A RECONNAISSANCE WATER-QUALITY APPRAISAL OF THE FOUNTAIN CREEK ALLUVIAL AQUIFER BETWEEN COLORADO SPRINGS AND PUEBLO, COLORADO, INCLUDING TRACE ELEMENTS AND ORGANIC CONSTITUENTS

By Doug Cain and Patrick Edelmann

U.S. Geological Survey Toxic Waste--Ground-Water Contamination Program

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METRIC CONVERSION FACTORS

Inch-pound units used in this report may be converted to International System of Units (SI) by using the following conversion factors:

Multiply inch-pound unit	*By*	*To obtain SI unit*
acre-foot (acre-ft)	1,233	cubic meter
acre-foot per year (acre-ft/yr)	1,233	cubic meter per annum
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
foot per mile (ft/mi)	0.3048	meter per mile
inch (in.)	25.40	millimeter
gallon per minute (gal/min)	0.06308	liter per second
mile (mi)	1.609	kilometer
mile per year (mi/yr)	1.609	kilometer per annum
square mile (mi^2)	2.590	square kilometer

Water-quality terms and abbreviations used in this report:

Degree Celsius (°C)
microgram per liter (μg/L)
microsiemens per centimeter at 25° Celsius (μS/cm)
milligram per liter (mg/L)
nanogram per liter (ng/L)

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ABSTRACT

This report describes the hydrology and chemical quality of water in the stream-aquifer system along Fountain Creek and relates ground-water quality to land use, water use, and wastewater discharges. The report was prepared as part of the first phase of a national study being made by the U.S. Geological Survey as part of its Toxic Waste--Ground-Water Contamination Program. The alluvial aquifer along Fountain Creek consists predominantly of sand and gravel as much as 100 feet thick and is underlain by shale bedrock. The aquifer has an area of 48 square miles and has about 160,000 acre-feet of ground water in storage. Ground water flows to the south at an average rate of about 20 feet per day, and the average residence time of ground water is less than 10 years. About 240 irrigation, municipal, and industrial-supply wells withdraw 15,000 to 20,000 acre-feet of water annually from the alluvial aquifer. Much of the recharge to the alluvial aquifer is from Fountain Creek, which receives a large volume of secondary treated sewage effluent in the northern end of the study area.

Land use is urban in the northern one-third and agricultural in the southern two-thirds of the area. Urban land is a mixture of residential, commercial, services, industrial, and transportation areas. Agricultural land primarily is flood-irrigated pasture, hay, or alfalfa, and unirrigated grazing land.

Ground-water quality varied downgradient in the study area. Specific conductance, major ions, boron, iron, lithium, selenium, strontium, and uranium increased in concentration downgradient in the alluvial aquifer. The increase in these constituents, except iron and selenium, is caused by evaporative concentration from water use and reuse, dissolution of minerals in the aquifer and shale bedrock, and tributary ground-water inflows. A downgradient increase in selenium concentrations may be caused by seleniferous beds in the shale bedrock. The reasons for a downgradient increase in iron concentrations is not known. Concentrations of nitrite plus nitrate and detergents in the alluvial aquifer were largest in the northern end of the study area because of recharge from Fountain Creek. Barium decreased in concentration downgradient because of precipitation of barite caused by increasing sulfate concentrations. Trace elements arsenic, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, molybdenum,

nickel, silver, and vanadium were present in concentrations less than 10 micrograms per liter in more than 80 percent of the ground-water samples analyzed. Zinc was detected in concentrations larger than 10 micrograms per liter in most samples analyzed.

Volatile organic compounds were detected, using a purge-and-trap technique, in concentrations greater than 1 microgram per liter in samples from 11 of 20 wells in urban and agricultural areas. Samples from 4 of the 20 wells also were analyzed for semivolatile organic compounds using a more sensitive closed-loop-stripping technique. Between 2 and 11 additional organic compounds were detected in concentrations of 20 nanograms per liter (ng/L) or more in these samples.

A preliminary statistical evaluation of the relation between land use and ground-water quality indicated that mean and median concentrations are larger in water from the agricultural (downgradient) land-use areas for inorganic constituents that have downgradient increases in concentration. Similarly, constituents that have downgradient decreases in concentration have larger mean and median concentrations in water from the urban (upgradient) land-use area. However, these differences in concentration do not necessarily indicate a causal relation between land use and ground-water quality because other factors, including water use and wastewater discharges, affect the concentrations of these constituents. A statistical evaluation of differences in the occurrence or concentrations of volatile or semivolatile organic compounds between urban and agricultural land use was not possible because of the limited data available.

INTRODUCTION

To assess the current quality of the Nation's ground-water resources, the U.S. Geological Survey began regional ground-water-quality appraisals in 14 areas during 1984 as part of its Toxic Waste--Ground-Water Contamination Program. The studies are intended to provide information about ground-water chemistry with emphasis on trace elements and organic constituents and to explain water quality in terms of local hydrology and human activities for a wide variety of hydrologic and human environments (Helsel and Ragone, 1984). The studies include an initial reconnaissance phase intended primarily to assemble and evaluate existing data and a second phase involving collection and statistical analysis of new data. The alluvial aquifer along Fountain Creek, a tributary to the Arkansas River, between Colorado Springs and Pueblo (fig. 1), is one of the 14 areas being studied, and this report documents results of the first phase of the study.

The Fountain Creek alluvial aquifer, which is located just east of the Front Range of the Rocky Mountains between Colorado Springs and Pueblo (fig. 1) is representative of the Alluvial Valleys ground-water region defined by Heath (1984). The alluvial aquifer consists of sand and gravel in the eroded ancestral channel of Fountain Creek. The sand and gravel are very permeable and transmissive in comparison to the underlying shale bedrock that is essentially impermeable to ground-water flow. The alluvial aquifer is part of a complex stream-aquifer system that is affected by many of the activities of man associated with urban and agricultural development. The alluvial

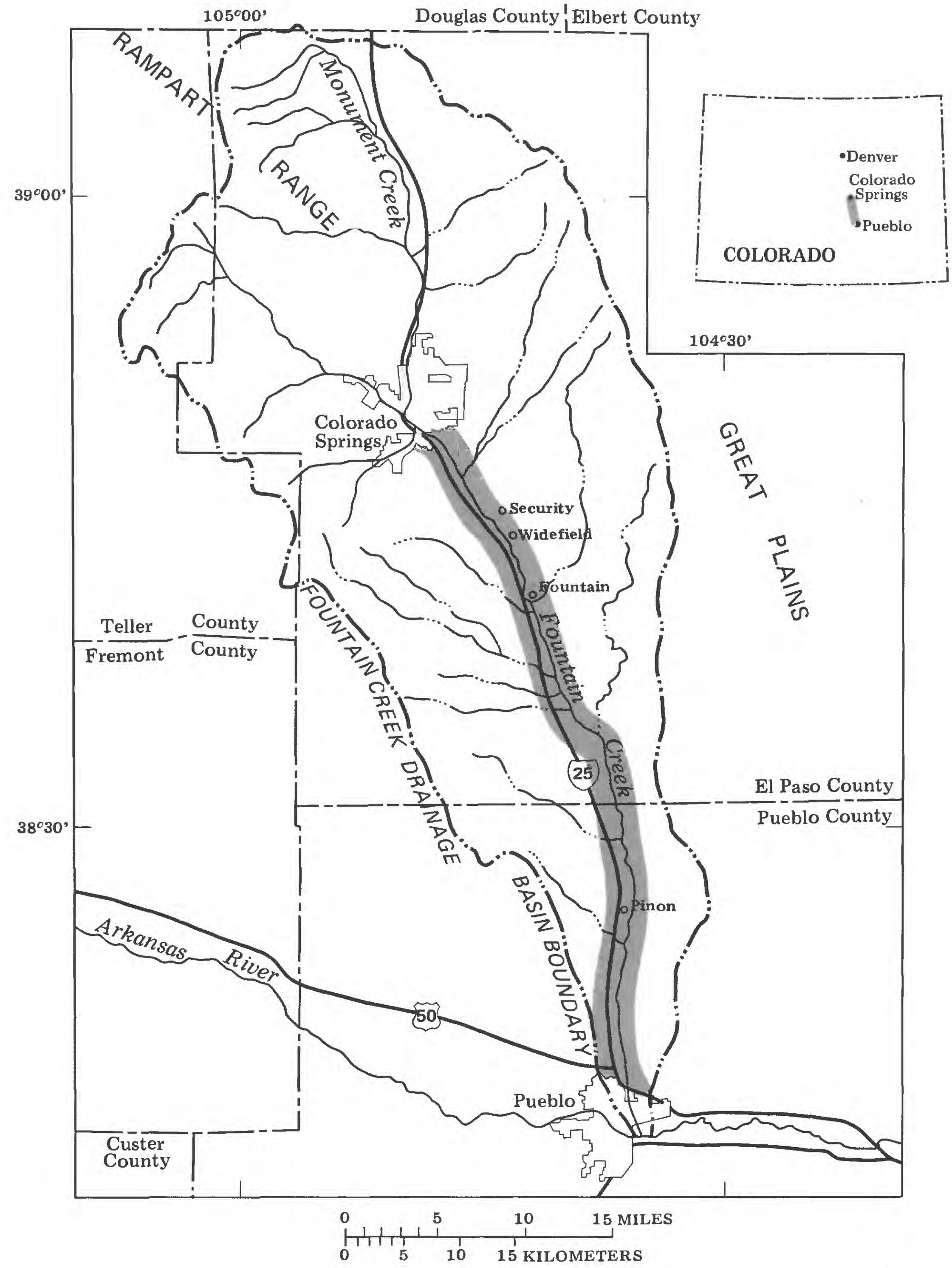


Figure 1.--Location of study area.

aquifer has been extensively developed as a municipal water supply for Colorado Springs and suburban areas south of the city and as a source of irrigation water. The study area is semiarid and ranges in elevation from 4,700 to 6,000 ft. Mean annual precipitation decreases with decreasing elevation in a southerly direction from about 16 in. at Colorado Springs to about 11 in. at Pueblo (U.S. Geological Survey, 1984).

Purpose and Scope

This report describes the results of the reconnaissance phase of a ground-water-quality appraisal of the alluvial aquifer along Fountain Creek. The report is intended to provide information about ground-water chemistry with emphasis on trace elements and organic constituents and to make a preliminary evaluation of the relation between water quality, local hydrology, and human activities. The reconnaissance included acquisition and compilation of data about the hydrologic system, present-day and historical land use, and water quality. Data have been compiled from aerial photographs, existing reports, and the files of State and local agencies and the U.S. Geological Survey. In addition, onsite mapping of land use and alluvial-aquifer boundaries and identification of potential point sources of ground-water contamination were done. Evaluation of existing water-quality data indicated a lack of data for concentrations of trace elements and organic compounds; therefore, reconnaissance samples for trace elements and organic constituents were collected from 20 existing wells and 6 surface-water sites during 1984. A preliminary assessment of possible relations between land use and ground-water quality was made using the existing and newly collected data.

Acknowledgments

The authors wish to thank well owners who permitted sampling of their wells and the city of Colorado Springs for permission to sample the effluent from the Colorado Springs Wastewater Treatment Plant. Special thanks are extended to Larry Barber, U.S. Geological Survey, for doing the closed-loop stripping of four ground-water samples.

HYDROLOGIC SYSTEM

The alluvial aquifer is only one part of a complex hydrologic system that also includes Fountain Creek. Such a system commonly is referred to as a stream-aquifer system to emphasize the strong interactions that can occur between surface water and ground water. A schematic diagram of the hydrologic system is shown in figure 2.

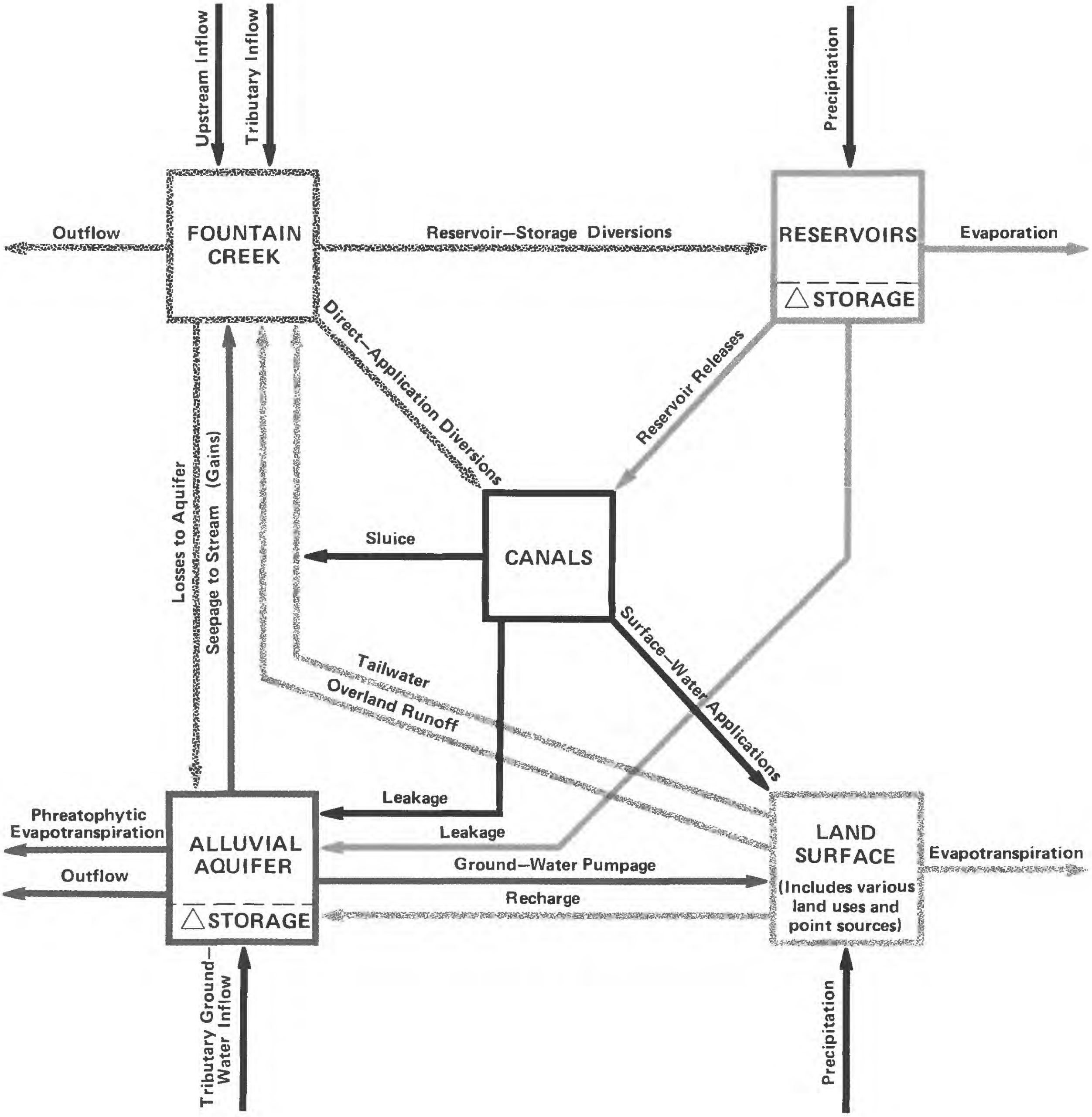


Figure 2.--Schematic diagram of the hydrologic system.

