HYDROGEOLOGY AND GROUND-WATER-QUALITY CONDITIONS AT THE GEARY COUNTY LANDFILL, NORTHEAST KANSAS, 1988

By Nathan C. Myers and Philip R. Bigsby

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 89-4114

Prepared in cooperation with
GEARY COUNTY, KANSAS

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

Lawrence, Kansas
1989

DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary
U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

For additional information
write to:

District Chief
U.S Geological Survey
4821 Quail Crest Place
Lawrence, Kansas 66049

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CONVERSION FACTORS

For those readers who may prefer metric units (International System), the inch-pound units in this report may be converted using the following factors:

Multiply inch-pound unit	*By*	*To obtain metric unit*
inch	25.4	millimeter
foot	0.3048	meter
mile	1.609	kilometer
acre	4,047	square meter
foot per mile	0.1894	meter per kilometer
gallon	3.785	liter
gallon per minute	0.06309	liter per second
degree Fahrenheit (°F)	(1)	degree Celsius (°C)

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[1] °C = (°F-32)/1.8.

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Sea Level Datum of 1929."

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ABSTRACT

An investigation of hydrogeology and water-quality conditions was conducted at the Geary County Landfill, northeast Kansas, from March 1988 through March 1989. Chemical analyses of water from monitoring wells installed at upgradient and downgradient locations indicate the presence of calcium bicarbonate, sodium chloride, and mixed calcium bicarbonate sodium chloride water types. For the dominant calcium bicarbonate water type, inorganic and organic constituents indicate the presence of reducing conditions in the landfill, and increased concentrations of calcium, magnesium, sodium, bicarbonate, sulfate, chloride, ammonia, iron, manganese, and other trace elements downgradient within a leachate plume that extends northeasterly away from the landfill. The orientation of the long axis of the leachate plume does not coincide with the direction of ground-water flow, based on measurements of water-level altitude, possibly due to the effect of abundant rainfall and high river stages at other times of the year or preferential flow in very transmissive zones, and thus may indicate the dominant direction of ground-water flow. None of the organic- or inorganic-constituent concentrations exceeded primary drinking-water standards, but iron and manganese concentrations exceeded secondary drinking-water standards. Concentrations of benzene, vinyl chloride, and 1,2-trans-dichloroethene exceeded Kansas notification levels.

INTRODUCTION

Shallow aquifers provide water for public and private drinking-water supplies, for irrigation and livestock, and for industrial uses. Information concerning the geologic nature of the aquifers, the sources and directions of ground-water flow, and the chemical nature of ground and surface water is an important contribution to informed public decision-making concerning water resources. To gain information about the effects of landfills on water quality, the Kansas Department of Health and Environment is requiring that ground-water-monitoring systems be installed at all public landfills in Kansas (Charles Linn, Kansas Department of Health and Environment, oral commun., 1988).

Purpose and Scope

This report presents the results of an investigation conducted by the U.S. Geological Survey in cooperation with Geary County from March 1988 through March 1989. The purpose of investigation was to describe the geology, hydrology, and the ground-water-quality conditions in the vicinity of the Geary County Landfill. This investigation is one of several being conducted in Kansas by the U.S. Geological Survey that focus on the effects of landfills on the quality of water in shallow aquifers.

General Description of Study Area

The Geary County Landfill is located near Junction City in northeast Kansas (figs. 1 and 2) in a physiographic region known as the Flint Hills Upland (fig. 3). The Flint Hills Upland is a north-south trending range of hills extending from Cowley County to Marshall County that has an average relief of 350 feet (Jewett, 1941). Erosion-resistant limestone and underlying, less-resistant shale give the Flint Hills Upland its characteristic form of rugged grasslands dissected by deep, steep-sided, wooded valleys.

Climatic conditions in northeast Kansas can be quite variable, with large ranges in precipitation and temperature from season to season and from year to year. Records from climatological stations at Chapman, Manhattan,

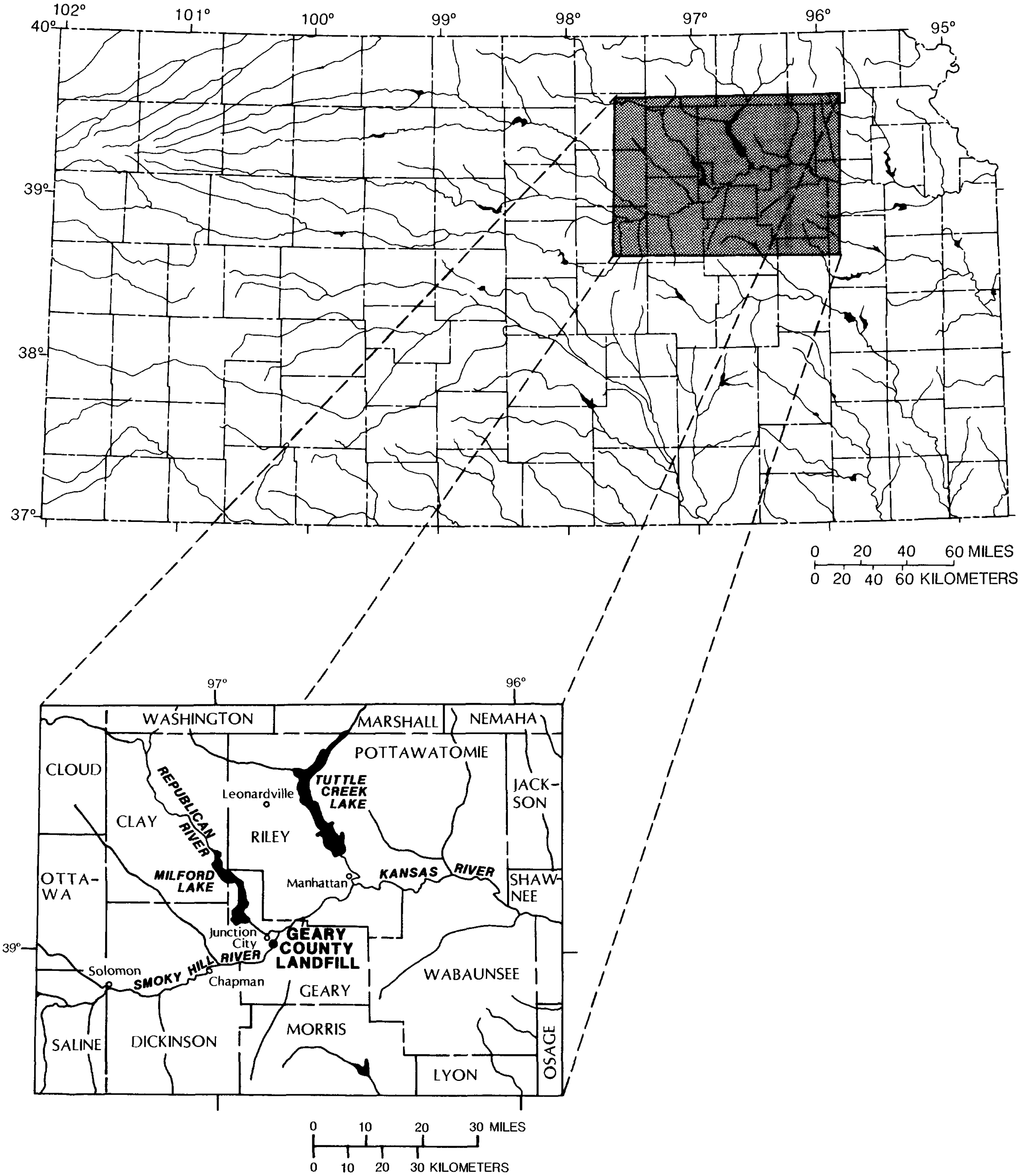

Figure 1. Location of Geary County Landfill near Junction City, Kansas.

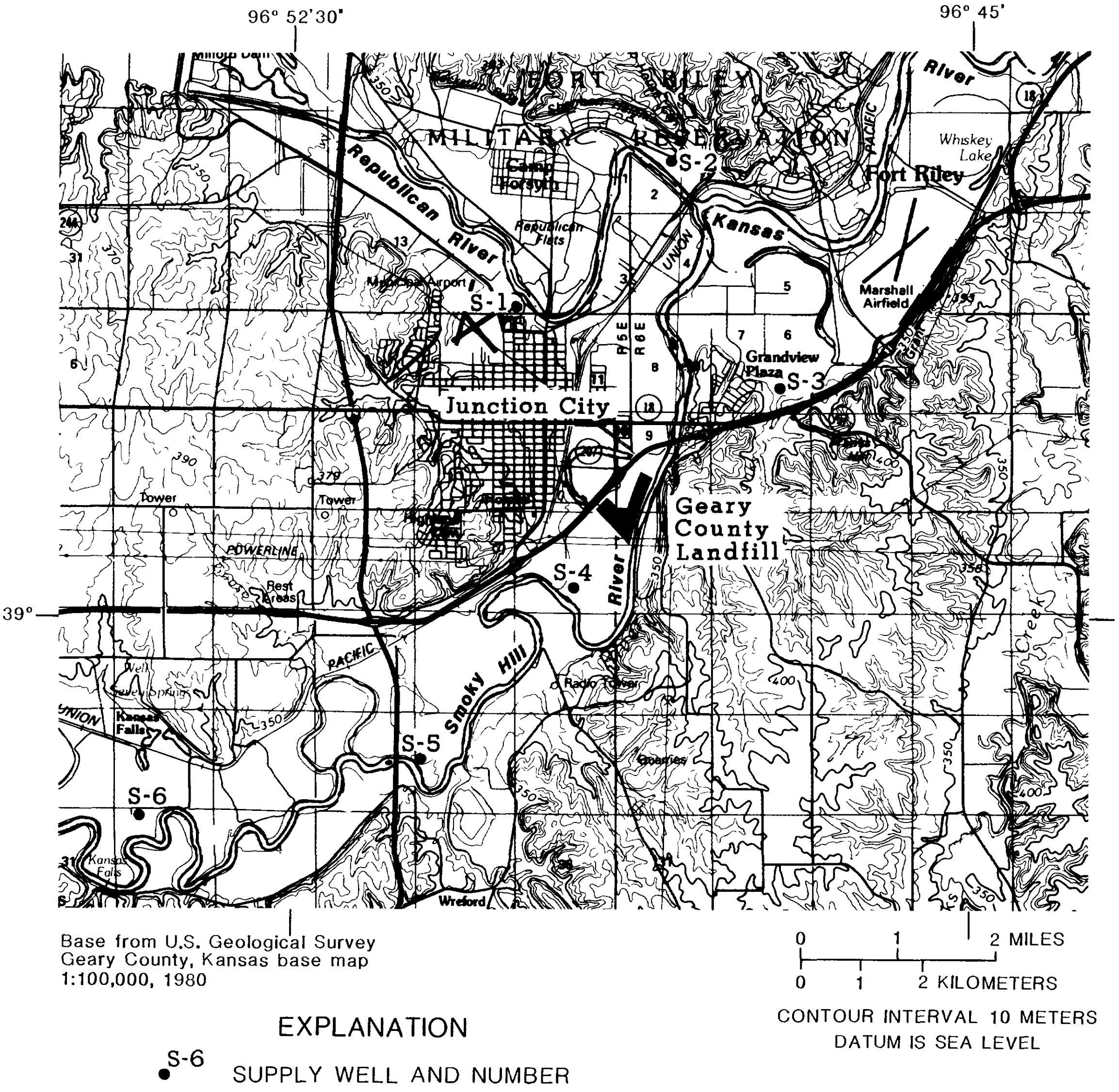

Figure 2. Topographic relief in vicinity of Geary County Landfill and location of supply wells for which chemical analyses have been published.

and Milford Lake (fig. 1) indicate that mean annual precipitation for 1951-80 was about 32 inches, and more than 50 percent of this occurred during the months of May through July. Temperatures may range from below zero to more than 100 °F. On the average, the coldest temperatures are recorded in January, the hottest in July.

Land in the general vicinity of the landfill is put to various uses (fig. 4). Junction City is primarily residential, with some areas of commercial, nonindustrial development. The Fort Riley Military Reservation lies north of Junction City (fig. 2). In the immediate vicinity of the landfill, land is used for growing wheat, corn, and soybeans.

Previous Studies

There are no published reports describing specifically the hydrogeology or water quality at the Geary County Landfill. Several regional studies of ground and surface water have been made that include data for the Junction City area. Parker (1911) and Haworth (1913) summarized known data on ground-water supplies in Kansas. Latta (1949) reported on ground-water quality in the Smoky Hill Valley in Saline, Dickinson, and Geary Counties. He

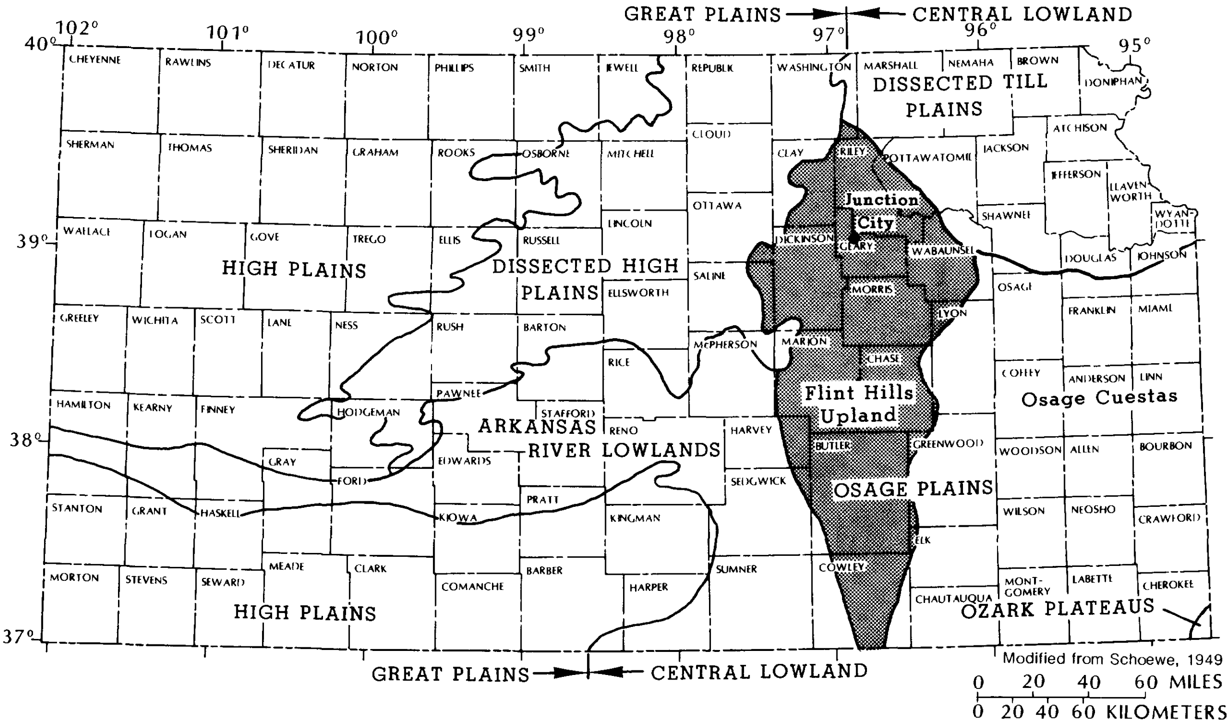

Figure 3. Physiographic areas of Kansas.

included chemical analyses of water from wells in the Junction City area. Fader (1974) reported on the ground water in the Kansas River valley from Junction City to Kansas City, Kansas. During World Wars I and II, two studies focused on the availability of natural resources for the national defense industry. Moore (1918) discussed the terrain and resources of Fort Riley and compared them to those of France. Lohman and others (1942) discussed ground-water supplies in Kansas, including those in the Smoky Hill Valley.

The geology of Geary County, including a description of rocks near the Geary County Landfill, has been described by Jewett (1941). The geology of the Smoky Hill Valley is discussed by Latta (1949). Jewett (1951) reported on structural features of subsurface rocks in Kansas.

SOLID-WASTE DEGRADATION IN PUBLIC LANDFILLS AND EFFECTS ON WATER QUALITY

The following is a general discussion of solid-waste composition, solid-waste degradation, and leachate production in landfills. Although the exact composition of solid wastes and chemical processes in the Geary County Landfill are not known, they may be inferred to be similar to the general compositions and chemical processes discussed here.

Solid-Waste Composition

Solid wastes are discarded, unwanted, usually solid materials. In the past, land-disposal sites often were merely convenient depressions, and solid wastes were considered as serviceable fill to level low-lying areas. Few if any sites were planned as engineering projects. Wastes commonly were left uncovered in open dumps. As an alternative, the sanitary landfill method was developed, incorporating engineering principles for maximum confinement and containment. Basic design features are an impermeable bottom and sides, exclusion of drainage, compaction and daily covering of the waste, and final impermeable capping (Salvato and others, 1971; Degner, 1974).

