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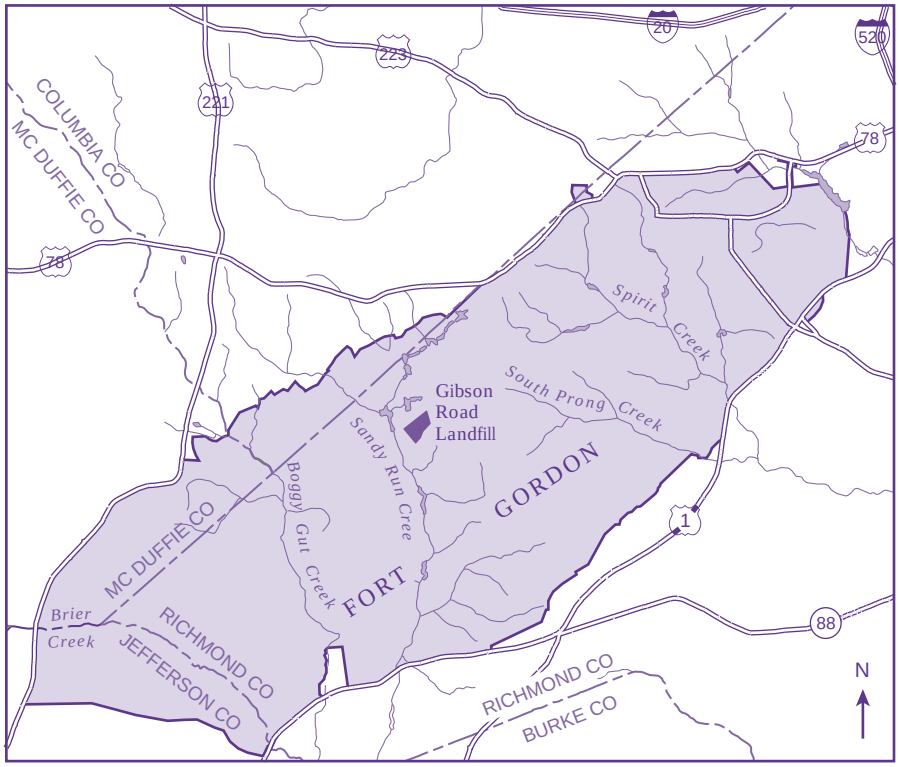
Hydrogeology and water quality of the Upper Three Runs aquifer in the vicinity of the Gibson Road Landfill, Fort Gordon, Georgia, June–November 1999

Water-Resources Investigations Report 02-4153
Version 1.1, January 2022



Prepared in cooperation with the
U.S. Department of the Army
Environmental and Natural Resources Management
Office of the U.S. Army Signal Center *and* Fort Gordon

U.S. Department of the Interior
U.S. Geological Survey

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Horizontal Datum

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83). Historical data collected and stored as North American Datum of 1927 (NAD 27) have been converted to NAD 83 for use in this report.

HYDROGEOLOGY AND WATER QUALITY OF THE UPPER THREE RUNS AQUIFER IN THE VICINITY OF THE GIBSON ROAD LANDFILL, FORT GORDON, GEORGIA, JUNE–NOVEMBER 1999

By Sherlyn Priest and Kristen Bukowski McSwain

ABSTRACT

Fort Gordon military installation, a U.S. Department of the Army facility, is located in east-central Georgia southwest of Augusta. The military base operates a three-phase unlined landfill—Gibson Road Landfill—to store a variety of wastes. Phases I and II stored only household wastes, and these phases were discontinued during the mid–1990s. Fort Gordon currently (1999) operates Phase III of the landfill that stores only construction and demolition debris. Water-quality monitoring detected selected trace elements and organic compounds exceeding the maximum contaminant levels of the U.S. Environmental Protection Agency, National Primary Drinking Water Standards. The selected trace elements and organic compounds detected showed that contamination of ground water had occurred in the vicinity of the landfill. In 1999, the U.S. Geological Survey, in cooperation with the Environmental and Natural Resources Management Office of the U.S. Army Signal Center and Fort Gordon, Georgia, began an assessment of the hydrogeology and water quality in shallow ground water in the vicinity of the Gibson Road Landfill to delineate the extent of a ground-water contamination plume in the vicinity of the landfill.

Hydrogeologic units in the Augusta area include the Upper Three Runs aquifer, the Gordon aquifer, the Millers Pond aquifer, and the Dublin aquifer. Only the shallowest aquifer, Upper Three Runs, was penetrated during this study. The Upper Three Runs aquifer is composed of sediments of the Barnwell Group. Mostly, these sediments are highly permeable fine to medium, well-sorted sand with lenses of clay.

Ground-water flow is from northwest to southeast and generally was unaffected by seasonal variation during the period of study (June–November 1999). Water-table altitudes in the landfill area for the study period ranged from 394 feet (ft) to 445 ft above sea level. Ground-water samples analyzed for organic compounds and selected trace elements by a U. S. Environmental Protection Agency (USEPA) approved statistical test revealed that increases in contaminant concentrations above the detection limits had occurred during March and September 1999 in five wells—one of which is located upgradient. These organic compounds, respective increases in concentration, and the wells in which they were detected are: methylene chloride—wells 28AA29 (24 parts per billion [ppb] and 46 ppb), 28AA30 (86 ppb and 130 ppb), and 28AA31 (240 ppb and 140 ppb); 1,1-dichloroethene—well 28AA31 (10 ppb and 5.7 ppb); 1,1-dichloroethane— wells 28AA30 (81 ppb and 140 ppb) and 28AA31 (200 ppb and 130 ppb); and 1,1,1-trichloroethane—well 28AA31 (61 ppb and 37 ppb). Although in some wells the concentration decreased from March to September, the median concentrations were still higher in certain groups. Trace element compounds, their respective increases in concentration, and the wells in which they were detected are: chromium—well 28AA30 (1,190 ppb), vanadium—well 28AA30 (104 ppb); barium—wells 28AA27 (42.2 ppb) and 28AA32 (140 ppb), and beryllium—well 28AA30 (6.3 ppb). These increases occurred in September, with the exception of

chromium in well 28AA30, which occurred in March. Although a statistical test indicated increases in contaminant concentrations had occurred, water from wells 28AA27, 28AA30, 28AA31, and 28AA32 had a decrease in contaminant concentrations from February 1998 to September 1999.

U.S. Environmental Protection Agency, National Primary Drinking Water Regulations Maximum Contaminant Levels (PMCLs), formerly (MCLs) were exceeded in water from four wells for organic compounds and in five wells by selected trace elements during the February 1998, March 1999, and September 1999 sampling periods. The concentrations for the following organic compounds and the associated wells are: methylene chloride (PMCL is 5 ppb)—wells 28AA27 (February, 37 ppb; March, 24 ppb; and September, 9.6 ppb), 28AA29 (February, 20 ppb; March, 24 ppb; and September, 46 ppb), 28AA30 (February, 50 ppb; March, 86 ppb; and September, 130 ppb), and 28AA31 (February, 330 ppb; March 240 ppb; and September, 140 ppb); vinyl chloride (PMCL is 2 ppb)—well 28AA29 (March, 3.6 ppb; and September, 4.4 ppb); 1,1-dichloroethene (PMCL is 7 ppb)—wells 28AA30 (March 10 ppb; and September, 17 ppb) and 28AA31 (February, 13 ppb; and March, 10 ppb); and 1,1,2-trichloroethane (PMCL is 5 ppb)—well 28AA30 (March, 33 ppb). Contaminant concentrations decreased in well 28AA31 from March to September 1999; however, concentrations still exceeded the PMCL. The concentrations for the following selected trace elements exceeding PMCL and the associated wells during the sampling periods February 1998, March 1999, and September 1999 are: mercury (PMCL is 2 ppb)—well 28AA24 (September, 2.82 ppb), well 28AA25 (February, 3.1 ppb; March, 2.11 ppb; and September, 2.28 ppb), and well 28AA30 (September, 2.82 ppb); arsenic (PMCL is 50 ppb)—well 28AA30 (February, 90 ppb; and September, 114 ppb); thallium (PMCL is 2 ppb)—wells 28AA27 (March, 2.08 ppb) and 28AA29 (February, 2.56); barium (PMCL is 2,000 ppb)—well 28AA30 (March, 4,490 ppb); chromium (PMCL is 30 ppb)—well 28AA30 (February, 630 ppb; and March, 1,190 ppb); and beryllium (PMCL is 4 ppb)—well 28AA30 (September, 6.3 ppb). Water from seven wells, three of which are upgradient of the landfill, contained organic compounds and/or selected trace elements exceeding PMCLs during the period February 1998 to September 1999 according to private consultants. Contaminants present in upgradient wells most likely were caused by chemical dispersion, leachate migration, incorrectly defined landfill area, or natural ground-water flow beneath the landfill.

INTRODUCTION

Fort Gordon military installation (Fort Gordon), a U.S. Department of the Army facility (Army), is located in east-central Georgia, about 10 miles (mi) southwest of Augusta, Ga. (fig. 1). In 1985, the Georgia Environmental Protection Division (GaEPD), Department of Solid Waste Management (DSWM), issued an operating permit for the Gibson Road Landfill facility (landfill). The landfill is located in the west-central part of Fort Gordon and currently (1999) is operating as an unlined landfill having three fill phases. Household wastes were stored during Phases I and II; however, these phases were discontinued in the mid–1990s. Phase III currently (1999) stores only construction and demolition debris.

As a requirement of the GaEPD operating permit, landfill personnel began conducting semiannual (twice a year) water-quality sampling at four ground-water monitoring wells and one surface-water outfall in 1985. In 1995, a water-quality monitoring plan was written for the landfill increasing the number of monitoring wells to 10 and changing the sampling protocol to that specified by Federal regulations (U.S. Environmental Protection Agency, 2000a, b). Water samples from the wells were analyzed for selected volatile organic compounds, selected trace elements, and field properties in ground water (pH, specific conductance, and temperature). Beginning in 1994, various consultants of the Army analyzed water samples for selected trace elements and organic compounds because some of these constituents were detected previously at concentrations that exceeded the USEPA PMCLs (highest legally allowable level of a contaminant in drinking water) (U.S. Environmental Protection Agency, 2000c).