Physical Description of the Alluvial Aquifer

The alluvial aquifer along Fountain Creek is about 40 mi in length, is 0.75 to 2 mi wide, and includes an area of about 48 mi^2 along Fountain Creek and an additional 7 mi^2 of tributary alluvial aquifer (fig. 3). The aquifer consists of sand and gravel and minor quantities of silt and clay (Jenkins, 1964, p. 15) that range in thickness from a few feet to about 100 ft. The thickness of saturated material varies with location and time and ranges from 0 to 50 ft and averages about 20 ft. Depth to water is shallow, ranging from a few feet in wells on the flood plain to about 40 ft in wells on the terraces. Hydraulic characteristics of the alluvial aquifer are in the range of values reported by Heath (1984) for the Alluvial Valleys ground-water region. Hydraulic conductivity ranges from 400 to 1,600 ft/d, based on 14 aquifer tests (Jenkins, 1964; Wilson, 1965; Taylor, 1975). Specific yield, which is used to approximate effective porosity, ranges from 0.2 to 0.3 in the northern part of the study area, and a value of 0.25 was selected as representative by Jenkins (1964, p. 25). Although little specific-yield data are available for the southern part of the study area, examination of drillers logs indicates a general consistency in the description of the lithology, and the same value for specific yield was used throughout the study area. An estimated 160,000 acre-ft of ground water are in storage in the alluvial aquifer along Fountain Creek during periods of average hydrologic conditions.

Flow in the alluvial aquifer generally is to the south (fig. 3), although localized and transient reversals of this direction may develop in areas of heavy pumpage (Edelmann and Cain, 1986). The hydraulic gradient is fairly constant throughout the study area and has a value of 0.006 or about 30 ft/mi. The rate of flow of ground water in the alluvial aquifer ranges from 10 to 40 ft/d and averages about 20 ft/d or 1.4 mi/yr. These large rates result from relatively large values of hydraulic conductivity and hydraulic gradient.

The aquifer has been developed extensively as a source of irrigation, municipal, and industrial supply (Bingham and Klein, 1973). According to records of the U.S. Geological Survey, as of 1984, there were approximately 240 wells in the area that had reported yields of more than 100 gal/min. More than 100 of these wells are located in the northern one-third of the aquifer, and most are used for municipal supply. Well yields typically are 400 to 700 gal/min, but yields more than 3,000 gal/min have been reported in the northern one-third of the area. Water levels fluctuate greatly in areas of heavy seasonal pumpage (Jenkins, 1964, p. 30; Livingston and others, 1976a, 1976b; Edelmann and Cain, 1986), but no long-term changes in water levels have occurred because Fountain Creek recharges the aquifer.

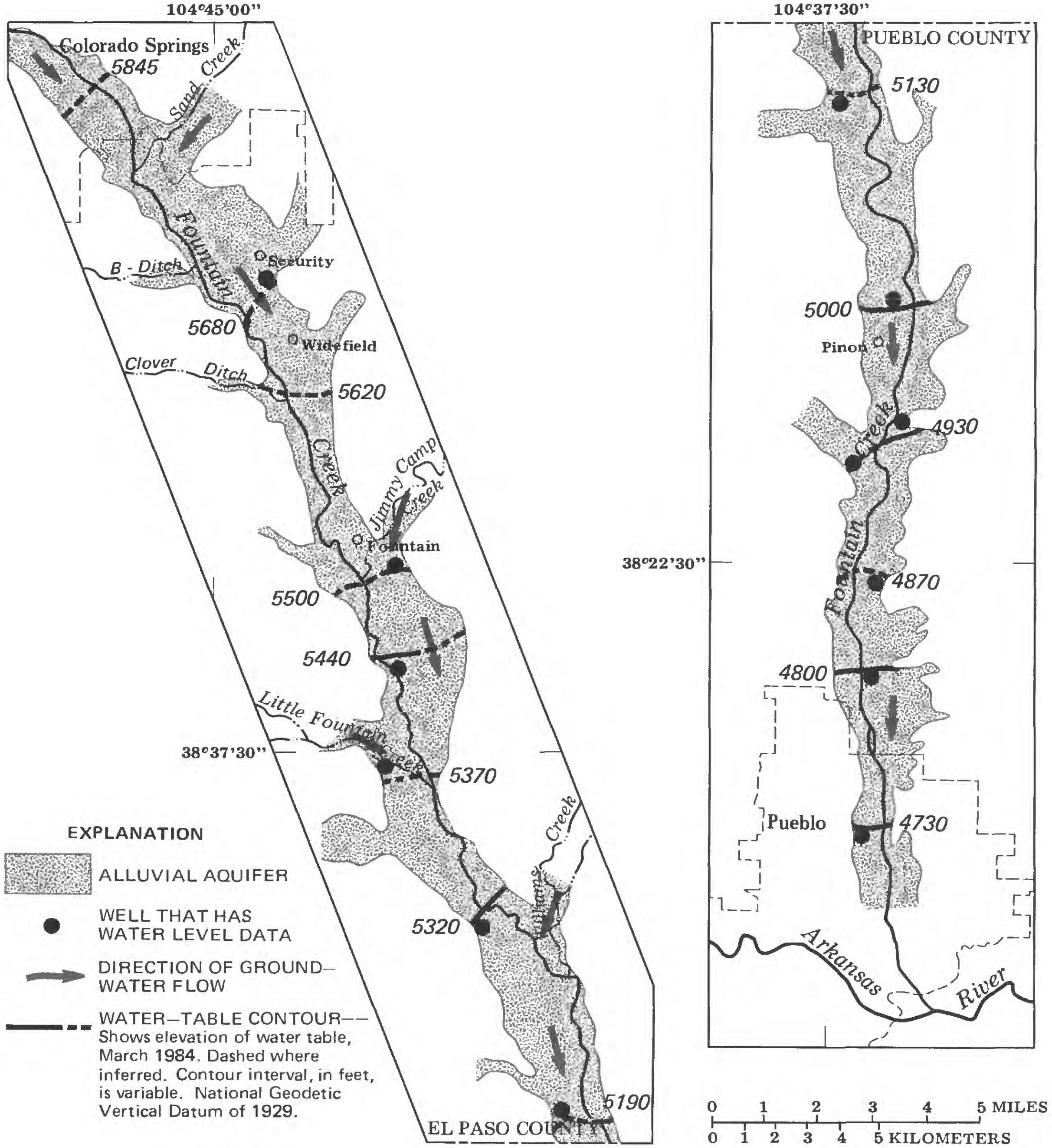


Figure 3.--Extent of the alluvial aquifer and direction of ground-water flow.

Recharge and Discharge

Recharge to the alluvial aquifer occurs as seepage losses from Fountain Creek, reservoir and canal leakage, ground-water inflows from tributary valleys, and percolation from land surface. Percolation from land surface may result from irrigation, artificial-recharge ponds, sewage lagoons, precipitation, and other minor sources. Discharge occurs as seepage to Fountain Creek, well pumpage, phreatophytic evapotranspiration, and outflow to the south (fig. 2). An accurate determination of recharge or discharge for all sources cannot be made using available data; however, some of the more important quantities were estimated.

The amount of exchange between Fountain Creek and the alluvial aquifer was estimated from 14 gain-loss investigations made between 1973 and 1977 (table 1 and fig. 4). A gain-loss investigation is an accounting of all surface water entering or leaving a stream. Differences in flow not caused by tributary inflows or diversions are attributed to an interchange between ground and surface water. Most of the recharge occurs in reach 1 where losses from Fountain Creek are caused by extensive pumpage near Security, and additional recharge occurs near the El Paso-Pueblo County line (fig. 4). Discharge from alluvial aquifers to Fountain Creek occurs primarily near Security and Widefield and just downstream from Fountain probably as a result of ground-water inflow from the alluvium of Jimmy Camp Creek. Fountain Creek and the alluvial aquifer exchange less water in the southern one-third of the study area.

Because the stream-aquifer system is in equilibrium (Emmons, 1977, p. 38; Edelmann and Cain, 1986), the mean gain or loss can be used to estimate the annual stream-aquifer exchange. Using this approach, about 11,000 acre-ft of water from Fountain Creek recharges the alluvial aquifer annually, and about 9,000 acre-ft of water per year is estimated to enter Fountain Creek as seepage from the alluvial aquifer. The sum of these annual gains and losses is about 13 percent of the total storage.

Ground-water pumpage and underflow can be estimated using available data. Bingham and Klein (1973) estimated pumpage of 18,000 acre-ft during 1972 from the alluvial aquifers along Fountain and Jimmy Camp Creeks. Most of the pumpage was from the alluvial aquifer along Fountain Creek, which has about six times as many large-capacity wells as the alluvial aquifer along Jimmy Camp Creek. Edelmann and Cain (1986) reported an average of 7,100 acre-ft was pumped annually from a 6-mi reach of the alluvial aquifer near Security and Widefield between 1973 and 1983. These estimates indicate that pumpage in the study area during most years is about 15,000 to 20,000 acre-ft, or about 10 percent of total storage. Underflow at the southern end of the study area near Pueblo is about 900 acre-ft/yr, based on a width of 3,000 ft, a saturated thickness of 18 ft, a hydraulic gradient of 0.005, and a hydraulic conductivity of 400 ft/d. Mean annual streamflow at this location is about 45,000 acre-ft/yr.

Table 1.--*Summary of gain-loss data for Fountain Creek, 1973-77*

Gain-loss reach	Gain or loss (cubic feet per second)		Maximum loss (cubic feet per second)	Maximum gain (cubic feet per second)	Number of investigations	
	Mean	Standard deviation			Loss	Gain
1	-11.0	9.2	-25	3.0	8	2
2	3.2	8.2	-14	15	2	9
3	1.2	11.5	-27	23	5	9
4	6.3	18.1	-24	34	3	10
5	-.5	11.1	-22	27	7	6
6	-3.6	4.6	-12	3.8	10	3
7	-.3	7.9	-18	16	6	7
8	1.3	8.9	-6.5	28	7	6

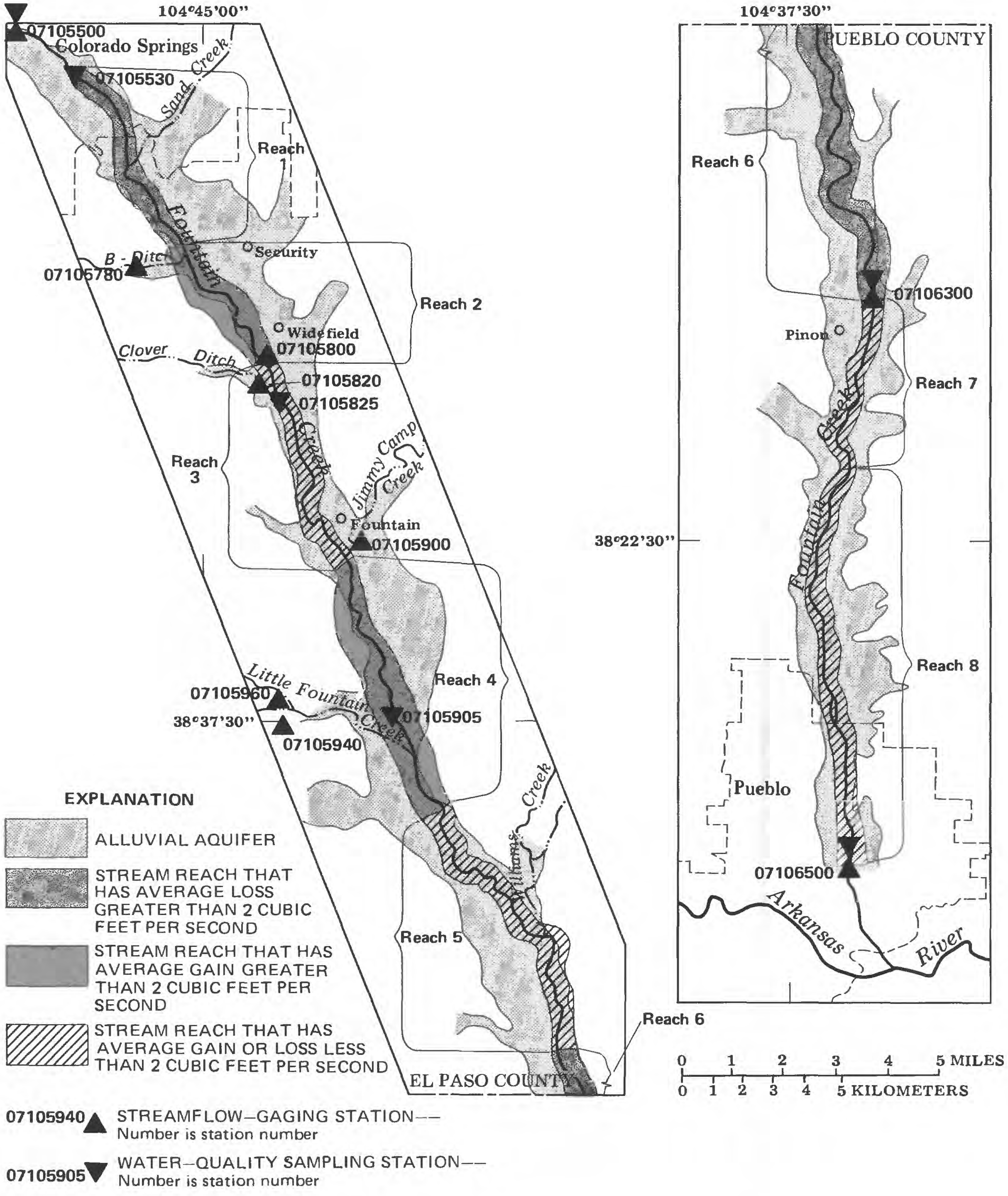


Figure 4.--Location of streamflow-gaging stations, water-quality sampling stations, and gaining and losing reaches of Fountain Creek.

Residence Time of Ground Water

Estimation of residence time of ground water is important because water younger than about 100 years may have been affected significantly by man's activities. Before making estimates of residence time for ground water in the alluvial aquifer, it is important to note that little underflow enters the alluvial aquifer at the northern boundary of the study area. The aquifer just north of the study area is limited in extent and ability to transmit water (Livingston and others, 1975); therefore, most ground water at the northern end of the study area is recently recharged. If this recently recharged water traveled the length of the alluvial aquifer at the average ground-water velocity without being withdrawn by wells or phreatophytes or seeping back to Fountain Creek, a residence time of about 30 years would result. However, an average residence time for water in the alluvial aquifer would be much shorter than 30 years because water is unlikely to traverse the entire aquifer because of many opportunities for inflow and outflow (fig. 2). Estimates made in the section entitled "Recharge and Discharge" indicate that 20 to 25 percent of the total storage is withdrawn by wells or interchanged with Fountain Creek annually, indicating that, on an average, most of the storage in the aquifer is replaced in 4 to 5 years. These estimates indicate that average residence time is probably less than 10 years and may be shorter than 5 years.

