	<20
		7-28-86	<10	<1	12,000	50	60	280	20	130	--	1,000	<20
		8-30-88	10	--	15,000	40	50	270	20	100	2	1,900	21
		8-30-88	10	--	15,000	40	50	270	20	100	2	1,900	21
9	3	7-15-86	10	3	17,000	30	60	350	20	28	--	910	<20
		7-28-86	<10	3	18,000	20	50	360	20	27	--	1,200	<20
		8-13-86	20	3	19,000	20	80	320	20	28	--	1,500	<20
	6	3-06-86	10	4	23,000	20	60	--	20	66	2	2,500	79
		7-16-86	10	4	24,000	60	70	240	20	66	--	2,400	<30
		7-28-86	30	4	24,000	30	80	230	20	69	--	2,200	<30
	9	2-11-86	20	3	25,000	40	80	--	20	160	1	5,600	130
		7-16-86	<10	3	25,000	70	80	350	20	140	--	4,500	<50
		7-28-86	10	3	26,000	70	80	330	20	140	--	4,300	<40

Table 4. Chemical analysis of dissolved trace elements--*Continued*

Cluster site	Well depth	Date	Aluminum	Arsenic	Boron	Chromium	Iron	Lithium	Manganese	Molybdenum	Nickel	Selenium	Vanadium
9	12	2-28-86	10	1	15,000	30	80	--	30	140	3	1,700	84
		7-15-86	10	<1	16,000	70	60	330	20	160	--	1,500	<20
		7-29-86	20	<1	16,000	60	60	310	20	160	--	1,500	<20
10	3	8-13-86	30	2	20,000	20	90	360	20	26	--	1,200	<20
	6	2-26-86	<10	4	24,000	20	70	--	20	64	<1	2,600	20
	9	2-25-86	10	2	25,000	40	110	--	40	150	<1	4,900	41
		2-26-86	10	2	25,000	30	90	--	30	140	<1	5,200	35
11	3	8-13-86	20	3	28,000	20	90	470	20	17	--	1,000	<40
	6	2-26-86	10	4	27,000	20	90	--	20	90	<1	4,600	27
	12	2-26-86	20	3	21,000	20	90	--	80	120	<1	2,600	65
12	3	7-16-86	40	3	40,000	20	140	480	30	25	--	980	<40
		7-29-86	30	3	39,000	20	100	450	20	19	--	900	<40
		8-13-86	20	3	40,000	20	80	500	20	26	--	1,000	40
	9	7-17-86	10	15	20,000	110	150	250	60	440	--	2,100	25
		7-31-86	10	13	25,000	60	60	270	60	74	--	2,400	<30
13	3	8-14-86	20	3	55,000	40	100	450	20	33	--	2,700	<50
	6	3-06-86	10	5	28,000	20	90	--	20	80	<1	2,400	80
		4-02-87	<10	--	17,000	30	40	240	20	110	1	1,100	<60
	12	2-27-86	--	1	11,000	40	--	--	--	100	1	790	42
		4-02-87	30	--	11,000	40	40	240	20	160	<1	870	<60
14	3	7-30-86	10	2	47,000	20	60	520	20	25	--	2,700	<50
		8-14-86	20	3	48,000	40	110	510	20	31	--	2,900	<50
	6	3-06-86	20	3	42,000	8	100	--	30	80	4	8,200	100
		4-02-87	10	--	48,000	<1	100	350	40	78	7	6,000	<60
	8	2-27-86	<10	2	47,000	4	130	--	70	85	14	9,500	130
		4-02-87	<10	--	45,000	7	100	300	60	100	12	7,300	<60
15	3	8-14-86	<10	2	21,000	20	60	400	20	16	--	440	<10
	6	3-06-86	10	2	28,000	30	80	--	20	140	1	4,200	35
		8-31-88	10	--	27,000	40	70	320	20	82	5	3,300	74
	12	2-27-86	10	2	9,700	40	70	--	30	68	<1	990	26
		8-31-88	<10	--	9,700	60	40	290	<10	60	1	960	33

Table 5. Chemical analysis of drilling-core samples

[Cluster site: Site at which one to five observation wells were installed at different depths. m, meter; µg/g, microgram per gram; --, no data]

Cluster site	Sample depth (m)	Aluminum (percent)	Arsenic (µg/g)	Barium (µg/g)	Calcium (percent)	Cerium (µg/g)	Chromium (µg/g)	Cobalt (µg/g)	Copper (µg/g)	Iron (percent)
4	0.2	6.9	7.3	880	2.7	33	150	14	31	3.3
	.8	8.8	8.2	830	2.5	47	170	17	49	4.6
	1.4	7.3	7.5	990	2.2	37	130	13	33	3.5
	2.0	7.3	7.3	970	2.2	36	130	14	33	3.4
	2.9	7.0	7.7	1,000	2.9	38	150	15	32	3.3
	3.2	7.8	7.1	290	3.9	44	180	17	41	4.2
	3.5	5.9	6.0	1,000	2.0	28	320	16	21	2.6
	4.0	5.4	5.4	980	1.8	25	160	12	17	2.1
	4.4	6.0	6.1	970	2.1	32	170	13	21	2.5
	4.7	6.2	6.5	1,100	1.9	31	160	13	21	2.6
	5.2	6.3	6.5	1,000	1.9	32	170	15	22	2.7
	5.6	5.9	5.9	1,100	2.0	29	160	14	19	2.4
	5.8	6.2	6.0	1,000	1.9	29	180	15	21	2.6
	6.0	6.4	6.4	1,000	1.9	34	190	17	24	2.8
	7.8	8.4	7.6	670	2.6	46	210	19	45	4.6
	9.3	5.7	6.1	1,000	2.0	26	120	10	20	2.3
	11.0	7.2	5.9	670	2.5	38	150	14	30	3.4
	11.3	7.4	6.0	780	2.3	39	160	15	33	3.6
5	.2	7.3	6.7	970	1.9	39	130	13	33	3.3
	.8	8.5	6.8	830	2.4	47	160	16	47	4.4
	1.4	5.6	4.6	1,400	1.7	28	99	9	17	2.2
	2.0	7.6	8.2	980	2.3	43	140	14	36	3.8
	3.2	7.0	6.2	970	2.3	38	160	15	31	3.4
	4.4	6.9	6.8	980	2.4	37	170	16	28	3.2
	5.9	6.4	5.7	1,000	1.9	30	150	14	25	2.8
	6.2	6.9	7.3	980	2.3	36	180	17	30	3.3
	6.6	6.7	5.6	950	1.9	33	160	16	27	3.0
	6.9	6.5	8.2	1,000	1.8	36	160	17	36	3.1
	7.3	7.3	7.7	48	3.7	41	150	17	35	3.8
	7.8	8.6	9.3	180	2.6	49	220	22	48	5.1
	9.0	8.3	9.8	200	2.6	46	220	23	46	5.0
6	.2	7.5	8.1	960	2.1	41	130	14	33	3.6
	.8	8.2	9.1	870	2.4	45	150	16	42	4.3
	2.0	7.4	7.8	940	2.3	41	110	15	32	3.6
	3.5	6.8	10.0	870	2.5	38	230	23	33	3.6
	3.8	7.2	9.0	700	2.6	45	160	18	32	3.6
	4.7	5.3	6.1	1,000	1.6	26	160	13	15	2.2
	5.0	7.7	9.6	730	2.3	44	190	19	37	4.2
	5.3	8.5	8.5	320	2.5	48	210	20	47	4.9
	6.6	6.1	6.7	1,100	1.9	33	150	13	17	2.6
	6.9	6.7	6.9	310	2.2	39	150	16	25	3.1
	7.2	8.1	9.0	120	3.1	48	180	19	40	4.5
	8.1	8.1	9.4	93	3.2	46	200	20	44	4.7
	9.3	6.7	7.5	1,000	2.2	37	120	15	26	3.1
	10.8	7.1	6.8	800	1.8	39	140	14	27	3.3
	11.4	7.4	6.7	170	2.2	42	140	16	31	3.8
	11.7	7.5	6.3	790	1.2	43	150	16	31	3.7
	12.0	7.3	5.9	870	1.3	43	170	16	29	3.7