Since 1998, organic compound and selected trace elements concentration increases were detected in water samples from five wells (Brent Cortelloni, Environmental Management Associates, LLC, written commun. with Sherlyn Priest, Hydrologist, USGS, 1998 and 1999). Four wells had concentration increases for volatile organic compounds and three wells had concentration increases for selected trace elements. In

June 1999, the U.S. Geological Survey (USGS), in cooperation with the Environmental and Natural Resources Management Office of the U.S. Army Signal Center and Fort Gordon, Georgia, began an assessment of hydrogeology at Fort Gordon and water quality in shallow ground water in the vicinity of the landfill.

Purpose and Scope

The purpose of this report is to increase the geohydrologic understanding in the vicinity of the Gibson Road Landfill, Fort Gordon, Georgia, to aid the Army in making sound environmental management decisions. This report describes the hydrogeology and water quality of shallow ground water in the landfill area, including the

- relation of the lithology, stratigraphy, and structure of the Upper Three Runs aquifer in the vicinity of the landfill to the regional hydrogeologic framework,
- configuration of the water table, and ground-water-flow directions at and near the landfill, and
- water quality of the Upper Three Runs aquifer downgradient from the landfill.

The investigation covered the period June–November 1999 and includes

- determination of water-bearing sediments by relating well construction to the hydrogeologic framework;
- geophysical logging of existing wells to verify well construction and delineate the local hydrogeologic framework;
- water-level measurements;
- testing of monitoring wells for the presence of landfill gas; and
- sampling of ground water using direct-push method—Hydropunch™ (Edge and Cordry, 1989) to penetrate and sample the shallow, water-bearing zone.

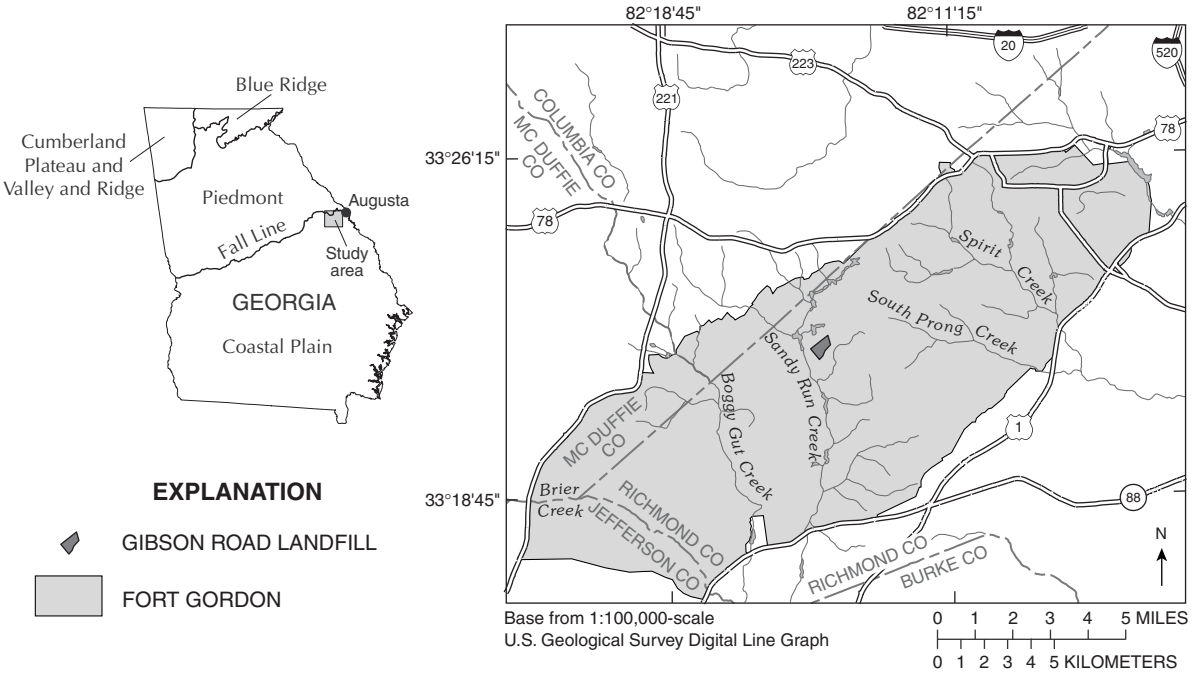


Figure 1. Gibson Road Landfill and drainages at Fort Gordon, Georgia, study area.

Description of Study Area

Fort Gordon (fig. 1) is located in the Coastal Plain physiographic province in northwestern Richmond County, southwest of Augusta, Georgia, and in small parts of adjacent counties of Columbia, Jefferson, McDuffie, and Warren. Fort Gordon is located near the Fall Line (Clark and Zisa, 1976)—a transition zone between the Coastal Plain and Piedmont physiographic provinces (fig. 1). The general topography along the Fall Line is typified by rolling hills, with some rock outcroppings in stream valleys. Topographic relief at Fort Gordon is moderate; minimum altitude is 225 ft above sea level to the east, and maximum altitude is about 475 ft to the northwest.

The climate of the Augusta area in eastern Georgia is humid subtropical, characterized by hot, wet summers and mild, dry winters. The average daily low temperature is about 35 degrees Fahrenheit (°F) in the winter, and the average daily high temperature is about 90°F in the summer. In 1999, the total precipitation recorded at Augusta Bush Field Airport was 36.74 inches (National Oceanic and Atmospheric Administration, 1999). Based on the 30-year normal (1961–90), average rainfall in the Augusta area is about 46 inches and snowfall is rare (National Oceanic and Atmospheric Administration, 1999).

The landfill is an unlined facility that is owned and operated by the Army to serve Fort Gordon. The landfill is located in the west-central part of Fort Gordon and encompasses an area of about 35 acres (figs. 1 and 2). The landfill is on the southern flank of a ridge east of Sandy Run Creek. The area surrounding the site is heavily wooded, with a few small drainage channels leading to perennial streams. The only surface-water body onsite is a constructed sediment pond (fig. 2) in the southeastern part of the landfill. Local topography slopes primarily to the southeast; however, the topography near the southwestern part of the landfill slopes to the southwest. The entire watershed of the site drains to Sandy Run Creek, which crosses Gibson Road about 0.7 mi to the west. Runoff is to the southwest to Sandy Run Creek and to the southeast to an unnamed tributary of Sandy Run Creek. Although streams are not directly adjacent to the landfill, a line of exposed ground-water seeps are located about 0.25 mi to the southeast.

Methods of Investigation

A review of available hydrogeologic data specific to the landfill (mostly data collected by the Army) and general information concerning the geology and hydrology of the Augusta, Ga., area was conducted early in 1999; these data are incorporated into this report. Within the study area, the Army installed 10 monitoring wells prior to this study to monitor ground-water contaminants. Historical data from these 10 wells include well construction, well drilling, and water-quality characteristics. Well locations are shown in figure 2, and construction data are listed in table 1. Three wells were designated as upgradient (28AA24, 28AA25, and 28AA27), two as midgradient (28AA31 and 28AA34), and five as downgradient (28AA28, 28AA29, 28AA30, 28AA32, and 28AA33) (fig. 2).

Screening for landfill gas in ground water was conducted in September 1999 to determine if migrating landfill gas could be the source of volatile organic compounds detected at low concentrations in samples from upgradient wells. Landfill gas consists mainly of methane and carbon dioxide with traces of volatile organic compounds, sulfur dioxide, and hydrogen sulfide. Organic compounds with high vapor pressure could comigrate with landfill gas to contaminate upgradient or midgradient wells. The wells were screened for landfill gas using the following procedure. In the late morning, each well was plugged using an unvented solid well cap. After 4 hours, the solid cap was removed and air inside the well was immediately sampled and analyzed using a portable gas detector calibrated to methane gas. The oxygen level and percentage of the lower explosive limit of methane gas contained in the air were recorded and a vented cap reinstalled.

To better define site hydrogeology, geophysical logs were run in October 1999 in each of the 10 monitoring wells that surround the landfill. Natural-gamma and electromagnetic-conductivity logs were run in each well to verify well construction and to help define the shallow hydrogeologic framework. Additional geologic data (depth to confining clay layer) were collected in November 1999 using direct-push methods (geoprobe). Locations of 10 direct-push sites are shown in figure 2, and sampling depths are listed in table 1.