Composition of the Geary County Landfill wastes is not specifically known, but typical nationwide composition, by weight, is 45-percent paper, 15-percent garbage, 11-percent yard and garden trimmings, 9-percent metal, 8-percent glass, 4-percent dirt, ashes, and concrete, 3-percent textiles, 3-percent plastics, and 2-percent wood (Tchobanoglous and others, 1977). About 80

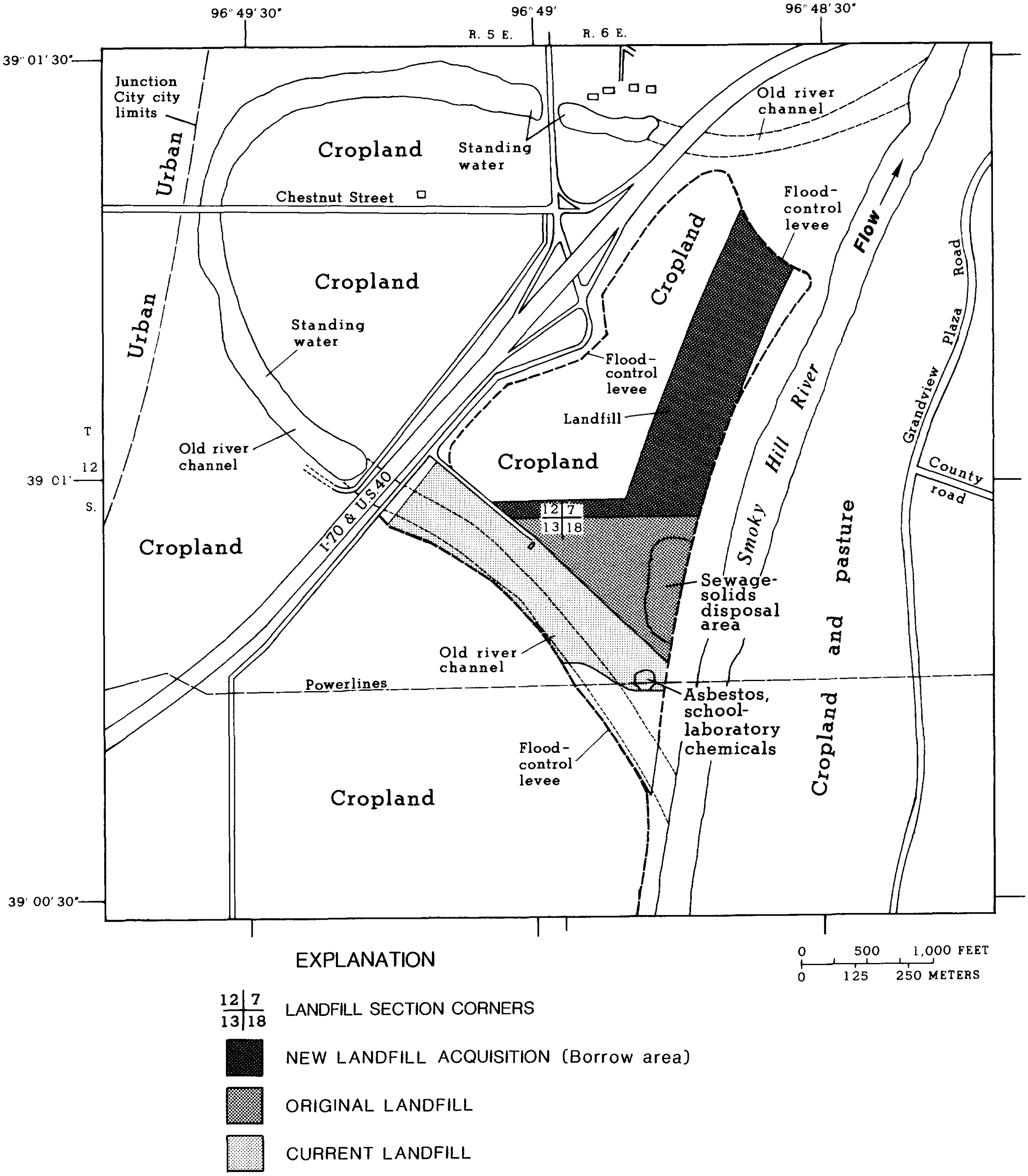

Figure 4. Land use in vicinity of Geary County Landfill.

percent of the material is combustible, of which aggregate amounts of fixed carbon, moisture, and volatile organic matter represent 7, 20, and 53 percent, respectively, of the waste. Waste composition varies due to climate, season,recycling, demography, packaging, and marketing (Tchobanoglous and others, 1977).

Solid-Waste Degradation

About 20 percent of typical solid waste is virtually inert, including glass, wood, rubber, plastics, and synthetic textiles. The other 80 percent, mostly paper, garbage, yard and garden trimmings, and ferrous metal is totally or partly degradable (Tchobanoglous and others, 1977). Initially, while wastes are exposed to the air, the landfill environment is oxidizing. After depletion of trapped or incoming oxygen by aerobic bacteria, the environment becomes reducing. Degradation processes in the landfill include biologic decomposition, solution, precipitation, sorption, ion exchange, and diffusion of gases (Baedecker and Back, 1979). Sufficient moisture, 40 to 60 percent, is essential, however, for significant degradation rates.

While oxygen is available, biologic decomposition is conducted by aerobic bacteria and then, in the absence of oxygen, by anaerobic bacteria. Aerobic decomposition proceeds rapidly and probably begins in easily degradable garbage soon after deposition of the waste. Decomposition by hydrolysis allows bacteria to convert complex organic molecules to smaller, soluble ones that the bacteria can use for growth. Net products are primarily carbon dioxide and water, plus sulfate and ammonia (Baedecker and Back, 1979).

When oxygen is depleted, only anaerobic decomposition of the solid waste occurs. Anaerobic decomposition is slower and more complex than aerobic decomposition, and apparently requires symbiotic relationships (Gaudy and Gaudy, 1980). It is thought of as occurring in two steps. Step one is fermentation by faculative bacteria to soluble smaller molecules, and then to fatty acids and alcohols. Step two is methane formation by obligate methanogenic bacteria. The actual symbiosis probably involves hydrogen transfer between the two types of bacteria and removal in methane. The hydrogen removal prevents buildup that would be toxic to methanogens and would suppress fatty-acid production (Gaudy and Gaudy, 1980). End products of fully completed anaerobic decomposition are methane, water, and carbon dioxide (Baedecker and Back, 1979), which probably first appear on the periphery of landfills (Metzler, 1975) where higher pH is more favorable to methanogenic bacteria.

At any one time, different parts of the same landfill may be in different stages of decomposition. Stage and rate also will vary from one landfill to another, depending primarily on moisture and putrescibility, but also on temperature and on local procedures for shredding, mixing, and compacting the waste. Many landfills complete the aerobic stage in a few weeks and anaerobiosis quickly enough to allow significant methane production to peak within 2 years and then decline for 25 years or longer (Tchobanoglous and others, 1977). The progress of anaerobic decomposition may be estimated from the attendant conditions. In step one, the pH is 4 to 5, chemical oxygen demand is relatively large, and specific conductance, due to acidic solution of metals, is also large (O'Leary and Tansel, 1986). In step two, methane concentrations are large, pH is 7 to 8, and specific conductance and chemical oxygen demand are relatively small (O'Leary and Tansel, 1986).

Leachate Production

Leachate is generated by the percolation of water through the waste, and the extraction from it of dissolved and suspended materials, both biological and chemical (Tchobanoglous and others, 1977). Because paper (about 45 percent of all waste) probably absorbs both original and metabolically generated water, leachate production above the water table requires infiltration of surface water. Solids, gases, and liquids from the waste are incorporated as dissolved, suspended, or sorbed, and miscible or immiscible components. Metabolic carbon dioxide, produced by bacterial action, dissolves easily, decreasing pH. The resulting dissolution of calcium carbonate increases hardness and dissolved solids. Solvent capability of the leachate is increased also by the bacterially generated organic acids, allowing some metals in the landfill to be dissolved.

Chemical processes in leachate production are oxidation, reduction, solution, precipitation, ion exchange, and sorption. In the landfill, these processes probably are mediated by the organic environment (Baedecker and Back, 1979). Physical processes are settlement, movement of evolved and ejected water by differential hydraulic heads, entrainment of colloidal and particulate material in flushing water, filtration, change of solute concentration by osmosis and concentration gradients, density separation of

Table 1. *Typical concentrations of constituents in and properties of landfill leachate*

Constituent or property	Concentrations, in milligrams per liter, except as noted		
	Salvato and others, 1971	Cameron, 1978	Tchobanoglous and others, 1977
pH (standard units)	5.6-8.3	7.5	6.0
Chemical oxygen demand	7,130	800	18,000
Biochemical oxygen demand	7,050-32,400	120	10,000
Hardness, total	537-8,120	--	3,500
Sodium	350-1,805	800	500
Potassium	655-1,860	490	300
Alkalinity, total as $CaCO_3$	1,290-8,100	3,400	3,000
Sulfate	99-1,220	5.3	300
Chloride	300-2,240	2,300	500
Dissolved solids	2,000-9,190	4,270	--
Nitrate, as NO_3	5-18	--	25
Ammonia nitrogen, as NH_4	141-845	427	200
Organic nitrogen, as N	152-550	--	200
Iron	219	24	60

immiscible phases, and vertical and horizontal migration of gases.

Leachate composition is quite variable. Some typical concentrations and composition ranges of the most abundant constituents are listed in table 1. Where ranges are given, the larger values are expected only in newer landfills.

Potassium and sodium tend to stay in solution, unabsorbed by clay when calcium is present. Alkalinity is always very large in leachate because bicarbonate is produced in anaerobic reactions, directly, and indirectly when carbon dioxide dissolves. Bicarbonate is dissolved also from landfill ash, soil, and rock. Sulfate, derived from ash and treatment wastes, may be reduced within the landfill anaerobic environment and precipitated as ferrous sulfide, but sulfate is otherwise conservative. Chloride is nonreactive, and its variation in leachate is due mostly to dilution. Nitrogen is present mostly as ammonia because of pH and redox conditions stemming from anaerobic decomposition and the presence of dissolved iron (Apgar and Langmuir, 1971). Iron also is commonly present in large concentrations derived both from the waste, and with manganese, from oxide cements in soil and coatings and cements in soil and rock.

Metals, such as cadmium, chromium, cobalt, copper, mercury, nickel, lead, strontium, and zinc, also may be detected in landfill leachate but are present in small and variable concentrations because, with the exception of lead, they are either in elemental form in insoluble metals and alloys, or are in special, unusual industrial wastes. Other environmentally significant species found in landfill leachate include arsenic, boron, and selenium. Arsenic originates mainly in toxic compounds, such as insecticides. Boron is found in soap, glazes, and rubber, and selenium is found in ink and rubber.

METHODS OF INVESTIGATION

There were four phases of investigation in the study of the Geary County Landfill. Data pertaining to the landfill's history, geology, hydrology, and land ownership were compiled during an initial information-gathering phase. On the basis of this information, temporary well sites and potential monitoring well sites were selected. The well-installation phase included the augering of test holes and the installation of temporary wells to determine the hydrology and geology of the area. Monitoring wells were installed on the basis of geologic and hydrologic information from the temporary wells. In the third phase, water samples were collected from all monitoring wells and from selected surface-water bodies, and were analyzed by the Kansas Department of Health and Environment and U.S. Geological Survey laboratories. This report concludes the fourth phase of data interpretation and reporting. The following sections relate details of investigation methods.

Information Survey

Prior to any field work, a survey of published literature, files of the Kansas Department of Health and Environment (Topeka), and Geary County files was completed. Geologic and hydrologic information enabled estimation of the directions of ground-water flow, depth to bedrock, and geology in the vicinity of the landfill. This information was useful for planning well locations, field activities, and material requirements.

Temporary Well Installation

Twelve temporary wells (TW-1 to TW-12) were installed using 3 1/4-inch inside diameter (6 5/8-inch outside diameter) hollow-stem augers with a plate in the bottom of the augers to prevent sediment from clogging the inside of the auger bit. In sandy sediments it was necessary to "load" the augers with potable water to prevent formation sand and water from surging into the augers when the bottom plate was knocked out to set the well. Temporary wells consisted of 1 1/2-inch polyvinyl-chloride pipe with glued joints, capped at the bottom, and screens slotted with a hacksaw. Wells were set to different depths at the same location (nested) to evaluate vertical ground-water movement. The location of temporary wells is shown in figure 5. Borehole BH-1 was augered in the same manner as the temporary wells; however, no well was set.

After all temporary wells had been installed, the top-of-casing altitude for each well was determined by a level survey (table 2). Water levels in the temporary wells were measured to the nearest 0.01 foot with a steel tape. Water-level altitudes were used to construct a potentiometric-surface map to show directions of ground-water flow.

Geologic information was collected while augering. Auger cuttings were sampled and described. Cores taken with a split spoon or with a continuous coring-bit assembly were sampled and described. Bedrock cores were taken with a split spoon at two locations to ascertain bedrock composition.

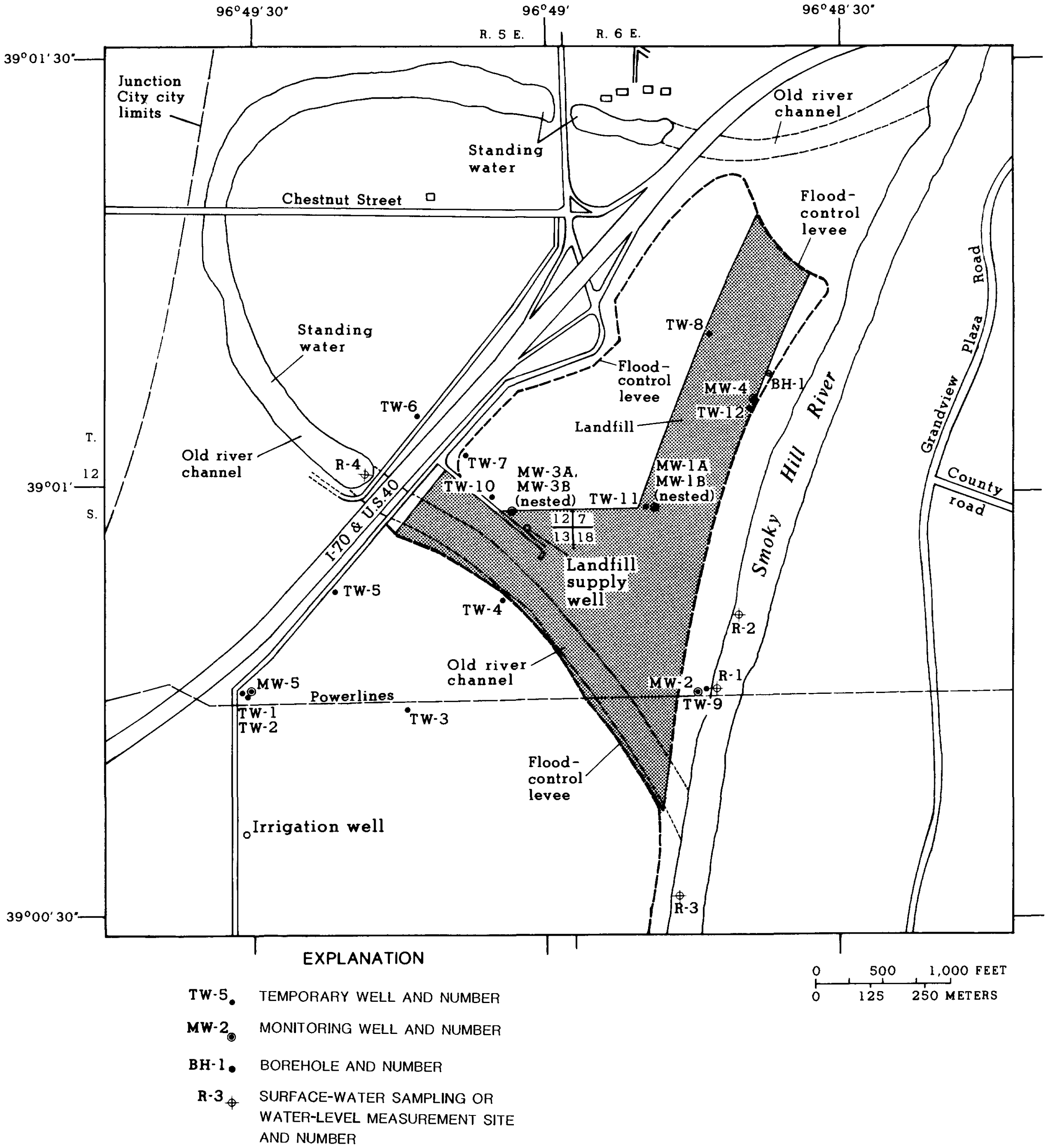

Figure 5. Location of wells, borehole, and surface-water sampling or water-level measurement sites.

Monitoring Well Installation

To avoid potential cross contamination between wells or from other sources, all equipment was cleaned prior to installation of each monitoring well (MW-1 to MW-5). Loose cuttings were removed from augers and other tools with a high-pressure jet of potable water. Augers and tools were scrubbed with a water and alconox mixture, rinsed with potable water, and finally rinsed with acetone. Potable water was purchased from Junction City and hauled to the site in a stainless-steel tank.

Seven monitoring wells were installed using 6 1/4-inch inside diameter (9 7/8-inch outside diameter) hollow-stem augers with a bottom center plate. The augers were "loaded" with

Table 2. *Top-of-casing altitudes and total depths for temporary (TW) and monitoring (MW) wells*

[Datum is sea level]

Well (fig. 5)	Top-of-casing altitude (feet)	Total depth below land surface (feet)
TW-1	1,067.46	55.14
TW-2	1,067.20	25.49
TW-3	1,068.42	25.09
TW-4	1,073.66	29.54
TW-5	1,068.31	25.19
TW-6	1,074.43	30.90
TW-7	1,071.73	30.95
TW-8	1,066.97	25.15
TW-9	1,061.98	25.84
TW-10	1,072.42	29.69
TW-11	1,069.90	24.87
TW-12	1,066.75	24.69
MW-1A	1,070.50	47.72
MW-1B	1,070.67	36.70
MW-2	1,062.59	25.34
MW-3A	1,073.13	44.72
MW-3B	1,073.12	35.31
MW-4	1,067.33	50.79
MW-5	1,067.47	39.84

water during drilling to keep formation sediment and water from entering and clogging the augers. After reaching a desired depth, the well casing was lowered into the hollow augers and used to punch out the bottom plate. Filter sand pack and bentonite chips were poured into place around each well as the augers were being withdrawn from the well.