Fountain Creek

Fountain Creek flows in a high-gradient (about 30 ft/mi) sand channel that overlies the alluvial aquifer. Flow is perennial in the northern end of the study area where it is augmented by discharge of sewage effluent from Colorado Springs and communities to the south (Edelmann and Cain, 1986). Downstream from Fountain, no-flow periods during the summer months of many years result from diversions for agricultural use. Mean annual streamflow varies from 61 to 99 ft^3/s at the four streamflow-gaging stations on Fountain Creek in the study area.

LAND USE

Land-use data for 1984 and for three previous dates were compiled from aerial photographs and onsite mapping. Identifiable point sources of potential ground-water contamination also were mapped during 1984. Because ground-water residence time is short and little change in land use occurred between the mid-1970's and 1984, only 1984 land-use data are presented.

Land use was classified using a modification of the system developed by Anderson and others (1976). In this system, land uses are divided into two levels--the first level indicates a broad land-use category and the second level provides more detail and further differentiation of land use. The system was modified by eliminating land uses not present in the area, by combining some categories, and by expanding other categories to include additional detail. The modified land-use classification is given in table 2, which also includes approximate percentages of various land uses in the study area. A generalized land-use map is shown in figure 5.

Table 2.--*Land use in the study area*

Land-use category	Approximate percentage
URBAN LAND	
Residential, commercial, and services	13
Industrial	3
Transportation	7
IRRIGATED LAND	
Irrigated cropland, by crop	23 (all crops)
Irrigated pasture	6
WATER	
Reservoirs	<1
RANGELAND	
Herbaceous rangeland	16
Shrub and brush rangeland	13
WETLAND	
Forested wetland	16
Nonforested wetland	3

Urban land is located mainly in the northern one-third of the study area, but a small area of urban land also is located near Pueblo. Urban land is primarily residential, but there are smaller commercial, service, and industrial areas. Residential areas generally have small lot sizes and are served by central sewer systems although a few small areas use septic tanks. Industries include gravel extraction, battery manufacture, and several electronics-related industries. Potential sources of ground-water contamination in the urban area include several sewage lagoons, numerous below-ground fuel-storage tanks, two artificial recharge sites, inadvertent commercial or industrial discharges, and transportation-related spills. However, no point sources of ground-water contamination have been documented in the study area. The types of ground-water contaminants expected from the urban area include low-molecular weight chlorinated organic solvents, such as trichloroethylene and tetrachloroethylene, and petroleum hydrocarbons. Trichloroethylene and tetrachloroethylene are among the most common contaminants found in ground water affected by urban areas (Greenberg and others, 1982; Fusillo and others, 1985).

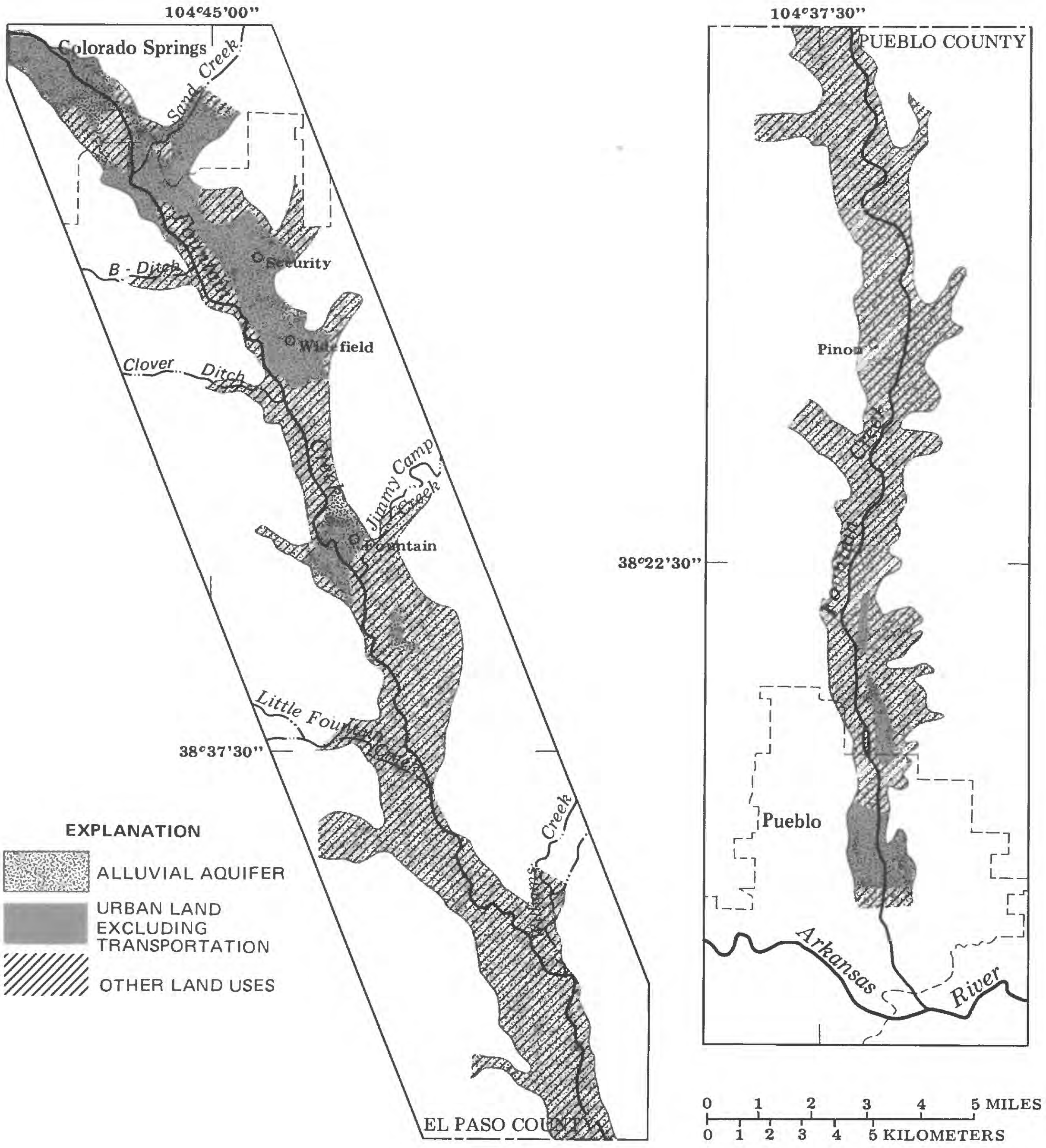


Figure 5.--Generalized land use, 1984.

Irrigated agricultural lands are located primarily in the southern two-thirds of the area. About 85 percent of the irrigated land is used for pasture, hay, or alfalfa. The remainder primarily is used for cultivation of wheat, oats, or corn. Flood irrigation is the predominant method of irrigation used. Water diverted from Fountain Creek is the primary source of irrigation water in most areas, and ground water is used as a supplemental supply. Rangeland and wetland along the flood plain of Fountain Creek occur throughout the area, but the percentage of these uses is larger in the agricultural areas. Potential sources of ground-water contamination in the agricultural area include several above-ground and a few below-ground fuel-storage tanks, an inactive landfill, a gold-ore processing mill, a sewage-sludge application area, and septic tanks at the widely separated farmhouses. Nitrogen and phosphorus fertilizers and several types of organophosphorus, carbamate, and organochlorine insecticides are used in the area (John McClave, Pueblo County Extension Agent, oral commun., 1985).

To evaluate relations between land use and ground-water quality, a method was needed to assign land use to wells from which water-quality samples were collected. During this reconnaissance evaluation, most water-quality data were obtained from large-capacity municipal, industrial, or irrigation wells. These wells draw water and potential contaminants from a large area around the well during extended periods of pumping. The radius of influence of these wells is about 1 mi (Jenkins, 1964). Because of the large hydraulic gradient, water from upgradient will be drawn into the wells from a larger distance than water from downgradient; therefore, land use was assigned to individual wells based on the predominant land use in an area within 1 mi upgradient and 0.25 mi downgradient of the wells. Because data for most constituents of primary interest during the study were available from only 20 wells, land uses for this reconnaissance effort were combined into two categories, urban and agricultural.

WATER QUALITY

Water-quality data have been collected in the study area by the U.S. Geological Survey, the Colorado Department of Health, local water suppliers, and wastewater dischargers during the past 30 years. Most of the data have been collected by the U.S. Geological Survey, but limited data generally have been collected by other agencies from the same wells or surface-water sites. Sample collection, analysis, and quality-assurance procedures for data collected by other agencies often were not documented, and these data were not used in statistical evaluations during this study.

Availability of Historic Data

Water-quality data collected as part of several previous and ongoing investigations in the study area were retrieved from WATSTORE (Water Storage and Retrieval System of the U.S. Geological Survey). Historic ground-water-quality data consisted of samples from 102 wells, most of which are located in the northern one-third of the area. Most of the data are for onsite measurements, major ions, nutrients, iron, and manganese. Fewer than 20 analyses for trace inorganic constituents and only 3 analyses for trace organic constituents were available. Historic data collected from six stations on Fountain Creek (fig. 4) between 1978 and 1984 are available to provide an overview of the quality of water in Fountain Creek. The data differ slightly between stations, but primarily consist of monthly measurements of temperature, specific conductance, pH, dissolved oxygen, 5-day biochemical oxygen demand (BOD_5), nitrogen species, and selected trace elements. Several pesticide analyses of water from Fountain Creek are available (Cain and Edelmann, 1980). The only historic analysis for volatile organic compounds in surface water is from a sample of the effluent from the Colorado Springs Wastewater Treatment Plant collected during summer 1983.

Data Collected During 1984

Because historic data were not adequate for a preliminary assessment of the occurrence, concentration, and distribution of most trace elements and organic substances in the Fountain Creek stream-aquifer system, additional data were collected during 1984. Water samples were collected from 20 wells (8 in urban land-use areas and 12 in agricultural land-use areas) and 6 surface-water sites (fig. 6). The data are in table 6 in the section entitled "Supplemental Data" at the back of the report.

Because of constraints on time and funding, the 20 wells sampled were existing wells perforated throughout the saturated thickness of the alluvial aquifer. Seventeen of the wells were municipal, irrigation, or industrial supply wells. Sixteen of these wells were equipped with turbine pumps; one was equipped with a submersible pump. The other three wells were domestic supply wells that had submersible pumps. All the wells were fitted with a low-volume spigot to minimize turbulence and loss of dissolved gases and volatile organic compounds during sampling. All wells were pumped at least 10 minutes before sampling resulting in at least 3, and often more than 10, casing volumes being pumped before sample collection. The wells were distributed along the alluvial aquifer in urban and agricultural areas and along gaining and losing reaches of Fountain Creek (fig. 6).

The surface-water sites included Fountain Creek where it flows into the study area, the effluent from the Colorado Springs Wastewater Treatment Plant, and four downstream sites on Fountain Creek (fig. 6). These six sites were sampled during the late summer base flow during September 1984 and again during the late fall base flow during November 1984.

Water from wells and surface-water sites was analyzed for the same constituents. Onsite measurements of temperature, specific conductance, pH, dissolved oxygen, bicarbonate, and carbonate were made using the methods of Wood (1976). Laboratory analyses were made by the Denver Central Laboratory of the U.S. Geological Survey. Analyses for inorganic constituents were made and included major ions, nitrogen and phosphorus species, cyanide, and the following dissolved trace elements: arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, iron, lead, lithium, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, uranium, vanadium, and zinc. Laboratory analyses for inorganic constituents were made using methods given by Skougstad and others (1979) and Fishman and Bradford (1982). Analyses for uranium were made using methods developed by Thatcher and others (1977).

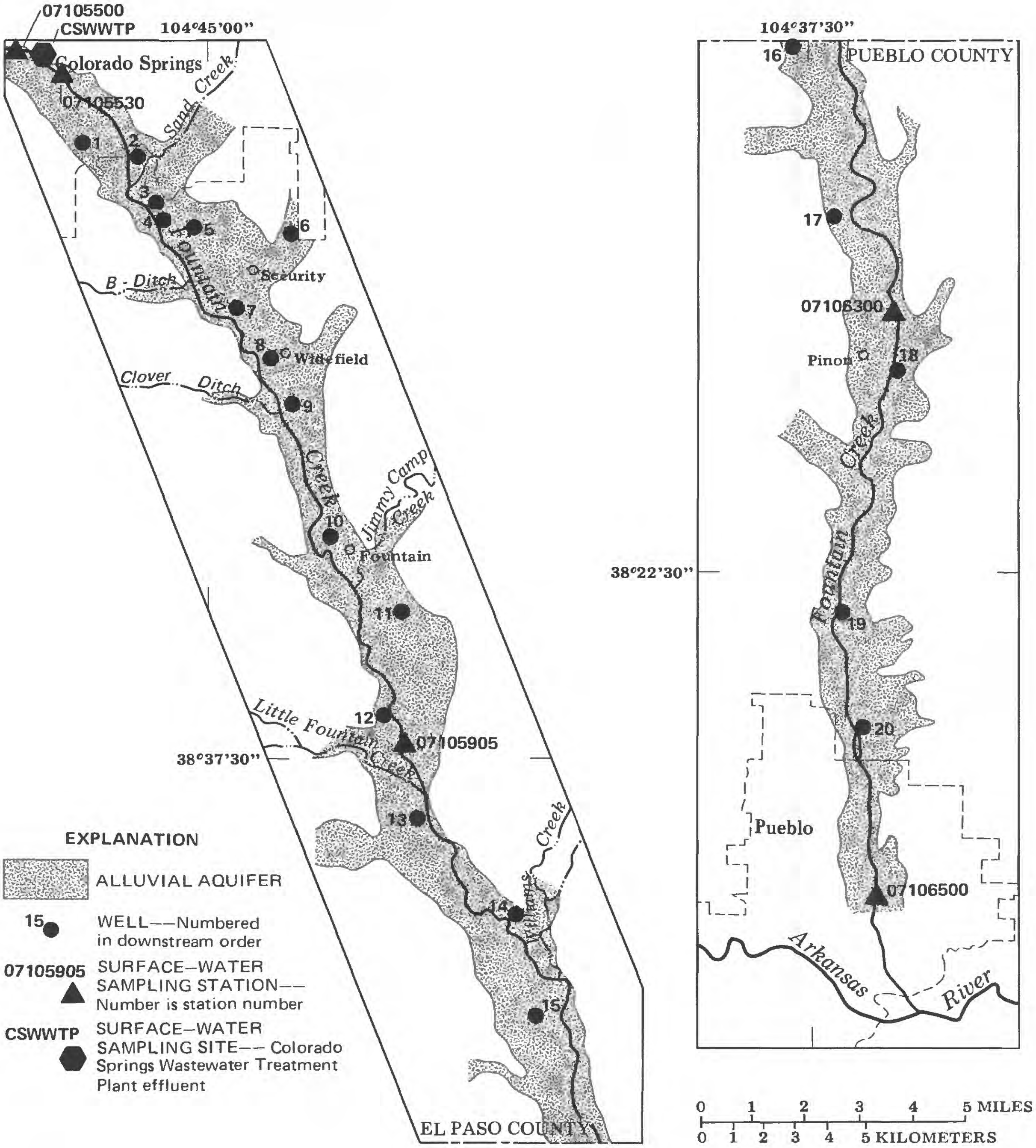


Figure 6.--Location of wells and surface-water sites sampled during 1984.