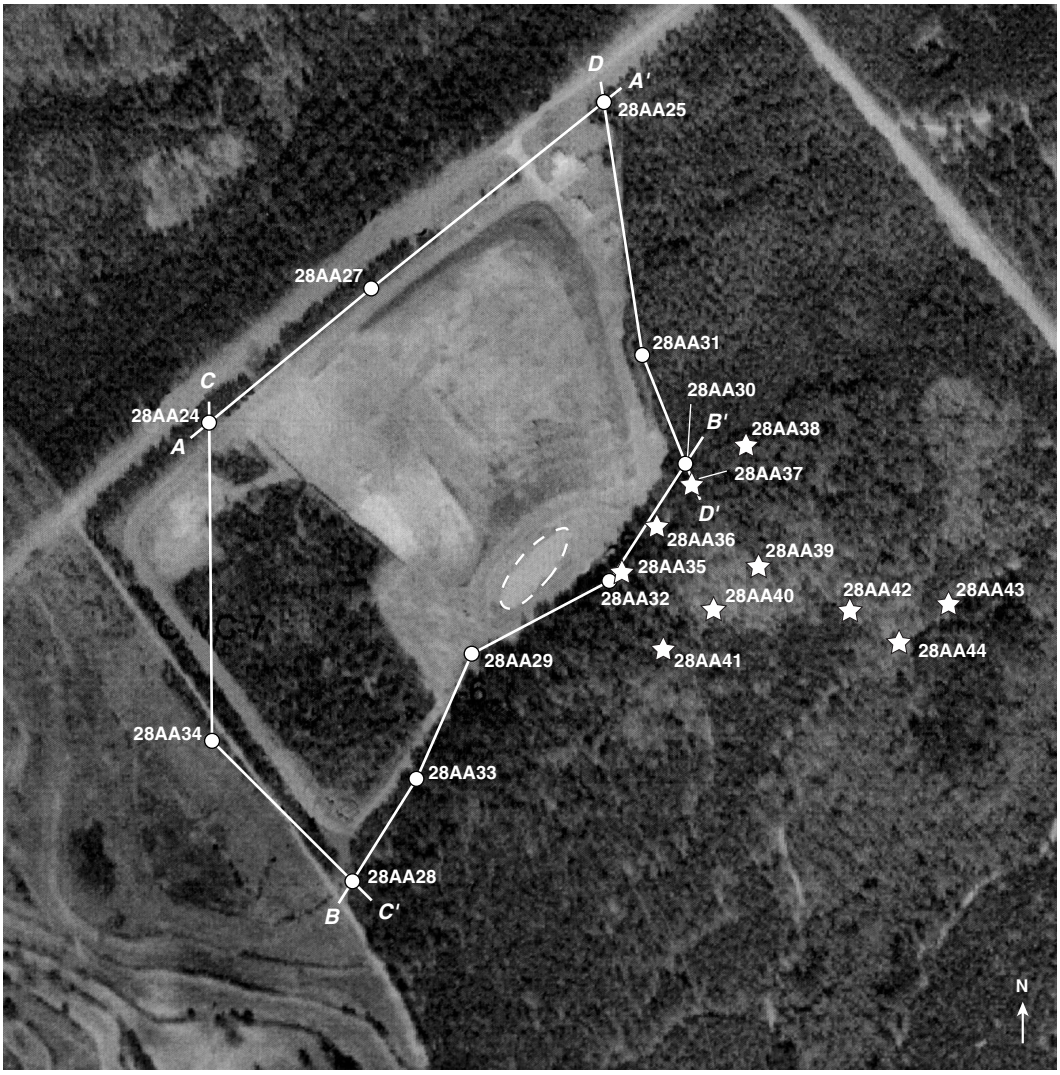


Figure 2. Aerial photograph of the Gibson Road Landfill, location of wells and geoprobe sites used to define the hydrogeology and water quality of the aquifer, and lines of geologic sections, Fort Gordon, Georgia.

Table 1. Location, construction, and water-level data for wells and borings in the vicinity of the Gibson Road Landfill, Fort Gordon, Georgia
[—, data not available; np, not penetrated; italic, geoprobe]

Well or boring number (see fig. 2)	Latitude	Longitude	Altitude (feet, above sea level)					Water level	
			Land surface	Top of screen or sample elevation	Bottom of screen	Tobacco Road Formation/Irwinton Sand Member contact	Confining clay penetrated	June 1999	November 1999
28AA24	33°22'09"	82°14'42"	494.33	446.33	436.33	447	441	441.29	441.24
28AA25	33°22'19"	82°14'29"	488.77	446.77	436.77	447	441	445.60	445.53
28AA27	33°22'12"	82°14'37"	491.50	446.50	436.50	448	442	444.19	444.38
28AA28	33°22'00"	82°14'39"	487.95	419.95	409.95	423	416	414.27	414.91
28AA29	33°22'03"	82°14'34"	460.34	433.34	423.34	436	430	426.68	426.80
28AA30	33°22'09"	82°14'28"	470.19	433.19	423.19	428	np	428.40	430.51
28AA31	33°22'08"	82°14'27"	481.95	439.95	429.95	443	438	440.80	440.36
28AA32	33°22'02"	82°14'29"	454.57	430.57	420.57	433	n p	427.54	429.67
28AA33	33°22'03"	82°14'36"	474.16	427.16	417.16	431	424	425.15	425.57
28AA34	33°22'01"	82°14'41"	492.11	438.11	428.11	440	np	434.16	434.41
28AA35	33°22'05"	82°14'30"	454.62	428.57	—	—	np	—	428.57
28AA36	33°22'06"	82°14'29"	460.41	431.15	—	—	423	—	431.15
28AA37	33°22'07"	82°14'27"	468.25	425.39	—	—	424	—	425.45
28AA38	33°22'08"	82°14'24"	467.67	419.42	—	—	417	—	419.42
28AA39	33°22'06"	82°14'25"	453.98	421.28	—	—	408	—	421.28
28AA40	33°22'04"	82°14'25"	448.07	417.37	—	—	409	—	417.37
28AA41	33°22'04"	82°14'26"	445.48	419.34	—	—	416	—	419.34
28AA42	33°22'04"	82°14'22"	442.49	417.46	—	—	403	—	417.46
28AA43	33°22'03"	82°14'20"	426.83	390.33	—	—	387	—	394.15
28AA44	33°22'02"	82°14'22"	425.43	412.58	—	—	400	—	412.58

Ten sites were selected to measure volatile organic compounds (VOCs) in ground-water samples using a direct-push sampling method—Hydropunch™ (Edge and Cordry, 1989). A direct-push sampling tool is a device made of 1-inch diameter stainless-steel drive pipe and screen. Teflon® tubing was used to collect in-place ground-water samples without installing a monitoring well. To collect a water sample, the drive pipe is pushed through soil to the desired depth. Soil and water are prevented from entering because the pipe remains in a closed position. When the desired sampling depth is reached, the drive pipe is retracted to expose a screen, allowing ground water to flow into the screen where water is collected through Teflon® tubing with a peristaltic pump into glass bottles with a septum top. Water samples collected were immediately analyzed onsite for VOCs (benzene, cis-1,2-dichloroethylene, m-xylene, tetrachloroethene, toluene, trans-1,2-dichloroethylene, trichloroethylene, and vinyl chloride) using a portable gas chromatograph. Quality control samples included duplicates and equipment blanks. After analysis, each direct-push site was abandoned by filling the hole with bentonite. All equipment was decontaminated before moving to the next location by removing the old plastic sleeve that collected the sample and replacing it with a new one. The tools were washed with soapy water, rinsed with clean water, rinsed with alcohol, and then rinsed with clean water between each site. The equipment was steam cleaned before sampling and after all samples had been collected.

Previous Investigations

Several hydrogeologic investigations have been conducted at the landfill. The most recent studies were conducted by a contractor to the U.S. Army (Joan A. Finkbeiner, G.N. Richardson and Associates, Inc., written commun. with Sherlyn Priest, Hydrologist, USGS, 1995). These unpublished reports include site-specific geology, hydrology, and ground-water quality data collected in accordance with the site water-quality-monitoring plan written by G.N. Richardson and Associates, Inc. (Joan A. Finkbeiner, written commun., 1995).

Prowell and others (1985) described regional Coastal Plain sediments along a geologic section from central Georgia into South Carolina; Huddlestun and Hetrick (1985) provided the initial definition of the Barnwell Group in east-central Georgia; Hetrick (1992) constructed a map showing surficial geology in the Wrens-Augusta area; and Huddlestun and Summerour (1996) evaluated the geology and stratigraphy of eastern Burke County, Ga.

LeGrand and Furcron (1956) described the regional geology and ground-water resources of east-central Georgia; Vincent (1982) described the geohydrology of the Jacksonian aquifer in central and east-central Georgia; Gorday (1985) described the hydrogeology of Coastal Plain strata in Richmond and northern Burke counties. Brooks and others (1985) described the hydrogeology of the Gordon aquifer system; and Clarke and others (1985) described the hydrogeology of the Dublin and Midville aquifer systems. Clarke and others (1994) and Leeth and others (1996) described geologic, hydrologic, and water-quality data at two well-cluster sites in Burke County; Summerour and others (1994) evaluated tritium concentrations in shallow ground water in Burke County; Clarke and West (1997) described ground-water levels and stream-aquifer relations near the Savannah River site; and Falls and others (1997) described the hydrogeology of Cretaceous and Tertiary strata near the Savannah River site.

Well-Naming System

In this report, wells inventoried by the USGS are named using a system based on USGS topographic maps. Each 7-1/2-minute topographic quadrangle map in Georgia has been assigned a number and letter designation beginning at the southwest corner of the State. Numbers increase eastward through 39, and letters advance northward through "Z," then double-letter designations "AA" through "PP" are used. The letters "I," "O," "II," and "OO" are not used. Wells inventoried in each quadrangle are numbered sequentially beginning with "1." Thus, the eighth well inventoried in the Blythe quadrangle (designated as 28AA) is designated as well 28AA08.

Acknowledgments

The authors extend thanks to John B. Wellborne, U.S. Army Signal Center and Fort Gordon, for his cooperation. A special thanks is extended to Judith D. Scholz, formerly with the U.S. Geological Survey, who analyzed water samples in the field. Appreciation also is extended to the many consultants who provided data collected as part of the monitoring process at the landfill.

HYDROGEOLOGY

Hydrogeology of the Coastal Plain Province in the vicinity of Fort Gordon near Augusta, Ga., is described in the following sections. These sections define the geologic setting and the hydrogeologic units of the area surrounding the landfill.

Geologic Setting

The landfill (fig. 1) is located in the Coastal Plain physiographic province of Georgia, and is underlain by sediments of Late Cretaceous through middle Tertiary age (fig. 3). These sediments unconformably overlie igneous and metamorphic rocks of Paleozoic age and consolidated beds of early Mesozoic age (Chowns and Williams, 1983). In this study, only sediments of the Eocene Barnwell Group were penetrated during drilling. The lithology of the Barnwell Group is predominantly quartz sand with lesser amounts of clay (kaolinite and montmorillonite), limestone, chert, and gravel. The quartz sand ranges from very fine to very coarse and may contain lenses of gravel. Maximum thickness of the Barnwell Group is about 200 ft in parts of southern Burke County and averages 100 ft thick or less in most places. The Barnwell Group thins from Burke County updip toward the Fall Line. The bottom of the Barnwell Group was not penetrated during drilling at the landfill, thus the thickness is unknown at this location.

The Barnwell Group in the west Augusta area is divided into the following formations and members (Huddlestun and Summerour, 1996): Utley Limestone Member of the Clinchfield Formation, Griffins Landing and Irwinton Sand Members of the Dry Branch Formation, and Tobacco Road Sand (fig. 3). Only sediments of the Irwinton Sand Member of the Dry Branch Formation and the Tobacco Road Sand were penetrated during drilling at the landfill in this study.

Irwinton Sand Member of the Dry Branch Formation

In this study, the deepest geologic formation penetrated in the area of the landfill was the Irwinton Sand Member of the Dry Branch Formation. The Irwinton Sand Member consists of loose, fine-to-medium, well-sorted, thinly laminated quartz sand that contains lenses or local laterally extensive beds of montmorillonitic clay (Huddlestun and Summerour, 1996; LaMoreaux, 1946). The thickness of the Irwinton Sand Member in the vicinity of the landfill is unknown because the member was not fully penetrated by any of the wells at the site. All of the monitoring wells at the landfill are completed in this member (figs. 4 and 5, table 1).