Each monitoring well is comprised of a 5-foot stainless-steel screen, a 10-foot stainless-steel riser, and schedule-40 polyvinyl-chloride pipe to the surface (fig. 6). Well casings are threaded, flush-coupled, 2- or 4-inch diameter pipe. Teflon[1] tape was used to seal each joint; no glue or cement was used. Filter sand-pack thicknesses are about 10 feet, extending from the bottom of the well screen to 5 feet above the top of the screen. The sand was followed by 2 or more feet of 3/8-inch bentonite chips. Natural formation sand was allowed to collapse or was added to the hole up to a depth of about 10 feet below land surface, then 3/8-inch bentonite chips were added to within 18 inches of the land surface. Finally, a cement pad and protective casing with a locking cap were set around the well casing.

Monitoring wells were developed using a surge block until water ran clear from the well. In cases where there was very little water in the well, a positive displacement hand pump or bailer was used to develop the wells.

Water-Sampling Methods

The seven monitoring wells at the Geary County Landfill were sampled on September 20-22, 1988. The well-sampling process began with the upgradient well (MW-5) and ended with the farthest downgradient well (MW-2).

The sampling procedure was as follows. Water levels and total depths in all monitoring wells were measured to the nearest 0.01 foot with a steel tape. The tape was cleaned with distilled water before each use. Each well was first purged of five water-column volumes to assure the sampling of representative ground water. The volume of water to purge from each well was determined from water-level and total-depth measurements (table 3). Wells were purged with a positive displacement hand pump that was washed with an alconox solution, rinsed with potable water, then rinsed with deionized water before each use. Water samples were retrieved with a Teflon-bottom check-valve bailer

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[1] The use of brand names in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

Table 3. *Water-column volumes purged from monitoring wells before sampling in September 1988*

Well (fig.5)	Nominal diameter of well (inches)	Height of water column (feet)	Volume in well (gallons)	Volume purged (gallons)
MW-1A	2	23.72	4.10	20.5
MW-1B	2	12.58	2.18	10.9
MW-2	2	8.06	1.39	6.9
MW-3A	4	19.23	12.69	63.4
MW-3B	2	9.81	1.70	8.5
MW-4	2	28.69	4.96	24.8
MW-5	2	21.86	3.78	18.9

suspended from a nylon cord. The bailer was decontaminated in the same fashion as the hand pump before each use, and the nylon cord was replaced before each use.

Water samples were collected in the order of volatile organic compounds, semivolatile organic compounds and pesticides, total organic carbon, common ions, and trace metals. Care was taken not to aerate the water when lowering the bailer to take a sample. Plastic sheeting was laid on the ground around the well to prevent the bailer cord from accidentally touching the ground. Samples were placed immediately on ice. Trace-metal samples were filtered through a 0.45-micron filter prior to collection. Each filter was flushed with about 250 milliliters of sample water before collecting a sample. Specific-conductance, pH, water-temperature, dissolved-oxygen, and alkalinity measurements were made at the time of sample collection. Dissolved-oxygen concentrations were determined by lowering a probe into the well to the approximate depth of sampling.

In addition to the monitoring-well samples, two samples from the Smoky Hill River (R-2, R-3), and one sample from the old Smoky Hill River channel north of I-70 (R-4) were collected (fig. 5). Surface-water site R-1 was used only to measure water levels in the Smoky Hill River. River water was collected near the west bank in running water by dipping bottles into the stream and allowing them to fill from mid-depth in the

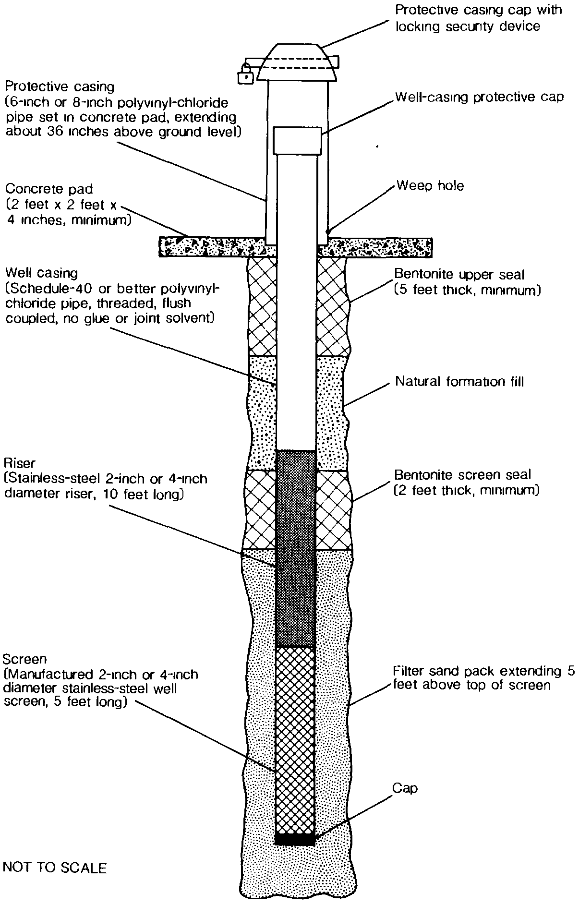

Figure 6. Monitoring well design.

stream. Samples were collected and processed in the same order and in the same way as for the monitoring wells, except that dissolved oxygen was not measured. River-water samples were collected upstream of and adjacent to the landfill. A water sample from the old river channel was collected near the bank in a manner similar to the river-water samples.

Water samples were delivered within 3 days of collection to the Kansas Department of Health and Environment laboratory (Topeka). Samples for triazine pesticide analyses were shipped within 4 days by mail to the U.S. Geological Survey laboratory in Denver, Colorado.

Hydraulic-Conductivity Determination

Hydraulic conductivity was determined by slug tests. For each slug test, a pressure transducer was lowered through a specially designed sealing well cap to a point 10 feet or less below the static water surface. The well then was pressurized with nitrogen to depress the water level within the well to a point above the pressure transducer. After the pressure in the well stabilized, the pressure was released suddenly. Pressure-transducer readings were recorded for about a 2-minute duration starting when pressure was released from the well.

REGIONAL HYDROGEOLOGY

The rocks of Geary County, Kansas, are primarily limestone and shale of Permian age (Jewett, 1941). The erosion-resistant limestone and softer underlying shale give the Flint Hills Upland its characteristic rugged appearance. Unconsolidated alluvium and loess deposits of Pleistocene age occur in places along river valleys and on uplands (Jewett, 1941). Consolidated rocks are structurally part of the Prairie Plains homocline, dipping generally westward at 30 feet per mile (Jewett, 1941). Local distortions of rock layers may change the degree and direction of dip from the regional gradient (Jewett, 1941; 1951).

Water supplies in Geary County are available from both alluvium and limestone. Alluvial deposits in the Smoky Hill, Republican, and Kansas River valleys are an important source of water for municipal, domestic, stock, industrial, and military use (Jewett, 1941). Precipitation is the primary source of ground-water recharge to the alluvium, although some water flows into the alluvium from adjacent rock formations and some water is recharged to the alluvium from the rivers (Latta, 1949; Fader, 1974).

Water in the alluvium of the Smoky Hill River valley generally is 20 to 30 feet below land surface (Latta, 1949). Well yields range from 50 to 1,700 gallons per minute, with an average of 860 gallons per minute, depending on such factors as permeability of aquifer materials, well depth, casing diameter, and depth to water (Latta, 1949). Ground water in the alluvium of the Smoky Hill and Kansas River valleys flows in the downstream direction of the river and towards the river channel during normal river stages (Latta, 1949; Fader, 1974). During high river stages, however, water may flow from the river into the alluvium, temporarily changing ground-water flow directions (Latta, 1949; Fader, 1974).

In areas remote from major stream valleys, limestone is a significant source of water. Jewett (1941) reports that two wells completed in the Permian Barneston Limestone at Leonardville in Riley County (fig. 1) yielded 23,874,800 gallons of water in 1 year or an average of more than 65,000 gallons per day. Ground water in upland limestone flows westward in the direction of regional dip (Jewett, 1941). This is especially evident on west-facing hillsides where many springs issue from ledges of the Fort Riley Member of the Barneston Limestone and the deeper Permian Cottonwood Member of the Beattie Limestone (Jewett, 1941).

LANDFILL DESCRIPTION AND HYDROGEOLOGY

Landfill Setting

The Geary County Landfill is located in the flood plain of the Smoky Hill River, about 3 miles upstream from the confluence of the Smoky Hill and Republican Rivers (fig. 2). The landfill is bounded by the Smoky Hill River on the east, by Interstate Highway 70 (I-70) on the northwest, and by croplands on other borders. Just upstream from the landfill, the Smoky Hill Valley is about

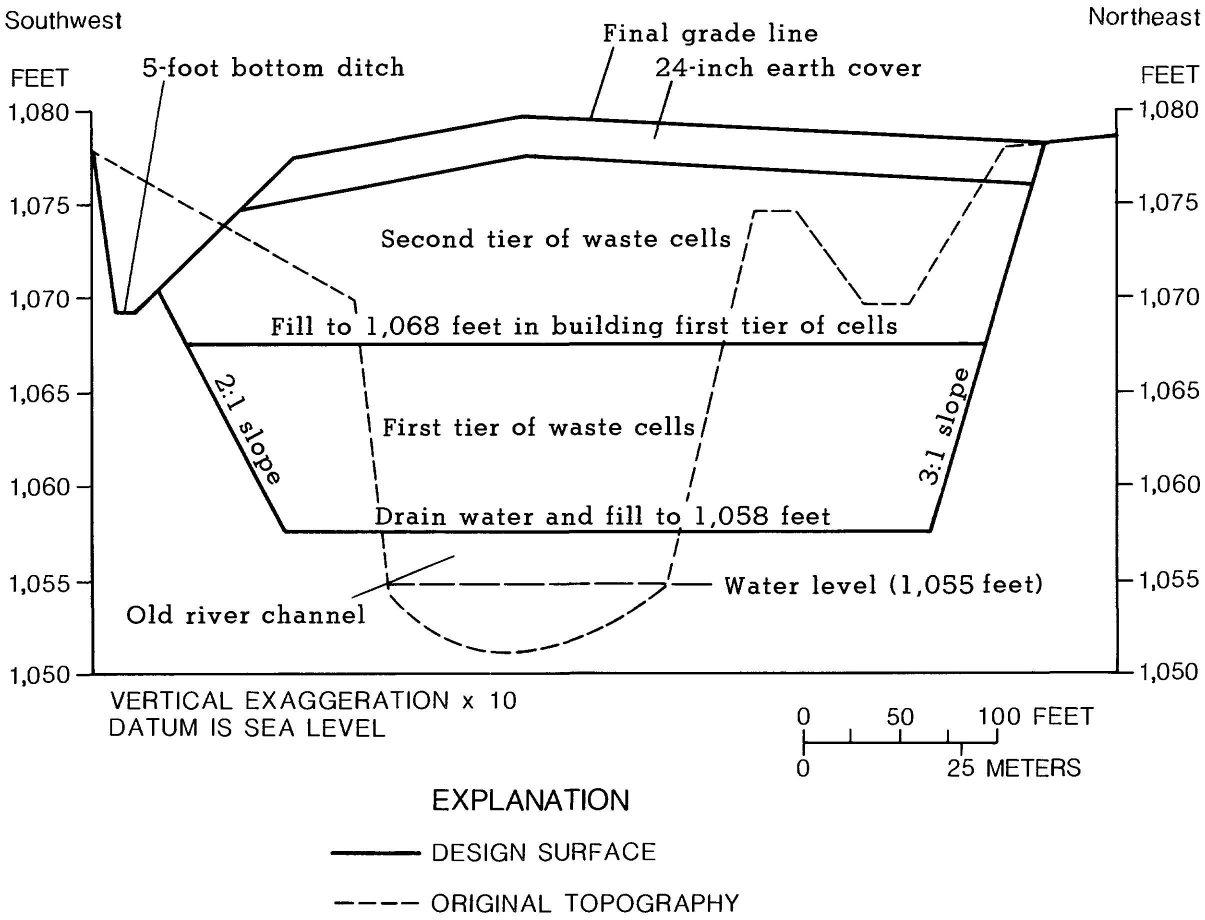

Figure 7. Generalized section of old river channel showing landfill-design specifications.

1.5 miles wide. The valley walls are steep on the east and gently rising on the west.

Landfill Siting, Design, and Management

The active part of the landfill was sited originally in an area just northeast of the abandoned Smoky Hill River channel (fig. 4) but has since been expanded to include the abandoned channel area. Geary County owns about 71 acres of landfill property, about 40 acres of which have been landfilled or are currently being landfilled. The remaining 31-acre tract, northeast of the fill area, is being used as a source of topsoil for covering wastes (fig. 4).

The current waste-disposal area (old river channel area) was designed to be filled using a cut-and-cover or an imported-cover method. A generalized section from original engineering plans for the current waste-disposal area is shown in figure 7. The bottom of the landfill was designed to be at an altitude of 1,058 feet above sea level. The channel was to be widened and filled with two tiers of waste cells. When finished, the area will have a 24-inch crowned earth cover with drainage toward the Smoky Hill River through a ditch on the west side of the landfill. This ditch will also carry drainage from 1-70.

The Geary County Landfill is managed as a sanitary landfill. Ordinary waste is deposited in cells and covered with soil each day. Sewage solids are deposited on the ground surface near the southeast edge of the landfill (fig. 4). The landfill also receives small quantities of hazardous wastes, including gasoline-tank bottoms, solvents, paints, asbestos, and high-school laboratory chemicals. In addition, the landfill receives surplus sand and molding cores from a local foundry. Hazardous wastes have been buried near the south end of the landfill and in the filled-channel area (fig. 4). Foundry sand and molds are deposited in working and on finished areas of the landfill. The landfill also receives lime from the Junction City water-

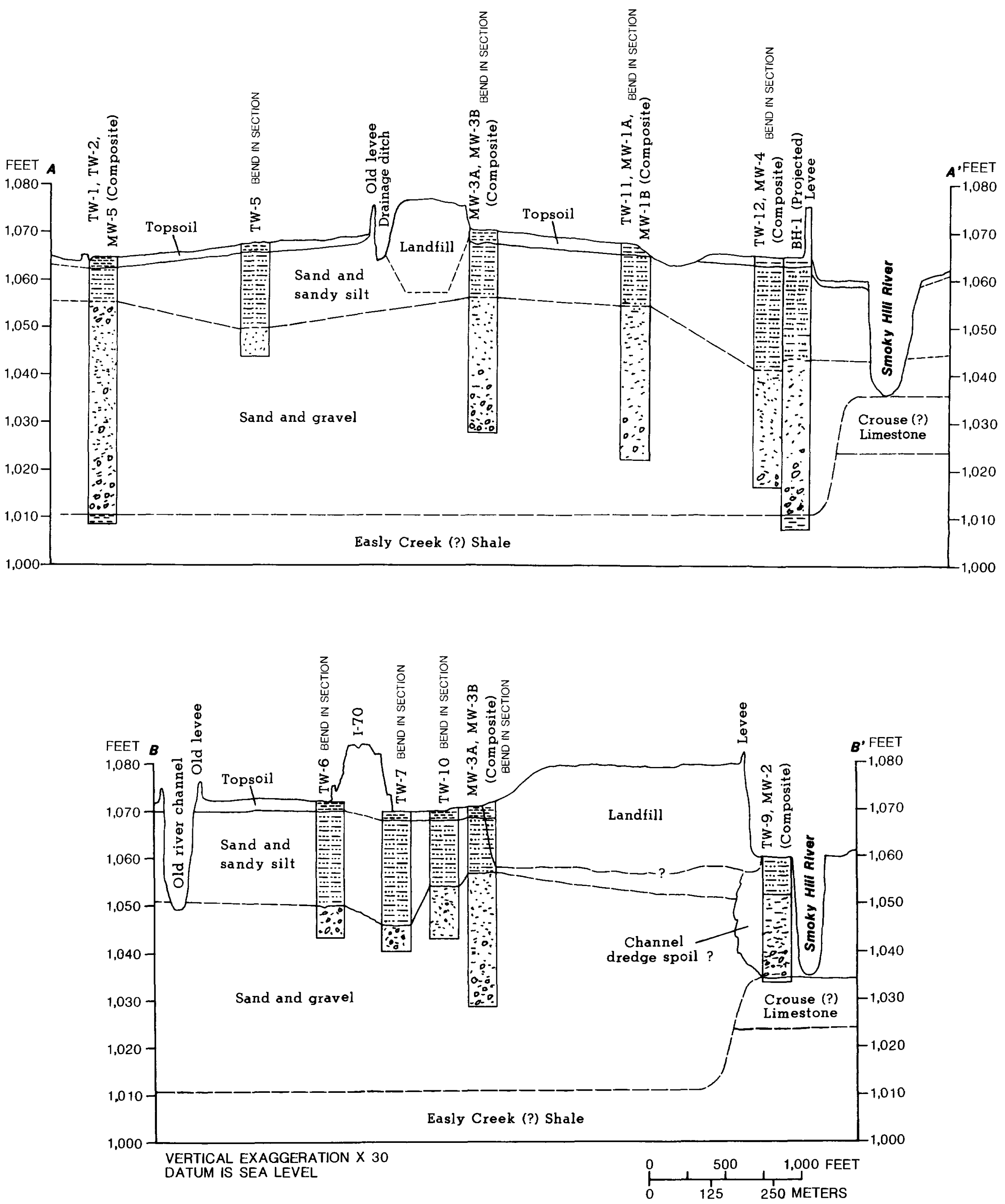

Figure 8. Lithologic sections of Geary County Landfill from (A) southwest to northeast and (B) northwest to southeast.

