Compilation and Preliminary Interpretations of Hydrologic and Water-Quality Data from the Railroad Industrial Area, Fairbanks, Alaska, 1993-94

By Michael R. Lilly, Kathleen A. McCarthy, Anne T. Kriegler, James Vohden, *and* Gwendolyn E. Burno

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CONTENTS

PLATE

FIGURES

TABLE

CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

Multiply	By	To obtain
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
acre	4.047×10^3	square meter
square mile (mi^2)	2.590	square kilometers
acre-foot (acre-ft)	1.233	hectare-meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
gallon (gal)	3.785	liter
gallons per minute (gal/min)	0.06308	liters per second
feet per day (ft/d)	0.0305	meter per day
square feet per day (ft^2/d)	9.29×10^{-2}	square meter per day

Abbreviated Water-Quality Units:

Chemical concentrations and water temperature are given only in metric units.

µg/L, micrograms per liter
mg/kg, milligrams per kilogram

Vertical Datum:

In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929), a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada from 1966, formerly called Sea Level Datum of 1929. All elevations in this report are referenced to the U.S. Coast and Geodetic Survey benchmark BMXX12, elevation 441.272 feet.

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By Michael R. Lilly[1], Kathleen A. McCarthy[2], Anne T. Kriegler[1], James Vohden[3], *and* Gwendolyn E. Burno[4]

Abstract

Commercial and industrial activities in the Railroad Industrial Area in Fairbanks, Alaska, have resulted in accidental releases of chemicals to the subsurface. Such releases have generated concern regarding local ground-water quality and the potential impact on nearby water-supply wells. Consequently, a study is being conducted to characterize the environmental and hydrologic conditions in the area.

Existing reports from numerous previous investigations in the area were reviewed and relevant information from these documents was compiled. Both ground- and surface-water elevations were measured approximately monthly at as many as 50 sites during mass measurements. Selected sites were measured more frequently to assess short-term changes in the ground- and surface-water systems. Supplemental data were also collected outside of the study area to aid in interpretation. Ground water was sampled and analyzed to define the extent of the area affected by petroleum hydrocarbons and chlorinated solvents.

Data show that water levels in nearby rivers and sloughs have a considerable influence on ground-water flow in the study area. Seasonal and shorter term changes in river stage frequently alter and even reverse the direction of ground-water flow. The local ground-water system typically has an upward flow component, but this component is reversed in the upper part of the aquifer during periods of high water levels in the Chena River. These periodic changes in the magnitude and direction of ground-water flow have a considerable influence on the transport of dissolved hydrocarbons in the subsurface.

Both petroleum hydrocarbons and chlorinated solvents were found in ground water at the study area. Typical degradation products of these compounds were also found, indicating that biodegradation by indigenous microorganisms is occurring.

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INTRODUCTION

The study area is located in the Railroad Industrial Area in Fairbanks, Alaska (fig. 1). Development in the vicinity began in the early 1900's, and the area, which still serves as the main railhead for Fairbanks, has been the location of commercial and industrial activities since that time. Previous studies have indicated the presence of petroleum hydrocarbons and chlorinated solvents in ground water in the area, but the extent of the area affected by these compounds and the hydrologic factors affecting their migration have not been investigated. Because the Chena River and the main water-supply wells for Fairbanks are located nearby, migration of these compounds is of particular interest. In response to these issues, the Alaska Department of Environmental Conservation (ADEC) has defined a 280-acre environmental assessment area, which encompasses the area of greatest concern (plate 1). The study started in the spring of 1993 and continues through the present (winter 1995-96). In the fall of 1993, the study was concentrated on defining the extent of petroleum hydrocarbons. Subsequent sampling has focused on collecting data for interpreting ground-water flow and on monitoring the extent of petroleum hydrocarbons. The primary focus of this report is the collection and preliminary interpretation of the 1993 data to provide information for subsequent analyses on ground-water flow and solute transport within this area.

Purpose and Scope

The overall purpose of this ongoing investigation is to assess environmental conditions and characterize the geohydrology of the study area. The purpose of this preliminary report is to present (1) information on historical site activities that has been compiled as part of this study, (2) hydrologic and water-quality data that were collected from the beginning of this project in 1993 through early 1994, and (3) preliminary interpretations of these data.

To meet the study objectives, (1) existing environmental reports covering the area of interest were reviewed for water-quality and hydrologic data, (2) all existing monitoring wells in the study area were located, (3) water levels were measured in wells and nearby streams, and (4) ground water and surface water were analyzed for a variety of organic and inorganic constituents. To provide more complete coverage of ground-water data-collection sites, 33 temporary wells—installed using drive points—and 12 permanent wells were installed.

Measurements of water levels at ground- and surface-water sites were made in coordination with other U.S. Geological Survey (USGS) projects in the Fairbanks area (fig. 1). Most sites were measured approximately monthly and selected sites were measured more frequently to assess short-term changes in the ground- and surface-water systems. Surface-water discharge data were available from long-term stream-gaging stations maintained by the USGS on the Tanana and Chena Rivers. Discharge measurements were also made on Noyes Slough and at additional sites on the Chena River to help characterize ground- and surface-water interactions.

Ground water was sampled and analyzed to define the extent of the area affected by petroleum hydrocarbons and chlorinated solvents. Ground-water samples were also analyzed for the typical degradation products of target compounds to assess whether natural biodegradation is occurring. In addition, wells, rivers, and sloughs were sampled and analyzed for inorganic constituents to aid understanding of the flow system.

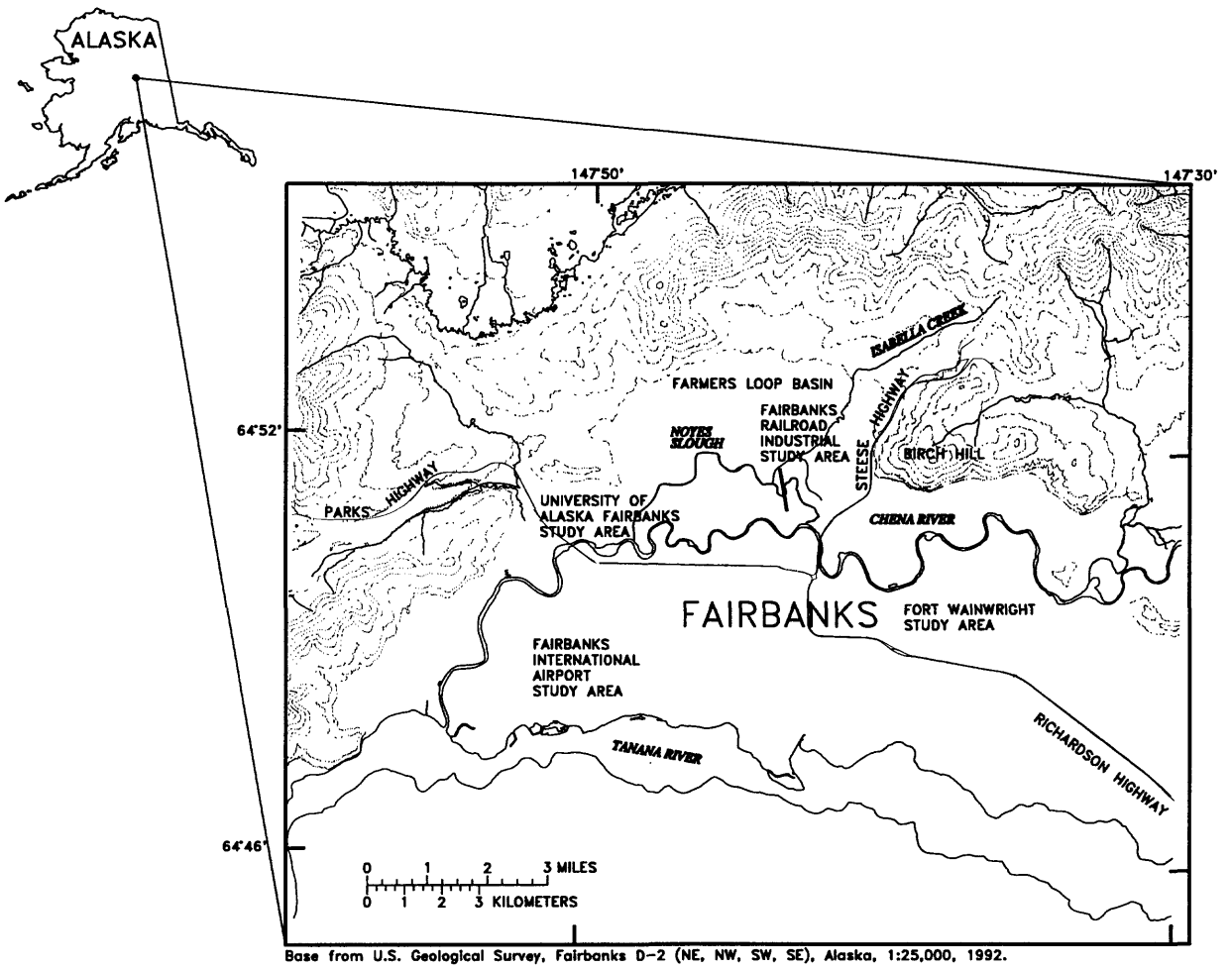


Figure 1. Location of Fairbanks, Alaska, and the Railroad Industrial Area study area.

The USGS has coordinated this project with other ongoing USGS projects in the Fairbanks vicinity so that hydrologic information collected throughout the area can be used to benefit all projects. The data from all projects contribute to a "numerical subregional ground-water model" that simulates ground-water conditions in the part of the Fairbanks region from the mouth of the Chena River to the Fort Wainwright study area. The other projects that have contributed to the data collection and subregional modeling include the University of Alaska Fairbanks (UAF), the Fairbanks International Airport (FIA), and Fort Wainwright, Alaska (FTWW). Each of these projects was initiated to characterize the geohydrology for a specific area within the Fairbanks alluvial plain. The first of these projects (FIA) was started in the winter of 1991 and continues to the present. In addition, the areal extent of a numerical subregional ground-water flow model being developed for other USGS projects throughout the Fairbanks vicinity was expanded to include this project study area. Early modeling results were used to identify the boundary conditions and other hydrogeologic factors that affect ground-water flow in the study area and to guide the collection of water-quality samples.

Acknowledgments

This project is a cooperative effort between the Alaska Department of Natural Resources, Division of Mining and Water Management (DOMWM), the Alaska Railroad Corporation (ARRC), and the USGS. We are grateful to the Alaska Department of Transportation and Public Facilities (ADOT&PF) for the support they provided by coordinating their related projects in the study area with our work. We express appreciation to Scott Ray, formerly of the DOMWM, for his important part in the inception of this project; and to Daniel Hawkins, Richard Snyder, and Robert Buchmiller for their valuable advice on sampling design and data interpretation. We also thank the many local business people who provided access to their property and support for our work.

Previous Investigations

Many studies have been conducted in the vicinity of the study area. To assess the extent of existing information, 79 existing reports were collected from property owners and lessees in the study area and from files of the ADEC. These reports were reviewed and information pertinent to the current study was compiled. Environmental chemistry data were entered into a data base by DOMWM personnel (Maurer and others, 1994). The data base contains general information about each report and general characteristics of the site investigated, such as observed odors or sheens on water surfaces, quality-control data, and the number of wells, borings, and soil samples that were used in the site investigation. The data base also contains data on ground water, subsurface soil, surface soil, and contaminated soil that has been excavated and removed from the site. The information in this data base represents data collected over a period of many years and does not indicate current conditions within the study area. An inventory of previously published reports and a map showing the area addressed in each report are included in Appendix A.

GEOHYDROLOGIC SETTING

The study area is located in Fairbanks, Alaska, between the Chena River and Noyes Slough, with a portion extending south of the Chena River in the vicinity of the City of Fairbanks, Municipal Utilities System (MUS) complex (plate 1). Artificial control structures have moved the mouth of the river to its current location, southwest of the Fairbanks International Airport. Before this change, the Chena River terminated in the alluvial plain above the Moose Creek Dam. The reach of the Chena River through Fairbanks is an old slough of the Tanana River that was abandoned as the Tanana River migrated southward to its current position.

Geology

The hills to the north of the study area are part of the metamorphic system that forms the Yukon-Tanana Upland (Péwé and others, 1976). Fairbanks is located in the northern part of the Tanana basin (Anderson, 1970). The boundary between the uplands and the Tanana River's alluvial valley trends northwest to the east of Fairbanks and southwest to the west of Fairbanks. The basin uplands consist of fractured schist. North-facing slopes are underlain by areas of discontinuous permafrost. Eolian silts of the Fairbanks Loess and reworked silt deposits cover the flanks of the bedrock uplands in the proximity of the Tanana River. These deposits vary in thickness and grade into alluvial-fan deposits and the Chena Alluvium (Péwé and others, 1976). The geometry of the

uplands and their relation to the study area are important in understanding the boundary conditions that govern ground-water flow within the study area. For example, outflow from the Farmers Loop basin (fig. 1), which lies directly north of the study area, has a considerable influence on the local hydrologic system. Except for Isabella Creek, which drains the eastern part of the basin, outflow from the Farmers Loop basin does not drain into well-defined surface-water channels. As a result, outflow from the basin is diffuse, but is nonetheless constrained to the valley between Birch Hill and the bedrock ridge at the University of Alaska Fairbanks. Because this valley directs flow toward the study area, an understanding of flow from the Farmers Loop basin is critical for accurate interpretation of the northern boundary of the study area.

The surface soils characteristic of the study area are derived from alluvial-plain deposits and generally cover the upper 5 to 15 ft of the alluvial plain. These soils are underlain by the Chena Alluvium (Péwé and others, 1976), which consists of braided Tanana River deposits of Quaternary age. Within the study area, the Chena Alluvium extends to depths of more than 400 ft, and the general stratigraphy consists of alternating layers and lenses of unconsolidated sandy gravels and gravelly sands, overlain by up to 15 ft of gray silt (Péwé and others, 1976). Well logs in the USGS Ground-Water Site Inventory (GWSI) data base indicate that in the vicinity of the study area there are no areally extensive confining units present within the Chena Alluvium.

Hydrology

This study focuses primarily on the subsurface flow system within the ADEC environmental-assessment area (plate 1). However, ground-water flow in this area is strongly influenced by local surface-water levels and is ultimately controlled by basin-wide ground- and surface-water processes. Knowledge of both ground- and surface-water hydrology throughout the greater Fairbanks area and the interaction between these two systems is therefore essential for a comprehensive understanding of ground-water flow and solute transport within the environmental-assessment area.

The Chena River is the dominant influence on ground-water flow in the study area. The annual discharge hydrograph for the Chena River is characterized by two peaks (fig. 2). The first is a result of spring snowmelt runoff, and the second peak is due to late-summer precipitation. The snowmelt peak is typically higher than the precipitation peak because the accumulated volume of winter snowfall is generally greater than that of summer rainfall, evapotranspiration rates are low in the spring, and soil, which is usually frozen in the spring but not in late summer, restricts infiltration of snowmelt. Noyes Slough is the controlling influence on ground-water flow in the northern part of the study area. The stage of Noyes Slough typically rises and falls in response to stage changes of the Chena River.

Although the Chena River and Noyes Slough dominate ground-water flow in the study area, the Tanana River, which is a braided river system, is the main influence on ground-water in the Fairbanks area (Nelson, 1978). In contrast to the Chena River, flow in the Tanana River is dominated by glacial runoff from the Alaska Range and typically increases in the middle of the summer when temperatures are high and cloud cover is thin (fig. 2). Both long-term average hydrologic conditions as well as short-term deviations from the average influence ground-water flow and solute transport. Information on such conditions is therefore critical for understanding the ground-water flow system in the study area.

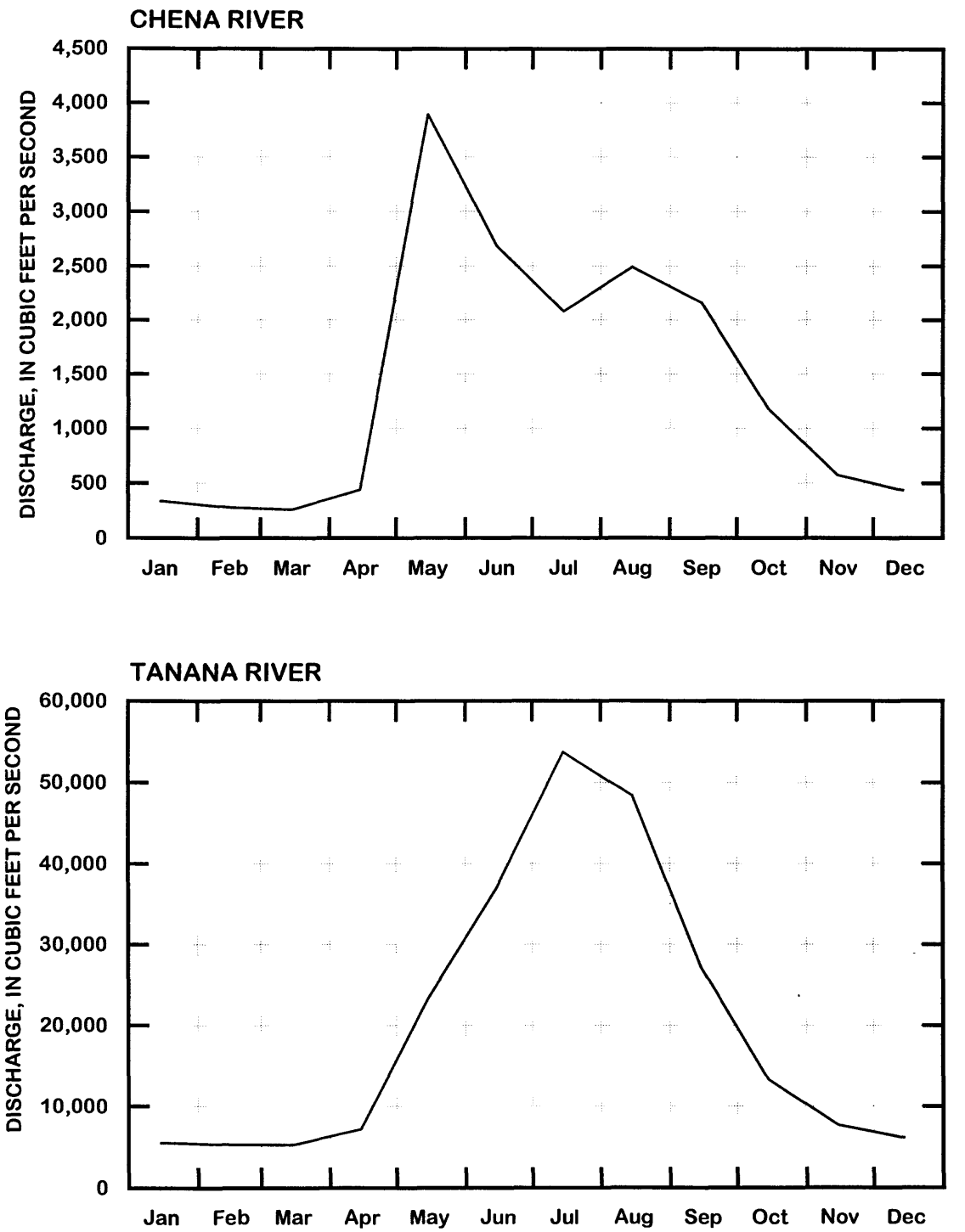


Figure 2. Mean monthly discharges of the Chena River for the period 1948-93 and the Tanana River for the period 1973-93.

LAND-USE DEVELOPMENT

The ADEC-defined environmental-assessment area consists of approximately 280 acres (plate 1). The boundaries of this area are Illinois Street to the east, the ARRC rail yards to the west, and the ARRC Eielson Branch line to the north. The southern boundary generally follows the Chena River, but a section of the study area extends south of the Chena River in the vicinity of the City of Fairbanks, MUS complex. The boundaries were established by ADEC to focus on potential environmental problems in the study area. The boundaries have no relation to hydrologic conditions in the study area.

Historical Land Use

From 1916 through 1923, the Alaska Railroad lines were extended from Seward to Fairbanks (Lazenby, 1990). At that time, the railroad right-of-way entered Fairbanks along the western edge of Illinois Street and rail sidings and spur lines were added to accommodate the railroad's customers. Businesses that depended on rail transportation for shipping tended to locate in this area, promoting industrial development.

Industrial activities in the Fairbanks Railroad Industrial Area have been considerable during the past 50 years. ARRC has the largest landholdings in the study area. Other past and present landowners include Sourdough Express, Golden Valley Electric Association (GVEA), U.S. Smelting, Refining and Mining Company, Alaska Chevron, and Kelly's Firestone.

Aerial photographs taken in 1948 and 1985 (fig. 3) show changes in the level of development in the study area over this time period. Initial development occurred along Illinois Street and continued in a westward direction along Well Street. The first fuel facility, Standard Oil Company, moved into the area in 1943 and remained on the property until 1966. Other petroleum facilities were constructed in the area beginning in 1953. The fuel businesses that have operated in the area are Chevron USA; Unocal; The Texas Company; Petroleum Sales; Standard Oil Company; Northern Gas and Oil Company, Inc.; Willner's Fuel Distributors, Inc.; Alaska Propane; and Suburban Propane and Petrolane. One bulk-fuel facility—Petroleum Sales (Chevron USA, Inc.)—remains in operation today; Willner's Fuel Distributors, Inc. ceased doing business in 1993.

Information obtained from ADEC on documented chemical releases that have occurred in the study area, along with associated soil and ground-water data, are provided in Appendix B.

Current Land Use

Current land use includes petroleum storage and industrial activities such as heavy equipment rental. A previous investigation (Fairbanks Metropolitan Area Transportation Study Technical Committee, 1985) identified a number of hazardous materials that are typically stored in the study area. These materials include motor oil, kerosene, liquid plastic urethane, no. 1 diesel, no. 2 diesel, hydrochloric acid, liquefied propane gas, and other petroleum hydrocarbons.

Bulk Petroleum Facilities

Existing bulk-petroleum distribution facilities are located primarily in the eastern part of the study area. The types of fuel stored in the area include aviation and automotive gasolines, heating

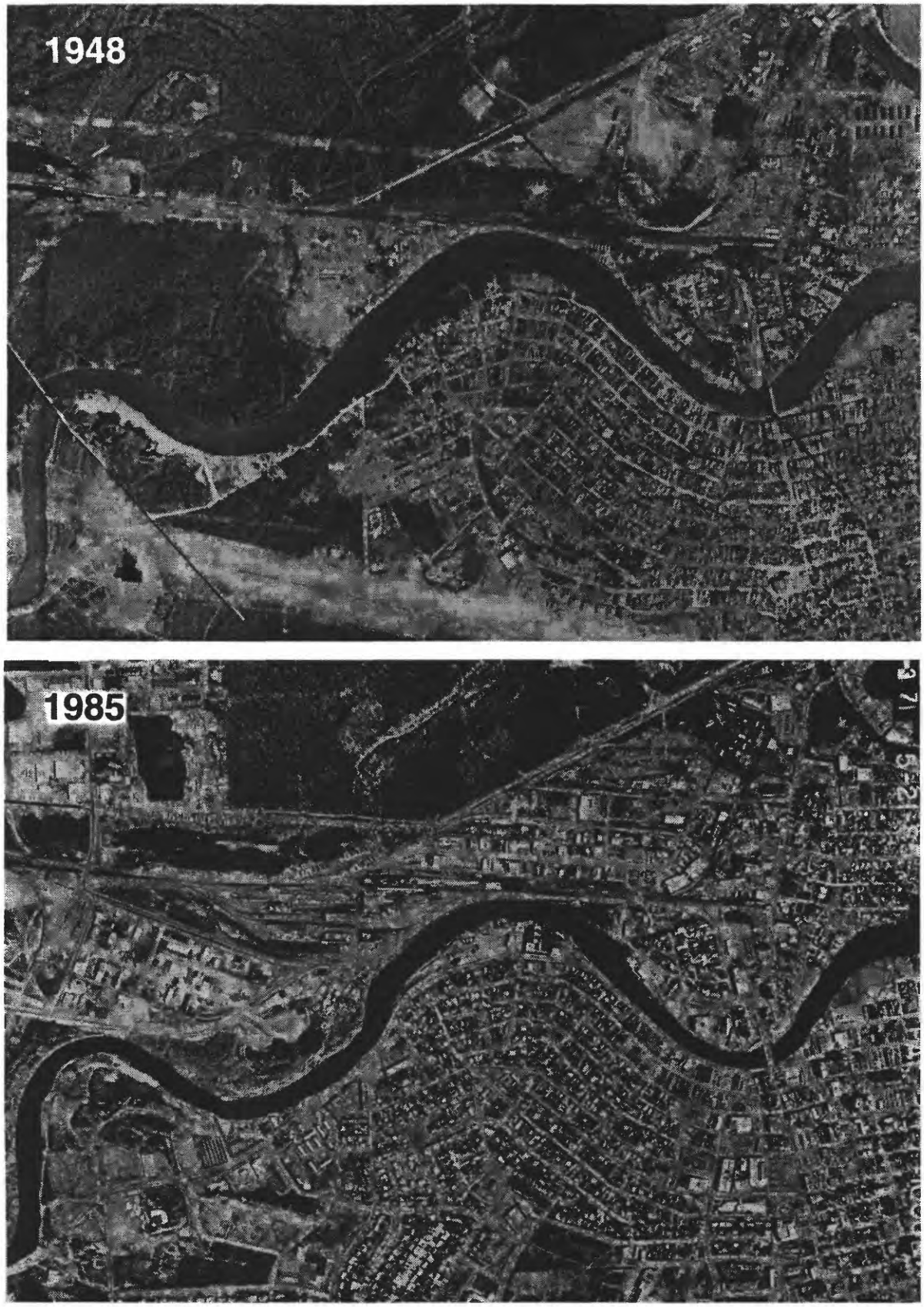


Figure 3. Aerial photographs showing development in the study area in 1948 and 1985.

fuel, and diesel fuel. The Fairbanks Metropolitan Area Transportation Study Technical Committee (1985) stated that during 1985 an average of 600,000 to 700,000 gallons of fuel were stored in the study area at any one time. In 1985, the actual capacity of storage facilities was approximately 1.4 million gallons. Site facilities have since changed, however, and in 1994, the average storage capacity was approximately 360,000 gallons.

Fuel is transported to the storage and distribution centers in the study area by ARRC rail cars and trucks. Surface-soil stains are visible along the rail sidings and can be identified in aerial photos taken as early as 1948. The off-loading procedures, which are generally handled by the fuel distributor, typically consist of connecting a hose to the tank car and pumping the fuel into storage tanks.

Small Storage Tanks and Hazardous Materials

In addition to the bulk-fuel facilities, local businesses in the area use smaller storage tanks for their individual fuel needs. Evidence of leakage has been discovered during the removal of some of these tanks. Most individual tanks, which range in size from approximately 250 to 1,000 gallons, are used to store heating fuel, the primary source of heat in the region. Some transportation businesses also maintain on-site fueling facilities for their trucks—typically gasoline or diesel. The average tank size at these facilities is approximately 1,000 gallons.

Shop-Waste Disposal Practices

The most common types of drain historically used in Fairbanks for the disposal of liquid shop waste or cleaning solvents are dry wells. A dry well is typically a gravel-filled culvert or box which is open at the bottom for drainage and connected to floor drains and sinks. Many of the facilities in the study area that were established before the installation of the current sewer system are still using dry wells to dispose of shop waste. Although a survey of specific shop-waste disposal practices was not conducted as part of this study, the use of dry wells and their potential impact on soil and ground water must be considered when interpreting distributions of dissolved solvent compounds in the ground-water system.

SOLUTE-TRANSPORT PROCESSES IN GROUND WATER

The following section provides a general discussion of selected processes that affect movement and changes in concentrations of solutes in ground water. These processes should be considered when interpreting chemical data collected from any area of suspected ground-water contamination.