Laterally extensive clay in the Irwinton Sand Member beneath the landfill is shown on the geologic sections, which were compiled using borehole geophysical data from 7 of 10 wells (figs. 4 and 5). Borehole geophysical data indicate that near the bottom of each well that penetrates the top of the clay, electromagnetic conductivity is noticeably increased, which is typical of clay. Although a similar increase in natural gamma radiation for clay would be expected, only small increases were indicated on the natural gamma log. This subdued gamma-log response is interpreted as a montmorillonitic or kaolinitic clay that contains little naturally occurring gamma-emitting radioisotopes (such as potassium-40 and daughter products of the uranium and thorium decay series).

The thickness of laterally extensive clay where present appears to exceed 3 ft, although the clay was not fully penetrated during drilling. In wells 28AA30 and 28AA32, the clay was not penetrated because the wells were either not deep enough or the clay bed is locally discontinuous. In well 28AA34, a blockage at 47 ft prevented logging below that depth. A map showing the approximate altitude of the top of the continuous clay layer is shown in figure 6; well and geoprobe data used to construct the map are listed in table 1. The altitude of the top of the clay ranges from 442 ft at well 28AA27 to 387 ft at geoprobe 28AA43.

Tobacco Road Sand

The Tobacco Road Sand overlies the Irwinton Sand Member and consists of fine-to-medium, well-sorted sand (Huddlestun and Summerour, 1996). The most characteristic lithology of the Tobacco Road Sand is a burrowed and bioturbated, massive-bedded, moderately to poorly sorted, medium- to coarse-grained, pebbly, weathered sand (Huddlestun and Summerour, 1996). Strata are generally thin-bedded and contain thin layers of montmorillonite clay. The contact between the Tobacco Road Sand and the underlying Irwinton Sand Member is clearly indicated on borehole geophysical logs by an increase in natural gamma radiation and electromagnetic conductivity (figs. 4 and 5). These increases probably represent a lag deposit of

heavy minerals and reworked sediments from the underlying Irwinton Sand Member (David C. Prowell, U.S. Geological Survey, oral commun. with Kristen Bukowski McSwain, USGS, Hydrologist, October 2000). Table 1 shows the altitude of the contact between the Irwinton Sand Member and the Tobacco Road Sand. At the landfill, the Tobacco Road Sand ranges in thickness from 65 ft at well 28AA28 to 22 ft at well 28AA32, with an average thickness of about 42 ft (figs. 4 and 5).

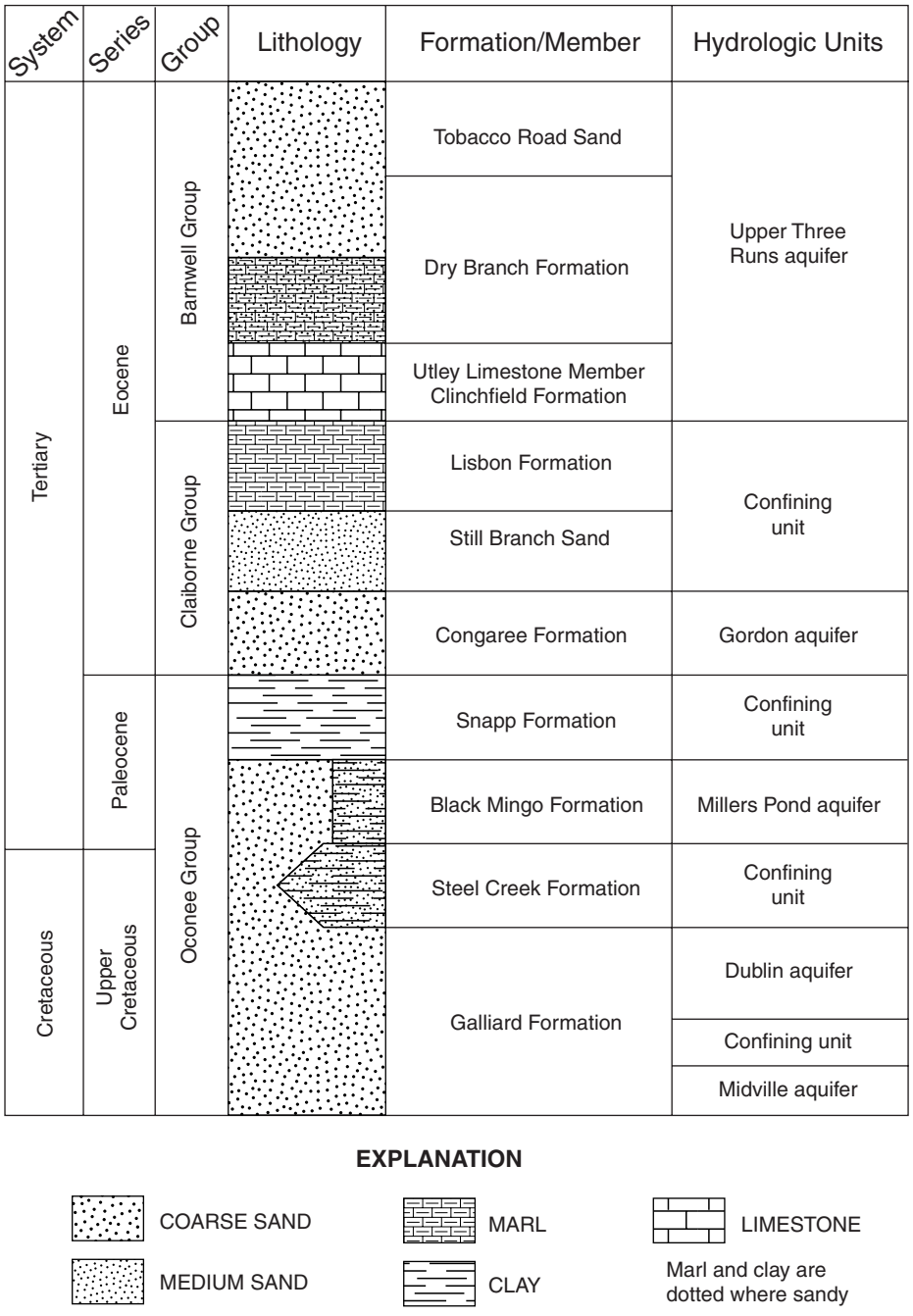


Figure 3. Generalized correlation of hydrologic and geologic units in east-central Georgia (modified from Huddlestun and Summerour, 1996; Falls and others, 1997).

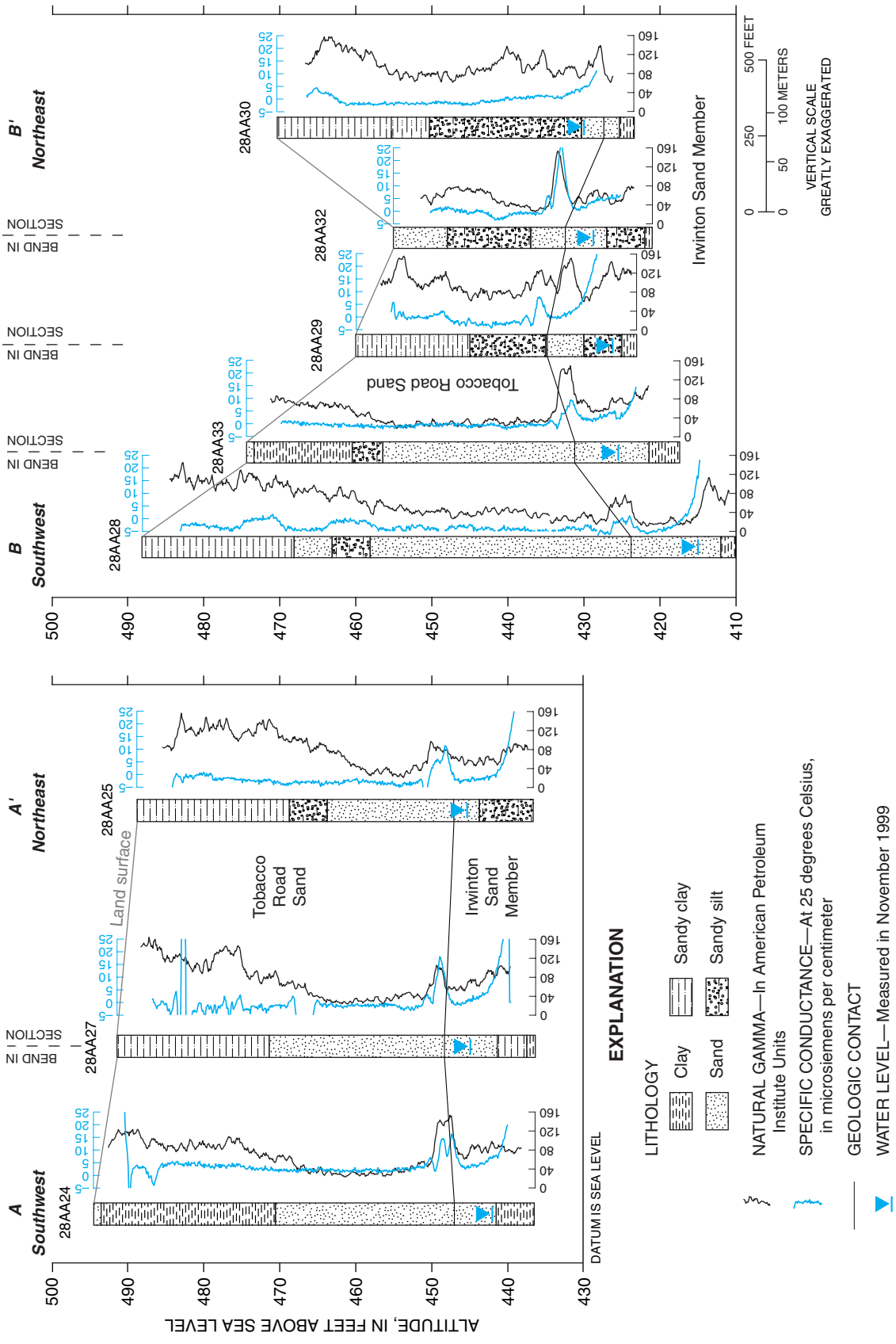


Figure 4. Geologic sections *A–A'* and *B–B* in the vicinity of Gibson Road Landfill, Fort Gordon, Georgia (boring lithologies from G. N. Richardson and Associates, Water Quality Monitoring Plan, July 1995).

