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HYDROGEOLOGY AND GEOCHEMISTRY OF AN INACTIVE
HAZARDOUS CHEMICAL AND LOW-LEVEL RADIOACTIVE
WASTE LANDFILL, MANHATTAN, KANSAS

BY E. NOLD

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HYDROGEOLOGY AND GEOCHEMISTRY OF AN
INACTIVE HAZARDOUS CHEMICAL AND LOW-
LEVEL RADIOACTIVE WASTE LANDFILL,
MANHATTAN, KANSAS

by

Eric Nold

B.S., Northwest Missouri State University, 1988

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

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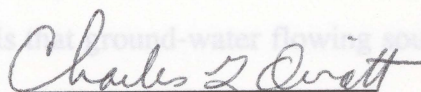
College of Arts and Sciences

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ABSTRACT

The KSU inactive hazardous chemical and low-level radioactive-waste landfill located on the North Agronomy Research farm was used for waste disposal from the early 1960s until 1988. The landfill is situated in sediments deposited during the Pleistocene glaciation. The Quaternary age sediments are approximately 65 ft thick, consist of a heterogeneous mixture of clayey silt and silty sand, and overlie Permian bedrock. Drainage across the landfill is east toward a small ephemeral stream which drains to the northeast and empties onto the flood plain of the Big Blue River. Ground-water flow generally mimics surface drainage, with an average slope of 0.03 eastward, but the water table directly east of the landfill has a low ground-water divide that separates flow to the northeast and southeast.

Nine monitoring wells were installed at the landfill at a 20 ft depth, screened in the lower 10 ft for water-table observation. One well was installed at 63 ft, screened in the lower 5 ft, to monitor the sand and gravel aquifer overlying Permian bedrock; and one well was installed 30 ft deep and screened in the lower 5 ft to help in determining the depth of ground-water contamination. The 63 ft and 30 ft well were screened below the water table and have hydraulic heads higher than the adjacent wells monitoring the water table, indicating an upward component of flow in the vicinity of the landfill. Pump tests performed on water-table monitoring wells revealed low hydraulic conductivities averaging 0.0014 in/min.

Chemical analysis of water samples reveals that ground-water flowing southeast from the landfill is consistently higher in total dissolved solids, is harder, and is more likely to precipitate calcium carbonate than water flowing to the northeast. Ground-

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The purpose of this investigation was threefold. The first purpose and overall focus of this investigation was to study in detail the hydrogeology and geochemistry at the KSU hazardous chemical and low-level radioactive waste landfill. The second purpose was to study the overall hydrogeology and geochemistry of the study area, covering much of the northern KSU campus, and compare it with similar

INTRODUCTION

The declining quality of ground water due to anthropogenic causes has become one of our nation's greatest area of environmental concern. A major portion of this problem is directly related to burying hazardous chemical and radioactive waste. Many federal and state regulations have been adopted for dealing with such landfills. One such regulation enforced by the Kansas Department of Health and Environment (KDHE) is testing prior to official closure of a chemical or radioactive waste landfill. A hydrogeologic investigation of the site must be conducted to ensure that (1) the soil and ground water associated with the site are not contaminated and (2) if contaminated, the contaminants do not adversely affect the surrounding environment. Prior to 1980, it was common practice for colleges and universities to dispose of chemical waste in campus landfills. Kansas State University (KSU) has such a landfill, which was the focus of this study.

Purpose of Investigation

The purpose of this investigation was threefold. The first purpose and overall focus of this investigation was to study in detail the hydrogeology and geochemistry at the KSU hazardous chemical and low-level radioactive waste landfill. The second purpose was to study the overall hydrogeology and geochemistry of the study area, covering much of the northern KSU campus, and compare it with similar

hydrogeologic settings in northeastern Kansas not influenced by a landfill. The third purpose was to determine if any adverse environmental affects to the study area can be attributed to the landfill.

Area of Investigation

The KSU landfill is located on the KSU North Agronomy Research Farm in the NW1/4, SE1/4, SE1/4, sec. 1., T.10S., R.7E., Manhattan 7.5-minute quadrangle (Figure 1). The landfill is approximately 0.43 mi. west of Denison Avenue and 0.17 mi. north of Kimball Avenue, just north of the KSU football stadium. The entire area of investigation is located on the northern portion of the KSU campus and is bounded on the west by College Avenue, on the north by Marlatt Avenue, on the east by a fence-line along the crest of Bluemont Hill, and on the south by Jardine Street No. 3 which was arbitrarily chosen so that a major drainage divide could be incorporated in the study area (Figure 1).

Land use

Most of the area under investigation is owned and operated by the KSU North Agronomy Research Farm. The land south of Kimball Avenue and east of Denison Avenue is used for horse and cattle pasture by the Department of Clinical Sciences. The land south of Kimball Avenue and west of Denison Avenue is used as intramural

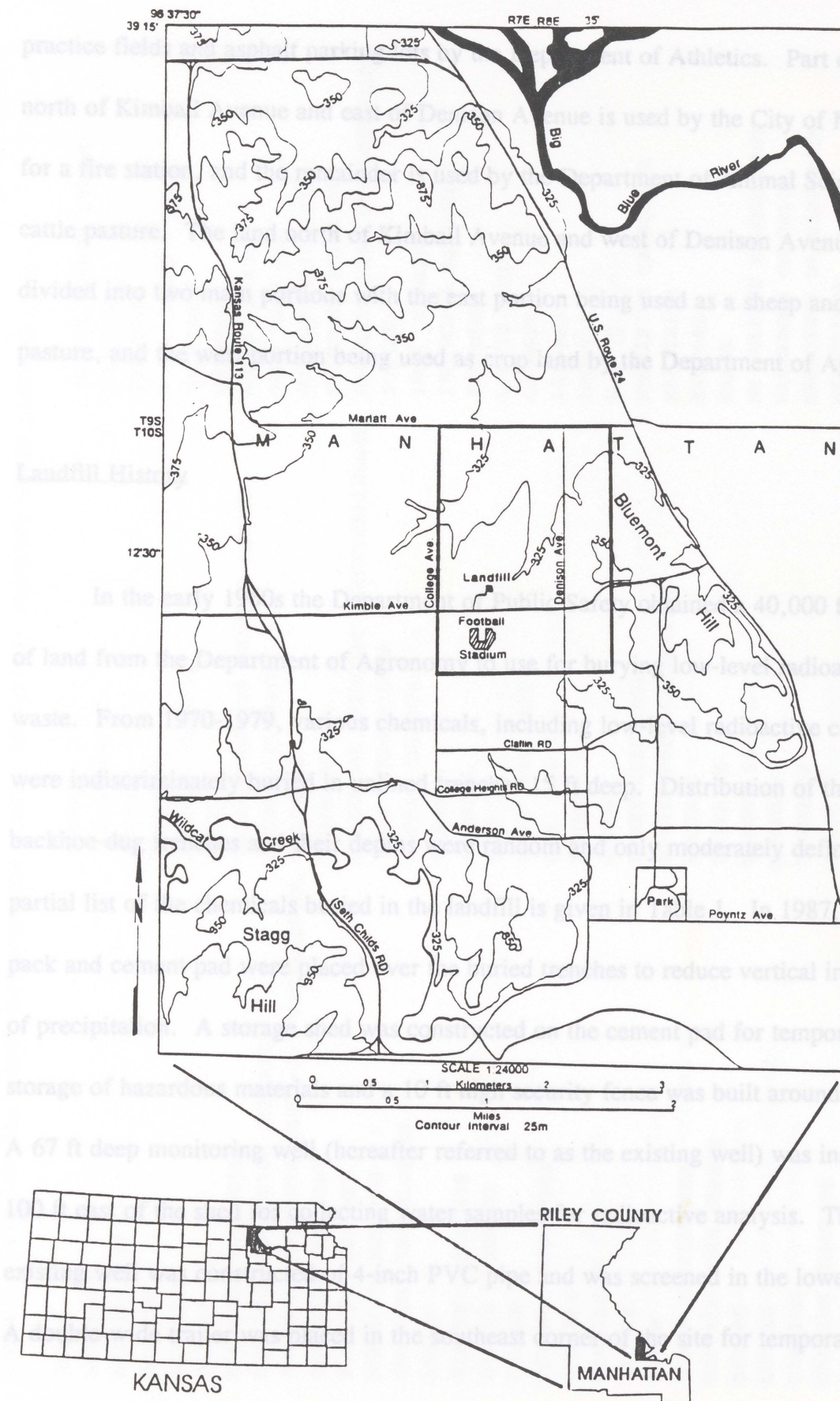


Figure 1. Location map for the hydrogeologic and geochemical investigation of the Kansas State University inactive hazardous waste landfill.

practice fields and asphalt parking lots by the Department of Athletics. Part of the area north of Kimball Avenue and east of Denison Avenue is used by the City of Manhattan for a fire station, and the remainder is used by the Department of Animal Sciences as a cattle pasture. The land north of Kimball Avenue and west of Denison Avenue is divided into two main portions with the east portion being used as a sheep and cattle pasture, and the west portion being used as crop land by the Department of Agronomy.

Landfill History

In the early 1960s the Department of Public Safety obtained a 40,000 ft² parcel of land from the Department of Agronomy to use for burying low-level radioactive waste. From 1970-1979, various chemicals, including low-level radioactive chemicals were indiscriminately buried in unlined trenches 15 ft deep. Distribution of the backhoe-dug trenches and their depths were random and only moderately defined. A partial list of the chemicals buried in the landfill is given in Table 1. In 1987, a gravel pack and cement pad were placed over the buried trenches to reduce vertical infiltration of precipitation. A storage shed was constructed on the cement pad for temporary storage of hazardous materials and a 10 ft high security fence was built around the site. A 67 ft deep monitoring well (hereafter referred to as the existing well) was installed 100 ft east of the shed for collecting water samples for radioactive analysis. The existing well was constructed of 4-inch PVC pipe and was screened in the lower 35 ft. A double-wide trailer was placed in the southeast corner of the site for temporary

TABLE 1. LIST OF ALL KNOWN CONSTITUENTS BURIED AT THE KSU INACTIVE WASTE LANDFILL.

2-4-D	CARBON	FLOTOX GARDEN SULFUR
ACARABIN	CGA 12596	FRUCTOSE
ACETIC ACID	CESIUM	FURADAN
ACETONE	CHLODONE	G. C. 12223
ACROLEIN	CHLORAL HYDRATE	GALECROSS
ALANAP	CIPC	GARDONA
ALDICOUS PESTICIDE	CLARA SOAPLESS SHAMPOO POWDER	GEIGY GA-479
ALUMINUM POTASSIUM SULFATE	CHLORAL HYDRATE	GULF CROP OIL
AMINO-2-(HYDROXYMETHYL)-1-3-PROPANEDIOL	CHLORINE	HYDROCHLORIC ACID
AMMONIUM CHLORIDE	CHROMIUM	HYDROGEN PEROXIDE
AMMONIUM OXALATE	COLLOIDAL SEEDCOAT METHYLCELLULOSE	HYDROXYLAMINE HYDROCHLORIDE
AMMONIUM SULFIDE	CRAB GRASS KILLER	IODINE
ANTIMONY TRICHLORIDE	CUPRIC SULFATE	IRON CHELATE
ASPEN	CYANIDE	ISOPROPYL ALCOHOL
5 BARIUM CARBONATE	CYANILB	KELTHANE
BARIUM CHLORIDE	DDT	LACTIC ACID
BAYGON	DDVP FLY BAIT	LANNATE
BENOMYE FUNGICIDE	D.S. 15647	LINDANE
BENZENE	DETHMOR	LORSBAN
BENZIDENE	DEXON	M-2279
BIDRIN	DIMETHYLSULFATE	MAGNESIUM CARBONATE
BIDUM	DINITROPHENYLHYDRAZINE	MALATHION
BORON TRIFLUORIDE	DOCTHAL	MALTOSE
BUFFALO CORN STARCH	DRIERITE	MANEB
BUTANE	DUPONT 1410-L	MN SULFATE MONOHYDRATE
BUX 10	DURSBAN	MANGANOUS CHLORIDE
CADMIUM	DYFONATE	MENADIONE NA BISULFITE
CALCIUM CHLORIDE	DYLOX	METASYSTOX
CALCIUM CHLORIDE DIHYDRATE	ETHER	METHYL MERCURY
CALCIUM LACTATE	FERRIC CHLORIDE	MICRO AL
CALCIUM NITRATE	FEROUS SULFATE	MIREX

TABLE 1 (CONT.). LIST OF ALL KNOWN CONSTITUENTS BURIED AT THE KSU INACTIVE WASTE LANDFILL.

MOCAP	RALION TECHNICAL	TEDION
N-2396	RESORCIN WHITE	TEGURON
NEMACUR	RESORCINOL	TERRACLOR
NICOTINIC ACID	SD-14999	TERTIARY BUTANOL
NITRATE	SAM. I 52-135	THIOUREA
ORGANIC MERCURY	SEVIN	THORIUM
ORGANOPHOSPHATES	SINEROL	TIMEN
OSMIUM	SLUG-KILL METAALDELYDE	TRICHLORACETIC ACID
OXALDIHYDRAZIDE	SODIUM	TRITHION
OXALIC ACID	SODIUM CARBONATE	TRITIUM
PARATHION	SODIUM CHLORIDE	U.C. 51762
PEN CAP METHY PARATHION	SODIUM ACETATE	URANIUM
PENCAP E	SODIUM BICARBONATE	UREA
PENCAP M	SODIUM CITRATE	UROX
PERCHLORIC ACID	SODIUM DITHIONATE	VAPAM
PHENYLPHENOL	SODIUM HYDROSULFITE	VELSICOL
PHOSDIN	SODIUM HYDROXIDE	VYDATE
PHOSPHORIC ACID	SODIUM METAPHOSPHATE	XYLENE
PHOSPHORUS	SODIUM NITRATE	ZINC POWDER
PHOSPHORUS PENTOXIDE	SODIUM NITRITE	ZINC SULFATE
POTASSIUM CYANIDE	SODIUM PHOSPHATE MONOBASIC	ZOLONE
POTASSIUM FERRICYANIDE	SODIUM SALICYLATE	
POTASSIUM HYDROGEN PHTHALATE	SODIUM THIOSULFATE	
POTASSIUM IODIDE	SPRAY OIL	
POTASSIUM PERMAGANATE	STICKEN SPECIAL	
POTASSIUM PHOSPHATE DIBASIC	SUCARYL	
POTASSIUM THIOCYANATE	SUCROSE	
PP505	SULFANILIC ACID	
PREFAR	SULFOSALICYLIC ACID	
RABON	SULFUR	
RAMROD	SULFURIC ACID	

storage of low-level radioactive waste. Burying of low-level radioactive waste ceased in 1988.

In 1989, the Department of Public Safety requested to officially close the inactive landfill and to comply with the KDHE regulations on landfill closure, the KSU Department of Geology began a hydrogeologic investigation of the landfill in October, 1989.

PHYSICAL SETTING

Physiography

The Kansas River lies approximately 4.5 miles south of the study area and the Big Blue River lies approximately 1.5 miles east of the study area. They flow to the east and south, respectively, and are the two major streams in the region (Figure 2). The maximum elevation in the study area is just over 1,150 ft (Bluemont Hill) and the minimum elevation is slightly below 1,050 ft (junction of Marlatt and Denison Avenues) giving a maximum relief of 100 ft. Bluemont Hill is underlain by Permian bedrock that is relatively resistant to weathering. Elevations within the landfill boundary range from 1,090 ft on the west to 1,083 ft on the east, giving it a maximum ground surface relief of 7 ft.

The land surface at the landfill has a gentle eastward slope (Figure 3) toward an ephemeral stream (Figure 1). The head of the ephemeral stream is 330 ft east of the

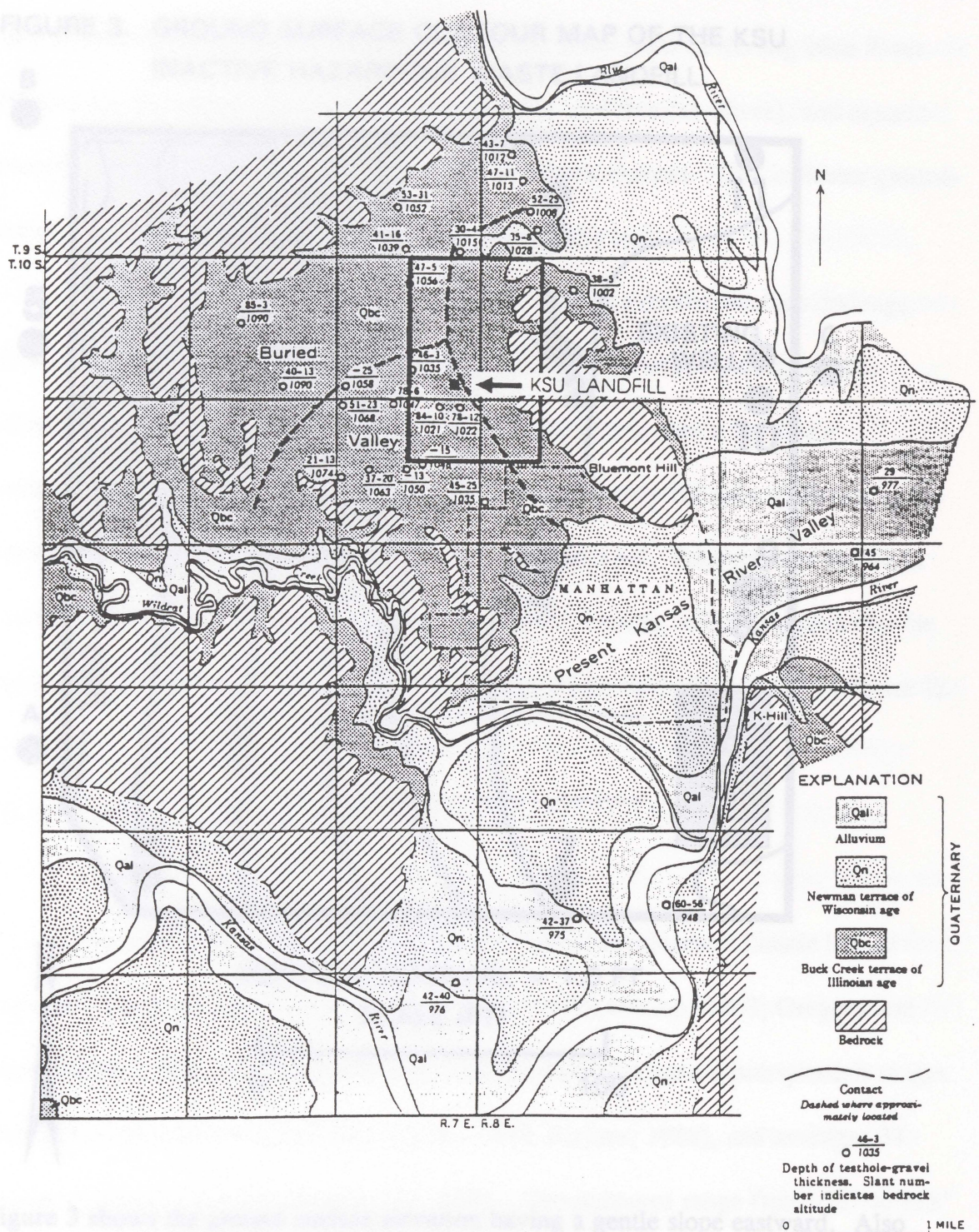


Figure 2. Geologic map of the Manhattan vicinity, showing the location of the KSU inactive landfill within the Y-shaped (dashed lines) abandoned river valley. The boundary of the study area is the thick lined rectangle (Modified from Beck, 1961).

FIGURE 3. GROUND SURFACE CONTOUR MAP OF THE KSU
INACTIVE HAZARDOUS WASTE LANDFILL.

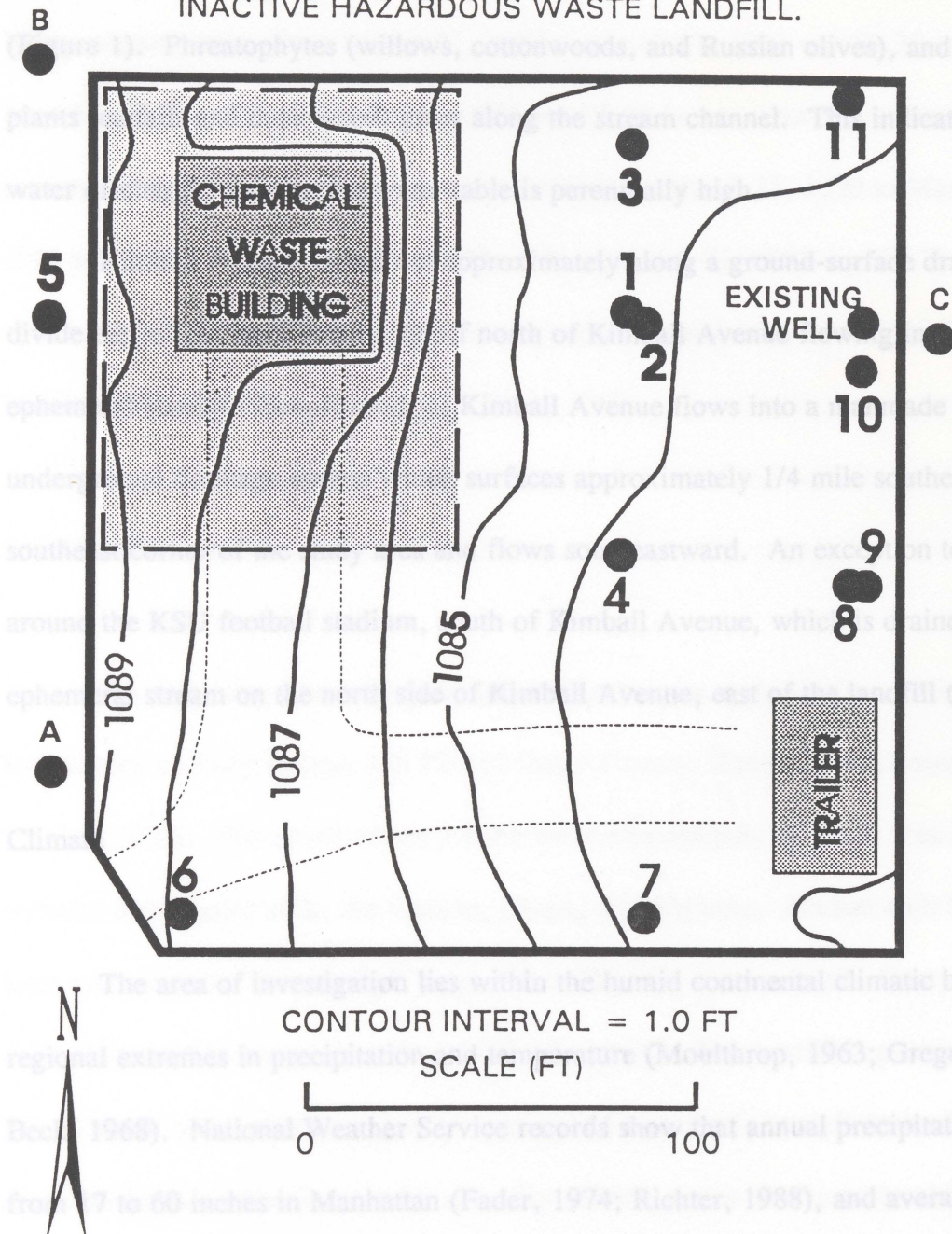


Figure 3 shows the ground surface elevation having a gentle slope eastward. Also shown on the figure are the locations of monitoring wells 1-11, preliminary test wells A, B, and C, an existing well, a gravel driveway which splits into a "Y" toward the temporary chemical waste storage building (dark gray area) and the temporary radioactive waste storage trailer (dark gray area). The probable lateral extent of the actual hazardous waste landfill is shown in light gray bounded by a dashed line.

landfill and the stream flows northeastward to the flood plain of the Big Blue River (Figure 1). Phreatophytes (willows, cottonwoods, and Russian olives), and aquatic plants (cattails and duck weed) grow along the stream channel. This indicates groundwater discharge, and that the water table is perennially high.

Kimball Avenue is laid out approximately along a ground-surface drainage divide east of the landfill with runoff north of Kimball Avenue flowing into the ephemeral stream. Runoff south of Kimball Avenue flows into a manmade underground drainage system which surfaces approximately 1/4 mile southeast of the southeast corner of the study area and flows southeastward. An exception to this is around the KSU football stadium, south of Kimball Avenue, which is drained by the ephemeral stream on the north side of Kimball Avenue, east of the landfill (Figure 1).

Climate

The area of investigation lies within the humid continental climatic belt of regional extremes in precipitation and temperature (Moulthrop, 1963; Gregory and Beck, 1968). National Weather Service records show that annual precipitation ranges from 17 to 60 inches in Manhattan (Fader, 1974; Richter, 1988), and averages 34 inches (National Climatic Data Center, 1992). Temperatures range from -32° to 115° F (Moulthrop, 1963; Gregory and Beck, 1968), and averages 55.1° F (National Climatic Data Center, 1992). Precipitation data during this investigation were taken from the North Agronomy Research Farm weather station that is located approximately

350 ft west of the landfill. Annual precipitation at the KSU North Agronomy Research Farm weather station from March 21, 1990 to March 21, 1991 was 29.25 inches, and from March 22, 1991 to March 31, 1992 was 25.30 inches, showing below-average precipitation. The average annual temperature from March 21, 1990 to March 21, 1991 was 55.8° F, and from March 22, 1991 to March 31, 1992 was 57.7° F, slightly above the last 30 year average. The average growing season is from April 20 to October 9 in Manhattan (Gregory and Beck, 1968).

Soil Classification

The following descriptions of soils located in the study area were taken from the Soil Survey of Riley County and Part of Geary County, Kansas (Soil Conservation Service, 1975). The Smolan-Geary association encompasses the study area and includes three major soils; the Smolan, Geary, and Wymore. Smolan soils have a silt loam and silty clay loam surface layer with a silty clay loam subsoil. Geary soils have a silt loam surface layer and a silty clay loam subsoil. The landfill is positioned in the Wymore soil series which are gently sloping and moderately to well drained, have a silty clay loam surface layer and a silty clay subsoil, and is slowly permeable. This soil has a high available water capacity, takes water well, and has a high shrink-swell potential which may be due to the fact that the clay fraction of the soil is montmorillonitic (Soil Conservation Service, 1975).

Permian bedrock

Many regional studies of the bedrock stratigraphy in the vicinity of Manhattan have been conducted and include papers by Jewett (1941), Byrne and others (1949), Moore and others (1951), and Chelikowsky (1972). The preglacial landscape of northeastern Kansas consisted of valleys dissected in gently dipping Pennsylvanian and Permian sedimentary bedrock. Bedrock in the area of investigation, including the poorly exposed outcrops on Bluemont Hill, consists of Permian-age marine limestone and shale of the Lower Permian Series, Gearyan Stage, Council Grove Group (Jewett, 1941; Byrne and others, 1949).

The only exposed bedrock outcrops within the study area are on Bluemont Hill in an abandoned quarry in which the Neva Limestone Member of the Grenola Limestone Formation was being mined. The bedrock below the unconsolidated Quaternary sediments at the landfill is the Hughes Creek Shale Member of the Foraker Limestone Formation (Figure 4). The Hughes Creek Shale consists of approximately 38 ft of dark gray to black shale, the uppermost of which is carbonaceous, and up to 5 thin limestone beds (Jewett, 1941). Regional dip of Permian bedrock is westward about 17 ft per mile (Smith, 1991).