The most basic ground-water solute-transport process is ***advection***—the macro-scale transport of dissolved constituents by the motion of the flowing ground water (at the average linear ground-water velocity) in which they are dissolved. The hydrologic data presented and discussed in following sections show that ground- and surface-water elevations change frequently within the study area. These changes indicate that both the magnitude and direction of ground-water flow in the study area change frequently, resulting in complex, transient patterns of advective transport.

Solutes may spread out from the original affected ground-water mass by ***hydrodynamic dispersion*** processes which are caused by mechanical mixing and molecular diffusion. Dispersion from mechanical mixing is caused by differences in flow rates and divergence in the flow field on both microscopic and macroscopic scales. Microscopic dispersion is related to ground-water velocity variations within intergranular voids in the aquifer material. Macroscopic dispersion is related to "field-scale" heterogeneities in the aquifer which result in variations of hydraulic conductivity and porosity of the aquifer material. ***Longitudinal dispersion*** is the term for spreading of solutes in the principal direction of ground-water flow. ***Transverse dispersion*** is the term for spreading perpendicular to the direction of ground-water flow—both horizontally and vertically.

All molecules are in continuous random motion due to thermal agitation, which results in the process known as ***molecular diffusion***. In ground water, the net effect of molecular diffusion is the movement of solutes from areas of higher concentration to areas of lower concentration. Diffusion occurs in all directions and results in three-dimensional spreading of solutes. Although solute transport due to molecular diffusion is typically negligible relative to advective and dispersive transport, molecular diffusion can be a significant—and sometimes dominant—component of vertical transport in areas where ground-water flow velocities are low. Dispersive spreading results in progressive dilution of the solute as it moves through the subsurface. Although this dilution process increases the volume of aquifer affected, the total mass of solute remains the same in the absence of chemical and biological transformations.

The reduction of solute transport in ground water is affected by another group of processes. Most organic compounds have a relatively low affinity for water and tend to adsorb onto the mineral surfaces of aquifer material or partition into naturally occurring organic matter. These and other similar processes, known collectively as ***sorption*** processes, tend to immobilize solutes in ground water and retard their movement. Individual compounds have unique sorptive characteristics, which result in different rates of migration for different compounds. This phenomenon is particularly relevant to the migration of petroleum-hydrocarbons, which are typically mixtures of many individual compounds. As these compounds move through the subsurface, their relative concentrations continually change as individual compounds are retarded at different rates.

Biodegradation can also be an important factor affecting solutes in ground water. When conditions are favorable, bacteria and other microorganisms can degrade a variety of organic compounds. In many cases, these compounds are mineralized to carbon dioxide and water, which results in lower concentrations of organic compounds in ground water and reduces the mass of these compounds that is transported downgradient. When biodegradation of a compound takes more than one step, or when complete mineralization of a compound does not occur, intermediate ***degradation products*** are formed. As with sorption, individual compounds tend to be degraded at different rates, which can result in complex changes in the relative concentrations of different compounds over time. In addition to reducing the concentrations of the compounds being degraded, the metabolic activity of microorganisms utilizes constituents such as nutrients (e.g., nitrogen and phosphorus) for growth, and electron acceptors (e.g., oxygen, nitrate, manganese, sulfate, or ferric iron) for the oxidation-reduction reactions involved in metabolism. Zones of high metabolic activity may therefore be characterized by decreased concentrations of nutrients and electron acceptors, and increased concentrations of reduced forms of nitrogen, manganese, sulphur, and iron. Metabolic activity also typically causes a reduction in water pH, which increases the solubility of metals

such as manganese and iron. Although biodegradation occurs to some degree under nearly all conditions in the environment, biodegradation rates are highly variable and depend on a large number of factors including temperature, pH, the availability of nutrients, oxygen and other electron acceptors, and the concentrations of the compounds being metabolized. Laboratory studies of soil samples from a particular site can be used to determine conditions that will optimize *in situ* biodegradation.

Contaminants are transported and the dimensions of plumes increased by the combined effects of advection, dispersion, and molecular diffusion. However, the effects of sorption and biodegradation can be substantial, and in many cases, the spread of contaminants can be either partially or fully arrested by these processes. The results of an experiment in which organic compounds and chloride were injected into a shallow sand aquifer and then monitored over time are shown in figure 4 (Barker and others, 1987; Chapelle, 1993). The transport of chloride is usually considered to be conservative because it is not subject to sorption or biodegradation. The combined effects of advection, dispersion, and molecular diffusion on chloride distribution after 3, 53, and 108 days of transport are shown in figure 4a. The more limited distribution extents of benzene and toluene show the effects of these same processes integrated with sorption and biodegradation (fig. 4a). The total mass of each contaminant remaining in the aquifer was also monitored during this experiment and these data clearly show the decrease in mass of organic compounds resulting from biodegradation (fig. 4b). This figure is intended to illustrate the processes that may be taking place at the ARRC study site, but the effects of these processes are expected to be different. At the ARRC study site, contaminant plumes do not appear to have spread widely, despite the considerable age of some of the spills and the complex nature of ground-water flow in this system. Although this lack of dispersal indicates that natural attenuation by sorption and biodegradation is likely occurring, a full understanding of the current extent of contamination and selection of the most appropriate approach to mitigation at this site requires a thorough investigation of all of the processes affecting contaminant fate and transport.

FIELD INVESTIGATIONS

The locations of all monitoring wells were surveyed during the data-collection phase of the study to accurately determine their locations and elevations. Ground- and surface-water elevations were measured and these data were used to help characterize the subsurface flow system. Ground water was sampled and analyzed for water-quality constituents and the results of these analyses were used to determine the nature and distribution of solutes.

Surveying and Identifying Data-Collection Sites

All permanent monitoring wells and temporary data-collection sites used over the course of the study were accurately located by horizontal and vertical surveys in May 1993. Elevations at each site are based on the National Geodetic Vertical Datum of 1929 and referenced to a preliminary adjustment from 1966. Elevations within the ADEC-defined environmental-assessment area are referenced to the U.S. Coast and Geodetic Survey (USCGS, 1966) reference benchmark BMXX12, which has an elevation of 441.272 ft. Horizontal coordinates are referenced to control provided by ADOT&PF. Horizontal locations were determined by traverse surveys, satellite global-positioning surveys and from published topographic maps of the study area. Elevations were

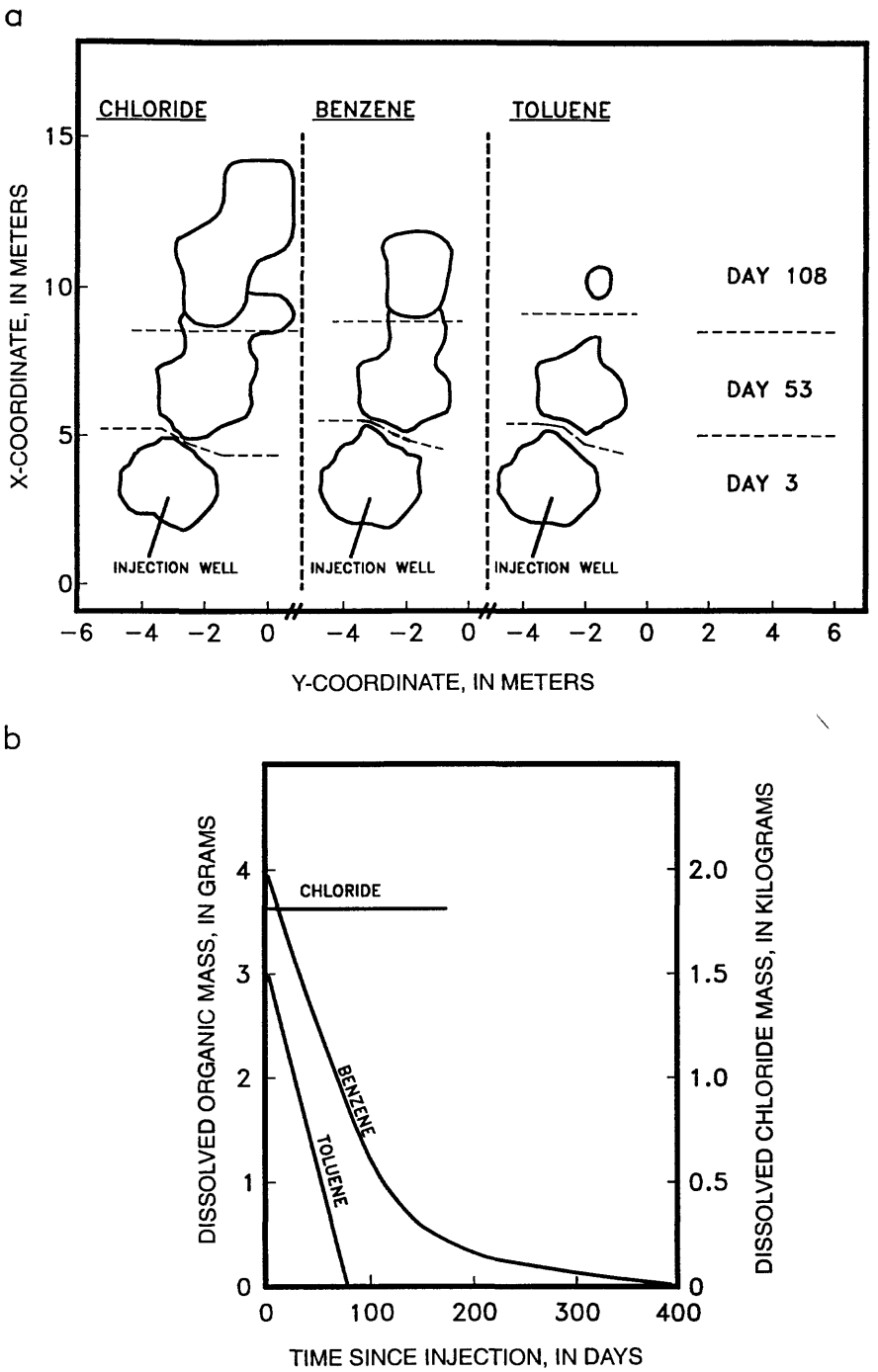


Figure 4. Results of a field-scale injection experiment showing a) extent of transport of benzene and toluene relative to chloride and b) decrease in mass of organic compounds relative to chloride. Modified from Barker and others (1987) and Chapelle (1993) and reprinted with permission.

determined by trigonometric or differential leveling. Selected wells were periodically resurveyed over the course of the study to check and adjust elevations for frost jacking. The survey net was connected to a benchmark south of Airport Way and to additional USCGS benchmarks east and north of the study area to establish a common base elevation. The same 1966 adjustment was used for this project and several other USGS projects in the western Fairbanks area. The survey data for the observation wells included in the original survey net are provided in Appendix C.

Once the locations of ground-water data-collection sites were accurately determined, a site-identification system and data base were established. All ground-water observation wells and permanently installed drivepoints in the study area were given a prefix of AR, and soil borings were given a prefix of ARB. Each site was then assigned a unique sequence number indicating the order in which the sites were located or reviewed. The site identifiers used in this study, cross-referenced to site identifiers used in earlier studies, are provided in a table in Appendix A. Reference to the earliest report in which each site is identified is also provided in this table, and details of drilling and well construction are typically available in those reports.

Hydrologic Investigations

Selected ground- and surface-water data collected during the current study are discussed in the following sections. Water levels at river, slough, and observation well sites were collected at monthly intervals. More frequent measurements were made to document short-term stage changes at surface-water sites and a smaller set of observation wells. Some observation wells were measured less frequently due to poor accessibility and time limitations. Discharges measured on Noyes Slough and all water-level data and hydrographs for ground- and surface-water sites are presented by Kriegler and Lilly (1995).

Surface-Water Hydrology

Data from the Tanana and Chena Rivers and Noyes Slough were collected to provide information on the relation between ground- and surface-water systems and to better understand the boundary conditions that control ground-water flow within the study area. Annual differences in discharge and stage in nearby streams are particularly critical for correct interpretation of the ground-water flow system in the study area because changes in the stage of a river can have considerable influence on the magnitude and direction of ground-water flow, and therefore solute transport.

Comparison of monthly mean flows measured during the study period with long-term mean-monthly flows shows that flows in the Chena and Tanana Rivers during the current study differed from the long-term average in the magnitude, duration, and timing of high flows (fig. 5). For example, the snowmelt discharges in the Chena River during the 1990 snowmelt period were less than the long-term average, but discharges during the late-summer precipitation period were considerably above average and lagged by a month. The flows in the winter of 1990 -1991 were slightly above average. The snowmelt discharge in 1991 was well above average and the summer precipitation peak was slightly above average. Snowmelt discharges in 1992 were again well above average and lagged by a month. No high flow caused by precipitation occurred in the late-summer period and the winter base-flow conditions were near average. The 1993 snowmelt discharges were near average but the late-summer discharges caused by precipitation were above average and

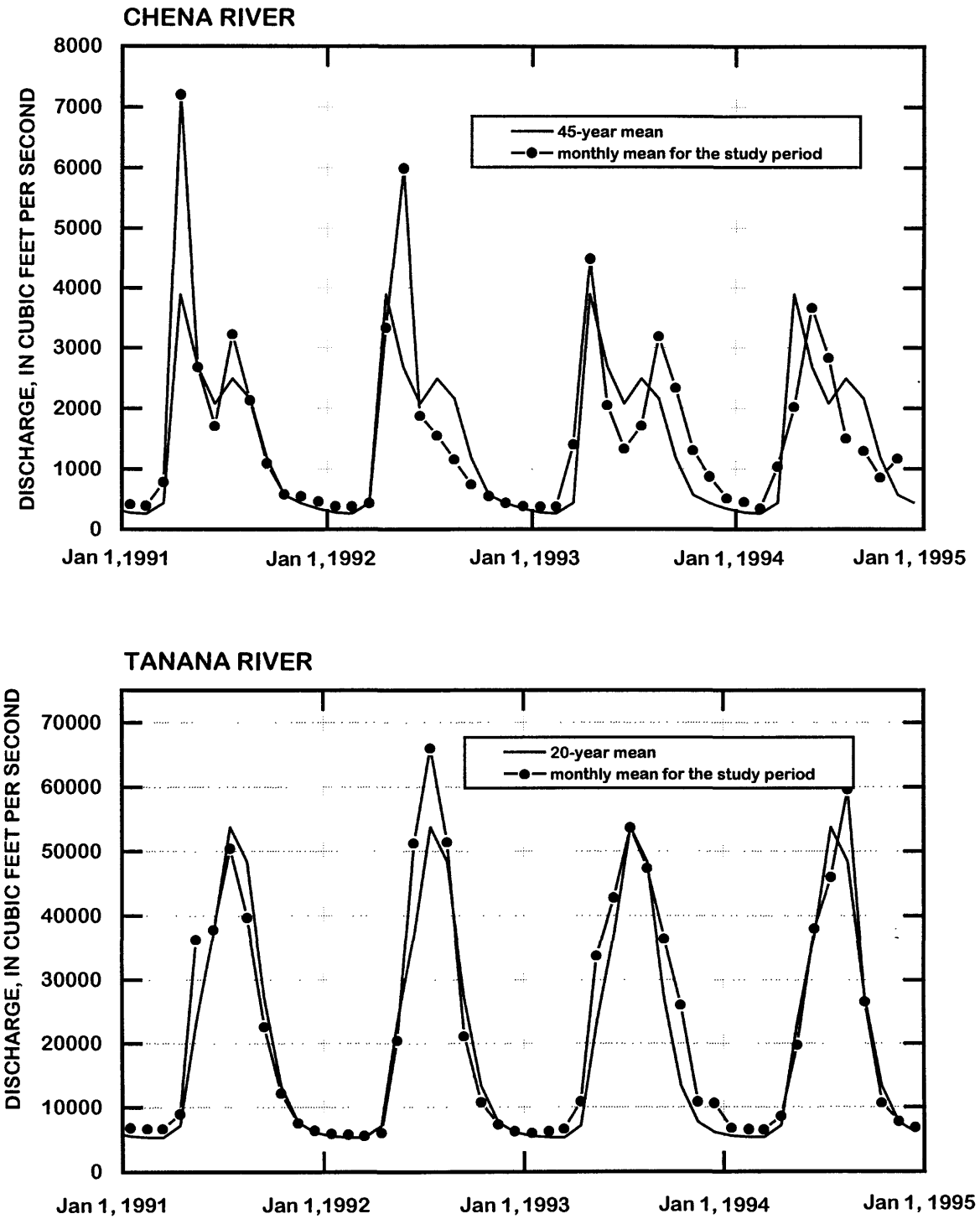


Figure 5. Monthly mean and 45-year mean for the Chena River and monthly mean and 20-year mean for the Tanana River discharges for the period 1991 through 1994.

lagged by a month. This lag resulted in record discharges of the Chena River during the winter of 1993 to 1994. These annual differences in discharge in the Chena River are particularly critical for correct interpretation of the ground-water flow system in the study area because of its proximity to the Chena River.

The annual range in stage of the Tanana River is approximately 7 ft (fig. 6). Stage increases on the Tanana typically occur during spring snowmelt, but are due primarily to the effects of ice jamming in the river rather than to increases in discharge. This indicates that changes in the stage of the Tanana, which cause changes in the surrounding ground-water system, are not necessarily related to the quantity of flow in the river. The annual range in stage of the Chena River is from 6 to 8 ft (fig. 6). Although the discharge of the Chena River is less than that of the Tanana River, differences in channel geometry and flow conditions affect the stage of the Chena River differently than they affect the stage of the Tanana River. These stage changes in the Chena River have direct impact on the ground-water levels in the study area. As with river discharge, seasonal and longer term fluctuations in stage must be considered when interpreting past ground-water data to determine directions and rates of ground-water flow.

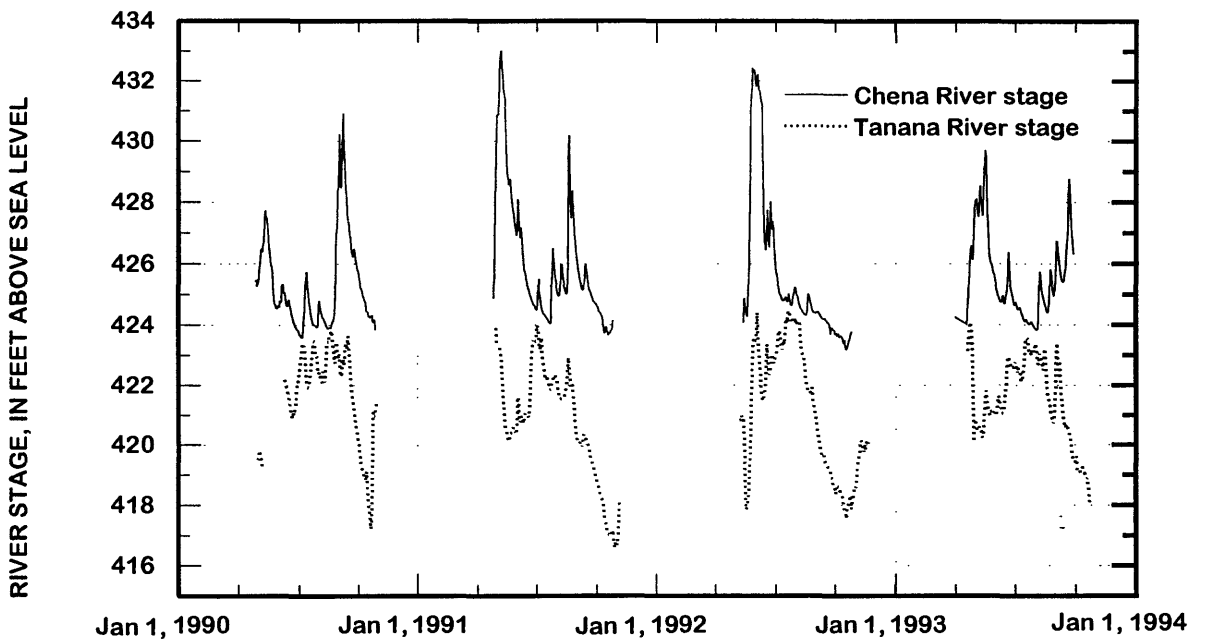


Figure 6. Stages of the Chena and Tanana Rivers for the period 1990-1993.

The stage hydrographs for the Tanana and Chena Rivers and Noyes Slough for the period February 1993 through February 1994 are presented to improve understanding of ground-water data collected during this same period (fig. 7). The difference in stage between the spring snowmelt peak and the mid-summer low-flow period is about 5.5 ft for both rivers. During the snowmelt peak on the Chena River, river stage rises above nearby ground-water levels and water flows from the river into the ground-water system. Following the snowmelt peak, the river level generally declines

and once it falls below the level of nearby ground water, the gradient reverses and ground water flows into the river. When differences between river and ground-water elevations are small, even minor changes in river stage can alter ground-water flow directions.

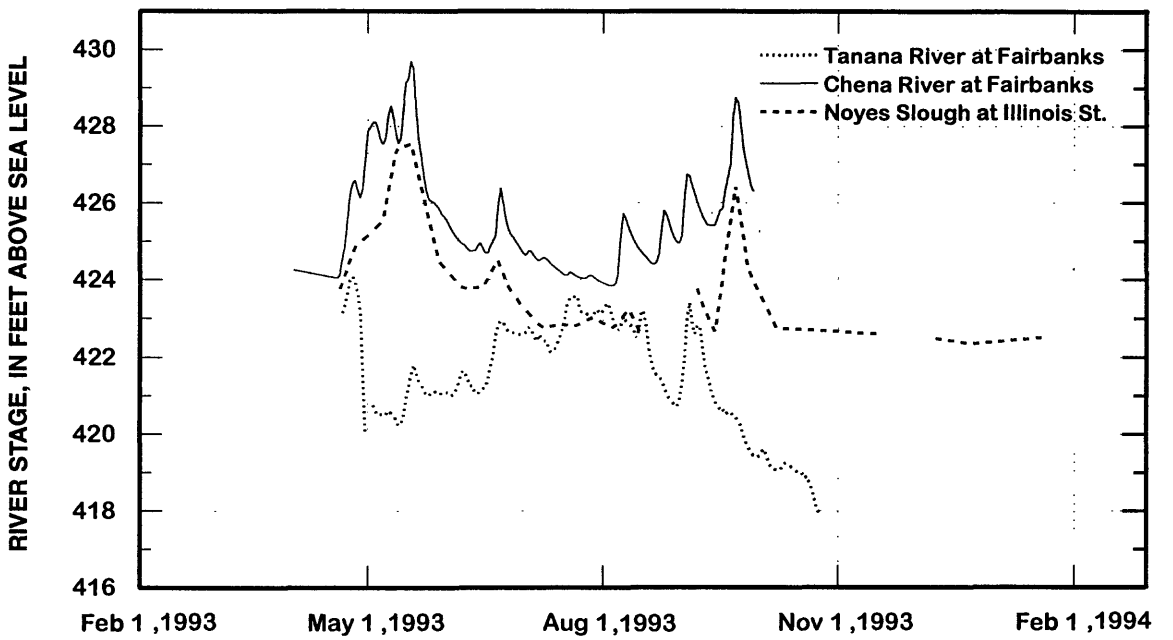


Figure 7. Stages of the Tanana and Chena Rivers and Noyes Slough for the period February 1993 through February 1994.

In addition to data available from long-term stream-gaging stations on the Tanana and Chena Rivers, surface-water data were collected from three additional sites on the Chena River and seven sites on Noyes Slough. The spring snowmelt peak and the June precipitation peaks are shown in figure 7. However, stage variations of shorter duration, such as multiple peaks during both the snowmelt and the late-summer precipitation periods (fig. 7) are not revealed in the hydrograph of Noyes Slough because of the reduced frequency of measurements at this site. Nevertheless, it is important to be aware of such short-term variations in surface-water stages, because they can affect the ground-water flow system in the study area. For example, the difference in stage between the Chena River and Noyes Slough varies throughout the year, resulting in changes in the magnitude and direction of the gradient between different reaches of these streams. This highly transient surface-water flow system has a considerable influence on ground-water flow in the nearby study area. Chena River and Noyes Slough are not hydrologic boundaries to the ground-water system within the study area, but are hydrologic controls, or internal boundaries. The connection of Noyes Slough

to the Chena River results in transient stages both north and south of the ground-water system within the study area.

Ground-Water Hydrology

The primary technique used in this report to evaluate the ground-water system in the study area is comparison of water-elevation hydrographs for surface- and ground-water sites. The spatial pattern of water elevations in wells indicates the general magnitude and direction of ground-water flow in the system, and changes in this pattern over time show that ground-water flows—and therefore subsurface solute transport—are dynamic. Ground water flows from high to low elevation; although there are seasonal shifts in direction, water in the vicinity of wells AR103 and AR102 demonstrates typical flow directions and generally flows southwestward from well AR103 to AR102 and towards the Chena River. Comparison of hydrographs for wells AR59, AR49, and AR102, located in the northern, middle, and south-central parts of the study area, respectively, provides insight for ground-water flow with respect to surface-water influence (fig. 8). The relative positions of the water levels in these wells changed several times during the study period. These changes in relative water levels indicate that ground-water flow between Noyes Slough and the Chena River frequently shifts direction. In addition, the rapid decline in the water level in well AR102 shows the effects of the aquifer discharging into the Chena River, which occurs when water levels in the river fall rapidly below ground-water levels in the adjacent aquifer. These effects are particularly apparent at well AR102 because of its proximity to the Chena River. Data from these three wells illustrate the complex and transient nature of ground-water flow in the study area.

Vertical head gradients, which indicate vertical components of ground-water flow, can be evaluated by comparing water levels in wells with open intervals at different depths at a single location. Wells AR102, 100, 111, and 101 have open intervals at 23, 53, 86, and 100 ft, respectively, and are within 10 ft of one another. Water-level data from these wells (fig. 9) show the vertical head gradient in the ground-water flow system in the study area, as well as the effects of stage changes in the Chena River on this gradient. Water levels in wells AR102, AR100, and AR111 generally rose with increasing well depth, indicating that the flow direction between depths of approximately 86 and 23 feet was upward during most of the hydrograph period. However, following rapid rises in the stage of the Chena River, when river stage rose above adjacent ground-water levels, the vertical gradient approached zero and briefly reversed, indicating that the river changes from a ground-water discharge zone to a source of ground-water recharge. In contrast to the shallow part of the aquifer, the water level in well AR101, at a depth of 100 feet, was occasionally lower than the water level in well AR111, indicating downward flow in the zone between 86 and 100 ft depths. This may be due to small-scale aberrations in the flow field caused by local changes in permeability or the effects of pumping from water-supply wells on the south side of the Chena River.