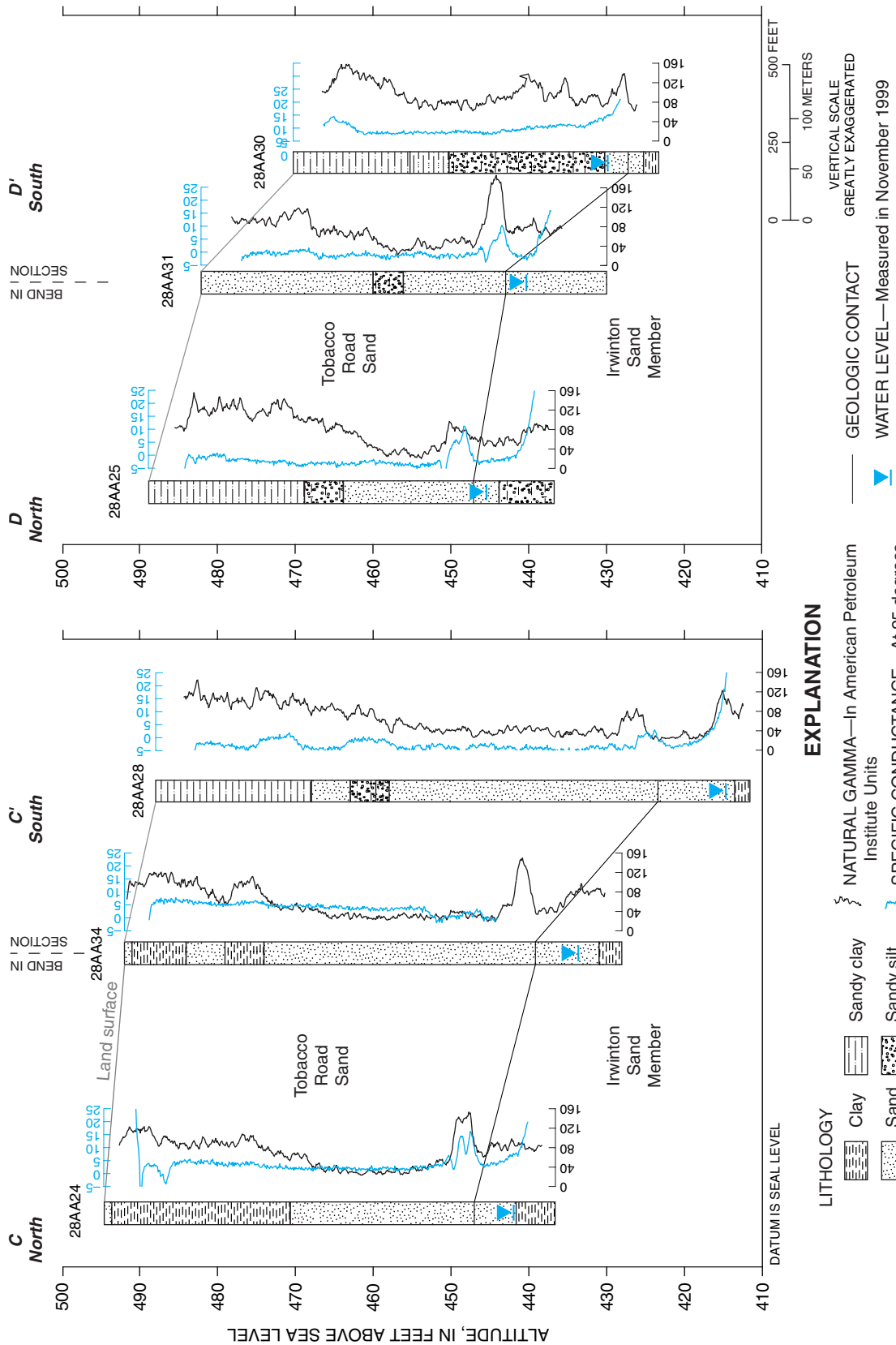


Figure 5. Geologic sections *C–C'* and *D–D'* in the vicinity of Gibson Road Landfill, Fort Gordon, Georgia (boring lithologies from G. N. Richardson and Associates, Water Quality Monitoring Plan, July 1995).

Hydrology

Hydrogeologic units in the Augusta area include the Upper Three Runs aquifer, the Gordon aquifer, the Millers Pond aquifer, the Dublin aquifer, and the Midville aquifer. In this report, only the shallowest aquifer—the Upper Three Runs aquifer—is described. For a complete discussion of the other units, see Clarke and others (1985), Brooks and others (1985), and Falls and others (1997).

Upper Three Runs Aquifer

In the area of the landfill, the Upper Three Runs aquifer is comprised of quartz sand, calcareous sand, and limestone of the Barnwell Group (fig. 3) (Summerour and others, 1994; Clarke and West, 1997). Mostly, these sands are highly permeable; however, clay beds and lenses within the Irwinton Sand Member of the Dry Branch Formation produce locally perched water tables (Huddlestun and Summerour, 1996). There is some evidence that the water-bearing zone tapped by monitoring wells at the landfill is perched on the clay unit in the Irwinton Sand Member. Water-table contours follow the dip of the lower clay layer (figs. 6, 7, and 8) and are coincident with the general land-surface topography.

Ground-water flow directions and gradients were evaluated by constructing maps of the water table using water-level data collected from 10 monitoring wells near the landfill during June and November 1999 (figs. 7 and 8, respectively). For both periods, ground water flowed from recharge areas to the northwest where water levels are higher to discharge areas to the southeast where water levels are lower (figs. 7 and 8).

For the period June to November 1999, the ground-water-flow direction generally was unaffected by seasonal water-level variations. Based on data from the 10 monitoring wells, the altitude and configuration of the water-table surface in June 1999 is similar to that in November 1999. In June 1999, the water-table altitude in the landfill area ranged from about 414 ft at well 28AA28 to about 445 ft at well 28AA25 (fig. 7, table 1). In November 1999, water-table altitudes ranged from about 415 ft at well 28AA28 to about 445 ft at well 28AA25 (fig. 8, table 1).

Geologic sections (figs. 4 and 5) and a structure-contour map of the top of the clay in the Irwinton Sand Member (fig. 6) indicate that the water table is parallel to the dip of the clay. Water levels generally are 3 ft above the top of the clay; and the water table follows the dip of the clay, which has the same general slope as the surface topography.

Data are insufficient to confirm whether the monitoring wells are completed in a perched zone. Construction of one or more wells downgradient of the landfill that penetrate the clay and terminate in the layer beneath the sand would help confirm perched conditions. If this layer is dry (unsaturated zone beneath a water-bearing zone), then the zone above may be perched. Also, the landfill is constructed near a topographic high; and, typically, topographic highs coincide with ground-water highs since ground water is a subdued replica of surface topography (Heath, 1983).

GROUND-WATER QUALITY

Selected trace elements and organic compounds have been detected in the ground water adjacent to the landfill, including upgradient wells. The origin of the contaminants in the upgradient wells is undefined; however, several physical processes have been identified as possible explanations for contamination in upgradient wells.

Contaminant Concentration

Nine ground-water sampling events were conducted at the landfill between June 1994 and September 1999 (Brent Cortelloni, Environmental Management Associates, LLC, written commun. with Sherlyn Priest, Hydrologist, USGS, 1999). Environmental Management Associates, LLC (Brent Cortelloni, written commun., 1999) conducted semiannual ground-water monitoring at the landfill from February 1998 to September 1999.

GaEPD (1997) regulations require statistical methods as the basis for investigating potential environmental impacts in a waste-disposal-facility operation. Groundwater monitoring results were evaluated using an analysis of variance (ANOVA) statistical method (GRITS/STAT)—USEPA statistical computer program (1997). Consultants performed nonparametric ANOVA tests based on the percentage of nondetects and/or the nonnormality of the data. Army consultants used the Kruskal-Wallis (K-W) statistical test to determine if a statistically significant increase in contaminant concen-

tration above background had occurred. The ANOVA tests compared selected trace elements concentrations in water from the midgradient and downgradient monitoring wells to concentrations in the upgradient wells. For the organic compound statistical tests, background concentrations were set at the detection limit for the associated compound. Organic concentrations were compared with those at the detection limit.