Quaternary sediments

Studies of the unconsolidated Quaternary sediments and glacial deposits in and

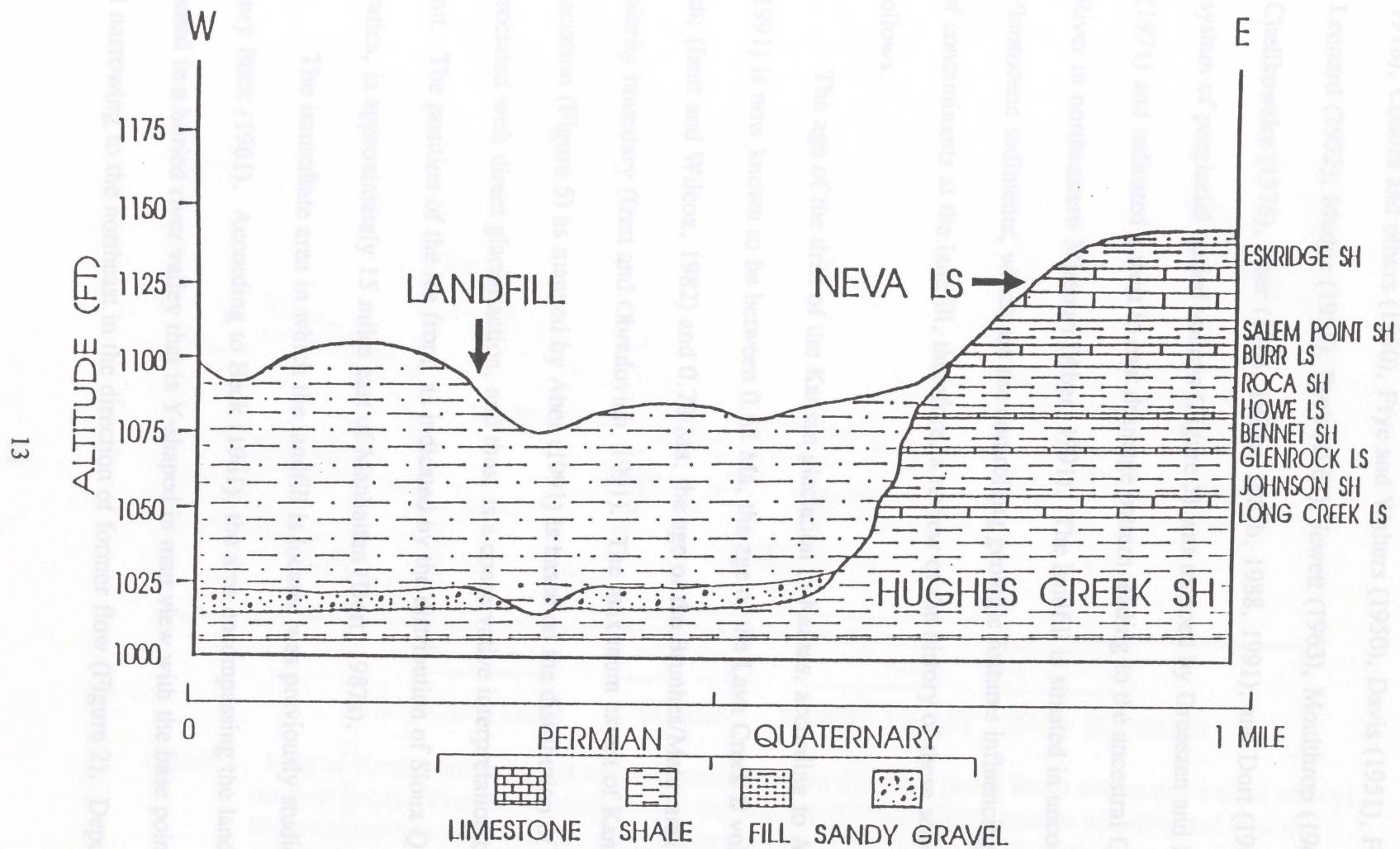


Figure 4. Schematic cross section along an east-west transect from Bluemont Hill on the east, through the landfill to the west. The landfill is situated in Quaternary sediments that fill a buried valley cut to the level of the Hughes Creek Shale. Vertical exaggeration is 15X (geology from Jewett, 1941; Beck, 1961; and unpublished field investigations).

around the Big Blue River and Kansas River valleys were conducted by Todd (1908, 1918), Condra and others (1950), Frye and Walters (1950), Davis (1951), Frye and Leonard (1952), Mudge (1955), Beck (1961), Jewett (1963), Moulthrop (1963), Chelikowsky (1976), Aber (1984, 1985a, 1985b, 1988, 1991), and Dort (1987a). A system of preglacial buried valleys (Figure 5) was mapped by Dreeszen and Burchett (1971) and indicated a west to east drainage pattern leading to the ancestral Grand River in northeastern Missouri (Aber, 1991). The landfill is situated in unconsolidated Pleistocene sediments, which are the controlling geologic features influencing the fate of contaminants at the landfill, therefore, a review of the history of these sediments follows.

The age of the drift of the Kansan glaciation in Kansas, according to Aber (1991) is now known to be between 0.62 Ma, the age of the Lava Creek B volcanic ash; (Izett and Wilcox, 1982) and 0.78 Ma, the age of the Brunhes/Matuyama magnetic polarity boundary (Izett and Obradovich, 1991). The maximum extent of Kansas glaciation (Figure 5) as mapped by Aber (1991) is based on the distribution of features associated with direct glacial action, and thus, is a conservative interpretation of the ice limit. The position of the ice front, as indicated by the distribution of Sioux Quartzite erratics, is approximately 15 miles east of Manhattan (Dort, 1987a).

The immediate area in which the landfill is located was previously studied by Henry Beck (1961). According to Beck (1961), the area encompassing the landfill is situated in a buried river valley that is Y-shaped in map view with the base pointing and narrowing to the northeast in the direction of former flow (Figure 2). Deposits

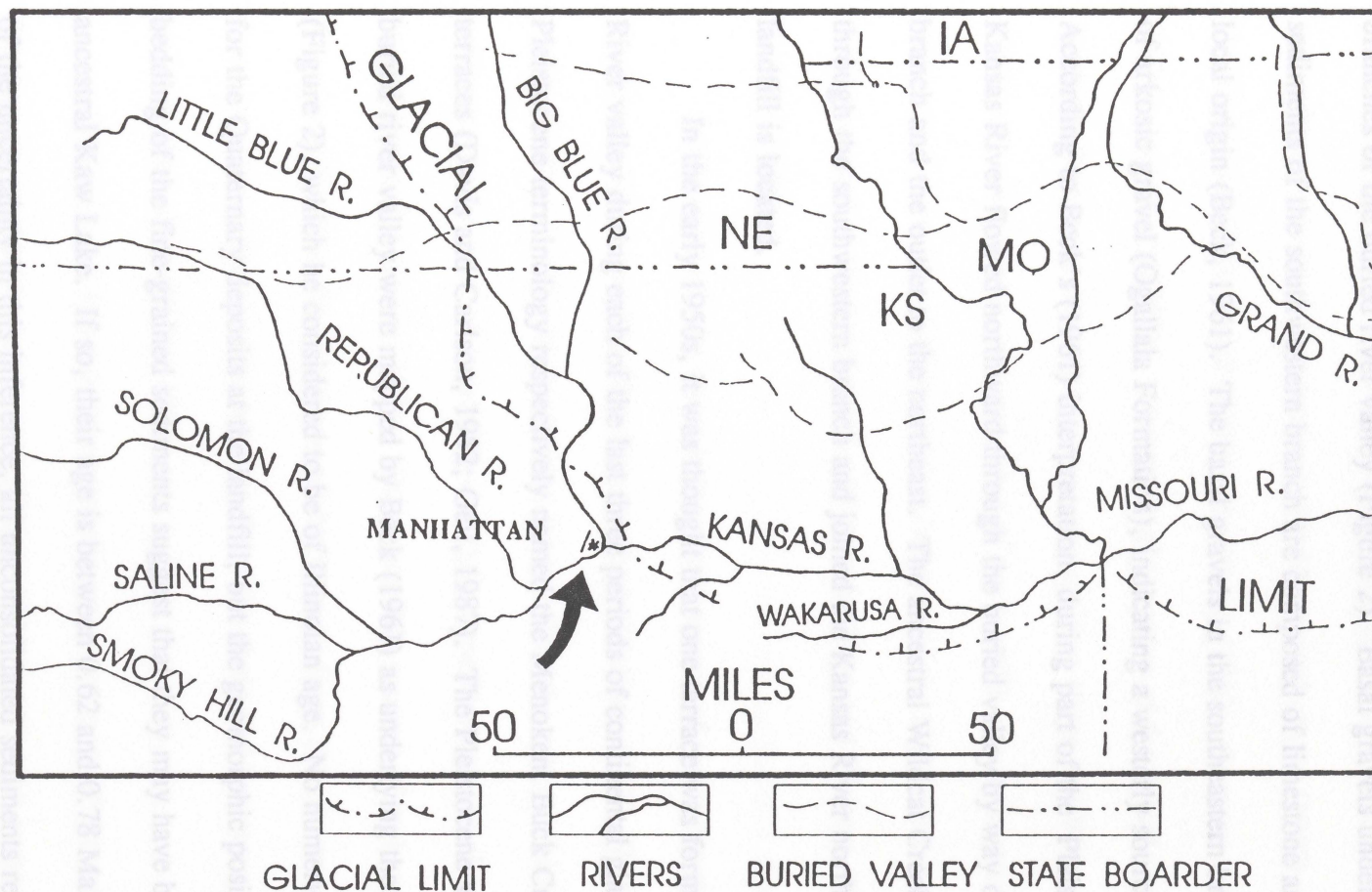


Figure 5. Map of Kansas and adjacent areas showing modern drainage (solid lines) and major buried valleys (dashed lines). Preglacial drainage into the ancestral Grand River system was diverted into the Blue/Kansas/Missouri valleys. Large arrow points to the buried valley under investigation (Modified from Dreezen and Burchett, 1971; Aber, 1988a, 1991).

filling these preglacial valleys range from clayey sediments to sand and gravel (Denne and others, 1987). The landfill is located between and close to the junction of the two branches of the buried river valley (Figure 2). Basal gravels underlying the Pleistocene sediments of the southwestern branch are composed of limestone and chert fragments of local origin (Beck, 1961). The basal gravels in the southeastern branch are composed of arkosic gravel (Ogallala Formation), indicating a westerly source (Beck, 1961). According to Beck's (1961) interpretation, during part of the Pleistocene, the ancestral Kansas River flowed northward through the buried valley by way of the southeastern branch and the outlet to the northeast. The ancestral Wildcat Creek flowed north through the southwestern branch and joined the Kansas River north of where the KSU landfill is located.

In the early 1950s, it was thought that one terrace was formed in the Kansas River valley during each of the last three periods of continental glaciation of classical Pleistocene terminology respectively named the Menoken, Buck Creek, and Newman terraces (Davis and Carlson, 1952; Geil, 1987). The Pleistocene sediments filling the buried river valley were mapped by Beck (1961) as underlying the Buck Creek terrace (Figure 2), which he considered to be of Illinoian age. No numerical ages are available for the Quaternary deposits at the landfill, but the geomorphic position, texture and bedding of the fine-grained sediments suggest that they may have been deposited in the ancestral Kaw Lake. If so, their age is between 0.62 and 0.78 Ma. However, because of the uncertainty in this inference, all unconsolidated sediments resting on Permian bedrock at the landfill are referred to as either Quaternary sediments or Quaternary fill.

Hydrogeology

The geology and ground-water resources of the Kansas River and Blue River valley have been studied extensively by Moore and others (1940), Beck (1949), Davis and Carlson (1952), Smith (1959), Moulthrop (1963), Gregory and Beck (1968), Fader (1974), and Dort (1987b). Almost ninety percent of the potable ground water in northeast Kansas is from Quaternary-age aquifers (Frye and Walters, 1950; Richter, 1988). In many areas, including that of the landfill, the most satisfactory sources of water are buried river-valley aquifers because of the high yields and water quality in wells screened in the basal sands and gravels (Frye and Walters, 1950; Beck, 1959; Richter, 1988).

Infiltration of rain water is the major source of water for most of the aquifers in the Kansas River and Big Blue River valleys (Walters, 1953; 1954; Beck, 1959; Smith, 1959; Richter, 1988). In the Kansas River valley the rate at which precipitation infiltrates to the zone of saturation is largely dependent on the clay content of the surficial material (Davis, 1951). Other possible sources of recharge in the Kansas River and Big Blue River valleys are by seepage from streams and ponds, by return flow from irrigation, and by seepage from the shale and limestone that border and underlie the valley (Fader, 1974).

The bedrock formations contribute small amounts of ground water to the valley-fill deposits in the Manhattan area (Fader, 1974). Although some shales of the Council Grove Group are capable of supplying small amounts of water to a well (Beck, 1959),

the most frequently used aquifers of the Council Grove Group are the Cottonwood, Burr, Neva, Howe, and Long Creek limestones (Beck, 1959; B. Smith, personal communication, 1991). Ground water in permeable limestone aquifers generally moves in the direction of dip when it encounters impermeable shale beds that inhibit direct vertical migration (Walters, 1954; Farley, 1987). Ground water contribution from bedrock to the fill deposits is most likely trivial except during periods of below-normal precipitation.

Geochemistry

The composition of the soils, sediments, and rocks has a direct bearing on the quality of ground water (Mazor, 1990). The ground water in northeastern Kansas is generally very hard and may contain as much as 58 milligrams per liter (mg/L) of total iron (Fader, 1974). Ground water temperature in the Kansas River valley is uniform (57-58° F) except where river-water infiltration causes seasonal variations of 5-10° F (Davis, 1951).

Studies similar to Beck's (1961) of buried valleys in counties adjacent to Riley County have been conducted at KSU by Carl (1980), Farley (1987), and Richter (1988). Farley (1987) collected ground water geochemical data from sediments in a buried valley in Marshall County, Kansas. Because Farley (1987) did not report evidence of any anthropogenically induced contamination of ground water, and the sediments contained in the buried valley of his study are similar to the Quaternary fill

at the landfill, his hydrochemical results are used as a background comparison for the present study. There are, however, differences in the overall systems of the two buried valleys. The greatest difference is in the overall size of the two systems. Variations in geochemistry of the large system in Marshall County tend to be less than those in the much smaller system in the vicinity of the landfill.

METHODS OF INVESTIGATION

Field Methods

Field methods used in this investigation included geologic reconnaissance, water well drilling, ground-water level readings, and pump tests. The ephemeral stream channel east of the landfill was examined for soil and sediment profiles and geologic reconnaissance was conducted to locate bedrock outcrops on the west side of Bluemont Hill.

Three types of water wells were drilled for this investigation. Preliminary test wells, monitoring wells, and test wells (Figures 3 and 6) were installed to gather information on the subsurface hydrogeology and geochemistry of the study area (Table 2). The monitoring wells are the most important of the wells. Since the monitoring wells are all located within the small area of the landfill boundary, the standard well numbering system used by the Bureau of Land Management (BLM) was not applied. Therefore the wells were assigned a number or letter according to the order in which they were drilled. The BLM system of well numbering for the preliminary wells and

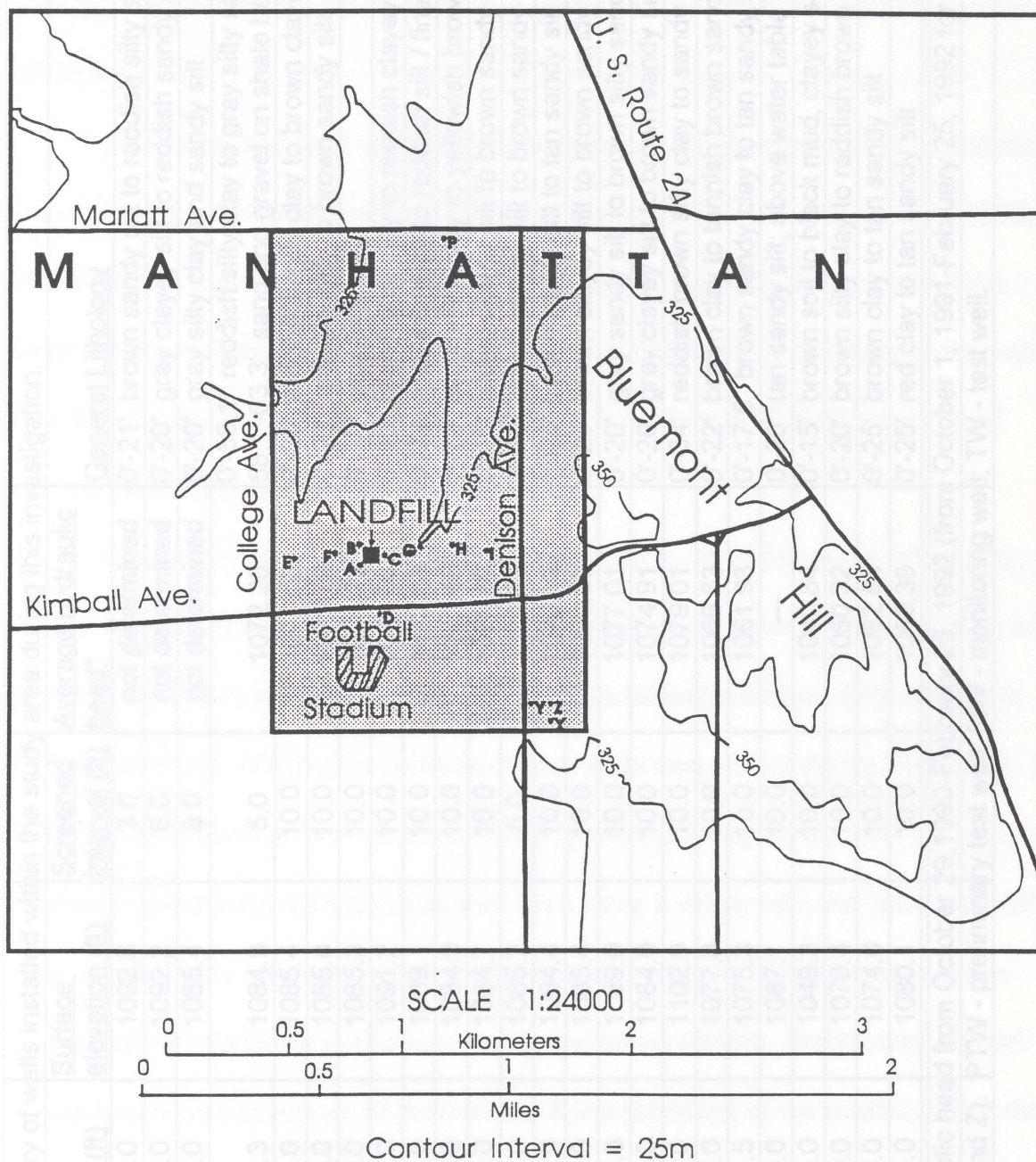


Figure 6. Location map showing the placement of preliminary wells A, B, C; and test wells D, E, F, G, H, I, P, X, Y, and Z.

Table 2. Summary of wells installed within the study area during this investigation.					
Well ID	Depth (ft)	Surface elevation (ft)	Screened interval (ft)	Average hydraulic head*	General Lithology
PTW-A	21.0	1092.8	3.0	not determined	0'-21' brown sandy silt to reddish silty sand
PTW-B	20.0	1092.2	6.0	not determined	0'-20' gray clayey silt to reddish sandy silt
PTW-C	20.0	1085.4	8.0	not determined	0'-20' gray silty clay and sandy silt
MW-1	63.3	1084.9	5.0	1072.26	0'-58.1' reddish silty clay to gray silty sand 58.1'-63.3' sand and gravel on shale bedrock
MW-2	20.0	1085.4	10.0	1071.52	0'-20' reddish sandy clay to brown clayey silt
MW-3	20.0	1085.8	10.0	1070.79	0'-20' red silty clay to brown sandy silt
MW-4	20.0	1085.3	10.0	1071.23	0'-20' gray silty clay
MW-5	20.0	1091.2	10.0	1074.08	0'-20' brown silty clay to reddish clayey silt
MW-6	20.0	1089.1	10.0	1072.63	0'-20' gray silty clay to reddish silt / fine sand
MW-7	20.0	1084.9	10.0	1071.46	0'-20' brown silty clay to yellowish brown silt
MW-8	20.0	1084.7	10.0	1070.82	0'-20' brown clayey silt to brown sandy silt
MW-9	30.0	1085.2	5.0	1070.85	0'-30' brown clayey silt to brown sandy silt
MW-10	20.0	1084.4	10.0	1070.93	0'-20' brown sandy silt to tan sandy silt
MW-11	20.0	1085.4	10.0	1069.52	0'-20' brown clayey silt to brown sandy silt
TW-D	20.0	1089.0	10.0	1077.01	0'-20' gray sandy silt to brown silty sand
TW-E	20.0	1084.0	10.0	1074.91	0'-20' gray clayey silt to brown sandy silt
TW-F	34.0	1102.9	10.0	1079.01	0'-34' reddish brown silty clay to sandy silt
TW-G	22.0	1077.8	10.0	1066.63	0'-22' brown clay to tannish brown sand
TW-H	17.5	1075.3	10.0	1061.93	0'-17.5' brown sandy clay to tan sandy silt
TW-I	20.0	1087.1	10.0	---	0'-20' tan sandy silt; above water table
TW-P	15.0	1049.3	10.0	1040.84	0'-15' brown soil to black mud, clayey sand
TW-X	20.0	1070.4	10.0	1060.32	0'-20' brown silty clay to reddish brown silt
TW-Y	25.0	1074.0	10.0	1062.84	0'-25' brown clay to tan sandy silt
TW-Z	25.0	1080.1	10.0	1060.39	0'-25' red clay to tan sandy silt
* Average hydraulic head from October 29, 1990-February 25, 1992 (from October 1, 1991-February 25, 1992 for test wells X, Y, and Z). PTW - preliminary test well; MW - monitoring well; TW - test well.					

the monitoring wells is given with their respective well logs in Oviatt and others (1992). Well numbering for the test wells can be obtained from the KSU Department of Geology.

A full explanation of the drilling, construction, and development of preliminary and monitoring wells was presented in reports to the KDHE (Oviatt and others, 1990; 1992). A full explanation of the drilling, construction, and development of the test wells can be obtained from the KSU Department of Geology. A summary of the well logs for all wells installed during this investigation is given in Table 2, and a brief description of each type of well follows.

Preliminary test wells: Preliminary test wells A, B, and C, were drilled just outside the landfill security fence to determine the depth to ground water, direction of ground-water flow, and particle size of the unconsolidated sediments (Figures 3 & 6; Oviatt and others, 1992). The preliminary test wells were drilled during September, 1989, with a trailer-mounted Giddings probe operated by Clay Dyer, KSU. A continuous sample for each borehole was taken using a shelby tube and was discarded after samples were selectively taken for particle-size analysis. Geologic logs of the preliminary test wells are available in Oviatt and others (1992). Preliminary test well A was located just southwest of the landfill, B just northwest of the landfill, and C due east of the landfill (Figures 3 and 6).

Monitoring wells: Based on information gained from the preliminary wells, monitoring wells 1-4 were drilled within 50 ft east (down gradient) of the landfill in a north-south transect so that possible contaminants flowing eastward would immediately

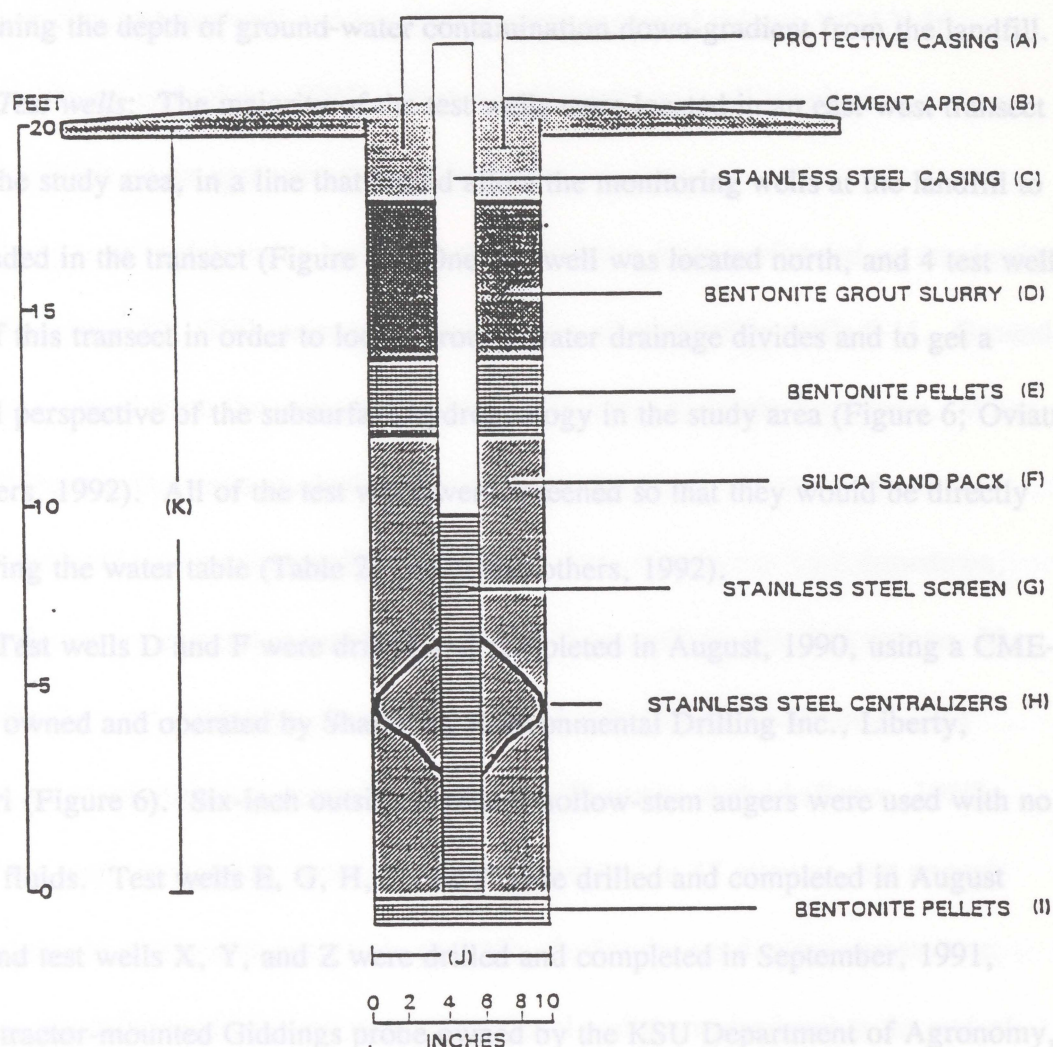
be detected. Monitoring well 5 was located within 50 ft west (up gradient) of the landfill to act as a background well so that representative conditions of ground water in the system which had not been affected by the landfill could be determined.

A second set of monitoring wells (6-11) were placed just inside the landfill security fence, east and south of the first tier of monitoring wells (Figure 3). The reason for placing these wells in their specific locations was to help define the extent of ground-water contamination. Their placement was based on the better understanding of the direction(s) of ground-water flow that had been obtained from the first set of monitoring wells.