Water-Table Mapping

Ten water-table elevation maps were constructed from water-level data collected from July 1993 to April 1994. Data were used from observation wells that were screened at the water table to avoid any vertical-gradient bias. Monthly water levels were obtained from observation wells and surface-water sites during mass measurements, and were usually made within a 24-hour period. Ground-water flow is controlled by both the Chena River and Noyes Slough. These effects are

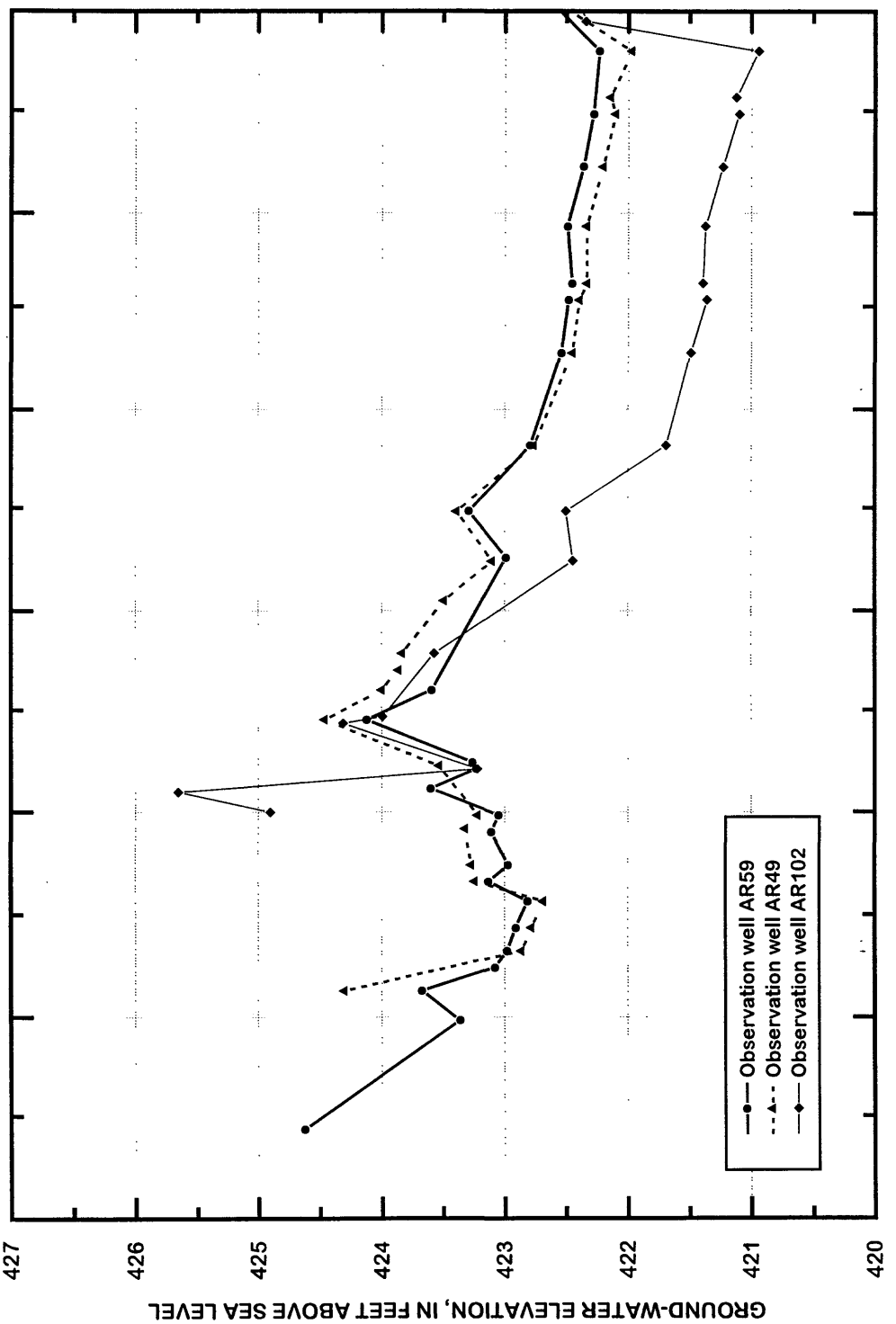


Figure 8. Ground-water elevations for observation wells AR59, AR49, and AR102.

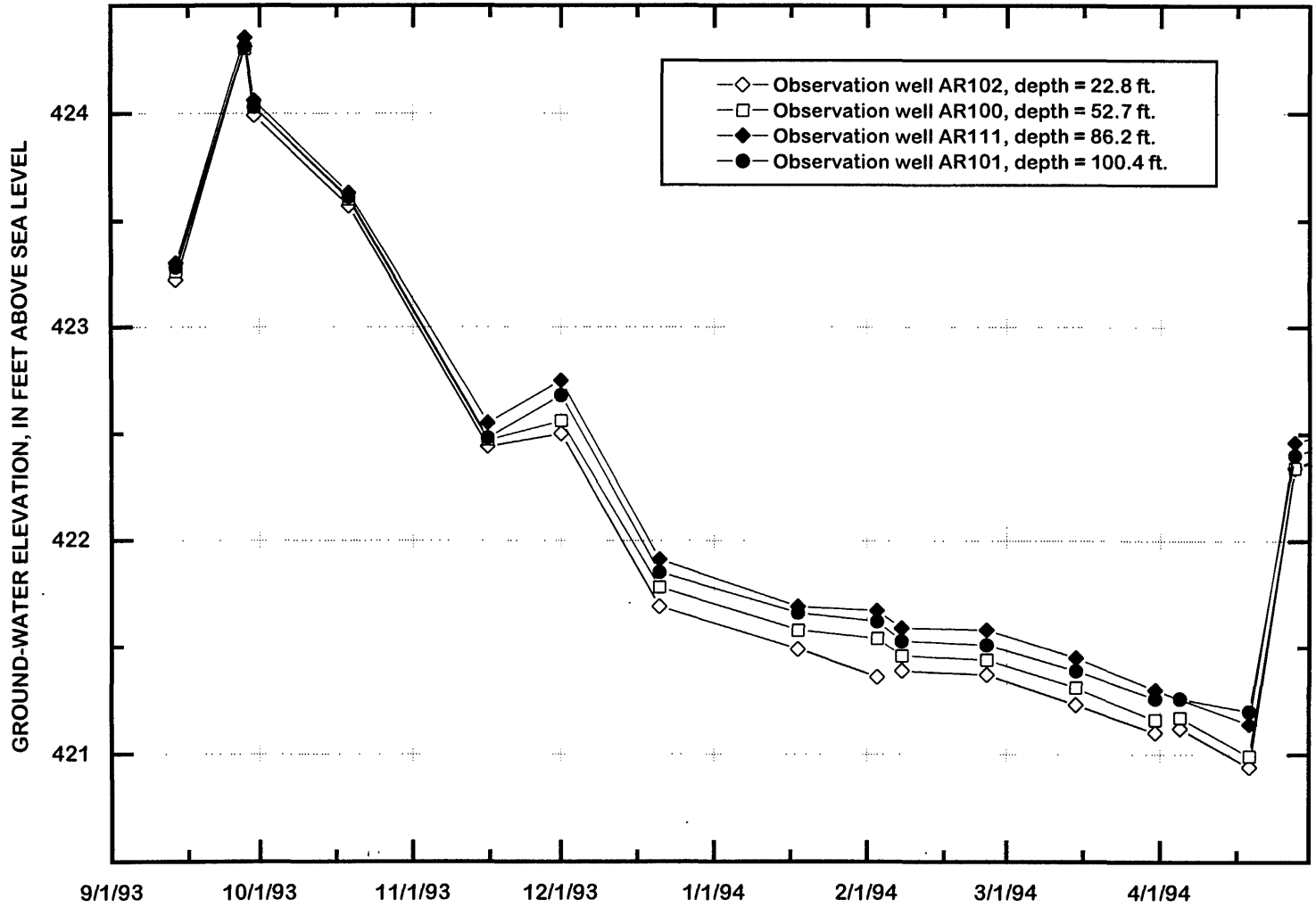


Figure 9. Ground-water elevations for obervation wells AR100, AR101, AR102, and AR111.
Wells are screened at bottom 5 ft for AR 100, AR101, and AR111; screened at bottom 10 ft for AR102.

shown in the water-table maps (figs. 10-14). During much of the year, both the Chena River and Noyes Slough act as a drainage for the study area.

Water levels were contoured in three main steps. The first was to calculate gradients for the Chena River and Noyes Slough based on water levels taken during mass measurements. Secondly, on the basis of the calculated elevations in the Chena River and Noyes Slough, ground-water elevations were added to the map and were contoured using computer contouring methods. The third step involved interpreting the hydrology and changing contours on the basis of the rising or falling stage of the Chena River and water levels in nearby continuous stage-observation well AR68. Areas of higher uncertainty are shown by dashed lines.

In July and August 1993 (fig. 10), the water level in Noyes Slough was lower than that in nearby wells, indicating that the slough was functioning as a drain for the ground-water system during this time.

During the September 1993 ground-water measurements (fig.11), the stage of the Chena River was just starting to rise (fig. 7). In September and October 1993 (fig. 11) the stage in Noyes Slough remained lower than water levels in the closest ground-water wells, indicating that the slough was still functioning as a drain. During the October ground-water measurements, the stage of the Chena River had just declined from the late-summer precipitation high, but was still higher than the water levels in nearby wells.

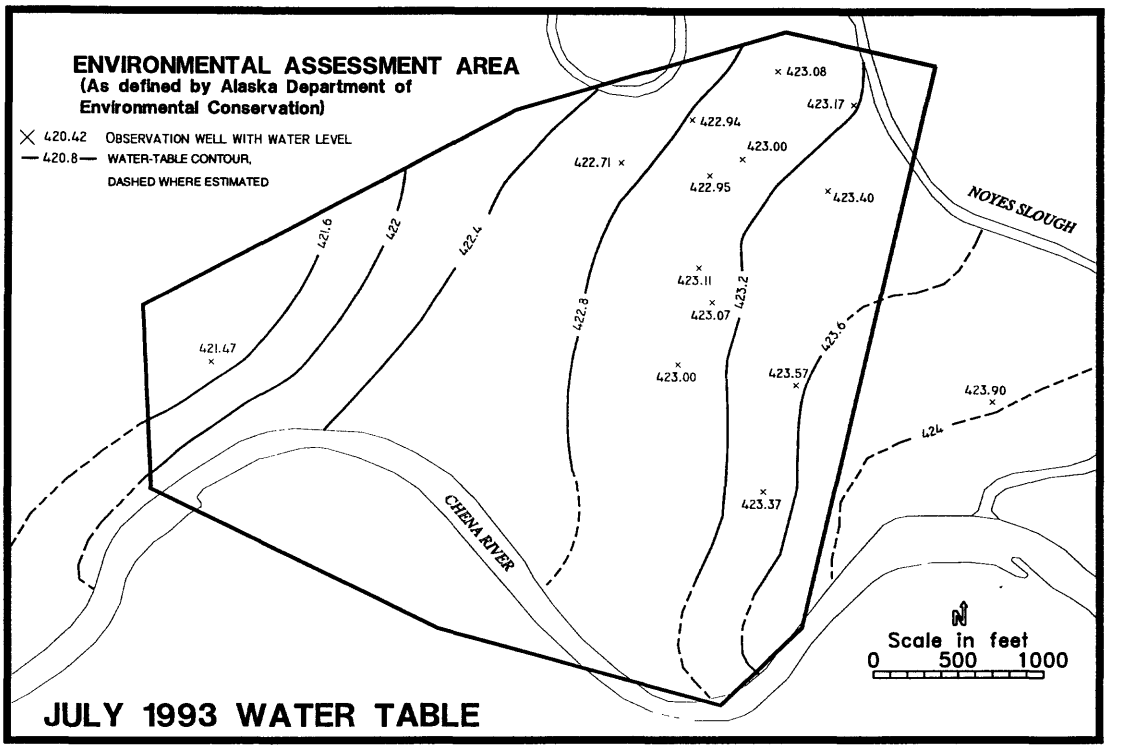
In November and December 1993, the stage in Noyes Slough remained lower than nearby ground-water levels (fig. 12), but the differences were smaller than in previous months. Ice cover on the Chena River during this period resulted in a slight rise in river stage, which influenced ground-water levels near the river. Compared to previous months, the general direction of ground-water flow shifted slightly from the northwest toward the west.

The water table declined slightly from January to February 1994 (fig. 13). In January, the stage in Noyes Slough indicated that the slough was still functioning as a drain for the nearby ground-water system, but the slough went dry before the February measurement and was no longer affecting the ground-water system.

The elevation of the water table declined further from March to April 1994 (fig. 14). During this time, the stage in Noyes Slough was higher than water levels in nearby wells, indicating that the slough was recharging the aquifer and no longer functioning as a drain for the system. Comparison of figure 14 with figures 10 through 13 shows how this change altered the shape of the water-table contours in the northern part of the study area.

Pumping and Flooding Effects

Pumping of ground water from several wells and gravel pits located in the study area probably affects the ground-water flow system. Sourdough Express, located in the central part of the study area, pumps ground water for nonpotable shop operations (Whitey Gregory, Sourdough Express, written commun., 1995). The Fairbanks Daily News-Miner also pumps ground water in the study area to provide cooling water for printing operations. Cooling water is pumped primarily in the summer at an estimated average rate of 60 gal/min (Dave Kosloski, Fairbanks Daily News-Miner, written commun., 1995). The City of Fairbanks, MUS, operates a fire-suppression well



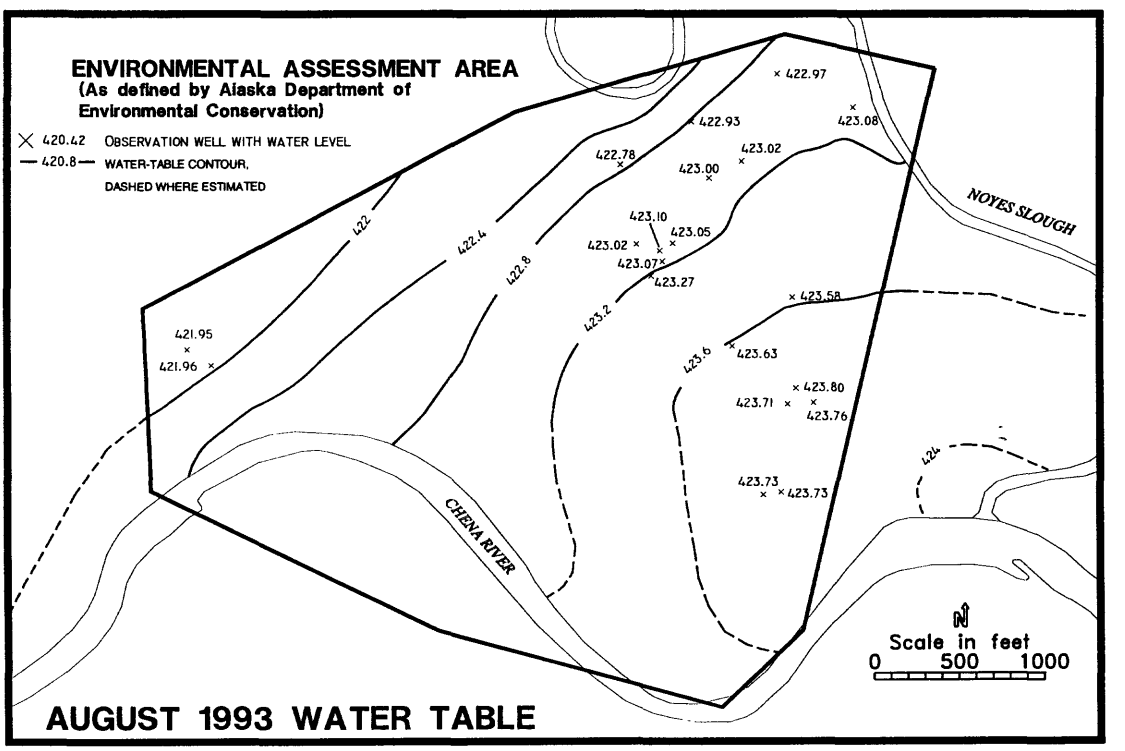


Figure 10. Configuration of the water table in the study area in July and August 1993. (Values in feet above sea level.)

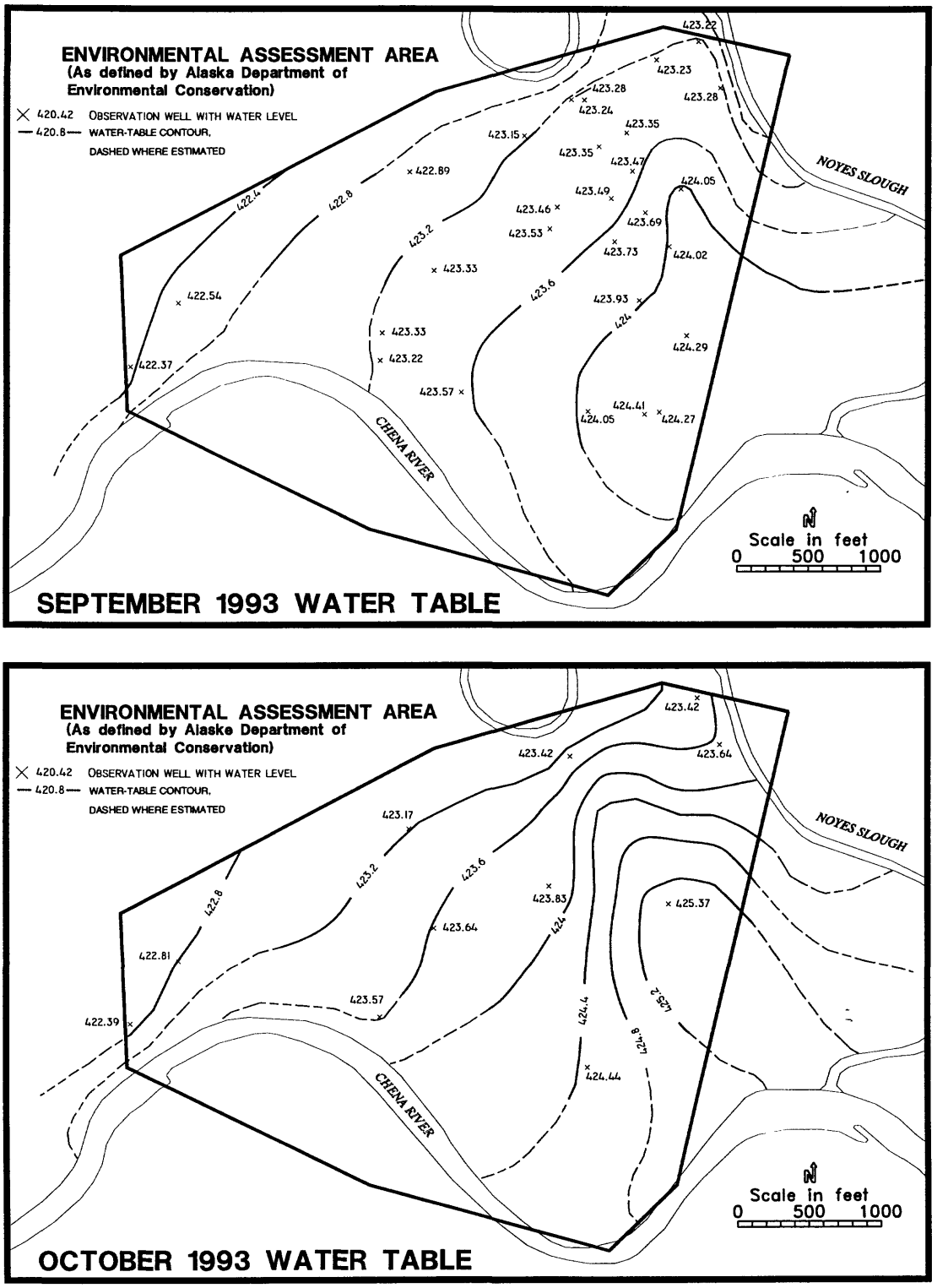


Figure 11. Configuration of the water table in the study area in September and October 1993. (Values in feet above sea level.)

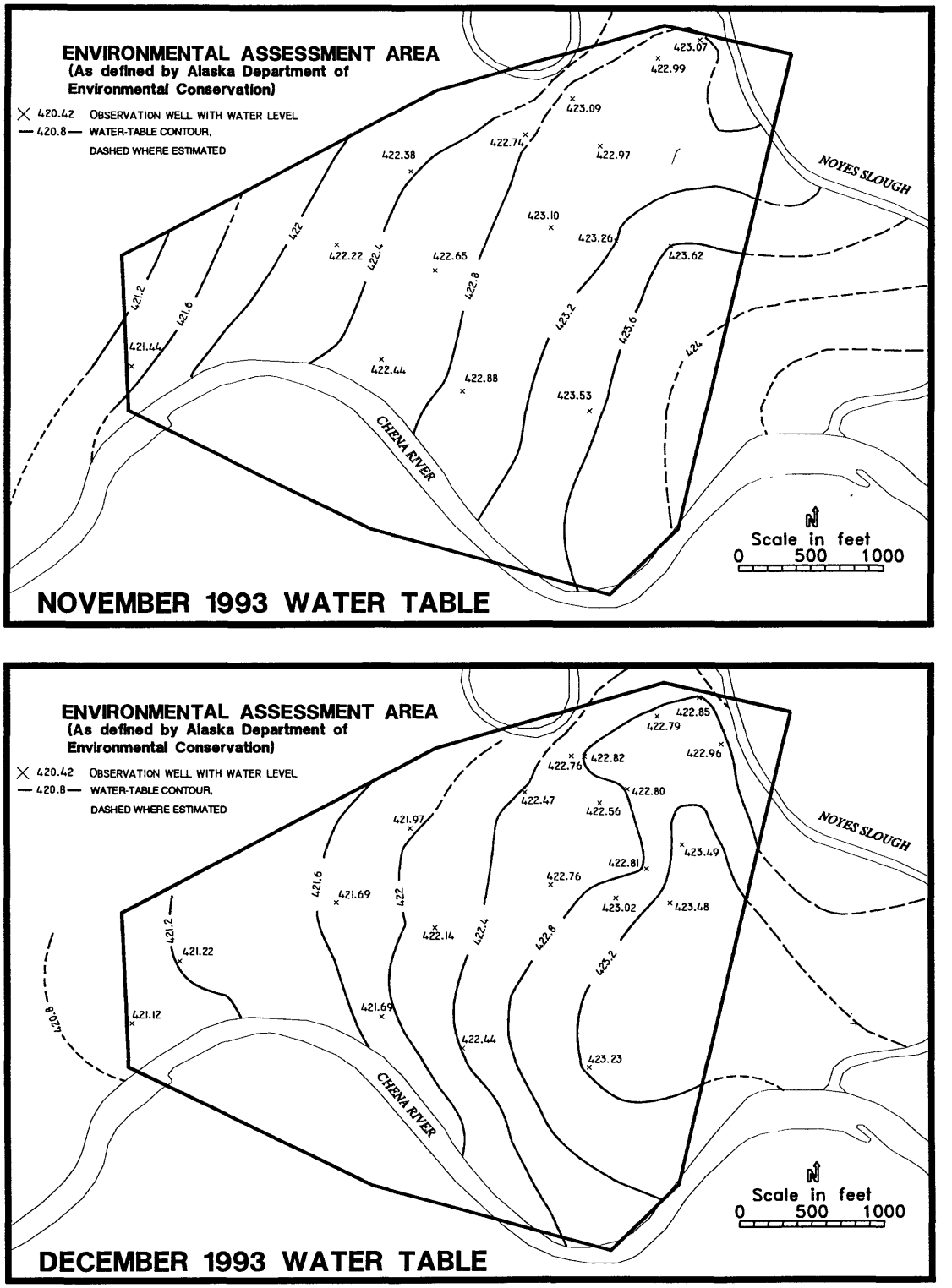


Figure 12. Configuration of the water table in the study area in November and December 1993. (Values in feet above sea level.)

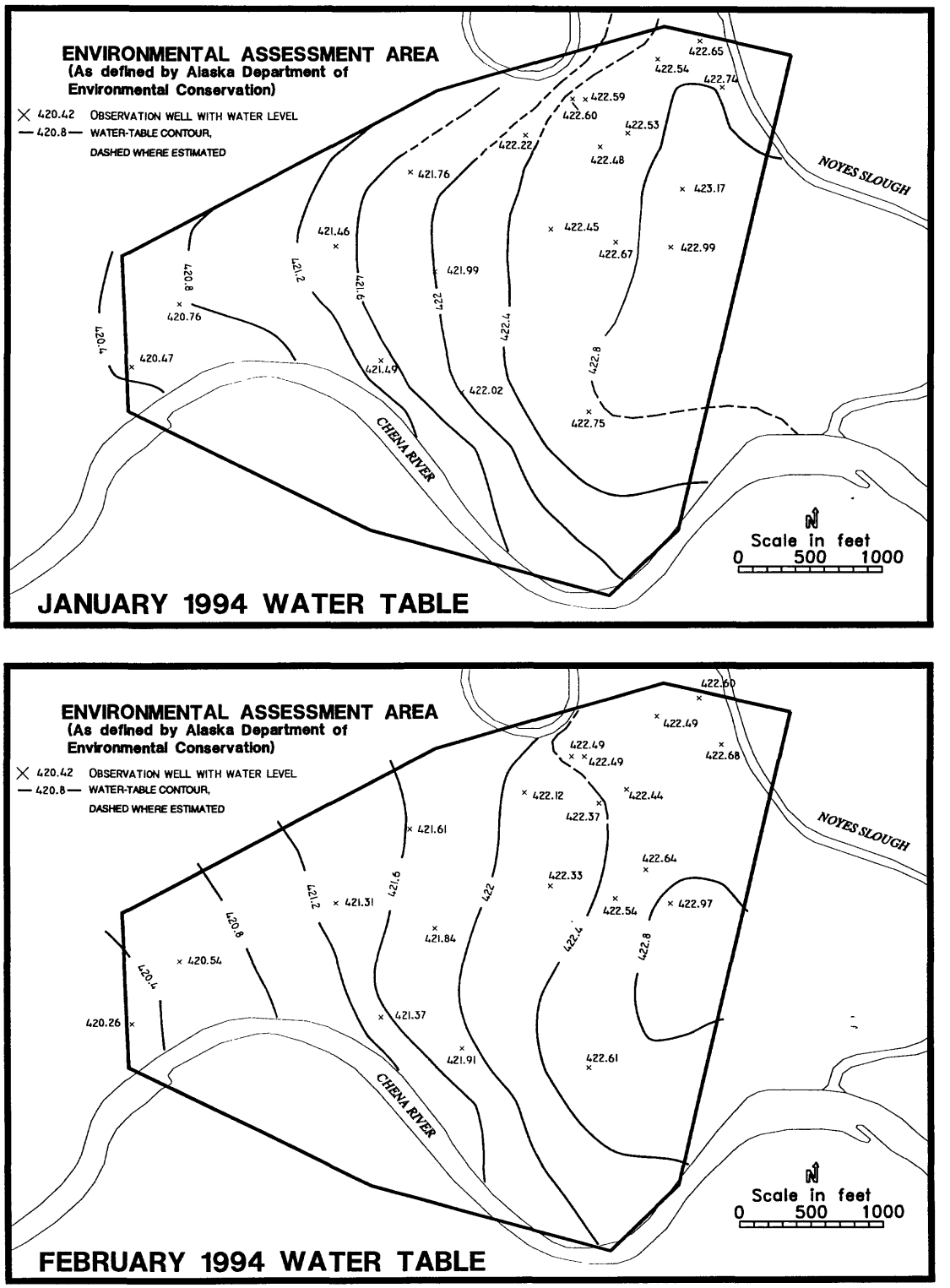


Figure 13. Configuration of the water table in the study area in January and February 1994. (Values in feet above sea level.)