Analyses for dissolved organic carbon (DOC) and detergents as methylene blue active substances (MBAS) were made using methods given by Wershaw and others (1983).

Analyses for trace organic constituents were made using three techniques to determine which would be best suited for use during the second phase of study. Analyses for organic constituents that can be extracted by using methylene chloride were made using a gas chromatography-flame ionization detector scan as a screening technique (Herman Feltz, U.S. Geological Survey, written commun., 1985). This technique was of limited use because the detection limit (approximately 1 to 3 μg/L) was inadequate for the small concentrations of organic constituents present and because of problems of contamination during analysis. Analyses for volatile organic constituents were made using a purge-and-trap technique with detection by gas chromatography-mass spectrometry (GC-MS) (Wershaw and others, 1983). Samples were spiked in the field using surrogate standards to monitor recovery from the time of sample collection to analysis. Concentrations as small as 1 μg/L can be quantified using the technique (Michael Brooks, U.S. Geological Survey, oral commun., 1985). Analyses for semivolatile organic constituents were made using a closed-loop-stripping technique followed by GC-MS. The technique, which is a modification of the technique developed by Grob (1973) and Grob and Zurcher (1976), is described in detail by Barber (1985). The technique, which analyzes organics that have a larger molecular weight than does the purge-and-trap technique, can concentrate semivolatile organic constituents about 250,000 times, resulting in detection limits that have nanogram-per-liter values. Because of limited availability of personnel and equipment, only four samples were analyzed using this technique, and no split samples were analyzed.

Overview of Water-Quality Conditions

The interaction of water use, wastewater discharges, and the hydrologic system produces areal variations in the concentrations of major inorganic constituents, nutrients, some trace elements, and some organic constituents in the alluvial aquifer and Fountain Creek. An understanding of the causes of these variations provides background for evaluation of the relation between land use and ground-water quality and emphasizes the effect of man on ground-water quality. Water quality of Fountain Creek is reported first because it often affects the quality of water in the alluvial aquifer.

Fountain Creek

Water-quality data from Fountain Creek indicate the significant effect of municipal wastewater discharges, especially in the northern end of the study area. Much of the flow of Fountain Creek in the northern end of the study area is treated sewage effluent. The effluent from the Colorado Springs Wastewater Treatment Plant, which is the largest municipal wastewater discharge in the study area, enters Fountain Creek about 0.5 mi downstream from the northern boundary of the study area. During 1977-82, the flow of Fountain Creek just downstream from the outfall of the Colorado Springs Wastewater Treatment Plant consisted of greater than or equal to 54-percent effluent from the plant 67 percent of the time (Edelmann and Cain, 1986). Nitrogen species and BOD_5 are the best indicators of the effect of municipal wastewater on Fountain Creek. Ammonia and BOD_5, which are discharged by wastewater treatment plants, have their largest concentrations between Colorado Springs and Fountain. Farther downstream, biological processes decrease concentrations of BOD_5 and convert ammonia to nitrite and nitrate (fig. 7). Similar downstream variations also occur for DOC and detergents as MBAS, both of which also have large concentrations in sewage effluent.

Downstream changes also occur in specific conductance and the concentrations of several trace constituents. Specific conductance of Fountain Creek increases from a mean value of 622 µS/cm at Colorado Springs to 1,840 µS/cm at Pueblo. Some of the increase is caused by discharge of sewage effluent, but most of the increase probably results from return flows entering Fountain Creek as seepage. Return flows have larger specific conductance because dissolved solids are concentrated by evapotranspiration. Similar downstream increases occur for all major dissolved inorganic constituents and for boron, lithium, selenium, strontium, and uranium. Limited data indicate that other trace constituents, including copper, iron, lead, silver, and zinc, probably are present primarily as suspended material, which is not recharged to the alluvial aquifer. Nickel and manganese, which occur naturally and are present in increased concentrations in sewage effluent, are present to some extent in the dissolved phase. Concentrations of nickel and manganese increase just downstream from the outfall of the Colorado Springs Wastewater Treatment Plant then decrease in concentration throughout the rest of the study area.

The only volatile organic constituents detected in surface water were chloroform, methylene chloride, tetrachloroethylene, 1,1,1-trichloroethane, and toluene, which were detected in samples collected from the effluent of the Colorado Springs Wastewater Treatment Plant. Methylene chloride and tetrachloroethylene were the only volatile organic constituents detected in Fountain Creek.

Alluvial Aquifer

Ground-water quality samples collected before and during the study provide data from 20 to 113 wells depending on the water-quality constituent of interest. A few wells have numerous analyses for specific conductance, nitrite plus nitrate, and chloride; some wells have several analyses for major ions; and most wells have only one or two analyses for trace elements and organic constituents. Multiple analyses from a single well cause the water-quality data to be spatially biased, so a single value for each well was used throughout this report. If a well had multiple analyses for water-quality constituents that had all values more than the detection limit, such as specific conductance, major ions, nutrients, and some trace elements, the median value was used. For the few wells that had multiple analyses for trace elements and organic constituents that had some values less than the detection limit, the most recent value was used because a median could not be calculated when one value was less than the detection limit and one or more other values were more than the detection limit.

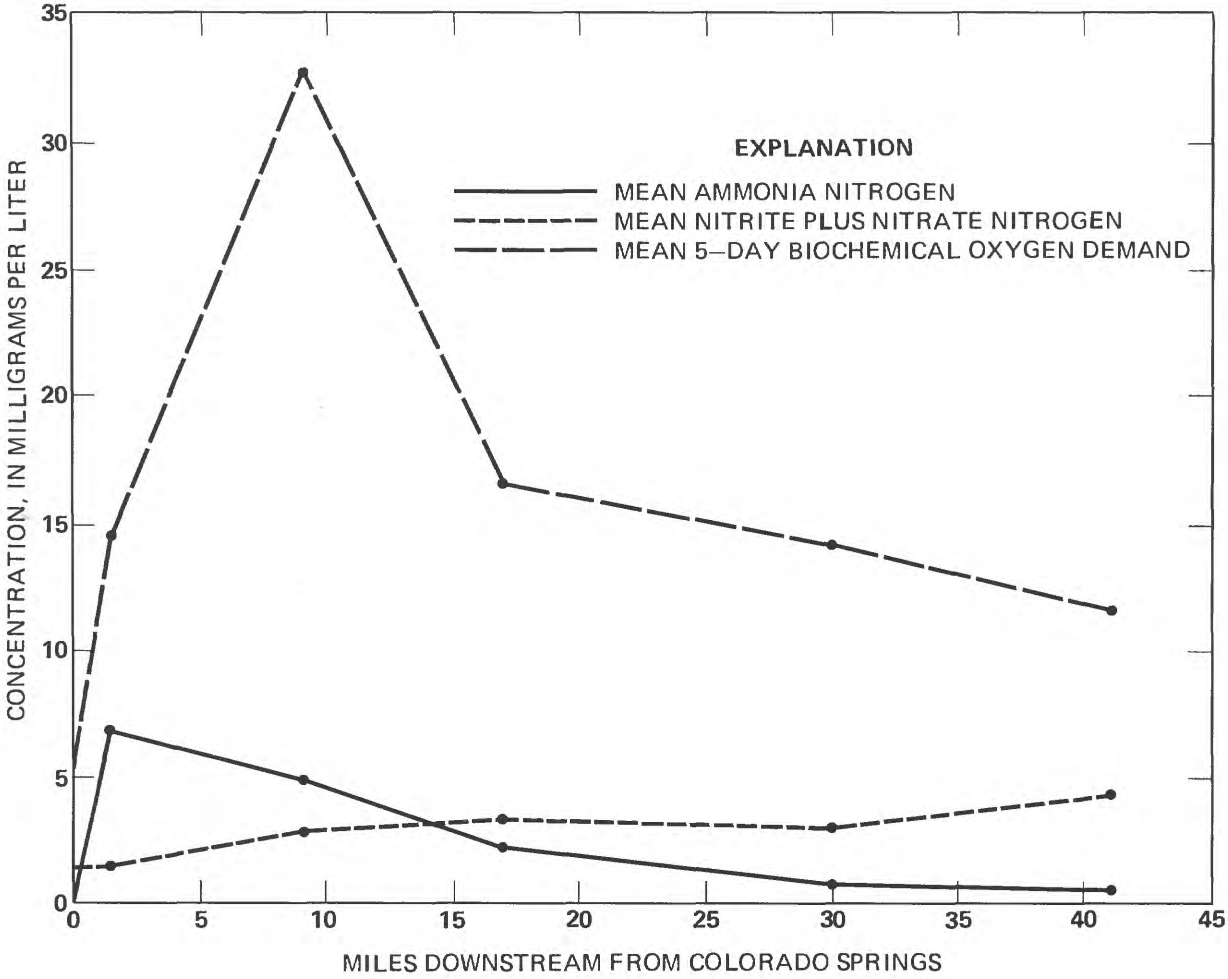


Figure 7.--Downstream changes in 5-day biochemical oxygen demand and mean concentrations of nitrogen species in Fountain Creek.

Specific Conductance and Major Ions

Areal variations in specific conductance and major ions in the alluvial aquifer are indicators of the interaction of water use and the hydrologic system. Specific conductance generally increases downgradient in water in the alluvial aquifer (fig. 8). The increase is caused by continual reuse of water, which results in evaporation of water and concentration of salts, and by longer ground-water residence time and dissolution of aquifer materials (Bingham and Klein, 1973, p. 5; Klein and Bingham, 1975, p. 17). The downgradient increase in specific conductance is not constant because of tributary ground-water inflows of differing specific conductance and variable volumes of recharge from Fountain Creek (fig. 4). The largest tributary ground-water inflow is from the alluvial aquifer along Jimmy Camp Creek, which enters the Fountain Creek alluvial aquifer about 12 mi south of Colorado Springs, and has an average specific conductance of more than 3,000 µS/cm (Bingham and Klein, 1973, pl. 2) compared to 1,000 to 1,500 µS/cm for the Fountain Creek alluvial aquifer just upgradient from the confluence of the two creeks.

As an aid in evaluating downstream variations in ground-water quality, correlation analysis between well location expressed as miles downstream from Colorado Springs and concentrations of water-quality constituents was used. Spearman correlation coefficients were used to detect linear and nonlinear trends. The results of the correlation analysis are in table 3. Significant downgradient increases were evident for specific conductance and concentrations of major ions in water from the alluvial aquifer.

The proportions of major ions in ground water also change in the study area. Calcium is the predominant cation throughout the area, but bicarbonate, which is the predominant anion north of Fountain, is replaced by sulfate as the predominant anion south of Fountain. This shift is caused by the inflow of water that has large sulfate concentrations from alluvium along Jimmy Camp Creek and from dissolution of gypsum, which is present in the shale bedrock underlying Fountain Creek (Bingham and Klein, 1973, p. 5).

Nitrite plus Nitrate

Areal variations in the concentrations of nitrite plus nitrate are indicators of the interaction between the hydrologic system and wastewater discharges, which have large concentrations of nitrogen. Concentrations of nitrite plus nitrate are largest in the extensively pumped northern end of the study area (fig. 9) and decrease significantly downgradient (table 3). The source of the nitrogen has been investigated by Edelmann and Cain (1986) who concluded that extensive pumpage of the alluvial aquifer near Security and Widefield induced recharge of water from Fountain Creek that had large concentrations of nitrogen. Nitrogen in Fountain Creek originated primarily from municipal wastewater discharges, the largest of which was from the Colorado Springs Wastewater Treatment Plant. Farther south, concentrations of nitrogen in the aquifer decreased for two reasons: (1) Water that had large concentrations of nitrogen was discharged from the aquifer by pumpage and seepage to Fountain Creek; and (2) the volume of recharge from Fountain Creek decreased in the southern part of the study area, and the water that did

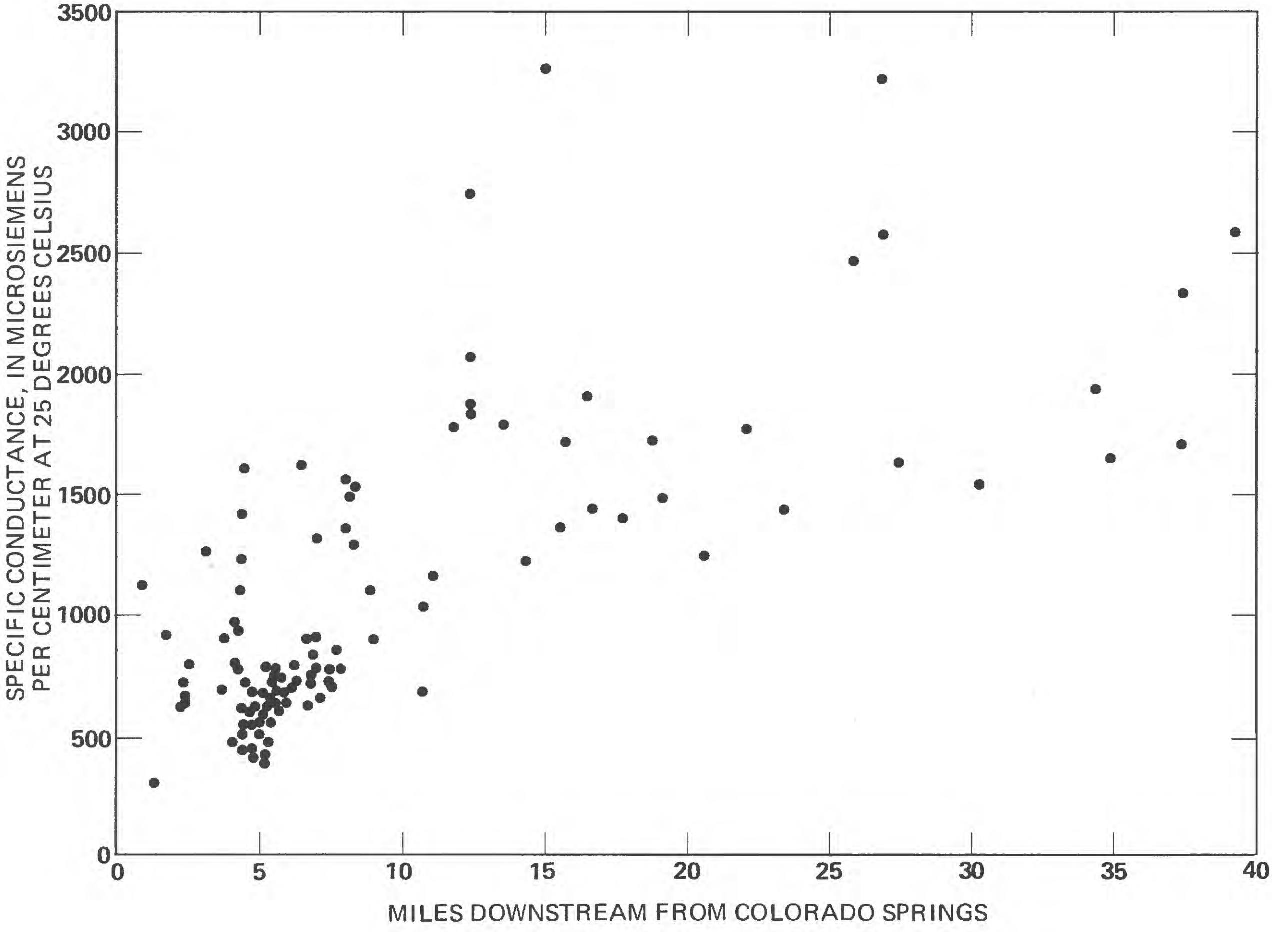


Figure 8.--Downgradient increase in specific conductance of ground water.