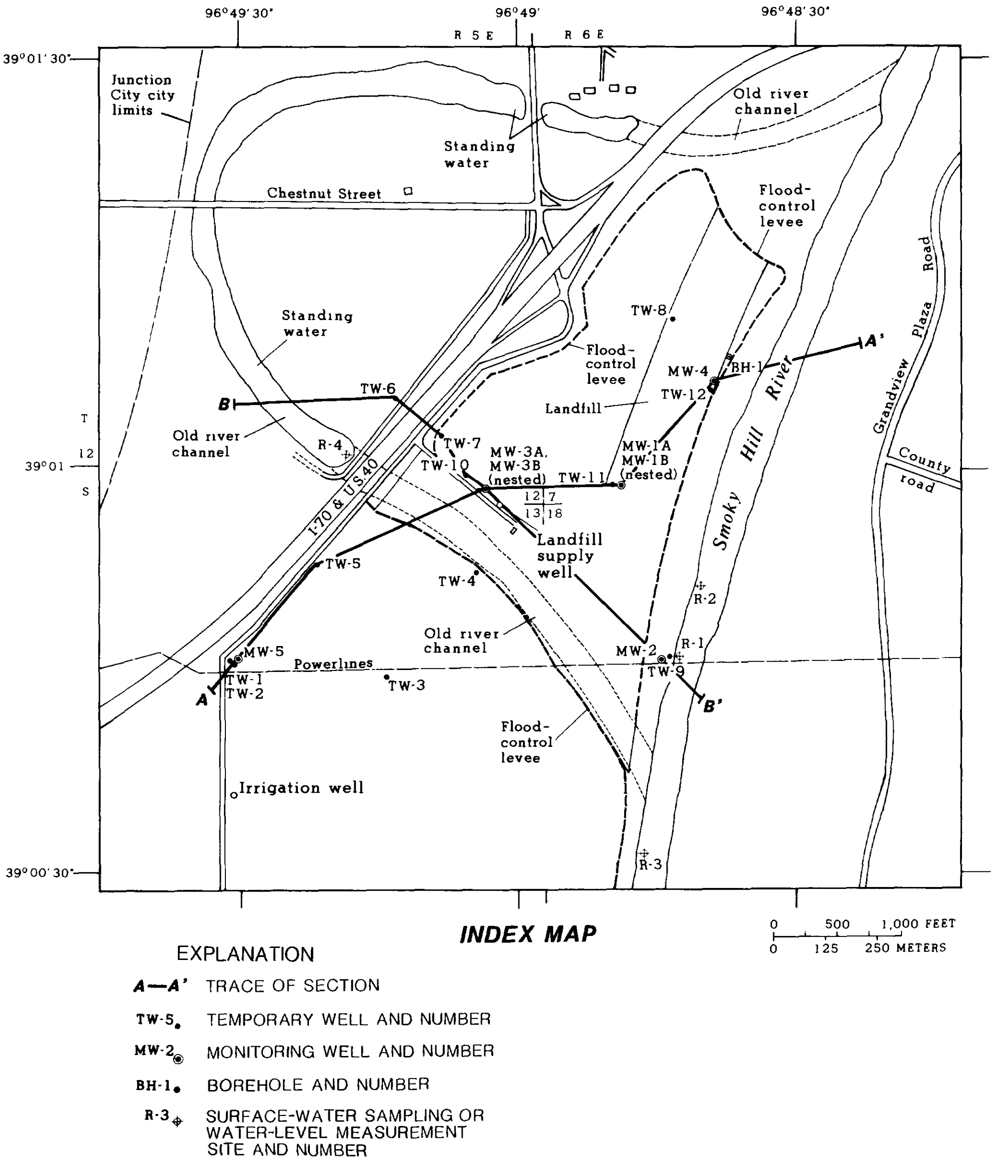

Figure 8. Lithologic sections of Geary County Landfill from (A) southwest to northeast and (B) northwest to southeast--Continued.

treatment plant.

Geology

The landfill is located in alluvium of the Smoky Hill River. From bottom to top, the alluvium generally consists of a 24- to 55-foot thick sequence of gravel, coarse-to-fine sand, and silt and clay layers. Lithologic logs show that there are lateral, as well as vertical, changes in the grain size of these deposits (figs. 8A and 8B). Generally, the coarsest sediments were found farther away from the river channels in wells TW-1, TW-2, and MW-5, and some of the finest sediments were found in wells TW-6 near the old river channel and in TW-9 and MW-2 at the side of the current channel. The fine-grained nature of sediments in wells TW-9 and MW-2 and the location of these wells near or in the old channel indicate that these wells may have been drilled in dredge spoil from the construction of the current river channel. In a vertical sense, the coarsest sediments were found to occur in the deepest part of the wells, with a gradational change to finer sediments near the ground surface. These lateral and vertical changes in grain size and types of sediments are the result of deposition by the ancestral Smoky Hill River as it meandered back and forth across the valley.

The alluvium is underlain by shale and limestone of Permian age. Blue shale encountered in borehole BH-1 and well TW-1 is probably the Permian Easly Creek (?) Shale (fig.8A). The thickness of the shale where encountered is at least 2 feet; augers could not penetrate any deeper into the shale. Zeller (1968) indicates that the Easly Creek (?) Shale is

Table 4. *Water-level altitudes in temporary (TW) and monitoring (MW) wells and at surface-water sampling or water-level measurement sites (R)*

[Datum is sea level. NA, not available; NM, not measured]

Location number (fig. 9)	Water-level altitude (feet)		
	August 15, 1988	August 23, 1988	September 20, 1988
TW-1	1,050.28	1,049.70	NA
TW-2	1,049.67	1,049.67	NA
TW-3	1,049.19	1,049.18	NA
TW-4	1,049,41	1,048.36	NA
TW-5	1,049.36	1,049.32	NA
TW-6	1,051.27	1,051.19	NA
TW-7	1,048.10	1,048.81	NA
TW-8	1,045.90	1,045.91	NA
TW-9	1,045.80	1,045.44	NA
TW-10	1,048.00	1,047.86	NA
TW-11	1,046.91	1,046.84	NA
TW-12	1,045.85	1,045.70	NA
MW-1A	NA	1,046.80	1,046.59
MW-1B	NA	1,046.79	1,046.58
MW-2	NA	1,045.84	1,045.34
MW-3A	NA	1,047.81	1,047.64
MW-3B	NA	1,047.81	1,047.62
MW-4	NA	1,045.64	1,045.24
MW-5	NA	NA	1,049.49
[1]R-1	1,045.62	NM	NM
[2]R-4	1,055.92	NM	NM

[1] Smoky Hill River near well MW-2.

[2] Old river channel.

between 10 and 20 feet thick. Limestone encountered in the bottom of wells TW-9 and MW-2 is probably the overlying Permian Crouse (?) Limestone (fig. 8B). The thickness of the limestone where encountered at the site is unknown, but Zeller (1968) indicates that it may be between 6 and 18 feet thick.

Hydrology

The direction and rate of ground-water movement in the alluvium in the vicinity of the landfill were determined by water-level measurements and slug tests. An analysis of water-level data from wells and nearby surface-water bodies (table 4, figs. 9A, 9B, and 9C) shows that ground water moves generally east-northeast in the downstream direction of and towards the Smoky Hill River. This direction of water movement is compatible with the regional direction of ground-water flow in the alluvium. Water ponded in the old river channel northwest of the landfill is a source of recharge to the alluvium but seems to affect ground-water movement only locally near the old channel. Fine sediments that have accumulated on the bottom of the old channel limit the rate at which water can percolate into the underlying sediments. Except in the vicinity of the old river channel and the existing river channel, there was very little vertical movement of ground water in the saturated zone at the time of these measurements (fig. 10).

Slug tests (table 5) show that hydraulic conductivity varies from 20 to 152 feet per day. The largest hydraulic-conductivity value was found in well MW-5, whereas the smallest value was found in well MW-2. The distribution of these values corresponds with visual observations of grain size and composition of sediments. The velocity of ground-water flow in the vicinity of the landfill, assuming a porosity of 30 percent, an average hydraulic gradient of 0.00118 for September 20, 1988, and a hydraulic conductivity of 152 feet per day, is about 0.6 foot per day in the vicinity of well MW-5. Flow velocities near the landfill will change as the hydraulic gradient changes. Changes in the hydraulic gradient may be caused by changes in Smoky Hill River stages, rainfall, or well pumping.

There are two supply wells in the vicinity of the landfill that at times may affect the movement of ground water (fig. 5). One is located on the landfill and is used to supply nonpotable water to the landfill. The other well is located about 0.5 mile southwest of the landfill and is used on a seasonal basis to supply a center-pivot irrigation system.

The direction of ground-water flow may reverse temporarily during high river stages. All water-level measurements were made during low river stages and so do not show what effect high river stages might have on ground-water flow direction. Fader (1974) has shown that during high river stages along the Kansas River the direction of ground-water flow may be predominantly away from the river, and this reversal of flow direction may extend to more than 3,000 feet away from the river.

WATER QUALITY

Regional

The quality of water in alluvial and limestone aquifers varies considerably in a regional sense. Latta (1949) reported that concentrations of hardness in ground water in the Smoky Hill Valley ranged from 274 to 1,980 mg/L (milligrams per liter); chloride ranged from less than 50 to more than 10,000 mg/L; dissolved solids ranged from 290 to 6,848 mg/L; and iron ranged from less than 100 to 11,000 µg/L (micrograms per liter). In general, the largest hardness, chloride, and dissolved-solids concentrations were found in ground water near the town of Solomon in Dickinson County. Iron concentrations in the vicinity of Junction City ranged from less than 10 to 9,100 µg/L (Latta, 1949).

Landfill

To evaluate ground-water quality in the vicinity of the Geary County Landfill, water samples were collected from wells upgradient of (well MW-5) and downgradient of (wells MW-1A, MW-1B, MW-2, MW-3A, MW-3B, and MW-4) the landfill (fig. 5). Water samples also were collected from the Smoky Hill River and from the old Smoky Hill River channel (fig. 5). Analyses of these water samples and analyses of water samples from supply wells (S1 to S6) in the Junction City area (fig. 2), as reported by Latta (1949) and Fader (1974), are used in the following description of water quality (table 6).

Inorganic Compounds

Three general types of water have been identified in the vicinity of the landfill--calcium bicarbonate type, sodium chloride type, and a mixed calcium carbonate sodium chloride type (fig. 11). Calcium bicarbonate type water is characteristic of water from the river alluvium (wells MW-1A, MW-1B, MW-3A, MW-3B, MW-4, MW-5, S-1, S-2, S-3, S-5, S-6), and sodium chloride type water is characteristic of the Smoky Hill River (samples R-2 and R-3). Water from two wells (MW-2 and S-4) appears to be a

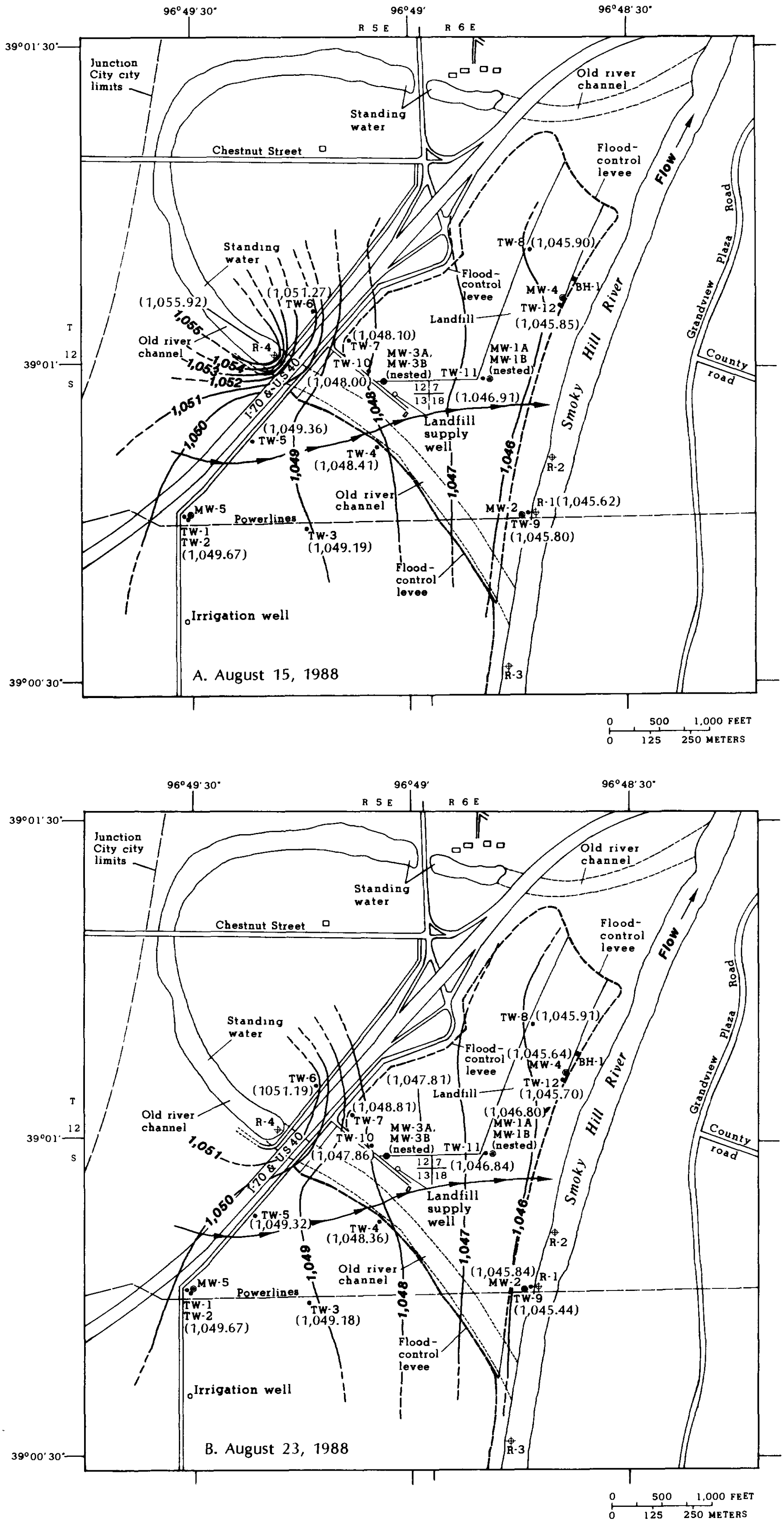

Figure 9. Potentiometric surface in vicinity of Geary County Landfill, (A) August 15, (B) August 23, and (C) September 20, 1988.

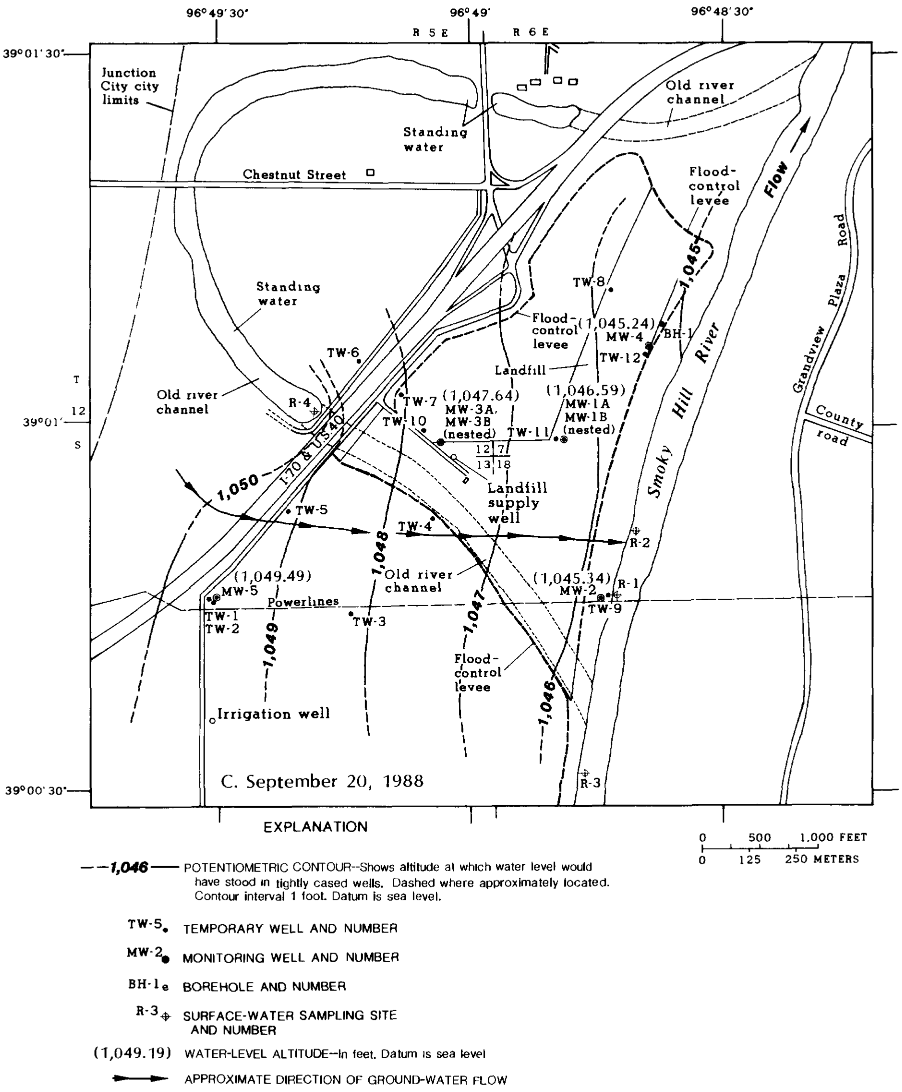

Figure 9. Potentiometric surface in vicinity of Gearry County Landfill, (A) August 15, (B) August 23, and (C) September 20, 1988--Continued.

mix of water from the alluvium and from the river. This results in a mixed calcium bicarbonate sodium chloride type water. Water from the old Smoky Hill River channel (sample R-4) also shows the characteristics of this mixed water type, but overall concentrations of solutes are much smaller than those of other water. Water in the old river channel probably is derived from a combination of ground-water outflow to the channel and surface runoff. Road salt used on Junction City streets may cause the elevated sodium and chloride concentrations measured in the old river channel sample.