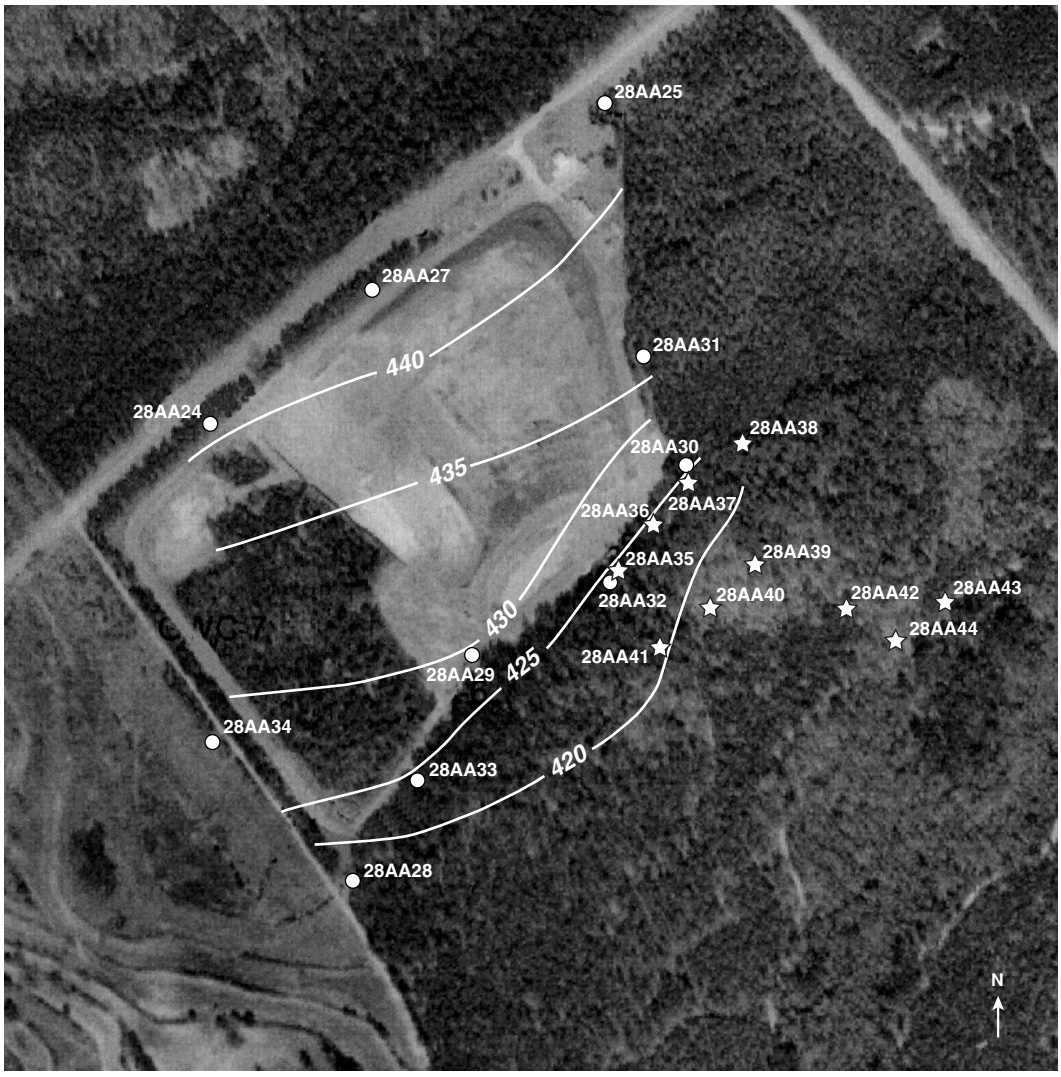
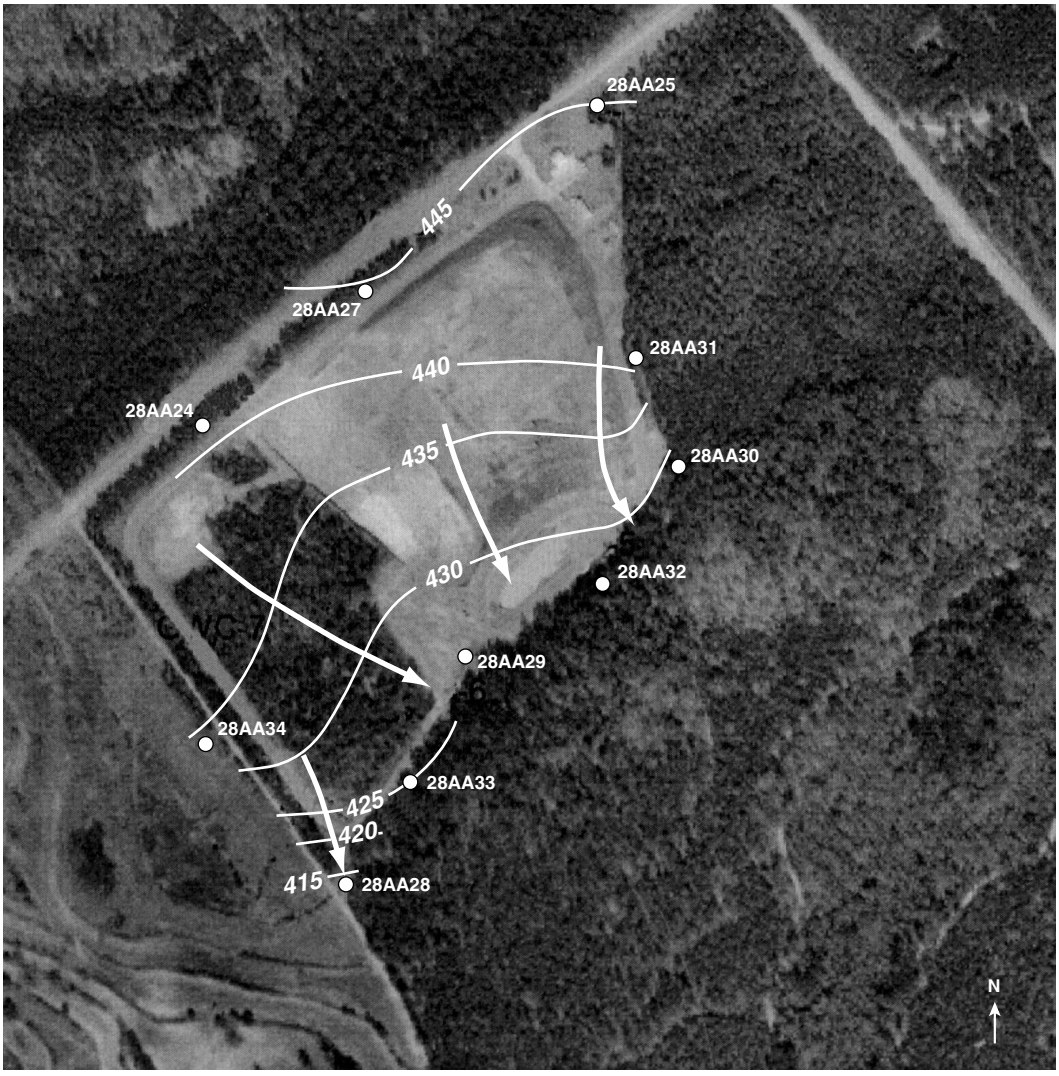


Figure 6. Aerial photograph and approximate altitude of the top of the clay layer in the Irwinton Sand Member in the vicinity of the Gibson Road Landfill, Fort Gordon, Georgia.



Base from U.S. Geological Survey
Blythe 1:100,000-scale digital orthophoto

0 250 500 FEET
0 50 100 METERS

EXPLANATION

—— *430* —— WATER-TABLE CONTOUR—Shows approximate altitude of water table, June 11, 1999. Contour interval 5 feet. Datum is sea level

GENERALIZED DIRECTION OF GROUND-WATER FLOW

28AA34 ○ WELL AND NUMBER

Figure 7. Aerial photograph and approximate altitude of the water table in the vicinity of the Gibson Road Landfill, June 11, 1999, Fort Gordon, Georgia.

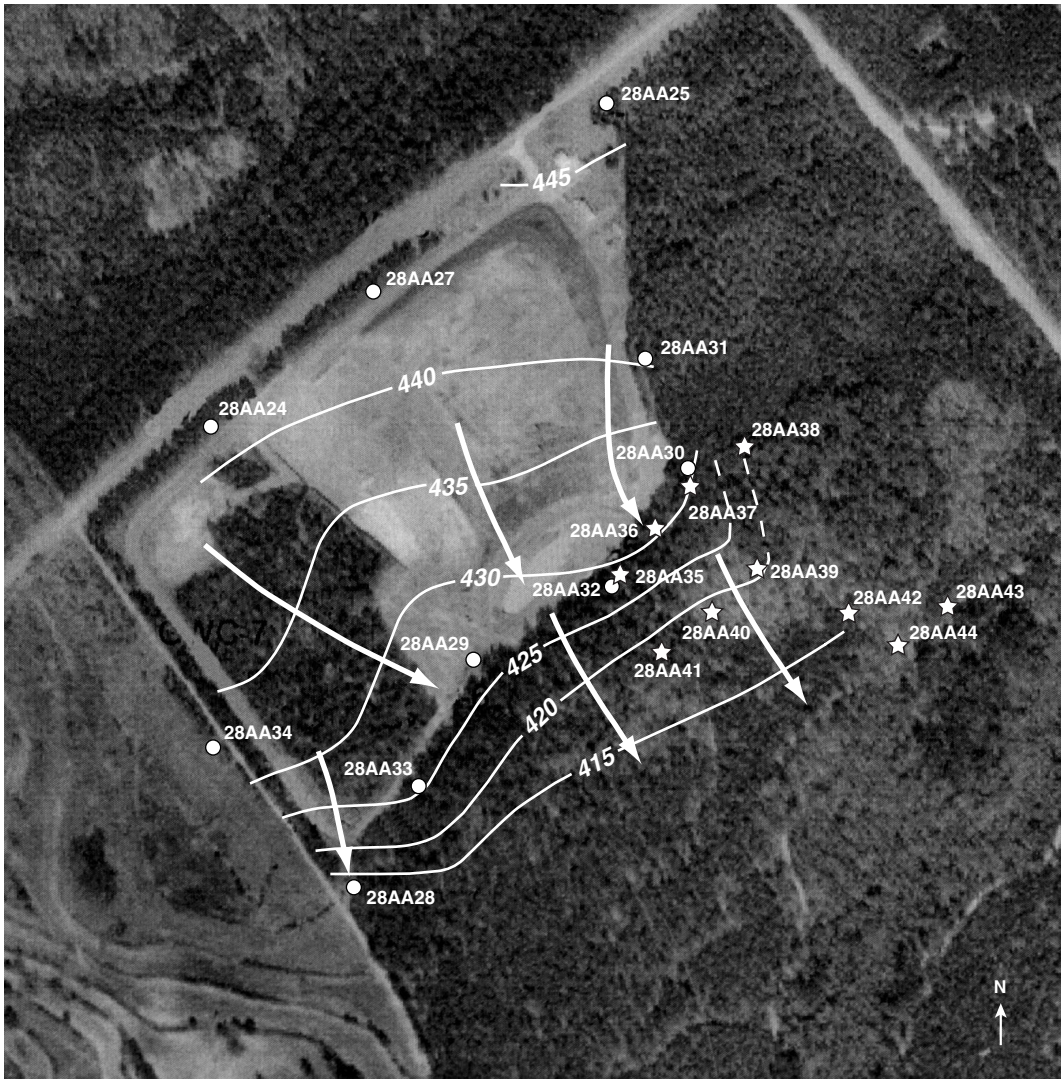


Figure 8. Aerial photograph and approximate altitude of the water table in the vicinity of the Gibson Road Landfill, November 8–11, 1999, Fort Gordon, Georgia.

Environmental Management Associates, LLC (Brent Cortelloni, written commun., 1999) reported, based on statistical analysis, increases in concentration of organic compounds and selected trace elements occurred during March and September 1999 in five monitoring wells adjacent to the landfill. The majority of the concentration increases (downgradient and midgradient) were in ground water from monitoring wells 28AA30 and 28AA31, located in the southeast corner of the landfill. However, concentration increases also occurred in downgradient wells 28AA29 and 28AA32, and in upgradient well 28AA27, even though the concentrations may have decreased over time. Organic compounds with concentration increases included 1,1-dichloroethane, 1,1-dichloroethene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, and methylene chloride (table 2). In well 28AA31, a decrease in concentration was noted for 1,1-dichloroethane, 1,1-dichloroethene, 1,1,1-trichloroethane, and methylene chloride; however, the concentrations are still statistically significant increases above the background. Concentrations of selected trace elements that also showed statistically significant increases included barium, beryllium, chromium, and vanadium (table 3).