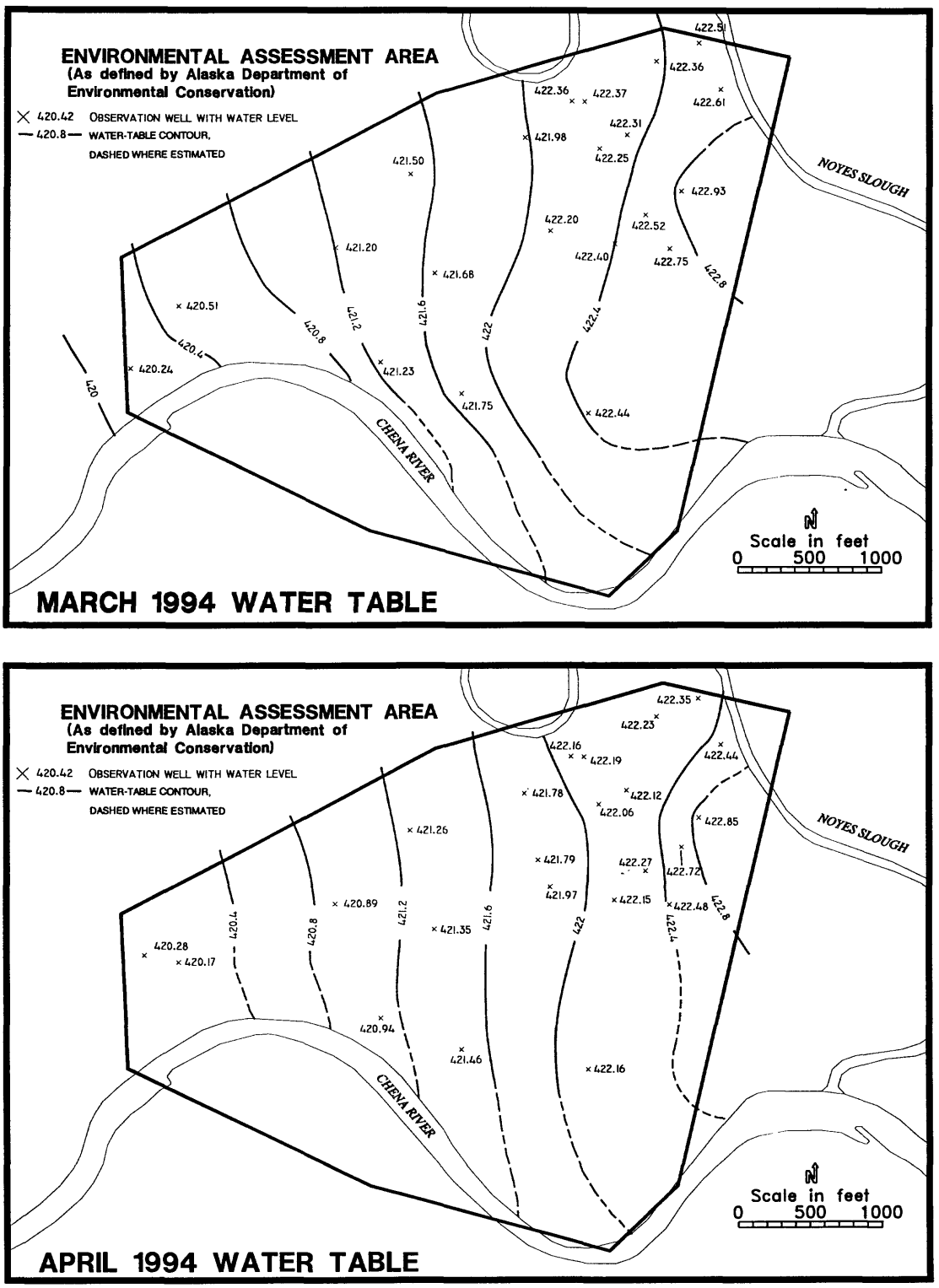


Figure 14. Configuration of the water table in the study area in March and April 1994. (Values in feet above sea level.)

located to the northwest of the Alaska Railroad Depot and just south of Phillips Field Road (fire well #4, plate 1). This well is part of the MUS central water-distribution system located at the MUS power plant, but is currently not in use (Bartley Klevens, FMUS, written commun., 1995).

The pumped wells of primary interest in the study area are water-supply wells on the south side of the Chena River, which are operated by the MUS facility (City Wells 1A, 2A, and 3A, plate 1). These wells are pumped at a rate of approximately 2,400 gal/min. The water is used first for cooling in the MUS power plant and then is fed into the MUS water-distribution system. Because the demand for power-plant cooling water is greater than that for the water-distribution system, excess cooling water is returned to the Chena River. The depths of the MUS wells range from approximately 80 to 120 ft. There is much interest in determining the nature of the hydrologic relation between the MUS wells and the study area. Delineating the source of water to the water-supply wells is of particular importance because the recharge area probably extends to the north side of the Chena River and therefore affects the ground-water system in the study area. Although delineation of the recharge area is not yet completed, many of the data that will be used for this purpose are included in this report.

Pumping from gravel pits in the area probably exerts a more significant hydraulic effect than pumping from water-supply wells. Water was pumped from a gravel pit to the west of the area shown in plate 1 during the summers of 1989 and 1990. The pit was reported to have yielded up to 26,500 gal/min during June and July of 1990 (ADEC, written commun., 1995). Observations of the pumping indicated the water levels in the pit were lowered by 40 to 60 ft. This drawdown probably had a significant effect on the magnitude and direction of ground-water flow and solute transport in the study area during that time. Pumping from another gravel pit to the north of the study area and south of Noyes Slough (plate 1) in the past also could have caused transient changes in the flow system.

During floods, such as the one in 1967, the stage of the Chena River rises above bank level and the water table temporarily rises above the land surface. Such large changes in the elevation of the water table serve to flush the subsurface and can strongly influence transport of both residual- and dissolved-phase hydrocarbons throughout the shallow subsurface.

Numerical Modeling

A three-dimensional numerical model of areawide ground-water flow is being developed to improve understanding of both flow and solute transport in the Fairbanks area. This report does not include descriptions of the numerical model; however, data collected by this project and presented in this report are being used in its development. In addition, understanding gained in the development of the model is contributing to the characterization of the geohydrologic system. Early numerical simulations were used to improve overall understanding of the hydrologic system and to guide the collection of data necessary for development of a more accurate, calibrated flow model. The current modeled area extends from the bedrock-hill ridge lines to the north and west, which are simulated as no-flow boundaries, to the southern boundary of the model, located south of the Tanana River. This southern boundary is represented as a specified-head boundary to simulate the very large supply of water available from south of the Tanana River. On parts of the eastern (upstream) and western (downstream) boundaries of the model, ground-water heads are equal to those observed in the alluvium near the boundaries. The boundary conditions and other model

characteristics are expected to change as more information and a better understanding of the ground-water system are obtained.

The internal hydrologic boundaries incorporated in the simulations included the Tanana and Chena River stages. These river levels dominate the direction of flow in the ground-water system between the two rivers. North of the Chena River, the primary factors that influence ground-water flow in the modeled area are the northern bedrock boundary and flow from the Farmers Loop basin.

Environmental Chemistry

A review of existing reports that cover the study area showed that 90 wells had been used as data-collection sites during previous investigations. Water from most of these wells had been analyzed for organic compounds, and 18 had been analyzed for metals including arsenic, mercury and iron. Benzene was detected in samples collected from 41 of 90 wells (46 percent). Water from three wells was analyzed for herbicides, and water from 11wells was analyzed for polychlorinated biphenyls; these compounds were not detected in any of the samples (Maurer and others, 1994).

A total of 198 subsurface soil samples were analyzed during previous investigations. Of those analyzed for benzene, toluene, ethylbenzene, and xylenes (BTEX), 23 percent exceeded the soil cleanup guideline of 10 mg/kg for the sum of BTEX compounds (ADEC, 1991). Trace concentrations of polychlorinated biphenyls were found in one of eight borings analyzed for these compounds. Herbicides in subsurface soil were below detection limits in the five borings analyzed. Analyses for trace metals such as mercury, arsenic, and lead were done on 63 samples collected near the northeast border of the study area. The highest values reported were 18,000 mg/kg arsenic, 587 mg/kg mercury, and 520 mg/kg lead (Maurer and others, 1994). Remediation efforts have since been undertaken to mitigate these contaminant levels.

Sample Collection, Analyses, and Results

The objective of the sampling conducted during this study was to determine the current extent of petroleum hydrocarbons and chlorinated solvents in ground water, particularly in areas where little or no water-quality data were collected previously. These classes of compounds are commonly associated with commercial and industrial activities and generally serve as indicators of anthropogenic ground-water contamination. To provide data from areas with no available wells, temporary drive points were installed by drilling a 3-inch-diameter hole approximately 10 ft deep and then hydraulically pounding a 1.25-inch-inner-diameter steel casing into the hole. In the resulting ground-water sampling network, there were approximately 500 ft between data-collection sites.

Sampling was done in two distinct phases over a two-week period during August 1993. Whenever possible, samples were collected in order of increasing anticipated concentration to minimize cross contamination. Each well was purged using 3/8-inch Teflon tubing with a peristaltic pump prior to sampling, and the temperature, pH, and specific conductance of the water were continuously monitored during this procedure. Once these parameters had stabilized and at least three well casing volumes had been purged, samples were collected in amber-colored volatile organic analysis (VOA) vials with a controlled-flow bottom valve bailer or with a copper bailer in wells with 1.25-inch-diameter casings. Samples were chilled after sampling and shipped on ice. Drive

points, tubing, and bailers were decontaminated before each use by cleaning with high-pressure hot water and liquinox solution followed by methanol and distilled-water rinses.

Quality Control

To provide quality control during the water-quality sampling program, a portable gas chromatograph (GC) unit was used to monitor ambient air and to analyze trip and equipment blanks. Also, duplicate pairs of samples from selected sites were collected and analyzed to assure that the field procedures were consistent. Standards for benzene, toluene, trichloroethylene (TCE), and tetrachloroethylene (PCE) were used. During the second phase of sampling, quality-control blanks and duplicate samples were collected for analysis in the laboratory. Results of the analyses of quality-control samples indicated that no significant sample contamination occurred and that the equipment operated consistently. A more detailed discussion of quality-control procedures and the results of quality-control analyses are included in Appendix D.

Phase-One Sampling, Analyses, and Results

During the first phase of sampling, samples were collected in copper bailers, chilled, and analyzed using a portable GC in a temporary laboratory within the study area. The temporary laboratory was set up within a temperature-controlled environment to ensure stable performance of the GC. Benzene was chosen as the primary target compound because its relatively high solubility in water makes it a good indicator of the presence of petroleum hydrocarbons in general, but samples were also analyzed for additional petroleum- and chlorinated-hydrocarbon compounds. Results of the field analyses are mapped in figure 15 and listed in table 1 and Appendix D. These data indicate that areas with dissolved petroleum- and chlorinated-hydrocarbon compounds exist in the central and northeastern parts of the study area, respectively. Results of GC analyses are reported as ranges because the precision of the analyses was not adequate for reporting discrete values. The GC analyses were intended to provide relative concentrations of petroleum hydrocarbons to be used in determining sites for phase-two sampling. By comparing GC results with the USGS National Water Quality Laboratory (NWQL) results, low concentrations are approximately <10 µg/L, medium 10-99 µg/L, and high concentrations would be >100 µg/L.

Phase-Two Sampling, Analyses, and Results

On the basis of data from phase one, 32 sites were selected for the second phase of sampling. In addition to a suite of parameters measured in the field (Appendix D), these additional samples were analyzed in the laboratory for a suite of petroleum hydrocarbons and selected chlorinated compounds. Analyses were done by both the NWQL and an independent contract laboratory. The NWQL analyzed for both petroleum hydrocarbons and selected chlorinated solvents. The contract laboratory was engaged primarily to provide analyses of hydrocarbon compounds typically found in gasoline. The results from laboratory analyses used more extensive analytical techniques than the gas chromatograph and provided quantitative values for a larger number of compounds, including breakdown products. The lab analyses reported lower detection limits and were used to qualify data from the first phase of sampling. Most of the wells sampled during the second phase were also analyzed again with the field GC (table 1) to determine the variability in sampling and methods of analysis (Appendix D). Samples from 17 wells and 5 surface-water sites were also analyzed for inorganic chemical constituents by DOMWM.

Laboratory analyses focused on the BTEX compounds—benzene, toluene, ethylbenzene, and xylenes—and selected chlorinated hydrocarbons. The BTEX compounds were selected as target compounds because they are generally good indicators of the presence of petroleum hydrocarbons in water. The chlorinated hydrocarbons investigated included tetrachloroethylene (PCE), trichloroethylene (TCE), and 1,1,1-trichloroethane (1,1,1-TCA), which are common components of solvents used in degreasing and dry-cleaning operations; and chlorofluorocarbons (CFC's) and trihalomethanes (THM's), which can be general indicators of anthropogenic influence. Samples were also analyzed for the most common products of the biological or chemical degradation of the chlorinated hydrocarbons. A listing of the breakdown products for which analyses were performed can be found in Appendix D.

To assure that the following discussion and associated figures are based upon comparable data that were analyzed using comparable methods, only analytical results from the USGS laboratory are included in the following sections.

Petroleum hydrocarbons.—Analyses for the BTEX compounds (figs. 16 and 17) show that moderate to high concentrations of these compounds occur in the east-central part of the study area. Samples from several sites contained concentrations of benzene that exceeded the maximum contaminant level for drinking water of 5 µg/L (ADEC, 1993). The data indicate that fewer sites are affected by ethylbenzene than by the other three BTEX compounds. This is probably due, at least partly, to the low solubility of ethylbenzene coupled with its low concentration—relative to the other BTEX compounds—in the source petroleum hydrocarbons.

Chlorinated solvents.—The pathways by which selected chlorinated hydrocarbons are transformed, primarily by biodegradation, and the resulting products are shown in figure 18. Knowledge of the concentrations and distribution of target compounds and their degradation products in ground water provides an indication of the natural attenuation processes that may be occurring in the study area.

PCE and TCE were detected primarily in the northeastern part of the study area (fig. 19). In addition to being a common industrial solvent, TCE can also occur as the result of biodegradation of PCE. The primary product of TCE degradation is cis-1,2-dichloroethene (cis-1,2-DCE) (fig. 20). The fact that cis-1,2-DCE was detected at only two sites (fig. 20) suggests that conditions in the study area restrict biodegradation of PCE and TCE, or that cis-1,2-DCE breaks down rapidly relative to PCE and TCE.

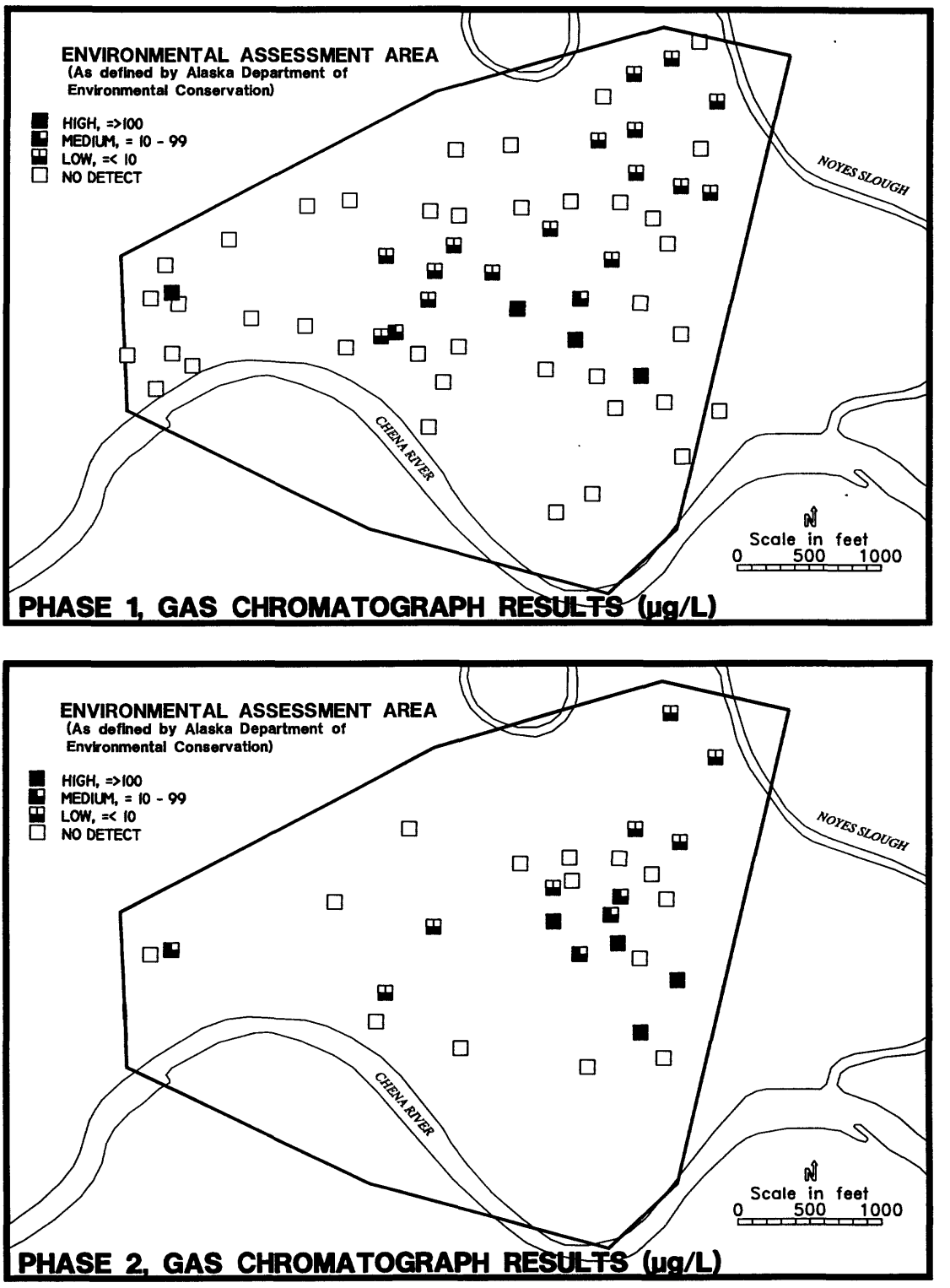
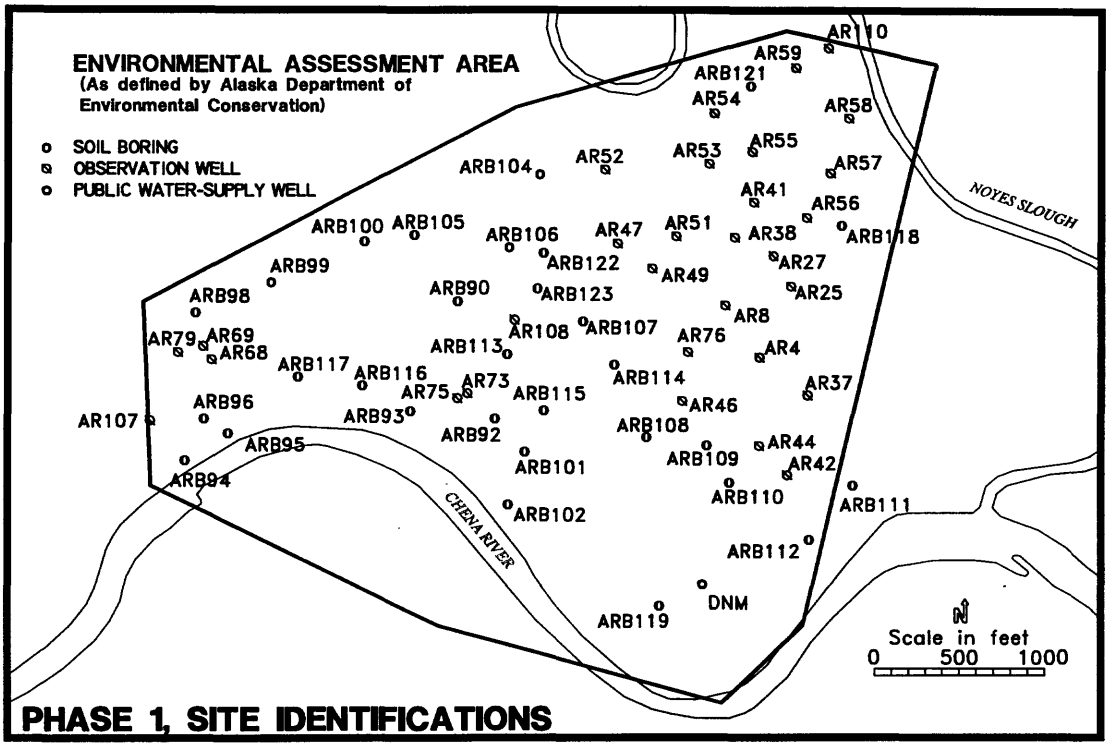


Figure 15. Distribution of organic constituents in ground water as determined by gas-chromatography done in the field, and site locations.



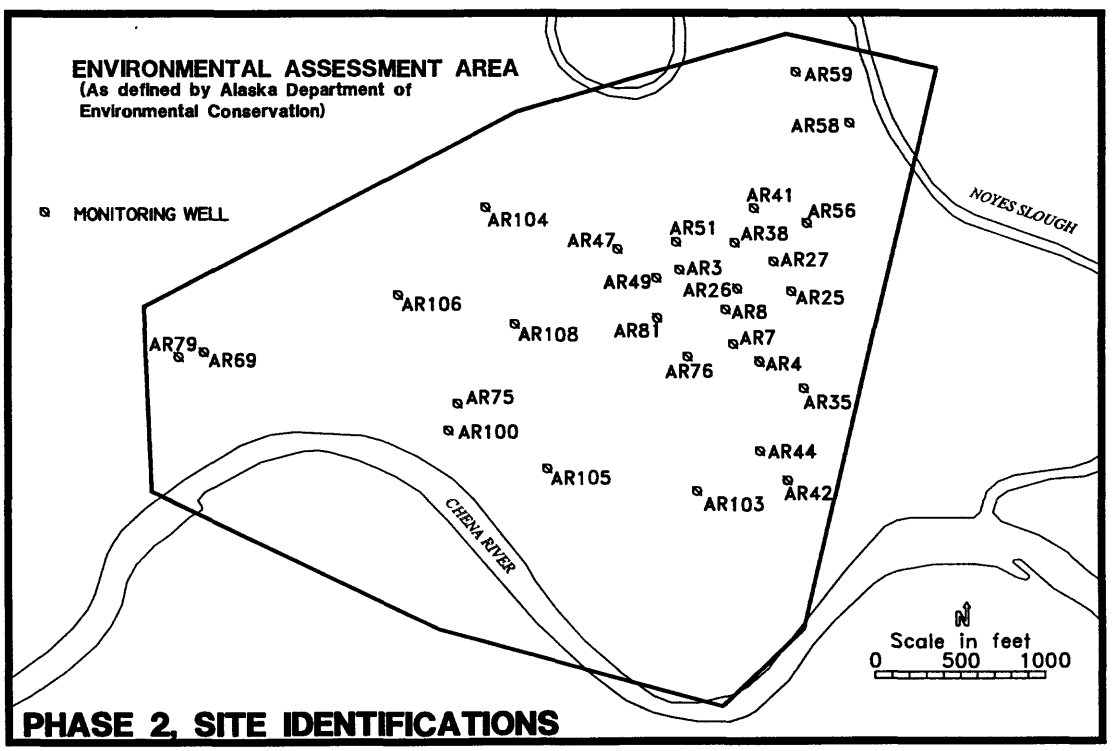


Figure 15. Continued.

Table 1. Relative levels of organic compounds in ground water from field gas chromatography
[C, no detect; L, low levels; M, medium levels; H, high levels; NA, not available]

Site Identification	Phase 1	Phase 2
AR3	NA	C
AR4	C	C
AR7	NA	H
AR8	L	M
AR25	C	C
AR26	NA	M
AR27	C	C
AR35	NA	H
AR37	C	NA
AR38	C	C
AR41	L	L
AR42	C	C
AR44	H	H
AR46[a]	H	NA
AR47	C	C
AR49	L	L
AR51	C	C
AR52	C	NA
AR53	L	NA
AR54	C	NA
AR55	L	NA
AR56	L	L
AR57	C	NA
AR58	L	L
AR59	L	L
AR68	C	NA
AR69	H	M
AR73	M	NA
AR75	L	L
AR76	M	M
AR79	C	C
AR81	NA	H
AR100	NA	C
AR103	NA	C
AR104	NA	C
AR105	NA	C

Site Identification	Phase 1	Phase 2
AR106 (ARB87)	NA	C
AR107 (ARB97)	C	NA
AR108 (ARB91)	L	L
AR110 (ARB120)	C	NA
Daily News Miner	C	NA
ARB90	L	NA
ARB92	C	NA
ARB93	C	NA
ARB94	C	NA
ARB95	C	NA
ARB96	C	NA
ARB98	C	NA
ARB99	C	NA
ARB100	C	NA
ARB101	C	NA
ARB102	C	NA
ARB104	C	NA
ARB105	C	NA
ARB106	C	NA
ARB107	L	NA
ARB109	C	NA
ARB108	C	NA
ARB110	C	NA
ARB111	C	NA
ARB112	C	NA
ARB113	L	NA
ARB114	H	NA
ARB115	C	NA
ARB116	C	NA
ARB117	C	NA
ARB118	L	NA
ARB119	C	NA
ARB121	L	NA
ARB122	C	NA
ARB123	L	NA

[a] floating product found; high level is assumed.

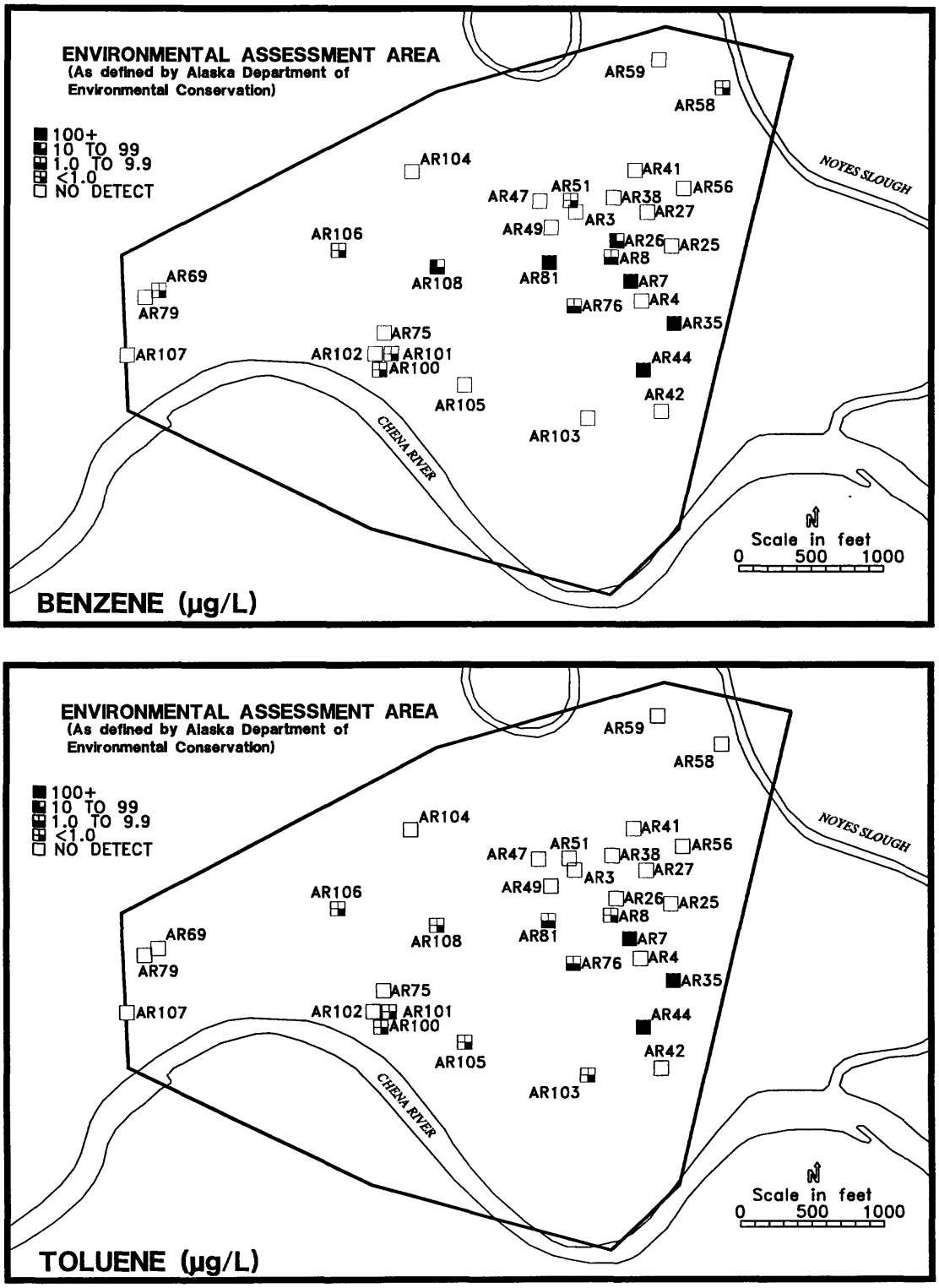
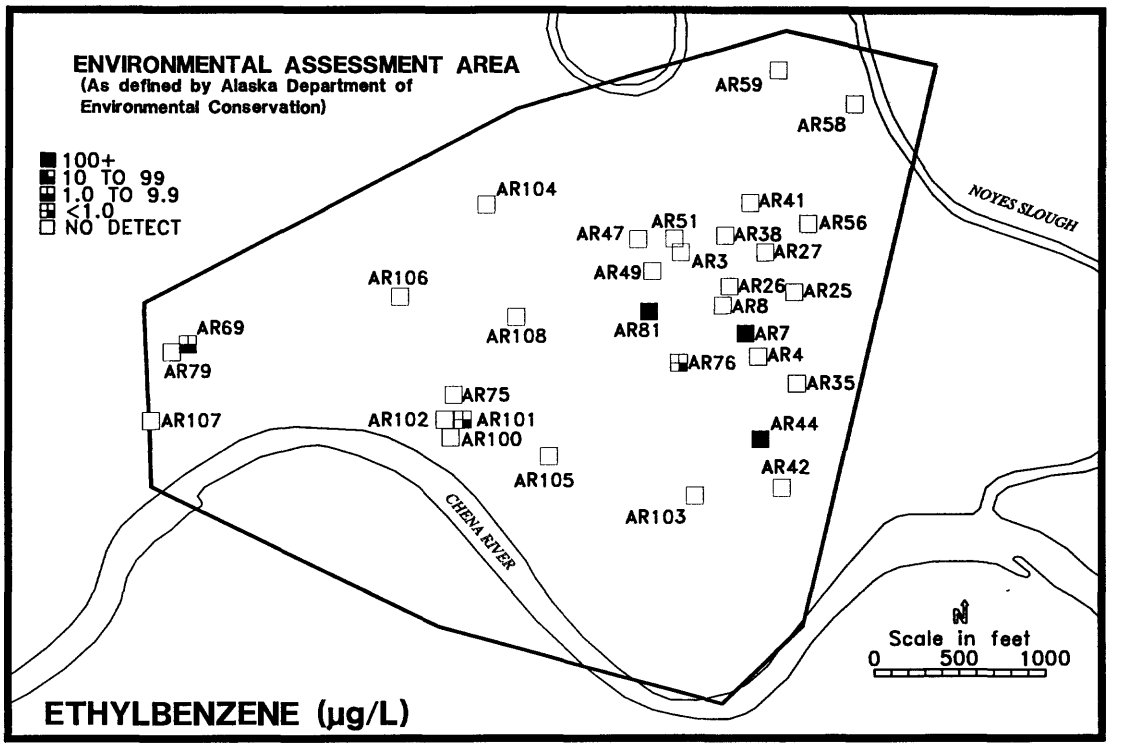


Figure 16. Distribution of benzene and toluene in ground water.