Table 5. Chemical analysis of drilling-core samples--*Continued*

Cluster site	Sample depth (m)	Lanthanum (µg/g)	Lead (µg/g)	Lithium (µg/g)	Magnesium (percent)	Manganese (µg/g)	Molybdenum (µg/g)	Neodymium (µg/g)	Nickel (µg/g)	Phosphorus (µg/g)
4	0.2	20	12	49	1.7	530	<2	17	110	0.06
	.8	27	17	80	1.7	590	3	22	91	.07
	1.4	21	14	55	1.4	530	<2	18	78	.06
	2.0	21	14	53	1.4	560	<2	15	81	.06
	2.9	21	14	50	1.8	590	<2	17	120	.06
	3.2	23	10	69	2.1	590	<2	20	120	.07
	3.5	16	12	31	2.2	480	<2	13	190	.05
	4.0	14	12	25	1.8	420	<2	10	140	.05
	4.4	17	12	32	1.7	500	<2	14	130	.05
	4.7	17	12	32	1.7	490	<2	14	120	.05
	5.2	17	11	34	2.1	510	<2	14	150	.05
	5.6	16	12	30	1.8	480	<2	14	130	.05
	5.8	17	12	32	2.1	510	<2	13	160	.05
	6.0	18	11	35	2.3	570	<2	15	180	.06
	7.8	25	15	73	2.5	660	<2	21	150	.08
	9.3	14	11	30	1.3	440	<2	13	84	.05
	11.0	21	12	51	1.7	520	<2	18	99	.06
	11.3	21	14	54	1.8	570	<2	18	110	.06
5	.2	22	15	54	1.3	480	<2	18	75	.06
	.8	26	14	76	1.7	600	<2	20	93	.06
	1.4	16	10	27	0.8	430	<2	13	55	.04
	2.0	24	14	60	1.5	540	<2	21	85	.06
	3.2	21	13	51	1.8	570	<2	17	120	.07
	4.4	20	12	43	1.9	610	<2	17	140	.06
	5.9	17	10	38	1.8	520	<2	14	130	.06
	6.2	20	12	44	2.1	570	<2	17	150	.06
	6.6	18	13	40	1.9	560	<2	15	140	.05
	6.9	19	15	38	2.0	570	<2	15	180	.05
	7.3	21	9	56	2.1	610	<2	19	120	.06
	7.8	26	13	76	2.7	750	2	22	170	.08
	9.0	25	12	72	2.8	700	<2	22	190	.07
6	.2	22	19	55	1.3	530	<2	18	77	.07
	.8	25	16	69	1.6	580	<2	21	90	.06
	2.0	22	15	52	1.4	560	<2	18	80	.06
	3.5	20	14	46	3.0	650	<2	17	260	.07
	3.8	25	13	50	2.0	630	<2	19	140	.07
	4.7	15	12	22	2.1	420	<2	11	160	.05
	5.0	24	14	58	2.3	660	<2	21	150	.07
	5.3	27	12	72	2.5	630	<2	22	160	.08
	6.6	18	14	29	1.6	520	<2	15	130	.05
	6.9	20	11	40	2.0	610	<2	16	140	.06
	7.2	25	11	67	2.4	690	<2	21	140	.08
	8.1	24	11	70	2.6	680	<2	22	160	.07
	9.3	20	14	40	1.5	580	<2	17	95	.06
	10.8	20	16	47	1.6	570	<2	17	100	.06
	11.4	22	12	53	1.7	680	<2	18	110	.06
	11.7	23	15	50	1.7	600	<2	19	110	.06
	12.0	24	14	46	1.7	640	<2	20	120	.08

Table 5. Chemical analysis of drilling-core samples--*Continued*

Cluster site	Sample depth (m)	Potassium (percent)	Scandium (µg/g)	Total selenium (µg/g)	Soluble selenium (µg/g)	Residual selenium (µg/g)	Silver (µg/g)	Sodium (percent)	Strontium (µg/g)
4	0.2	1.9	10	1.7	1.49	0.21	<2	1.5	280
	.8	1.7	16	1.4	.59	.81	<2	1.2	240
	1.4	2.0	11	1.1	.49	.61	<2	1.4	260
	2.0	2.0	11	1.0	.39	.61	<2	1.5	270
	2.9	1.9	10	.6	.12	.48	<2	1.6	290
	3.2	1.7	14	.7	.23	.47	<2	1.1	330
	3.5	2.0	7	.6	.23	.37	<2	1.6	270
	4.0	2.2	6	.6	.29	.31	<2	1.5	250
	4.4	2.1	8	.6	.29	.31	<2	1.5	260
	4.7	2.1	8	.6	.39	.21	<2	1.7	270
	5.2	1.9	8	.7	.47	.23	<2	1.7	280
	5.6	2.1	7	.6	.42	.18	<2	1.6	260
	5.8	2.0	8	.8	.46	.34	<2	1.8	270
	6.0	1.9	8	1.1	.91	.19	<2	1.8	260
	7.8	1.7	16	1.1	.85	.25	<2	1.3	280
	9.3	2.1	7	1.5	1.60	.00	<2	1.6	270
	11.0	2.0	11	.8	.42	.38	<2	1.3	270
	11.3	2.0	12	.6	.24	.36	<2	1.4	250
5	.2	2.1	11	.8	.01	.79	<2	1.1	230
	.8	1.6	16	.7	.34	.36	<2	1.2	240
	1.4	2.1	6	.6	.32	.28	<2	1.5	240
	2.0	1.9	13	1.1	.48	.62	<2	1.4	260
	3.2	2.0	11	.6	.12	.48	<2	1.4	260
	4.4	1.8	10	.8	.42	.38	<2	1.7	280
	5.9	2.0	9	.8	.51	.29	<2	1.6	270
	6.2	1.9	10	.9	.56	.34	<2	1.7	280
	6.6	2.0	9	.7	.78	.00	<2	1.8	270
	6.9	1.9	9	1.1	.89	.21	<2	1.7	270
	7.3	1.7	12	1.1	.76	.32	<2	1.4	570
	7.8	1.7	18	1.1	.80	.30	<2	1.2	250
	9.0	1.7	17	1.5	1.22	.28	<2	1.1	240
6	.2	1.9	11	.9	.01	.89	<2	1.2	240
	.8	1.7	15	1.0	.19	.81	<2	1.3	240
	2.0	1.9	11	1.2	.40	.80	<2	1.7	270
	3.5	1.7	11	.7	.35	.35	<2	1.5	260
	3.8	1.6	11	.7	.34	.36	<2	1.5	280
	4.7	2.0	6	.5	.27	.23	<2	1.5	240
	5.0	1.7	14	.8	.42	.38	<2	1.4	240
	5.3	1.7	17	.8	.47	.33	5	1.1	230
	6.6	2.1	7	1.1	.88	.22	<2	1.8	280
	6.9	1.8	9	1.1	.95	.15	<2	1.8	340
	7.2	1.8	15	1.2	1.00	.20	<2	1.4	320
	8.1	1.6	16	1.4	1.09	.31	<2	1.2	260
	9.3	1.9	9	1.2	1.16	.04	<2	1.8	280
	10.8	2.0	11	.6	.31	.29	<2	1.4	270
	11.4	1.9	12	.6	.23	.37	<2	1.3	240
	11.7	1.8	12	.5	.16	.34	<2	1.4	240
	12.0	2.0	12	.5	.19	.31	<2	1.5	250

Table 5. Chemical analysis of drilling-core samples--*Continued*

Cluster site	Sample depth (m)	Thorium (µg/g)	Titanium (µg/g)	Tin (percent)	Vanadium (µg/g)	Yttrium (µg/g)	Zinc (µg/g)	Total carbon (percent)	Organic carbon (percent)	Carbonate (percent)
4	0.2	8	0.29	<20	98	14	80	0.41	0.14	0.27
	.8	13	.39	<20	150	17	130	.82	.43	.39
	1.4	10	.31	<20	110	14	95	.54	.26	.28
	2.0	10	.31	<20	100	15	91	.53	.26	.27
	2.9	8	.31	<20	95	15	80	.57	.14	.43
	3.2	10	.37	<20	130	17	100	.50	.19	.31
	3.5	6	.22	<20	66	12	53	.31	.06	.25
	4.0	4	.17	<20	51	10	43	.26	.05	.21
	4.4	5	.24	<20	68	13	57	.26	.06	.20
	4.7	6	.24	<20	69	13	56	.30	.07	.23
	5.2	5	.25	<20	72	12	58	.27	.07	.20
	5.6	6	.23	<20	65	11	57	.27	.06	.21
	5.8	6	.24	<20	69	12	55	.28	.08	.20
	6.0	9	.26	<20	75	13	59	.31	.09	.22
	7.8	11	.38	<20	140	17	120	.40	.14	.26
	9.3	4	.22	<20	63	11	52	.34	.07	.27
5	11.0	9	.30	<20	100	15	85	.30	.08	.22
	11.3	9	.31	<20	110	15	90	.32	.15	.17
	.2	10	.29	<20	100	15	92	.92	.68	.24
	.8	12	.38	<20	150	17	120	.76	.37	.39
	1.4	5	.22	<20	56	10	49	.34	.12	.22
	2.0	11	.33	<20	120	17	98	.50	.20	.30
	3.2	8	.31	<20	97	15	81	.52	.20	.32
	4.4	7	.30	<20	88	15	72	.46	.11	.35
	5.9	6	.25	<20	80	13	65	.26	.09	.17
	6.2	8	.31	<20	91	14	75	.38	.12	.26
	6.6	7	.27	<20	81	13	69	.34	.13	.21
	6.9	7	.28	<20	80	13	110	.30	.10	.20
	7.3	8	.34	<20	110	15	93	.31	.10	.21
	7.8	11	.41	<20	160	17	120	.45	.15	.30
	9.0	11	.39	<20	150	17	120	.44	.15	.29
6	.2	10	.31	<20	110	14	100	1.01	.76	.25
	.8	12	.36	<20	140	15	120	.69	.31	.38
	2.0	9	.33	<20	100	14	92	.47	.20	.27
	3.5	8	.30	<20	96	14	77	.49	.15	.34
	3.8	11	.34	<20	100	15	85	.42	.12	.30
	4.7	5	.18	<20	52	9	44	.26	.06	.20
	5.0	10	.37	<20	120	16	99	.41	.15	.26
	5.3	12	.40	<20	160	17	120	.43	.17	.26
	6.6	6	.27	<20	65	11	53	.22	.05	.17
	6.9	7	.29	<20	85	14	71	.28	.07	.21
	7.2	12	.39	<20	130	17	110	.43	.12	.31
	8.1	11	.38	<20	140	16	110	.47	.13	.34
	9.3	9	.28	<20	82	13	72	.36	.08	.28
	10.8	9	.29	<20	97	13	81	.22	.03	.19
	11.4	8	.32	<20	110	14	93	.18	.05	.13
	11.7	10	.33	<20	110	14	92	.10	.03	.07
	12.0	9	.34	<20	100	15	88	.08	.03	.05