Monitoring wells 1-5 were drilled during January 30-February 1, 1990, using a B-61 Mobil drill owned and operated by the Kansas Department of Transportation (Figure 3). Eight-inch outside diameter steam cleaned augers were used with no drilling fluids. Monitoring wells 6-11 were drilled during October 22-November 10, 1990, using a CME-55 drill owned and operated by Shamrock Environmental Drilling Inc., Liberty, Missouri (Figure 3). Ten-inch outside diameter steam cleaned augers were used with no drilling fluids. Geologic logs for monitoring wells 1-11 are given in Oviatt and others (1992). Monitoring wells 1-11 were drilled and constructed according to Environmental Protection Agency (EPA) specifications for wells installed at a hazardous waste site (Figure 7; Oviatt and others, 1992).

The monitoring wells are 2 inches in diameter and constructed of stainless steel. They are 20 ft deep and screened in the lower 10 ft to observe the water table, except for monitoring wells 1 and 9 (Table 2; Oviatt and others, 1992). Monitoring well 1 is

Figure 7. Schematic diagram of monitoring well construction.



A = 6 or 8 inch diameter, 1/4 inch thick protective casing with pad lock; B = minimum of 6 inch thick cement apron with a 4 inch slump, reinforced with wire mesh; each apron slopes away from the well and is a 6 x 6 ft square pad (except for wells 1 and 2, and wells 8 and 9, which are 6 x 9 ft rectangles); C = 2 inch diameter stainless steel casing with stainless steel cap and flush-joints; D = bentonite grout slurry made on site from granular (powdered) bentonite; E = 1/4 inch bentonite pellets; F = 16-40 mesh pure Colorado silica sand pack with a uniformity coefficient of 1.831; G = 2 inch diameter stainless steel screen with flush-joint fitting and wire-wound 0.001 inch openings; H = adjustable stainless steel centralizers; I = 1/4 inch bentonite pellets (not always used at the bottom of the borehole); J = borehole diameter (8 or 10 inches for monitoring wells); K = total borehole depth (20 ft for all monitoring wells except well 1 which is 63.3 ft and well 9 which is 35 ft deep).

63.3 ft deep and screened in the lower 5 ft to check the sand and gravel aquifer directly above bedrock. Monitoring well 9 is 30 ft deep and screened in the lower 5 ft to aid in determining the depth of ground-water contamination down-gradient from the landfill.

Test wells: The majority of the test wells were located in an east-west transect across the study area, in a line that would allow the monitoring wells at the landfill to be included in the transect (Figure 6). One test well was located north, and 4 test wells south of this transect in order to locate ground-water drainage divides and to get a regional perspective of the subsurface hydrogeology in the study area (Figure 6; Oviatt and others, 1992). All of the test wells were screened so that they would be directly monitoring the water table (Table 2; Oviatt and others, 1992).

Test wells D and F were drilled and completed in August, 1990, using a CME-55 drill owned and operated by Shamrock Environmental Drilling Inc., Liberty, Missouri (Figure 6). Six-inch outside diameter hollow-stem augers were used with no drilling fluids. Test wells E, G, H, I, and P were drilled and completed in August 1990, and test wells X, Y, and Z were drilled and completed in September, 1991, using a tractor-mounted Giddings probe owned by the KSU Department of Agronomy, and operated by the author (Figure 6). Four-inch outside diameter hollow-stem augers were used with no drilling fluids. Well I was drilled through what is believed to be a perched water table and the screening interval failed to reach the underlying water table or the overlying perched water. Therefore, well I was dry throughout this investigation and will not be discussed further (Table 2).

All wells were developed utilizing pumping techniques. Purged water from the

monitoring wells was stored in plastic lined metal drums until the first water analysis for each well was obtained, and then disposed of properly. The locations of the tops of each monitoring and test well and benchmark were surveyed using a Wild T-16 theodolite (Oviatt and others, 1992). Water-level readings in all monitoring and test wells were taken on an approximate weekly basis.

Pump tests to determine hydraulic characteristics were performed on monitoring wells 1-5 on June 22, 1990, prior to the installation of monitoring wells 6-11. Ground water was pumped from the wells with a peristaltic pump to create drawdown. When the water level in the wells reached an equilibrium, the pump was stopped and the initial water level was recorded. While the wells were recovering from drawdown, water levels were measured at timed intervals of 15 seconds for the first minute, 30 seconds for the next 4 minutes, then again at 7, 10, 15, 30 and 45 minutes. The hydraulic conductivities were calculated using the Hvorslev method (Fetter, 1988). None of the wells completely recovered from drawdown in 45 minutes, but enough data points were obtained to accurately plot h/h_0 (hydraulic head ratio) verses time, where h is the difference between static water level and the water level at the end of pumping, and h_0 is the difference between static water level and the water level at the end of each time interval. The plot of head ratio vs. time was used to calculate the hydraulic conductivity using the Hvorslev method (Fetter, 1988):

$$K = [r^2 \ln(L/R)] / 2LT_0 \quad \text{where:}$$

K = hydraulic conductivity; r = radius of sand pack; L = length of sand pack; R = radius of screen; and T_0 = the time it takes for the water level to rise 37 percent of the

initial change (using the plot of hydraulic head ratio vs. time). Because monitoring well 1 is screened in the lower sand and gravel aquifer, the hydraulic conductivity was high enough that the rate of inflow into the well was greater than the pumping rate of approximately 1.5 gpm, therefore, drawdown did not occur, and the hydraulic conductivity of monitoring well 1 could not be determined using this method.

Sampling Methods

Samples of sediments were taken from the augers each time there was a texture or appearance change. At every texture or appearance change, the driller would allow the augers to rotate at the same elevation until all of the sediment reached the surface. This helped to insure that the sample was being taken from the bottom of the borehole, and allowed the depth below the ground surface of the sample to be determined.

Ground-water samples were taken from the monitoring wells every 4 months. Samples collected for the first six sampling events were analyzed by Wilson analytical laboratory, Salina, Kansas. Samples collected for the seventh sampling event were analyzed by PSI analytical laboratory, Lawrence, Kansas. Both laboratories conform to standards set by the EPA and its' Contract Laboratory Program. Samples were analyzed for pesticides and PCBs, base neutral compounds, acid compounds, KDHE volatile list, and metals. Small aliquots of sample were collected and radioactive emissions of tritium (^3H), carbon (^{14}C), and phosphorus (^{32}P), were determined at the

KSU Department of Public Safety using liquid scintillation techniques. Samples were also collected by the author for in-house analysis of major ions.

Samples for the analytical laboratory were put into containers supplied by the lab and cooled in an ice chest until analysis. Samples taken by and for the author were put into polypropylene bottles. Prior to taking the sample bottles to the field, 5 ml of undiluted laboratory grade nitric acid was added to the one-liter bottles used for metals analysis for sample preservation.

Separate pump tubing was dedicated to each well to prevent cross-contamination. Prior to sampling, a minimum of three well volumes of ground water was purged from each well to remove stagnant water and permit the flow of fresh ground water into the well. Sampling equipment and containers were rinsed several times with sample water prior to final sample collection to insure constant temperature and hydrochemistry was been reached. Samples were bottled and immediately placed inside an ice chest and kept at 40° F.

Laboratory Methods

The laboratory methods used by Wilson and PSI analytical laboratories for conducting a spectrum analysis were modified from "Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans" and "Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act" respectively (Oviatt and others, 1990; 1992). Wilson Laboratory also computed some

standard parameters such as ionic balance, saturation pH, Ryznar stability and Langelier saturation indexes, and total free carbon dioxide. Additional analysis was provided by chemically analyzing major ions at KSU for comparison with results of the analytical laboratories. Specific procedures used in the chemical analyses at KSU are similar to those used by Farley (1987), and a brief description of each method is provided in Appendix A.

Particle size analysis was performed on samples taken from continuous sample cores from the preliminary test wells. Analysis was performed by Darin Duncan at the KSU Agronomy Research Lab using sieve and pipette methods. A sample from the borehole at the bottom of monitoring well 1 was sieved to study the sand and gravel fraction, and to see if any glacial exotics were intermixed with limestone and chert gravels.

RESULTS

Geology

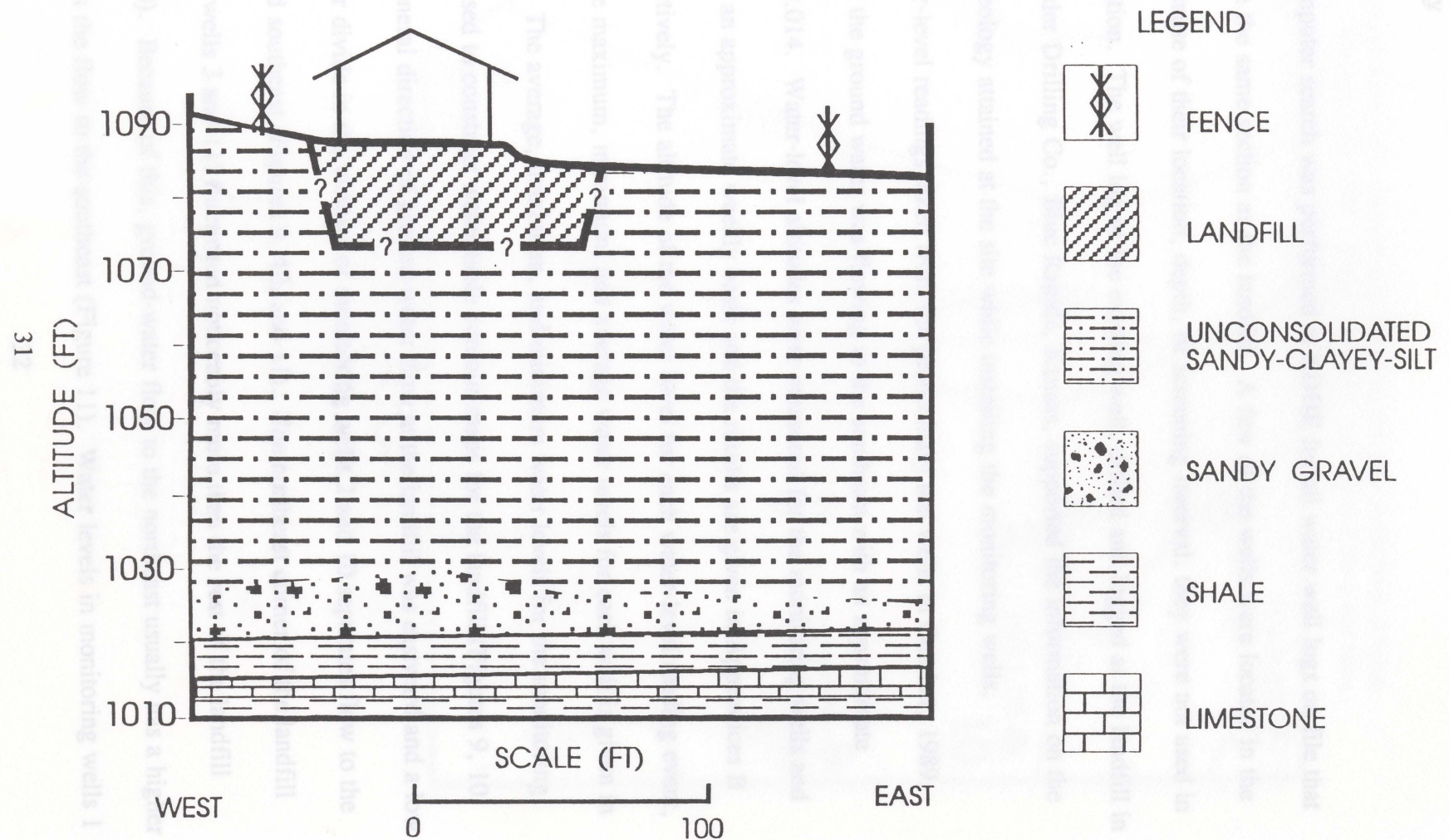
The Permian bedrock flanking and underlying the landfill is of the Council Grove Group. The bedrock underlying the landfill was determined by using the thicknesses and description of the Council Grove Group by Jewett (1941), the regional bedrock dip of approximately 17 ft/mi. (Smith, 1991), and the altitude of a Neva Limestone outcrop on Bluemont Hill (Figure 4). Thus, the bedrock underlying the landfill at approximately 1022 ft is the Hughes Creek Shale Member of the Foraker

Limestone Formation (Figure 4). Several geologic reports prepared for construction of new buildings south of Kimball Avenue on the KSU campus, reveal that highly weathered Hughes Creek Shale is encountered between elevations of 1,020-1,030 ft.

The Quaternary fill at the landfill is a 55-60 ft thick sequence of heterogeneous sand, silt, and clay, having faintly recognizable horizontal bedding. The percentages of sand, silt, and clay, according to the Wentworth scale, are given in Oviatt and others (1992) and range from 6-42 % sand, 32-56 % silt, and 21-38 % clay. The sediments range in color from reddish-brown near the surface to light brown or light gray as depth increases. Mottling is common in the lower parts of the soil profile and near the water table, suggesting periodic wetting and drying of these zones. Underlying these sediments, and overlying the Permian bedrock, is coarse sand and gravel with a thickness of approximately 7 ft (Figure 8).

A sample of the coarse sand and gravel directly above the Permian bedrock was collected while drilling monitoring well 1. The fine sand, silt, and clay fraction of the sample was washed away so that the coarse sand and gravel could be studied. The coarse sand fraction of the sample was composed primarily of quartz and feldspar. The gravel size fraction was composed of chert and limestone fragments of local origin, along with arkosic gravel, and sandstone from the Dakota Formation of Cretaceous age (P. C. Twiss, personal communication, 1992). No glacially derived igneous or metamorphic fragments were identified in the sample.

FIGURE 8. SCHEMATIC CROSS SECTION OF THE KSU
INACTIVE CHEMICAL WASTE LANDFILL



Hydrogeology

Figure 9. Average water-table contour map for all monitoring wells from October 29, 1990-April 05, 1992. Wells 1 and 9 do not measure the water table

A computer search was performed at KDHE for all water well logs on file that are located in the same section as the landfill. A few of the wells were located in the field, but because of their location, depth, or screening interval, they were not used in this investigation. The well log of the existing well, drilled and logged at the landfill in 1984 by Strader Drilling Co., Blue Rapids, Kansas, supported the information on the subsurface geology attained at the site while installing the monitoring wells.

Water-level readings taken from the preliminary test wells in October, 1989, revealed that the ground water was flowing to the southeast with an approximate gradient of 0.014. Water-level altitudes were measured for the monitoring wells and test wells on an approximate weekly basis and the results are given in Appendices B and C respectively. The altitude of the water level for each water-level reading event, as well as the maximum, minimum, and average water levels for each well is given in these tables. The average, maximum, and minimum water levels for the monitoring wells were used to construct water-table contour maps for the landfill (Figures 9, 10, and 11). General direction of ground-water flow at the landfill was eastward and a low ground-water divide in the vicinity of monitoring wells 2 and 10 separates flow to the northeast and southeast (Figures 9, 10, and 11). The northeast corner of the landfill (monitoring wells 3 and 11) fluctuated noticeably more than the rest of the landfill (Appendix B). Because of this, ground-water flow to the northeast usually has a higher gradient than the flow to the southeast (Figure 11). Water levels in monitoring wells 1

Figure 9. Average water-table contour map for all monitoring wells from October 29, 1990-April 08, 1992. Wells 1 and 9 do not measure the water table and were not used to construct this map.

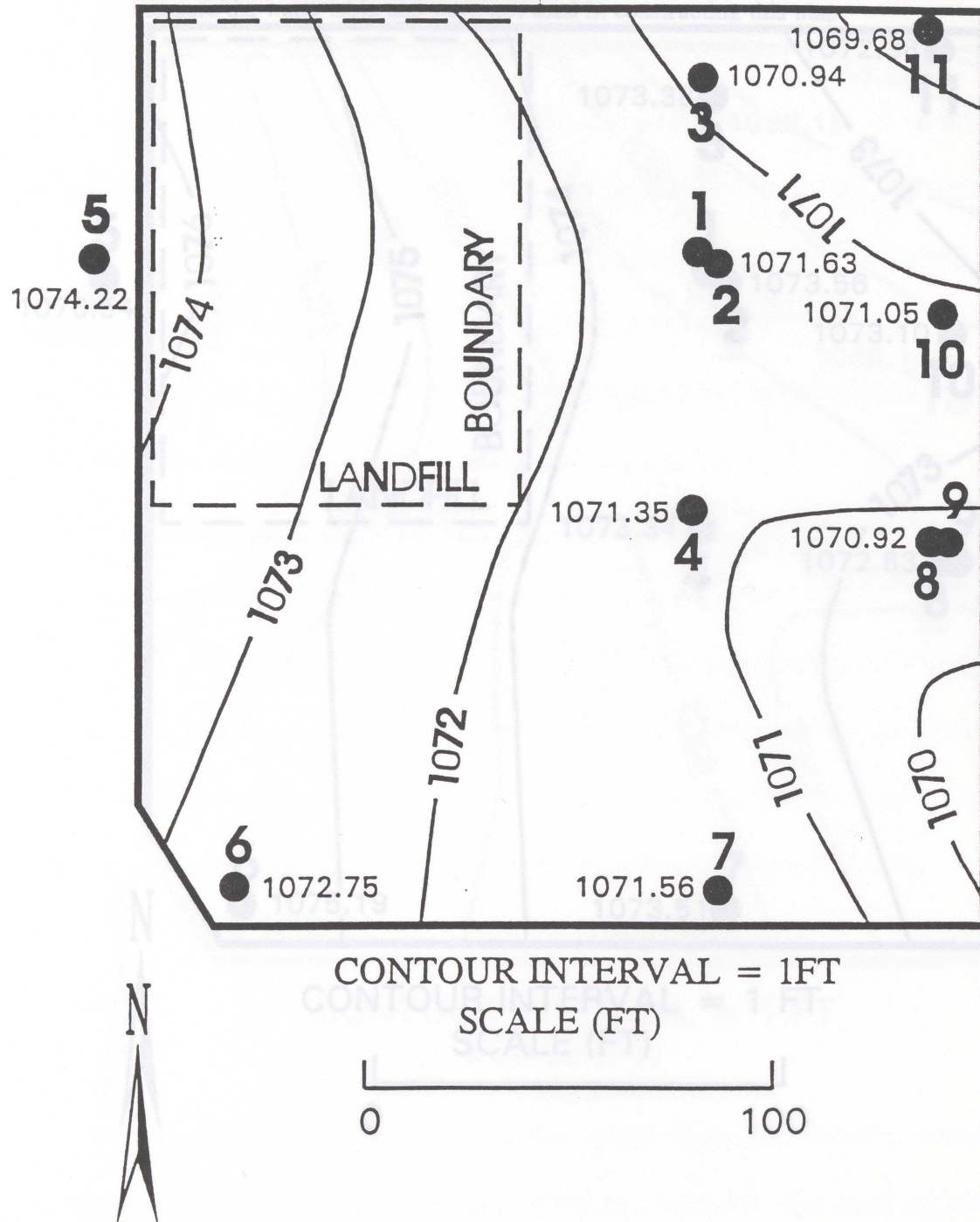


Figure 10. Water-table contour map for one of the highest water-level readings encountered between February 14, 1990 and April 08, 1992. Water-level readings were taken on April 08, 1992. Wells 1 and 9 do not measure the water table and were not used in constructing this map.

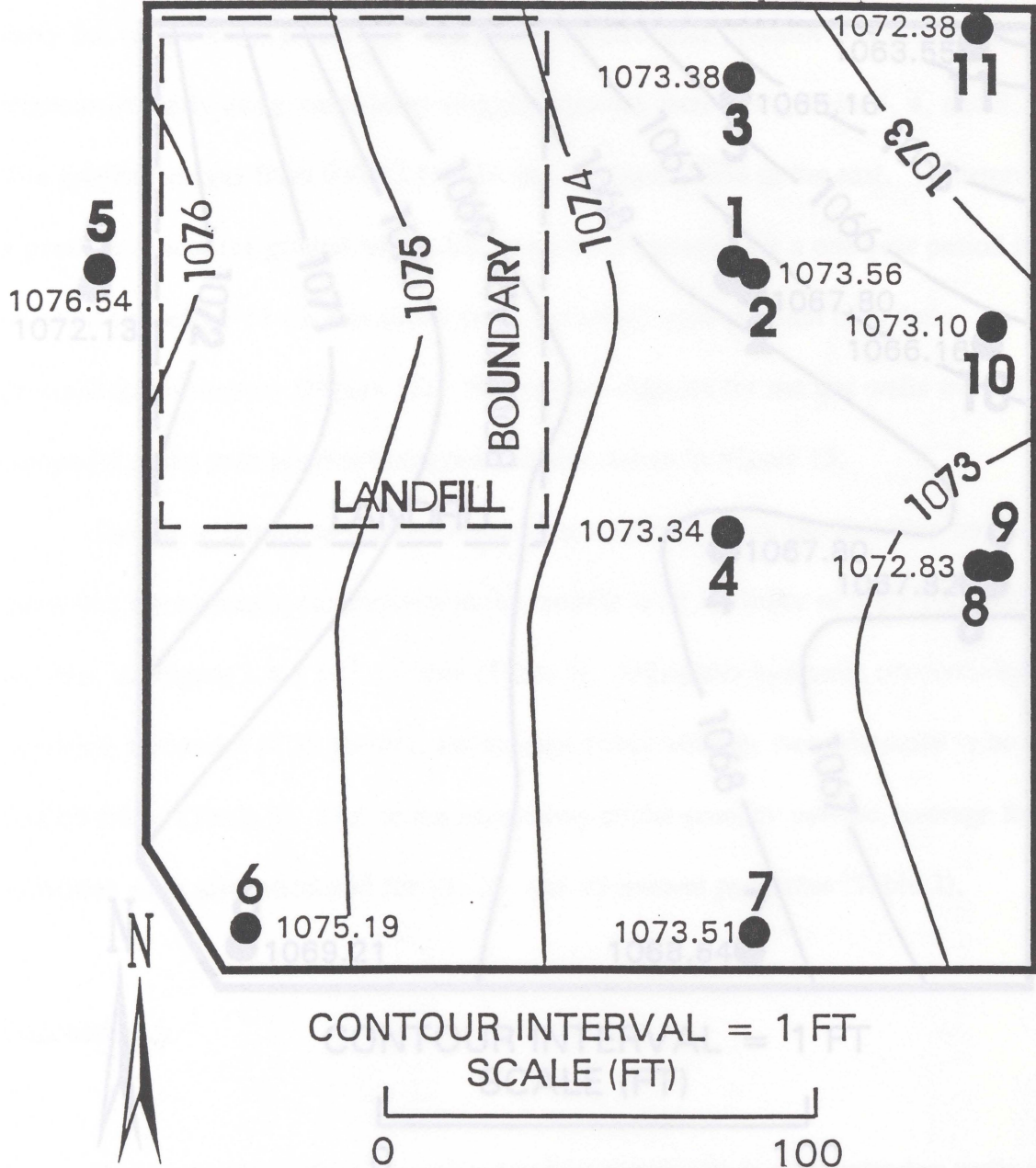
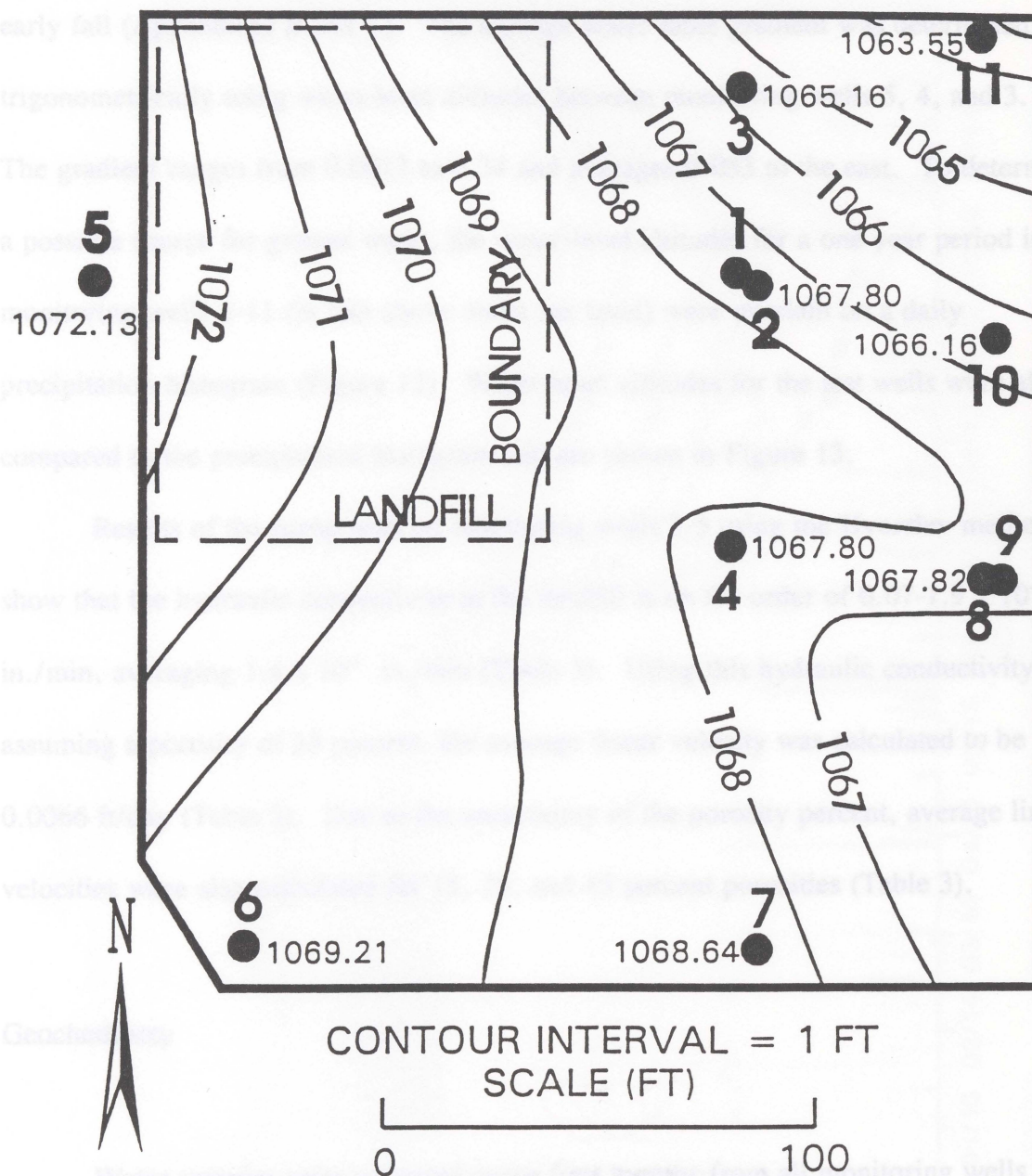


Figure 11. Water-table contour map for the lowest water-level reading encountered between February 14, 1990 and April 08, 1992. Water-level readings were taken on October 16, 1991. Wells 1 and 9 do not measure the water table and were not used in constructing this map.



and 9, whose screening interval is below the water table, were generally higher than those in adjacent monitoring wells 2 and 8, which measure the water table. Variations in the water-table configuration at the landfill occurred mainly during the summer and early fall (Appendices B and C). The average water-table gradient was determined trigonometrically using water-level altitudes between monitoring wells 5, 4, and 3. The gradient ranges from 0.0013 to 0.34 and averages 0.033 to the east. To determine a possible source for ground water, the water-level altitudes for a one year period in monitoring wells 1-11 (in feet above mean sea level) were overlain on a daily precipitation histogram (Figure 12). Water-level altitudes for the test wells were also compared to the precipitation histogram and are shown in Figure 13.