Table 3.--*Significant downgradient trends in water-quality constituents in the alluvial aquifer*

[All correlations shown are significant at the 95-percent confidence level]

Constituents	Downgradient trend	Spearman correlation coefficient
Specific conductance	Increase	0.67
Dissolved solids	Increase	.69
Sodium	Increase	.75
Calcium	Increase	.67
Magnesium	Increase	.66
Chloride	Increase	.62
Fluoride	Increase	.47
Sulfate	Increase	.73
Alkalinity	Increase	.66
Boron	Increase	.72
Iron	Increase	.39
Lithium	Increase	.58
Selenium	Increase	.46
Strontium	Increase	.44
Uranium	Increase	.64
Nitrite plus nitrate	Decrease	-.53
Barium	Decrease	-.78
Detergents as methylene blue active substances	Decrease	-.87

recharge the aquifer from Fountain Creek had smaller total nitrogen concentrations (fig. 7). Denitrification is not likely to be a major factor in the decrease because the dissolved oxygen concentration of water from all but two wells sampled was greater than 2.0 mg/L (table 6 in the Supplemental Data section at the back of the report).

Trace Elements

Seven of 21 trace elements analyzed, including cadmium, chromium, cobalt, lead, mercury, molybdenum, and vanadium, were not detected in water samples from any wells or were detected in only 1 well of 20 or more sampled. Six other trace elements, including arsenic, beryllium, copper, manganese, nickel, and silver, were detected at concentrations less than 10 μg/L in samples analyzed from more than 80 percent of the wells.

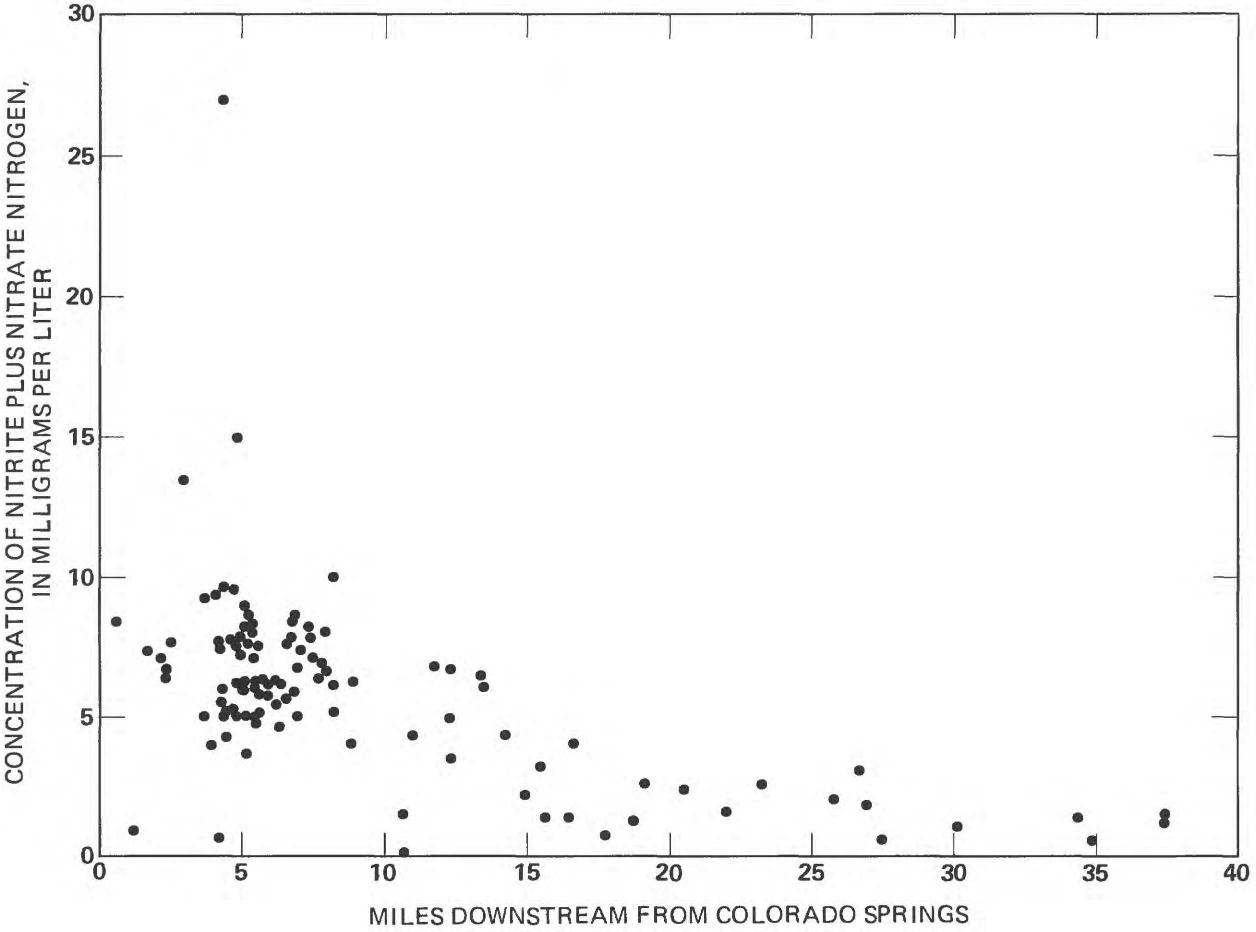


Figure 9.--Downgradient decrease in concentration of nitrite plus nitrate in ground water.

The six trace elements boron, iron, lithium, selenium, strontium, and uranium had significant downgradient increases in concentration similar to increases in specific conductance (fig. 8) and major ions (table 3). These trace elements, except selenium and iron, probably are affected by the same mechanisms as major ions. These mechanisms are: (1) Concentration by evaporation caused by water use and reuse, and (2) longer residence time resulting in increased concentrations from dissolution of aquifer materials. The downgradient increase in concentration of selenium may be caused by seleniferous beds in the shale bedrock, which occur in the southern end of the study area. The shale bedrock in this part of Colorado contains significant concentrations of selenium that may contaminate ground water (Cain and others, 1980; Mustard and Cain, 1981). The reason for the downgradient increase in concentrations of iron is not known.

Only one trace element, barium, had a significant downgradient decrease in concentration in water from the alluvial aquifer (table 3). Concentrations of barium are inversely related to the concentration of sulfate in ground water. Barium and sulfate combine chemically to form barite, a relatively insoluble mineral. Based on equilibrium calculations using WATEQ (a computer program for calculating chemical equilibria of natural waters) (Truesdale and Jones, 1974), as concentrations of sulfate increase downgradient, it appears that barite is precipitated, and less barium remains in the dissolved phase in ground water.

Dissolved Organic Carbon and Detergents

Concentrations of dissolved organic carbon in water from the alluvial aquifer range from 1 to 3 mg/L and do not have a significant downgradient trend. The range in concentrations indicates that much of the organic matter in Fountain Creek, which has dissolved organic-carbon concentrations between 3.5 and 35 depending on the site and time of year, is removed during infiltration to the ground-water system. The process of infiltration of water from Fountain Creek to the alluvial aquifer has many similarities to the treatment of sewage effluent through rapid infiltration. The removal of organic material during rapid infiltration has been the subject of several recent investigations (Clark and Baxter, 1982; Matthew and others, 1982; Bouwer and Rice, 1984) that have indicated that 70 to 90 percent of dissolved organic carbon is removed. The range of concentrations found in water from the alluvial aquifer is consistent with this percentage of removal. The mechanisms of removal are believed to be biodegradation and adsorption.

Concentrations of detergents as MBAS in water from the alluvial aquifer range from 0.02 to 0.13 mg/L and significantly decrease downgradient (table 3). Concentrations of detergents as MBAS also decrease downstream in Fountain Creek. Detergents as MBAS comprise about 5 percent of the dissolved organic carbon in water from the alluvial aquifer. Detergents associated with sewage effluent are quite mobile in a glacial-outwash aquifer that is similar in composition to the Fountain Creek alluvial aquifer (Barber, 1985). Detergents as MBAS at the site studied by Barber were useful in delineating a plume of ground-water contamination from a rapid-infiltration site and may be useful as an indicator of contamination of the Fountain Creek alluvial aquifer by sewage effluent.

Trace Organic Constituents

Volatile organic compounds in concentrations greater than 1 µg/L were detected, using the purge-and-trap technique, in 11 of the 20 wells sampled. A summary of the compounds detected is in table 4, and the sites where volatile organics were detected are shown in figure 10. The concentrations of individual volatile organic compounds were less than 5 µg/L in all samples, except well 2 where methylene chloride was 15 µg/L and well 13 where chloroform was 26 µg/L. As shown in figure 10, volatile organics were detected in ground water in urban and agricultural areas.

Table 4.--*Volatile organic compounds detected in ground water using the purge-and-trap technique*

[20 wells sampled]

Compound detected	Number of wells where compound was detected	Percent of wells where compound was detected
Chlorobenzene	1	5
Chloroform	4	20
Dichlorobromomethane	1	5
1,2-Dichloroethylene	1	5
Ethylbenzene	2	10
Methylene chloride	1	5
Tetrachloroethylene	2	10
Toluene	1	5
1,1,1-Trichloroethane	4	20
Trichloroethylene	2	10

The volatile organic compounds detected in ground water may originate from several sources. Three of the compounds detected, 1,1,1-trichloroethane, trichloroethylene, and tetrachloroethylene, are some of the most common organic contaminants of ground water (Mackay and others, 1985). They may be present in secondary sewage effluents, commonly are used in industrial operations as solvents and degreasers, and are used domestically as dry-cleaning fluids and septic-tank cleaners (Barber, 1985). In the study area, these compounds could originate from urban land use or recharge from Fountain Creek. Based on the results of a study by Schwartzenbach and others (1983) about the movement of these three constituents and chloroform from a river into an adjacent alluvial aquifer during aerobic and anaerobic conditions, a similar movement of the constituents and chloroform is likely to occur from Fountain Creek to the alluvial aquifer. However, volatile organic compounds present in Fountain Creek at the northern end of the study area are likely to decrease in concentration downstream because of volatilization losses. This decrease in concentration of volatile organic compounds and the decrease in

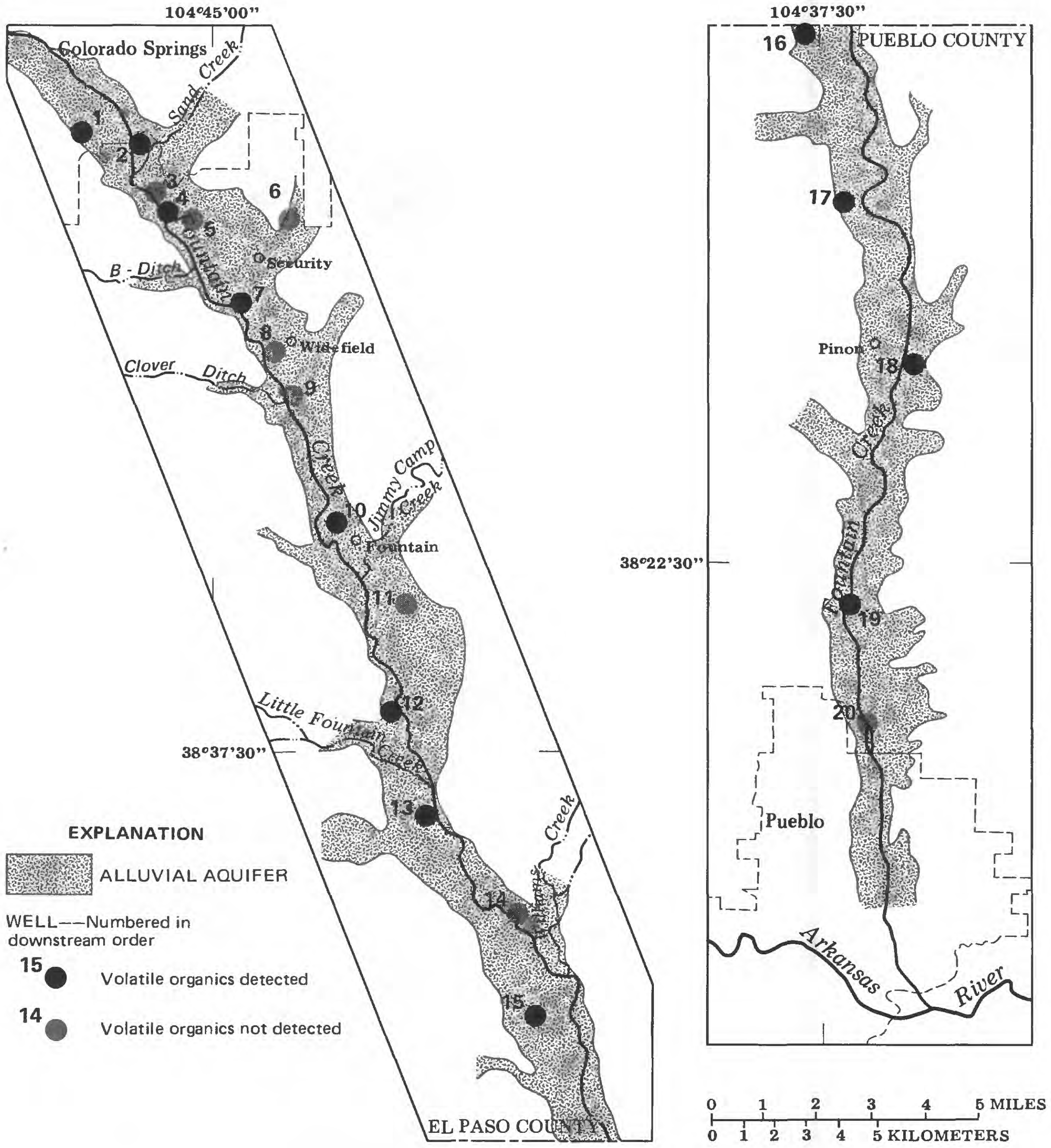


Figure 10.--Location of wells where volatile organic compounds were detected using the purge-and-trap technique.