Water samples from supply wells S-1, S-2, S-3, S-5, and S-6 in the Smoky Hill and Republican River valleys (fig. 2), and well MW-5 reflect ambient water-quality conditions in the vicinity of the landfill for the dominant calcium bicarbonate water type. For this water type in these wells, calcium concentrations range from 70 to 170 mg/L; sodium from 7.6 to 37 mg/L; bicarbonate, from 280 to 620 mg/L; chloride, from 22 to 37 mg/L; nitrate-nitrogen (hereafter referred to as nitrate), from 0.6 to 32 mg/L; iron, from <10 to 9,100 µg/L; and manganese, from 30 to 200 µg/L (table 6).

Water samples from wells MW-1A, MW-1B, MW-3A, MW-3B, and MW-4 reflect water-quality conditions downgradient of the landfill for the dominant calcium bicarbonate water type. For water from these wells, calcium concentrations range from 130 to 190 mg/L; sodium, from 36 to 51 mg/L; bicarbonate, from 600 to 980 mg/L; chloride, from 53 to 74 mg/L;

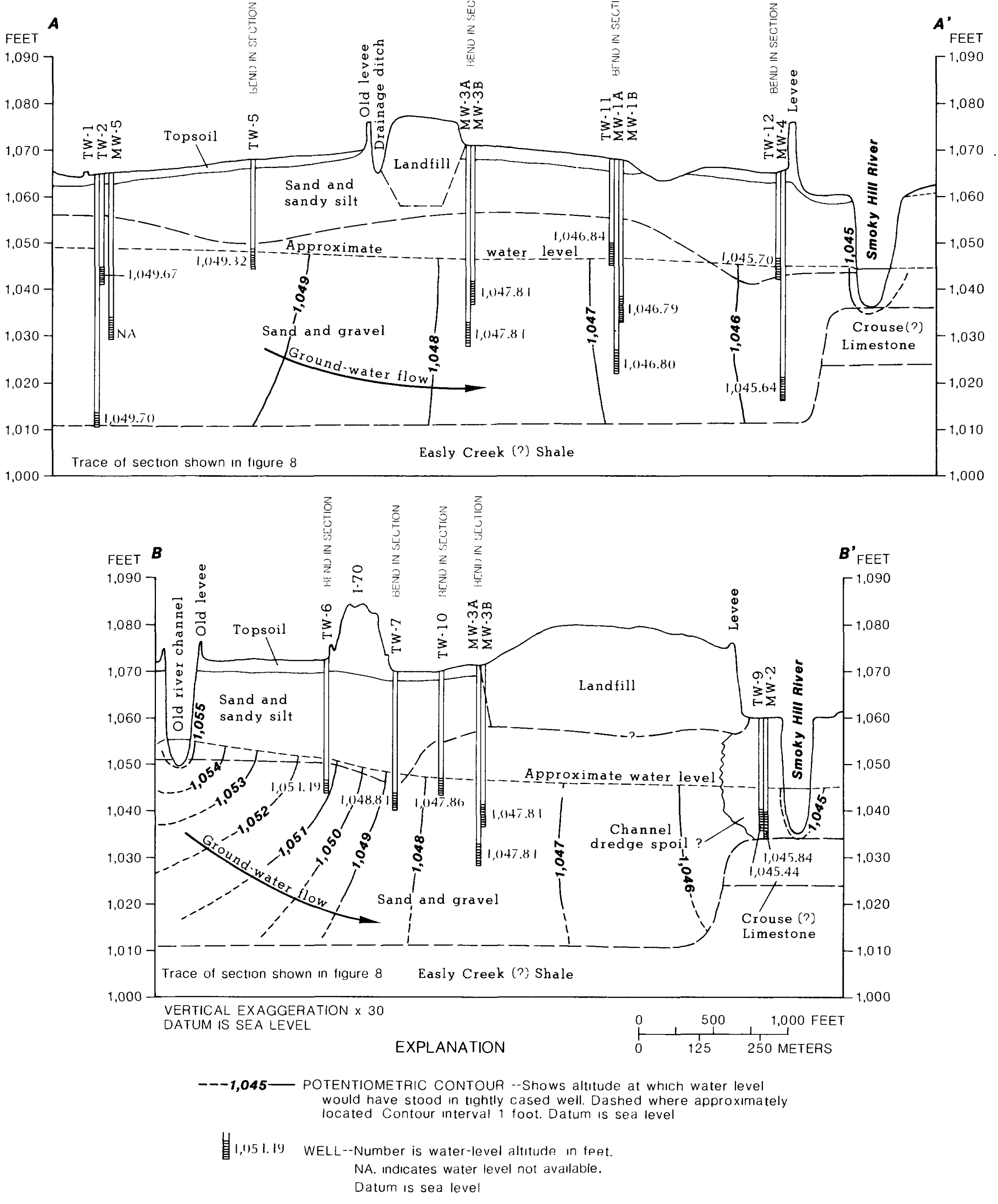

Figure 10. Hydrogeologic sections of Geary County Landfill showing lines of equal potential, August 23, 1988. Ground-water flow is perpendicular to the potentiometric contours.

Table 5. *Hydraulic conductivity calculated from slug-test data*

[Calculation method--Nguyen and Pinder (1984)]

Well number (fig. 5)	Hydraulic conductivity (feet per day)
MW-1A	108
MW-1B	--
MW-2	20
MW-3A	--
MW-3B	74
MW-4	--
MW-5	152

nitrate, from <0.01 to 0.02 mg/L; iron, from 4,200 to 19,600 µg/L; and manganese, from 1,300 to 3,700 µg/L (table 6).

None of the concentrations of inorganic constituents measured in landfill monitoring wells exceeded Kansas or Federal primary drinking-water standards. However, Kansas secondary drinking-water standards were exceeded for total hardness in water from all monitoring wells; and for dissolved solids in water from all monitoring wells and the river; for chloride and sulfate in river water; and for iron and manganese in all downgradient monitoring wells (table 6). Primary drinking-water standards have been established for constituents that can produce adverse health effects. Secondary drinking-water standards have been developed for constituents that affect the aesthetic properties and desirability of drinking water but which are not believed to have adverse health effects.

Organic Compounds

Water samples from landfill monitoring wells were analyzed for 111 organic compounds (table 7). Benzene, chloroform, 1,2-trans-dichloroethene, toluene, vinyl chloride, and the pesticide metolachlor (Dual) were detected in water samples from landfill monitoring wells (table 8). Benzene was detected in water from wells MW-3A and MW-3B at 0.6 and 2.0 µg/L, respectively. Chloroform was detected in water from well MW-5 at 0.7 µg/L. 1,2-trans-dichloroethene was detected in water from wells MW-1B at 5.4 µg/L, MW-3B at 16.1 µg/L, and MW-4 at 1.8 µg/L. Toluene was detected in water from well MW-5 at 1.6 µg/L. Vinyl chloride was detected in well MW-3B at 6.3 µg/L. None of these compounds were detected in river water or old river channel water samples. Total organic carbon (TOC) was detected in water from all wells except MW-1A at concentrations ranging from 4.4 to 180 µg/L. The large TOC concentration of 180 µg/L in water from well MW-1B may be due to the high turbidity of this sample (table 6).

None of the concentrations of organic compounds detected in water from landfill monitoring wells exceeded Kansas primary drinking-water standards or Kansas action levels. The Kansas notification level was exceeded for benzene in water from well MW-3B, for 1,2-trans-dichloroethene in water from wells MW-1B, MW-3B, and MW-4, and for vinyl chloride in water from well MW-3B (table 8). Kansas primary drinking-water standards are established for concentrations that have adverse health effects. Kansas action levels are established for concentrations that could produce chronic health effects after long-term consumption of the water. Kansas notification levels are established for concentrations that likely would produce no adverse health effects for lifetime consumption or, in the case of carcinogens, would increase the risk of cancer by no more than 1 in 1,000,000 (Kansas Department of Health and Environment, 1986).

In addition to the organic compounds previously discussed, natural gas, probably methane, was detected during and after

Table 6. *Physical properties and inorganic constituents detected in water samples*

[Concentrations in mg/L (milligrams per liter), except where noted; µS/cm, microsiemens per centimeter at 25 °C; JTU, Jackson turbidity units; mm of Hg, millimeters of mercury; µg/L, micrograms per liter. <, constituent not detected at the constituent detection limit; NA, not analysed]

Well number (figs. 2 and 5)	Date of collection (month/ day/year)	Specific conduct-ance (µS/cm)	pH (standard units)	pH, laboratory (standard units)	Water temper-ature (degree Celsius)	Turbidity (JTU)	Oxygen, dissolved (mg/L)	Barometric pressure (mm of Hg)	Hardness, total (mg/L as $CaCO_3$)	Solids, sum of constit-uents, dissolved (mg/L)	Calcium, dissolved (mg/L as Ca)
MW-1A	9/21/88	1,080	7.1	7.3	16.0	510	1.9	734	430	608	140
MW-1B	9/21/88	1,100	7.1	7.2	16.0	6,300	1.8	733	440	627	140
MW-2	9/22/88	1,370	7.1	7.1	15.5	130	4.0	730	430	770	130
MW-3A	9/21/88	1,010	7.1	7.1	15.5	130	1.8	737	420	571	130
MW3B	9/21/88	1,440	7.0	7.0	16.5	200	2.4	736	600	723	190
MW-4	9/21/88	1,230	6.8	7.2	15.0	75	3.5	733	490	664	150
MW-5	9/20/88	1,010	7.0	7.1	14.5	15	4.4	736	460	571	140
R-2	9/22/88	2,900	8.1	7.8	23.0	30	--	729	400	1,560	110
R-3	9/22/88	2,800	8.1	7.8	22.5	24	--	730	390	1,550	100
R-4	9/21/88	270	7.8	7.7	20.0	33	4.5	737	98	152	32
[1]S-1	4/1/60	450	7.7	--	24.0	--	--	--	480	452	90
[1]S-2	1/9/68	620	7.6	--	12.0	--	--	--	250	383	70
[2]S-3	8/4/43	--	--	--	14.5	--	--	--	420	444	120
[2]S-4	8/5/43	--	--	--	14.5	--	--	--	760	1,320	260
[2]S-5	7/20/43	--	--	--	15.0	--	--	--	500	584	170
[2]S-6	8/4/43	--	--	--	15.5	--	--	--	390	451	130
Kansas drinking-water standards[3]											
Primary		--	--	--	--	[5]1.0	--	--	--	--	--
Secondary		--	6.5-8.5	6.5-8.5	--	--	--	--	400	500	--
Federal primary drinking-water standards[4]		--	--	--	--	[5]1.0	--	--	--	--	--

Table 6. *Physical properties and inorganic constituents detected in water samples*--Continued

	Well number (figs. 2 and 5)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Bicarbonate (mg/L as HCO_3)	Alkalinity, total, field (mg/L as $CaCO_3$)	Alkalinity, total, laboratory (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)
	MW-1A	22	50	5	660	540	370	73	72
	MW-1B	24	51	8	660	540	370	74	74
	MW-2	23	100	11	550	450	320	120	160
	MW-3A	21	36	7	600	490	370	71	53
	MW-3B	32	43	7	980	800	550	28	60
	MW-4	26	49	6	710	580	460	52	71
	MW-5	25	20	5	620	510	410	36	37
	R-2	33	430	10	250	200	160	280	600
	R-3	33	430	10	260	210	170	280	590
	R-4	4.4	15	6	110	92	91	12	19
	[1]S-1	17	[6]37	--	280	--	--	35	29
	[1]S-2	--	--	--	280	--	--	60	23
	[2]S-3	28	[6]7.6	--	440	--	--	38	22
	[2]S-4	28	[6]150	--	420	--	--	150	270
	[2]S-5	21	[6]18	--	480	--	--	71	37
	[2]S-6	18	[6]15	--	400	--	--	58	25
Kansas drinking-water standards[3]									
Primary	--	--	--	--	--	--	--	--	--
Secondary	--	--	--	--	--	--	--	250	250
Federal primary drinking-water standards[4]	--	--	--	--	--	--	--	--	--

Table 6. *Physical properties and inorganic constituents detected in water samples*--Continued

Well number (figs. 2 and 5)	Fluoride, dissolved (mg/L as F)	Silica, dissolved, (mg/L as SiO_2)	Nitrogen, nitrate, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Phos-phorous, dissolved (mg/L as P)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)
MW-1A	0.4	26	<0.01	0.24	0.84	25	140	<1	<10
MW-1B	.4	20	<.01	.45	5.1	14	130	<1	<10
MW-2	.4	29	<.01	1.1	.54	11	140	<1	<10
MW-3A	.4	26	.02	2.0	.49	28	360	<1	<10
MW-3B	.4	29	<.01	.11	.92	24	570	<1	<10
MW-4	.3	29	<.01	.46	.32	22	120	<1	<10
MW-5	.3	34	5.0	.07	.29	3	220	<1	<10
R-2	.3	5.6	<.01	.06	.24	2	190	<1	<10
R-3	.3	5.5	<.01	.02	.23	1	120	<1	<10
R-4	.2	8	<.01	<.01	.24	3	160	--	--
[1]S-1	--	27	[7]27	--	--	--	--	--	--
[1]S-2	.5	26	[7].6	--	--	--	--	--	--
[2]S-3	.1	--	[7]5.3	--	--	--	--	--	--
[2]S-4	.2	--	[7]250	--	--	--	--	--	--
[2]S-5	.1	--	[7]32	--	--	--	--	--	--
[2]S-6	.1	--	[7]2.0	--	--	--	--	--	--
Kansas drinking-water standards[3]									
Primary	1.8	--	10	--	--	50	1,000	10	50
Secondary	--	--	--	--	--	--	--		--
Federal primary drinking-water standards[4]	1.4	--	10	--	--	50	1,000	10	50

Table 6. *Physical properties and inorganic constituents detected in water samples*--Continued

Well number (figs. 2 and 5)	Copper, dissolved (µg/L as Cu)	Iron, dissolved (µg/L as Fe)	Lead, dissolved (µg/L as Pb)	Manganese, dissolved (µg/L as Mn)	Mercury, dissolved (µg/L as Hg)	Selenium, dissolved (µg/L as Se)	Silver, dissolved (µg/L as Ag)	Zinc, dissolved (µg/L as Zn)
MW-1A	<10	4,200	<1	1,300	<0.5	4	<1	90
MW-1B	<10	4,600	<1	1,600	<.5	3	<1	20
MW-2	20	7,000	<1	1,800	<.5	2	<1	30
MW-3A	<10	12,700	<1	2,400	<.5	<1	<1	40
MW-3B	<10	19,600	2	3,700	<.5	<1	<1	30
MW-4	30	5,200	<1	1,900	<.5	2	<1	30
MW-5	<10	60	<1	30	<.5	<1	<1	40
R-2	50	50	<1	70	<.5	<1	<1	200
R-3	<10	30	38	80	<.5	<1	<1	40
R-4	<10	20	<1	20	<.5	<1	<1	<10
[1]S-1	--	160	--	200	--	--	--	--
[1]S-2	--	220	--	--	--	--	--	--
[2]S-3	--	480	--	--	--	--	--	--
[2]S-4	--	180	--	--	--	--	--	--
[2]S-5	--	<10	--	--	--	--	--	--
[2]S-6	--	9,100	--	--	--	--	--	--
Kansas drinking-water standards[3]								
Primary	--	--	50	--	2.0	10	50	--
Secondary	1,000	300	--	50	--	--	--	5,000
Federal primary drinking-water standards[4]	--	--	50	--	2.0	10	50	--

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[1] Data from Fader (1974).

[2] Data from Latta (1949).

[3] Kansas Department o f Health and Environment, 1986.

[4] U.S. Environmental Protection Agency, 1986.

[5] Treated surface water.

[6] Sodium plus potassium.

[7] Nitrogen, NO_3.