Results of the pump tests on monitoring wells 2-5 using the Hvorslev method show that the hydraulic conductivity at the landfill is on the order of $0.07-1.9 \times 10^{-3}$ in./min, averaging 1.4×10^{-3} in./min (Table 3). Using this hydraulic conductivity and assuming a porosity of 35 percent, the average linear velocity was calculated to be 0.0066 ft/day (Table 3). Due to the uncertainty of the porosity percent, average linear velocities were also calculated for 15, 25, and 45 percent porosities (Table 3).

Geochemistry

Water samples were collected every four months from all monitoring wells and chemically analyzed. Water samples from monitoring wells 1-5 were analyzed seven times, and monitoring wells 6-11 analyzed five times. Results of the chemical analyses

FIGURE 12. PRECIPITATION AND WATER-LEVEL ALTITUDES FOR WELLS 1-11.

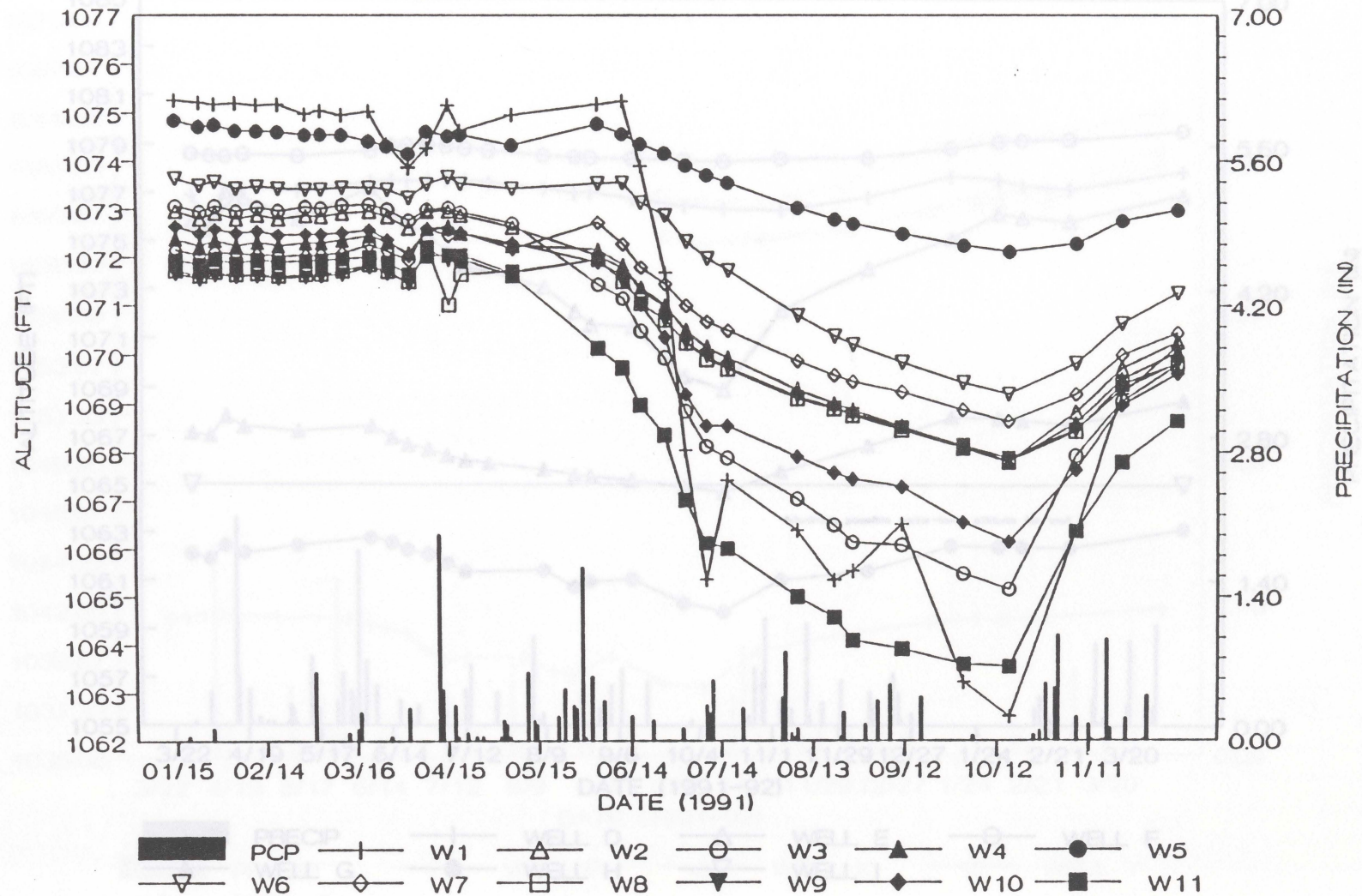


FIGURE 13. PRECIPITATION AND WATER-LEVEL ALTITUDES FOR TEST WELLS D,E,F,G,H, & I.

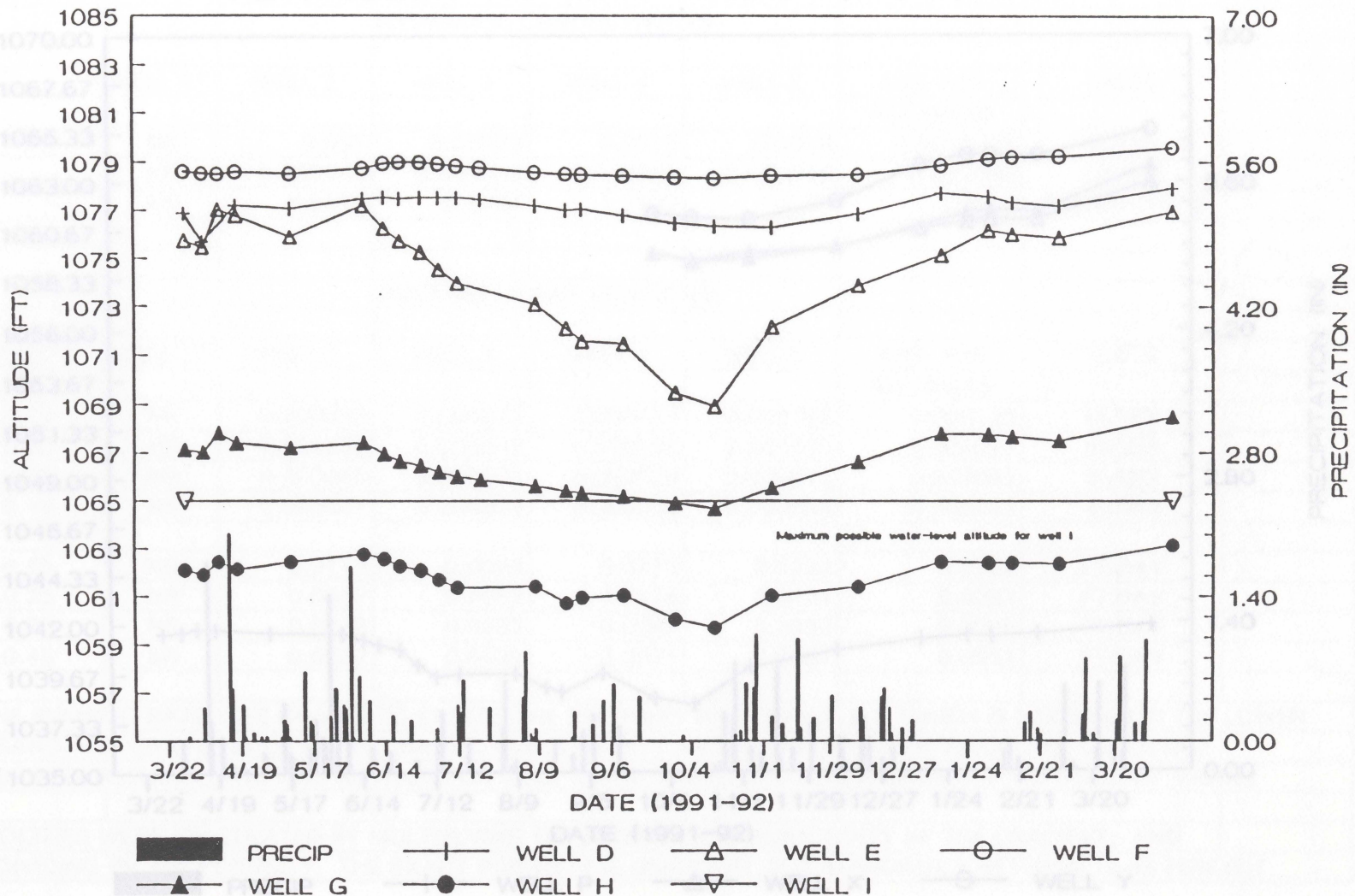


FIGURE 13 cont. PRECIP. AND WATER-LEVEL ALTITUDES FOR TEST WELLS P, X, Y, & Z.

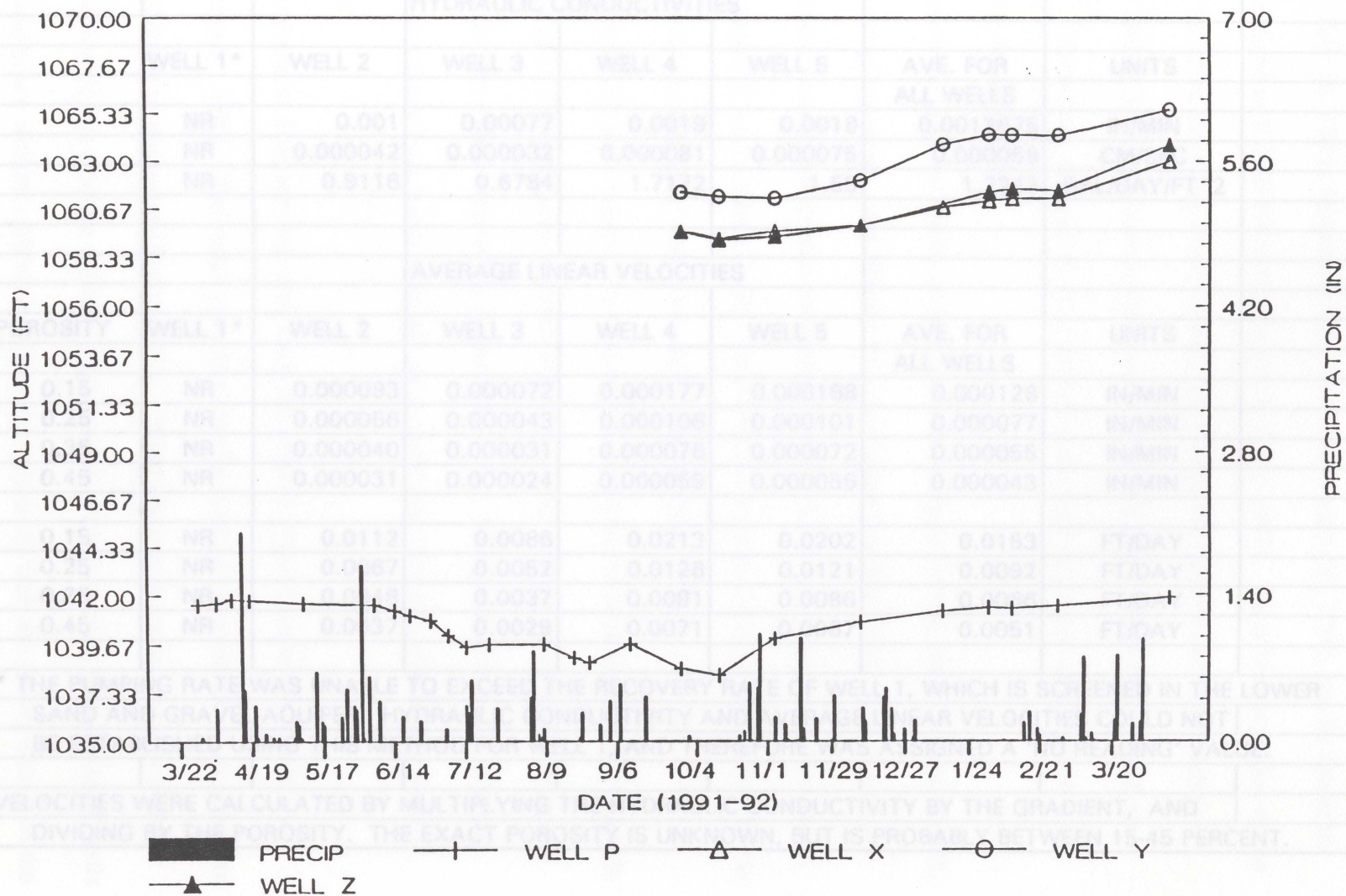


TABLE 3. RESULTS OF PUMP TESTS CONDUCTED JUNE 22, 1990, FOR HYDRAULIC CONDUCTIVITIES IN MONITORING WELLS 1-5, AND PROBABLE AVERAGE LINEAR VELOCITIES OF GROUND-WATER FLOW IN THE VICINITY OF THE LANDFILL CALCULATED FROM THE HYDRAULIC CONDUCTIVITIES.			
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			HYDRAULIC CONDUCTIVITIES					
	WELL 1*	WELL 2	WELL 3	WELL 4	WELL 5	AVE. FOR	UNITS	
						ALL WELLS		
	NR	0.001	0.00077	0.0019	0.0018	0.0013675	IN/MIN	
	NR	0.000042	0.000032	0.000081	0.000075	0.000058	CM/SEC	
	NR	0.9116	0.6784	1.7172	1.59	1.2243	GAL/DAY/FT^2	
			AVERAGE LINEAR VELOCITIES					
POROSITY	WELL 1*	WELL 2	WELL 3	WELL 4	WELL 5	AVE. FOR	UNITS	
						ALL WELLS		
0.15	NR	0.000093	0.000072	0.000177	0.000168	0.000128	IN/MIN	
0.25	NR	0.000056	0.000043	0.000106	0.000101	0.000077	IN/MIN	
0.35	NR	0.000040	0.000031	0.000076	0.000072	0.000055	IN/MIN	
0.45	NR	0.000031	0.000024	0.000059	0.000056	0.000043	IN/MIN	
0.15	NR	0.0112	0.0086	0.0213	0.0202	0.0153	FT/DAY	
0.25	NR	0.0067	0.0052	0.0128	0.0121	0.0092	FT/DAY	
0.35	NR	0.0048	0.0037	0.0091	0.0086	0.0066	FT/DAY	
0.45	NR	0.0037	0.0029	0.0071	0.0067	0.0051	FT/DAY	
* THE PUMPING RATE WAS UNABLE TO EXCEED THE RECOVERY RATE OF WELL 1, WHICH IS SCREENED IN THE LOWER SAND AND GRAVEL AQUIFER. HYDRAULIC CONDUCTIVITY AND AVERAGE LINEAR VELOCITIES COULD NOT BE ESTABLISHED USING THIS METHOD FOR WELL 1, AND THEREFORE WAS ASSIGNED A 'NO READING' VALUE.								
VELOCITIES WERE CALCULATED BY MULTIPLYING THE HYDRAULIC CONDUCTIVITY BY THE GRADIENT, AND DIVIDING BY THE POROSITY. THE EXACT POROSITY IS UNKNOWN, BUT IS PROBABLY BETWEEN 15-45 PERCENT.								

for samples collected on March 21, 1990; July 16, 1990; December 01, 1990; April 19, 1991; July 16, 1991; November 22, 1991; and March 06, 1992, can be found in year-end reports to KDHE (Oviatt and others, 1990; 1992). After interpretation of the results of the third sampling event, it was determined that analysis for herbicides, pesticides and PCBs, base neutral compounds, and acid compounds were no longer necessary. Therefore, analysis of these compounds were no longer requested in order to minimize analytical cost.

Accompanying the results of the chemical analyses for the second, third, fourth, and sixth sampling events, was Wilson labs Standard Chemical Water Analysis which gives computed results for certain parameters such as TDS, hardness, saturation index, and ionic strength (Appendices D-G). Total dissolved solids (TDS) ranged from 388 to 1652 ppm and the Langelier saturation index ranged from -0.92 to +0.71.

A Piper trilinear diagram and fingerprint diagrams of these waters are plotted in Figures 14 and 15 respectively to determine water type. Figure 14 is a Piper diagram including all major ions reported in Appendices D-G. Most waters at the landfill are calcium bicarbonate-type water although they grade into mixed to alkali bicarbonate-type water.

Fingerprint diagrams can also show the type of ground water in a particular system (Mazor, 1990). The water type of a sample is assigned using the most abundant cation and anion in the water (Terry, 1991). The ground water at the landfill and immediate vicinity, is calcium carbonate-type water, except for that in monitoring wells 4 and 8, which are sodium carbonate-type water, agreeing with the results shown in the

Figure 14. Piper trilinear diagram including all major ions analyzed in monitoring wells. Taken from Appendices D-G. Water types are predominately calcium bicarbonate and sodium bicarbonate. Dashed ovals indicate groupings outside the average chemistry at the landfill for monitoring wells 4, 5, and 6.

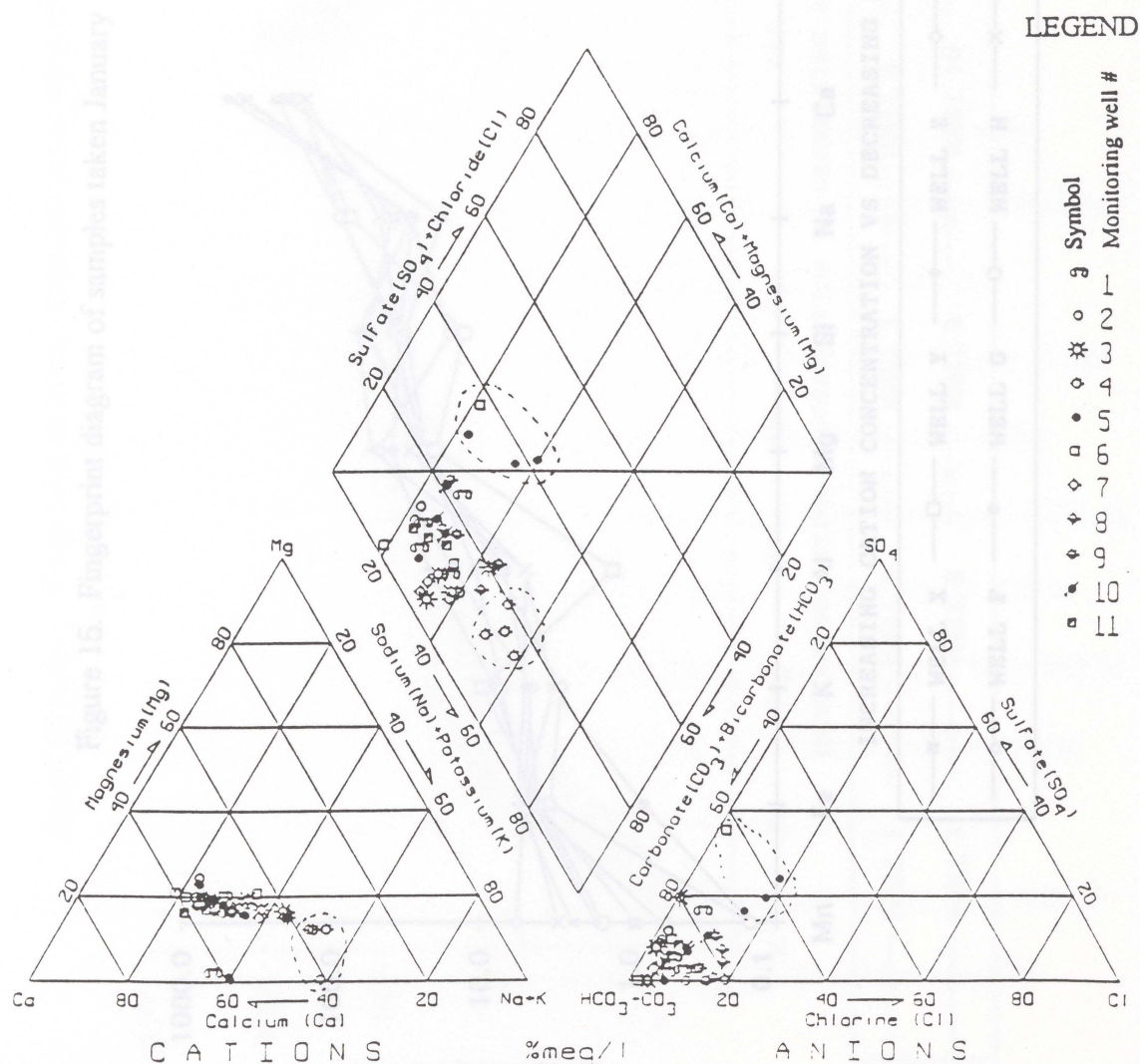


Figure 15 (cont.) Fingerprint diagram of samples taken April 19, 1991, for

Figure 15. Fingerprint diagram of samples taken January 14, 1992, for test wells.

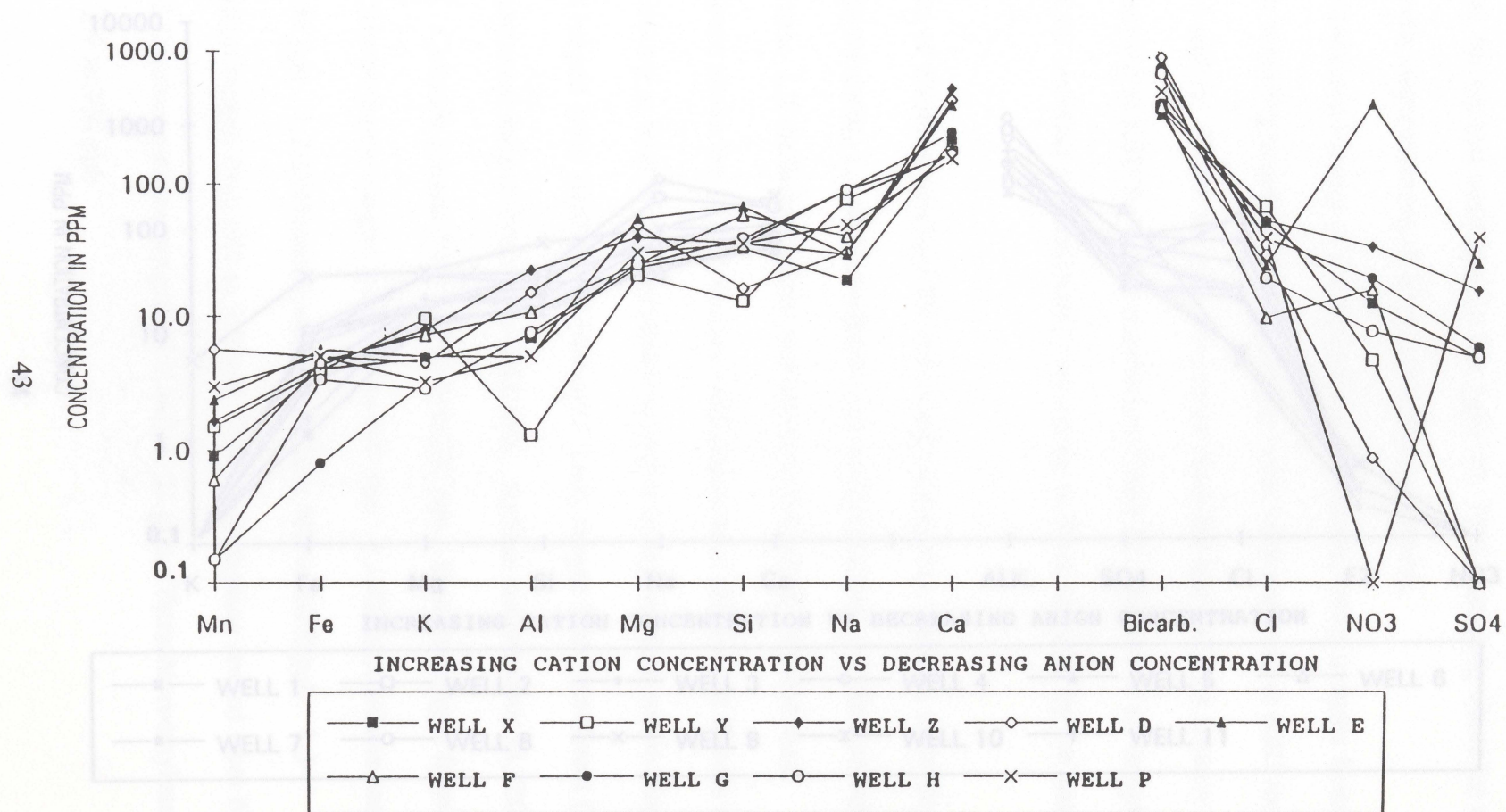
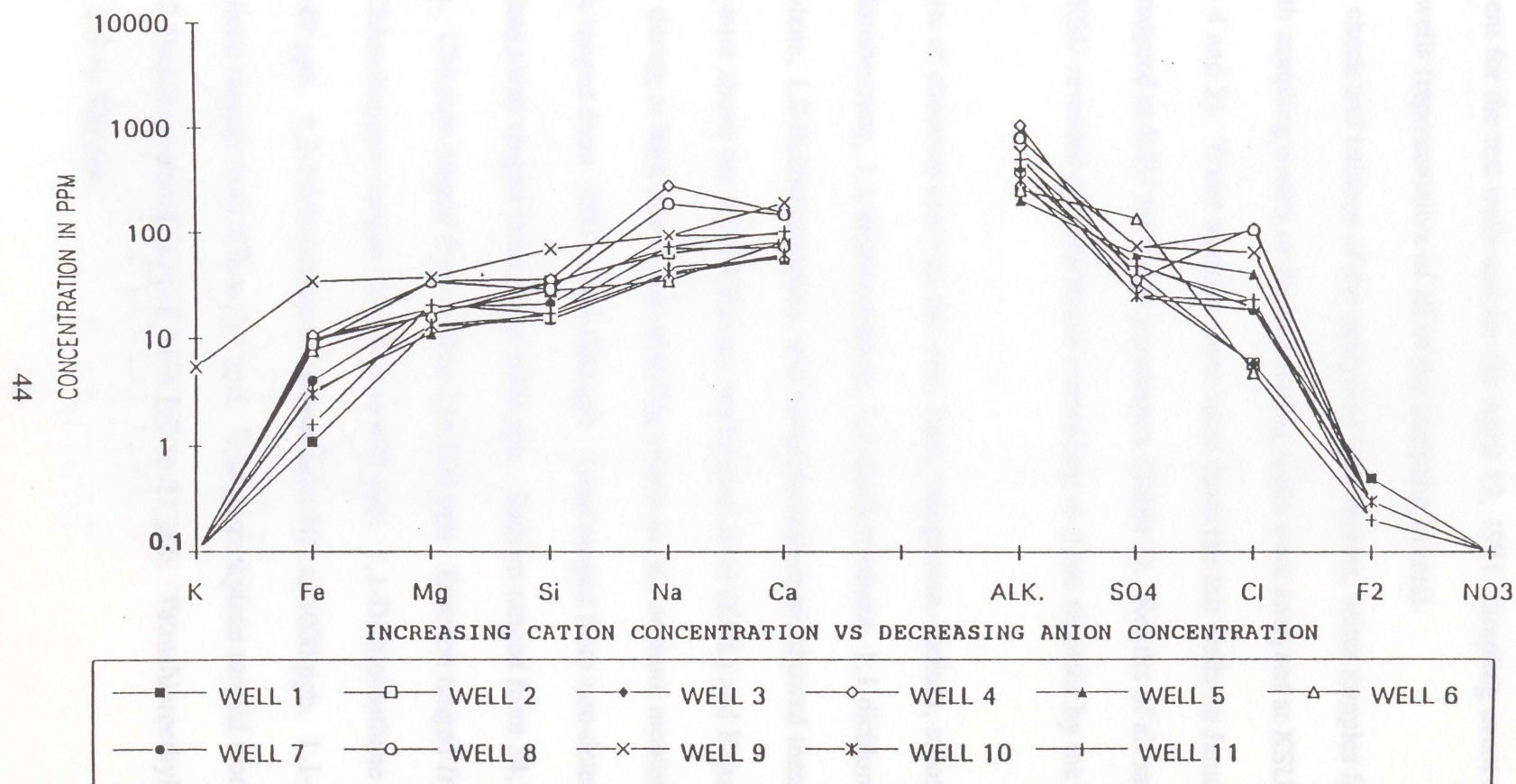


Figure 15 (cont.). Fingerprint diagram of samples taken April 19, 1991, for monitoring wells 1-11.