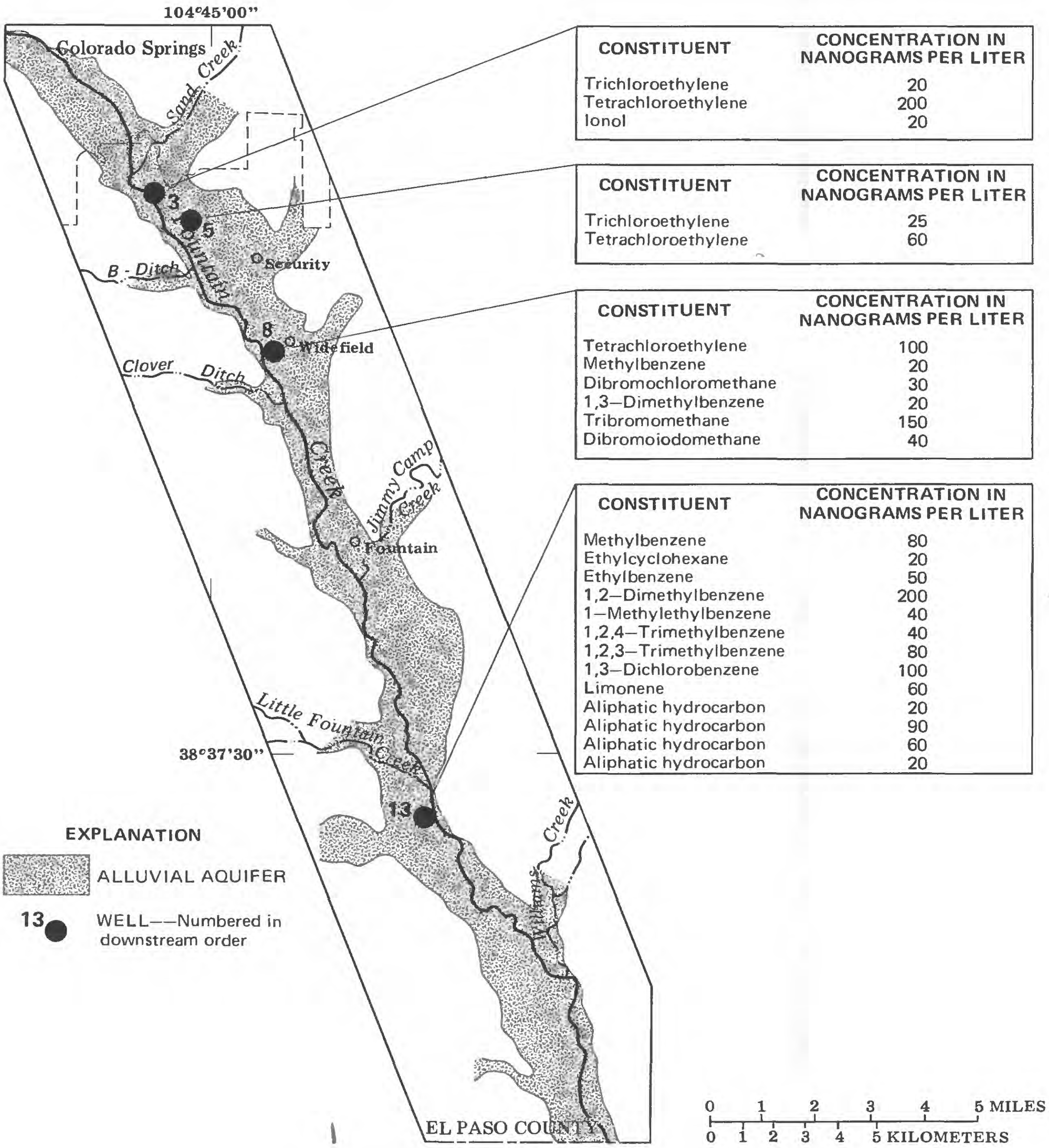
water loss to the alluvial aquifer in the southern end of the study area indicate that Fountain Creek should become less important as a source of volatile organic compounds for the alluvial aquifer as it flows through the study area.

The locations of the four wells where water samples were collected and analyzed using the closed-loop-stripping technique are shown in figure 11. Samples from these wells were also analyzed using the purge-and-trap technique; no organic compounds were detected in three of the samples, and only two compounds were detected in the fourth (well 13). The compounds detected using the closed-loop-stripping technique and approximate concentrations are shown in figure 11. Compound identifications were based on comparison with standard materials for trichloroethylene, tetrachloroethylene, 1,3-dichlorobenzene, and 1,2-dichlorobenzene. Identification of other compounds was based on a National Bureau of Standards library search, and identifications are tentative. Concentrations in figure 11 are approximations within a factor of one to five times (Michael Schroeder, U.S. Geological Survey, written commun., 1985). Because no split samples were analyzed using the closed-loop-stripping technique during this reconnaissance study, the reproducibility of the technique was not documented for the study area. However, Barber (1985) reports results for several replicate samples, using the same technique, that indicate good reproducibility. A blank consisting of prestripped distilled water analyzed with the samples contained some organic compounds in concentrations less than 10 ng/L. Because rigorous quality assurance could not be done for the four samples analyzed during this reconnaissance study, the results are considered tentative and subject to confirmation during the second phase of study.

In addition to trichloroethylene and tetrachloroethylene, many of the compounds detected using the closed-loop-stripping technique were alkylbenzenes, chlorinated benzenes, and halogenated methanes, all of which can be found in secondary sewage effluents (Barber, 1985), although other sources are possible for some of these constituents. The reason for the large number of compounds detected in the sample from well 13 is not known but may be due to the application of small quantities of sewage sludge on the land surface near this well.

PRELIMINARY EVALUATION OF RELATION BETWEEN LAND USE AND GROUND-WATER QUALITY

Summary statistics for specific conductance, major ions, trace elements, and organic constituents in ground water from urban and agricultural land-use areas are shown in table 5. Trace elements and volatile organics are included in the table only if they were detected in a sample from at least one well. A listing of all the constituents analyzed is given in table 6 in the Supplemental Data section at the back of the report. Data for volatile organic constituents are from the purge-and-trap technique; the four analyses using the closed-loop-stripping technique are not included because of the tentative nature of the results and because the small number of samples is not sufficient to calculate summary statistics.



CONSTITUENT	CONCENTRATION IN NANOGRAMS PER LITER
Trichloroethylene	20
Tetrachloroethylene	200
Ionol	20

CONSTITUENT	CONCENTRATION IN NANOGRAMS PER LITER
Trichloroethylene	25
Tetrachloroethylene	60

CONSTITUENT	CONCENTRATION IN NANOGRAMS PER LITER
Tetrachloroethylene	100
Methylbenzene	20
Dibromochloromethane	30
1,3–Dimethylbenzene	20
Tribromomethane	150
Dibromoiodomethane	40

CONSTITUENT	CONCENTRATION IN NANOGRAMS PER LITER
Methylbenzene	80
Ethylcyclohexane	20
Ethylbenzene	50
1,2–Dimethylbenzene	200
1–Methylethylbenzene	40
1,2,4–Trimethylbenzene	40
1,2,3–Trimethylbenzene	80
1,3–Dichlorobenzene	100
Limonene	60
Aliphatic hydrocarbon	20
Aliphatic hydrocarbon	90
Aliphatic hydrocarbon	60
Aliphatic hydrocarbon	20

Figure 11.--Location of wells where water samples were collected for analysis by the closed-loop-stripping technique and the results of the analyses.

Table 5.--*Summary water-quality statistics for the two land-use areas*

[µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; MBAS, methylene blue active substances; asterisk indicates statistic estimated using the method developed by Helsel and Gilliom (1985); dashes indicate insufficient data to calculate statistic]

		Urban land use						Agricultural land use					
Constituent	Units	Number of wells	Number of detections	Mean	Standard deviation	Median	Interquartile range	Number of wells	Number of detections	Mean	Standard deviation	Median	Interquartile range
INORGANIC CONSTITUENTS OR PHYSICAL PROPERTIES													
Specific conductance	µS/cm	74	74	780	270	720	220	39	39	1,670	660	1,650	580
Dissolved solids	mg/L	42	42	488	204	442	175	24	24	1,260	546	1,300	560
Sodium	mg/L	43	43	61	29	56	23	34	34	170	75	160	80
Potassium	mg/L	43	43	4.4	1.8	4.0	1.9	33	33	4.3	1.5	4.2	2.1
Calcium	mg/L	46	46	77	26	72	24	35	35	169	65	160	65
Magnesium	mg/L	46	46	18	9.2	17	11	35	35	51	24	46	18
Chloride	mg/L	74	74	32	17	29	15	39	39	49	19	53	19
Fluoride	mg/L	44	44	1.4	0.8	1.2	1.2	34	34	2.1	0.9	2.2	1.2
Sulfate	mg/L	45	45	156	91	141	90	34	34	645	349	605	290
Alkalinity	mg/L	46	46	173	45	167	45	35	35	255	44	260	43
Ammonia plus organic nitrogen	mg/L	65	65	1.4	.5	1.4	.4	20	20	1.0	.9	1.0	.8
Nitrite plus nitrate nitrogen	mg/L	72	71	6.6*	2.1*	6.5*	2.2*	37	37	4.3	4.7	3.1	3.6
Phosphorus	mg/L	8	8	.12	.25	.03	.04	12	9	.07*	.19*	.01*	.01*
TRACE ELEMENTS													
Arsenic	µg/L	16	3	.42*	.76*	.47*	.55*	18	2	--	--	--	--
Barium	µg/L	8	8	86	32	88	45	12	12	41	23	30	22
Beryllium	µg/L	8	2	--	--	--	--	12	6	1.4*	.8*	1.1*	1.3*
Boron	µg/L	16	16	166	66	175	110	19	19	268	103	260	80
Chromium	µg/L	9	0	--	--	--	--	12	1	--	--	--	--
Copper	µg/L	11	1	--	--	--	--	12	11	--	--	--	--

Table 5.--*Summary water-quality statistics for the two land-use areas*--Continued

		Urban land use						Agricultural land use					
Constituent	Units	Number of wells	Number of detections	Mean	Standard deviation	Median	Inter-quartile range	Number of wells	Number of detections	Mean	Standard deviation	Median	Inter-quartile range
TRACE ELEMENTS--Continued													
Iron	µg/L	43	41	17*	19*	8.0*	15*	33	30	59*	223*	20*	24*
Lead	µg/L	11	1	--	--	--	--	12	0	--	--	--	--
Lithium	µg/L	8	8	41	8.2	40	13	12	12	72	24	72	19
Manganese	µg/L	42	7	--	--	--	--	33	6	--	--	--	--
Molybdenum	µg/L	8	1	--	--	--	--	12	0	--	--	--	--
Nickel	µg/L	10	10	2.4	1.5	2.0	2.0	12	9	2.9*	2.1*	3.0*	2.3*
Selenium	µg/L	16	12	2.4*	1.5*	2.5*	1.9*	18	18	9.4	12	5.5	5.0
Silver	µg/L	8	1	--	--	--	--	12	2	--	--	--	--
Strontium	µg/L	8	8	440	140	420	240	12	12	800	280	830	330
Uranium	µg/L	8	8	6.4	2.8	6.4	3.8	12	12	13	3.4	13	3.5
Zinc	µg/L	11	10	16*	12*	13*	6*	12	12	23	14	21	19
ORGANIC CONSTITUENTS													
Dissolved organic carbon	mg/L	8	8	1.9	.5	1.9	.8	12	12	2.0	.5	2.1	.6
Detergents as MBAS	mg/L	8	8	.10	.02	.10	.02	12	12	.06	.03	.05	.02
Chlorobenzene	µg/L	8	0	--	--	--	--	12	1	--	--	--	--
Chloroform	µg/L	8	1	--	--	--	--	12	3	2.6*	7.4*	.2*	1.0*
Dichlorobromo-methane	µg/L	8	0	--	--	--	--	12	1	--	--	--	--
1,2-dichloro-ethylene	µg/L	8	0	--	--	--	--	12	1	--	--	--	--
Ethylbenzene	µg/L	8	1	--	--	--	--	12	1	--	--	--	--
Methylene chloride	µg/L	8	0	--	--	--	--	12	1	--	--	--	--
Tetrachloro-ethylene	µg/L	8	2	--	--	--	--	12	0	--	--	--	--
Toluene	µg/L	8	0	--	--	--	--	12	1	--	--	--	--
1,1,1-Trichloro-ethane	µg/L	8	1	--	--	--	--	12	3	.80*	.32*	.81*	.35*
Trichloroethylene	µg/L	8	0	--	--	--	--	12	2	--	--	--	--

Mean and median concentrations are larger in water from the agricultural land-use areas for constituents that have downgradient increases in concentration (table 3) because the agricultural land primarily is in the southern (downgradient) part of the study area (fig. 5). Similarly, constituents that have significant decreases in concentration downgradient (table 3) have larger mean and median concentrations in water from the urban (upgradient) land-use area. Differences in concentration between the two land-use areas were tested using the nonparametric Kruskal-Wallis test (Conover, 1980) at the 0.05 significance level. Significant differences were found for all constituents that have downgradient changes in concentration.

Although there are significant differences in concentration between the two land-use areas for constituents that had downgradient trends, land use is not the primary factor responsible for these differences. Other activities of man and natural processes in the hydrologic system are more important in controlling concentrations of these constituents. Water use and reuse, longer ground-water residence time, and tributary ground-water inflows probably are responsible for most of the differences for specific conductance, major ions, and several trace elements (boron, lithium, strontium, and uranium). Geologic conditions probably affect the difference in selenium concentrations, and chemical controls affect barium concentrations. The reason for larger concentrations of iron in the agricultural area is not known but could be related to differences in well-casing materials between agricultural wells and public supply wells. Differences between the land-use areas for nitrite plus nitrate and detergents as MBAS primarily are related to discharges of sewage effluent into Fountain Creek and subsequent recharge of this water to the alluvial aquifer caused by intense pumping in the northern one-third of the study area.

Trace elements that did not have downgradient trends were evaluated for differences in concentration between land-use areas, if sufficient data were available. Nickel and zinc were the only other trace elements that had enough values greater than the detection limit to evaluate differences using the Kruskal-Wallis test. There was no significant difference between the areas for nickel, but zinc was present in significantly larger concentrations in wells in the agricultural land-use area. The reason for this difference is not known, but it may be related to differences in well-casing materials rather than differences in land use. Three other trace elements, arsenic, beryllium, and manganese, were detected in fewer than one-half of the samples analyzed and were evaluated for differences between the areas using contingency-table analysis of the frequency of exceeding the detection limit (Conover, 1980; Helsel and Ragone, 1984). The significance level of the test was again set at 0.05. The frequency of detection of arsenic, beryllium, and manganese did not differ significantly between land-use areas. No evaluation of differences in concentration or frequency of detection could be made for cadmium, chromium, cobalt, copper, mercury, molybdenum, nickel, silver, or vanadium because these trace elements were detected infrequently.