To determine concentrations of chlorinated solvents downgradient of the landfill, screening was conducted at 10 geoprobe sites using a portable gas chromatograph. The sites are located beyond the cover of the landfill by as much as about 750 ft from the eastern edge of the landfill (fig. 2). At each of the 10 geoprobe sites, water samples were analyzed for the eight compounds in a mixed standard (methanol) (Supelco, 1999) to calibrate the gas chromatograph, including benzene, cis-1,2-dichloroethylene, m-xylene, tetrachloroethene, toluene, trans-1,2-dichloroethylene, trichloroethylene, and vinyl chloride (table 4). These compounds are organic solvents that produce separate and distinct chemical signatures or "spikes" on a portable gas chromatograph. Because screening results are based on calibration to a standard (Supelco, 1999), sample results are reported in an amount relative to the chemical concentrations in the standard. If the gas chromatograph recorded a spike larger in a sample than in the standard, the constituent was assigned a value proportionally higher than the standard. If the gas chromatograph recorded a spike in a sample that was smaller than that produced by the standard, the constituent was given a proportionally lower value than the standard. If a spike was not detected, the constituent was considered to be a nondetect in the sample.

A sample from geoprobe 28AA37 close to wells 28AA30 and 28AA31 had concentrations above the standard—most likely from leachate transport. Seven of the eight standard compounds were present in ground-water samples collected at geoprobe 28AA37 (table 4). Only geoprobe 28AA41 appeared to be unaffected by contaminants from the landfill. Water-table maps (figs. 7 and 8) indicate that the ground-water flow direction near geoprobe 28AA37 and wells 28AA30 and 28AA31 is to the southeast. Insufficient data are available to properly define the hydrologic system and assess the potential for future contaminant migration. Gas chromatograph screening at each of the 10 geoprobe sites indicates that ground-water sites closest to wells 28AA30 and 28AA31 show substantial impacts on water quality (table 4). Seven of eight compounds analyzed were detected in ground-water samples collected from geoprobe 28AA37; and 9 of the 10 geoprobe sites indicate detections of organic compounds (table 4).

Selected trace elements in ground water at six wells and organic compounds at four wells exceeded the USEPA National Primary Drinking Water Regulations PMCL for organic compounds and selected trace elements (U. S. Environmental Protection Agency, 2000c, d). Well 28AA30 had the most detections (a total of seven) of selected trace elements that exceeded PMCLs including: arsenic, barium, chromium, lead, mercury, thallium, and beryllium (table 3). Four wells—28AA27, 28AA29, 28AA30, and 28AA31—each had compounds that exceeded PMCLs for organic compounds (table 2). These compounds include methylene chloride, vinyl chloride, 1,1,2-trichloroethane, and 1,1-dichloroethene. The three upgradient wells (28AA24, 28AA25, and 28AA27) each had trace elements (table 3) that exceeded PMCLs, and one well (28AA27) had an organic compound that exceeded a PMCL (table 2).

Table 2. Organic compounds detected in monitoring wells in the vicinity of the Gibson Road Landfill, February 1998–September 1999[1)], Fort Gordon, Georgia

[—, data not available; PMCL, Primary Maximum Contaminant Level; nd(5), not detected at reporting level of 5 ppb; ppb, parts per billion; bold, exceeded PMCL; SVOC, semivolatile organic chemical; shaded, statistically significant increases above background]

Well number	Organic compounds	PMCL (ppb)	February 1998 (ppb)	March1999 (ppb)	September 1999 (ppb)
28AA24	1,1-Dichloroethene	7	—	nd(5)	5
	Dichlorofluoromethane	—	8	nd(5)	nd(5)
	Trichlorofluoromethane	—	20	9.7	24
	1,1-Dichloroethane	—	6	13	24
	1,1,1-Trichloroethane	200	15	44	5
28AA25	Diethylphthalate (SVOC)	—	42	nd(10)	—
28AA27	Chloroethane	—	19	13	nd(10)
	Methylene chloride	5	**37**	**24**	**9.6**
	1,1,1-Trichloroethane	200	36	15	17
	Tetrachloroethene	5	5	nd(5)	—
	Xylene	10,000	9	nd(5)	5.3
	Diethylphthalate (SVOC)	—	33	nd(10)	—
28AA28	Diethylphthalate (SVOC)	—	20	nd(10)	—
28AA29	Methylene chloride	5	**20**	**24**	46
	1,1-Dichloroethane	—	19	23	33
	Vinyl chloride	2	nd(2)	3.6	4.4
	2,4-D (Herb.)	70	—	—	—
	Chloroethane	—	—	nd(10)	11
28AA30	1,1-Dichloroethene	7	6	**10**	17
	Methylene chloride	5	**50**	**86**	130
	1,1-Dichloroethane	—	42	81	140
	1,1,1-Trichloroethane	200	21	33	42
	1,1,2-Trichloroethane	5	nd(5)	**33**	nd(5)
28AA31	Chloroethane	—	25	28	20
	1,1-Dichloroethene	7	**13**	**10**	5.7
	Acetone	—	270	nd(100)	—
	Methylene chloride	5	**330**	**240**	140
	1,1-Dichloroethane	—	210	200	130
	1,1,1-Trichloroethane	200	75	61	37
	Tetrachloroethene	5	5	nd(5)	—
	Xylene	10,000	14	12	9.7
28AA32	1,1-Dichloroethane	—	22	nd(5)	—
	1,1,1-Trichloroethane	200	13	nd(5)	—
28AA33	Diethylphthalate (SVOC)	—	38	nd(10)	—
	Bis-(2-ethylhexyl) phthalate	—	—	nd(20)	42

[1)]Table modified from Brent Cortelloni, Environmental Management Associates, LLC, written commun. with Sherlyn Priest, USGS, Hydrologist, 1998; 1999.

Table 3. Selected trace elements detected in monitoring wells in the vicinity of the Gibson Road Landfill, February 1998–September 1991[1)], Fort Gordon, Georgia

[—, data not available; PMCL, Primary Maximum Contaminant Level; nd(5), not detected at reporting level of 5 ppb; ppb, parts per billion; bold, exceeded PMCL; shaded; statistically significant increases above background; NTU, nephelometric turbidity units]

Well number	Selected trace elements	PMCL (ppb)	September 1999 Turbidity (NTUs)	February 1998 (ppb)	March 1999 (ppb)	September 1999 (ppb)
28AA24	Barium	2,000	93	216	21.3	60.2
	Chromium	100	—	15	nd(20)	—
	Copper	—	—	15	nd(20)	—
	Mercury	2	—	0.29	nd(0.5)	**2.82**
	Vanadium	—	—	20	nd(50)	—
	Zinc	—	—	29	25.4	nd(20)
28AA25	Barium	2,000	4.27	101	nd(20)	21.4
	Chromium	100	—	28	nd(20)	—
	Copper	—	—	10	nd(20)	—
	Mercury	2	—	3.1	2.11	2.28
	Vanadium	—	—	48	nd(50)	—
	Zinc	—	—	740	nd(20)	—
28AA27	Barium	2,000	94	260	127	42.2
	Chromium	100	—	7	nd(0.5)	—
	Cobalt	—	—	28	nd(50)	—
	Mercury	2	—	0.35	nd(0.5)	—
	Thallium	2	—	nd(2)	2.08	nd(2)
	Zinc	—	—	24	nd(20)	—
28AA28	Barium	2,000	26.6	118	nd(20)	—
	Chromium	100	—	26	nd(20)	—
	Copper	—	—	13	nd(20)	—
	Vanadium	—	—	21	nd(50)	—
	Zinc	—	—	30	nd(20)	—
28AA29	Barium	2,000	0.1	43	164	89.4
	Cobalt	—	—	nd(20)	173	101
	Mercury	2	—	1.17	nd(0.5)	—
	Sulfide	—	—	nd(1,000)	1,000	—
	Thallium	2	—	nd(2)	2.56	nd(2)
	Zinc	—	—	nd(20)	27.5	26.1
28AA30	Arsenic	50	>200	**90**	nd(300)	114
	Barium	2,000	—	1,530	**4,490**	—
	Beryllium	4	—	—	nd(4)	**6.3**
	Chromium	100	—	**630**	**1,190**	nd(20)
	Lead	50	—	**390**	**766**	nd(10)
	Mercury	2	—	0.71	nd(0.5)	**2.28**
	Thallium	2	—	nd(20)	10.2	nd(2)
	Vanadium	—	—	1,090	2,090	104
	Zinc	—	—	560	494	113
28AA31	Barium	2,000	9.01	40	34.5	27.9
	Zinc	—	—	nd(20)	21.8	nd(20)
28AA32	Barium	2,000	1.06	141	83.8	140
	Chromium	100	—	15	nd(20)	—
	Sulfide	—	—	1,800	nd(1000)	—
	Vanadium	—	—	24	nd(50)	—
28AA33	Barium	2,000	10.5	27	nd(20)	21.7
	Cadmium	5	—	7	nd(5)	—
	Lead	50	—	20	nd(10)	—
28AA34	Barium	2,000	2.16	28	nd(20)	—

[1)]Table modified from Brent Cortelloni, Environmental Management Association, LLC, written commun. with Sherlyn Priest, USGS, Hydrologist, 1998; 1999.