Piper diagram. Figure 15 contains fingerprint diagrams for the January 14, 1992, sampling event for the test wells and for the April 19, 1991, sampling event for the monitoring wells (representative of all of the sampling events).

As a check and balance of the analytical laboratories, water samples from the first and sixth sampling events of the monitoring wells were analyzed at KSU for major ions (Tables 4 and 5). Water samples were taken from the test wells on January 14, 1991, and analyzed at KSU for major parameters (Table 6). Results of all samples analyzed at KSU revealed concentrations resembling to those reported by the analytical laboratories.

Results of chemical analyses for iron, lead, manganese, sodium, chloride, benzene, chlorobenzene, 1,1-dichloroethane, 1,2-dichloroethane, 1,1-dichloroethylene, trichloroethylene, 1,2-dichloropropane, and tetrachloroethylene, showed these constituents were above the KDHE Kansas notification level (KNL) and Kansas action level (KAL) during at least one of the sampling events in one or more monitoring wells. Iron ranged from 1000 to 147,000 ppb. Lead ranged from non-detect (ND) to 232 ppb. Manganese ranged from 80 to 3600 ppb. Sodium ranged from 34,700 to 350,500 ppb. Chloride ranged from 400 to 216,000 ppb. Benzene ranged from ND to 4900 ppb. Chlorobenzene ranged from ND to 670 ppb. 1,1-Dichloroethane ranged from ND to 49 ppb. 1,2-Dichloroethane ranged from ND to 1000 ppb. 1,1-Dichloroethylene ranged from ND to 9.3 ppb. Trichloroethylene ranged from ND to 420 ppb. 1,2-Dichloropropane ranged from ND to 21 ppb. Tetrachloroethylene ranged from 2.9 to 320 ppb.

TABLE 4. CHEMICAL ANALYSIS OF MAJOR IONS. ANALYSES PERFORMED AT KSU.							
	SAMPLES TAKEN ON:		3/21/90				
Analytes	WELL 1	WELL 2	WELL 3	WELL 4	WELL 5	KAL	UNITS
-----	-----	-----	-----	-----	-----	-----	-----
TEMP. (FIELD)	13.3	12.5	12.8	11.3	12.8	-----	DEGREES C
pH (FIELD)	7.48	6.84	6.78	6.82	6.95	5.5-9.5	STND UNIT
MANGANESE	0.5	0.8	1.2	2	0.1	0.05	MG/L
IRON	0.88	1.69	6.25	2.25	1.69	0.3	MG/L
MAGNESIUM	16.9	32.6	12.9	49.6	15.7	-----	MG/L
POTASSIUM	35.8	42.9	19.4	58.2	19.7	-----	MG/L
SODIUM	64	118.6	131	1569.6	103.8	100	MG/L
CALCIUM	94.88	138	133	220.9	83.7	-----	MG/L
CHLORIDE	18.9	6.1	5.3	71.4	19.7	250	MG/L
SULFATE	3.6	16.2	11.2	2.9	21.9	250	MG/L
NITRATE	0.1	3.9	0.4	0.1	2.2	10	MG/L AS N
ND = NONE DETECTED; CATIONS ANALYZED ON ATOMIC ABSORPTION; ANIONS ANALYZED BY CHARLES GRAY, DEPARTMENT OF AGRONOMY.							

	SAMPLES TAKEN ON:		11/22/91					
Analytes	WELL 1	WELL 2	WELL 3	WELL 4	WELL 5	WELL 6	KAL	UNITS
TEMP. (FIELD)	13.0	14.4	14.0	12.0	13.0	12.9	-----	DEGREES C
pH (FIELD)	6.44	6.40	6.35	6.45	6.78	6.81	5.5-9.5	STND UNIT
CONDUCT. (FIELD)	0.48	0.37	0.51	0.95	0.55	0.40	-----	uS
RUBIDIUM	0.00	0.00	0.00	0.02	0.00	0.04	-----	MG/L
MANGANESE	0.30	0.06	0.06	0.12	0.60	1.92	0.05	MG/L
IRON	0.67	1.16	1.25	1.92	3.66	14.19	0.3	MG/L
POTASSIUM	5.50	2.70	2.40	5.80	4.40	12.90	-----	MG/L
MAGNESIUM	16.20	26.90	15.40	45.00	23.70	32.60	-----	MG/L
SODIUM	46.60	56.00	78.00	311.20	56.70	168.80	100	MG/L
CALCIUM	78.88	116.30	84.40	223.60	103.10	150.00	-----	MG/L
CHLORIDE	25.00	10.00	15.00	115.00	45.00	20.00	250	MG/L
NITRATE	0.44	1.76	0.44	1.32	7.92	1.76	10	MG/L AS N
SULFATE	ND	2.00	ND	ND	12.00	12.00	250	MG/L

ND = NONE DETECTED; CATIONS ANALYZED ON ATOMIC ABSORPTION; ANIONS ANALYZED USING A HACH KIT;

TABLE 5. CONT. CHEMICAL ANALYSIS OF MAJOR IONS. ANALYSES PERFORMED AT KSU.

	SAMPLES TAKEN ON:	11/22/91					
Analytes	WELL 7	WELL 8	WELL 9	WELL 10	WELL 11	KAL	UNITS
TEMP. (FIELD)	13.0	13.3	12.0	14.0	11.0	-----	DEGREES C
pH (FIELD)	6.74	6.70	6.61	6.30	6.10	5.5-9.5	STND UNIT
CONDUCT. (FIELD)	0.42	0.77	0.87	0.32	0.40	-----	uS
RUBIDIUM	0.00	0.00	0.00	0.00	0.00	-----	MG/L
MANGANESE	1.20	2.70	3.00	2.40	0.06	0.05	MG/L
IRON	4.71	2.04	0.49	1.45	0.61	0.3	MG/L
POTASSIUM	8.10	7.90	5.10	2.70	6.30	-----	MG/L
MAGNESIUM	26.60	39.60	41.60	18.20	24.20	-----	MG/L
SODIUM	104.40	237.40	158.20	50.10	57.60	100	MG/L
CALCIUM	145.30	198.30	225.00	106.90	145.30	-----	MG/L
CHLORIDE	15.00	137.50	117.50	25.00	27.50	250	MG/L
NITRATE	0.44	0.44	0.44	0.44	0.88	11	MG/L AS N
SULFATE	ND	5.00	ND	2.00	ND	250	MG/L

ND = NONE DETECTED; CATIONS ANALYZED ON ATOMIC ABSORPTION; ANIONS ANALYZED USING A HACH KIT.

Table 6. Chemical analysis of major ions performed at KSU for test wells and their average, compared compared to the average of all five water samples collected from monitoring well 6.

[illegible]

Concentrations for iron, lead, sodium, and chloride have been plotted in Figure 16 for all seven sampling events for monitoring wells 1-5, and five sampling events for monitoring wells 6-11. Concentrations for all eight of the organics above KAL have been plotted in Figure 17, which shows the variation of each constituent within each well.

Separate samples were collected from the monitoring wells during sampling events 2-7 and analyzed at the KSU Department of Public Safety for ^3H , ^{14}C , and ^{32}P , so that a radiological survey of the wells could be conducted (Figure 18, Appendix H). Tritium was the only one of the three constituents that gave results higher than background. Monitoring wells 4, 8, and 9 consistently have tritium levels above background, but well below the KAL of 6600 disintegrations per minute (Figure 18). Ground-water temperatures from December, 1990, to November, 1991, are plotted in Figure 19 showing a range of $10^\circ - 30^\circ \text{C}$.

DISCUSSION

Interpretation of hydrogeology

Well logs from the 24 water-wells (Oviatt and others, 1992; Table 2), drilled in the Quaternary deposits for this investigation, show many similarities to previous descriptions of these deposits (Beck, 1961; Moulthrop, 1963; Fader, 1974). The sediments are reddish-brown heterogeneous silty clays grading downward to tannish-

Figure 16. Concentration of Pb, Fe, Na, & Cl for seven sampling events.

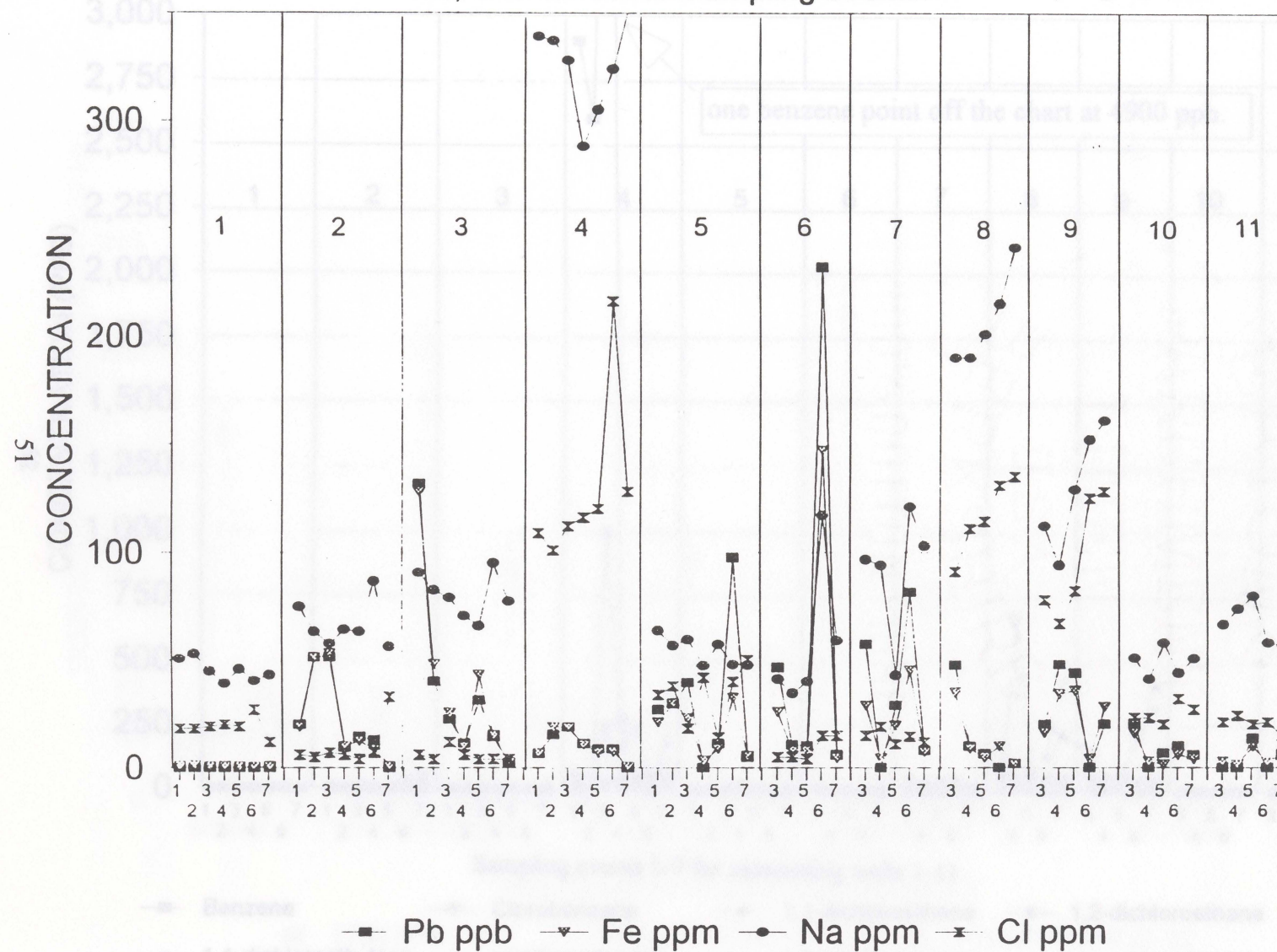




FIGURE 18. RADIOACTIVITY ANALYSIS
ARROW = APPROX. BACKGROUND LEVEL

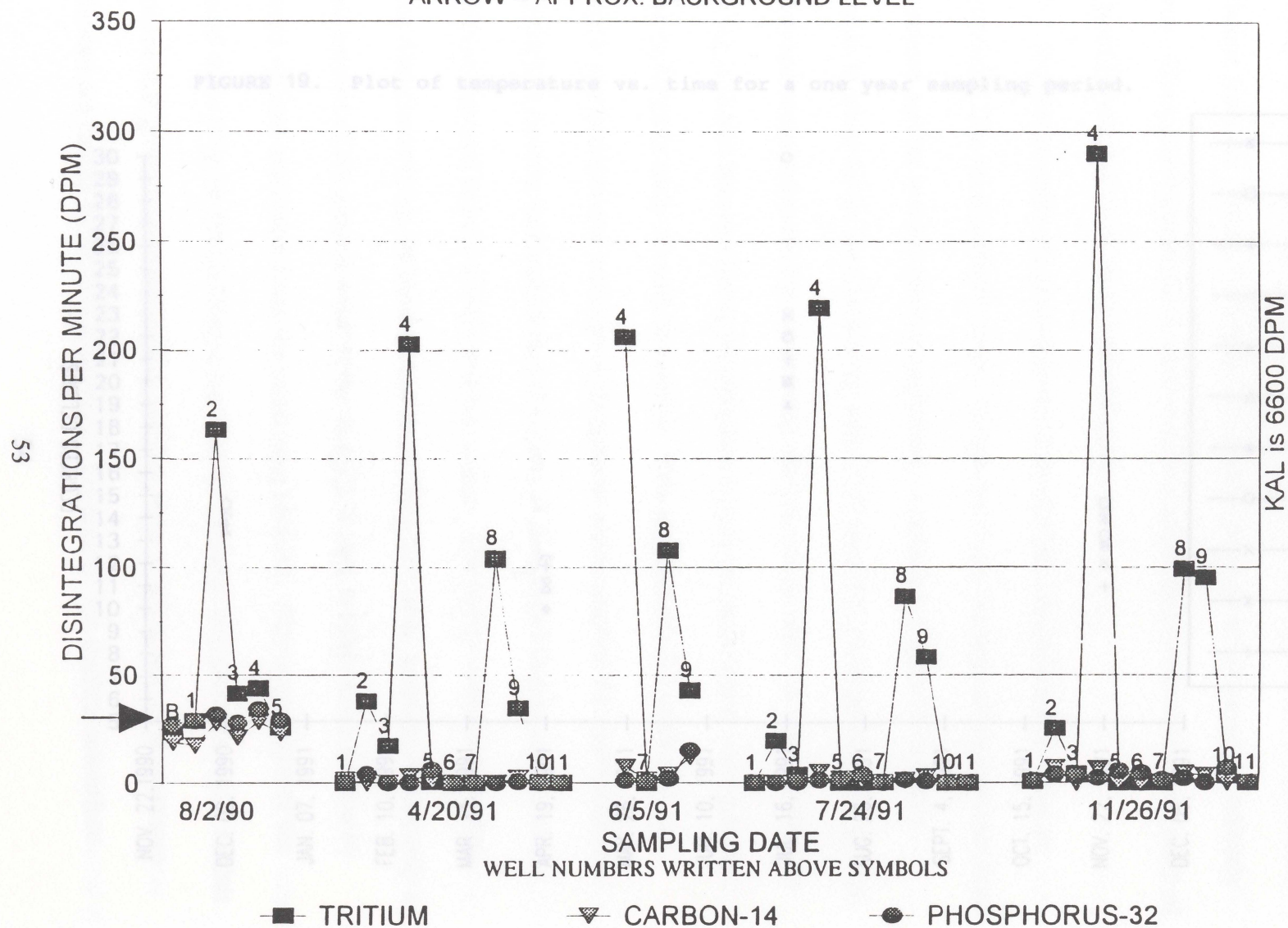
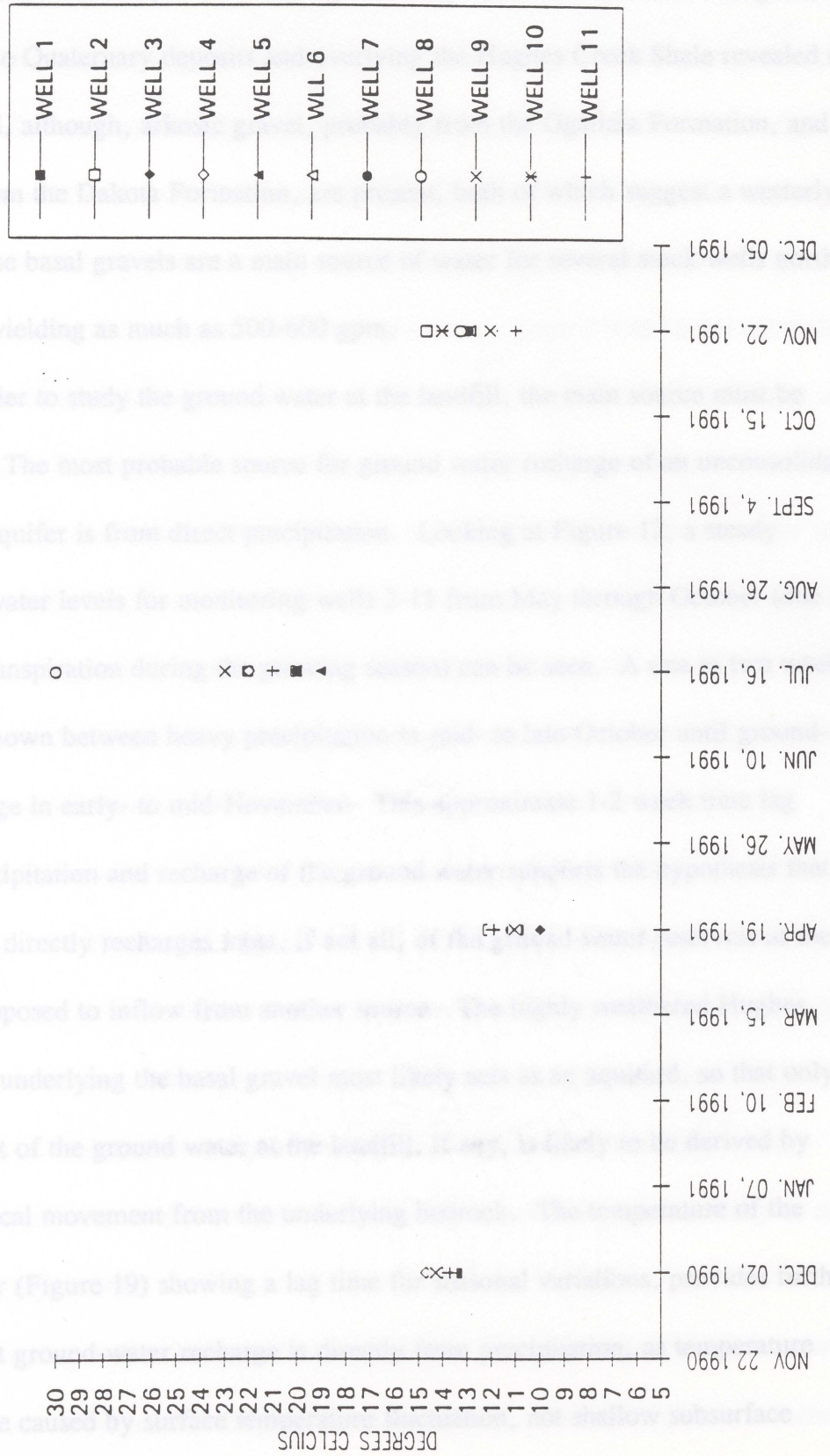


FIGURE 19. Plot of temperature vs. time for a one year sampling period.



brown silty sands. A sample taken during this study from the basal sand and gravel underlying the Quaternary deposits and overlying the Hughes Creek Shale revealed no glacial gravel, although, arkosic gravel, probably from the Ogallala Formation, and sandstone from the Dakota Formation, are present, both of which suggest a westerly source. These basal gravels are a main source of water for several stock wells north of the landfill, yielding as much as 500-600 gpm.

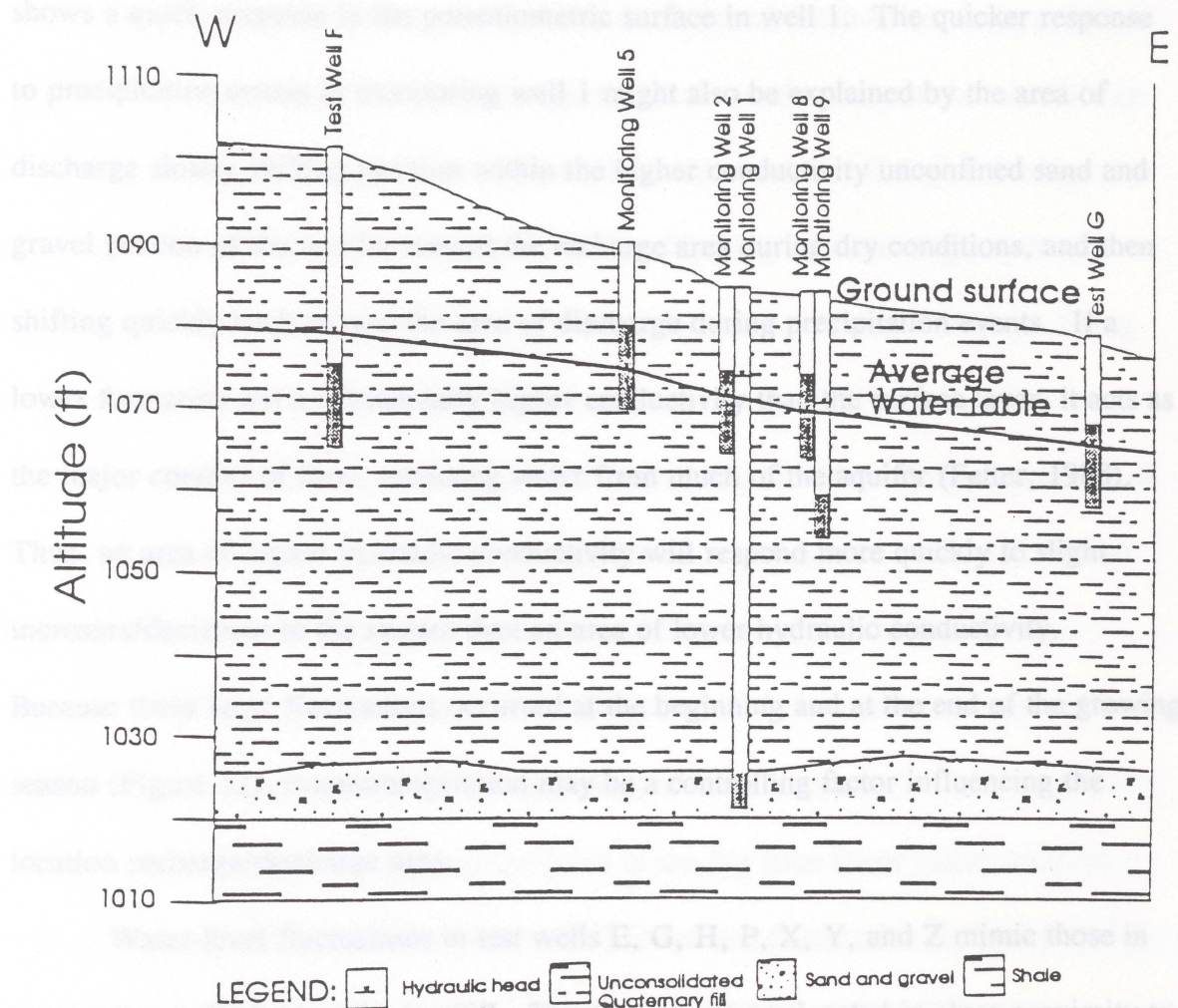
In order to study the ground water at the landfill, the main source must be determined. The most probable source for ground water recharge of an unconsolidated unconfined aquifer is from direct precipitation. Looking at Figure 12, a steady decrease in water levels for monitoring wells 2-11 from May through October (due to high evapotranspiration during the growing season) can be seen. A one to two week time lag is shown between heavy precipitation in mid- to late-October until ground-water recharge in early- to mid-November. This approximate 1-2 week time lag between precipitation and recharge of the ground water supports the hypothesis that precipitation directly recharges most, if not all, of the ground-water reservoir at the landfill as opposed to inflow from another source. The highly weathered Hughes Creek Shale underlying the basal gravel most likely acts as an aquitard, so that only a small amount of the ground water at the landfill, if any, is likely to be derived by upward vertical movement from the underlying bedrock. The temperature of the ground water (Figure 19) showing a lag time for seasonal variations, provides further evidence that ground-water recharge is directly from precipitation, as temperature variations are caused by surface temperature fluctuation, not shallow subsurface

temperature fluctuations.

Once the source for ground water was determined, ground water movement was studied. As discussed previously, it was explained that horizontal movement of ground water at the landfill was to the southeast and northeast, with a low ground-water divide occurring in the vicinity of monitoring wells 2 and 10. Vertical movement of ground water is less simple to determine. In certain places in a ground water potential field, in adjacent wells of different depths, there will be a higher water level in the deeper well. Here, the hydraulic potential increases with depth, indicating upward flow, hence a discharge area (Fetter, 1988). This situation exists at the landfill when the water level in monitoring well 1 (screened from 58.3-63.3 ft) is higher than the water level in the adjacent monitoring well 2 (screened from 10-20 ft), and when the water level in monitoring well 9 (screened from 25-30 ft) is higher than the water level in adjacent monitoring well 8 (screened from 10-20 ft). The one time the water level in the existing well (screened from 32-67 ft) was checked, it was higher than the water level in monitoring well 10 (screened from 10-20 ft) located approximately 10 ft south of the existing well. This shows that the hydraulic potential increases with depth, indicating an upward flow (Figure 20) (Fetter, 1988). Thus, the landfill is situated in a discharge area which causes an upward component of flow in the vicinity of the landfill. The hill west of the landfill, monitored by test well F, is most likely an area of recharge (Figure 20).