Table 5. Chemical analysis of drilling-core samples--*Continued*

Cluster site	Sample depth (m)	Aluminum (percent)	Arsenic (µg/g)	Barium (µg/g)	Calcium (percent)	Cerium (µg/g)	Chromium (µg/g)	Cobalt (µg/g)	Copper (µg/g)	Iron (percent)
7	0.2	7.4	7.7	930	2.0	45	110	14	32	3.6
	.8	8.8	8.5	900	2.6	52	150	18	46	4.7
	2.0	7.4	8.3	950	2.2	42	120	15	34	3.7
	3.2	8.4	9.1	140	3.2	49	190	19	41	4.7
	3.8	7.3	9.1	760	2.7	44	170	19	35	3.9
	4.7	5.6	6.3	1,300	1.8	32	150	12	15	2.2
	5.2	8.5	8.0	770	2.1	43	200	19	48	4.8
	5.6	7.3	5.5	860	2.2	37	180	19	36	3.8
	5.9	5.6	5.3	1,100	1.9	27	170	13	18	2.2
	6.9	6.6	7.2	1,000	2.0	32	150	16	25	2.8
	7.2	8.2	9.3	530	3.0	45	160	17	44	4.4
	8.4	8.5	7.4	730	2.2	45	190	20	45	4.7
	10.5	7.1	5.9	880	2.6	36	130	13	31	3.2
	11.4	7.7	6.0	860	1.5	40	150	16	32	3.7
	12.1	7.1	5.6	880	1.9	38	170	16	29	3.5
11	.2	7.6	7.6	980	2.0	39	110	14	34	3.5
	.8	8.7	8.0	910	2.4	46	150	17	47	4.5
	2.0	7.6	8.3	990	2.3	41	120	15	36	3.7
	3.2	6.9	5.5	930	2.4	33	170	16	28	3.3
	4.3	7.4	7.8	930	2.3	38	130	16	31	3.3
	5.3	8.5	5.9	740	2.7	43	200	21	49	4.9
	5.6	7.7	7.9	890	2.7	42	170	18	38	4.0
	5.9	7.2	8.2	840	2.8	40	170	18	37	3.7
	6.2	6.9	7.8	990	2.1	36	160	16	30	3.2
	6.6	6.6	6.8	1,100	1.9	32	160	15	25	2.9
	6.9	6.9	7.5	98	4.0	36	130	15	31	3.3
	7.8	7.9	8.7	550	3.1	43	180	19	44	4.3
	8.7	8.6	8.2	700	2.4	44	210	22	47	4.9
	9.6	7.4	9.5	180	3.5	39	150	17	38	3.8
	10.5	7.5	6.4	850	2.1	37	140	14	30	3.5
	11.4	7.7	5.1	820	1.8	39	140	15	31	3.6
	11.7	7.4	5.5	860	1.9	41	150	16	32	3.5
12	.2	7.5	8.0	980	2.0	40	130	14	34	3.5
	.8	7.9	7.6	850	2.4	41	120	15	58	3.9
	1.4	8.0	8.6	920	2.3	41	130	15	40	3.9
	2.0	7.1	6.2	1,000	1.9	37	110	14	31	3.4
	2.3	7.0	8.1	1,100	2.3	37	120	15	29	3.2
	3.5	6.6	7.3	890	2.9	34	210	22	31	3.3
	5.3	8.1	8.7	770	2.6	44	190	21	42	4.5
	6.2	7.9	6.2	670	2.6	41	170	18	42	4.2
	7.2	7.4	8.5	660	2.7	39	160	18	37	3.8
	8.2	8.0	8.4	710	2.5	44	180	20	43	4.5
	9.0	6.2	4.7	1,100	1.3	32	110	12	20	2.3
M5	.2	6.3	7.0	1,100	1.6	37	100	12	21	2.6
	.7	7.7	8.6	900	2.2	42	130	15	37	3.7
	1.0	8.8	8.8	790	2.4	49	160	17	48	4.7
	1.5	8.4	8.3	770	2.5	45	150	17	42	4.4
	2.0	7.7	8.8	840	1.9	42	150	16	38	3.9
	2.2	8.9	8.6	800	2.6	51	170	20	51	4.9

Table 5. Chemical analysis of drilling-core samples--*Continued*

Cluster site	Sample depth (m)	Lanthanum (µg/g)	Lead (µg/g)	Lithium (µg/g)	Magnesium (percent)	Manganese (µg/g)	Molybdenum (µg/g)	Neodymium (µg/g)	Nickel (µg/g)	Phosphorus (µg/g)
7	0.2	25	17	55	1.3	510	<2	19	74	0.07
	.8	28	18	75	1.7	680	2	23	97	.07
	2.0	22	17	55	1.5	580	<2	19	95	.06
	3.2	26	12	71	2.2	700	2	22	130	.08
	3.8	23	14	54	2.2	650	<2	19	150	.07
	4.7	17	12	23	1.5	480	<2	14	130	.05
	5.2	26	20	76	2.5	610	<2	22	150	.07
	5.6	21	17	57	2.1	610	<2	19	150	.07
	5.9	16	17	27	1.8	430	<2	14	150	.05
	6.9	18	16	38	1.9	530	<2	14	140	.05
	7.2	26	17	76	2.3	630	<2	23	120	.07
	8.4	25	18	77	2.6	660	<2	23	150	.08
	10.5	21	15	51	1.7	500	<2	16	97	.06
	11.4	22	16	57	1.8	580	<2	19	110	.06
	12.1	21	16	46	1.9	600	<2	18	130	.07
11	.2	22	17	59	1.3	520	<2	18	77	.06
	.8	26	21	79	1.7	600	<2	23	92	.07
	2.0	23	20	59	1.4	590	<2	20	84	.06
	3.2	19	16	48	2.1	560	<2	17	140	.07
	4.3	22	19	51	1.7	580	<2	18	120	.06
	5.3	25	18	76	2.5	660	<2	22	150	.08
	5.6	24	17	62	2.2	620	<2	19	140	.07
	5.9	21	18	55	2.3	610	<2	19	150	.06
	6.2	21	17	46	2.0	550	<2	18	140	.06
	6.6	19	17	39	2.0	500	<2	15	140	.05
	6.9	20	9	51	1.9	560	<2	19	110	.06
	7.8	24	16	71	2.4	630	<2	22	140	.06
	8.7	25	16	79	2.6	710	<2	23	170	.07
	9.6	22	12	63	2.0	580	<2	19	130	.06
	10.5	22	15	56	1.7	510	<2	20	98	.06
	11.4	22	16	56	1.7	550	<2	17	100	.06
	11.7	23	17	50	1.8	580	<2	19	120	.06
12	.2	22	19	59	1.4	510	<2	21	80	.06
	.8	23	16	68	1.4	550	<2	19	82	.06
	1.4	23	18	66	1.5	560	<2	20	88	.07
	2.0	20	15	51	1.4	570	<2	17	87	.06
	2.3	20	15	48	1.5	530	<2	16	100	.06
	3.5	18	14	46	3.0	590	<2	15	260	.06
	5.3	24	15	70	2.6	660	<2	21	160	.07
	6.2	23	14	66	2.4	610	<2	22	140	.07
	7.2	22	12	60	2.3	570	<2	20	140	.06
	8.2	24	14	73	2.4	610	<2	22	150	.07
	9.0	17	13	31	1.3	480	<2	15	88	.05
M5	.2	22	16	39	1.0	440	<2	16	61	.05
	.7	26	20	63	1.4	530	<2	19	75	.06
	1.0	30	17	82	1.7	590	<2	23	93	.07
	1.5	27	15	77	1.7	560	<2	20	95	.06
	2.0	25	14	64	1.6	560	<2	20	95	.06
	2.2	30	16	86	2.0	610	<2	23	110	.07

Table 5. Chemical analysis of drilling-core samples--*Continued*

Cluster site	Sample depth (m)	Potassium (percent)	Scandium (µg/g)	Total selenium (µg/g)	Soluble selenium (µg/g)	Residual selenium (µg/g)	Silver (µg/g)	Sodium (percent)	Strontium (µg/g)
7	0.2	1.9	11	0.8	0.02	0.78	<2	1.1	240
	.8	1.7	16	.9	.17	.73	<2	1.2	250
	2.0	1.9	12	1.2	.33	.87	<2	1.5	260
	3.2	1.8	16	.9	.26	.64	<2	1.2	280
	3.8	1.6	12	.7	.62	.08	<2	1.5	280
	4.7	2.0	6	.5	.46	.04	<2	1.6	260
	5.2	1.7	17	.7	.82	.00	<2	1.1	220
	5.6	1.9	13	.6	.46	.14	<2	1.3	250
	5.9	2.2	6	.9	.38	.52	<2	1.5	260
	6.9	2.0	8	1.1	.84	.26	<2	1.8	290
	7.2	1.8	15	1.4	1.17	.23	<2	1.3	410
	8.4	1.8	16	1.4	1.12	.28	<2	1.2	270
	10.5	2.0	11	.5	.19	.31	<2	1.4	280
	11.4	2.0	12	.7	.22	.48	<2	1.4	240
	12.1	2.0	10	.5	.12	.38	<2	1.5	260
11	.2	2.0	11	.9	.01	.89	<2	1.1	240
	.8	1.7	15	1.0	.20	.80	<2	1.2	250
	2.0	1.9	11	1.3	.45	.85	<2	1.7	280
	3.2	2.1	10	.5	.17	.33	<2	1.4	280
	4.3	1.9	10	.6	.36	.24	<2	1.8	300
	5.3	1.7	17	.6	.68	.00	<2	1.1	230
	5.6	1.8	13	1.0	.52	.48	<2	1.4	280
	5.9	1.7	12	1.2	.76	.44	<2	1.6	300
	6.2	2.0	10	1.0	.54	.46	<2	1.6	270
	6.6	2.1	8	1.3	.74	.56	<2	1.7	310
	6.9	1.7	10	1.7	.99	.71	<2	1.6	550
	7.8	1.6	15	1.7	1.09	.61	<2	1.4	270
	8.7	1.7	17	1.2	.53	.68	<2	1.2	240
	9.6	1.6	12	.9	--	--	<2	1.5	420
	10.5	2.0	11	.6	.26	.34	<2	1.4	260
	11.4	2.0	12	.6	.16	.44	<2	1.4	260
	11.7	2.1	12	.5	.14	.36	<2	1.4	260
12	.2	2.0	11	1.0	.02	.98	<2	1.1	240
	.8	1.8	13	1.0	.19	.81	<2	1.3	240
	1.4	1.9	13	1.4	.46	.94	<2	1.4	250
	2.0	1.9	10	.9	.26	.64	<2	1.5	250
	2.3	2.0	10	.9	.40	.50	<2	1.6	260
	3.5	1.7	10	.6	.06	.54	<2	1.6	280
	5.3	1.7	15	1.0	.67	.33	<2	1.4	260
	6.2	1.8	14	.9	.62	.28	<2	1.4	270
	7.2	1.8	12	1.7	1.39	.31	<2	1.5	320
	8.2	1.7	16	1.0	.60	.40	<2	1.2	250
	9.0	2.3	7	.6	.38	.22	<2	1.7	270
M5	.2	2.2	9	.8	.01	.79	<2	1.3	230
	.7	2.0	13	1.1	.01	1.09	<2	1.2	240
	1.0	1.8	17	1.0	.09	.91	<2	1.1	230
	1.5	1.9	16	.9	.12	.78	<2	1.2	230
	2.0	2.0	14	.8	.09	.71	<2	1.2	230
	2.2	1.8	18	.8	.05	.75	<2	1.0	240