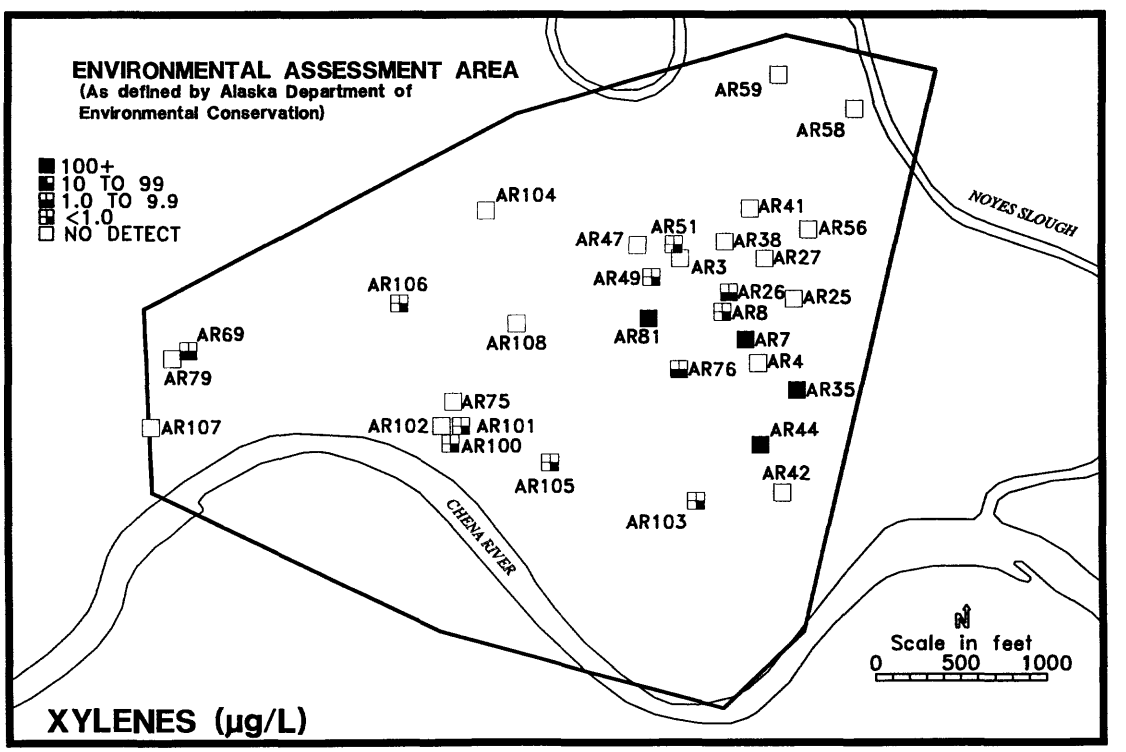


Figure 17. Distribution of ethylbenzene and total xylenes in ground water.

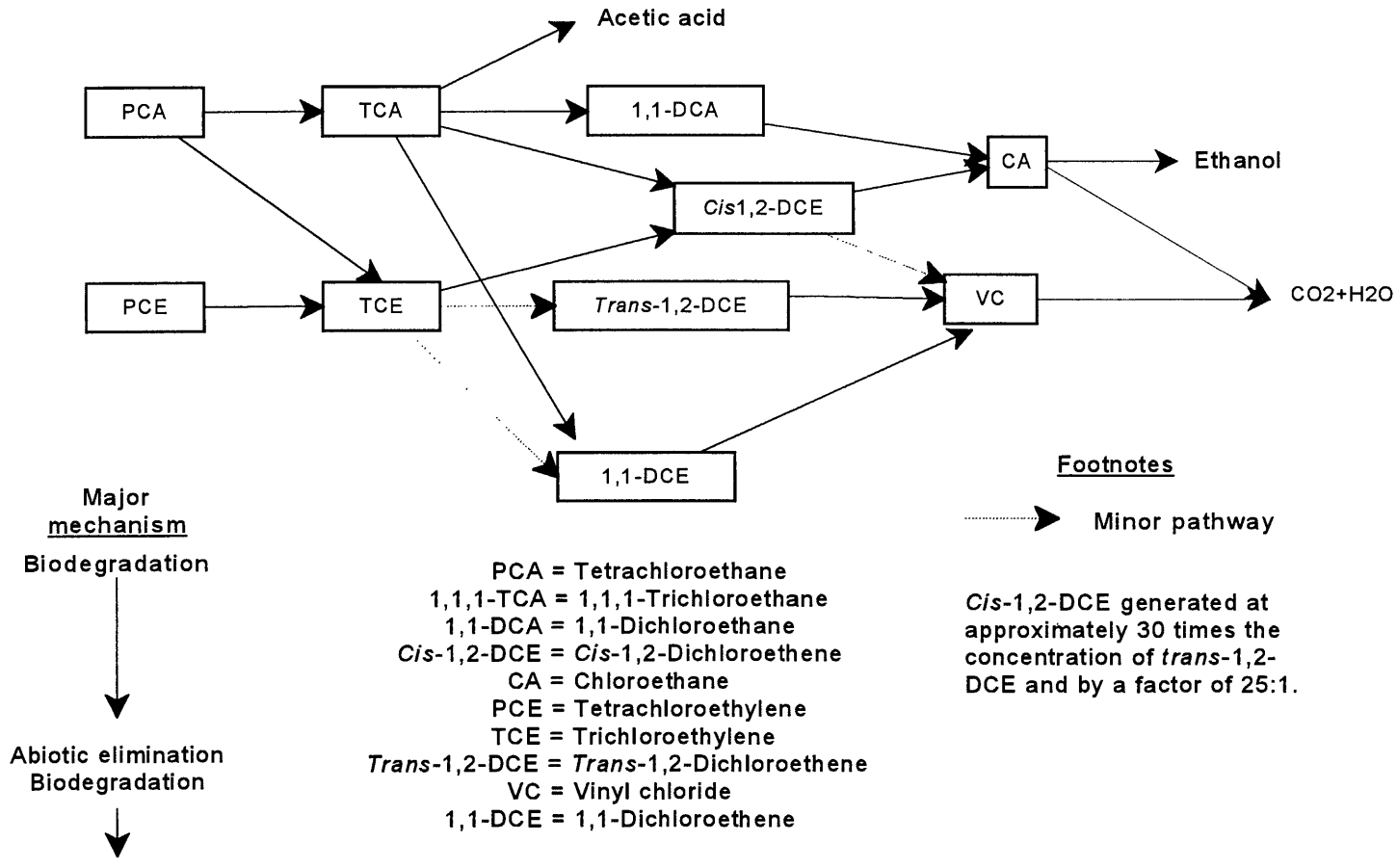


Figure 18. Transformation pathways and products of selected chlorinated hydrocarbons. Modified from Davis and Olsen (1990) and reprinted with permission.

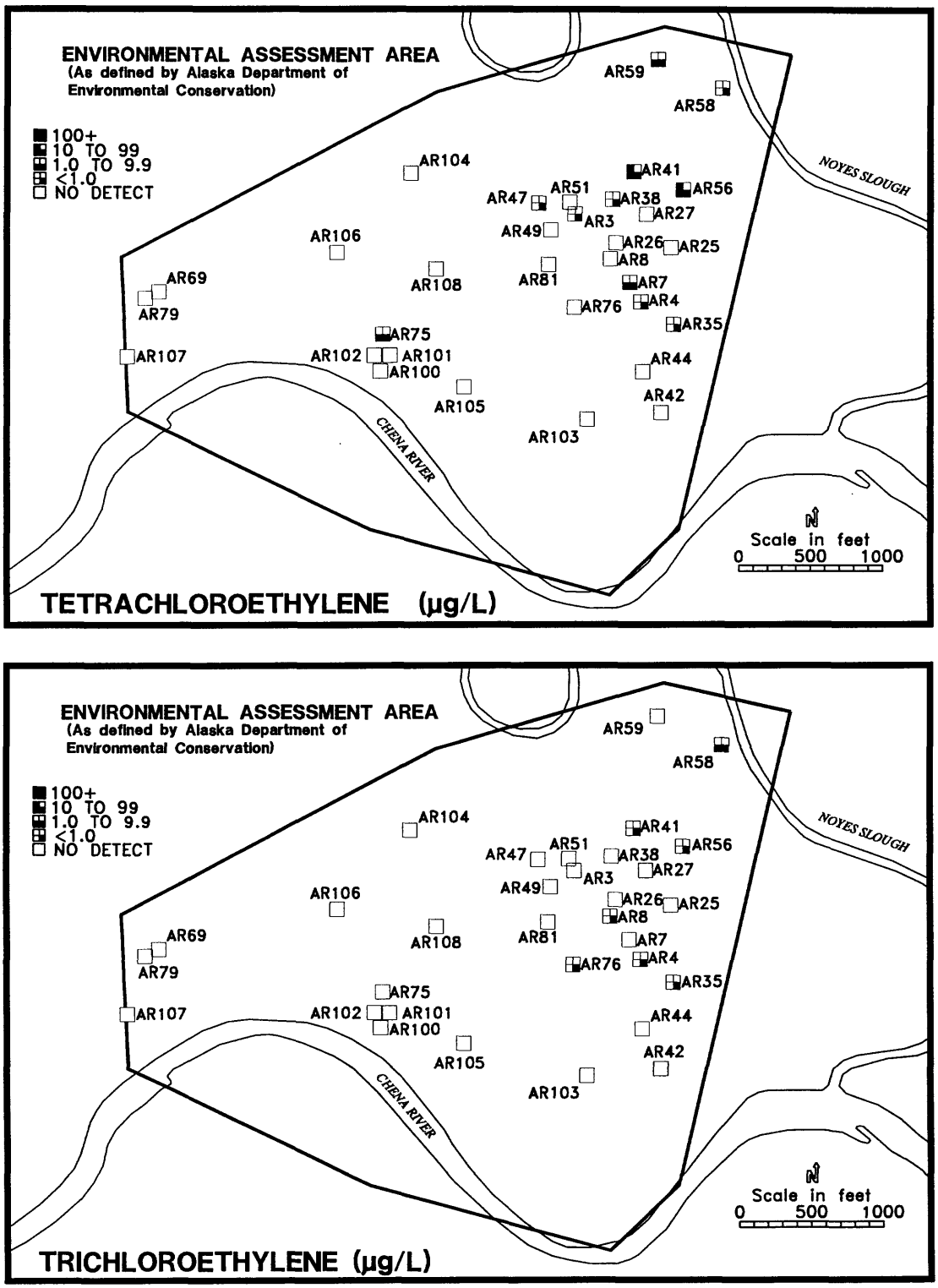


Figure 19. Distribution of tetrachloroethylene and trichloroethylene in the study area as determined by laboratory analyses.

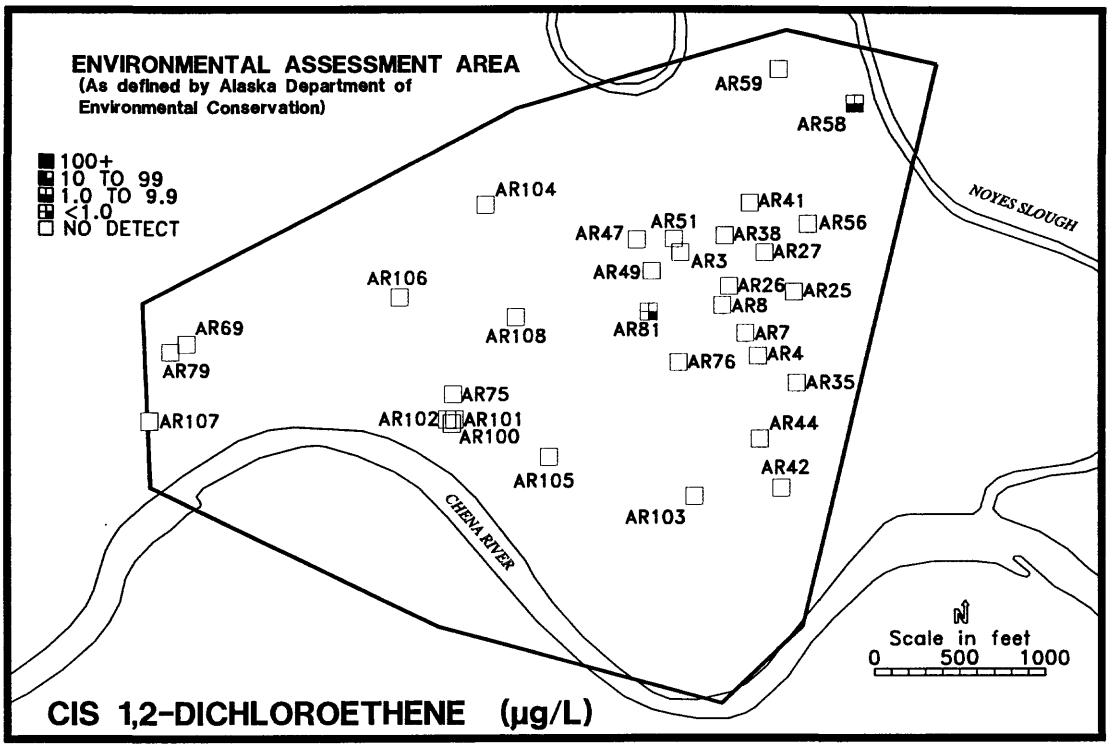
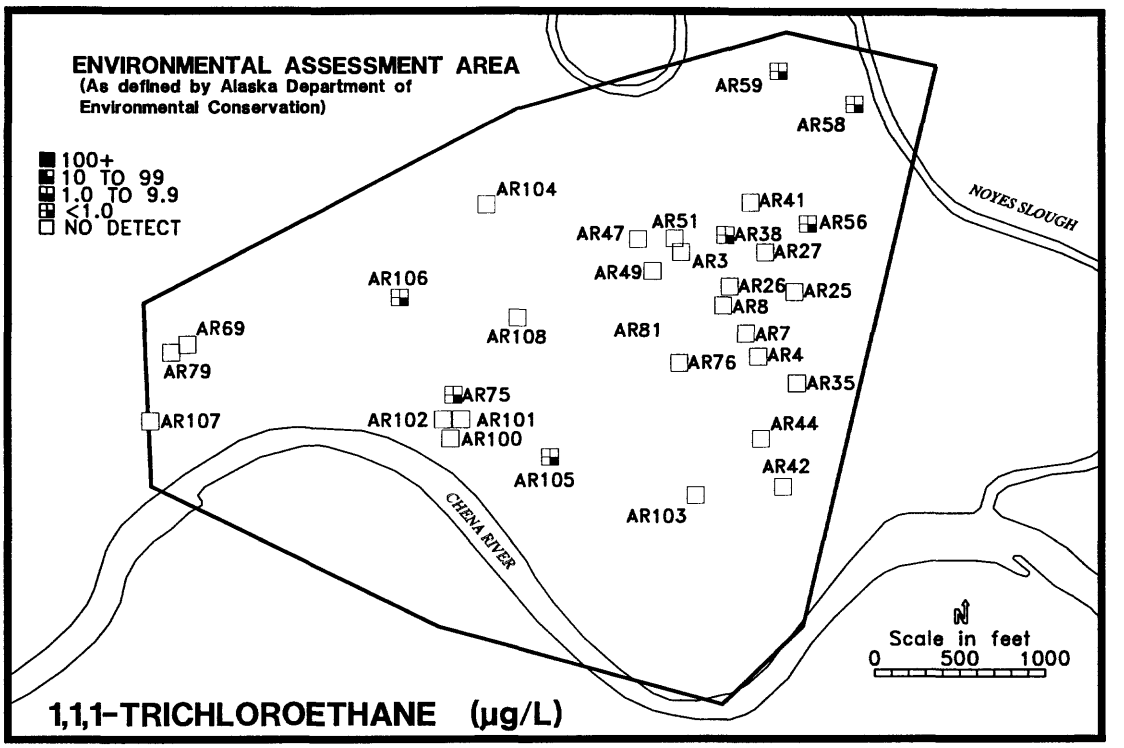


Figure 20. Distribution of cis-1,2-dichloroethene in the study area as determined by laboratory analyses.

Detectable concentrations of 1,1,1-TCA were measured at only seven sites scattered across the study area (fig. 21). However, one of the primary degradation products of 1,1,1-TCA—1,1- and 1,2-dichloroethane (1,1- & 1,2-DCA)—was detected at 15 sites in the northern part of the study area (fig. 21). The presence of 1,1- and 1,2-DCA and cis-1,2-DCE (fig. 20), which is also a product of 1,1,1-TCA degradation, suggests that either chemical or biological degradation of 1,1,1-TCA may be occurring.

The distribution of the CFC's, trichlorofluoromethane and dichlorodifluoromethane, in the study area varied (fig. 22). Trichlorofluoromethane was detected at 12 sites distributed throughout the study area. However, samples from only two sites had detectable concentrations of dichlorodifluoromethane.

The THM's chloroform and dichlorobromomethane were detected at several locations across the study area (fig. 23). THM's typically form as the result of interaction between chlorinated water and naturally occurring organic material. Wells AR100 and AR101 were installed as part of the current study and it is possible that the chlorinated water from MUS used during the well-drilling process was a significant source of the THM's detected.



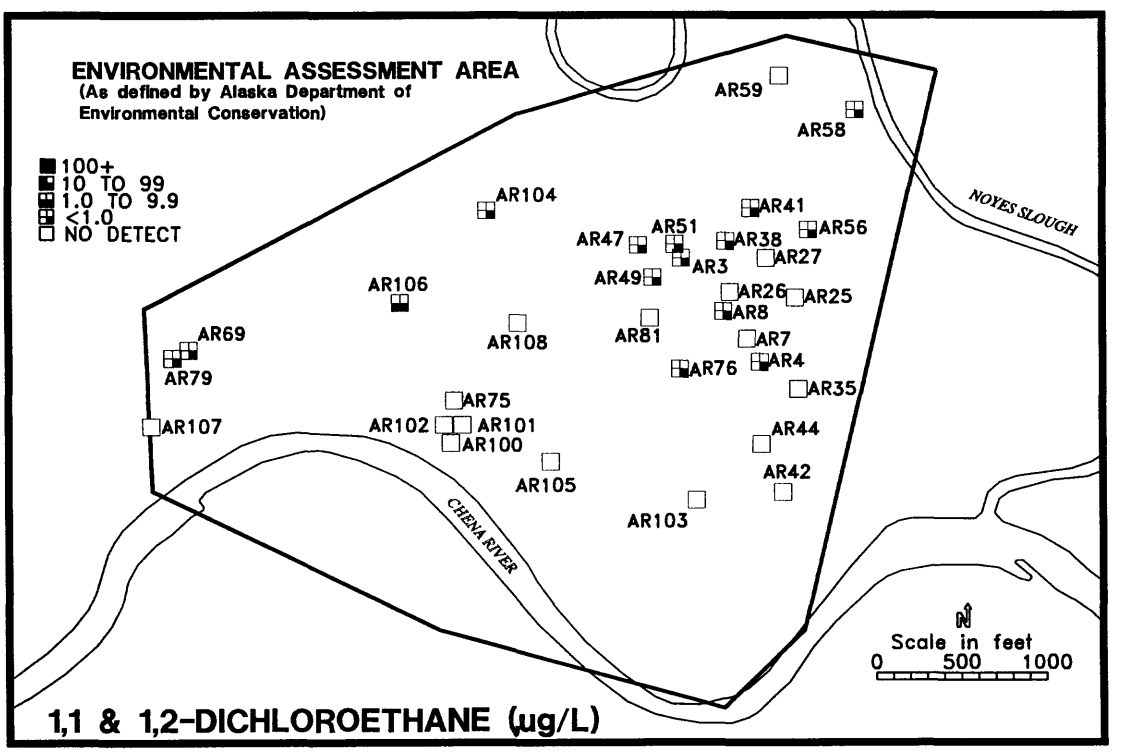


Figure 21. Distribution of 1,1,1-trichloroethane and 1,1- and 1,2-dichloroethane in the study area as determined by laboratory analyses.

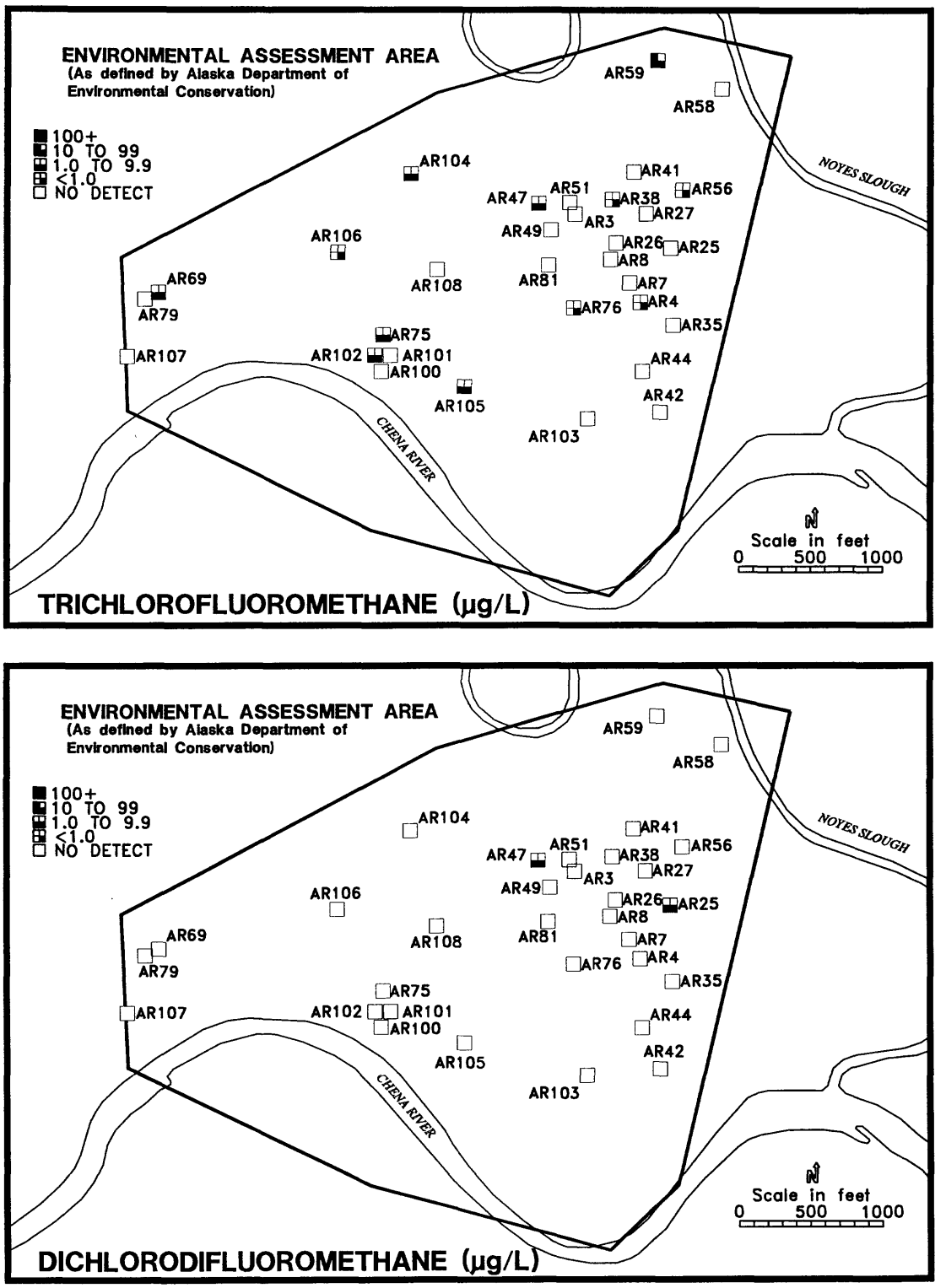


Figure 22. Distribution of trichlorofluoromethane and dichlorodifluoromethane in the study area as determined by laboratory analyses.

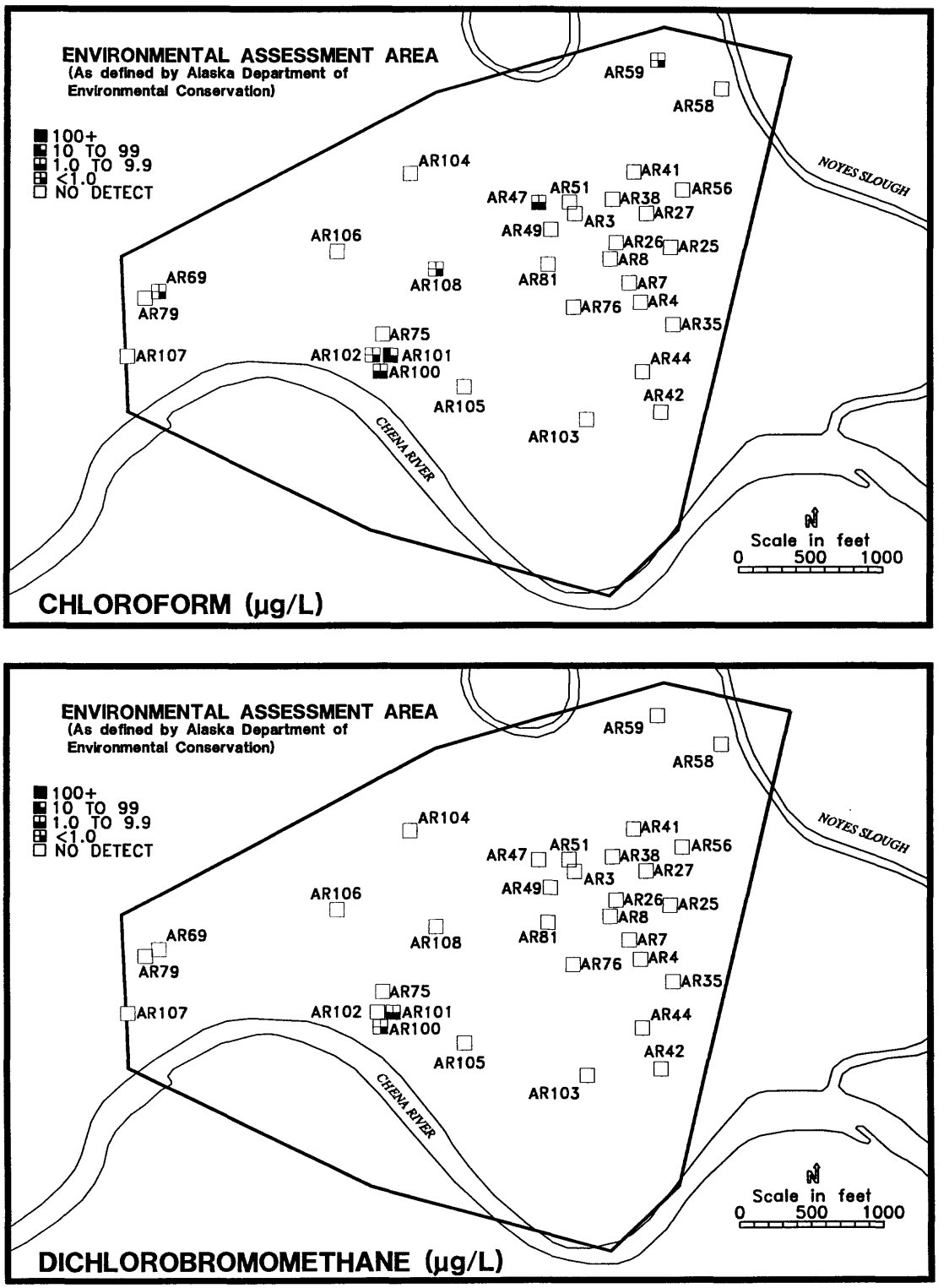


Figure 23. Distribution of chloroform and dichlorobromomethane in the study area as determined by laboratory analyses.