Detergents as MBAS was the only organic constituent that had a significant difference in concentration between the two land-use areas. Dissolved organic carbon was not present in significantly different concentrations in the two land-use areas. A statistical evaluation of differences in concentrations of volatile organic compounds between the two areas was not possible because volatile organics were detected too infrequently using the purge-and-trap technique. However, the available data indicated that several volatile organic compounds occur in ground water from urban and agricultural land-use areas (table 4 and fig. 10). To evaluate differences in concentration or frequency of detection of trace organic constituents between land-use areas, additional analyses using techniques that have smaller detection limits are needed. The limited evaluation using the closed-loop-stripping technique indicated that volatile and semivolatile organic compounds that were not detectable using the purge-and-trap technique also were present in ground water of the study area.

SUMMARY AND CONCLUSIONS

Water quality in the Fountain Creek alluvial aquifer is characterized by downgradient trends in the concentrations of numerous constituents. The trends were determined using correlation analysis between concentration and downgradient distance. Downgradient increases in specific conductance and concentrations of major ions, boron, lithium, strontium, and uranium are caused by water use and reuse resulting in concentration of the constituents through evaporation and by longer ground-water residence time and dissolution of minerals in the aquifer and underlying bedrock. A downgradient increase in selenium concentrations probably is controlled by the occurrence of seleniferous beds in the shale bedrock in the southern part of the area. Reasons for a downgradient increase in the concentration of iron are not known. Downgradient decreases in concentration occur for nitrite plus nitrate, detergents as MBAS, and barium. Concentrations of nitrite plus nitrate are largest in the northern (upgradient) end of the study area where water containing large proportions of sewage effluent from Fountain Creek recharges the alluvial aquifer as a result of intense ground-water pumpage. The downgradient decrease in barium concentrations is caused by precipitation of barite resulting from increasing sulfate concentrations downgradient.

The trace elements cadmium, chromium, cobalt, lead, mercury, molybdenum, and vanadium were not detected in ground water in the study area or were found in only one well of 20 or more sampled. Arsenic, beryllium, copper, manganese, nickel, and silver were reported in concentrations less than 10 μg/L in samples from more than 80 percent of the wells.

Volatile organic compounds in concentrations greater than 1 μg/L were detected, using the purge-and-trap technique in samples from 11 of 20 wells located in urban and agricultural areas. The compounds detected included chlorobenzene, chloroform, dichlorobromomethane, 1,2-dichloroethylene, ethylbenzene, methylene chloride, tetrachloroethylene, toluene, 1,1,1-trichloroethane, and trichloroethylene. Because individual compounds were detected in samples from only 20 percent or less of the wells, statistical evaluation of downgradient trends or differences between urban and agricultural land uses was not possible.

A preliminary evaluation of a closed-loop-stripping technique, which could be used more extensively during the second phase of the study for analysis of semivolatile organic compounds, was made. The evaluation indicated that more compounds could be detected using closed-loop stripping than using the purge-and-trap technique because of the smaller detection limits that were possible using closed-loop stripping and because of somewhat larger molecular weights of the analyzed compounds.

Because urban land primarily is located in the northern (upgradient) end of the study area and agricultural land primarily is in the southern (downgradient) end of the study area, differences occur in concentration between the areas for water-quality constituents that have downgradient concentration trends. These differences do not indicate a causal relation between land use and ground-water quality because other factors control ground-water quality.

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SUPPLEMENTAL DATA

Table 6.--*Water-quality data collected from wells and surface-water sites during 1984*

[GW, ground water; SW, surface water; °C, degrees Celsius, ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter; It-fld, onsite incremental titration; µg/L, micrograms per liter; dashes indicate data not available]

Number in figure 6	Name	Type of site	Date of sample	Time	Temperature (°C)	Streamflow, instantaneous (ft^3/s)
1	SC01406632AAD Harrison High School	GW	09-07-84	1700	13.0	--
2	SC01406633DAA Barnes	GW	09-07-84	1500	13.0	--
3	SC01506603BAC1 Mars Gas	GW	09-12-84	1500	14.5	--
4	SC01506603CAD1 Stratmoor Hills-4	GW	09-10-84	1330	14.0	--
5	SC01506603DDB Security-14	GW	09-12-84	1045	12.5	--
6	SC01506601DDB Widefield-8	GW	09-12-84	1715	13.5	--
7	SC01506614AAD Security-2	GW	09-10-84	1500	13.0	--
8	SC01506624BAD1 Widefield-4	GW	09-12-84	1315	13.5	--
9	SC01506625AAD Widefield-14	GW	09-10-84	1645	13.5	--
10	SC01606506ACD Fountain School	GW	09-06-84	1445	12.5	--
11	SC01606517AAA2 West Turf Farm	GW	09-06-84	1645	13.5	--
12	SC01606520DCA Hanna Ranch 8	GW	09-07-84	1300	13.0	--
13	SC01606533CCB Hanna Ranch 6	GW	09-18-84	1015	13.0	--
14	SC01706511CCA Frost	GW	09-08-84	1145	13.0	--
15	SC01706523CAB Sandrup	GW	09-06-84	1115	12.0	--
16	SC01806501BAB Rutledge	GW	09-07-84	1100	12.5	--
17	SC01806524AAC Stidham	GW	09-18-84	1200	15.0	--
18	SC01906406AAD Pace	GW	09-18-84	1345	12.5	--
19	SC01906525DAB Nichols	GW	09-18-84	1500	13.0	--
20	SC02006501DDA Barr	GW	09-18-84	1615	13.0	--
07105500	Fountain Creek at Colorado Springs	SW	09-11-84	0930	15.0	53
			11-26-84	0900	2.0	110
CSWWTP	Colorado Springs Wastewater Treatment Plant effluent	SW	09-11-84	1430	25.5	53
			11-26-84	1130	14.0	65
07105530	Fountain Creek below Janitell Road below Colorado Springs	SW	09-11-84	1145	17.5	90
			11-26-84	1345	4.5	170
07105905	Fountain Creek above Little Fountain Creek, below Fountain	SW	09-11-84	1620	20.5	73
			11-26-84	1615	4.0	214
07106300	Fountain Creek near Pinon	SW	09-11-84	1800	20.5	40
			11-27-84	0900	.0	197
07106500	Fountain Creek at Pueblo	SW	09-11-84	1945	19.5	58
			11-27-84	1130	3.0	212

Table 6.--*Water-quality data collected from wells and surface-water sites during 1984*--Continued

Number in figure 6	Date of sample	Specific conductance (µS/cm)	Specific conductance, laboratory (µS/cm)	pH (standard units)	Oxygen, dissolved (mg/L)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)
1	09-07-84	847	940	6.9	5.7	71	4.8	97	22	42	3.0
2	09-07-84	1,270	1,390	7.3	--	87	4.5	160	48	42	1.1
3	09-12-84	1,030	1,000	7.1	3.2	64	4.5	110	30	30	1.1
4	09-10-84	900	984	7.2	2.9	54	3.2	120	27	35	.80
5	09-12-84	570	566	7.6	6.6	33	2.2	66	9.6	22	.40
6	09-12-84	450	460	7.6	6.0	30	2.0	51	7.3	6.8	.40
7	09-10-84	520	508	6.8	6.3	34	3.5	50	9.9	16	1.3
8	09-12-84	735	712	6.7	2.4	60	3.8	59	14	27	1.3
9	09-10-84	1,060	1,030	7.3	--	76	3.5	95	32	35	.90
10	09-06-84	690	670	7.4	<.1	65	5.4	50	15	30	2.0
11	09-06-84	1,830	1,820	7.2	6.4	210	3.3	150	44	47	1.7
12	09-07-84	1,220	1,350	6.9	2.3	130	5.7	110	32	47	2.0
13	09-18-84	1,910	1,920	7.4	5.9	140	4.4	220	56	53	2.3
14	09-08-84	1,730	1,920	7.2	<1.9	200	6.3	180	46	61	2.4
15	09-06-84	1,250	1,220	7.5	3.0	120	5.3	110	28	47	2.5
16	09-07-84	1,440	1,610	7.4	4.2	150	3.5	150	41	67	2.4
17	09-18-84	3,220	3,130	7.3	6.4	280	3.5	350	110	68	1.0
18	09-18-84	1,530	1,530	7.4	5.3	140	3.7	130	34	59	2.7
19	09-18-84	1,650	1,620	7.3	3.2	160	5.4	120	39	56	3.1
20	09-18-84	1,710	1,680	7.4	5.4	160	4.8	140	42	65	3.0
07105500	09-11-84	332	376	8.2	9.9	19	3.5	39	7.9	10	2.3
	11-26-84	425	333	8.3	11.0	18	3.3	37	7.6	10	2.1
CSWWTP	09-11-84	938	930	7.2	2.1	98	11	43	17	43	2.7
	11-26-84	1,020	995	7.1	2.1	100	8.3	50	22	45	2.7
07105530	09-11-84	604	609	7.9	8.1	55	6.4	44	13	23	2.3
	11-26-84	890	856	--	9.1	95	5.5	55	17	84	2.0
07105905	09-11-84	940	926	8.1	6.7	88	5.8	68	23	34	2.2
	11-26-84	742	716	--	8.6	66	4.6	55	19	26	2.0
07106300	09-11-84	1,180	1,130	8.4	6.9	110	5.8	87	28	44	2.4
	11-27-84	980	943	8.4	10.4	93	5.2	75	24	47	2.0
07106500	09-11-84	1,370	1,340	8.5	7.2	130	5.8	100	37	47	2.5
	11-27-84	1,060	1,020	8.2	11.0	110	4.9	83	28	50	2.1

Table 6.--*Water-quality data collected from wells and surface-water sites during 1984*--Continued

Number in figure 6	Date of sample	Sulfate, dissolved (mg/L as SO_4)	Alkalinity, onsite (mg/L as $CaCO_3$)	Alkalinity, laboratory (mg/L as $CaCO_3$)	Bicarbonate, It-fld (mg/L as HCO_3)	Carbonate, It-fld (mg/L as CO_3)	Nitrogen, ammonia + organic dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, NO^2+NO^3, dissolved (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Phosphorus, ortho, dissolved (mg/L as P)
1	09-07-84	250	150	151	190	0.000	0.70	0.010	8.5	<0.010	0.060
2	09-07-84	380	300	300	373	.000	.60	.040	13	<.010	.050
3	09-12-84	260	200	197	243	.000	.90	.590	8.0	<.010	.120
4	09-10-84	210	245	240	301	.000	1.3	.620	6.8	<.010	.170
5	09-12-84	69	160	156	194	.000	1.1	.660	6.6	<.010	.370
6	09-12-84	47	160	158	200	.000	.90	.570	5.1	<.010	.040
7	09-10-84	68	130	128	156	.000	.60	.680	6.9	<.010	.160
8	09-12-84	140	170	166	208	.000	.80	.720	6.3	.010	.280
9	09-10-84	250	230	228	288	.000	.60	.670	7.4	<.010	.310
10	09-06-84	150	165	134	208	.000	1.7	1.30	<.10	<.010	.780
11	09-06-84	670	250	246	309	.000	.60	.050	3.4	<.010	.040
12	09-07-84	440	190	243	234	.000	.60	<.010	4.3	<.010	.690
13	09-18-84	750	260	255	310	.000	.20	.060	1.4	<.010	<.010
14	09-08-84	720	270	222	338	.000	.50	.040	1.3	<.010	.040
15	09-06-84	360	230	224	282	.000	.50	.020	2.3	<.010	.040
16	09-07-84	520	255	252	316	.000	.40	.040	2.5	<.010	.030
17	09-18-84	1,600	320	314	393	.000	.20	.140	3.0	<.010	<.010
18	09-18-84	470	255	251	318	.000	4.1	.040	1.1	<.010	<.010
19	09-18-84	480	310	308	384	.000	.20	.020	.64	<.010	.030
20	09-18-84	550	260	258	320	.000	.30	.040	1.5	<.010	<.010
07105500	09-11-84	62	96	88	116	.000	.20	.020	.88	<.010	.030
	11-26-84	57	83	76	101	.000	.40	.060	1.2	<.010	.110
CSWWTP	09-11-84	190	195	187	241	.000	20	20.0	.12	.020	6.30
	11-26-84	240	190	160	224	.000	19	18.0	.43	.130	6.80
07105530	09-11-84	130	130	129	161	.000	8.0	6.40	1.0	.110	2.00
	11-26-84	160	140	114	164	8.0	6.0	5.30	1.9	.110	1.50
07105905	09-11-84	240	150	144	182	.000	.90	.730	4.5	.210	1.30
	11-26-84	190	--	113		--	1.8	.960	3.8	.050	1.20
07106300	09-11-84	330	195	188	223	8.0	.80	.030	2.8	.010	.790
	11-27-84	250	170	148	187	7.0	1.4	.770	3.9	.020	1.10
07106500	09-11-84	430	--	200		--	1.2	.040	3.5	<.010	.460
	11-27-84	290	170	159	204	.000	.90	.230	4.4	.020	.980

Table 6.--*Water-quality data collected from wells and surface-water sites during 1984*--Continued