Table 5. Chemical analysis of drilling-core samples--*Continued*

Cluster site	Sample depth (m)	Thorium (µg/g)	Titanium (µg/g)	Tin (percent)	Vanadium (µg/g)	Yttrium (µg/g)	Zinc (µg/g)	Total carbon (percent)	Organic carbon (percent)	Carbonate (percent)
7	0.2	9	0.31	<20	110	14	99	1.05	0.80	0.25
	.8	13	.40	<20	150	16	130	.81	.42	.39
	2.0	10	.32	<20	110	14	94	.49	.20	.29
	3.2	11	.41	<20	140	17	120	.53	.17	.36
	3.8	8	.36	<20	110	16	91	.48	.14	.34
	4.7	5	.22	<20	54	11	44	.23	.04	.19
	5.2	12	.40	<20	150	17	120	.42	.13	.29
	5.6	9	.32	<20	110	14	89	.42	.14	.28
	5.9	6	.21	<20	57	10	46	.19	.01	.18
	6.9	7	.26	<20	75	13	62	.24	.08	.16
	7.2	12	.38	<20	130	17	110	.39	.13	.26
	8.4	12	.38	<20	140	16	120	.37	.13	.24
	10.5	9	.29	<20	98	13	79	.44	.10	.34
	11.4	10	.32	<20	110	14	93	.13	.06	.07
	12.1	9	.29	<20	93	14	82	.16	.02	.14
11	.2	10	.31	<20	110	14	96	.95	.69	.26
	.8	14	.38	<20	140	16	120	.71	.33	.38
	2.0	11	.33	<20	110	15	95	.52	.21	.31
	3.2	10	.28	<20	92	12	76	.40	.11	.29
	4.3	11	.32	<20	93	15	78	.42	.11	.31
	5.3	13	.39	<20	150	17	120	.48	.17	.31
	5.6	10	.36	<20	120	16	97	.50	.15	.35
	5.9	10	.33	<20	100	15	83	.52	.22	.30
	6.2	8	.29	<20	91	13	74	.33	.11	.22
	6.6	7	.26	<20	77	12	65	.24	.07	.17
	6.9	9	.32	<20	95	14	79	.27	.08	.19
	7.8	11	.38	<20	130	16	100	.48	.14	.34
	8.7	13	.39	<20	150	17	120	.41	.12	.29
	9.6	9	.34	<20	110	15	92	.46	.12	.34
	10.5	11	.30	<20	100	14	86	.28	.04	.24
	11.4	9	.32	<20	110	14	91	.14	.05	.09
	11.7	9	.31	<20	100	14	86	.10	.05	.05
12	.2	12	.31	<20	110	14	99	1.08	.82	.26
	.8	12	.34	<20	120	15	110	.72	.39	.33
	1.4	12	.34	<20	120	15	110	.56	.26	.30
	2.0	10	.29	<20	97	14	90	.36	.13	.23
	2.3	9	.30	<20	92	13	77	.47	.11	.36
	3.5	8	.28	<20	89	13	70	.57	.14	.43
	5.3	11	.38	<20	140	16	110	.43	.13	.30
	6.2	12	.36	<20	130	16	100	.32	.11	.21
	7.2	10	.33	<20	110	15	90	.39	.09	.30
	8.2	13	.37	<20	140	16	110	.43	.10	.33
	9.0	7	.21	<20	60	11	53	.12	.02	.10
M5	.2	8	.24	<10	76	12	74	.67	.47	.20
	.7	10	.33	<10	120	16	100	.79	.41	.38
	1.0	14	.40	<10	160	18	130	.77	.37	.40
	1.5	13	.37	<10	150	17	120	.65	.29	.36
	2.0	11	.32	<10	120	15	100	.46	.22	.24
	2.2	14	.40	<10	160	18	130	.69	.30	.39

Table 5. Chemical analysis of drilling-core samples--*Continued*

Cluster site	Sample depth (m)	Aluminum (percent)	Arsenic (µg/g)	Barium (µg/g)	Calcium (percent)	Cerium (µg/g)	Chromium (µg/g)	Cobalt (µg/g)	Copper (µg/g)	Iron (percent)
M5	2.5	6.2	7.7	960	3.7	35	130	15	25	2.7
	3.0	6.6	7.9	1,100	2.0	34	140	15	26	3.0
	3.7	7.8	8.6	850	2.7	44	170	18	39	4.2
	4.5	6.3	6.8	890	2.2	33	220	21	27	3.1
	5.1	7.1	8.2	870	3.0	42	170	18	32	3.6
	5.3	7.7	10.0	900	2.1	49	90	13	28	3.4
	5.5	5.1	5.8	160	3.6	26	130	11	15	2.0
	6.4	8.3	8.7	770	2.5	48	200	20	46	4.7
	7.5	7.1	7.8	260	3.8	43	160	18	33	3.7
	8.0	6.8	7.9	530	2.9	36	140	16	30	3.3
	8.4	8.5	8.7	700	2.8	47	200	22	47	4.9
	8.8	7.8	9.0	850	2.4	44	140	20	35	3.8
	9.3	8.5	9.8	750	2.5	45	190	21	42	4.5
	9.6	12.0	8.0	1,500	2.7	62	220	29	44	5.1
	10.0	6.4	8.3	1,100	2.0	32	110	14	21	2.5
	10.3	6.3	7.1	990	1.7	30	100	13	19	2.3
	10.6	7.1	9.0	910	2.8	38	120	17	29	3.3
	10.8	7.9	10.0	115	3.5	42	140	17	40	3.9
	11.4	6.5	7.60	980	1.9	32	130	14	23	2.8
	12.1	5.3	5.90	130	2.5	25	120	10	14	2.0
	12.9	5.0	6.60	880	1.6	25	190	12	14	2.0
	13.3	6.3	6.50	820	1.9	29	120	13	21	2.5
	13.5	5.2	3.90	770	2.2	24	84	8	11	1.5
	13.7	6.7	6.90	880	1.5	31	160	15	23	2.8
	14.1	6.7	8.50	740	3.3	36	150	15	25	3.0
	14.6	7.8	10.00	390	4.8	41	210	21	42	4.3
	15.2	7.7	9.20	790	3.6	42	160	19	34	3.9
	15.7	7.5	6.70	370	4.5	41	200	20	37	3.9
M10	.5	7.8	8.90	980	2.2	42	130	15	35	3.5
	1.0	5.9	8.60	1,500	1.8	35	100	10	20	2.5
	1.2	5.6	6.70	2,500	1.7	54	140	12	15	2.6
	2.0	8.2	8.50	910	2.1	47	130	16	37	3.9
	3.0	7.6	8.20	900	2.1	41	120	16	33	3.6
	3.4	7.6	10.00	1,000	4.0	41	150	18	36	3.6
	3.7	8.3	8.60	810	3.2	46	160	16	41	4.3
	4.1	7.8	7.70	950	2.8	43	170	18	35	3.7
	4.6	6.5	6.40	1,000	2.2	35	180	19	23	2.9
	5.1	6.8	6.80	1,100	1.9	38	130	16	23	2.7
	5.5	7.8	8.50	870	3.3	42	200	21	37	4.0
	5.9	8.6	8.30	750	2.9	45	220	22	46	4.6
	6.3	6.9	7.30	1,000	2.4	38	120	17	26	2.9
	6.7	7.9	8.40	950	2.9	44	170	19	39	4.0
	7.1	8.1	8.20	810	3.2	46	160	19	39	4.1
	7.5	7.2	6.20	810	2.5	41	130	17	28	3.2
	7.9	7.0	10.00	960	3.0	39	170	18	34	3.5
	8.2	7.0	8.70	850	2.7	41	160	17	32	3.5
	8.5	8.3	9.50	660	3.1	47	200	21	45	4.7
	9.2	5.9	6.40	1,000	2.0	34	120	13	20	2.5
	9.8	5.6	7.00	1,300	1.9	33	110	14	17	2.3
	10.1	6.6	8.30	980	2.2	37	140	16	27	3.1