Monitoring well 1 fluctuates more quickly in response to precipitation events than other wells at the landfill (Figure 12, Appendix B). Because well 1 is screened at

Figure 20. Schematic cross section from test well F on the west to test well G on the east and running through the landfill. Screening intervals and depths, average hydraulic head, and average water table reveal an upward component of flow in the vicinity of the landfill.



a depth of 58.3-63.3 ft it is under greater pressure than the wells screened at a depth of 10-20 ft. Therefore, a precipitation event may only show a gradual increase of the water table in wells 2-11 as the water moves from the surface down to the water table after a lag time has occurred, whereas the added pressure by this addition to the system shows a quick response in the potentiometric surface in well 1. The quicker response to precipitation events in monitoring well 1 might also be explained by the area of discharge slowly shifting position within the higher conductivity unconfined sand and gravel portion of the aquifer toward the recharge area during dry conditions, and then shifting quickly back toward the area of discharge during precipitation events. If a lower formation has a substantially higher conductivity than the surface layer, it acts as the major conduit of flow, attracting water from much of the aquifer (Fetter, 1988). Thus, an area of higher hydraulic conductivity will respond more quickly to slight increases/decreases to the system than an area of lower hydraulic conductivity. Because these large fluctuations occurred at the beginning and at the end of the growing season (Figure 12), evapotranspiration may be a controlling factor influencing the location recharge/discharge area.

Water-level fluctuations in test wells E, G, H, P, X, Y, and Z mimic those in monitoring wells 2-11 at the landfill. These test wells are located in close proximity to intermittent streams or drainage ditches and would be expected to respond fairly quickly to precipitation events (Figure 13). Test well D is located on the down-gradient edge of a large paved parking lot which inhibits downward infiltration of precipitation and therefore prevents the water table from revealing large fluctuations

(Figure 13). Test well F is located at the summit of a major drainage divide, adjacent to a large building, and the majority of precipitation in this area is most likely diverted by the adjacent structure or lost to overland flow prior to infiltration, thus preventing large fluctuations of the water table at this well (Figure 13).

The rate of ground water movement is fundamental when determining an area's suitability for use as a landfill. The average hydraulic conductivity at the landfill was determined to be 1.4×10^{-3} in./min using the Hvorslev method. Using an average saturated thickness of 51 ft for the aquifer and multiplying by the average hydraulic conductivity, the transmissivity at the landfill was calculated to be 8.7 ft²/day. Using the average hydraulic conductivity and assuming a porosity of 35 percent, the average linear velocity was calculated to be 0.0066 ft/day (Table 3). Most likely, a porosity of 35 percent is greater than the average porosity of the upper portion of the aquifer and therefore the above calculations for ground-water flow would be the maximum expected. This shows that flow rate of the ground water in immediate contact of the landfill is very low and inhibits quick movement of contaminants.

Gregory and Beck (1968) reported that in the Big Blue River valley south of Tuttle Creek Reservoir, the water table is both lower and flatter after dry spells than after rainy periods. This has not been the case at the KSU landfill. By comparing the maximum water-table contour map (Figure 10) and the minimum water-table contour map (Figure 11), it can be seen that during rainy periods (Figure 10) the water table is gently dipping and during dry spells (Figure 11) there is an appreciable slope. Evapotranspiration may play a significant role in causing the steeper slope during

periods of low precipitation. According to Gregory and Beck (1968), the highest water-table level in 1966 was reached in mid-October, after the growing season; the lowest level was during April, just before the growing season and during below-normal precipitation. During my study, the highest water-level readings were taken on April 08, 1992; the lowest levels were on October 16, 1991, opposite of Gregory and Beck's observations. This can be explained by the fact that the observation wells being used by Gregory and Beck were located in the Big Blue River valley in either the Newman terrace deposits or the modern alluvium at a lower elevation than the Quaternary deposits at the landfill. The closer proximity to the area of discharge and the far below-normal precipitation for 1966 (total of 15 inches) may have caused this reversal. Therefore, the Big Blue River changed from a gaining stream to a losing stream, reversing the direction of flow near the river and smoothing the slope of the water table. During my study, the annual precipitation was only 4.5-8.5 inches below average (National Climatic Data Center, 1992).

In 1966, Beck calculated the transmissivity in two wells in Riley County to be 17,300 ft²/day (Fader, 1974). Fader (1974) calculated transmissivities ranging from 5,300 to 48,000 ft²/day for 18 wells in valley-fill deposits in the Kansas River valley. These results cannot be directly compared to the transmissivity of 8.7 ft²/day determined at the landfill due to the difference in hydrogeologic settings. Tests conducted by Beck and Fader were conducted in wells with large screening intervals, some of which included the higher conductivity sand and gravel portion of the aquifer, whereas tests at the landfill did not. Pump tests on monitoring wells 1 (which is

screened in the basal sand and gravel) were not performed because the transmissivity exceeded the pumping rate, and drawdown in the well did not occur.

Comparatively, the low transmissivity at the landfill and the distance to the nearest private well or surface drainage warranted using the site as a disposal area for hazardous chemical and radioactive waste. Low rates of horizontal ground water flow and an upward component of flow in the area of the landfill help to impede contaminant transport towards the ephemeral stream or downward to the sand and gravel aquifer.

Interpretation of major chemical constituents

In order to determine the major ground water chemistry at the landfill, the ground water chemistry of the unaffected surrounding area was studied. Water samples taken from test wells on January 14, 1992, were analyzed for major ions at KSU. The results for each ion analyzed for each well were averaged so that a standardized concentration for the major ions would be known (Table 6). Nitrate analysis for one sample (test well E) was not used in the average because it was contaminated (Table 6). Test well E was located less than 50 ft directly down-gradient of a septic tank (Clarence Swallow, personal communication, 1992) which most likely contaminated the water sample with over 400 ppm nitrate (Table 6). Test wells X, Y, and Z, are not located in the same drainage basin as the other test wells, and have slightly different chemical signatures (Figure 15). The pH for test wells X, Y, and Z averaged 7.3 while the

other test wells have an average pH of 6.7 (Table 6). Chloride concentrations ran higher for these three test wells (Table 6). These three wells are situated very close and down gradient from Bluemont Hill and may receive a significant amount of recharge from limestone aquifers in the Council Grove group (Figure 6), which could account for the higher pH. Thin shale layers within the limestone aquifers might account for the higher chloride concentrations. Test well P (which is located a substantial distance north of the other test wells) was drilled through a different soil type, and was much shallower than the other test wells (Table 2) which may explain its slightly different chemical signature (Table 6). Sulfate was detected at much higher concentrations in test well P than in any other test wells (Table 6). One possibility for the higher sulfate concentrations (although it has not been corroborated) could be from biochemistry studies on plants being conducted by the KSU Agronomy Department on small plots of farm land less than 200 ft southwest of the well.

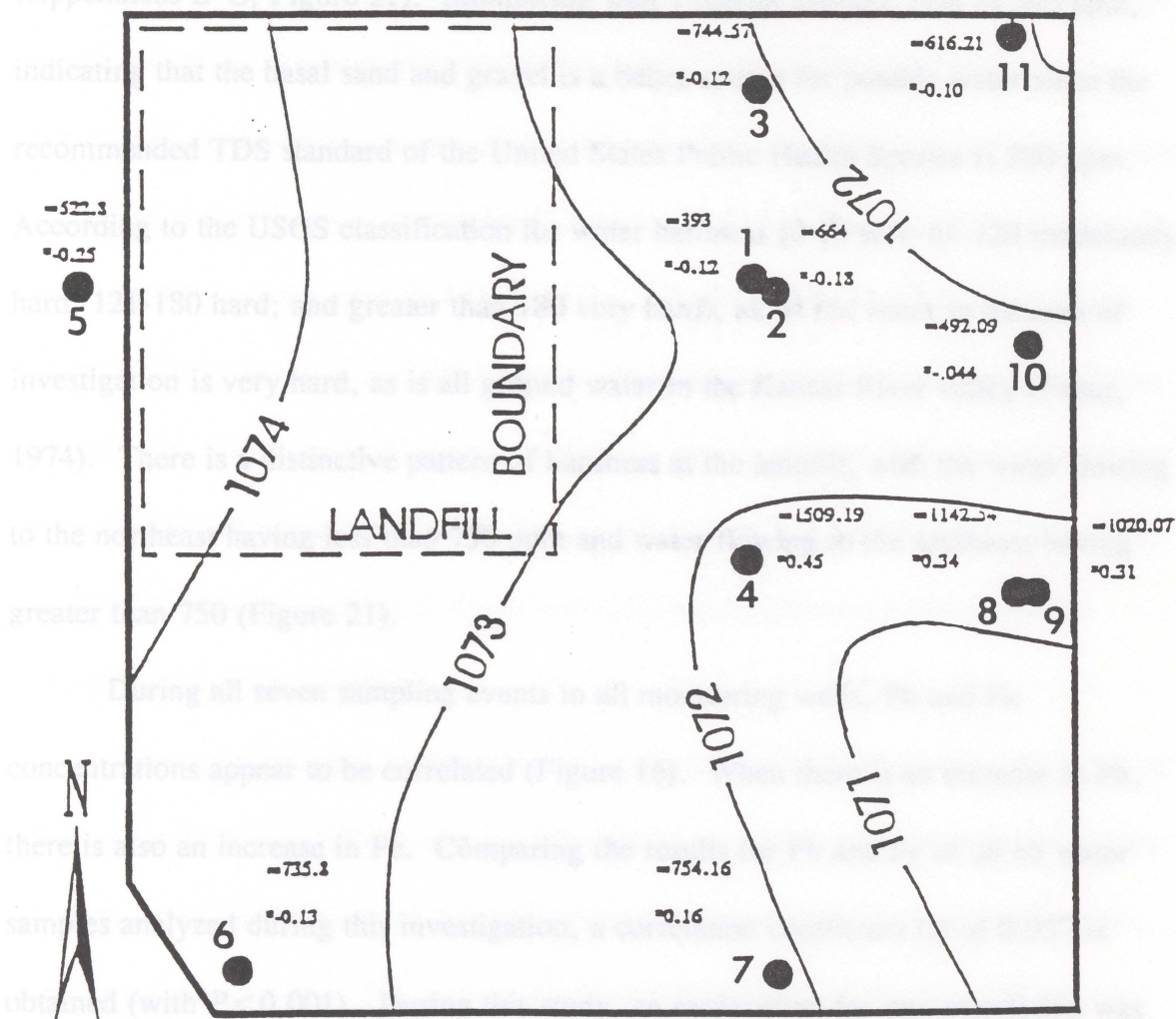
The results from the test wells were directly compared to monitoring well 6 which was installed upgradient of the landfill. Averaging the major ions in monitoring well 6 for all sampling events resulted in concentrations similar to the test wells major ion average results, implying that well 6 could in fact be used as a background well for water chemistry at the landfill (Table 6). High concentrations of iron, manganese, and potassium detected in well 6 on November 22, 1991, and a high average for sulfate, may negate this well from being used as a background well in the future (Table 6). However, because of the position of monitoring well 6 relative to the burial area, it is not likely that the source of these metals or sulfate was the landfill. With the data

available, an alternate source for the high metals and average sulfate concentrations could not be determined. Additional information revealing that monitoring well 6 has not been adversely affected by the landfill is revealed in the Piper diagram (Figure 14). The diagram shows small groupings outside the main groupings at the landfill for monitoring wells 4, 5, and 6. This diagram indicates that wells 5 and 6 are outside and upgradient from the landfill trenches and that they have not been as affected by the landfill as has well 4, which has been the most affected.

The concentrations of major ions analyzed from the monitoring well samples were compared against the average concentrations found in the test wells. The concentrations of major ions from the monitoring wells had such a high degree of fluctuation between each sampling event that a direct comparison to the test well concentrations could not be made, and trends in spatial or seasonal variations could not be detected. Therefore, certain parameters of the Standard Chemical Water Analysis (Appendices D-G) and the fingerprint diagrams (Figures 15 and 15 cont.) were used to interpret the hydrochemistry of the landfill.

The Langelier saturation index is calculated as the water pH minus the saturation pH. A Langelier saturation index of zero indicates calcium carbonate equilibrium, or a stable water. A negative saturation index indicates a tendency to dissolve calcium carbonate. A positive value indicates a tendency to deposit calcium carbonate. Only monitoring wells 4, 7, 8, and 9, have Langelier saturation indexes that indicate CaCO_3 will precipitate (Appendices D-G; Figure 21). The highest potential for CaCO_3 precipitation was in monitoring well 4 and the potential decreased

Figure 21. Plot of Standard Chemical Water Analysis (Appendices G-J) averages for those parameters showing spatial trends. Water flowing to the southeast is distinctively more highly mineralized than water flowing to the northeast, and has more potential for precipitation of calcium carbonate.



= TDS (ave)

* Langelier Saturation Index (ave)

with distance and depth as ground water flowed to wells 8 and 9 (Figure 21).

The TDS at the landfill ranged between 490-750 ppm near the water table, except for monitoring wells 4, 8, and 9, which averaged between 1000-1500 ppm. TDS decreases with distance and depth in the direction of ground-water flow (Appendices D-G; Figure 21). Monitoring well 1 had an average TDS of 390 ppm, indicating that the basal sand and gravel is a better source for potable water since the recommended TDS standard of the United States Public Health Service is 500 ppm. According to the USGS classification for water hardness (0-60 soft; 61-120 moderately hard; 121-180 hard; and greater than 180 very hard), all of the water in the area of investigation is very hard, as is all ground water in the Kansas River valley (Fader, 1974). There is a distinctive pattern of hardness at the landfill, with the water flowing to the northeast having less than 750 ppm and water flowing to the southeast having greater than 750 (Figure 21).

During all seven sampling events in all monitoring wells, Pb and Fe concentrations appear to be correlated (Figure 16). When there is an increase in Pb, there is also an increase in Fe. Comparing the results for Pb and Fe of all 65 water samples analyzed during this investigation, a correlation coefficient (r) of 0.957 is obtained (with $P < 0.001$). During this study, an explanation for this correlation was not determined.

The basal gravels underlying the landfill are principally composed of chert and limestone fragments with arkosic gravels also present. Soluble minerals such as gypsum and halite were probably not deposited with these sediments. The relatively

large reservoir of the water in the saturated alluvium of the Quaternary fill at the landfill could act to buffer any significant changes in hydrochemistry of the basal sand and gravel.

The fingerprint diagrams (Figure 15) plotted for all seven sampling events show that the ground water at the landfill and immediate vicinity, is calcium carbonate-type water, except for that in monitoring wells 4 and 8, which is sodium carbonate-type water. The concentration of ions were arranged with increasing order of cations versus decreasing order of anions so that simple chemical imprint lines might be obtained and pattern differences between the lines on the diagrams could be seen (Mazor, 1990).

There is a large range in concentrations of major ions considering the very small area (40,000 ft²). This is most likely due directly to the constituents that were disposed of at the landfill. The churning affect, that would have occurred during the disposal process, of topsoil and the underlying unconsolidated sediments could have also influenced the major chemistry.

The hydrochemical evolution of ground water in the buried valley deposits and alluvium in Farley's (1987) southeast Marshall County study appears to be dominated by dissolution-precipitation of carbonate minerals such as calcite and dolomite under open system conditions. This is most likely also the case at the landfill. Water samples collected from the buried valley deposits studied by Farley (1987) are calcium bicarbonate type water and the pH range is 6.98 to 7.10. Ground water in the alluvium is similar to ground water in the buried valley having calcium bicarbonate type water with TDS of about 300 ppm (Farley, 1987), similar to that in monitoring wells 1, 2, 3,

5, 6, 7, 10, and 11. The type of rocks the water interacts with may be deduced from the cations in the ground water, i.e., calcium-dominated water has passed limestone, calcium- and magnesium-dominated bicarbonate water has passed dolomite (Mazor, 1990).

Hydrochemical data from Farley's (1987) study indicate that ground water sampled from the buried valley and glacial deposits showed no systematic temporal variations in response to changes in wet or dry climate conditions (Farley, 1987). The relatively constant hydrochemistry of the buried valley waters is most likely due to the deep burial of the aquifer by glacial drift (Farley, 1987). The time required for recharge waters to reach these deposits acts to buffer changes in the hydrochemistry. The absence of significant temporal changes in the hydrochemistry of the glacial sediments is related to the low ground-water velocities and slow recharge rate (Farley, 1987). This is not the case at the landfill where there are large variations in hydrochemistry throughout the year, most likely due to the shallow burial at the landfill. A severe drought would most likely cause a large change in the hydrochemistry at the landfill. If the water table dropped below the bottom boundary of the landfill, the landfill would most likely not be a major influence on the water chemistry and the large range in concentrations of the major ions would become less prevalent.

Results of radioactive analysis of ground water from the monitoring wells revealed concentrations well below established actions levels (Figure 18; Appendix H). The fact that certain monitoring wells (monitoring wells 4, 8, and 9) have

concentrations above background while others do not is evidence that a minimal amount of radioactivity in the ground water can be directly attributed to the disposal of low-level radioactive waste at the landfill. The detectable concentrations being confined to the southeast flow path can most likely be attributed to the area of disposal of the low-level radioactive waste being south of the low ground water divide between monitoring wells 2 and 10.

Interpretation of organic constituents

Concentrations of organic constituents in the ground water at the landfill of greatest concern have been plotted in Figure 17. Most of these contaminants were disposed of as solvent wastes from various KSU departments. The highest detection for all of the organic constituents has been concentrated in the southeastern flow path at the landfill through monitoring wells 4, 8, and 9 (Figures 9 and 17). The most likely explanation for this is that the containers of organic solvents were buried to the south of the low ground water divide in the vicinity of monitoring wells 2 and 10.

The highest concentration of organics was from benzene, which was detected as high as 4900 ppb in monitoring well 4, far above the KAL of 5.0 ppb (Figure 17). The only other organic constituent detected above 500 ppb was 1,2-dichloroethane in monitoring wells 4 and 8 (Figure 17). The concentration of benzene dropped substantially from December, 1990 to the most recent sampling event in March, 1992 (Figure 17). This decrease seems to be directly related to the decrease in precipitation,

and the decrease in water-level readings. A plot of benzene concentration, water-level readings in well 4, and precipitation for approximately two years is shown in Figure 22. Several large precipitation events during July 1990, prevented the water level in monitoring well 4 from dropping, and the benzene concentration remained high. During July 1991, there were no large precipitation events and the water level and benzene concentration in monitoring well 4 dropped significantly. The containers in which the benzene was disposed may be only leaking from the top portions of the containers. If the containers are buried at such a level that benzene can only flow out when the water table is above a certain altitude (approximately 1,072 ft) a significant benzene plume will form only during high water-table levels. Therefore, spatial and temporal variation in the concentration of the organics could be attributed to unequal dispersement of the chemicals as they leak from their source. Therefore, the high concentration of benzene detected early in the study may have: 1) migrated past the landfill fence, and was not detected at high concentrations in monitoring wells 8 and 9 because of the timing of the sampling events; 2) been retarded, and has not yet reached wells 8 and 9; or 3) multiple plumes migrated through the landfill quickly, possibly each time a different container at the landfill released its contents. Changes in the concentrations during each sampling event may be due to differential plume migration.

Taking the relatively low hydraulic conductivity of the upper portion of the aquifer and the fact that montmorillonitic clay is located in at least the top two feet of the sediments (Soil Conservation Service, 1975), it is most likely that the core of the plume has not yet reached monitoring wells 8 and 9. Using the average linear velocity

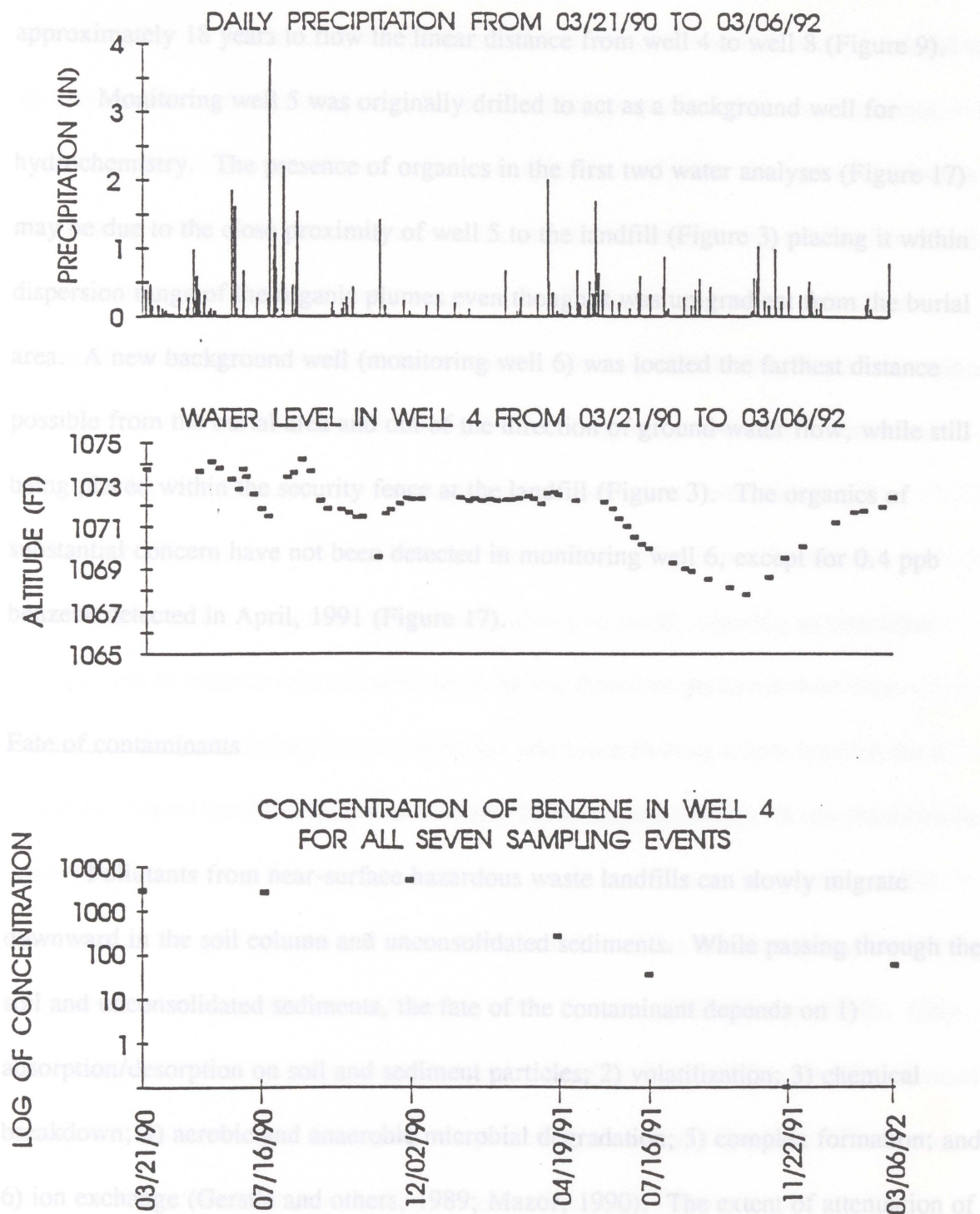


FIGURE 22. COMPARISON OF DAILY PRECIPITATION, WATER-LEVEL READINGS IN WELL 4, AND CONCENTRATION OF BENZENE IN WELL 4.

for well 4 assuming a 35 percent porosity (Table 3), it would take the ground water approximately 18 years to flow the linear distance from well 4 to well 8 (Figure 9).

Monitoring well 5 was originally drilled to act as a background well for hydrochemistry. The presence of organics in the first two water analyses (Figure 17) may be due to the close proximity of well 5 to the landfill (Figure 3) placing it within dispersion range of the organic plumes even though it was up-gradient from the burial area. A new background well (monitoring well 6) was located the farthest distance possible from the burial area and out of the direction of ground-water flow, while still being placed within the security fence at the landfill (Figure 3). The organics of substantial concern have not been detected in monitoring well 6, except for 0.4 ppb benzene detected in April, 1991 (Figure 17).

Fate of contaminants

Pollutants from near-surface hazardous waste landfills can slowly migrate downward in the soil column and unconsolidated sediments. While passing through the soil and unconsolidated sediments, the fate of the contaminant depends on 1) absorption/desorption on soil and sediment particles; 2) volatilization; 3) chemical breakdown; 4) aerobic and anaerobic microbial degradation; 5) complex formation; and 6) ion exchange (Gerstle and others, 1989; Mazor, 1990). The extent of attenuation of a pollutant is dependent on the soil and sediment type, hydrogeologic conditions, and the type of contaminant (Patrick, 1987). The rate and amount of contaminant

penetration through the unsaturated zone is controlled by 1) the extent of sorption to soil and sediment particles; 2) the thickness and nature of the vadose zone as related to its clay content and organic matter; 3) the chemical properties of the contaminants, especially their water solubilities; and 4) precipitation and water management (Gerstle and others, 1989). Humic substances in the soil and sediments may exhibit functional groups which absorb or partition contaminants. When contaminants reach a depth at which biotic activity is retarded, clay mineral surfaces dominate the abiotic interactions of organic pollutants (Gerstle and others, 1989). Clay-mineral surface interactions during downward migration play a major role in contaminant retardation and breakdown (Gerstle and others, 1989; Sposito, 1989). Clay minerals such as montmorillonite (2:1 clay mineral) have the ability to swell, allowing an interlayer surface area to interact with contaminants and are therefore preferred over clay minerals such as kaolinite (1:1 clay mineral) when determining a new location for a hazardous waste landfill (Gerstle and others, 1989; Sposito, 1989). It can therefore be seen that because of different types of interactions, contaminants do not flow at the same rate as the ground water, and in some cases, beneficial reactions can occur during contaminant transport (Gerstle and others, 1989; Sposito, 1989; Mazor, 1990). Clay mineralogy, humic substances, and microbial activity at the landfill were not examined during this study but most likely play a significant role in their fate here. These areas could be the focus of detailed studies at the landfill in the future.

Because alluvial material usually does not have equal permeability either horizontally or vertically, and the monitoring wells at the landfill are screened over a

ten-foot interval, the concentrations and rate of migration of contaminants is an average over potentially a ten-foot thickness. Contaminants could be flowing at different rates at different elevations within the screened interval. Because the sediments in which the landfill is situated have, on the average, a very low permeability, and may contain a high content of montmorillonitic clay, it is unlikely that contaminants are moving very far horizontally or vertically from the site.

Water samples taken from within the landfill security fence are considerably more highly mineralized than those of the surrounding sediments. Ground water at the landfill can be divided into three chemically distinct areas. The sand and gravel portion of the aquifer is relatively low in TDS and hardness, and organic contaminants have not been detected. This can be attributed to its depth and the fact that there is an upward component of flow in the vicinity of the landfill which inhibits the downward migration of contaminants. It is very unlikely that the landfill could ever affect this portion of the aquifer. Ground water flowing to the southeast has higher TDS, is harder, and more likely to precipitate CaCO_3 than water flowing to the northeast. Shallow ground water flowing to the southeast also has higher concentrations of organic contaminants than the shallow water flowing to the northeast. The hydrochemical difference between flow to the northeast and southeast at the landfill may be associated with the proximity of the burial trenches, but this has not been determined.