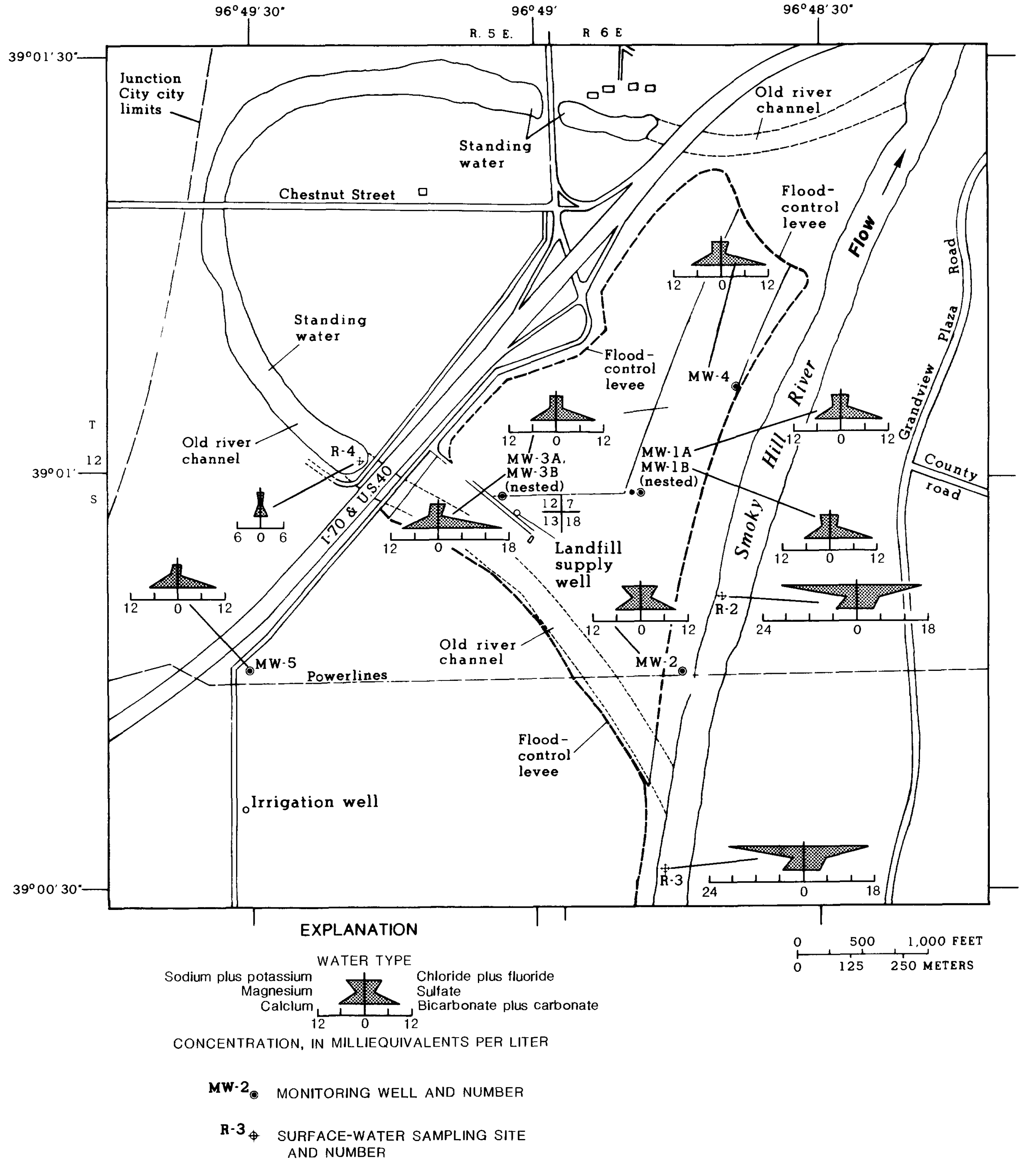

Figure 11. Stiff diagrams for surface- and ground-water samples collected in vicinity of Geary County Landfill.

installation of wellsMW-3A and MW-3B. Analysis of the gas by colorimetric-detector tubes indicated that natural gas was present at a concentration of about 0.5 percent by volume.

EFFECTS OF LANDFILL ON WATER QUALITY

Inorganic Compounds

For the dominant calcium bicarbonate water type, a comparison of water-quality data from wells reflecting ambient water-quality conditions and wells downgradient of the landfill indicates that the landfill is affecting the

Table 7. *List of organic compounds for which water samples were analyzed*

Volatile Organic Compounds

benzene
carbon tetrachloride
chloroethane
1,2-dichlorobenzene
1,4-dichlorobenzene
1,1-dichloroethane
1,1-dichloroethylene
cis-1,3-dichloropropene
ethylbenzene
methyl chloride
1,1,2,2-tetrachloroethane
toluene
1,1,1-trichloroethane
trichloroethylene
m-xylene
bromoform
chlorobenzene
chloroform
1,3-dichlorobenzene
dichlorobromomethane
1,2-dichloroethane
1,2-dichloropropane
trans-1,3-dichloropropene
methyl bromide
methylene chloride
tetrachloroethylene
1,2-trans-dichloroethene
1,1,2-trichloroethane
vinyl chloride
p-xylene

Semivolatile, Acid Extractable

2,4-dichlorophenol
4,6-dinitro-o-cresol
o-chlorophenol
p-nitrophenol
pentachlorophenol
2,4,6-trichlorophenol
2,4-dimethylphenol
2,4-dinitrophenol
o-nitrophenol
parachlorometa cresol
phenol

Semivolatile, Base-Neutral Extractable

acenaphthene
anthracene
1,2,4 trichlorobenzene
benzo (b) fluoranthene
benzo(g,h,i) perylene
bis (2-chloroethoxy) methane
bis (2-ethylhexyl) phthalate
2-chloronaphthalene
chrysene
diethyl phthalate
di-n-butyl phthalate
2,4-dinitrotoluene
fluorene
hexachlorobenzene
hexachloroethane
naphthalene
phenanthrene
acenaphthylene
benzo (A) anthracene
benzo (a) pyrene
benzo (k) fluoranthene
bis (2-chloroethyl) ether
bis (2-chloroisopropyl)ether
4-bromophenylphenylether
4-chlorophenylphenylether
1,2:5,6-dibenzanthracene
dimethyl phthalate
di-n-octyl phthalate
2,6-dinitrotoluene
fluoranthene
hexachlorobutadiene
indeno (1,2,3-c,d) pyrene
butylbenzyl phthalate
pyrene, total

Table 7. *List of organic compounds for which analyses were done--Continued*

Pesticides

- alachlor
- aldrin
- BHC
- ametryn
- aroclor 1016 pcb
- aroclor 1221 pcb
- aroclor 1232 pcb
- aroclor 1242 pcb
- aroclor 1248 pcb
- aroclor 1254 pcb
- aroclor 1260 pcb
- atrazine
- β-benzene hexachloride
- Δ-benzene hexachloride
- cyanazine
- Y-benzene hexachloride
- dieldrin
- endosulfan I
- endosulfan II
- endrin
- endosulfane sulfate
- heptachlor
- heptachlor epoxide
- metolachlor (Dual)
- metribuzin
- p,p' ddd
- p,p' dde
- p,p' ddt
- prometon
- prometryn
- propazine
- simazine
- simetryn
- toxaphene
- trifluralin
- chlordane

chemistry of water in the alluvial aquifer. Downgradient wells have water with larger median specific-conductance values and larger concentrations of calcium, sodium, bicarbonate, sulfate, chloride, iron, and manganese (table 9). The median concentration for nitrate in water from downgradient wells is smaller than in water from upgradient wells, whereas the median concentration for ammonia is larger in water from downgradient wells than in water from well MW-5 (table 9). Concentrations of the trace elements arsenic, copper, lead, and selenium in water from some or all downgradient wells exceed concentrations detected in water from upgradient well MW-5 (table 6).

Changes in concentrations of ions and trace metals in ground water are caused by several factors. A change in the amount of a specific mineral or minerals present in aquifer material can cause changes in ion concentrations. For example, the solution of halite (sodium chloride) may cause an increase in sodium and chloride concentrations. A change in the pH of water may affect the solubility of minerals and thus the concentrations of ions present. A change in the oxidation-reduction characteristics of water may change the concentrations of ions present, in that depletion of oxygen as the primary oxidizing agent may lead to other constituents acting as oxidizing agents. Oxidation of organic matter, such as that found in landfills, can use up the available oxygen (Freeze and Cherry, 1979, p. 117). In the absence of oxygen, nitrate, manganese oxide, iron oxide, sulfate, and water can act as oxidizing agents for organic matter (Freeze and Cherry, 1979, p. 118). In the process of oxidizing organic matter, the oxidizers themselves are reduced to forms that are more soluble and thus are detected in larger concentrations in landfill leachate, except that nitrate nitrogen is reduced to ammonia nitrogen (Baedecker and Back, 1979; Freeze and Cherry, 1979, p. 118). In this oxygen-depleted environment, the oxidation of organic matter also may lead to the production of methane gas (Freeze and Cherry, 1979, p. 118).

Several factors indicate the presence of reducing and metastable chemical conditions in

Table 8. *Summary of organic compounds detected*

[Concentrations in µg/L, micrograms per liter. KPDWS, Kansas primary drinking-water standard; KAL, Kansas action level; KNL, Kansas notification level; +, total of trihalomethane compounds; !, any positive detection]

Compound	Sampling site (fig. 5)										Drinking-water standard[1]		
	MW-1A	MW-1B	MW-2	MW-3A	MW-3B	MW-4	MW-5	R-2	R-3	R-4	KPDWS	KAL	KNL
Benzene	<0.4	<0.4	<0.4	0.6	2.0	<0.4	<0.4	<0.4	<0.4	<0.4	5.0	6.7	0.67
Chloroform	< .5	< .5	< .5	< .5	< .5	< .5	0.7	< .5	< .5	< .5	--	100+	100+
1,2-trans-dichloroethene	< .5	5.4	< .5	< .5	16.1	1.8	< .5	< .5	< .5	< .5	--	270.0	!
Toluene	< .5	< .5	< .5	< .5	< .5	< .5	1.6	< .5	< .5	< .5	--	240.0	3.5
Vinyl chloride	< .8	< .8	< .8	< .8	6.3	< .8	< .8	< .8	< .8	< .8	1.0	10.0	1.0
Metolachlor (Dual)	< .25	< .25	< .25	< .25	< .25	< .25	.35	< .25	< .25	< .25	--	--	--
Total organic carbon	< .1	180.0	12.0	7.9	40.0	6.4	4.4	11.0	10.0	17.0	--	--	--

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[1] Kansas Department of Health and Environment, 1986.

Table 9. *Ranges and median concentrations of constituents or properties in calcium bicarbonate type water*

[Concentrations in mg/L, milligrams per liter; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius]

Relation to landfill	Wells (figs. 2 and 5)		Specific conductance (µS/cm)	Calcium (mg/L)	Sodium (mg/L)	Bicarbonate (mg/L)	Sulfate (mg/L)	Chloride (mg/L)
Upgradient (ambient)	MW-5, S-1, S-2, S-3, S-5, S-6	Range Median	450-1,010 620	70-170 120	7.6-37 18	280-620 420	35-71 48	22-37 27
Downgradient	MW-1A, MW-1B, MW-3A, MW-3B, MW-4	Range Median	1,010-1,440 1,100	130-190 140	36-51 49	600-980 660	28-74 71	53-74 71

Relation to landfill	Wells (figs. 2 and 5)		Nitrogen, nitrate (mg/L)	Nitrogen, ammonia (mg/L)	Iron (µg/L)	Manganese (µg/L)
Upgradient (ambient)	MW-5, S-1, S-2, S-3, S-5, S-6	Range Median	0.6-32 5.2	0.07 0.07	<10-9,100 190	30-200 115
Downgradient	MW-1A, MW-1B, MW-3A, MW-3B, MW-4	Range Median	<0.01-0.02 <0.01	0.11-2.0 0.45	4,200-19,600 5,200	1,300-3,700 1,900

the Geary County Landfill. Natural gas was detected during installation of wells MW-3A and MW-3B. Nitrate and ammonia concentrations indicate that nitrate is being reduced to ammonia in areas downgradient of the landfill. Smaller dissolved-oxygen concentrations in water from downgradient wells indicate that oxygen is being used in redox reactions in the vicinity of the landfill. The presence of ammonia and dissolved oxygen in the same samples indicates that chemical equalibria are metastable.

On the basis of chemical analyses from the Geary County Landfill and the preceding discussion, the landfill is affecting ground-water quality primarily because of reducing conditions in the landfill or in the landfill leachate. Increased concentrations of the common ions calcium, magnesium, sodium, bicarbonate, sulfate, and chloride may be caused by leaching of these compounds from landfill wastes. Sodium and chloride concentrations also may be increased by mixing sodium chloride type water from the Smoky Hill River with ground water, as is evident in well MW-2. Iron and manganese may be derived either from the landfill wastes or by mobilization of iron-oxide and manganese-oxide coatings on aquifer materials by leachate from the landfill. Iron concentrations in ground water in the Junction City area as large as 9,100 µg/L have been reported (Latta, 1949), so it is evident that iron is occurring naturally in the area. However, the relatively small concentrations of iron in water from upgradient well MW-5 and much larger concentrations in water from all downgradient wells indicate that the landfill is playing a significant role in the mobilization of iron. Arsenic, copper, lead, and selenium also may be mobilized from landfill wastes but are not present in very large concentrations due to two possible factors--scarcity in landfill wastes and (or) sorbtion of these trace elements to organic matter and clay material in sediments (Kimmel and Braids, 1980).

At the time of sampling, landfill leachate did not appear to be affecting ground-water quality in public- or private-supply wells or the quality of water in the Smoky Hill River. Other than the landfill-supply well, there are no private- or public-supply wells downgradient of the landfill as indicated by ground-water flow directions reported here. Inflow of leachate-contaminated ground water to the river probably does not occur in a large enough volume to significantly affect the chemistry of water in the Smoky Hill River.

Organic Compounds

The organic compounds chloroform, metolachlor, and toluene were detected in water from upgradient well MW-5. Chloroform is used as a refrigerant, as an aerosol propellant, in the synthesis of fluorinated resins, as a solvent, in fire extinguishers, and as a pesticide (National Research Council, 1977, p. 713). The U.S. Environmental Protection Agency has found chloroform to be present in 95 to 100 percent of finished chlorinated drinking water, the median concentration being 20 µg/L (National Research Council, 1977, p. 713). Metolachlor is used as a pre-emergent herbicide for field crops. Toluene is used in the production of benzene derivatives, saccharin, perfumes, dyes, medicines, solvents, TNT, and detergent, and is used as a gasoline component (National Research Council, 1977, p. 770). Toluene has been reported in finished drinking-water supplies at concentrations of 11 µg/L (National Research Council, 1977, p. 770).

There are several possible sources for the organic compounds detected in water from upgradient well MW-5. Chloroform and toluene are common compounds found in a number of household and commercial products. Light-industrial and urban areas of Junction City, upgradient of well MW-5, could be the source of these compounds. Also, both compounds have been found in finished drinking water and could have been present in the finished drinking water used during well construction. However, one would have expected to detect these compounds in the other monitoring wells because finished drinking water also was used in their construction. Metolachlor probably originated from application of this herbicide to fields in the area.

Several volatile organic compounds were detected in water from downgradient wells. Benzene, detected in water from wells MW-3A and MW-3B, is used as a chemical intermediate in the manufacture of styrene, cyclohexane, detergents, and pesticides, and has been reported in gasoline at concentrations of less than 5 percent by volume (National Research Council, 1977, p. 688). Benzene has been listed as a carcinogen by the U.S. Environmental Protection Agency (1987). Vinyl chloride, detected in water from well MW-3B, is used primarily in the production of polyvinyl-chloride resins and, prior to 1974, was used in some propellants and aerosols (National Research Council, 1977, p. 783). Vinyl chloride has been listed as a carcinogen by the U.S. Environmental Protection Agency (1987). Both benzene and vinyl chloride have been detected in finished drinking water at concentrations of as much as 10 µg/L and 5.6 µg/L, respectively (National Research Council, 1977, p. 688, 783). The compound 1,2-trans-dichloroethene, detected in water from wells MW-1B, MW-3B, and MW-4, is used as a general solvent for dye extraction, perfumes, lacquers, and thermoplastics (Sax and Lewis, 1987, p. 278).

There are several possible sources for the organic compounds found in water from downgradient wells. Benzene may have originated from landfill wastes, such as the gasoline-tank bottoms that have been disposed of at the landfill. Vinyl chloride and 1,2-trans-dichloroethene could have been leached directly from landfill wastes or could be degradation products of other organic compounds. Both compounds have been found to be products of anaerobic biodegradation of trichloroethylene and tetrachloroethylene, which are used extensively in the United States (Wood and others, 1985, p. 494-495). Benzene and vinyl chloride may have been present in the finished drinking water used during well completion, but, if so, these compounds should have been detected in water from other monitoring wells. Vinyl chloride may have been leached from polyvinyl-chloride shavings produced during well construction, but if so it should have been detected in water from other wells.

Total organic carbon (TOC) was detected in measurable quantities in water from all but well MW-1A (table 8). TOC is a measure of the amount of organic carbon that is dissolved and suspended in water and is a good indicator of the presence of volatile and semivolatile organic compounds in water. In water from well MW-5, TOC was detected at 4.4 µg/L. For water from downgradient wells, TOC values ranged from <0.1 to 180 µg/L, with a median concentration of 7.9 µg/L. Excluding well MW-1B, the largest concentration of TOC, 40 µg/L, was detected in water from well MW-3B, which also had the largest concentrations of benzene, 1,2-trans-dichloroethene, and vinyl chloride. TOC concentrations in water from other wells do not correspond well to the sum of the concentrations of organic compounds detected. This may be an indication that there are other organic compounds present that were not identified.

Definition of Leachate Plume

Dissolved oxygen, nitrate, ammonia, iron, manganese, and TOC concentrations can be used to generally define the extent of a leachate plume at the Geary County Landfill. Dissolved-oxygen, nitrate, and ammonia concentrations can be used to approximate the zones of oxidizing, reducing, and transition from reducing to oxidizing conditions (figs. 12, 13, and 14). The distribution of iron and manganese concentrations indicate the presence of a leachate plume extending from the landfill to the northeast towards the Smoky Hill River in the general direction of ground-water flow (figs. 15 and 16). Specific conductance, which is a measure of the ability of water to conduct electricity due to inorganic and organic constituents in the water, also indicates the presence of a plume extending northeastward from the landfill (figs. 17 and 18). The distribution of TOC and the presence of organic compounds in the leachate plume are indicated in figures 19 and 20.