Table 5. Chemical analysis of drilling-core samples--*Continued*

Cluster site	Sample depth (m)	Lanthanum (µg/g)	Lead (µg/g)	Lithium (µg/g)	Magnesium (percent)	Manganese (µg/g)	Molybdenum (µg/g)	Neodymium (µg/g)	Nickel (µg/g)	Phosphorus (µg/g)
M5	2.5	21	21	41	1.5	470	<2	13	100	0.06
	3.0	21	15	45	1.5	520	<2	16	110	.07
	3.7	26	17	65	1.9	610	<2	21	120	.07
	4.5	19	13	39	2.7	580	<2	15	240	.06
	5.1	24	14	54	2.0	590	<2	18	140	.06
	5.3	28	18	61	1.3	520	<2	21	64	.05
	5.5	16	11	24	1.4	380	<2	11	110	.05
	6.4	28	17	76	2.6	640	<2	23	150	.08
	7.5	25	14	56	2.1	610	<2	19	130	.07
	8.0	23	16	49	1.9	530	<2	16	110	.07
	8.4	28	17	83	2.7	710	<2	21	150	.07
	8.8	26	18	56	2.1	590	<2	21	130	.06
	9.3	27	17	69	2.6	630	<2	23	150	.07
	9.6	38	26	70	2.9	870	<2	30	180	.11
	10.0	20	14	30	1.5	460	<2	16	110	.05
	10.3	20	15	29	1.5	470	<2	14	110	.05
	10.6	24	18	48	1.9	550	<2	18	120	.06
	10.8	26	13	64	2.1	540	<2	20	120	.06
	11.4	20	14	36	1.6	430	<2	15	100	.06
	12.1	16	11	22	1.5	370	<2	11	110	.05
	12.9	18	14	20	1.8	360	<2	12	120	.06
	13.3	18	14	36	1.7	350	<2	12	120	.06
	13.5	17	12	16	1.1	250	<2	12	72	.05
	13.7	20	16	35	1.7	450	<2	15	130	.04
	14.1	22	14	42	1.8	520	<2	17	120	.06
	14.6	25	13	68	2.8	550	<2	22	170	.07
	15.2	25	15	57	2.3	590	<2	22	140	.07
	15.7	25	14	59	2.4	550	<2	21	160	.06
M10	.5	26	20	56	1.4	500	<2	19	79	.06
	1.0	22	15	32	.9	440	<2	17	56	.06
	1.2	32	15	23	.6	53	<2	25	47	.06
	2.0	28	18	61	1.5	560	<2	21	90	.07
	3.0	25	17	53	1.6	520	<2	19	95	.07
	3.4	25	16	54	1.9	570	<2	18	120	.08
	3.7	27	17	67	2.2	630	<2	22	130	.08
	4.1	27	18	54	2.0	580	<2	20	130	.07
	4.6	21	16	33	2.3	510	<2	17	200	.06
	5.1	22	15	34	1.7	520	<2	17	140	.05
	5.5	26	17	57	2.4	650	<2	20	170	.07
	5.9	27	18	69	2.6	640	<2	23	160	.08
	6.3	22	17	37	1.8	520	<2	18	130	.06
	6.7	27	16	58	2.0	640	<2	22	130	.07
	7.1	27	18	62	2.1	620	<2	22	120	.07
	7.5	25	15	44	1.8	630	<2	19	120	.07
	7.9	24	15	53	2.1	640	<2	18	140	.07
	8.2	24	13	52	1.9	620	<2	20	120	.06
	8.5	27	17	78	2.4	660	<2	21	140	.07
	9.2	21	13	33	1.3	440	<2	16	85	.05
	9.8	22	14	30	1.2	480	<2	13	90	.04
	10.1	22	15	45	1.6	470	<2	16	110	.06

Table 5. Chemical analysis of drilling-core samples--*Continued*

Cluster site	Sample depth (m)	Potassium (percent)	Scandium (µg/g)	Total selenium (µg/g)	Soluble selenium (µg/g)	Residual selenium (µg/g)	Silver (µg/g)	Sodium (percent)	Strontium (µg/g)
M5	2.5	2.0	10	0.7	0.01	0.69	<2	1.6	290
	3.0	2.1	11	.7	.01	.69	<2	1.5	250
	3.7	1.8	15	.7	.02	.68	<2	1.3	250
	4.5	1.9	10	.5	.03	.47	<2	1.7	260
	5.1	1.9	13	.7	.05	.65	<2	1.4	280
	5.3	2.3	12	.7	.08	.62	<2	1.7	280
	5.5	2.0	7	.7	.06	.63	<2	1.5	260
	6.4	1.8	18	.9	.40	.50	<2	1.4	240
	7.5	1.8	13	1.2	1.07	.13	<2	1.7	310
	8.0	1.9	12	.8	.46	.34	<2	1.8	290
	8.4	1.7	18	.8	.17	.63	<2	1.2	250
	8.8	1.9	14	.8	.24	.56	<2	1.7	320
	9.3	1.8	17	.8	.26	.54	<2	1.4	270
	9.6	3.9	18	.8	.19	.61	<2	2.9	460
	10.0	2.3	8	.7	.09	.61	<2	1.8	280
	10.3	2.3	8	.5	.06	.44	<2	1.7	260
	10.6	1.9	11	.7	.04	.66	<2	1.7	290
	10.8	1.8	14	.7	.04	.66	<2	1.4	360
	11.4	2.2	10	.7	.03	.67	<2	1.4	270
	12.1	2.3	7	.5	.02	.48	<2	1.4	290
	12.9	2.3	6	.5	.02	.48	<2	1.4	240
	13.3	2.3	6	.5	.03	.47	<2	1.4	240
	13.5	2.3	5	.4	.06	.34	<2	1.6	370
	13.7	2.2	10	.4	.03	.37	<2	1.6	260
	14.1	1.8	11	.6	.04	.56	<2	1.6	320
	14.6	1.6	17	.6	.06	.54	<2	1.2	560
	15.2	1.8	15	.7	.12	.58	<2	1.5	610
	15.7	1.6	15	.5	.09	.41	<2	1.4	460
M10	.5	2.2	16	.9	.02	.88	<2	1.2	240
	1.0	2.2	8	.6	.01	.59	<2	1.3	230
	1.2	2.2	8	.6	.00	.60	<2	1.5	260
	2.0	2.0	14	.8	.01	.79	<2	1.2	240
	3.0	2.1	13	.8	.01	.79	<2	1.2	240
	3.4	2.0	13	1.0	.02	.98	<2	1.3	290
	3.7	1.8	16	.9	.18	.72	<2	1.1	260
	4.1	2.0	14	.7	.01	.69	<2	1.4	280
	4.6	2.2	9	.5	.01	.49	<2	1.7	260
	5.1	2.2	9	.5	.03	.47	<2	1.8	270
	5.5	1.8	14	.6	.04	.56	<2	1.6	290
	5.9	1.9	17	.7	.04	.66	<2	1.2	270
	6.3	2.0	10	.6	.05	.55	<2	1.8	310
	6.7	1.8	14	.7	.09	.61	<2	1.6	350
	7.1	1.8	15	.6	--	--	<2	1.5	320
	7.5	2.2	12	.5	--	--	<2	1.6	280
	7.9	1.9	12	.7	.05	.65	<2	1.7	300
	8.2	1.8	13	.6	.10	.50	<2	1.7	280
	8.5	1.8	18	.7	.07	.63	<2	1.1	260
	9.2	2.2	9	.4	.06	.34	<2	1.6	250
	9.8	2.2	8	.5	.05	.45	<2	1.5	250
	10.1	1.9	11	.6	.09	.51	<2	1.6	250

Table 5. Chemical analysis of drilling-core samples--*Continued*

Cluster site	Sample depth (m)	Thorium (µg/g)	Titanium (µg/g)	Tin (percent)	Vanadium (µg/g)	Yttrium (µg/g)	Zinc (µg/g)	Total carbon (percent)	Organic carbon (percent)	Carbonate (percent)
M5	2.5	6	0.25	<10	79	13	68	0.87	0.10	0.77
	3.0	8	.28	<10	87	14	76	.42	.12	.30
	3.7	11	.37	<10	130	18	110	.52	.15	.37
	4.5	7	.26	<10	81	13	64	.43	.09	.34
	5.1	10	.34	<10	100	16	88	.52	.14	.38
	5.3	12	.33	<10	100	16	95	.26	.10	.16
	5.5	6	.20	<10	52	10	42	.26	.05	.21
	6.4	12	.39	<10	150	18	120	.44	.15	.29
	7.5	10	.34	<10	110	16	90	.37	.10	.27
	8.0	9	.30	<10	94	15	78	.34	.08	.26
	8.4	13	.40	<10	160	18	120	.43	.15	.28
	8.8	10	.34	<10	110	16	97	.35	.11	.24
	9.3	12	.38	<10	140	17	110	.44	.15	.29
	9.6	14	.47	<10	140	23	120	.21	.06	.15
	10.0	7	.24	<10	66	12	56	.28	.04	.28
	10.3	6	.22	<10	61	11	54	.22	.04	.18
	10.6	9	.31	<10	91	15	82	.34	.10	.24
	10.8	10	.35	<10	120	16	100	.40	.13	.27
	11.4	8	.25	<10	79	12	68	.20	.04	.16
	12.1	4	.18	<10	49	9	42	.19	.02	.17
	12.9	6	.15	<10	47	9	42	.08	.01	.09
	13.3	7	.23	<10	71	11	60	.07	.01	.06
	13.5	5	.16	<10	36	9	34	.01	.01	.02
	13.7	6	.25	<10	75	12	63	.01	.01	.01
	14.1	8	.28	<10	86	14	72	.36	.07	.29
	14.6	11	.36	<10	130	16	110	.56	.10	.46
	15.2	11	.35	<10	110	16	96	.51	.15	.36
	15.7	11	.34	<10	110	16	98	.49	.09	.40
M10	.5	11	.31	<10	110	15	99	.62	.30	.32
	1.0	8	.24	<10	66	12	60	.39	.15	.24
	1.2	12	.43	<10	65	16	53	.22	.04	.18
	2.0	12	.35	<10	120	16	110	.58	.26	.32
	3.0	10	.32	<10	110	15	95	.47	.19	.28
	3.4	10	.34	<10	110	16	93	.82	.18	.64
	3.7	12	.39	<10	130	18	110	.62	.27	.35
	4.1	10	.36	<10	110	17	96	.50	.15	.35
	4.6	8	.25	<10	74	13	63	.35	.09	.26
	5.1	8	.27	<10	73	14	63	.33	.10	.23
	5.5	10	.37	<10	140	17	120	.67	.20	.47
	5.9	12	.38	<10	140	17	120	.59	.23	.36
	6.3	8	.28	<10	79	14	69	.40	.12	.28
	6.7	12	.38	<10	110	17	100	.58	.21	.37
	7.1	12	.39	<10	120	18	110	.57	.24	.33
	7.5	10	.30	<10	86	15	76	.33	.11	.22
	7.9	10	.33	<10	100	16	83	.60	.17	.43
	8.2	10	.35	<10	100	16	85	.50	.14	.36
	8.5	13	.39	<10	150	18	120	.57	.18	.39
	9.2	9	.24	<10	65	12	55	.33	.04	.29
	9.8	6	.22	<10	60	12	52	.34	.01	.33
	10.1	8	.29	<10	87	14	73	.45	.11	.34