Table 4. Selected volatile organic compounds in water samples measured against a standard by portable gas chromatograph collected at geoprobe sites southeast of the Gibson Road Landfill, Fort Gordon, Georgia, November 1999
[nd, not detected; >, greater than; <, less than]

Geoprobe number	Sample depth (feet below land surface)	Volatile organic compounds (in micrograms per liter)							
		Benzene	Cis-1,2-dichloroethylene	M-Xylene	Tetrachloro-ethene	Toluene	Trans-1,2-dichloroethylene	Trichloro-ethylene	Vinyl chloride
28AA35	26.05	nd	nd	nd	nd	nd	>11	nd	>15
28AA36	29.26	nd	nd	nd	<50	<30	>11	<50	>15
28AA37	42.96	<30	<50	nd	<50	<30	<11	<50	<15
28AA38	48.25	<30	<50	nd	nd	nd	<11	<50	<15
28AA39	32.70	nd	<50	nd	nd	nd	<11	<50	<15
28AA40	30.70	nd	<50	nd	nd	nd	<11	nd	<15
28AA41	26.14	nd	nd	nd	nd	nd	nd	nd	nd
28AA42	25.03	nd	<50	nd	nd	nd	<11	nd	<15
28AA43	36.50	nd	<50	nd	nd	nd	<11	<50	<15
28AA44	12.85	nd	nd	nd	nd	nd	<11	nd	<15

To determine if landfill gas is causing or contributing to organic compound concentration increases in monitoring wells, each monitoring well was plugged for at least 4 hours, then the plug was removed and air measurements were made using a vapor meter (table 5). The vapor meter displays the lower explosive limits (LEL), in percent, of the gases detected and the percentage of oxygen present. The LEL for methane gas is 5 percent by volume methane in air. If landfill gases were not present in a well, one would expect the LEL percentage to be zero and the oxygen percentage to be 20.8 (under natural atmospheric conditions, methane gas is not detectable and the percentage of oxygen in the atmosphere is 20.8 percent). Two wells—28AA24 and 28AA27 (figs. 7 and 8)—may contain landfill gas as indicated by reduced oxygen levels and an increase in LEL (table 5). These two wells are located close to a topographic high, which typically coincides with ground-water highs. In addition, these ground-water highs can move because of changes in water-level fluctuations. These movements can cause any number of perturbations to the water table, including short-term, and sometimes rapid, changes in gradient and flow direction. Nevertheless, the presence of landfill gas at well 28AA27 may be causing increases in organic compounds detected in water from the well.

Elevated selected trace element concentrations may be caused by low pH and low dissolved oxygen concentrations (table 5), resulting in reducing conditions that favor movement of inorganic constituents into the water column. A decrease in pH and dissolved oxygen typically occur in landfills as a result of decomposition. The low pH causes metals such as beryllium, cadmium, chromium, and zinc to leach and eventually migrate. At the landfill, selected trace elements detected in upgradient wells likely are the result of normal ground-water flow or leachate migration. The landfill is located near a topographic high and consequently near a ground-water high. A seasonal variation in the water-table configuration could allow ground water to flow toward what is currently (1999) considered an upgradient direction. Furthermore, the top of the closed landfill phases (I and II) is topographically higher than the upgradient wells. As a result, leachate can migrate in all directions around the landfill including an upgradient direction. With time, the leachate can reach the water table and, depending on the direction and gradient of ground-water flow, contaminate the upgradient wells. Data are insufficient, however, to adequately define the long-term geometry of the water table beneath the landfill and surrounding area or the current direction of leachate migration.

Physical Processes Affecting Contaminant Movement

The presence of organic compounds in upgradient wells can be attributed to a number of physical processes. These physical processes include normal ground-water transport as a result a shifting hydraulic gradient, chemical dispersion (molecular diffusion), leachate migration, gas movement, incorrectly defined

landfill area, or a combination of several of these physical processes. Although water-table maps (figs. 7 and 8) do not show seasonal variation, it is possible that ground water flows in an upgradient direction during wet periods. Water-level data were collected during the dry period of the year and at the onset of the 2000 drought. As a consequence, the hydraulic gradient is based on synoptic measurements collected during a very limited time period. Furthermore, upgradient wells are near a topographic high and ground-water flow direction beneath such a feature is highly variable. A ground-water high could cause short-term changes in gradient and flow direction during seasonal variation (Leeth, 1998).

Table 5. Gas measurements, pH, and specific conductance in water samples from wells and borings in the vicinity of the Gibson Road Landfill, Fort Gordon, Georgia
[LEL, lower explosive limit; ºC, degrees Celsius]

Well number	Digiflame 2000 gas measurement, 9/27/1999 (percent)		August 1999	
	LEL	Oxygen	Specific conductance[1] (microsiemens per centimeter at 25°C)	pH[1]
28AA24	36.0	18.0	150.0	5.02
28AA25	0.0	20.8	39.0	5.54
28AA27	52.0	12.9	188.0	7.32
28AA28	0.0	20.8	32.0	6.20
28AA29	0.0	20.8	755.0	4.78
28AA30	1.0	20.4	22.0	5.88
28AA31	3.0	20.2	72.0	5.61
28AA32	0.0	20.8	248.0	5.63
28AA33	0.0	20.8	61.0	5.96
28AA34	0.0	20.8	31.0	5.63

[1]Specific conductance and pH data from Environmental Associates, LLC, written commun., Brent Cortelloni, 1999.

Contaminants may enter the soil in the absence of ground-water flow by chemical dispersion (molecular diffusion). In chemical dispersion, a high-concentration contaminant moves from its point of origin toward a point of lower concentration. In the case of upgradient dispersion, a landfill gas that is lighter than air (such as methane) could disperse vertically, especially if the soil upgradient from the point of origin is less consolidated than the soil downgradient from the point of origin. Because a landfill gas is lighter than air, the gas will rise and continue to disperse laterally.

Physical processes controlling gas movement through refuse and soil are complicated and beyond the scope of this report. However, gas generally moves along a path of least resistance through the refuse and adjacent soils. The movement can be accelerated along macropores, such as those paths along a plant-root system or animal burrows. The rate of movement is strongly influenced by weather conditions. When barometric pressure falls, gas tends to be forced out of a landfill and into the surrounding sediment. If a landfill is surrounded by a sandy soil—like the Gibson Road Landfill—the landfill gas will move more quickly through the soil. Clay caps, which are installed at completion of a landfill (for the purpose of excluding moisture infiltration and restricting leachate generation), tend to trap landfill gas.

Another physical process that could account for the presence of contaminants in upgradient wells is the movement of leachate containing organic and selected trace elements out of the landfill into the adjacent area. Most leachates are collected and treated; however, even under the best conditions, some leachates seep into the ground-water system. At the landfill, leachates are neither collected nor treated. Lastly, the subsurface landfill area may extend farther out than the surface expression of the landfill. If this is the case, the upgradient wells are actually landfill wells. Ground-water contamination near a landfill is a complicated problem. As a result, it is likely that the contamination observed in the landfill is a result of several sources. Insufficient data are available to properly identify the source of the contaminants in the upgradient wells.

SUMMARY AND CONCLUSIONS

Fort Gordon military installation, a U.S. Department of the Army facility, is located in east-central Georgia southwest of Augusta, Ga. The military base operates a three-phase unlined landfill—Gibson Road Landfill—to store a variety of wastes. Phases I and II stored only household wastes, and these phases were discontinued during the mid–1990s. Fort Gordon currently (1999) operates Phase III of the landfill that stores only construction and demolition debris.

Water-quality monitoring by the U.S. Army during a period of nearly 15 years detected selected trace elements and organic compounds exceeding the maximum contaminant levels of the U.S. Environmental Protection Agency, National Primary Drinking Water Standards. The selected trace element and organic compound detections showed that a ground-water contaminant plume was present in the vicinity of the landfill. In 1999, the U.S. Geological Survey, in cooperation with the Environmental and Natural Resources Management Office of the U.S. Army Signal Center and Fort Gordon, Ga., began an assessment of the hydrogeology and water quality in shallow ground water in the vicinity of the Gibson Road Landfill to delineate the extent of a ground-water contaminant plume at the landfill.

The Gibson Road Landfill is underlain by the Upper Three Runs aquifer, consisting of sediments of the Tobacco Road Sand and the Irwinton Sand Member of the Dry Branch Formation. All monitoring wells at the Gibson Road Landfill are completed within the Irwinton Sand Member. The overall thickness of the Irwinton Sand Member at the site is unknown because none of the wells fully penetrate the unit. All wells at the Gibson Road Landfill terminate within or above a laterally extensive clay with a thickness that exceeds 3 feet (ft) where present within the Irwinton Sand Member. The Tobacco Road Sand overlies the Irwinton Sand Member, and ranges in thickness from 22 ft to 65 ft, with an average thickness of 42 feet.

Ground-water flow was evaluated by constructing water-table maps in the area of the Gibson Road Landfill for June 1999 and November 1999. Ground-water flow generally is from northwest to southeast and was unaffected by seasonal water-level variations determined by short-term synoptic measurements made during the period of study. Wells 28AA24, 28AA25, and 28AA27 are upgradient with respect to the direction of flow.

Some evidence exists that indicates the water-bearing zone tapped by monitoring wells at the Gibson Road Landfill may be perched on top of a clay unit in the Irwinton Sand Member. Water-table maps parallel the altitude of this clay unit and also parallel the land-surface topography. Insufficient data are available to determine whether the monitoring wells are completed in a perched zone. This determination would require construction of additional wells that terminate in the sand beneath the clay. If this layer is dry (unsaturated zone beneath water-bearing zone), then the zone may be considered perched.

Several concentration increases of organic compounds and selected trace elements determined on the basis of statistical analysis were reported previously in five monitoring wells surrounding the Gibson Road Landfill. The concentration increases most likely were caused by chemical dispersion, leachate migration, incorrectly identified landfill area, or natural ground-water flow beneath the landfill. Gas chromatograph screening at 10 geoprobe sites indicates that ground-water sites closest to monitoring wells 28AA30 and 28AA31 show significant impacts on water quality—most likely from leachate transport. Seven of eight organic compounds were detected in ground-water samples taken at geoprobe 28AA37. Nine of the 10 geoprobe sites indicate some water-quality impact from leachate. Only geoprobe 28AA 41 appears to be unaffected by contaminants from the Gibson Road Landfill. Data from two upgradient wells—28AA24 and 28AA27—indicate that these wells may be contaminated. Physical processes that may explain the contamination observed in these wells include the fact that the landfill is topographically higher than the surrounding area. Because the water table typically is a subdued replica of the surface topography, it is possible that ground water is flowing radially from the landfill, accounting for contaminant detection in upgradient wells. Although a clay layer is present beneath the landfill and the clay layer appears to dip in the general direction of the surface topography, data are insufficient to define the extent of the clay beyond the landfill cover. Consequently, a systematic approach to defining the ground-water flow in the area surrounding the landfill and the presence of a perched water table are needed to conclusively explain the observed contamination.

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