Inorganic constituents.—Water from 17 wells and 4 surface-water sites was analyzed for inorganic constituents (figs. 24 and 25) (Vohden, 1994). Previous work has shown that ground water throughout the Fairbanks area is of the calcium bicarbonate type (Nelson, 1978). Data collected during the current study show that both ground water and surface water within the study area are consistently of this type also (fig. 25) and water from all sites sampled, with the exception of well AR105, Daily News Miner, and the Tanana River, have highly similar chemical characteristics.

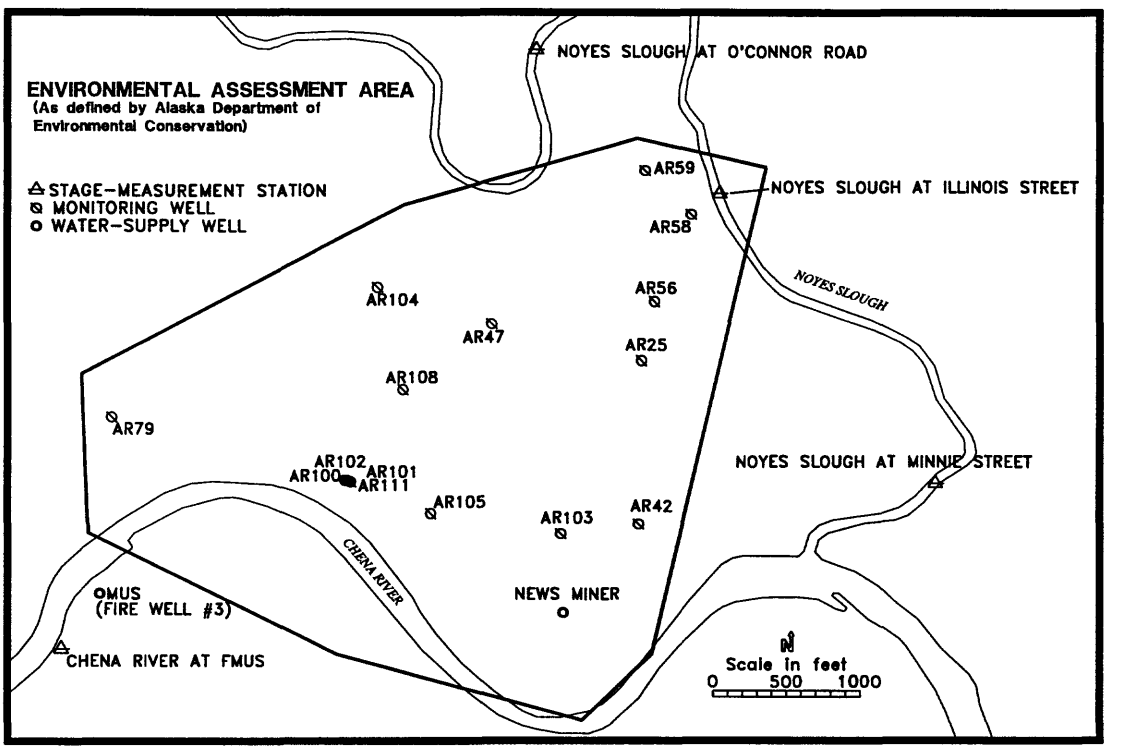


Figure 24. Ground- and surface-water locations sampled for inorganic analyses during August and September 1993.

Relative to other wells in the study area, water from well AR105 had high chloride and nitrate concentrations, high specific conductance, and a dark brown color. These characteristics are typical of ground water affected by waste water. It is possible that leakage from a nearby sewer line affected water quality in this well. Differences between the chemical composition of the sample from the Tanana River and samples from the other sites can be attributed to the large size of the Tanana basin; water in the river near the study area is a mixture of waters from the entire basin upstream from the study area and its chemical composition reflects the diversity of these waters. Conversely, the chemical composition of most of the ground water in the study area is a result of the interaction of the water with minerals in the local aquifer.

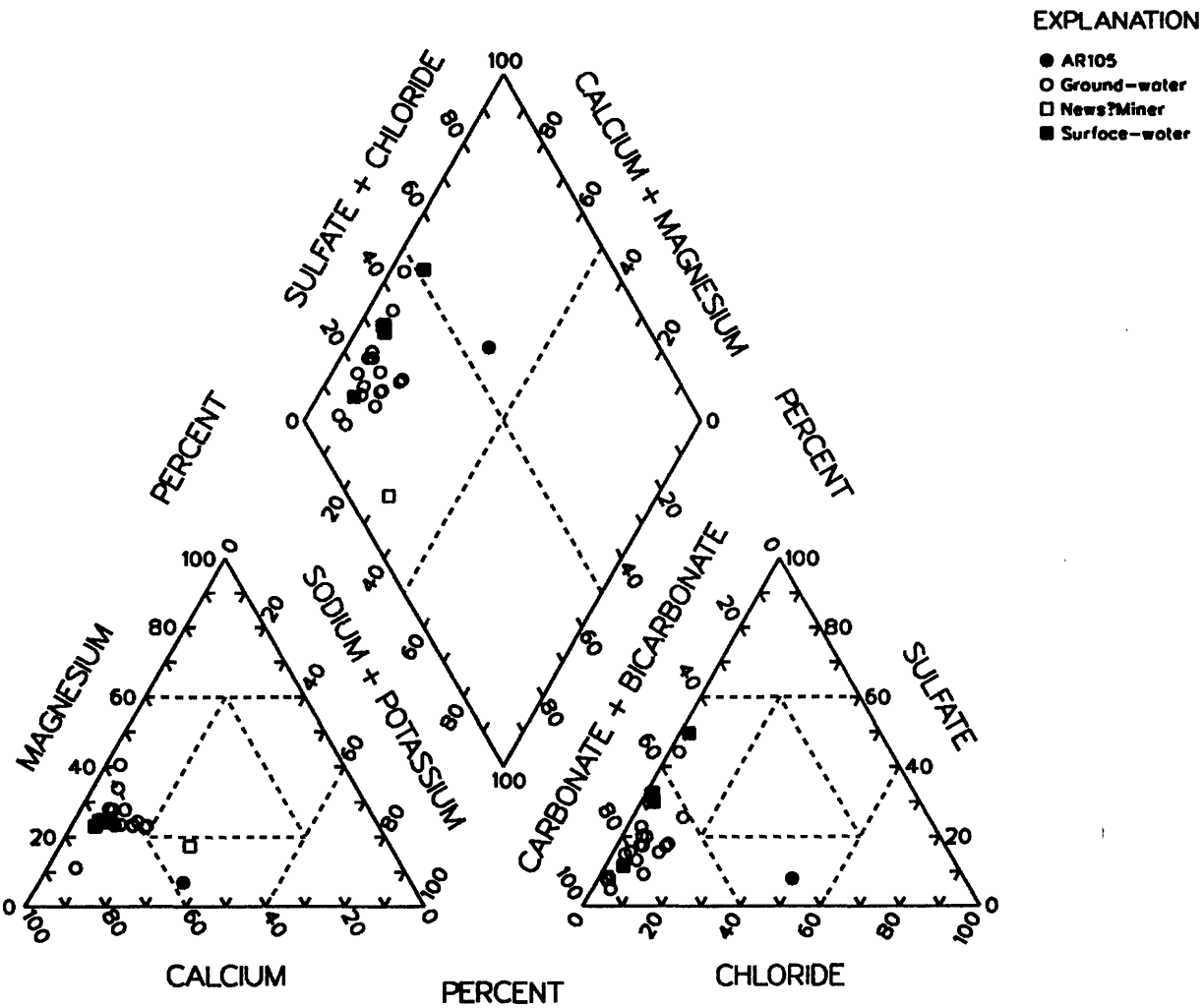


Figure 25. Major cations and anions in selected wells and surface-water sites.

Data from the cluster of wells AR100, AR101, AR102, and AR111, located near the center of the study area provide insight into the chemical variability of ground water with depth within the study area. These wells are located within 10 ft of one another horizontally and each is exposed to water at a different depth. Temperature, specific conductance, alkalinity, and concentrations of chloride, nitrate, sulfate, calcium, magnesium, sodium and potassium were higher and pH was lower in the sample from well AR102, the shallowest well in the cluster, than in samples from any of the other wells in the cluster (tables D-4, -5, and -6, Appendix D). In contrast to this observed trend, concentrations of chemical constituents in ground water commonly increase with depth because water at greater depth typically has followed a longer flow path. This longer flow path provides more time for the dissolution of aquifer materials to add chemical constituents to the ground water. Deep water also tends to be influenced to a lesser degree by precipitation, which may tend to dilute upper layers of shallow ground-water systems. The opposite pattern observed in the study area suggests that shallow ground-water chemistry is altered by the processes of evapotranspiration and vertical moisture redistribution associated with soil freezing, which tend to concentrate solutes in the unsaturated and shallow saturated zones.

SUMMARY AND CONCLUSIONS

Activities in the Railroad Industrial Area in Fairbanks, Alaska, have resulted in accidental releases of chemicals to the subsurface. Previous investigations, which indicated that petroleum hydrocarbons are present in ground water beneath the site, have generated concern regarding local ground-water quality and its potential impact on nearby water-supply wells and the Chena River. This ongoing study is being conducted to characterize the environmental and hydrologic conditions in the study area and to contribute to the development of the numerical subregional ground-water flow model. Data collection for the study is being coordinated with other environmental and hydrologic studies throughout the Fairbanks area so that data collected for all projects can be combined into an areawide data base. Numerical modeling efforts for area projects are also being coordinated to maximize model coverage. This coordination among projects will provide a more accurate and comprehensive understanding of conditions throughout the area.

During the first part of the study, existing reports from previous investigations in the area were reviewed and relevant information from these documents was compiled. All monitoring wells referenced in these reports were then located. To provide a more comprehensive data-collection network, 12 additional permanent wells and 33 drivepoints, which were later removed, were installed.

Water-surface elevations were measured approximately monthly at both ground- and surface-water sites. Selected sites were measured more frequently to assess short-term changes in the ground- and surface-water systems. Discharge data of the Tanana and Chena Rivers were available from long-term USGS stream-gaging stations. Supplementary discharge measurements were made on Noyes Slough and at additional sites on the Chena River to help characterize the interaction between ground water and surface water.

Ground water was sampled and analyzed to define the extent of the area affected by petroleum hydrocarbons and chlorinated solvents. In addition to these target compounds, water samples were analyzed for selected inorganic constituents to aid interpretation of the ground-water flow system, and for selected degradation products of the chlorinated solvents to help assess the fate of these compounds.

The ground-water system is affected by seasonal variations in the stage of the Chena River. During periods of high water levels in the Chena River, when river stage is above the nearby water table, the local ground-water system is recharged by the river. During periods of low water levels in the Chena River, this relation reverses and ground water discharges into the river. In the past, it is likely that pumping to dewater nearby gravel pits also affected the ground-water system by changing the magnitude and direction of the hydraulic gradients in the study area. The ground-water system typically has an upward flow component near the Chena River, but data indicate that this is reversed in the upper part of the aquifer during periods of high water levels in the Chena River. These periodic changes in the magnitude and direction of ground-water flow will influence the fate and transport of dissolved hydrocarbons in the subsurface.

Laboratory analyses showed that both petroleum hydrocarbons and chlorinated solvents are present in ground-water within the study area. The compounds are dispersed, with a concentration of chlorinated solvents in the northeast part of the study area and petroleum hydrocarbons concentrated near the center of the study area (fig. 26). Furthermore, the presence of compounds that are typical degradation products of chlorinated solvents suggests that biodegradation by indigenous microorganisms is occurring.

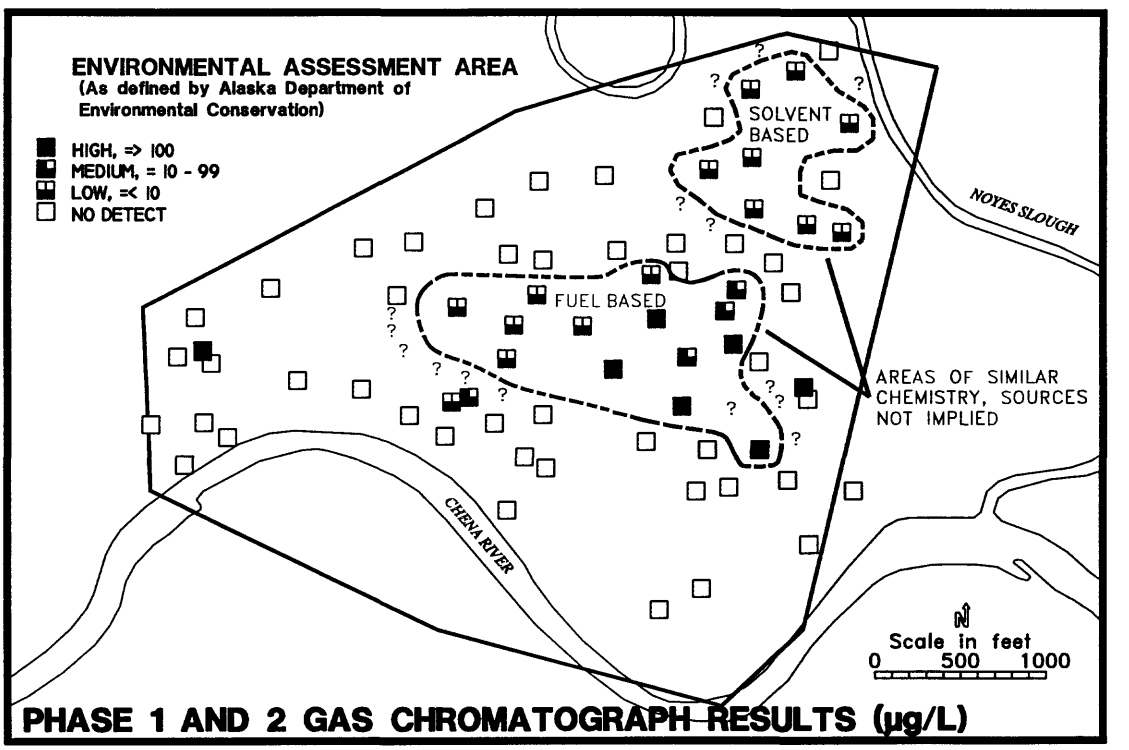


Figure 26. Zones of dissolved petroleum hydrocarbons and solvent-based compounds in the study area, August and September 1993.

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Alaska Department of Environmental Conservation, 1993, Drinking water regulations, 18 AAC 80: Juneau, Alaska, Title 18 Alaska Administration Code Chapter 80, 134 p.

Anderson, G.S., 1970, Hydrologic reconnaissance of the Tanana Basin, Central Alaska: U.S. Geological Survey Hydrologic Investigations Atlas HA-319, 4 sheets.

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Maurer, M.A., Ireland, R., and Vohden, J., 1994, Presentation of ground water and soil information collected in previous site investigations, Railroad Industrial Area, Fairbanks, Alaska: Alaska Division of Geological and Geophysical Surveys Public-Data File 94-49, 434 p.

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Péwé, T.L., Bell, J.W., Forbes, R.B., and Weber, F.R., 1976, Geologic map of the Fairbanks D-2 SW Quadrangle, Alaska: U.S. Geological Survey Miscellaneous Investigation Series Map I-829-A, scale 1:24000.

U.S. Coast and Geodetic Survey, 1966, Vertical control datum: U.S. Department of Commerce, Environmental Sciences Services Administration, 26 p.

Vohden, J., 1994, Water quality sampling for the Task 2 drilling and sampling extension of the subsurface and hydrologic field investigations in the railroad industrial area, Fairbanks, Alaska: Alaska Division of Geological and Geophysical Surveys, Public-Data File 94-38, 55 p.

APPENDIX A

Previously published environmental reports about the study area

Appendix A. Previously existing environmental reports about the study area.

Reports are numbered as they are received or obtained and processed. The numbering scheme does not indicate the author, date or intent of the report.

No. Report

67 Alaska Department of Environmental Conservation, 1992, Standard quality assurance program plan for underground storage tank systems: Fairbanks, Alaska, March. 67 p.

69 _____1992, Letter regarding quality assurance program plan for underground storage tank systems to Gilfilian Engineering, Fairbanks, Alaska, 2 p.

78 _____1994, Oil spill report, Fairbanks, Alaska, 53 p.

35 Alaska Petroleum Environmental Engineering Inc., 1991, Alaska Chevron Station underground storage tank site remediation quality assurance project plan 90-12015: Fairbanks, Alaska, variously paged.

45 _____1991, Alaska Chevron site characterization work plan 91-10013: Fairbanks Alaska, 6 p.

16 _____1992, Alaska Chevron, site characterization work plan: Fairbanks, Alaska, 11 p.

47 _____1992, Alaska Chevron revised site characterization work plan A-110132: Fairbanks, Alaska, 10 p.

36 _____1992, Results of the phase II environmental site investigation conducted at 333 Illinois Street: Fairbanks, Alaska, variously paged.

37 _____1992-93, Various short reports and memos pertaining to Dale's Alaska Chevron, 333 Illinois Street: Fairbanks, Alaska, variously paged.

46 _____1993, Alaska Chevron, Inc., Corrective action plan air sparging/vapor extraction system: Fairbanks, Alaska, 9 p.

41 America North Inc., 1990-1991, Alaska Gold USSR&M site; responses & reports pertaining to USSR&M site: Fairbanks, Alaska, variously paged.

27 _____1991, USSR&M site investigation report and proposed remedial plan: Nome, Alaska, variously paged.

40 America North/EMCON Inc., 1992, Remedial alternatives evaluation report USSR&M Site: Fairbanks, Alaska, variously paged.

39 _____1992, Workplan for excavation and disposal of contaminated soils USSR&M site: Fairbanks, Alaska, variously paged.

54 Bunch, Rufus, City of Fairbanks Engineering Dept., 1992, Site assessment for Municipal Utilities System Tank Farm Dike project: Fairbanks, Alaska, 8 p.

76 City of Fairbanks, 1969, Proposal to develop the Alaska Railroad Industrial area: Fairbanks, Alaska, 18 p.

79 Dames and Moore, 1993, Monitoring well installation, Minnie Street Land Users Group: Fairbanks, Alaska, 41 p.

19 Ecology and Environment, Inc., 1989, Site inspection report for USSR&M, Contract # 18-444-88: Fairbanks, Alaska, 26 p.

14 Environmental Systems, Inc., 1990, Nerlands property on Illinois St. - Gold Storage Room, project # UGVE-032: Fairbanks, Alaska, 6 p.

77 Fairbanks Metropolitan Area Transportation Study Policy Committee, 1985, Fairbanks Railroad Industrial area relocation: Fairbanks, Alaska, 63 p.

17 FPE/Roen Engineers, Inc., 1992, Alaska Gold building site, 612 Illinois Street, limited site sampling: Fairbanks, Alaska, 12 p.

62 Franklin & Allen Inc., 1985, MUS Chena Power Plant bulk fuel storage implementation plan: Fairbanks, Alaska, 41 p.

22 Gilfilian Engineering, Inc., 1991, UST removal environmental site assessment/groundwater characterization study for Kelly's Tire and Wheel, 269 Illinois Street: Fairbanks, Alaska, 13 p.

32 _____1991, Preliminary report on groundwater condition and proposed locations for additional groundwater monitoring wells at Kelly's Tire and Wheel: Fairbanks, Alaska, variously paged.

33 _____1992, Environmental site assessment/groundwater characterization study for Kelly's Tire & Wheel: Fairbanks, Alaska, 6 p.

20 _____1993, Site assessment report for Kelly's Tire & Wheels; 269 Illinois Street: Fairbanks, Alaska, 21 p.

68 _____1993, Letter to ADEC regarding proposed pilot test of air sparging and soil vapor extraction wells at Alaska Chevron: Fairbanks, Alaska, 3 p.

65 _____1993, Proposed corrective action plan for 1995 at Alaska Chevron: Fairbanks, Alaska, 7 p.

66 _____1993, CAP-Task 1 site assessment for UST removal on Alaska Chevron: Fairbanks, Alaska, 10 p.

72 _____1994, Quarterly ground-water characterization report, Alaska Chevron: Fairbanks, Alaska, 7 p.

52 Golden Valley Electric Assoc., 1993, Letter to ADEC and chemistry results for GVEA: Fairbanks, Alaska, 5 p.

75 _____1994, Letter to ADEC and chemistry results for GVEA, Fairbanks, Alaska, 9 p.

48 Lazenby, C., 1990, Historical resources along Illinois Street, Fairbanks, Alaska: University of Alaska Fairbanks, Department of Anthropology, 237 p.

10 Martech Construction, Inc., 1989, Tank closure site environmental assessment of the OK Lumber site location: Fairbanks, Alaska, variously paged.

4 James M. Montgomery Consulting Engineers, Inc., 1984, Municipal Utilities System Water Treatment Plant, City of Fairbanks: Alaska, 12 p.

53 _____1984, Hydrologic evaluation and aquifer test analysis, Municipal Utilities System: Fairbanks, Alaska, 12 p.

31 Nortech, 1993, Lucky Sourdough interim report: Fairbanks, Alaska, 17 p.

64 PTI Environmental Services, 1990, Transport of benzene in the unsaturated zone at the MUS Power Plant site: Fairbanks, Alaska, 18 p.

61 Radian Corporation, 1991, Recommended remedial alternative for contaminated soils, Municipal Utilities System: Fairbanks, Alaska, variously paged.

56 ROEN Design Associates, Inc. Geotechnical Consultants, 1989, Water system master plan, Municipal Utilities System: Fairbanks, Alaska, variously paged.

8 RZA-AGRA Engineering & Environmental Services, 1992, Phase I & II environmental site assessment; Alaska Railroad Corporation/Nerland Corporation leaseholds: Fairbanks, Alaska, variously paged.

26 _____1993, Preliminary report, GVEA RR/Industrial complex chemistry: Fairbanks, Alaska, 15 p.

49 _____1993, Monitoring well soil analytical results and GVEA purchasing orders: Fairbanks, Alaska, variously paged.

18 _____1993, Final report, Results of ground water sampling, Nerlands leasehold property: Fairbanks, Alaska, 5 p.

51 _____1993, Interim report, Subsurface investigation, GVEA: Fairbanks, Alaska, 44p.

57 Shannon & Wilson, Inc., 1987, Power plant petroleum spill cleanup project, Municipal Utilities System: Fairbanks, Alaska, 18 p.

13 _____1988, Progress report, Hydrocarbon recovery operations, Saupe Enterprises Bulk Plant: Fairbanks, Alaska, 6 p.

6 _____ 1988, Progress report, Hydrocarbon recovery operations, Saupe Enterprises Bulk Plant: Fairbanks, Alaska, 3 p.

7 _____1988, Installation of five new monitoring wells, Saupe Enterprises Bulk Plant: Fairbanks, Alaska, 16 p.

23 _____1989, Soil contamination investigation, Geist Road extension Illinois Street: Fairbanks, Alaska, variously paged.

1 _____1989, Preliminary hazardous waste site evaluation, proposed Minnie Street connector: Fairbanks, Alaska, 31 p.

44 _____1989, Soil sampling and installation of groundwater monitoring wells, Petroleum Sales: Fairbanks, Alaska, 10 p.

55 _____1990, Site contamination assessment report, MUS Power Plant petroleum product spill cleanup project: Fairbanks, Alaska, variously paged.

38 _____1990, Exploratory drilling and sampling program for Illinois Street widening and Minnie Street connector projects: Fairbanks, Alaska, 2 p.

34 _____1990, Monitoring of underground tank removal, 1733 Well Street: Fairbanks, Alaska, 12 p.

2 _____1990, Final report Illinois Street and Minnie Street connector, hazardous waste field investigations, phase II: Fairbanks, Alaska, 46 p.

12 _____1991, Contamination of a Municipal Well Field; A case history of a phased approach to site characterization and remediation: Fairbanks, Alaska, variously paged.

11 _____1991, Hazardous waste assessment; Illinois Street & Minnie Street Connector: Fairbanks, Alaska, 38 p.

5 _____1991, Installation of ground-water monitoring wells, 1733 Well Street: Fairbanks, Alaska, 3 p.

42 _____1991, Environmental studies regarding groundwater quality at Sourdough Express: Fairbanks, Alaska, 11 p.

29 _____1991, Monitoring removal of underground fuel storage tank at Sig Wold Storage and Transfer Inc., 1301 Well St.: Fairbanks, Alaska, 15 p.

25 _____1991, Project work plans Illinois Street contaminated soil removal plan: Fairbanks, Alaska, 22 p.

24 _____1991, Contaminated soil removal, Illinois Street right of way: Fairbanks, Alaska, variously paged.

28 _____1991, Underground storage tank closure and site assessment, Sourdough Express, 600 Driveway Street: Fairbanks, Alaska, 11 p.

3 _____1992, Preliminary assessment of potential off-site hydrocarbon source, Municipal Utilities System, Fire Well 3: Fairbanks, Alaska, 20 p.

60 _____ 1992, Environmental drilling and laboratory services, MUS Power Plant: Fairbanks, Alaska, 5 p.

21 _____1992, Geist/Johansen Expressway, Illinois Street hazardous waste investigation: Fairbanks, Alaska, 17 p.

30 _____1992, Project work plans release investigation Sig Wold Storage and Transfer, Inc. UST Site: Fairbanks, Alaska, 12 p.

50 _____1993, Release investigation, Sig Wold Storage And Transfer, 1301 Well St., Fairbanks, Alaska, April 26, 24 p.

73 _____1994, Release investigation, Sig Wold Storage and Transfer, Inc.: Fairbanks, Alaska, 13 p.

70 _____1994, Well logs for monitoring wells at Saupe Enterprises: Fairbanks, Alaska, variously paged.

71 _____1994, Data showing impact of gravel pit dewatering on ground-water levels in the Minnie Street area: Fairbanks, Alaska, 9 p.

74 _____1994, Work plan, preliminary site investigation Phillips Field Road upgrade, Fairbanks, Alaska, 19 p.

43 State of Alaska Department of Highways Materials Section, 1967, Materials report, College Road project no. F037-1(20) Fairbanks district: Fairbanks, Alaska, 55 p.