Table 5. Chemical analysis of drilling-core samples--*Continued*

Cluster site	Sample depth (m)	Aluminum (percent)	Arsenic (µg/g)	Barium (µg/g)	Calcium (percent)	Cerium (µg/g)	Chromium (µg/g)	Cobalt (µg/g)	Copper (µg/g)	Iron (percent)
M10	10.3	5.8	7.50	1,200	1.9	34	130	13	20	2.6
	10.7	5.4	7.10	1,200	1.6	31	130	12	16	2.2
	11.5	4.9	5.70	1,100	1.6	28	150	11	13	2.0
	12.4	4.2	6.70	1,200	2.4	21	310	17	14	2.5
	13.2	6.9	7.90	900	2.3	41	130	14	27	3.2
	13.5	6.9	8.80	980	2.1	39	150	16	30	3.4
	13.8	6.0	6.20	1,100	1.9	32	130	12	17	2.4
	14.0	7.1	7.60	410	2.3	41	79	11	21	2.9
	14.5	7.3	8.70	900	3.0	42	180	19	36	3.8
	15.1	6.8	9.40	1,000	2.5	39	170	17	27	3.3
	15.5	6.1	7.50	900	2.6	32	200	16	21	2.7
NW1	1.8	6.6	7.4	1,000	2.7	32	150	14	25	3.0
	3.7	7.2	8.6	930	2.1	40	160	16	31	3.5
NW4	1.8	7.6	8.5	880	2.1	42	160	15	35	3.8
	3.7	7.0	9.4	960	2.5	40	180	16	30	3.5
NW7	1.8	7.8	8.5	830	2.2	43	190	16	37	4.0
	3.7	7.4	8.9	990	2.6	42	180	17	33	3.7
NW10	1.8	8.0	9.4	810	2.4	44	180	16	40	4.2
	3.7	6.3	6.9	1,000	2.0	33	200	16	23	3.0
NW13	1.8	7.1	6.4	910	2.1	39	160	14	30	3.4
	3.7	6.4	7.1	1,000	2.3	34	170	15	24	2.9
SE1	.9	7.1	8.5	960	2.6	40	150	14	30	3.4
	1.5	7.0	8.1	910	2.0	36	150	14	25	3.2
SE4	.9	7.1	8.0	1,000	2.3	39	140	14	30	3.4
	1.5	6.8	8.4	920	2.3	35	190	17	29	3.3
SE7	.9	7.2	7.9	930	2.0	39	140	14	31	3.4
	1.5	7.6	8.7	860	2.6	41	180	16	35	4.0
SE10	.9	7.4	8.4	940	2.4	39	140	14	33	3.5
	1.5	7.6	8.2	860	2.9	43	180	17	37	4.0
SE13	.9	6.6	7.6	1,200	2.1	37	120	11	24	2.8
	1.5	6.9	8.1	960	2.4	34	160	15	28	3.2
EW2	1.2	6.9	8.0	940	4.1	38	160	16	31	3.5
	1.5	6.3	7.0	1,000	2.2	33	180	13	22	2.8
EW3	1.2	7.2	8.9	850	3.0	42	180	16	33	3.7
	1.5	6.6	7.5	980	2.3	39	200	17	26	3.2

Table 5. Chemical analysis of drilling-core samples--*Continued*

Cluster site	Sample depth (m)	Lanthanum (µg/g)	Lead (µg/g)	Lithium (µg/g)	Magnesium (percent)	Manganese (µg/g)	Molybdenum (µg/g)	Neodymium (µg/g)	Nickel (µg/g)	Phosphorus (µg/g)
M10	10.3	20	13	31	1.2	470	<2	15	98	0.05
	10.7	18	14	24	1.1	440	<2	13	86	.04
	11.5	17	12	21	1.2	400	<2	13	98	.04
	12.4	15	11	19	2.4	490	<2	13	230	.08
	13.2	25	16	51	1.6	490	<2	20	94	.08
	13.5	23	16	48	1.7	570	<2	18	110	.07
	13.8	20	13	30	1.3	480	<2	14	99	.06
	14.0	25	16	53	1.1	430	<2	20	47	.05
	14.5	24	15	58	2.1	560	<2	17	140	.07
	15.1	24	15	45	1.9	570	<2	18	130	.07
	15.5	20	12	35	1.9	470	<2	15	150	.06
NW1	1.8	18	19	43	1.5	470	<2	16	110	.05
	3.7	20	18	51	1.8	610	<2	18	110	.06
NW4	1.8	22	21	61	1.5	550	<2	19	87	.06
	3.7	21	17	50	1.8	570	<2	21	110	.07
NW7	1.8	23	20	65	1.7	630	<2	18	110	.06
	3.7	22	19	56	1.8	600	<2	20	110	.07
NW10	1.8	23	20	70	1.7	570	<2	20	99	.06
	3.7	17	18	38	1.9	590	<2	15	160	.07
NW13	1.8	21	19	51	1.6	500	<2	17	93	.06
	3.7	17	17	40	1.8	500	<2	15	130	.06
SE1	.9	21	19	52	1.5	540	<2	18	91	.06
	1.5	19	18	46	1.7	530	<2	18	100	.06
SE4	.9	20	19	52	1.3	550	<2	17	81	.06
	1.5	19	18	45	2.0	600	2	16	150	.06
SE7	.9	21	20	52	1.4	520	<2	17	83	.06
	1.5	22	18	62	1.8	560	<2	20	110	.07
SE10	.9	21	21	55	1.4	540	<2	18	83	.06
	1.5	22	20	63	1.9	600	<2	21	110	.07
SE13	.9	19	17	40	1.0	470	<2	15	65	.06
	1.5	19	17	48	1.6	550	<2	18	100	.06
EW2	1.2	20	18	54	1.8	550	<2	19	110	.06
	1.5	17	18	39	1.6	470	<2	13	110	.05
EW3	1.2	22	19	57	1.7	590	<2	21	110	.07
	1.5	20	17	43	2.0	530	<2	19	150	.07

Table 5. Chemical analysis of drilling-core samples--*Continued*

Cluster site	Sample depth (m)	Potassium (percent)	Scandium (µg/g)	Total selenium (µg/g)	Soluble selenium (µg/g)	Residual selenium (µg/g)	Silver (µg/g)	Sodium (percent)	Strontium (µg/g)
M10	10.3	2.0	9	0.6	0.11	0.49	<2	1.7	240
	10.7	2.2	7	.5	--	--	<2	1.6	240
	11.5	2.2	6	.4	.07	.33	<2	1.4	210
	12.4	1.8	7	.6	.26	.34	<2	1.3	230
	13.2	2.1	11	1.0	.48	.52	<2	1.6	270
	13.5	1.9	12	1.0	.49	.51	<2	1.7	260
	13.8	2.2	8	.9	.55	.35	<2	1.8	270
	14.0	2.2	11	.8	.47	.33	<2	1.7	280
	14.5	1.8	14	1.0	.54	.46	<2	1.4	270
	15.1	1.8	11	1.0	.55	.45	<2	1.8	280
	15.5	1.9	10	1.9	.64	1.26	<2	1.8	290
NW1	1.8	1.9	9	.8	.03	.77	<2	1.6	250
	3.7	1.9	11	.9	.02	.88	<2	1.7	260
NW4	1.8	1.9	12	1.5	.28	1.22	<2	1.5	240
	3.7	1.8	11	.8	.12	.68	<2	1.7	260
NW7	1.8	1.8	14	.9	.02	.88	<2	1.2	230
	3.7	1.8	12	.7	.00	.70	<2	1.5	260
NW10	1.8	1.7	14	1.0	.02	.98	<2	1.1	240
	3.7	2.0	9	.6	.05	.55	<2	1.5	250
NW13	1.8	2.0	11	.8	.02	.78	<2	1.3	240
	3.7	2.0	9	.7	.02	.68	<2	1.5	260
SE1	.9	1.9	11	1.1	.07	1.03	<2	1.7	260
	1.5	1.9	10	.8	.10	.70	<2	1.8	270
SE4	.9	1.9	10	1.4	.26	1.14	<2	1.7	260
	1.5	1.7	10	1.1	.35	.75	<2	1.8	280
SE7	.9	2.0	11	1.7	.67	1.03	<2	1.8	240
	1.5	1.8	13	2.0	.52	1.48	<2	1.7	250
SE10	.9	1.9	11	1.5	.25	1.25	<2	1.6	260
	1.5	1.8	13	2.0	.87	1.13	<2	1.5	290
SE13	.9	2.0	8	.9	.02	.88	<2	1.5	250
	1.5	1.8	10	1.3	.38	.92	<2	1.5	260
EW2	1.2	1.7	11	1.5	--	--	<2	1.4	280
	1.5	2.1	8	1.5	.26	1.24	<2	1.6	250
EW3	1.2	1.7	12	1.1	--	--	<2	1.5	260
	1.5	1.8	10	.8	.16	.64	<2	1.7	270