CONCLUSIONS

Concentrations of four inorganic and eight organic constituents were detected above the KAL in one or more of the monitoring wells at the landfill. Sample analysis from the test wells located outside the landfill revealed similar chemical signatures as previously studied buried river valleys. Based on the information gained in this investigation, it is highly unlikely that private wells, aquifers, or streams down-gradient from the landfill will be affected by the contaminants for several years, if at all.

The results of this investigation should provide the necessary data needed to instigate future studies. The clay mineralogy, humic substances, and microbial activity, are possible factors that may retard the migration of contaminants off the site for a considerable length of time. The fact that the landfill is in a discharge area will keep the contaminants from migrating deep into the aquifer and therefore should inhibit any long-term adverse affects, allowing time for future studies at the KSU landfill to be conducted. Statistical analysis and computer modeling of the present data, along with possible soil probe analysis and a multi-level sampling well located to the southeast of the site to study clay mineralogy, humic substances, and microbial activity, could gain enough information to conduct a feasibility study to determine if remediation is necessary in the future, and if so, which type. If it is determined that reclamation should be pursued, I suggest planting a north-south row of phreatophytes to the east of the landfill security fence. Phreatophytes have been proven to preferentially uptake

metals (Jewell and others, 1983; Francis, 1985), and their root systems could act as a vertical conduit for hydrocarbons (such as benzene) to aerate and volatilize naturally.

no. 2, p. 134-141.

Aber, J. S., 1982a, *Drainage and erosion in Kansas glaciolacustrine Tertiary-Quaternary* Symposium Series 1, *Initiation for Tertiary-Quaternary Studies*, p. 53-60.

Aber, J. S., 1982b, *Quaternary drainage development and drainage development in eastern Kansas*, Tertiary-Quaternary Symposium Series 1, *Initiation for Tertiary-Quaternary Studies*, p. 100-105.

Aber, J. S., 1985, *The glaciolacustrine Tertiary-Quaternary (TQ) system: Heritage of the Great Plains*, *Geology*, v. 13, no. 6, p. 47-50.

Aber, J. S., 1987, *The glaciolacustrine Tertiary-Quaternary (TQ) system*, *Geology*, v. 15, p. 297-314.

Beck, H. V., 1947, *The geology of Riley County, Kansas* (M.S. Thesis); *Manhattan, Kansas: Kansas State University*, 78 p.

Beck, H. V., 1948, *The geology of Riley County, Kansas*, *Kansas Geological Survey Bulletin* 135, 78 p.

Beck, H. V., 1949, *The geology of Riley County, Kansas*, U. S. Geological Survey Bulletin 744-A, p. D181-D185.

Byrne, F. C., 1949, *The geology of Riley County, Kansas*, U. S. Geological Survey Bulletin 744-A, p. D181-D185.

Carl, M. P., 1949, *The geology of Riley County, Kansas*, U. S. Geological Survey Bulletin 744-A, p. D181-D185.

Chalkley, J. B., 1949, *The geology of Riley County, Kansas*, U. S. Geological Survey Bulletin 744-A, p. D181-D185.

Chalkley, J. B., 1949, *The geology of Riley County, Kansas*, U. S. Geological Survey Bulletin 744-A, p. D181-D185.

Condit, R. B., 1949, *The geology of Riley County, Kansas*, U. S. Geological Survey Bulletin 744-A, p. D181-D185.

REFERENCES CITED

- Aber, J. S., 1984, History of Kansas glacial geology: *Earth Sciences History*, v. 3, no. 2, p. 134-142.
- Aber, J. S., 1985a, Definition and model for Kansan glaciation: Tertiary-Quaternary Symposium Series 1, Institute for Tertiary-Quaternary Studies, p. 53-60.
- Aber, J. S., 1985b, Quartzite-bearing gravels and drainage development in eastern Kansas: Tertiary-Quaternary Symposium Series 1, Institute for Tertiary-Quaternary Studies, p. 105-110.
- Aber, J. S., 1988, The glaciation of Kansas (special theme issue): *Heritage of the Great Plains*, v. 21, no. 4, p. 1-36.
- Aber, J. S., 1991, The glaciation of northeastern Kansas: *Boreas*, v. 20, p. 297-314.
- Beck, H. V., 1949, The Quaternary geology of Riley County, Kansas [M.S. Thesis]: Manhattan, Kansas, Kansas State University, 70 p.
- Beck, H. V., 1959, Geology and Ground-Water Resources of Kansas River Valley Between Wamego and Topeka Vicinity: *Kansas Geology Survey Bulletin* 135, 88 p.
- Beck, H. V., 1961, A buried valley northwest of Manhattan, Kansas: U. S. Geological Survey Professional Paper 424-D, p. D182-D185.
- Byrne, F. E., Mudge, M. R., Beck, H. V., and Burton, R. H., 1949, Preliminary report and map on the geologic construction material resources in Riley County, Kansas: U.S. Geological Survey Open-File Report 49-128, 45 p.
- Carl, M. F., 1980, Quaternary history of northeast Washington County, Kansas [M.S. Thesis]: Manhattan, Kansas, Kansas State University, 56 p.
- Chelikowsky, J. R., 1972, Structural geology of the Manhattan, Kansas area: *Kansas Geological Survey Bulletin* 204, Part 4, 13 p.
- Chelikowsky, J. R., 1976, Pleistocene drainage reversal in the upper Tuttle Creek Reservoir area in Kansas: *Kansas Geological Survey Bulletin* 211, Part One, 10 p.
- Condra, G. E., Reed, E. C., and Gordon, E. D., 1950, Correlation of the Pleistocene deposits of Nebraska: *Nebraska Geological Survey Bulletin* 15-A, 74 p.

- Frye, J. C., and Walters, K. L., 1930, Subsurface reconnaissance of glacial deposits in
- Davis, S. N., 1951, Studies of Pleistocene gravel lithologies in northeastern Kansas: State Geological Survey of Kansas Bulletin 90, Part 7, 17 p.
- Davis, S. N., and Carlson, W. A., 1952, Geology and ground water resources of the Kansas River valley between Lawrence and Topeka, Kansas: Kansas Geological Survey Bulletin 96, Part 5, 72 p.
- Denne, J. E., Yager, H. L., Macfarlane, P. A., Knapp, R. W., Sophocleous, M. A., Lucas, J. R., Steeples, D. W., 1987, Remote sensing and geophysical investigations of glacial buried valleys in northeastern Kansas, *in* Johnson, W. C., ed., Quaternary environments of Kansas: Kansas Geological Survey Guidebook Series 5, p. 85-92.
- Dort, W., Jr. 1987a, Salient aspects of the terminal zone of continental glaciation in Kansas, *in* Johnson, W. C., ed., Quaternary environments of Kansas: Kansas Geological Survey Guidebook Series 5, p. 55-66.
- Dort, W., Jr. 1987b, Type descriptions for Kansas River terraces, *in* Johnson, W. C., ed., Quaternary environments of Kansas: Kansas Geological Survey Guidebook Series 5, p. 103-107.
- Dreeszen, V. H., and Burchett, R. R., 1971, Buried valleys in the lower part of the Missouri River Basin. Kansas Geological Survey Special Dist. Publication 53, p. 21-25.
- Fader, S. W., 1974, Ground water in the Kansas River valley, Junction City to Kansas City, Kansas: Kansas Geological Survey Bulletin 206, Part 2, 12 p.
- Farley, S. M., 1987, Hydrogeochemistry of a buried preglacial channel in southeast Marshall County, Kansas [M.S. Thesis]: Manhattan, Kansas, Kansas State University, 104 p.
- Fetter, C. W., 1988, Applied Hydrogeology (second edition): Merrill Publishing Company, Columbus, Ohio, 592 p.
- Francis, J. K., 1985, The roots of plantation cottonwood: Their characteristics and properties: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, 4 p.
- Frye, J. C., and Leonard, A. B., 1952, Pleistocene geology of Kansas: Kansas Geological Survey Bulletin 99, 230 p.

- Frye, J. C., and Walters, K. L., 1950, Subsurface reconnaissance of glacial deposits in northeastern Kansas: Kansas Geological Survey Bulletin 86, Part 6, p. 141-158.
- Gerstl, Z., Chen, Y., and Yaron, B., eds., 1989, Toxic organic chemicals in porous media: New York, Springer-Verlag, 343 p.
- Geil, S. A., 1987, Significance and dating of a volcanic ash located within terrace fill north of De Soto, Kansas, *in* Johnson, W. C., ed., Quaternary environments of Kansas: Kansas Geological Survey Guidebook Series 5, p. 33-37.
- Gregory, J. L., and Beck, H. V., 1968, Analysis of Variables Affecting the Fluctuation of the Water Table in the Blue River Valley below Tuttle Creek Reservoir: Agricultural Experiment Station Bulletin 512, Kansas State University, 45 p.
- Izett, G. A., and Obradovich, J. D., 1991, Dating of the Matuyama-Bruhnes boundary based on ^{40}Ar - ^{39}Ar ages of the Bishop Tuff and Cerro San Luis Rhyolite: Geological Society of America Abstracts with Programs, v. 23, p. A106.
- Izett, G. A., and Wilcox, R. E., 1982, Map showing localities and inferred distributions of the Huckleberry Ridge, Mesa Falls, and Lava Creek ash beds (Pearlette family ash beds) of Pliocene and Pleistocene age in the western United States and southern Canada: U. S. Geological Survey, Miscellaneous Investigations Series, Map I-1325.
- Jewell, W. J., and Robert S. Kerr Environmental Research Laboratory, 1983, Wastewater treatment with plants in nutrient film: Center for Environmental Research information, U.S. Environmental Protection Agency, Cincinnati, OH, 5 p.
- Jewett, J. M., 1941, The geology of Riley and Geary Counties, Kansas: Kansas Geological Survey Bulletin 39, 164 p.
- Jewett, J. M., 1963, Pleistocene geology in Kansas: Kansas Academy of Science Transactions, v. 52, no. 3, p.347-358.
- Mazor, E., 1990, Applied chemical and isotopic groundwater hydrology: Open University Press, Great Britain, 274 p.
- Moore, R. C., Lohman, S. W., Frye, J. C., Waite, H. A., McLaughlin, T. G., and Latta, B., 1940, Ground water resources of Kansas: Kansas State Geological Survey Bulletin 27, 112 p.

- Moore, R. C., Lohman, S. W., Frye, J. C., Waite, H. A., McLaughlin, T. G., and Latta, B., 1951, The Kansas rock column: Kansas Geological Survey Bulletin 89, 132 p.
- Moulthrop, J., 1963, Pleistocene geology and ground water of Kansas River Valley between Manhattan and Junction City, Kansas [M.S. Thesis]: Manhattan, Kansas, Kansas State University, 38 p.
- Mudge, M. R., 1955, Early Pleistocene geomorphic history of Wabaunsee, southeastern Riley, and southern Pottawatomie Counties, Kansas: Kansas Academy of Science Transactions, v. 58, no. 2, p. 271-281.
- National Climatic Data Center, 1992, Climatological Data: Kansas, Asheville, North Carolina, National Oceanic and Atmospheric Administration, Department of Commerce.
- Office of the Federal Register National Archives and Records Administration, 1984, Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act: 40CFR, Part 136, US. Government Printing Office, Washington, D.C., 1049 p.
- Oviatt, C. G., Galitzer, S. J., Tracy, J., Nold, E., 1990, Investigations into the Kansas State University inactive chemical waste landfill: Annual report to KDHE, unpublished.
- Oviatt, C. G., Galitzer, S. J., Tracy, J., Nold, E., 1992 (revised), Investigations into the Kansas State University inactive chemical waste landfill. Annual report to KDHE, unpublished.
- Patrick, R., 1989, Groundwater contamination in the United States, 2nd ed.: Philadelphia, PA, University of Pennsylvania Press, 513 p.
- Richter, J. G., 1988, Hydrogeology of a buried valley and adjacent aquifers in southwest Pottawatomie County, Kansas [M.S. Thesis]: Manhattan, Kansas, Kansas State University, 185 p.
- Smith, G. N., 1991, Geomorphology and geomorphic history of the Konza Prairie Research Natural Area, Riley and Geary Counties, Kansas [M.S. Thesis]: Manhattan, Kansas, Kansas State University, 121 p.
- Smith, J. T., 1959, Ground water resources of Big Blue and Kansas River valleys from Manhattan to Wamego, Kansas [M.S. Thesis]: Manhattan, Kansas, Kansas

State University, 72, p.

Soil Conservation Service, 1980, Soil Survey of Riley County and Part of Geary County, Kansas: U.S. Department of Agriculture, 71 p.

Sposito, G., 1989, The chemistry of soils: New York, NY, Oxford University Press, 513 p.

Terry, D. B., 1991, The chemical and isotopic composition and the origin of ground water in the Dakota Aquifer, southwestern Kansas [M.S. Thesis]: Manhattan, Kansas, Kansas State University, 99 p.

Todd, J. E., 1908, Drainage of the Kansas ice sheet: Kansas Academy of Science Transactions, v. 22, p. 107-112.

Todd, J. E., 1911, History of Wakarusa Creek: Kansas Academy of Science Transactions, v. 23-24, p. 211-218.

U.S. Environmental Protection Agency, 1983, Interim Guidelines and Specifications for preparing Quality Assurance Project Plans: Office of Exploratory Research, Washington, D.C., 36 p.

Walters, K. L., 1953, Geology and groundwater resources of Jackson County, Kansas: Kansas Geological Survey Bulletin 101, 91 p.

Walters, K. L., 1954, Geology and groundwater resources of Marshall County, Kansas: Kansas Geological Survey Bulletin 106, 116 p.

APPENDIX A.

Analytical Procedures Conducted at KSU

Analysis procedures used at KSU are very similar to those used and reported by Farley (1987), therefore, only a brief description of each method is provided. Major cations were analyzed by atomic absorption and flame emission spectrophotometry on a Perkin-Elmer 305B atomic absorption spectrophotometer. The samples for cation analyses were acid preserved and analyzed within two weeks of sample collection. Bicarbonate concentrations were determined by titration with standardized H_2SO_4 to an end point of pH 4.5. The bicarbonate measurements were made on a chilled, unacidified sample within 48 hours of sample collection. Chloride concentration was measured by mercuric nitrate titration to an endpoint using the method described in the Hach procedures manual. Sulfate was determined by turbidimetry using the Hach kit. Nitrate concentrations were analyzed by reduction methods using the Hach kit. Chloride, sulfate, and nitrate were analyzed within one week of sample collection and were kept refrigerated at approximately 40° F until that time.

APPENDIX A.

Analytical Procedures Conducted at KSU

Analysis procedures used during chemical analysis at KSU are very similar to those used and reported by Farley (1987), therefore, only a brief description of each method is provided. Metals concentrations were determined by atomic absorption and flame emission spectrophotometry on a Perkin-Elmer 305B atomic absorption spectrophotometer. The samples for cation analyses were acid preserved and analyzed within two weeks of sample collection. Bicarbonate concentrations were determined by titration with standardized H_2SO_4 to an end point of pH 4.5. The bicarbonate measurements were made on a chilled, unacidified sample within 48 hours of sample collection. Chloride concentration was measured by mercuric nitrate titration to an endpoint using the method described in the Hach procedures manual. Sulfate was determined by turbidimetry using the Hach kit. Nitrate concentrations were analyzed by reduction methods using the Hach kit. Chloride, sulfate, and nitrate were analyzed within one week of sample collection and were kept refrigerated at approximately 40° F until that time.

APPENDIX B

Water-level altitudes for monitoring wells

APPENDIX B WATER LEVEL ALTITUDES FOR MONITORING WELLS 1-11 AT THE KCU INACTIVE CHEMICAL WASTE LANDFILL										
ALTITUDE OF WATER-LEVELS IN FEET ABOVE MEAN SEA LEVEL										
DATE	WELL 1	WELL 2	WELL 3	WELL 4	WELL 5	WELL 6	WELL 7	WELL 8	WELL 10	WELL 11
02/14/98	1074.16	1072.53	1072.58	1072.06	1073.29					
03/21/98	1076.35	1073.95	1073.91	1073.74	1075.18					
05/11/98	1077.54	1074.15	1074.20	1073.63	1075.95					
05/23/98	1078.15	1074.32	1074.27	1074.11	1076.09					
05/30/98	1078.30	1074.17	1074.00	1073.80	1075.98					
06/11/98	1077.32	1073.65	1073.10	1073.24	1075.76					
06/16/98	1075.40	1073.36	1073.00	1072.80	1075.85					
06/22/98	1076.37	1073.71	1073.11	1073.75	1075.69					
06/25/98	1078.24	1073.42	1073.71	1073.11	1075.61					
07/01/98	1075.40	1073.26	1071.05	1072.04	1075.19					
07/15/98	1075.24	1073.57	1070.88	1071.88	1074.20					
07/28/98	1075.78	1073.71	1073.46	1073.17	1074.20					
08/05/98	1075.24	1073.71	1073.46	1073.17	1074.20					
08/12/98	1075.24	1073.71	1073.46	1073.17	1074.20					
08/19/98	1075.24	1073.71	1073.46	1073.17	1074.20					
08/26/98	1075.24	1073.71	1073.46	1073.17	1074.20					
09/02/98	1075.24	1073.71	1073.46	1073.17	1074.20					
09/09/98	1075.24	1073.71	1073.46	1073.17	1074.20					
09/16/98	1075.24	1073.71	1073.46	1073.17	1074.20					
09/23/98	1075.24	1073.71	1073.46	1073.17	1074.20					
09/30/98	1075.24	1073.71	1073.46	1073.17	1074.20					
10/07/98	1075.24	1073.71	1073.46	1073.17	1074.20					
10/14/98	1075.24	1073.71	1073.46	1073.17	1074.20					
10/21/98	1075.24	1073.71	1073.46	1073.17	1074.20					
10/28/98	1075.24	1073.71	1073.46	1073.17	1074.20					
11/04/98	1075.24	1073.71	1073.46	1073.17	1074.20					
11/11/98	1075.24	1073.71	1073.46	1073.17	1074.20					
11/18/98	1075.24	1073.71	1073.46	1073.17	1074.20					
11/25/98	1075.24	1073.71	1073.46	1073.17	1074.20					
12/02/98	1075.24	1073.71	1073.46	1073.17	1074.20					
12/09/98	1075.24	1073.71	1073.46	1073.17	1074.20					
12/16/98	1075.24	1073.71	1073.46	1073.17	1074.20					
12/23/98	1075.24	1073.71	1073.46	1073.17	1074.20					
12/30/98	1075.24	1073.71	1073.46	1073.17	1074.20					
01/06/99	1075.24	1073.71	1073.46	1073.17	1074.20					
01/13/99	1075.24	1073.71	1073.46	1073.17	1074.20					
01/20/99	1075.24	1073.71	1073.46	1073.17	1074.20					
01/27/99	1075.24	1073.71	1073.46	1073.17	1074.20					
02/03/99	1075.24	1073.71	1073.46	1073.17	1074.20					
02/10/99	1075.24	1073.71	1073.46	1073.17	1074.20					
02/17/99	1075.24	1073.71	1073.46	1073.17	1074.20					
02/24/99	1075.24	1073.71	1073.46	1073.17	1074.20					
03/03/99	1075.24	1073.71	1073.46	1073.17	1074.20					
03/10/99	1075.24	1073.71	1073.46	1073.17	1074.20					
03/17/99	1075.24	1073.71	1073.46	1073.17	1074.20					
03/24/99	1075.24	1073.71	1073.46	1073.17	1074.20					
03/31/99	1075.24	1073.71	1073.46	1073.17	1074.20					
04/07/99	1075.24	1073.71	1073.46	1073.17	1074.20					
04/14/99	1075.24	1073.71	1073.46	1073.17	1074.20					
04/21/99	1075.24	1073.71	1073.46	1073.17	1074.20					
04/28/99	1075.24	1073.71	1073.46	1073.17	1074.20					
05/05/99	1075.24	1073.71	1073.46	1073.17	1074.20					
05/12/99	1075.24	1073.71	1073.46	1073.17	1074.20					
05/19/99	1075.24	1073.71	1073.46	1073.17	1074.20					
05/26/99	1075.24	1073.71	1073.46	1073.17	1074.20					
06/02/99	1075.24	1073.71	1073.46	1073.17	1074.20					
06/09/99	1075.24	1073.71	1073.46	1073.17	1074.20					
06/16/99	1075.24	1073.71	1073.46	1073.17	1074.20					
06/23/99	1075.24	1073.71	1073.46	1073.17	1074.20					
06/30/99	1075.24	1073.71	1073.46	1073.17	1074.20					
07/07/99	1075.24	1073.71	1073.46	1073.17	1074.20					
07/14/99	1075.24	1073.71	1073.46	1073.17	1074.20					
07/21/99	1075.24	1073.71	1073.46	1073.17	1074.20					
07/28/99	1075.24	1073.71	1073.46	1073.17	1074.20					
08/04/99	1075.24	1073.71	1073.46	1073.17	1074.20					
08/11/99	1075.24	1073.71	1073.46	1073.17	1074.20					
08/18/99	1075.24	1073.71	1073.46	1073.17	1074.20					
08/25/99	1075.24	1073.71	1073.46	1073.17	1074.20					
09/01/99	1075.24	1073.71	1073.46	1073.17	1074.20					
09/08/99	1075.24	1073.71	1073.46	1073.17	1074.20					
09/15/99	1075.24	1073.71	1073.46	1073.17	1074.20					
09/22/99	1075.24	1073.71	1073.46	1073.17	1074.20					
09/29/99	1075.24	1073.71	1073.46	1073.17	1074.20					
10/06/99	1075.24	1073.71	1073.46	1073.17	1074.20					
10/13/99	1075.24	1073.71	1073.46	1073.17	1074.20					
10/20/99	1075.24	1073.71	1073.46	1073.17	1074.20					
10/27/99	1075.24	1073.71	1073.46	1073.17	1074.20					
11/03/99	1075.24	1073.71	1073.46	1073.17	1074.20					
11/10/99	1075.24	1073.71	1073.46	1073.17	1074.20					
11/17/99	1075.24	1073.71	1073.46	1073.17	1074.20					
11/24/99	1075.24	1073.71	1073.46	1073.17	1074.20					
12/01/99	1075.24	1073.71	1073.46	1073.17	1074.20					
12/08/99	1075.24	1073.71	1073.46	1073.17	1074.20					
12/15/99	1075.24	1073.71	1073.46	1073.17	1074.20					
12/22/99	1075.24	1073.71	1073.46	1073.17	1074.20					
12/29/99	1075.24	1073.71	1073.46	1073.17	1074.20					
01/05/00	1075.24	1073.71	1073.46	1073.17	1074.20					
01/12/00	1075.24	1073.71	1073.46	1073.17	1074.20					
01/19/00	1075.24	1073.71	1073.46	1073.17	1074.20					
01/26/00	1075.24	1073.71	1073.46	1073.17	1074.20					
02/02/00	1075.24	1073.71	1073.46	1073.17	1074.20					
02/09/00	1075.24	1073.71	1073.46	1073.17	1074.20					
02/16/00	1075.24	1073.71	1073.46	1073.17	1074.20					
02/23/00	1075.24	1073.71	1073.46	1073.17	1074.20					
02/29/00	1075.24	1073.71	1073.46	1073.17	1074.20					
03/06/00	1075.24	1073.71	1073.46	1073.17	1074.20					
03/13/00	1075.24	1073.71	1073.46	1073.17	1074.20					
03/20/00	1075.24	1073.71	1073.46	1073.17	1074.20					
03/27/00	1075.24	1073.71	1073.46	1073.17	1074.20					
04/03/00	1075.24	1073.71	1073.46	1073.17	1074.20					
04/10/00	1075.24	1073.71	1073.46	1073.17	1074.20					
04/17/00	1075.24	1073.71	1073.46	1073.17	1074.20					
04/24/00	1075.24	1073.71	1073.46	1073.17	1074.20					
05/01/00	1075.24	1073.71	1073.46	1073.17	1074.20					
05/08/00	1075.24	1073.71	1073.46	1073.17	1074.20					
05/15/00	1075.24	1073.71	1073.46	1073.17	1074.20					
05/22/00	1075.24	1073.71	1073.46	1073.17	107					

APPENDIX B	WATER LEVEL	WELL 1	WELL 2	WELL 3	WELL 4	WELL 5	WELL 6	WELL 7	WELL 8	WELL 9	WELL 10	WELL 11
ALTITUDES OF WATER-LEVELS IN FEET ABOVE MEAN SEA LEVEL												
02/14/90	1074.16	1072.53	1072.58	1072.06	1074.29							
03/21/90	1076.15	1073.95	1073.91	1073.74	1075.18							
05/11/90	1077.54	1074.15	1074.20	1073.65	1075.90							
05/23/90	1078.25	1074.42	1074.27	1074.11	1076.09							
05/30/90	1078.30	1074.17	1074.00	1073.80	1075.98							
06/11/90	1077.33	1073.45	1073.10	1073.28	1075.76							
06/18/90	1077.40	1073.38	1073.00	1072.80	1075.65							
06/22/90	1078.37	1073.71	1073.11	1073.75	1075.69							
06/25/90	1078.06	1073.22	1073.71	1073.41	1075.64							
07/02/90	1076.88	1072.26	1071.65	1072.54	1075.39							
07/10/90	1075.26	1071.87	1070.88	1071.86	1074.89							
07/16/90	1074.78	1071.52	1070.49	1071.50	1074.77							
08/03/90	1077.25	1072.99	1072.20	1073.37	1076.55							
08/09/90	1078.17	1073.25	1072.48	1073.59	1075.72							
08/17/90	1079.05	1074.07	1073.63	1074.22	1076.86							
08/25/90	1078.70	1073.50	1072.05	1073.65	1076.40							
09/04/90	1075.15	1071.92	1070.08	1072.24	1075.81							
09/10/90	1075.07	1071.61	1070.06	1071.86	1075.55							
09/24/90	1074.75	1070.75	1069.95	1071.82	1075.26							
10/01/90	1075.86	1070.05	1070.81	1071.65	1075.09							
10/08/90	1076.05	1071.52	1070.59	1071.43	1074.85							
10/14/90	1075.84	1071.50	1070.76	1071.47	1074.87							
10/29/90	1074.62	1071.10	1071.78	1069.55	1074.63	1073.13	1071.54	1070.93	1070.75	1071.60	1069.75	
11/05/90	1075.22	1071.94	1070.51	1071.62	1074.65	1073.32	1071.80	1071.20	1071.04	1072.07	1070.33	
11/10/90	1075.37	1072.16	1070.87	1071.82	1074.68	1072.94	1071.93	1071.36	1071.22	1072.24	1069.50	
11/19/90	1074.70	1072.45	1071.28	1072.10	1073.77	1073.75	1071.80	1069.90	1071.55	1072.49	1069.14	
11/26/90	1075.21	1072.68	1072.58	1072.35	1075.11	1073.10	1072.35	1071.91	1071.77	1071.61	1071.50	
12/01/90	1075.28	1072.53	1069.27	1072.30	1074.89	1073.47	1072.24	1071.72	1071.38	1072.51	1071.42	
12/10/90	1075.31	1072.80	1072.73	1072.33	1072.70	1073.71	1072.22	1071.73	1071.65	1071.53	1071.67	
ALTITUDES OF WATER-LEVELS WERE DETERMINED USING AN ELECTRONIC WATER-LEVEL METER												