Note that concentrations of solutes decrease in a downgradient direction. This is due to lateral and vertical diffusion of the plume, dilution of the plume by "ambient" ground water, and chemical reactions of plume constituents with aquifer materials and ambient ground water. In apparent contradiction, water from wells MW-1A and MW-1B in general indicates smaller concentrations of solutes than does water from well MW-4, which is farther from the landfill. This may be due to one or a combination of factors; well MW-4 may be nearer the "axis" of the plume than wells MW-1A and MW-1B, or solute concentrations in water from well MW-4 may reflect a seasonal leachate pulse from the landfill, the bulk of the leachate may be produced in the northernmost part of the current landfill area, or the direction of plume movement is more northerly than indicated by

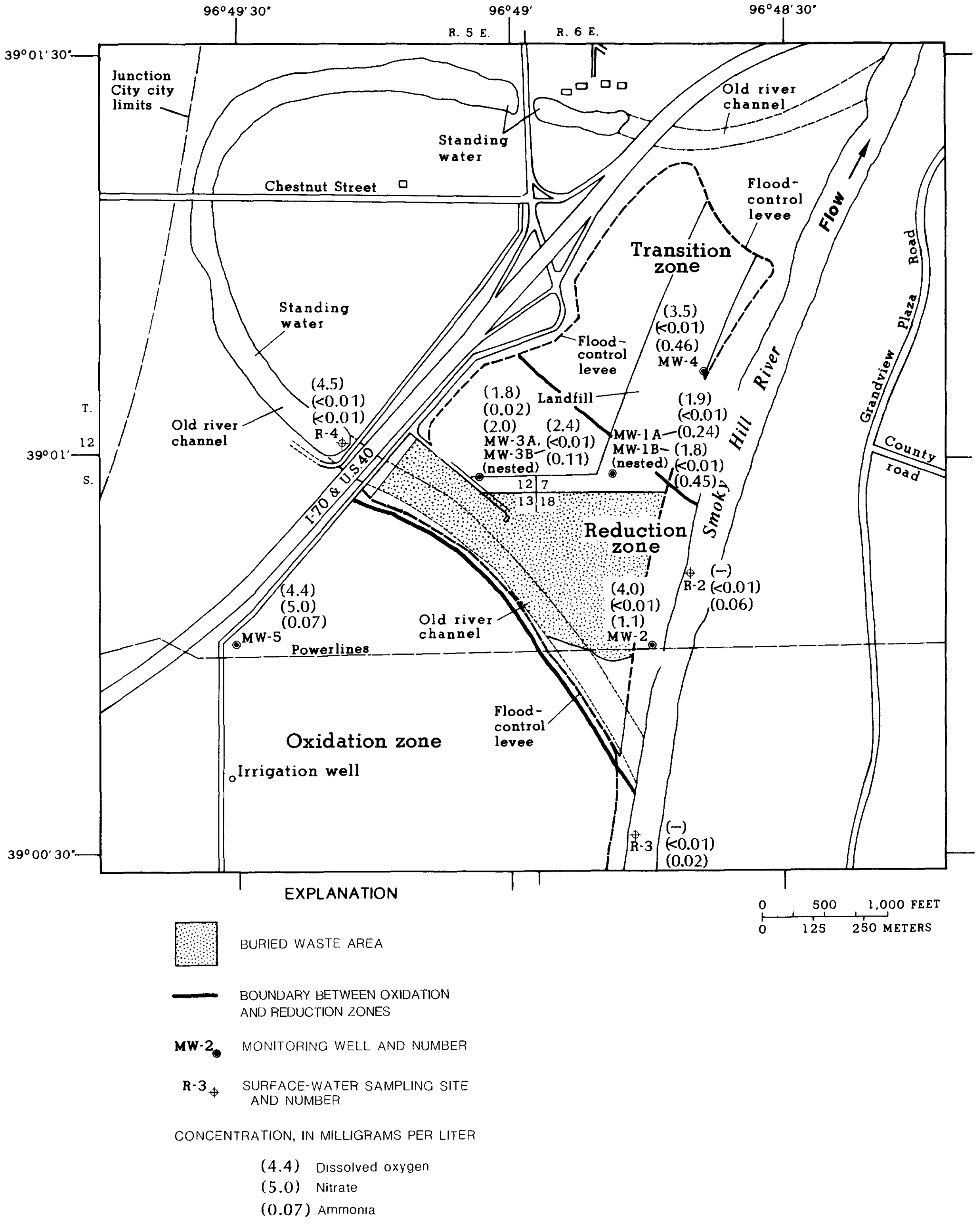
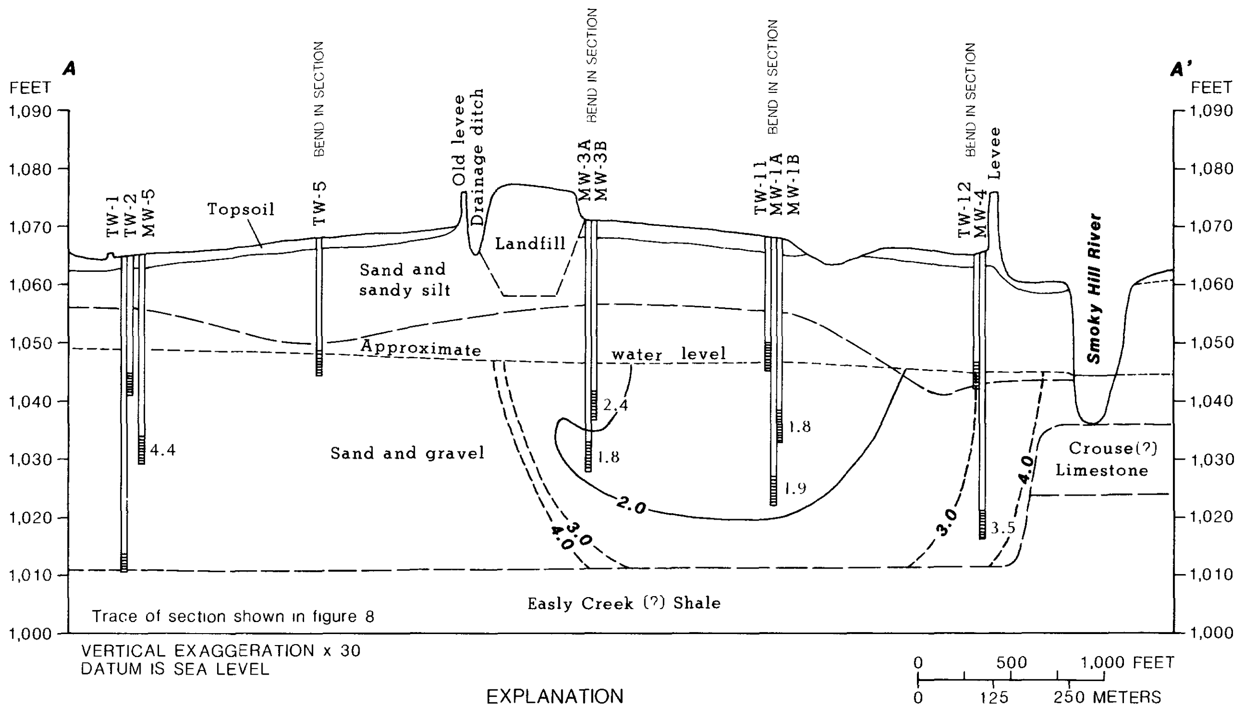


Figure 12. Concentrations of dissolved oxygen, nitrate, and ammonia in vicinity of Geary County Landfill, September 1988, and approximate location of oxidation, reduction, and transition zones.



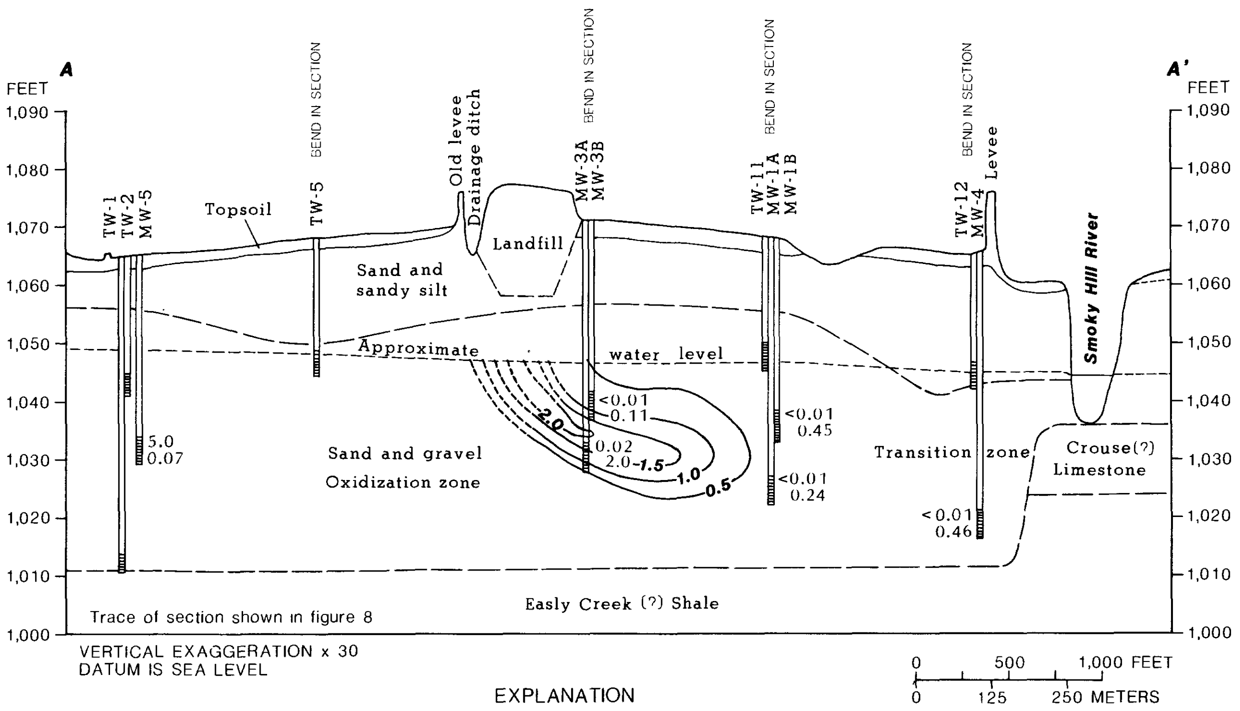
EXPLANATION

—4.0— LINE OF EQUAL DISSOLVED OXYGEN--Interval is 1.0 milligram per liter. Dashed where approximately located

— — — GEOLOGIC CONTACT

▯ 1.8 WELL--Number is dissolved oxygen, in milligrams per liter

Figure 13. Hydrogeologic section showing distribution of dissolved-oxygen concentrations and general location of leachate plume, September 1988.



EXPLANATION

—2.0— LINE OF EQUAL AMMONIA CONCENTRATION--Interval 0.5 milligram per liter

▯ 0.02 / 2.0 WELL--Upper number is nitrate concentration, in milligrams per liter; lower number is ammonia concentration, in milligrams per liter

Figure 14. Hydrogeologic section showing distribution of nitrate and ammonia concentrations and general location of leachate plume, September 1988.

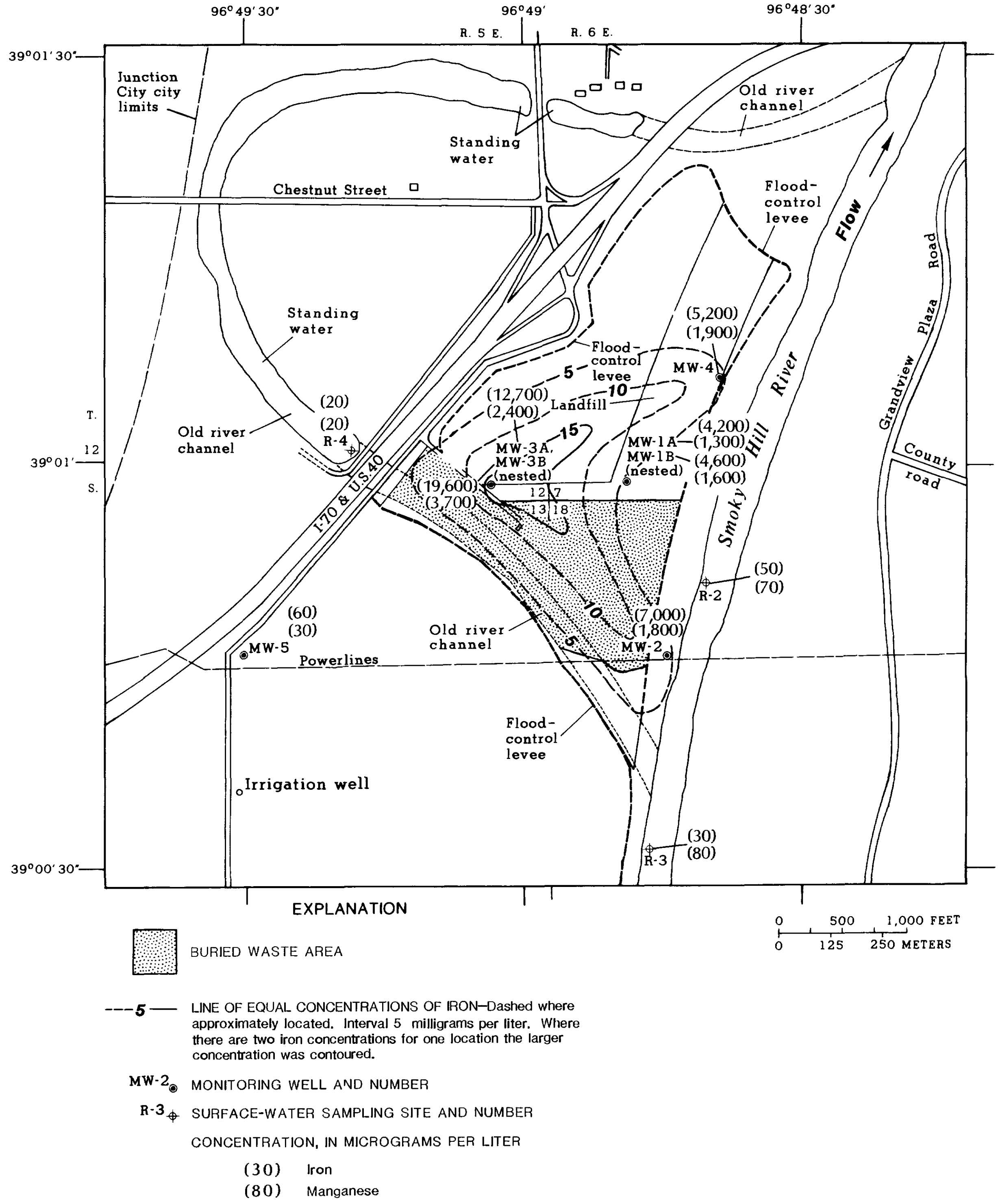


Figure 15. Distribution of iron and manganese concentrations and general location of leachate plume in vicinity of Geary County Landfill, September 1988.

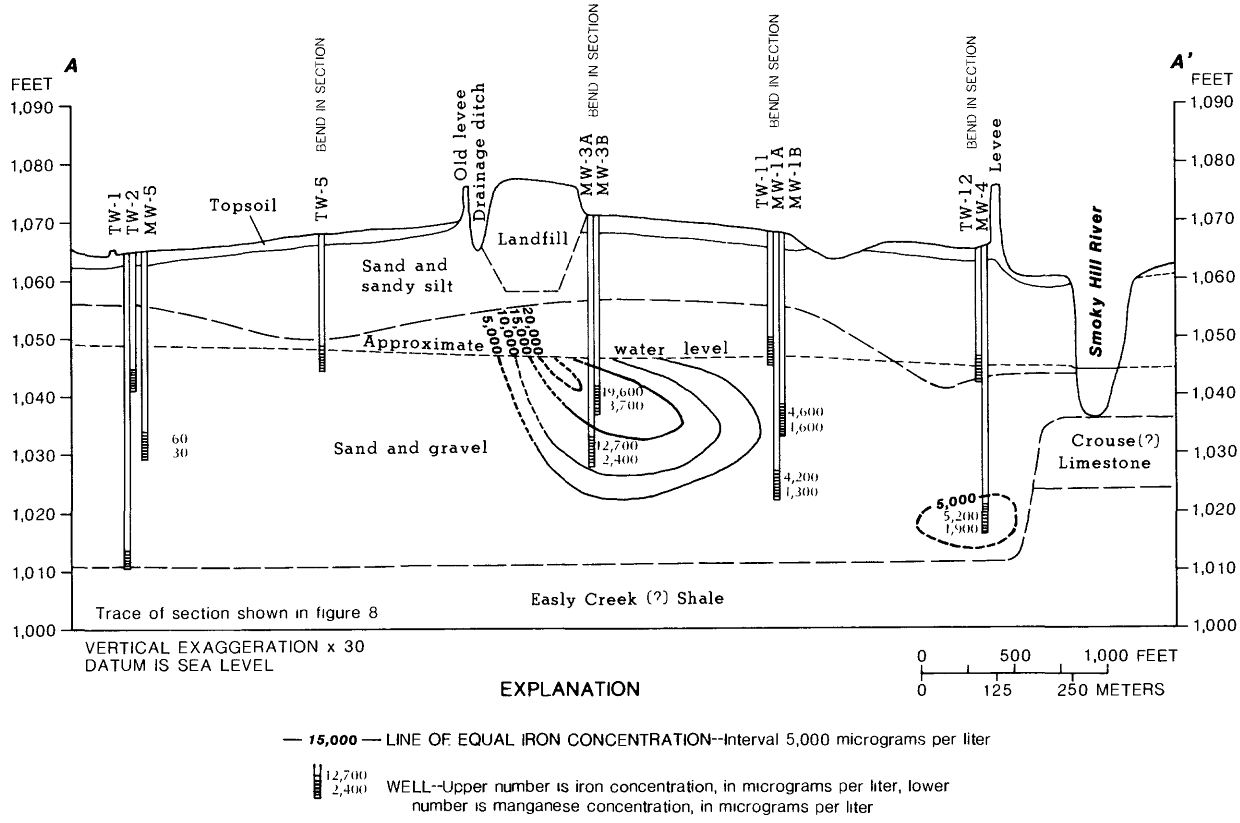


Figure 16. Hydrogeologic section showing distribution of iron and manganese concentrations and general location of leachate plume, September 1988.

ground-water flow directions (figs. 9A, 9B, and 9C). Ground-water flow directions during high river stages and zones of larger hydraulic conductivity may play important roles in determining the direction of plume movement.