Table 5. Chemical analysis of drilling-core samples--*Continued*

Cluster site	Sample depth (m)	Thorium (µg/g)	Titanium (µg/g)	Tin (percent)	Vanadium (µg/g)	Yttrium (µg/g)	Zinc (µg/g)	Total carbon (percent)	Organic carbon (percent)	Carbonate (percent)
M10	10.3	6	0.24	<10	66	12	57	0.34	0.03	0.31
	10.7	5	.22	<10	54	11	47	.25	.02	.23
	11.5	7	.19	<10	48	10	38	.26	.05	.21
	12.4	7	.17	<10	51	11	38	.46	.01	.46
	13.2	9	.30	<10	92	19	83	.29	.05	.24
	13.5	10	.32	<10	96	16	84	.39	.09	.30
	13.8	7	.23	<10	62	12	55	.25	.02	.23
	14.0	12	.30	<10	87	15	78	.19	.04	.15
	14.5	9	.34	<10	110	16	93	.56	.08	.48
	15.1	9	.33	<10	93	16	76	.46	.06	.40
	15.5	8	.26	<10	74	13	58	.39	.07	.32
NW1	1.8	8	.26	<20	86	12	73	.63	.16	.47
	3.7	9	.31	<20	100	15	88	.46	.14	.32
NW4	1.8	11	.32	<20	120	15	100	.55	.26	.29
	3.7	9	.33	<20	100	15	86	.43	.09	.34
NW7	1.8	11	.33	<20	130	15	110	.50	.22	.28
	3.7	9	.35	<20	110	16	94	.48	.11	.37
NW10	1.8	11	.36	<20	140	16	110	.53	.23	.30
	3.7	7	.26	<20	81	12	67	.30	.06	.24
NW13	1.8	9	.29	<20	100	13	92	.39	.16	.23
	3.7	8	.26	<20	82	12	69	.42	.10	.32
SE1	.9	9	.31	<20	100	14	89	.48	.18	.30
	1.5	8	.30	<20	90	14	77	.35	.09	.26
SE4	.9	9	.31	<20	100	14	90	.46	.19	.27
	1.5	7	.30	<20	92	14	78	.48	.14	.34
SE7	.9	9	.30	<20	100	14	90	.43	.20	.23
	1.5	10	.35	<20	120	15	100	.54	.18	.36
SE10	.9	10	.31	<20	110	14	95	.46	.20	.26
	1.5	12	.35	<20	120	16	100	.59	.17	.42
SE13	.9	8	.28	<20	82	13	73	.41	.15	.26
	1.5	9	.29	<20	96	14	81	.49	.13	.36
EW2	1.2	8	.31	<20	100	14	86	.83	.16	.67
	1.5	8	.25	<20	78	12	68	.40	.11	.29
EW3	1.2	8	.35	<20	110	15	95	.52	.16	.36
	1.5	9	.31	<20	92	14	74	.43	.13	.30

Table 6. Selenium, dissolved solids, and stable isotope data for wells with multiple samples

[Cluster site: Site at which one to five observation wells were completed at different depths. Well depth: Depth, in meters below land surface, of each observation well completed at cluster site. --, no data; µg/L, microgram per liter; mg/L, milligram per liter]

Cluster site	Well depth	Date	Selenium, dissolved (µg/L)	Solids, sum of constituents, dissolved (mg/L)	² H/ ¹ H stable- isotope ratio (per mil)	¹⁸ O/ ¹⁶ O stable- isotope ratio (per mil)
EW1	4	2-04-86	1,000	--	-58.5	-6.85
		7-17-86	510	7,690	--	--
		7-30-86	390	8,420	--	--
EW4	4	7-17-86	2,200	18,000	--	--
		7-30-86	2,000	13,600	--	--
EW5	4	7-17-86	1,900	16,600	--	--
		7-30-86	1,800	15,700	--	--
EW6	4	7-17-86	19	5,400	--	--
		7-30-86	39	6,150	--	--
MBS	9	4-01-87	3,900	17,000	-56.0	-5.55
		9-01-88	4,600	19,100	-55.0	-5.00
M1	3	6-11-87	310	8,950	-67.5	-8.75
		7-20-88	27	8,210	-66.0	-8.65
	6	6-11-87	11	8,240	-63.0	-8.25
		7-20-88	25	8,390	-67.0	-8.25
M4	6	6-10-87	4,100	18,200	-56.5	-6.25
		7-22-88	3,100	19,600	-57.5	-6.40
	9	6-10-87	190	13,100	--	--
		7-20-88	970	15,700	-61.5	-7.35
	15	6-10-87	330	9,810	-61.0	-7.45
		7-20-88	340	10,700	-62.5	-7.55
M5	6	6-09-87	820	9,450	-59.5	-7.50
		7-21-88	500	8,220	-62.0	-7.50
	9	6-09-87	520	12,000	-63.0	-7.85
		7-21-88	240	13,100	-62.5	-7.70
	12	7-01-87	200	4,020	-61.5	-8.10
		7-21-88	170	6,420	-64.0	-8.10
	15	6-09-87	200	12,200	-61.0	-7.55
		7-21-88	110	9,400	-63.0	-8.05
NW10	3	1-31-86	370	13,700	-60.0	-7.15
		7-22-88	160	6,340	-66.5	-8.60
SE1	4	2-05-86	330	12,300	-56.0	-5.55
		5-23-86	320	12,800	--	--
		7-16-86	290	12,600	--	--
		7-29-86	370	12,400	--	--
SE4	4	2-05-86	1,300	10,400	-57.0	-5.85
		5-22-86	540	9,250	--	--
		7-15-86	1,000	9,960	--	--
		7-29-86	1,100	11,600	--	--

Table 6. Selenium, dissolved solids, and stable isotope data for wells with multiple samples--*Continued*

Cluster site	Well depth	Date	Selenium, dissolved (µg/L)	Solids, sum of constituents, dissolved (mg/L)	² H/ ¹ H stable- isotope ratio (per mil)	¹⁸ O/ ¹⁶ O stable- isotope ratio (per mil)
SE7	4	2-05-86	4,400	21,000	-56.5	-5.70
		5-21-86	3,900	21,200	--	--
		7-16-86	4,400	18,100	--	--
		7-29-86	4,100	20,500	--	--
SE10	4	2-05-86	3,000	14,200	-58.5	-6.15
		5-21-86	630	11,400	--	--
		7-31-86	620	10,700	--	--
		9-01-88	990	12,900	-61.5	-7.00
SE13	4	2-05-86	2,000	11,900	-62.5	-6.15
		5-21-86	2,600	11,800	--	--
1	3	7-30-86	1,100	11,400	--	--
		8-12-86	1,100	10,800	--	--
		8-30-88	480	9,390	-65.0	-7.70
	6	3-05-86	2,200	--	-54.0	-4.75
		8-30-88	1,200	14,600	-55.0	-5.20
2	3	5-23-86	430	14,900	--	--
		7-30-86	690	14,300	--	--
		9-01-88	970	12,500	-56.0	-5.80
	12	2-28-86	800	6,250	-58.0	-6.70
		9-01-88	700	6,170	-59.5	-6.85
3	3	7-31-86	280	7,840	--	--
		8-12-86	320	10,100	--	--
4	3	1-30-86	--	--	-62.5	-7.25
		5-22-86	860	11,400	--	--
		7-16-86	950	11,300	--	--
		7-29-86	960	10,300	--	--
		8-12-86	1,000	13,300	--	--
	6	2-06-86	3,000	14,600	-53.5	-6.50
		7-16-86	2,900	15,200	--	--
		7-29-86	2,400	13,100	--	--
	12	2-06-86	1,100	8,160	-58.0	-6.50
		7-16-86	860	7,620	--	--
		7-29-86	1,100	8,580	--	--
7	3	5-22-86	890	10,500	--	--
		7-15-86	1,100	10,500	--	--
		7-28-86	970	9,420	--	--
		8-12-86	960	10,500	--	--
		8-30-88	1,100	10,600	-59.5	-6.65
	6	3-06-86	2,500	12,900	-55.5	-5.15
		7-15-86	2,500	13,400	--	--
		7-29-86	2,300	11,900	--	--
		8-30-88	1,700	13,900	-55.5	-5.30

Table 6. Selenium, dissolved solids, and stable isotope data for wells with multiple samples--*Continued*