15 Swan Drilling, 1986, Drilling logs and well measurements at Willner's Texaco: Fairbanks Alaska, 5 p.

59 URS Corporation, 1987, Water Treatment Plant water supply development project: Fairbanks, Alaska, 88 p.

63 VRCA Environmental Services Inc., 1991, MUS Power Plant monitoring well installation: Fairbanks, Alaska, variously paged.

9 Woodward-Clyde Consultants, 1988, Fairbanks fuel facility: Fairbanks, Alaska, 46 p.

58 _____1991, Environmental audit, Municipal Utilities System garage/warehouse: Fairbanks, Alaska, variously paged.

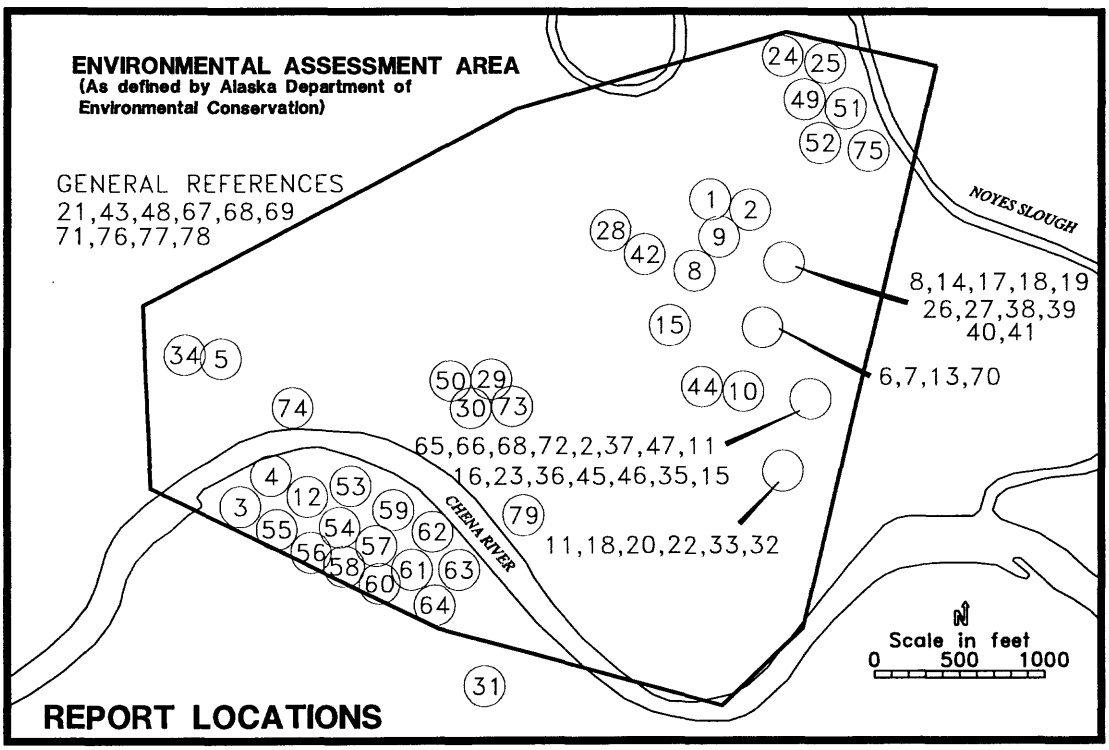


Figure A-1. Locations of study areas addressed in existing environmental reports.

Table A-1. Current well designations cross referenced to historical designations and original report in which each well is discussed. [NA, not available]

This report well ID	Other report well ID	Report number (appendix A)	This report well ID	Other report well ID	Report number (appendix A)	This report well ID	Other report well ID	Report number (appendix A)
AR1	GW-123	2	AR38	MW-4	27	AR75	MW-3	50
AR2	GW-128	2	AR39	MW-3	27	AR76	NA	NA
AR3	GW-116	2	AR40	PR-1	27	AR77	NA	NA
AR4	GW-115	2	AR41	PR-2	27	AR78	NA	NA
AR5	GW-114	2	AR42	K-1	33	AR79	MW-2	5
AR6	PW-113	2	AR43	K-2	33	AR80	NA	NA
AR7	PW-112	2	AR44	K-3	33	AR81	Well 2	15
AR8	GW-111	2	AR45	NA	44	AR82	Well 4	15
AR9	PW-110	2	AR46	MW-42	44	AR83	NA	NA
AR10	PW-109	2	AR47	MW-1	42	AR84	NA	NA
AR11	PW-108	2	AR48	MW-2	42	AR85	Well 1	15
AR12	PW-107	2	AR49	MW-3	42	AR86	MW-21	NA
AR13	PW-106	2	AR50	MW-4	42	AR87	MW-22	NA
AR14	PW-105	2	AR51	MW-5	42	AR88	MW-23	NA
AR15	PW-104	2	AR52	MW-1	51	AR89	MW-24	NA
AR16	GW-101	2	AR53	MW-2	51	AR90	MW-25	NA
AR17	MW-25	3	AR54	MW-3	51	AR91	MW-41	44
AR18	MW-26	3	AR55	MW-4	51	AR92	Well 3	15
AR19	MW-27	3	AR56	MW-5	51	AR93	Well 5	15
AR20	MW-28	3	AR57	MW-6	51	AR94	Well 6	15
AR21	MW-29	3	AR58	MW-7	51	AR95	MW-17	NA
AR22	MW-30	3	AR59	Zehnder	51	AR96	MW-7	NA
AR23	MW-31	3	AR60	NA	NA	AR97	NA	NA
AR24	MW-32	3	AR61	NA	NA	AR98	MW-16	12
AR25	MW-1	8	AR62	NA	NA	AR99	DW-3	3
AR26	MW-2	8	AR63	NA	NA	AR100	NA	79
AR27	MW-3	8	AR64	NA	NA	AR101	NA	79
AR28	M-1	34	AR65	NA	NA	AR102	NA	79
AR29	MW-K4	20	AR66	NA	NA	AR103	NA	79
AR30	B-6	23	AR67	NA	NA	AR104	NA	79
AR31	B-7	23	AR68	NA	NA	AR105	NA	79
AR32	B-9	23	AR69	MW-1	5	AR106	NA	79
AR33	B-10	23	AR70	N/A	N/A	AR107	NA	NA
AR34	AKC-B1	36	AR71	N/A	N/A	AR108	NA	NA
AR35	AKC-B2	36	AR72	USGS	NA	AR109	NA	NA
AR36	AKC-B3	36	AR73	MW-1	50	AR110	NA	NA
AR37	AKC-B4	36	AR74	MW-2	50	AR111	NA	79

APPENDIX B

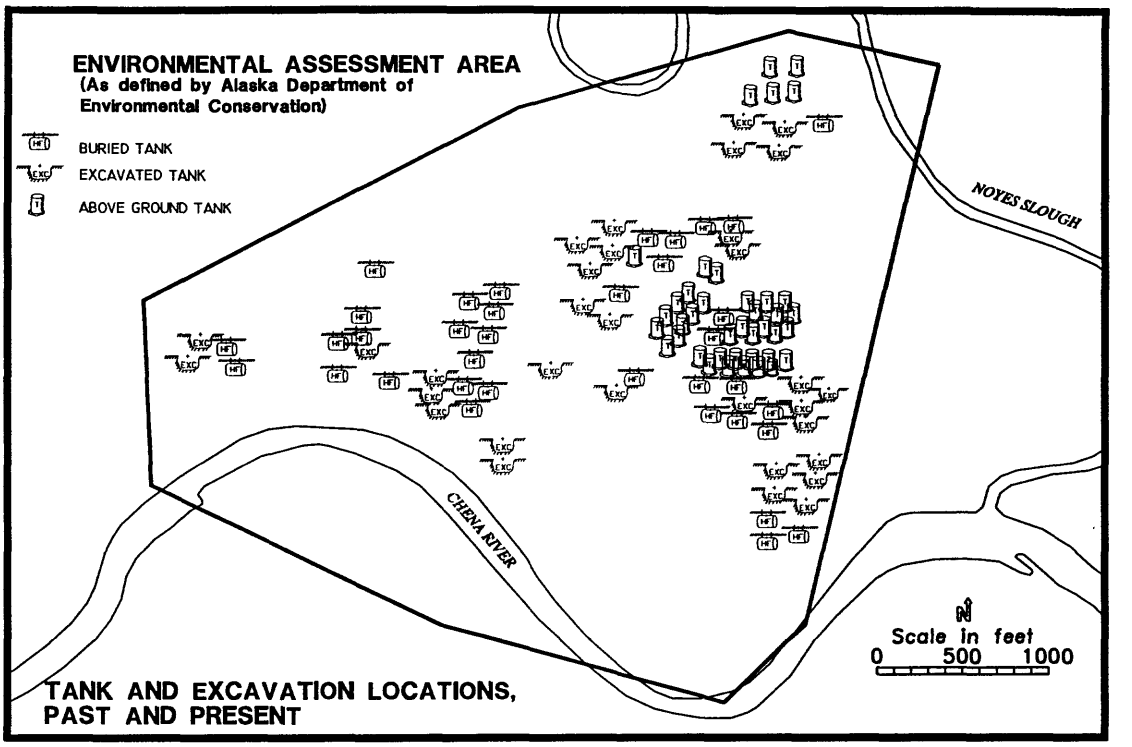
Historical spills in the study area

Table B-1. Historical chemical-spill information (ADEC, written commun., 1993)

Responsible Party	Spill number	Date	Location	Type
Odom Company	81310105401	02/23/81	1700 Well St.	gasoline
Alaska Railroad	81310108201	03/23/81	Illinois St.	aviation fuel
Alaska Railroad/ARCO	81310929501	10/22/81	Philips Field Rd.	acid
Halliburton Services	81310931401	11/10/81	unknown	
Texaco	83310109501	04/05/83	Bulk storage	fuel oil
Saupe Enterprises	85310128301	10/10/85	419 Illinois St.	gasoline
Alaska Railroad	86310117702	06/26/86	Fairbanks Industrial area	gasoline
Willner's Texaco	87310126501	09/22/87	Railroad yard	antifreeze/oil/water
Fbks. North Star School District	88310101201	01/12/88	Minnie St.	gasoline
Alaska Railroad	88310109902	04/08/88	Fairbanks yard	gasoline
Alaska Railroad	88310109901	04/08/88	Industrial area	gasoline
Alaska Railroad	88310111601	04/25/88	Fairbanks yard	Jet-A fuel
City of Fairbanks Police	88310114001	05/19/88	West part of FRIA	
Alaska Railroad	88310116602	06/14/88	Fairbanks yard	gasoline
Alaska Railroad	88310116601	06/14/88	Fairbanks yard	gasoline
Alaska Railroad	88310117307	06/21/88	Tank car	gasoline
Alaska Railroad	88310117301	06/21/88	Fairbanks yard	gasoline
Alaska Railroad	89310101601	01/16/89	Fairbanks yard	Jet-A fuel
Halliburton Services	89310905802	02/27/89	Alaska Railroad scale	acid
Chevron Service Station	89310113804	05/18/89	Illinois/Minnie St.	
Kelly Firestone	89310114501	05/25/89	269 Illinois St.	gasoline
Municipal Utilities System	89310115301	06/02/89	#2 Power plant	
Municipal Utilities System	89310115302	06/02/89	Power plant	diesel
Craig Taylor Equipment	8931022701	08/15/89	1409 Well St.	diesel
Craig Taylor Equipment	89310122702	08/15/89	1733 Well St.	gasoline
Alaska Railroad	89310934701	12/13/89	Peger Rd./Fairbanks yard	corrosion inhibitor
Saupe Enterprises	90310121502	08/02/90	418 Illinois St.	aviation fuel
Alaska Railroad	92310111204	05/01/92	Fairbanks yard	hydraulic oil
Petroleum Sales	92310122002	08/07/92	Illinois St.	fuel oil
Alaska Railroad	93310126301	09/20/93	Industrial area	engine lubricant
Alaska Railroad	93310126601	09/23/93	Fairbanks yard	engine lubricant
Fairbanks North Star Borough	94310101401	01/14/94	FMUS power plant	gasoline

Table B-2. Alaska Department of Environmental Conservation contaminated sites (ADEC, written commun., 1993)

Location	Nature of contamination
1204 First Ave.	Benzene detected in water samples in 1981 Leakage Detected in 4 UST in 1987
1205 First Ave.	Spillage of transformer oil
1301 Well St.	Soil and possible ground-water contamination
138 Minnie St.	ground-water contamination
1733 Well St.	Soil and ground-water contamination by diesel fuel
223 Illinois St.	Soil samples exceeded cleanup levels for DRPH
269 Illinois St.	Subsurface hydrocarbon contamination gasoline detected in ground-water
272 Illinois St.	Soil contamination exists beneath building foundation
328.5 Illinois St.	High levels of petroleum contamination in soil Hydrocarbons and various solvents in ground-water
333 Illinois St.	Gasoline found in soil and ground-water
410 Driveway St.	Floating hydrocarbon on water table, hydrocarbon contaminated soils
418 Illinois St.	Diesel leaked to soil and ground-water, floating hydrocarbon found on water table
512 Illinois St.	Hydrocarbon contamination in soil near ground-water extensive
600 Driveway St.	Contaminated ground-water from leaking UST pipes
600 Driveway St.	Elevated levels of arsenic and mercury in soil
612 Illinois St.	Arsenic, cadmium, lead, mercury, silver, PCB's
NE corner of Driveway St.	Soil and water sampling revealed high levels of hydrocarbons
Minnie St.	High levels of hydrocarbon in soil and ground-water



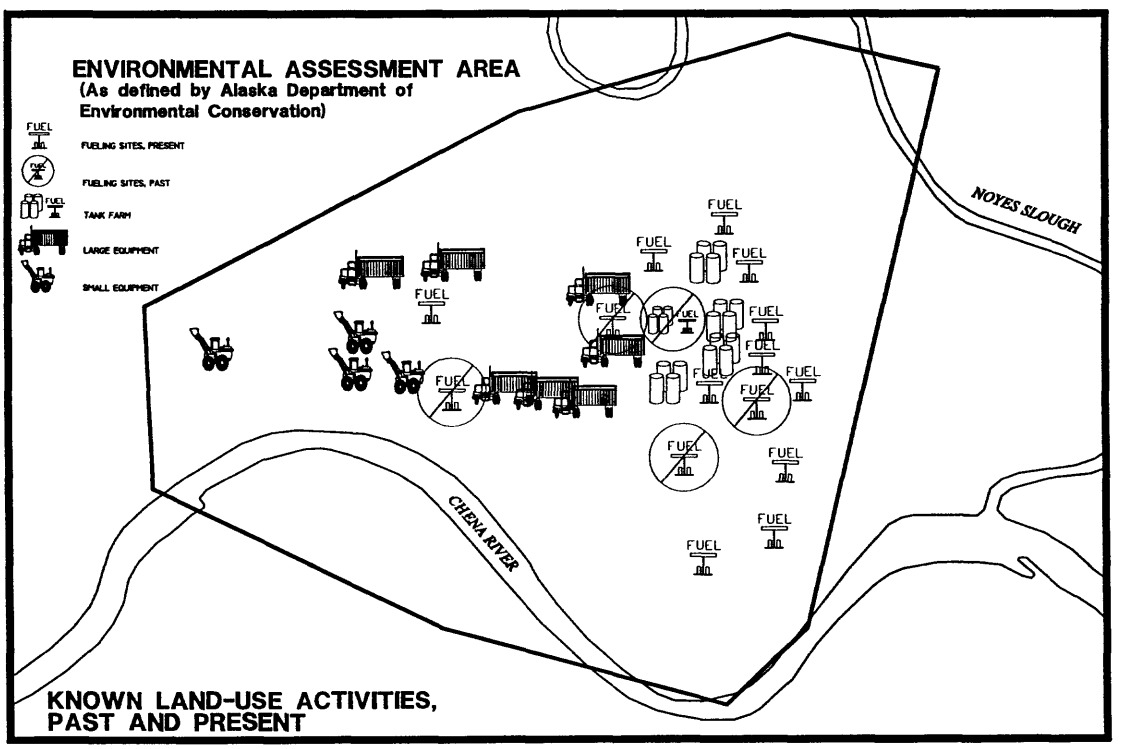


Figure B-1. Locations of A) historical tank and excavation locations and B) known land-use activities in the study area through summer 1993.

APPENDIX C

Survey data for ground-water data-collection sites

Table C-1. Vertical and horizontal controls of observation wells in the Alaska Railroad Industrial Area
[MP, measuring point; NA, not available; FMUS, Fairbanks Municipal Utilities System; GVEA, Golden Valley Electric Association; RR, railroad]

Horizontal Datum					Vertical Datum		
This report well ID (plate 1)	Latitude	Longitude	X East	Y North	MP elevation	Ground elevation	Location
AR1	645005	1474311	232599.8	3968336.5	440.36	440.5	Kelly Tire, in street
AR2	645059	1474302	232752.6	3968784.2	439.56	439.9	Chevron
AR3	645107	1474317	232100.8	3969578.1	440.62	438.1	Suburban Propane
AR4	645101	1474306	232559.6	3968964.5	439.69	436.9	Texaco storage yard
AR5	NA	NA	NA	NA	NA	NA	Texaco storage yard
AR6	NA	NA	NA	NA	NA	NA	Saupe
AR7	645102	1474308	232483.1	3969100.9	440.08	437.7	Saupe
AR8	645104	1474311	232348.1	3969264.6	440.19	NA	Saupe
AR9	645106	1474316	232161.8	3969491.6	438.24	438.4	Suburban Propane
AR10	645104	1474314	232249.1	3969291.6	439.23	NA	Texaco storage yard
AR11	645104	1474313	232293.4	3969290.4	436.89	437.0	RR tracks
AR12	645105	1474315	232196.6	3969399.7	NA	438.7	Suburban Propane
AR13	645105	1474313	232274.3	3969420.2	438.21	NA	Suburban Propane
AR14	645104	1474314	232229.3	3969282.6	437.81	438.0	Suburban Propane
AR15	645106	1474315	232212.5	3969494.7	440.81	437.8	Suburban Propane
AR16	645103	1474320	231985.4	3969617.2	437.32	437.4	Sourdough Express
AR17	645050	1474417	229482.9	3967989.9	439.05	NA	FMUS
AR18	645049	1474417	229473.7	3967885.9	433.87	NA	FMUS
AR19	645047	1474411	229740.1	3967698.5	434.91	435.0	Badger Street
AR20	645047	1474411	229741.0	3967693.9	434.99	435.0	Badger Street
AR21	NA	NA	NA	NA	NA	NA	Downtown location
AR22	NA	NA	NA	NA	NA	NA	Downtown location
AR23	NA	NA	NA	NA	NA	NA	Downtown location
AR24	NA	NA	NA	NA	NA	NA	Downtown location
AR25	645104	1474302	232770.7	3969343.7	442.44	439.5	GVEA near Nerlands
AR26	645105	1474311	232387.5	3969378.6	440.25	437.7	GVEA near Nerlands
AR27	645107	1474306	232600.3	3969579.7	441.51	439.0	GVEA near Nerlands
AR28	645100	1474423	229269.1	3968990.4	434.43	NA	Craig Taylor
AR29	645055	1474304	232668.2	3968400.3	440.29*	NA	Kelly Tire
AR30	NA	NA	NA	NA	NA	NA	Kelly Tire
AR31	645055	1474303	232676.2	3968350.7	439.96	440.6	Kelly Tire
AR32	645059	1474300	232825.7	3968796.5	438.85	439.6	Chevron Station
AR33	645059	1474300	232815.7	3968759.6	440.09	440.4	Chevron Station
AR34	645058	1474302	232739.1	3968713.6	440.59	440.8	Chevron Station
AR35	645059	1474301	232788.5	3968807.1	439.30	439.6	Chevron Station
AR36	645059	1474300	232840.4	3968741.6	440.49	440.8	Chevron Station
AR37	645058	1474259	232891.8	3968723.6	441.28	441.5	Chevron Station
AR38	645108	1474311	232362.2	3969679.1	440.70	438.2	Alaska Gold
AR39	645108	1474307	232552.2	3969664.9	441.65	439.1	Alaska Gold
AR40	645110	1474309	232460.7	3969912.9	441.17	438.1	Alaska Gold

Table C-1. Vertical and horizontal controls of observation wells in the Alaska Railroad Industrial Area -- Continued
[MP, measuring point; NA, not available; FMUS, Fairbanks Municipal Utilities System; GVEA, Golden Valley Electric Association; RR, railroad]

Horizontal Datum					Vertical Datum		
This report well ID (plate 1)	Latitude	Longitude	X East	Y North	MP elevation	Ground elevation	Location
AR41	645110	1474308	232511.3	3969871.4	441.42	438.0	Alaska Gold
AR42	645053	1474303	232701.3	3968197.1	439.93	440.5	Kelly Tire
AR43	645053	1474305	232596.0	3968181.1	439.89	440.1	Kelly Tire
AR44	645052	1474304	232572.4	3968482.3	439.68	439.8	Ace Hardware
AR45	645100	1474316	232153.0	3968889.5	440.58	438.2	Petroleum Sales
AR46	645058	1474319	232071.2	3968719.9	436.07*	436.1	Petroleum Sales
AR47	645107	1474323	231935.2	3969466.2	438.07	438.3	Sourdough Express
AR48	645108	1474324	231810.2	3969724.5	437.25	437.6	Sourdough Express
AR49	645105	1474321	231934.0	3969467.7	439.31	437.0	Sourdough Express
AR50	645106	1474320	232000.0	3969553.7	437.33	437.4	Sourdough Express
AR51	645107	1474318	232062.3	3969659.7	436.86	437.4	Sourdough Express
AR52	645112	1474326	231756.6	3970115.5	438.53	435.9	GVEA
AR53	645111	1474314	232276.0	3970041.7	440.42	437.4	GVEA
AR54	645114	1474326	232174.3	3970366.9	439.59	436.9	GVEA
AR55	645112	1474309	232468.8	3970137.7	439.16	436.5	GVEA
AR56	645108	1474300	232853.0	3969746.7	441.08	438.2	GVEA
AR57	645110	1474257	232973.3	3969950.3	NA	439.9	GVEA
AR58	645115	1474254	233124.2	3970451.7	440.31	437.5	GVEA
AR59	645117	1474305	232678.0	3970650.2	440.10	437.6	GVEA
AR60	645058	1474225	234355.0	3968685.7	439.17	NA	Minnie Street
AR61	645059	1474224	234186.8	3968764.3	438.01	NA	Minnie Street
AR62	645058	1474226	234306.0	3968664.6	438.61	438.7	Minnie Street
AR63	645059	1474230	234142.5	3968712.8	NA	439.9	Minnie Street
AR64	645058	1474234	233943.5	3968711.3	438.18	438.2	Minnie Street
AR65	645042	1474251	233174.0	3967022.6	437.84	437.7	Aurora Motors
AR66	645041	1474249	232501.1	3968183.9	438.68	438.5	Aurora Motors
AR67	NA	NA	NA	NA	NA	NA	Aurora Motors
AR68	645100	1474421	229341.0	3968945.0	436.62	436.1	Craig Taylor
AR69	645100	1474424	229200.2	3969037.5	434.44	434.9	Craig Taylor
AR70	645101	1474300	232857.8	3968944.3	NA	NA	FC1-1-3DDCC1-5
AR71	645116	1474245	233547.3	3970450.3	NA	NA	FC1-1-3DADB1-7
AR72	645101	1474250	233298.6	3967110.2	437.91	NA	1st Avenue on median
AR73	645058	1474346	230822.3	3968785.1	438.13	438.3	Sig Wold Property
AR74	645058	1474348	230773.6	3968787.9	437.61	437.9	Sig Wold Property
AR75	645058	1474348	230763.6	3968739.8	437.87	438.2	Sig Wold Property
AR76	645101	1474317	232090.8	3968927.4	436.92	436.9	Well on RR tracks
AR77	645102	1474316	232161.7	3969052.0	436.52	NA	Well on RR tracks
AR78	645100	1474426	229212.0	3969026.9	NA	NA	Craig Taylor
AR79	645100	1474426	229105.0	3968990.9	434.60	434.7	Craig Taylor
AR80	645101	1474307	232518.9	3968996.9	438.18	NA	Under Oil Rd. pavement

Table C-1. Vertical and horizontal controls of observation wells in the Alaska Railroad Industrial Area -- Continued
[MP, measuring point; NA, not available; FMUS, Fairbanks Municipal Utilities System; GVEA, Golden Valley Electric Association; RR, railroad]

Horizontal Datum					Vertical Datum		
This report well ID (plate 1)	Latitude	Longitude	X East	Y North	MP elevation	Ground elevation	Location
AR81	645103	1474321	231916.4	3969225.9	437.09	437.1	Texaco storage yard
AR82	645104	1474314	232259.5	3969303.7	437.48	NA	Texaco storage yard
AR83	645103	1474312	232202.0	3969491.6	440.47	NA	Saupe
AR84	645058	1474228	234205.4	3968621.1	438.51	438.6	Clara Street
AR85	645104	1474320	231979.2	3969346.2	437.31	NA	Texaco Storage Yard
AR86	645104	1474310	232454.2	3969285.3	439.86	438.4	Saupe
AR87	NA	NA	NA	NA	NA	NA	Saupe
AR88	645104	1474312	232352.0	3969275.2	438.31	437.0	Saupe
AR89	NA	NA	NA	NA	NA	NA	Saupe
AR90	645104	1474311	232399.9	3969147.7	440.79	NA	Saupe - 12" casing
AR91	645059	1474317	232119.1	3968796.0	439.80	NA	Petroleum Sales
AR92	NA	NA	NA	NA	NA	NA	Texaco storage yard
AR93	NA	NA	NA	NA	NA	NA	Texaco storage yard
AR94	NA	NA	NA	NA	NA	NA	Texaco storage yard
AR95	645103	1474315	232208.9	3969166.4	435.53	435.9	Well on RR tracks
AR96	645104	1474311	232372.2	3969238.7	440.21	NA	Saupe
AR97	645103	1474545	225738.2	3969322.1	440.97	437.5	Johansen Overpass
AR98	NA	NA	NA	NA	NA	NA	Well at FMUS
AR99	NA	NA	NA	NA	NA	NA	NA
AR100	645057	1474349	230728.9	3968595.7	440.82	438.9	FMUS coal transfer
AR101	645057	1474348	230772.2	3968594.5	440.70	439.3	FMUS coal transfer
AR102	645057	1474349	230728.9	3968595.7	440.92	438.5	FMUS coal transfer
AR103	645053	1474315	232187.4	3968149.4	440.79	438.3	Railroad depot station
AR104	645110	1474345	230954.0	3969863.0	440.31	437.2	Eielson branch of RR
AR105	645055	1474335	231328.0	3968376.1	441.49	438.2	Heat Inc.
AR106	645104	1474356	230445.0	3969315.0	438.74	435.7	H&S
AR107	645056	1474429	228982.2	3968587.1	438.74	436.7	Alaska RR yard
AR108	645103	1474340	231134.6	3969194.5	438.40	436.4	Bourough warehouse
AR109	645115	1474319	232083.0	3970370.0	441.94	440.1	Eielson branch of RR
AR110	645119	1474259	232971.0	3970777.0	436.62	434.6	Eielson branch of RR
AR111	645057	1474348	230750.0	3968554.0	441.16	439.0	FMUS coal transfer

APPENDIX D

Results of chemical analyses

Appendix D. Results of chemical analyses.

The results of all laboratory and field chemical analyses are presented in this appendix. Results of organic analyses done at USGS laboratories are reported in table D-1. Comparison of BTEX analyses from USGS and Enseco laboratories are presented in table D-2 and figure D-1. Results of inorganic analyses are reported in tables D-3, D-4, and D-5. Quality-control data are summarized in table D-6.

Comparison of data from USGS & Enseco laboratories.—Analyses were done by both the USGS and Enseco Laboratories in Arvada, Colorado. Results of duplicate analyses by the two laboratories agreed well (fig. D-1). There are several possible reasons for the differences that do exist. First, samples sent to the Enseco laboratory were preserved with acid prior to shipping, and those sent to the USGS laboratory were not. Second, the two laboratories follow slightly different methods of analyses for these compounds—Enseco follows U.S. Environmental Protection Agency (USEPA) methods 413.1 and 418.1 and the USGS follows USEPA method 524.2. Finally, for the calibration of equipment for analyses of low-concentration samples, the USGS laboratory uses standards with concentrations at the reporting level of each compound whereas the Enseco laboratory uses higher-concentration standards.