SUMMARY AND CONCLUSIONS

An investigation of hydrogeologic and water-quality conditions in the vicinity of the Geary County Landfill near Junction City, Kansas, was undertaken from March 1988 through March 1989. Twelve temporary wells were installed to determine the direction of ground-water movement. Subsequently, seven monitoring wells were installed in positions upgradient and downgradient of the landfill.

Chemical analyses of water samples from the monitoring wells and from the old and new river channels indicate that the landfill is affecting water quality by creating an anaerobic, metastable reducing environment in which calcium, magnesium, sodium, bicarbonate, sulfate, chloride, iron, manganese, and other trace metals are mobilized and organic compounds are released to the ground water. None of the concentrations of inorganic or organic constituents exceed State or Federal primary drinking-water standards, but concentrations of iron and manganese in water from downgradient wells exceed State secondary drinking-water standards. Concentrations of benzene, vinyl chloride, and 1,2-trans-dichloroethene exceed Kansas notification levels for these compounds.

The distribution of specific conductance, iron, manganese, TOC, and organic-compound concentrations indicates that a leachate plume extends downgradient from the landfill towards the northeast. The axis of the plume seems to indicate ground-water flow in a more northerly direction than indicated by water-level

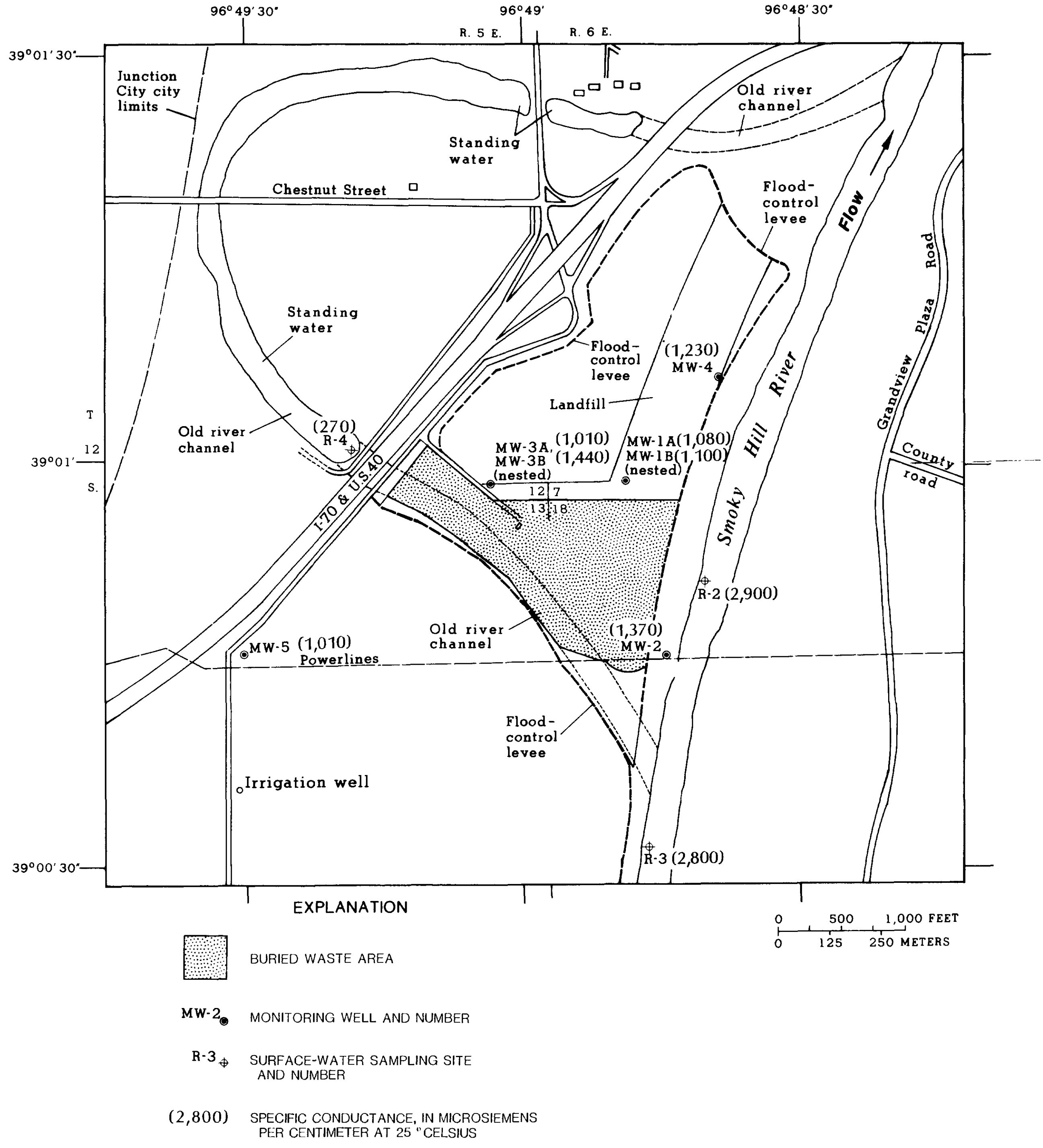


Figure 17. Specific conductance of water in vicinity of Geary County Landfill, September 1988.

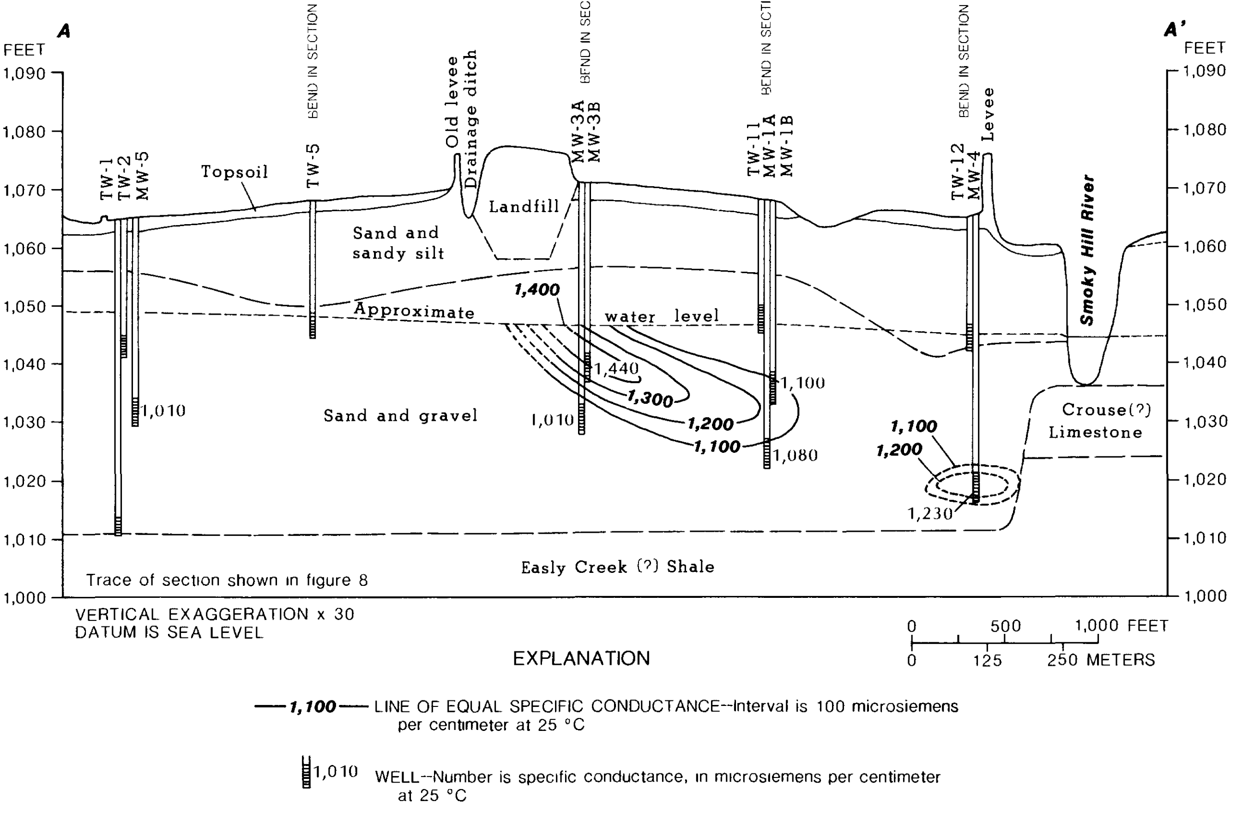


Figure 18. Hydrogeologic section showing distribution of specific-conductance values and general location of leachate plume, September 1988.

measurements. This may indicate that ground-water flow directions are north or northeast during periods of high river stages or abundant rainfall during the spring and early summer. Landfill leachate is diluted, dispersed, and chemically altered as it flows away from the landfill. Landfill leachate does not appear, at the time of sampling, to be affecting the water quality in public- or private-supply wells or in the Smoky Hill River.

Continued yearly analyses of inorganic and volatile organic constituents would provide long-term information on the effect of the landfill on water quality. Quarterly water-level measurements and short-term continuous water-level measurements would give a better understanding of seasonal fluctuations in water levels and direction of ground-water movement.

It is unknown whether the fine-grained sediments found in wells TW-9 and MW-2 are characteristic of the subsurface near the new river channel. Fine-grained, clay-rich sediments of this type could provide an important buffer for moderating the effects of landfill leachate on river water quality.

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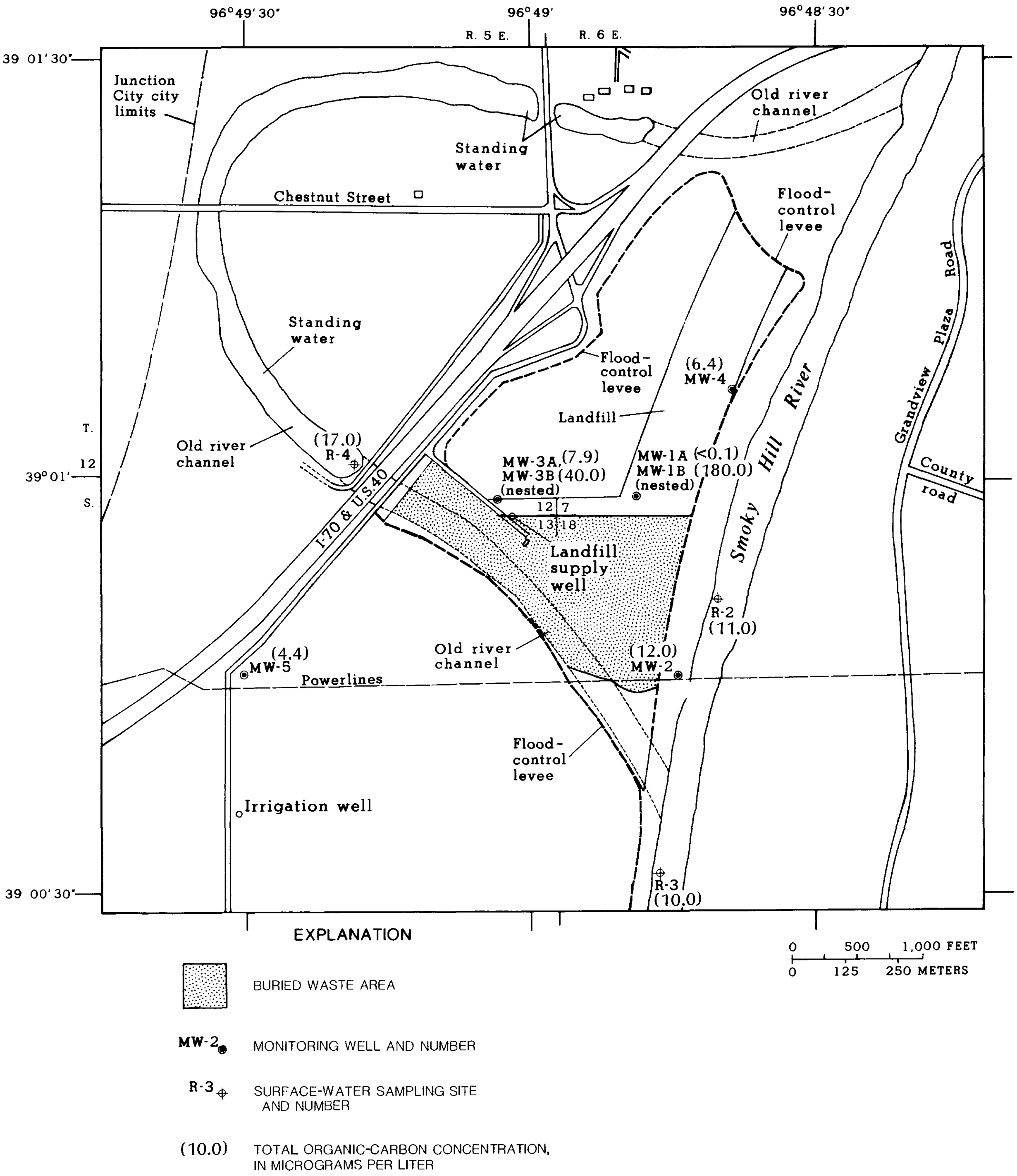

Figure 19. Total organic-carbon concentrations in vicinity of Geary County Landfill, September 1988.

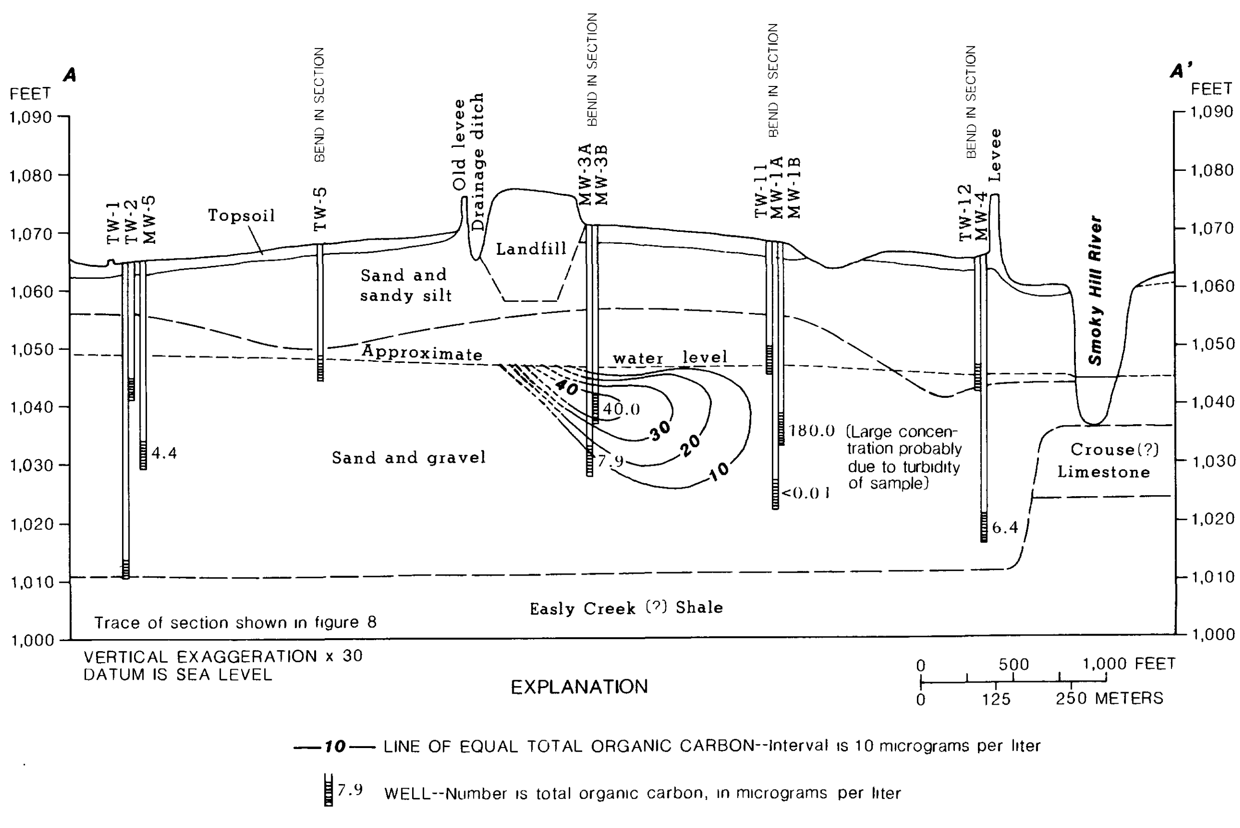

Figure 20. Hydrogeologic section showing distribution of total organic-carbon concentrations and general location of leachate plume, September 1988.

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