Cluster site	Well depth	Date	Selenium, dissolved (µg/L)	Solids, sum of constituents, dissolved (mg/L)	² H/ ¹ H stable- isotope ratio (per mil)	¹⁸ O/ ¹⁶ O stable- isotope ratio (per mil)
7	9	2-11-86	5,500	20,400	-53.0	-4.45
		7-15-86	4,400	19,700	--	--
		7-29-86	4,400	16,400	--	--
		8-30-88	4,000	18,800	-52.5	-4.70
	12	2-11-86	1,500	9,560	-58.5	-6.45
		7-15-86	1,200	9,210	--	--
		7-28-86	1,000	9,710	--	--
		8-30-88	1,900	12,100	-57.0	-5.85
9	3	7-15-86	910	10,600	--	--
		7-28-86	1,200	11,600	--	--
		8-13-86	1,500	10,700	--	--
	6	3-06-86	2,500	12,000	-54.5	-4.80
		7-16-86	2,400	12,700	--	--
		7-28-86	2,200	11,800	--	--
	9	2-11-86	5,600	19,000	-53.5	-4.50
		7-16-86	4,500	19,200	--	--
		7-28-86	4,300	18,700	--	--
	12	2-28-86	1,700	11,700	-58.5	-6.55
		7-15-86	1,500	12,400	--	--
		7-29-86	1,500	15,400	--	--
10	9	2-25-86	4,900	18,900	-55.5	-4.80
		2-26-86	5,200	18,600	--	--
12	3	7-16-86	980	15,700	--	--
		7-29-86	900	13,700	--	--
		8-13-86	1,000	15,700	--	--
	9	7-17-86	2,100	12,900	--	--
		7-31-86	2,400	16,300	--	--
13	6	3-06-86	2,400	14,900	-56.0	-5.45
		4-02-87	1,100	10,100	-60.0	-6.85
	12	2-27-86	790	7,830	-59.5	-6.95
		4-02-87	870	7,760	-60.0	-7.30
14	3	7-30-86	2,700	17,400	--	--
		8-14-86	2,900	18,600	--	--
	6	3-06-86	8,200	22,900	-54.0	-4.45
		4-02-87	6,000	24,900	-55.0	-4.65
	8	2-27-86	9,500	27,800	-51.0	-3.40
		4-02-87	7,300	26,900	-52.5	-4.05
15	6	3-06-86	4,200	16,700	-56.0	-5.70
		8-31-88	3,300	18,100	-57.5	-5.70
	12	2-27-86	990	6,910	-60.0	-6.85
		8-31-88	960	7,270	-61.0	-6.90

Table 7. Field measurements and chemical analysis of drainwater

[$\mu\text{S/cm}$, microsiemen per centimeter at 25 °C; °C, degree Celsius; mg/L, milligram per liter; TU, tritium unit. --, no data; <, actual value is less than value shown]

Date	Time	Specific conductance ($\mu\text{S/cm}$)	pH (standard units)	Temperature, water (°C)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Bicarbonate water (mg/L as HCO_3)	Sulfate, dissolved (mg/L)
<i>1986</i>										
May										
29	1100	7,400	--	25.0	500	170	1,200	3.2	--	3,500
June										
10	1210	7,730	7.35	19.5	430	170	1,400	3.7	294	3,700
Sept.										
26	1300	--	--	--	450	260	2,900	5.3	--	5,200
<i>1987</i>										
Mar.										
27	0900	9,770	7.30	16.0	580	190	1,400	2.7	252	3,400
Apr.										
16	1500	9,880	7.30	17.0	550	200	1,600	3.2	271	3,700
May										
07	0930	10,700	7.50	17.5	560	210	1,900	3.4	296	3,800
July										
31	0815	7,020	7.20	21.0	470	160	1,500	3.2	270	360
Oct.										
15	1130	8,840	7.16	--	470	180	1,600	4.0	--	1,400
20	1730	10,600	7.21	22.0	500	220	2,200	5.8	352	4,300
21	1530	11,300	7.16	22.0	340	230	2,100	5.6	--	4,300
22	1130	11,300	7.07	21.0	490	230	2,400	5.5	300	4,400
Nov.										
04	1500	12,100	7.30	21.5	390	230	2,200	5.6	324	5,000
05	1645	12,100	7.30	21.5	430	230	2,300	5.5	326	5,000
13	1130	12,900	7.20	20.5	380	250	2,300	5.7	332	4,900
24	1615	13,900	7.40	19.0	490	290	2,600	6.2	335	5,000
<i>1988</i>										
Jan.										
24	1345	13,000	7.30	17.5	510	270	2,500	4.7	283	4,000
Feb.										
03	0930	13,300	7.32	16.0	480	260	2,200	4.1	295	4,200
25	1545	10,500	7.10	16.5	490	210	1,800	4.0	270	4,200
Mar.										
25	1100	10,800	7.10	17.5	520	230	2,000	3.2	266	4,100
Apr.										
14	0830	10,400	6.70	--	--	--	--	--	270	--
27	1530	7,470	6.70	23.0	460	170	1,300	3.4	250	3,600
May										
11	1615	7,170	6.55	19.5	--	--	--	--	232	--
23	1500	7,170	7.09	22.5	430	160	1,200	3.3	243	3,500
June										
08	1200	6,840	6.80	23.0	--	--	--	--	240	--
Sept.										
20	1030	14,400	7.20	21.5	450	270	2,700	5.5	404	5,500
Oct.										
03	1400	12,100	7.31	22.5	--	--	--	--	344	--

Table 7. Field measurements and chemical analysis of drainwater--*Continued*

Date	Chloride, dissolved (mg/L)	Silica, dissolved (mg/L)	Solids, sum of consti- tuents, dissolved (mg/L)	Nitrogen, nitrate, dissolved (mg/L as N)	Nitrogen, nitrate plus nitrite, dissolved (mg/L as N)	Aluminum, dissolved (mg/L)	Boron, dissolved (mg/L)	Chromium, dissolved (mg/L)	Iron, dissolved (mg/L)	Lithium, dissolved (mg/L)
<i>1986</i>										
May										
29	580	52	6,020	--	--	<10	9,500	10	60	250
June										
10	--	51	--	--	--	20	9,900	10	90	--
Sept.										
26	2,000	55	10,900	--	--	<10	21,000	10	60	360
<i>1987</i>										
Mar.										
27	1,300	55	7,460	0.030	91.0	<10	9,700	5	60	240
Apr.										
16	1,400	54	8,060	.010	92.0	<10	11,000	5	60	250
May										
07	1,200	52	8,320	.250	100	10	14,000	7	50	360
July										
31	870	53	3,880	<.010	72.0	<10	11,000	7	40	230
Oct.										
15	960	7.9	4,630	--	--	<10	11,000	20	30	320
20	1,300	55	9,070	.040	67.0	10	17,000	20	50	360
21	1,200	54	8,550	.040	68.0	<10	16,000	20	40	370
22	1,400	54	9,440	.030	67.0	<10	17,000	20	50	360
Nov.										
04	1,500	52	9,940	.030	88.0	10	19,000	10	50	360
05	1,500	52	10,100	.030	88.0	10	19,000	10	50	360
13	1,800	54	10,300	.040	100	20	20,000	20	50	350
24	2,000	51	10,700	.020	24.0	10	21,000	10	9	320
<i>1988</i>										
Jan.										
24	2,200	52	9,780	.060	20.0	<10	17,000	10	4	260
Feb.										
03	2,200	50	10,200	.080	140	<10	17,000	10	50	320
25	760	--	8,010	.030	90.0	<10	13,000	10	60	280
Mar.										
25	1,300	50	8,830	<.010	110	<10	13,000	10	40	270
Apr.										
14	--	--	--	--	--	--	--	--	--	--
27	620	48	6,500	<.010	40.0	<10	9,100	10	30	250
May										
11	--	--	--	--	--	--	--	--	--	--
23	460	45	6,080	<.010	35.0	<10	8,700	10	30	230
June										
08	--	--	--	--	--	--	--	--	--	--
Sept.										
20	1,700	14	11,300	<.010	100	10	22,000	20	30	350
Oct.										
03	--	--	--	--	--	--	--	--	--	--

Table 7. Field measurements and chemical analysis of drainwater--*Continued*

Date	Manganese, dissolved (mg/L)	Molybdenum, dissolved (mg/L)	Nickel, dissolved (mg/L)	Selenium, dissolved (mg/L)	Vanadium, dissolved (mg/L)	Carbon, organic, dissolved (mg/L as C)	² H/ ¹ H stable isotope ratio (per mil)	¹⁸ O/ ¹⁶ O stable isotope ratio (per mil)	Tritium in water molecules (Tu)
<i>1986</i>									
May									
29	20	31	5	330	18	--	--	--	--
June									
10	20	30	5	310	20	--	--	--	--
Sept.									
26	20	27	--	1,400	<200	--	--	--	--
<i>1987</i>									
Mar.									
27	20	44		630	<60	6.1	-66.5	-8.30	--
Apr.									
16	20	39	3	860	<60	7.0	-66.0	-8.15	--
May									
07	10	34	4	820	34	8.2	-63.5	-7.90	--
July									
31	10	--	3	860	29	7.2	-66.9	-8.30	--
Oct.									
15	30	--	6	470	31	9.8	-65.5	-8.20	7.7
20	20	26	6	710	31	13	-63.5	-7.70	11.3
21	20	23	1	760	20	13	-63.0	-7.65	9.9
22	20	27	6	850	19	13	-62.5	-7.60	9.0
Nov.									
04	10	23	8	780	30	12	-63.5	-7.50	7.1
05	20	23	7	900	32	12	-63.0	-7.45	--
13	20	25	6	980	39	12	-62.5	-7.35	--
24	30	31	9	1,300	41	14	-62.0	-7.10	--
<i>1988</i>									
Jan.									
24	20	38	8	1,400	48	--	-64.5	-7.35	--
Feb.									
03	--	40	2	1,500	47	10	-65.4	-7.40	--
25	20	35	5	1,200	37	7.0	-65.5	-7.90	--
Mar.									
25	20	41	6	850	38	7.6	-65.9	-7.90	--
Apr.									
14	--	--	--	960	--	--	-63.5	-7.80	9.8
27	20	33	5	310	15	4.5	-67.5	-8.50	8.6
May									
11	--	--	--	190	--	--	-66.9	-8.60	--
23	10	29	5	190	17	4.7	-67.9	-8.70	7.3
June									
08	--	--	--	180	--	--	-68.0	-8.60	--
Sept.									
20	10	32	10	920	65	10	-60.5	-7.00	7.5
Oct.									
03	--	--	--	740	--	--	-62.5	-7.65	--