The greatest discrepancies in analytical results from the two laboratories were detected in samples from well AR49 (tables D-1 and D-2; refer to samples AR49 and AR49-dup). Neither benzene nor toluene was detected in samples AR49 or AR49-dup analyzed at the USGS laboratory. However, a concentration of more than 10 µg/L of these compounds was detected in samples AR49 and AR49-dup analyzed at the Enseco laboratory. The lower concentration in the sample sent to the USGS laboratory may have been the result of microbial degradation; acid preservation of samples sent to the Enseco laboratory would have inhibited similar degradation in the Enseco sample. In the future, all samples will be preserved with acid and analyzed by the method used in the USGS laboratory.

Quality-control data.—No target compounds were detected in any of the three trip blanks. Some of the equipment blanks indicated slight cross contamination among samples; however, no cross contamination was detected in the wells sampled with copper bailers. For example, on the first day of sampling, before any samples had been collected, 0.3 µg/L of trichlorofluoromethane was detected in a blank collected from a cleaned bailer. On the second day of the sampling, 0.3 µg/L of toluene and xylene was detected in a sample collected from a cleaned bailer (table D-6). However, these concentrations are near the detection level and, therefore, did not pose a problem to the interpretation of the data. Nonetheless, future samples will be collected using disposable Teflon bailers, except in the 1.25-inch wells where copper bailers will continue to be used, to minimize cross contamination among wells and to reduce the amount of waste hexane and methanol generated by the cleaning of equipment.

Concentrations of BTEX compounds detected in an equipment blank on the third day of sampling were high enough to indicate a potential problem. However, concentrations of BTEX compounds in samples collected after this equipment blank indicate that these samples were not compromised.

Agreement between duplicate sample pairs collected for organic (table D-6) and inorganic (tables D-4 and D-5) constituents during the two-week sampling period, and agreement between the field and laboratory results show that the quality of the data is good.

Table D-1. Concentrations of organic compounds in ground water samples analyzed at the U.S. Geological Survey laboratory
[Values in micrograms per liter; <, less than; Eq., equipment; dup, duplicate; * , no indication of organic constituents; all constituents are totals, unfiltered, recoverable]

	Sampling site ID								
	AR79	**AR47**	**AR58**	**AR42***	**AR25**	**AR59**	**AR27***	**AR56**	**AR38**
Date Sampled:	08/30/93	08/30/93	08/31/93	08/31/93	08/31/93	08/31/93	08/31/93	08/31/93	08/31/93
Constituent **Time Sampled:**	1815	1940	0902	0940	1104	1230	1315	1330	1413
Dichlorobromomethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Carbontetrachloride	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,2-Dichloroethane	**0.2**	**0.2**	**0.2**	<0.2	<0.2	<0.2	<0.2	**0.5**	**0.6**
Bromoform	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chlorodibromomethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chloroform	<0.2	**1.0**	<0.2	<0.2	<0.2	**0.2**	<0.2	<0.2	<0.2
Toluene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzene	<0.2	<0.2	**0.2**	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chlorobenzene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Methylenechloride	<0.2	**0.2**	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Tetrachloroethylene	<0.2	**0.9**	**0.3**	<0.2	<0.2	**6.5**	<0.2	**16.0**	**0.9**
Trichlorofluoromethane	<0.2	**5.2**	<0.2	<0.2	<0.2	**19.0**	<0.2	**0.5**	**0.3**
1,1-Dichloroethane	**0.2**	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	**0.2**	**0.2**
1,1-Dichloroethylene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,1,1-Trichloroethane	<0.2	<0.2	**0.2**	<0.2	<0.2	**0.7**	<0.2	**0.2**	**0.2**
Benzene, o-chloro	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,2-Dichloropropane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,2-Transdichloroethene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzene, 1,3-dichloro	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzene, 1,4-dichloro	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Dichlorodifluoromethane	<0.2	**1.2**	<0.2	<0.2	**7.2**	<0.2	<0.2	<0.2	<0.2
Vinylchloride	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Trichloroethylene	<0.2	<0.2	**2.2**	<0.2	<0.2	<0.2	<0.2	**0.8**	<0.2
Cis-1,2-dichloroethene	<0.2	<0.2	**1.4**	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Styrene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Freon 113	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Xylenes	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Table D-1. Concentrations of organic compounds in ground water samples analyzed at the U.S. Geological Survey laboratory -- Continued
[Values in micrograms per liter; <, less than; Eq., equipment; dup, duplicate; * , no indication of organic constituents; all constituents are totals, unfiltered, recoverable]

	Sampling site ID								
	AR49	**AR49-dup**	**AR51**	**AR81**	**AR4**	**AR3**	**AR26**	**AR41**	**AR75**
Date Sampled:	08/31/93	08/31/93	08/31/93	08/31/93	08/31/93	08/31/93	08/31/93	08/31/93	08/31/93
Constituent Time Sampled:	1445	1446	1511	1537	1648	1711	1725	1750	1830
Dichlorobromomethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Carbontetrachloride	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,2-Dichloroethane	**0.6**	**0.6**	**0.6**	<0.2	**0.6**	**0.8**	<0.2	**0.5**	<0.2
Bromoform	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chlorodibromomethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chloroform	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	<0.2	<0.2	<0.2	**6.2**	<0.2	<0.2	<0.2	<0.2	<0.2
Benzene	<0.2	<0.2	**0.5**	**150.0**	<0.2	<0.2	**28.0**	<0.2	<0.2
Chlorobenzene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	<0.2	<0.2	<0.2	**110.0**	<0.2	<0.2	<0.2	<0.2	<0.2
Methylenechloride	<0.2	<0.2	**0.3**	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Tetrachloroethylene	<0.2	<0.2	<0.2	<0.2	**0.3**	**0.2**	<0.2	**11.0**	**6.0**
Trichlorofluoromethane	<0.2	<0.2	<0.2	<0.2	**0.2**	<0.2	<0.2	<0.2	**2.8**
1,1-Dichloroethane	**0.2**	**0.2**	<0.2	<0.2	**0.2**	<0.2	<0.2	**0.2**	<0.2
1,1-Dichloroethylene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,1,1-Trichloroethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	**0.4**
Benzene, o-chloro	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,2-Dichloropropane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,2-Transdichloroethene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzene, 1,3-dichloro	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzene, 1,4-dichloro	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Dichlorodifluoromethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Vinylchloride	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Trichloroethylene	<0.2	<0.2	<0.2	<0.2	**0.3**	<0.2	<0.2	**0.5**	<0.2
Cis-1,2-dichloroethene	<0.2	<0.2	<0.2	**0.9**	<0.2	<0.2	<0.2	<0.2	<0.2
Styrene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Freon 113	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Xylenes	**0.9**	**0.7**	**0.3**	**300.0**	<0.2	<0.2	**9.7**	<0.2	<0.2

Table D-1. Concentrations of organic compounds in ground water samples analyzed at the U.S. Geological Survey laboratory -- Continued
[Values in micrograms per liter; <, less than; Eq., equipment; dup, duplicate; *, no indication of organic constituents; all constituents are totals, unfiltered, recoverable]

	Sampling site ID								
	AR44	**AR8**	**AR7**	**AR35**	**AR76**	**AR69**	**AR108**	**AR103**	**AR104**
Date Sampled:	08/31/93	09/01/93	09/01/93	09/01/93	09/01/93	09/01/93	09/01/93	09/01/93	09/01/93
Constituent Time Sampled:	1911	0835	0846	0918	0935	1013	1108	1215	1239
Dichlorobromomethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Carbontetrachloride	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,2-Dichloroethane	<0.2	**0.7**	<0.2	<0.2	**0.2**	**0.6**	<0.2	<0.2	**0.4**
Bromoform	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chlorodibromomethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chloroform	<0.2	<0.2	<0.2	<0.2	<0.2	**0.2**	**0.3**	<0.2	<0.2
Toluene	**1800.**	**0.2**	**1900.**	**2000.**	**6.8**	<0.2	**0.3**	**0.3**	<0.2
Benzene	**780.**	**5.9**	**560.**	**1500.**	**3.3**	**0.5**	**13.0**	<0.2	<0.2
Chlorobenzene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	**600.**	<0.2	**450.**	<0.2	**0.2**	**4.6**	<0.2	<0.2	<0.2
Methylenechloride	<0.2	**0.2**	<0.2	<0.2	**0.3**	<0.2	<0.2	<0.2	<0.2
Tetrachloroethylene	<0.2	<0.2	**8.5**	**0.3**	<0.2	<0.2	<0.2	<0.2	<0.2
Trichlorofluoromethane	<0.2	<0.2	<0.2	<0.2	**0.6**	**3.0**	<0.2	<0.2	**2.4**
1,1-Dichloroethane	<0.2	**0.2**	<0.2	<0.2	**0.2**	**0.3**	<0.2	<0.2	**0.2**
1,1-Dichloroethylene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,1,1-Trichloroethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzene, o-chloro	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,2-Dichloropropane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,2-Transdichloroethene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzene, 1,3-dichloro	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzene, 1,4-dichloro	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Dichlorodifluoromethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Vinylchloride	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Trichloroethylene	<0.2	**0.2**	<0.2	<0.2	**0.2**	<0.2	<0.2	<0.2	<0.2
Cis-1,2-dichloroethene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Styrene	<0.2	<0.2	<0.2	**2.6**	<0.2	<0.2	<0.2	<0.2	<0.2
Freon 113	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Xylenes	**3000.**	**0.2**	**3000.**	**2000.**	**3.7**	**9.8**	<0.2	**0.2**	<0.2

Table D-1. Concentrations of organic compounds in ground water samples analyzed at the U.S. Geological Survey laboratory -- Continued
[Values in micrograms per liter; <, less than; Eq., equipment; dup, duplicate; * , no indication of organic constituents; all constituents are totals, unfiltered, recoverable]

	Sampling site ID							
	AR106	**AR105**	**AR100**	**AR100-dup**	**AR102**	**AR107***	**AR101**	**AR101-dup**
Date Sampled:	09/01/93	09/01/93	09/01/93	09/01/93	09/01/93	09/09/93	09/09/93	09/09/93
Constituent Time Sampled:	1433	1459	1600	1601	1634	1111	1258	1259
Dichlorobromomethane	<0.2	<0.2	**0.2**	<0.2	<0.2	<0.2	**1.6**	**2.1**
Carbontetrachloride	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,2-Dichloroethane	**0.4**	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Bromoform	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chlorodibromomethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chloroform	<0.2	<0.2	**3.7**	**2.7**	**0.2**	<0.2	**15.0**	**17.0**
Toluene	**0.5**	**0.4**	<0.2	**0.9**	<0.2	<0.2	**0.6**	**0.8**
Benzene	**0.3**	<0.2	<0.2	**0.2**	<0.2	<0.2	**0.6**	**0.8**
Chlorobenzene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	**0.2**
Methylenechloride	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Tetrachloroethylene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Trichlorofluoromethane	**0.3**	**1.7**	<0.2	<0.2	**1.6**	<0.2	<0.2	<0.2
1,1-Dichloroethane	**1.6**	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,1-Dichloroethylene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,1,1-Trichloroethane	**0.3**	**0.2**	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzene, o-chloro	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,2-Dichloropropane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,2-Transdichloroethene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzene, 1,3-dichloro	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzene, 1,4-dichloro	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Dichlorodifluoromethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Vinylchloride	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Trichloroethylene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Cis-1,2-dichloroethene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Styrene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Freon 113	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Xylenes	**0.3**	**0.3**	<0.2	**0.2**	<0.2	<0.2	**0.6**	**1.0**

Table D-2. Comparison of BTEX concentrations in samples analyzed at the Enseco and U.S. Geological Survey laboratories
[Values in micrograms per liter]

Constituent	AR79		AR47		AR58		AR42		AR25	
	Enseco	USGS	Enseco	USGS	Enseco	USGS	Enseco	USGS	Enseco	USGS
Benzene	<0.5	<0.2	<0.5	<0.2	<0.5	**0.2**	<0.5	<0.2	<0.5	<0.2
Toluene	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2
Ethylbenzene	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2
Xylenes (total)	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2
Gasoline Range Organics	<10	NA	<10	NA	<10	NA	<10	NA	<10	NA

	AR59		AR27		AR38		AR56		AR49	
	Enseco	USGS	Enseco	USGS	Enseco	USGS	Enseco	USGS	Enseco	USGS
Benzene	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2	**16**	<0.2
Toluene	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2	<1.0	<0.2
Ethylbenzene	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2	**2.2**	<0.2
Xylenes (total)	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2	**6.6**	**0.9**
Gasoline Range Organics	<10	NA	<10	NA	10	NA	<10	NA	**100**	NA

	AR49-D		AR51		AR81		AR4		AR3	
	Enseco	USGS	Enseco	USGS	Enseco	USGS	Enseco	USGS	Enseco	USGS
Benzene	**21**	<0.2	**0.6**	**0.5**	**130**	**150**	<0.5	<0.2	**3.1**	<0.2
Toluene	<1.0	<0.2	<0.5	<0.2	<10	**6.2**	<0.5	<0.2	<0.5	<0.2
Ethylbenzene	**4.2**	<0.2	<0.5	<0.2	**83**	**110**	<0.5	<0.2	<0.5	<0.2
Xylenes (total)	**11**	**0.7**	<0.5	**0.3**	**250**	**300**	<0.5	<0.2	<0.5	<0.2
Gasoline Range Organics	**170**	NA	<10	NA	**1100**	NA	<10	NA	**17**	NA

	AR26		AR41		AR75		AR44		AR8	
	Enseco	USGS	Enseco	USGS	Enseco	USGS	Enseco	USGS	Enseco	USGS
Benzene	**35**	**28**	<0.5	<0.2	<0.5	<0.2	**820**	**780**	**7**	**5.9**
Toluene	<2.5	<0.2	<0.5	<0.2	<0.5	<0.2	**2400**	**1800**	**0.6**	**0.2**
Ethylbenzene	**20**	<0.2	<0.5	<0.2	<0.5	<0.2	**180**	**600**	<0.5	<0.2
Xylenes (total)	**16**	**9.7**	<0.5	<0.2	<0.5	<0.2	**4100**	**3000**	**0.6**	**0.2**
Gasoline Range Organics	**330**	NA	<10	NA	<10	NA	**18000**	NA	**97**	NA

Table D-2. Comparison of BTEX concentrations in samples analyzed at the Enseco and U.S. Geological Survey laboratories -- Continued
[Values in micrograms per liter]

	Sampling site ID									
	AR7		AR35		AR76		AR108		AR104	
Constituent	Enseco	USGS	Enseco	USGS	Enseco	USGS	Enseco	USGS	Enseco	USGS
Benzene	**830**	**560**	**2100**	**1500**	**2.3**	**3.3**	**20**	**13**	<0.5	<0.2
Toluene	**5400**	**1900**	**5400**	**2000**	**3.9**	**6.8**	**0.6**	**0.3**	**0.6**	<0.2
Ethylbenzene	**1300**	**450**	**2000**	<0.2	**5**	**0.2**	<0.5	<0.2	<0.5	<0.2
Xylenes (total)	**6600**	**3000**	**3900**	**2000**	**36**	**3.7**	**0.8**	<0.2	<0.5	<0.2
Gasoline Range Organics	**24000**	NA	**24000**	NA	**400**	NA	**45**	NA	<10	NA
	AR69		AR103		AR106		AR100		AR102	
	Enseco	USGS	Enseco	USGS	Enseco	USGS	Enseco	USGS	Enseco	USGS
Benzene	**0.9**	**0.5**	<0.5	<0.2	<0.5	**0.3**	<0.5	<0.2	<0.5	<0.2
Toluene	**0.9**	<0.2	<0.5	**0.3**	<0.5	**0.5**	**0.8**	<0.2	<0.5	<0.2
Ethylbenzene	**16**	**4.6**	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2
Xylenes (total)	**17**	**9.8**	<0.5	**0.2**	<0.5	**0.3**	**0.6**	<0.2	<0.5	<0.2
Gasoline Range Organics	**370**	NA	<10	NA	<10	NA	<10	NA	<10	NA
	AR105		AR107		AR101		AR101-D		AR100-D	
	Enseco	USGS	Enseco	USGS	Enseco	USGS	Enseco	USGS	Enseco	USGS
Benzene	<0.5	<0.2	<0.5	<0.2	**0.5**	**0.6**	**0.73**	**0.8**	<0.5	**0.2**
Toluene	<0.5	**0.4**	<0.5	<0.2	<0.5	**0.6**	**0.76**	**0.8**	**1.1**	**0.9**
Ethylbenzene	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2	<0.5	**0.2**	<0.5	<0.2
Xylenes (total)	<0.5	**0.3**	<0.5	<0.2	<0.5	**0.6**	**0.68**	**1**	**0.6**	**0.2**
Gasoline Range Organics	<10	NA	**11**	NA	**11**	NA	**12**	NA	**10**	NA

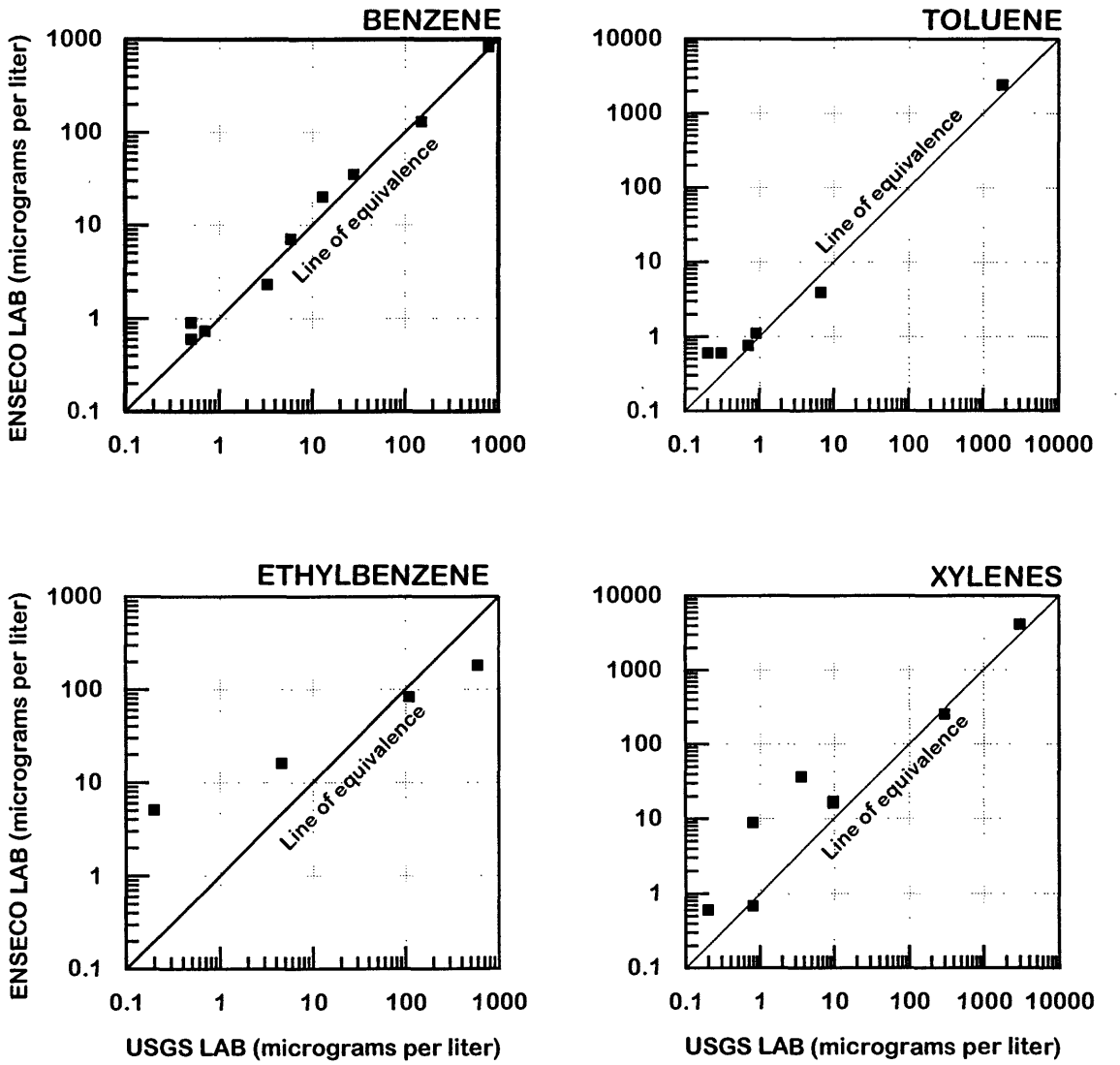


Figure D-1. Comparison of BTEX concentrations in samples analyzed at the U.S. Geological Survey and Enseco laboratories.

Table D-3. Miscellaneous water-quality characteristics of ground water as determined by analyses performed in the field [SC, specific conductance]

Site Identification	Temperature (°C)	pH	SC (µg/L)	Alkalinity (mg/L)
AR100	5.0	7.1	329	163
AR100-2	5.0	7.0	337	156
AR101	4.5	7.1	289	144
AR102	8.0	6.8	662	305
AR103	6.0	6.5	1022	577
AR104	4.5	6.7	689	363
AR105	4.5	7.0	2044	646
AR106	5.0	6.9	754	NA
AR107	5.0	6.7	645	NA
AR107-2	5.0	6.7	713	NA
AR108	5.0	6.9	418	231
AR109	5.0	6.9	798	NA
AR110	5.5	6.9	560	NA
AR111	4.5	7.0	316	154
AR25	NA	NA	NA	380
AR26	4.5	7.1	1174	NA
AR27	6.0	6.9	674	NA
AR3	4.0	7.1	534	NA
AR35	5.5	6.8	764	NA
AR38	4.0	6.7	618	NA
AR4	4.0	6.7	462	NA
AR41	4.5	6.8	559	NA
AR42	5.5	6.7	417	954
AR42-2	6.0	6.6	416	NA
AR44	7.5	6.7	846	NA
AR47	9.5	6.4	508	229
AR49	4.5	6.7	616	NA
AR51	5.0	6.8	606	NA
AR56	6.5	6.7	529	253
AR56	6.5	6.7	529	NA
AR58	5.5	6.5	552	229
AR59	4.0	6.4	1486	645
AR69	3.5	7.0	793	NA
AR7	5.5	6.8	668	NA
AR75	3.5	6.9	764	NA
AR76	5.5	6.8	499	NA
AR79	4.0	6.9	747	365
AR8	4.5	7.2	442	NA
AR81	5.0	6.8	640	NA

Table D-4. Concentrations of major anions in ground water and surface water
[All units in mg/L]

Ground water

Site identification	Fluoride	Chloride	Nitrate	Phosphate	Sulfate
Daily News Miner	0.1	1.7	<0.02	13.8	7.61
AR79	0.1	20.2	<0.02	0.05	37.2
AR108	0.1	3.9	<0.02	<0.05	5.99
AR100 duplicate	0.2	3.8	<0.02	<0.05	17.1
AR100	0.2	4.6	<0.02	<0.05	17.8
AR101	0.1	1.8	<0.02	<0.05	12.6
MUS	0.1	3.3	<0.02	<0.05	12.1
AR111	0.1	2.6	<0.02	<0.05	14.5
AR59	0.08	7.65	13.8	<0.05	191
AR103	0.09	3.84	11.8	<0.05	25
AR47	0.35	10.2	4.41	<0.05	12.7
AR105	0.21	259	4.28	<0.05	57.8
AR25	0.09	8.81	3.21	<0.05	49
AR58	0.1	16.5	0.75	<0.05	45.4
AR56	0.11	7.28	0.54	<0.05	32.6
AR42	0.1	2.76	0.43	<0.05	25.9
AR104	0.1	11	0.39	<0.05	28.8
AR102 duplicate	0.15	19.3	0.15	<0.05	36.8
AR102	0.15	19.4	0.14	<0.05	37.5

Surface water

Site identification	Fluoride	Chloride	Nitrate	Phosphate	Sulfate
Noyes Slough at Minnie St.	0.12	0.3	0.24	<0.05	15.9
Chena River	0.12	0.35	0.14	<0.05	16.1
Noyes Slough at O'Connor St.	0.12	1.17	0.11	<0.05	17.5
Noyes Slough at Illinois St.	0.12	0.8	0.11	<0.05	16.2
Tanana River	0.11	1.06	0.1	<0.05	36.5

Table D-5. Concentrations of major cations in ground water and surface water
[All units in mg/L]

Ground water

Well identification	Calcium	Magnesium	Sodium	Potassium
Daily News Miner	44	9.17	24.5	13.1
AR79	132	10.9	9.49	5.76
AR108	66.6	14.4	6.36	4.44
AR100 duplicate	44.9	10.3	10	4.23
AR100	43.7	9.97	10	4.06
AR101	39.1	8.36	5.01	3.74
MUS	52.2	11.4	5.98	3.65
AR111	42.1	9.3	5.21	3.53
AR59	187	82.3	8.87	7.43
AR103	147	40.4	19.7	17.7
AR47	68.1	16.8	14.6	10.1
AR105	304	22.2	212	8.62
AR25	115	30	10.6	6.04
AR58	76.9	26.4	6.26	4.92
AR56	81.2	17.9	14.1	5.37
AR42	50.1	13.1	5.45	2.9
AR104	124	24.7	9.23	6.34
AR102	89	21.4	28.9	6.42
AR102 duplicate	91.9	21.5	29	6.61

Surface water

Well identification	Calcium	Magnesium	Sodium	Potassium
Noyes Slough at Minnie St.	23.4	5.16	1.92	1.31
Chena River	24	5.21	1.63	1.36
Noyes Slough at O'Connor St.	28.6	6.29	2.65	1.61
Noyes Slough at Illinois St.	28.8	5.67	1.92	1.43
Tanana River	30.4	7.02	2.99	2.26

Table D-6. Quality control data samples analyzed at the U.S. Geological Survey laboratory

[Values in micrograms per liter; <, less than; Eq., equipment; dup, duplicate; *, no indication of organic constituents; all constituents are totals, unfiltered, recoverable]

	Sampling site ID								
	Eq. Blank	**Eq. Blank**	**Eq. Blank**	**Trip Blank***	**Trip Blank***	**Trip Blank***	**AR49-dup**	**AR100-dup**	**AR101-dup**
Date Sampled:	08/30/93	08/31/93	09/01/93	08/31/93	09/02/93	09/09/93	08/31/93	09/01/93	09/09/93
Constituent **Time Sampled:**	1311	1631	1349	0930	0811	1400	1446	1601	1259
Dichlorobromomethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	**2.1**
Carbontetrachloride	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,2-Dichloroethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	**0.6**	<0.2	<0.2
Bromoform	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chlorodibromomethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chloroform	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	**2.7**	**17.0**
Toluene	<0.2	**0.3**	**8.2**	<0.2	<0.2	<0.2	<0.2	**0.9**	**0.8**
Benzene	<0.2	<0.2	**2.6**	<0.2	<0.2	<0.2	<0.2	**0.2**	**0.8**
Chlorobenzene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	<0.2	<0.2	**0.5**	<0.2	<0.2	<0.2	<0.2	<0.2	**0.2**
Methylenechloride	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Tetrachloroethylene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Trichlorofluoromethane	**0.3**	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,1-Dichloroethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	**0.2**	<0.2	<0.2
1,1-Dichloroethylene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,1,1-Trichloroethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzene, o-chloro	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,2-Dichloropropane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1,2-Transdichloroethene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzene, 1,3-dichloro	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzene, 1,4-dichloro	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Dichlorodifluoromethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Vinylchloride	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Trichloroethylene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Cis-1,2-dichloroethene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Styrene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Freon 113	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Xylene	<0.2	**0.3**	**6.4**	<0.2	<0.2	<0.2	**0.7**	**0.2**	**1.0**