Number in figure 6	Date of sample	Phosphorus, dissolved (mg/L as P)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Beryllium, dissolved (µg/L as Be)	Boron, dissolved (µg/L as B)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Cobalt, dissolved (µg/L as Co)	Copper, dissolved (µg/L as Cu)	Iron, dissolved (µg/L as Fe)
1	09-07-84	0.030	<1	95	2.0	110	<1	<10	<3	<10	5
2	09-07-84	.020	<1	75	2.0	180	<1	<10	<3	<10	10
3	09-12-84	.010	<1	80	<1.0	170	<1	<10	<3	10	19
4	09-10-84	.080	<1	120	<1.0	120	<1	<10	<3	<10	5
5	09-12-84	.040	<1	130	<1.0	50	<1	<10	<3	<10	5
6	09-12-84	.050	<1	39	<1.0	30	<1	<10	<3	<10	5
7	09-10-84	.020	<1	98	<1.0	90	<1	<10	<3	<10	5
8	09-12-84	.030	<1	73	<1.0	200	<1	<10	<3	<10	4
9	09-10-84	.030	<1	32	<1.0	160	<1	<10	<3	<10	13
10	09-06-84	.750	3	56	1.0	170	<1	<10	<3	<10	25
11	09-06-84	.010	<1	25	2.0	250	<1	<10	<3	<10	4
12	09-07-84	.680	4	93	1.0	230	<1	<10	<3	<10	4
13	09-18-84	.010	<1	52	<1.0	160	<1	190	<3	<10	7
14	09-08-84	.010	<1	43	2.0	320	<1	<10	<3	<10	25
15	09-06-84	.010	<1	32	3.0	290	<1	<10	<3	<10	6
16	09-07-84	.010	<1	27	2.0	330	<1	<10	<3	<10	50
17	09-18-84	<.010	<1	21	<1.0	510	<1	<10	<3	10	23
18	09-18-84	<.010	<1	28	<1.0	260	<1	<10	<3	<10	8
19	09-18-84	.010	<1	24	<1.0	330	<1	<10	<3	<10	4
20	09-18-84	<.010	<1	27	<1.0	290	<1	<10	<3	<10	9
07105500	09-11-84	.040	<1	43	<1.0	50	<1	<10	<3	<10	10
	11-26-84	.140	<1	50	<1.0	40	<1	30	<3	<10	680
CSWWTP	09-11-84	6.60	<1	32	<1.0	270	<1	<10	<3	<10	37
	11-26-84	6.70	<1	28	<1.0	240	2	<10	<3	10	44
07105530	09-11-84	2.30	<1	42	<1.0	150	<1	<10	<3	<10	12
	11-26-84	1.80	<1	42	<1.0	110	1	<10	<3	10	110
07105905	09-11-84	1.50	2	46	<1.0	190	<1	<10	<3	<10	<3
	11-26-84	1.30	<1	37	<1.0	130	2	<10	<3	<10	170
07106300	09-11-84	.830	2	54	<1.0	240	<1	<10	<3	<10	<3
	11-27-84	1.10	<1	44	<1.0	160	1	20	<3	<10	30
07106500	09-11-84	.510	2	57	<1.0	250	<1	<10	<3	<10	<3
	11-27-84	.990	1	40	<1.0	170	1	<10	<3	<10	15

Table 6.--*Water-quality data collected from wells and surface-water sites during 1984*--Continued

Number in figure 6	Date of sample	Lead, dissolved (µg/L as Pb)	Lithium, dissolved (µg/L as Li)	Manganese, dissolved (µg/L as Mn)	Mercury, dissolved (µg/L as Hg)	Molybdenum, dissolved (µg/L as Mo)	Nickel, dissolved (µg/L as Ni)	Selenium, dissolved (µg/L as Se)	Silver, dissolved (µg/L as Ag)	Strontium, dissolved (µg/L as Sr)	Uranium, natural, dissolved (µg/L as U)
1	09-07-84	<10	43	2	<.1	<10	6	3	<1	470	5.6
2	09-07-84	<10	78	3	<.1	<10	<1	9	<1	960	13
3	09-12-84	<10	49	4	<.1	<10	3	6	<1	660	11
4	09-10-84	<10	45	2	<.1	<10	2	4	<1	570	8.5
5	09-12-84	<10	36	3	<.1	<10	3	3	<1	320	6.5
6	09-12-84	<10	25	3	<.1	<10	5	2	<1	310	9.0
7	09-10-84	<10	31	3	<.1	<10	1	3	1	280	3.2
8	09-12-84	<10	37	2	<.1	<10	3	2	<1	360	7.9
9	09-10-84	<10	54	3	<.1	<10	1	3	<1	560	6.2
10	09-06-84	10	32	2,200	<.1	20	2	<1	<1	330	2.6
11	09-06-84	<10	80	4	<.1	<10	<1	7	1	740	12
12	09-07-84	<10	59	4	<.1	<10	2	6	<1	650	6.9
13	09-18-84	<10	61	<1	<.1	<10	3	20	<1	1,300	16
14	09-08-84	<10	84	15	<.1	<10	3	4	<1	980	13
15	09-06-84	<10	59	3	<.1	<10	<1	4	<1	640	12
16	09-07-84	<10	70	4	<.1	<10	1	12	1	1,100	12
17	09-18-84	<10	130	<1	<.1	<10	3	54	<1	400	20
18	09-18-84	<10	64	<1	<.1	<10	3	5	<1	790	15
19	09-18-84	<10	77	<1	<.1	<10	4	4	<1	860	14
20	09-18-84	<10	74	<1	<.1	<10	8	8	<1	900	16
07105500	09-11-84	<10	27	24	<.1	<10	3	2	<1	250	3.4
	11-26-84	<10	26	58	<.1	<10	4	2	<1	220	3.0
CSWWTP	09-11-84	<10	35	120	<.1	<10	10	4	<1	310	1.0
	11-26-84	<10	40	140	<.1	<10	13	7	<1	400	5.0
07105530	09-11-84	<10	34	60	<.1	<10	13	3	<1	300	3.0
	11-26-84	<10	40	82	<.1	<10	9	6	<1	380	4.7
07105905	09-11-84	<10	46	24	<.1	<10	5	5	<1	470	5.9
	11-26-84	<10	39	100	<.1	<10	8	4	<1	390	5.2
07106300	09-11-84	<10	54	4	<.1	<10	5	4	<1	620	8.6
	11-27-84	<10	44	15	<.1	<10	7	5	<1	500	6.3
07106500	09-11-84	<10	64	3	<.1	<10	2	28	<1	740	11
	11-27-84	<10	49	6	.2	<10	6	12	<1	570	7.4

Table 6.--*Water-quality data collected from wells and surface-water sites during 1984*--Continued

Number in figure 6	Date of sample	Vanadium, dissolved (µg/L as V)	Zinc, dissolved (µg/L as Zn)	Cyanide, dissolved (mg/L as CN)	Carbon, organic, dissolved (mg/L as C)	Methylene blue active substances (mg/L)	Benzene, total (µg/L)	Bromoform, total (µg/L)	Carbontetrachloride, total (µg/L)	Chlorobenzene, total (µg/L)	Chlorodibromomethane, total (µg/L)
1	09-07-84	<6	5	<0.01	1.1	0.10	<1.0	<1.0	<1.0	<1.0	<1.0
2	09-07-84	<6	17	<.01	2.0	.13	<1.0	<1.0	<1.0	<1.0	<1.0
3	09-12-84	<6	51	<.01	2.3	.12	<1.0	<1.0	<1.0	<1.0	<1.0
4	09-10-84	<6	15	<.01	2.0	.12	<1.0	<1.0	<1.0	<1.0	<1.0
5	09-12-84	<6	13	<.01	1.7	.09	<1.0	<1.0	<1.0	<1.0	<1.0
6	09-12-84	<6	17	<.01	1.1	.08	<1.0	<1.0	<1.0	<1.0	<1.0
7	09-10-84	<6	12	<.01	1.3	.10	<1.0	<1.0	<1.0	<1.0	<1.0
8	09-12-84	<6	12	<.01	2.3	.10	<1.0	<1.0	<1.0	<1.0	<1.0
9	09-10-84	<6	12	<.01	1.8	.11	<1.0	<1.0	<1.0	<1.0	<1.0
10	09-06-84	<6	16	<.01	2.7	.07	<1.0	<1.0	<1.0	<1.0	<1.0
11	09-06-84	<6	45	<.01	2.3	.05	<1.0	<1.0	<1.0	<1.0	<1.0
12	09-07-84	<6	19	<.01	2.1	.07	<1.0	<1.0	<1.0	2.5	<1.0
13	09-18-84	<6	25	<.01	2.4	.05	<1.0	<1.0	<1.0	<1.0	<1.0
14	09-08-84	<6	47	<.01	2.2	.04	<1.0	<1.0	<1.0	<1.0	<1.0
15	09-06-84	<6	7	<.01	1.7	.05	<1.0	<1.0	<1.0	<1.0	<1.0
16	09-07-84	<6	41	<.01	1.6	.05	<1.0	<1.0	<1.0	<1.0	<1.0
17	09-18-84	<6	22	<.01	1.8	.06	<1.0	<1.0	<1.0	<1.0	<1.0
18	09-18-84	<6	11	<.01	1.9	.02	<1.0	<1.0	<1.0	<1.0	<1.0
19	09-18-84	<6	6	<.01	2.6	.04	<1.0	<1.0	<1.0	<1.0	<1.0
20	09-18-84	<6	24	<.01	2.8	.05	<1.0	<1.0	<1.0	<1.0	<1.0
07105500	09-11-84	<6	11	<.01	4.8	.04	<1.0	<1.0	<1.0	<1.0	<1.0
	11-26-84	<6	23	.01	17	.04	<1.0	<1.0	<1.0	<1.0	<1.0
CSWWTP	09-11-84	<6	54	<.01	11	.17	<1.0	<1.0	<1.0	<1.0	<1.0
	11-26-84	<6	67	.01	20	.22	<1.0	<1.0	<1.0	<1.0	<1.0
07105530	09-11-84	<6	24	<.01	5.9	.17	<1.0	<1.0	<1.0	<1.0	<1.0
	11-26-84	<6	19	.01	30	.17	<1.0	<1.0	<1.0	<1.0	<1.0
07105905	09-11-84	<6	18	<.01	4.0	.12	<1.0	<1.0	<1.0	<1.0	<1.0
	11-26-84	<6	20	.03	35	.09	<1.0	<1.0	<1.0	<1.0	<1.0
07106300	09-11-84	<6	16	<.01	3.5	.09	<1.0	<1.0	<1.0	<1.0	<1.0
	11-27-84	<6	26	.01	30	.11	<1.0	<1.0	<1.0	<1.0	<1.0
07106500	09-11-84	<6	10	<.01	3.7	.08	<1.0	<1.0	<1.0	<1.0	<1.0
	11-27-84	<6	13	.01	15	.11	<1.0	<1.0	<1.0	<1.0	<1.0

Table 6.--*Water-quality data collected from wells and surface-water sites during 1984*--Continued

Number in figure 6	Date of sample	Chloroethane, total (µg/L)	2-Chloroethyl vinylether, total (µg/L)	Chloroform, total (µg/L)	Dichlorobromomethane, total (µg/L)	Dichlorodifluoromethane, total (µg/L)	1,1-Dichloroethane, total (µg/L)	1,2-Dichloroethane, total (µg/L)	1,1-Dichloroethylene, total (µg/L)	1,2-Transdichloroethylene, total (µg/L)	1,2-Dichloropropane, total (µg/L)
1	09-07-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2	09-07-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
3	09-12-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
4	09-10-84	<1.0	<1.0	4.6	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
5	09-12-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
6	09-12-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
7	09-10-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
8	09-12-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
9	09-10-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
10	09-06-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
11	09-06-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
12	09-07-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.0	<1.0
13	09-18-84	<1.0	<1.0	26	1.5	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
14	09-08-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
15	09-06-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
16	09-07-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
17	09-18-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
18	09-18-84	<1.0	<1.0	1.8	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
19	09-18-84	<1.0	<1.0	3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
20	09-18-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
07105500	09-11-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	11-26-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
CSWWTP	09-11-84	<1.0	<1.0	3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	11-26-84	<1.0	<1.0	2.1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
07105530	09-11-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	11-26-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
07105905	09-11-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	11-26-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
07106300	09-11-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	11-27-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
07106500	09-11-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	11-27-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

Table 6.--*Water-quality data collected from wells and surface-water sites during 1984*--Continued

Number in figure 6	Date of sample	1,3-Dichloropropene, total (µg/L)	Ethylbenzene, total (µg/L)	Methylbromide, total (µg/L)	Methylene chloride, total (µg/L)	1,1,2,2 Tetrachloroethane, total (µg/L)	Tetrachloroethylene, total (µg/L)	Toluene, total (µg/L)	1,1,1-Trichloroethane, total (µg/L)	1,1,2-Trichloroethane, total (µg/L)
1	09-07-84	<1.0	<1.0	<1.0	<1.0	<1.0	3.8	<1.0	4.3	<1.0
2	09-07-84	<1.0	<1.0	<1.0	15	<1.0	<1.0	<1.0	<1.0	<1.0
3	09-12-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
4	09-10-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
5	09-12-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
6	09-12-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
7	09-10-84	<1.0	<1.0	<1.0	<1.0	<1.0	1.0	<1.0	<1.0	<1.0
8	09-12-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
9	09-10-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
10	09-06-84	<1.0	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
11	09-06-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
12	09-07-84	<1.0	3.0	<1.0	<1.0	<1.0	<1.0	2.1	1.3	<1.0
13	09-18-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
14	09-08-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
15	09-06-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.4	<1.0
16	09-07-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.0	<1.0
17	09-18-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
18	09-18-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
19	09-18-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
20	09-18-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
07105500	09-11-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	11-26-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
CSWWTP	09-11-84	<1.0	<1.0	<1.0	<1.0	<1.0	3.0	<1.0	<1.0	<1.0
	11-26-84	<1.0	<1.0	<1.0	12	<1.0	<1.0	1.2	<1.0	<1.0
07105530	09-11-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	11-26-84	<1.0	<1.0	<1.0	5.1	<1.0	<1.0	<1.0	<1.0	<1.0
07105905	09-11-84	<1.0	<1.0	<1.0	<1.0	<1.0	2.2	<1.0	<1.0	<1.0
	11-26-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
07106300	09-11-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	11-27-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
07106500	09-11-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	11-27-84	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

Table 6.--*Water-quality data collected from wells and surface-water sites during 1984*--Continued

Number in figure 6	Date of sample	Tri-chloro-ethyl-ene, total (μg/L)	Tri-chloro-fluoro-methane, total (μg/L)	Vinyl chlo-ride, total (μg/L)
1	09-07-84	<1.0	<1.0	<1.0
2	09-07-84	4.4	<1.0	<1.0
3	09-12-84	<1.0	<1.0	<1.0
4	09-10-84	<1.0	<1.0	<1.0
5	09-12-84	<1.0	<1.0	<1.0
6	09-12-84	<1.0	<1.0	<1.0
7	09-10-84	<1.0	<1.0	<1.0
8	09-12-84	<1.0	<1.0	<1.0
9	09-10-84	<1.0	<1.0	<1.0
10	09-06-84	<1.0	<1.0	<1.0
11	09-06-84	<1.0	<1.0	<1.0
12	09-07-84	2.0	<1.0	<1.0
13	09-18-84	<1.0	<1.0	<1.0
14	09-08-84	<1.0	<1.0	<1.0
15	09-06-84	<1.0	<1.0	<1.0
16	09-12-84	<1.0	<1.0	<1.0
17	09-18-84	<1.0	<1.0	<1.0
18	09-18-84	<1.0	<1.0	<1.0
19	09-18-84	<1.0	<1.0	<1.0
20	09-18-84	<1.0	<1.0	<1.0
07105500	09-11-84	<1.0	<1.0	<1.0
	11-26-84	<1.0	<1.0	<1.0
CSWWTP	09-11-84	<1.0	<1.0	<1.0
	11-26-84	<1.0	<1.0	<1.0
07105530	09-11-84	<1.0	<1.0	<1.0
	11-26-84	<1.0	<1.0	<1.0
07105905	09-11-84	<1.0	<1.0	<1.0
	11-26-84	<1.0	<1.0	<1.0
07106300	09-11-84	<1.0	<1.0	<1.0
	11-27-84	<1.0	<1.0	<1.0
07106500	09-11-84	<1.0	<1.0	<1.0
	11-27-84	<1.0	<1.0	<1.0