APPENDIX B CONT. WATER LEVEL ALTITUDES FOR MONITORING WELLS 1-11 AT THE KSU INACTIVE CHEMICAL WASTE LANDFILL.											
		ALTITUDE OF WATER-LEVELS IN FEET ABOVE	MEAN SEA LEVEL								
DATE	WELL 1	WELL 2	WELL 3	WELL 4	WELL 5	WELL 6	WELL 7	WELL 8	WELL 9	WELL 10	WELL 11
01/15/91	1075.27	1072.96	1073.07	1072.38	1074.85	1073.65	1072.15	1071.72	1071.66	1072.64	1071.94
01/23/91	1075.22	1072.80	1072.95	1072.23	1074.72	1073.50	1072.04	1071.61	1071.55	1072.49	1071.85
01/28/91	1075.19	1072.92	1073.07	1072.35	1074.76	1073.58	1072.11	1071.69	1071.63	1072.58	1071.95
02/04/91	1075.21	1072.80	1072.96	1072.24	1074.64	1073.44	1072.07	1071.64	1071.60	1072.50	1071.87
02/11/91	1075.17	1072.88	1073.04	1072.31	1074.63	1073.48	1072.06	1071.66	1071.61	1072.54	1071.95
02/18/91	1075.18	1072.80	1072.97	1072.24	1074.61	1073.44	1072.03	1071.61	1071.56	1072.46	1071.90
02/27/91	1074.98	1072.87	1073.05	1072.30	1074.55	1073.42	1072.04	1071.64	1071.59	1072.48	1071.93
03/04/91	1075.05	1072.85	1073.02	1072.30	1074.56	1073.42	1072.06	1071.65	1071.61	1072.48	1071.94
03/11/91	1074.97	1072.92	1073.09	1072.36	1074.55	1073.46	1072.09	1071.72	1071.65	1072.51	1071.97
03/20/91	1075.04	1072.96	1073.10	1072.45	1074.42	1073.46	1072.26	1071.85	1071.80	1072.57	1072.01
03/26/91	1074.37	1072.85	1073.00	1072.32	1074.32	1073.42	1072.13	1071.71	1071.67	1072.37	1071.90
04/02/91	1073.87	1072.61	1072.77	1072.10	1074.16	1073.25	1071.94	1071.50	1071.46	1072.03	1071.65
04/08/91	1074.27	1072.96	1073.00	1072.60	1074.62	1073.53	1072.60	1072.22	1072.19	1072.59	1072.03
04/15/91	1075.17	1072.97	1073.04	1072.65	1074.53	1073.68	1072.45	1071.02	1071.96	1072.60	1072.05
04/19/91	1074.65	1072.88	1072.94	1072.50	1074.55	1073.54	1072.52	1071.65	1072.05	1072.50	1071.96
05/06/91	1074.97	1072.63	1072.71	1072.25	1074.34	1073.44	1072.18	1071.72	1071.68	1072.30	1071.62
06/03/91	1075.19	1072.04	1071.44	1072.17	1074.78	1073.55	1072.73	1071.96	1071.97	1071.90	1070.14
06/11/91	1075.25	1071.78	1071.15	1071.85	1074.57	1073.56	1072.28	1071.50	1071.50	1071.62	1069.74
06/17/91	1073.90	1071.30	1070.48	1071.38	1074.36	1073.15	1071.80	1071.04	1071.05	1071.01	1068.98
06/25/91	1071.69	1070.98	1069.94	1071.02	1074.17	1072.88	1071.45	1070.70	1070.71	1070.35	1068.36
07/02/91	1068.05	1070.46	1068.85	1070.51	1073.92	1072.34	1071.00	1070.24	1070.26	1069.20	1067.03
07/09/91	1065.37	1070.12	1068.13	1070.16	1073.72	1071.99	1070.67	1069.91	1069.98	1068.55	1066.13
07/16/91	1067.43	1069.94	1067.89	1069.95	1073.56	1071.74	1070.49	1069.72	1069.75	1068.55	1066.02
08/08/91	1066.40	1069.31	1067.05	1069.28	1073.04	1070.80	1069.88	1069.11	1069.15	1067.92	1065.01
08/20/91	1065.36	1069.02	1066.51	1069.01	1072.80	1070.38	1069.59	1068.90	1068.93	1067.59	1064.58
08/26/91	1065.55	1068.86	1066.15	1068.88	1072.71	1070.21	1069.46	1068.76	1068.80	1067.46	1064.10
09/11/91	1066.53	1068.55	1066.09	1068.53	1072.50	1069.85	1069.25	1068.46	1068.51	1067.30	1063.92
10/01/91	1063.23	1068.09	1065.49	1068.11	1072.26	1069.44	1068.88	1068.10	1068.15	1066.57	1063.60
10/16/91	1062.51	1067.80	1065.16	1067.80	1072.13	1069.21	1068.64	1067.82	1067.88	1066.16	1063.55
ALTITUDES OF WATER-LEVELS WERE DETERMINED USING AN ELECTRONIC WATER-LEVEL METER											

APPENDIX B CONT. WATER LEVEL ALTITUDES FOR MONITORING WELLS 1-11 AT THE KSU INACTIVE CHEMICAL WASTE LANDFILL.											
		ALTITUDE OF WATER-LEVELS IN FEET ABOVE	MEAN SEA LEVEL								
DATE	WELL 1	WELL 2	WELL 3	WELL 4	WELL 5	WELL 6	WELL 7	WELL 8	WELL 9	WELL 10	WELL 11
11/07/91	1066.38	1068.83	1067.93	1068.60	1072.30	1069.83	1069.20	1068.43	1068.46	1067.64	1066.38
11/22/91	1069.20	1069.73	1069.05	1069.51	1072.77	1070.64	1070.00	1069.40	1069.30	1068.97	1067.80
12/10/91	1070.18	1070.26	1069.80	1070.05	1072.99	1071.27	1070.44	1069.82	1069.84	1069.62	1068.65
01/11/92	1072.36	1071.24	1070.89	1071.20	1074.32	1072.36	1071.85	1071.22	1071.25	1071.11	1070.18
01/29/92	1072.72	1071.75	1071.47	1071.69	1074.95	1073.26	1072.24	1071.56	1071.58	1071.55	1070.60
02/07/91	1072.82	1071.91	1071.63	1071.76	1075.08	1073.56	1072.16	1071.48	1071.49	1071.62	1069.72
02/25/92	1072.94	1072.18	1071.93	1071.95	1075.26	1073.91	1072.21	1071.56	1071.55	1071.79	1070.93
03/06/92	1072.92	1072.48	1072.18	1072.39	1075.46	1073.19	1072.51	1071.90	1071.89	1072.10	1071.09
04/08/92	1073.71	1073.56	1073.38	1073.34	1076.54	1075.19	1073.51	1072.83	1072.83	1073.10	1072.38
MAX	1079.05	1074.42	1074.27	1074.22	1076.86	1075.19	1073.51	1072.83	1072.83	1073.10	1072.38
MIN	1062.51	1067.80	1065.16	1067.80	1072.13	1069.21	1068.64	1067.82	1067.88	1066.16	1063.55
VARIATION (MAX-MIN)	16.54	6.62	9.11	6.42	4.73	5.98	4.87	5.01	4.95	6.94	8.83
AVERAGE	1073.77	1071.96	1071.30	1071.80	1074.62	1072.70	1071.53	1070.88	1070.92	1071.01	1069.62
AVERAGE WATER LEVELS IN ALL 11 WELLS SINCE 10/29/90											
	1072.31	1071.59	1070.88	1071.31	1074.17	1072.70	1071.53	1070.88	1070.92	1071.01	1069.62
ALTITUDES OF WATER-LEVELS WERE DETERMINED USING AN ELECTRONIC WATER-LEVEL METER											

[illegible]

APPENDIX D

Standard Chemical Water Analysis for
samples taken on 07/16/90

APPENDIX D: WILSON LAB STANDARD CHEMICAL WATER ANALYSIS FOR THE SECOND SAMPLING EVENT									
SAMPLES TAKEN ON	7/16/90	WELL 1	WELL 2	WELL 3	WELL 4	WELL 5	WELL 6	WELL 7	WELL 8
CATION TOTAL									
ANION TOTAL									
ION BALANCE									
STANDARD DEVIATION									
SILICA									
DRINKING WATER HEAVY METALS									
ARSENIC TOTAL									
BARIUM TOTAL									
CADMIUM TOTAL									
CHROMIUM TOTAL									

APPENDIX D. WILSON LAB STANDARD CHEMICAL WATER ANALYSIS FOR THE SECOND SAMPLING EVENT.

	SAMPLES TAKEN ON:	7/16/90		WELL 1	WELL 2	WELL 3	WELL 4	WELL 5
CATIONS								
	CALCIUM	CA + 2	MG/L	78.30	145.00	111.00	208.00	78.30
	HYDROGEN	H + 1	MG/L	0.00	0.00	0.00	0.00	0.00
	IRON, TOTAL	FE	MG/L	1.31	51.10	48.10	18.90	30.10
	MAGNESIUM	MG + 2	MG/L	16.20	40.10	23.80	42.80	20.70
	MANGANESE	MN + 2	MG/L	0.15	3.07	1.83	0.85	0.92
	POTASSIUM	K + 1	MG/L	0.00	8.61	7.79	0.00	5.14
	SODIUM	NA + 1	MG/L	52.90	63.30	82.50	337.00	56.80
ANIONS								
	BICARBONATE	HCO3-1	MG/L	389.13	399.73	453.07	1233.82	208.99
	CARBONATE	CO3-2	MG/L	0.26	0.07	0.12	0.21	0.08
	CHLORIDE	CL-1	MG/L	18.00	5.00	4.00	101.00	38.00
	FLUORIDE	F-1	MG/L	0.20	0.20	0.20	0.20	0.30
	HYDROXIDE	OH-1	MG/L	0.00	0.00	0.00	0.00	0.00
	NITRATE	NO3-1	MG/L	0.00	30.10	0.89	0.00	8.85
	PHOSPHATE	PO4-3	MG/L	0.00	0.31	0.31	0.31	0.31
	SULFATE	SO4-2	MG/L	12.00	43.00	31.00	32.00	68.00
CATION TOTAL			MEQ/L	7.59	15.45	13.07	29.27	9.32
ANION TOTAL			MEQ/L	7.15	8.10	8.23	23.77	6.09
ION BALANCE			MEQ/L	0.44	7.35	4.85	5.50	3.24
STANDARD DEVIATION				-2.0181	-31.6795	-20.7164	-11.5796	-16.109
SILICA		SIO2	MG/L	35.08	192.94	171.76	109.73	144.38
DRINKING WATER HEAVY METALS								
	ARSENIC TOTAL	AS	MG/L	0.00	0.01	0.00	0.00	0.00
	BARIUM TOTAL	BA	MG/L	0.23	1.62	1.15	1.27	0.83
	CADMIUM TOTAL	CD	MG/L	0.00	0.00	0.00	0.00	0.00
	CHROMIUM TOTAL	DR	MG/L	0.01	0.09	0.07	0.04	0.04

APPENDIX D. CONT.								
	SAMPLES TAKEN ON:	7/16/90						
				WELL 1	WELL 2	WELL 3	WELL 4	WELL 5
DRINKING WATER HEAVY METALS CONT.								
	LEAD TOTAL	PB	MG/L	0.00	0.05	0.04	0.02	0.03
	MERCURY TOTAL	HG	MG/L	0.00	0.00	0.00	0.00	0.00
	SELENIUM TOTAL	SE	MG/L	0.00	0.00	0.00	0.00	0.00
	SILVER TOTAL	AG	MG/L	0.00	0.25	0.00	0.00	0.02
TOTAL DISSOLVED SOLIDS (CALC)		AS CaCO3	MG/L	405.87	706.37	654.29	1458.08	530.19
TOTAL ALKALINITY		AS CaCO3	MG/L	320.00	328.00	372.00	1012.00	172.00
CARBONATE ALKALINITY		AS CaCO3	MG/L	319.78	327.79	371.68	1011.82	171.52
CALCIUM ALKALINITY		AS CaCO3	MG/L	195.52	327.79	277.17	519.38	171.52
MAGNESIUM ALKALINITY		AS CaCO3	MG/L	66.68	0.00	94.51	176.16	0.00
SODIUM ALKALINITY		AS CaCO3	MG/L	54.96	0.00	0.00	280.86	0.00
TOTAL HARDNESS		AS CaCO3	MG/L	264.81	624.28	464.66	730.96	336.34
CALCIUM HARDNESS		AS CaCO3	MG/L	195.52	362.06	277.17	519.38	195.52
MAGNESIUM HARDNESS		AS CaCO3	MG/L	66.68	165.05	97.96	176.16	85.20
NON-CARB. HARDNESS		AS CaCO3	MG/L	0.00	296.49	92.98	0.00	164.81
CA NON-CARB. HARDNESS			MG/L	0.00	34.27	0.00	0.00	23.99
MG NON-CARB. HARDNESS			MG/L	0.00	165.05	3.45	0.00	85.20
PH		PH UNITS		7.34	6.69	6.89	6.66	7.07
SATURATION PH		PH UNITS		7.05	6.80	6.86	6.18	7.33
STABILITY INDEX		PH UNITS		6.77	6.92	6.83	5.71	7.59
SATURATION INDEX		PH UNITS		0.29	-0.11	0.03	0.48	-0.26
TTL FREE CARBON DIOXIDE		CO2	MG/L	25.99	115.46	83.36	367.43	25.78
NECESSARY FREE CARB. DIOXIDE		CO2	MG/L	50.31	89.25	90.17	1108.27	14.15
EXCESS CARBON DIOXIDE		CO2	MG/L	-24.31	26.20	-6.81	-740.84	11.63
TEMPERATURE OF ANALYSIS		FAHRENHEIT		77.00	77.00	77.00	77.00	77.00
CONDUCTIVITY, MEAS. @ 25C		MICROMHOS/CM		822.00	610.00	719.00	2320.00	532.00
CONDUCTIVITY, CALC. @ 25C		MICROMHOS/CM		605.07	880.07	818.68	1995.34	651.10
CALC. COND./MEAS. COND.				0.7361	1.4427	1.1386	0.8601	1.2239
IONIC STRENGTH			MOL/L	0.0101	0.0185	0.0156	0.0342	0.0118

APPENDIX E. WILSON LAB STANDARD CHEMICAL WATER ANALYSIS FOR THE THIRD SAMPLING EVENT.									
SAMPLES TAKEN ON:	12/1/90								
			WELL 1	WELL 2	WELL 3	WELL 4	WELL 5	WELL 6	
CATIONS									
CALCIUM	CA + 2	MGL	77.90	132.00	97.80	215.00	101.00	124.00	
HYDROGEN	H + 1	MGL	0.00	0.00	0.00	0.00	0.00	0.00	
IRON, TOTAL	FE	MGL	0.79	52.80	25.60	18.60	23.00	26.10	
MAGNESIUM	MG + 2	MGL	14.80	33.90	24.80	42.40	1.80	26.10	
MANGANESE	MN + 2	MGL	0.29	2.74	1.00	1.18	0.78	0.94	
POTASSIUM	K + 1	MGL	0.00	7.70	6.00	0.00	0.00	6.40	
SODIUM	NA + 1	MGL	44.80	67.50	79.10	332.00	13.00	41.10	
ANIONS									
BICARBONATE	HCO3-1	MGL	398.60	613.90	501.60	1450.00	100.00	424.70	
CARBONATE	CO3-2	MGL	0.31	0.14	0.16	0.14	0.00	0.00	
CHLORIDE	CL-1	MGL	19.00	7.00	12.00	112.00	0.00	0.00	
FLUORIDE	F-1	ND/L	0.20	0.34	0.10	0.10	0.00	0.00	
HYDROXIDE	OH-1	MGL	0.00	0.00	0.00	0.00	0.00	0.00	
NITRATE	NO3-1	MGL	0.00	8.80	0.00	0.00	0.00	0.00	
PHOSPHATE	PO4-3	MGL	0.00	0.11	0.00	0.00	0.00	0.00	
SULFATE	SO4-2	MGL	0.00	0.00	0.00	0.00	0.00	0.00	
STANDARD DEVIATION									
SILICA									
DRINKING WATER									
ARSENIC TOTAL	AS	MGL	0.00	0.00	0.00	0.00	0.00	0.00	
BARIUM TOTAL	BA	MGL	0.00	0.00	0.00	0.00	0.00	0.00	
CADMIUM TOTAL	CD	MGL	0.00	0.00	0.00	0.00	0.00	0.00	
CHROMIUM TOTAL	CR	MGL	0.00	0.00	0.00	0.00	0.00	0.00	

APPENDIX E

Standard Chemical Water Analysis for
samples taken on 12/01/90

APPENDIX E. WILSON LAB STANDARD CHEMICAL WATER ANALYSIS FOR THE THIRD SAMPLING EVENT.									
	SAMPLES TAKEN ON:	12/1/90							
				WELL 1	WELL 2	WELL 3	WELL 4	WELL 5	WELL 6
CATIONS									
	CALCIUM	CA + 2	MG/L	77.90	132.00	97.80	215.00	101.00	124.00
	HYDROGEN	H + 1	MG/L	0.00	0.00	0.00	0.00	0.00	0.00
	IRON, TOTAL	FE	MG/L	0.79	52.80	25.60	18.60	23.00	26.10
	MAGNESIUM	MG + 2	MG/L	14.90	33.90	24.90	42.40	21.80	26.10
	MANGANESE	MN + 2	MG/L	0.29	2.74	1.00	1.18	0.76	0.94
	POTASSIUM	K + 1	MG/L	0.00	7.70	6.00	0.00	0.00	6.40
	SODIUM	NA + 1	MG/L	44.80	57.50	79.10	328.00	59.50	41.10
ANIONS									
	BICARBONATE	HCO3-1	MG/L	398.69	513.99	501.66	1486.97	409.13	474.85
	CARBONATE	CO3-2	MG/L	0.31	0.14	0.16	0.36	0.13	0.16
	CHLORIDE	CL-1	MG/L	19.00	7.00	12.00	112.00	18.00	5.00
	FLUORIDE	F-1	MG/L	0.20	0.30	0.30	0.30	0.30	0.02
	HYDROXIDE	OH-1	MG/L	0.00	0.00	0.00	0.00	0.00	0.00
	NITRATE	NO3-1	MG/L	0.00	8.85	0.89	0.00	30.10	25.23
	PHOSPHATE	PO4-3	MG/L	0.00	0.31	0.00	0.31	0.00	0.31
	SULFATE	SO4-2	MG/L	0.00	40.00	32.00	0.00	0.00	0.00
CATION TOTAL			MEQ/L	7.10	14.07	11.48	29.19	10.27	11.26
ANION TOTAL			MEQ/L	7.09	9.63	9.26	27.57	7.72	8.36
ION BALANCE			MEQ/L	0.01	4.43	2.21	1.62	2.55	2.90
STANDARD DEVIATION				-0.0436	-17.3329	-8.8546	-3.0379	-11.2944	-12.2628
SILICA		SIO2	MG/L	32.51	143.31	149.73	100.96	98.18	97.97
DRINKING WATER HEAVY METALS									
	ARSENIC TOTAL	AS	MG/L	0.00	0.00	0.00	0.00	0.00	0.00
	BARIUM TOTAL	BA	MG/L	0.24	1.19	0.68	1.34	0.82	0.77
	CADMIUM TOTAL	CD	MG/L	0.00	0.00	0.00	0	0.00	0.00
	CHROMIUM TOTAL	DR	MG/L	0.00	0.07	0.04	0.02	0.10	0.02

APPENDIX E. CONT.									
	SAMPLES TAKEN ON:	12/1/90							
				WELL 1	WELL 2	WELL 3	WELL 4	WELL 5	WELL 6
DRINKING WATER HEAVY METALS CONT.									
	LEAD TOTAL	PB	MG/L	0.00	0.05	0.02	0.02	0.04	0.05
	MERCURY TOTAL	HG	MG/L	0.00	0.00	0.00	0.00	0.00	0.00
	SELENIUM TOTAL	SE	MG/L	0.00	0.00	0.00	0.00	0.00	0.00
	SILVER TOTAL	AG	MG/L	0.00	0.04	0.07	0.00	0.00	0.00
TOTAL DISSOLVED SOLIDS (CALC)			MG/L	386.87	715.96	646.41	1550.71	554.16	587.22
TOTAL ALKALINITY			AS CaCO3 MG/L	328.00	422.00	412.00	1220.00	336.00	390.00
CARBONATE ALKALINITY			AS CaCO3 MG/L	327.76	421.67	411.65	1219.77	335.72	389.65
CALCIUM ALKALINITY			AS CaCO3 MG/L	194.52	329.60	244.21	536.85	252.20	309.63
MAGNESIUM ALKALINITY			AS CaCO3 MG/L	61.33	92.07	102.49	174.52	83.52	80.03
SODIUM ALKALINITY			AS CaCO3 MG/L	69.97	0.00	17.26	472.92	0.00	0.00
TOTAL HARDNESS			AS CaCO3 MG/L	257.79	568.75	394.39	746.85	384.52	465.54
CALCIUM HARDNESS			AS CaCO3 MG/L	194.52	329.60	244.21	536.85	252.20	309.63
MAGNESIUM HARDNESS			AS CaCO3 MG/L	61.33	139.53	102.49	174.52	89.73	107.43
NON-CARB. HARDNESS			AS CaCO3 MG/L	0.00	147.08	0.00	0.00	48.80	75.89
CA NON-CARB. HARDNESS			MG/L	0.00	0.00	0.00	0.00	0.00	0.00
MG NON-CARB. HARDNESS			MG/L	0.00	47.47	0.00	0.00	6.21	27.40
PH		PH UNITS		7.40	6.90	7.00	6.80	7.00	7.00
SATURATION PH		PH UNITS		7.04	6.73	6.87	6.09	6.93	6.79
STABILITY INDEX		PH UNITS		6.69	6.57	6.73	5.38	6.87	6.57
SATURATION INDEX		PH UNITS		0.36	0.17	0.13	0.71	0.07	0.21
TTL FREE CARBON DIOXIDE			CO2 MG/L	23.25	91.72	71.91	319.80	59.04	68.11
NECESSARY FREE CARB. DIOXIDE			CO2 MG/L	52.96	135.05	98.45	1652.59	69.01	112.05
EXCESS CARBON DIOXIDE			CO2 MG/L	-29.70	-43.33	-26.53	*****	-9.97	-43.93
TEMPERATURE OF ANALYSIS			FAHRENHEIT	77.00	77.00	77.00	77.00	77.00	77.00
CONDUCTIVITY, MEAS. @ 25C			MICROMHOS/CM	636.00	850	813.00	*****	813.00	805.00
CONDUCTIVITY, CALC. @ 25C			MICROMHOS/CM	582.06	886.48	813.95	2125.12	719.85	755.80
CALC. COND./MEAS. COND.				0.9152	1.0429	1.0012	0.0944	0.8854	0.9389
IONIC STRENGTH			MOL/L	0.0097	0.018	0.0146	0.0359	0.0128	0.0145

APPENDIX E. CONT								
	SAMPLES TAKEN ON:	12/1/90						
				WELL 7	WELL 8	WELL 9	WELL 10	WELL 11
CATIONS								
	CALCIUM	CA + 2	MG/L	141.00	155.00	185.00	97.00	120.00
	HYDROGEN	H + 1	MG/L	0.00	0.00	0.00	0.00	0.00
	IRON, TOTAL	FE	MG/L	28.90	35.00	16.20	15.80	2.91
	MAGNESIUM	MG + 2	MG/L	28.20	37.90	34.10	20.30	22.20
	MANGANESE	MN + 2	MG/L	1.06	2.92	2.47	1.77	0.27
	POTASSIUM	K + 1	MG/L	7.30	7.40	0.00	5.00	0.00
	SODIUM	NA + 1	MG/L	96.80	190.00	112.00	50.90	66.40
ANIONS								
	BICARBONATE	HCO3-1	MG/L	686.88	840.03	747.86	445.93	584.99
	CARBONATE	CO3-2	MG/L	0.23	0.30	0.21	0.11	0.15
	CHLORIDE	CL-1	MG/L	15.00	91.00	78.00	23.00	21.00
	FLUORIDE	F-1	MG/L	0.20	0.30	0.20	0.30	0.30
	HYDROXIDE	OH-1	MG/L	0.00	0.00	0.00	0.00	0.00
	NITRATE	NO3-1	MG/L	0.00	0.00	0.00	0.89	3.54
	PHOSPHATE	PO4-3	MG/L	0.00	1.23	1.23	0.00	0.00
	SULFATE	SO4-2	MG/L	0.00	0.00	0.00	32.00	31.00
CATION TOTAL			MEQ/L	14.83	20.67	17.58	9.48	10.82
ANION TOTAL			MEQ/L	11.70	16.42	14.53	8.66	10.90
ION BALANCE			MEQ/L	3.13	4.25	3.05	0.83	-0.09
STANDARD DEVIATION				-10.8676	-11.7724	-9.1887	-3.4291	0.3152
SILICA		SIO2	MG/L	113.37	134.76	95.61	80.85	40.64
DRINKING WATER HEAVY METALS								
	ARSENIC TOTAL	AS	MG/L	0.00	0.00	0.00	0.00	0.00
	BARIUM TOTAL	BA	MG/L	0.91	0.86	0.55	0.43	0.38
	CADMIUM TOTAL	CD	MG/L	0.00	0.00	0.00	0.00	0.00
	CHROMIUM TOTAL	DR	MG/L	0.02	0.04	0.02	0.01	0.00

APPENDIX E. CONT								
	SAMPLES TAKEN ON:	12/1/90						
				WELL 7	WELL 8	WELL 9	WELL 10	WELL 11
DRINKING WATER HEAVY METALS CONT.								
	LEAD TOTAL	PB	MG/L	0.06	0.05	0.02	0.02	0.00
	MERCURY TOTAL	HG	MG/L	0.00	0.00	0.00	0.00	0.00
	SELENIUM TOTAL	SE	MG/L	0.00	0.00	0.00	0.00	0.00
	SILVER TOTAL	AG	MG/L	0.00	0.00	0.00	0.00	0.00
TOTAL DISSOLVED SOLIDS (CALC)			MG/L	770.10	1054.15	893.03	547.39	596.23
TOTAL ALKALINITY		AS CaCO3	MG/L	564.00	690.00	614.00	366.00	480.00
CARBONATE ALKALINITY		AS CaCO3	MG/L	563.67	689.40	613.56	365.81	479.91
CALCIUM ALKALINITY		AS CaCO3	MG/L	352.08	387.03	461.95	242.21	299.64
MAGNESIUM ALKALINITY		AS CaCO3	MG/L	116.07	156.00	151.62	83.55	91.38
SODIUM ALKALINITY		AS CaCO3	MG/L	41.80	78.33	0.00	8.51	83.19
TOTAL HARDNESS		AS CaCO3	MG/L	521.87	611.07	635.83	357.30	396.71
CALCIUM HARDNESS		AS CaCO3	MG/L	352.08	387.03	461.95	242.21	299.64
MAGNESIUM HARDNESS		AS CaCO3	MG/L	116.07	156.00	140.36	83.55	91.38
NON-CARB. HARDNESS		AS CaCO3	MG/L	0.00	0.00	22.27	0.00	0.00
CA NON-CARB. HARDNESS			MG/L	0.00	0.00	0.00	0.00	0.00
MG NON-CARB. HARDNESS			MG/L	0.00	0.00	-11.26	0.00	0.00
PH		PH UNITS		7.00	7.00	6.90	6.90	6.90
SATURATION PH		PH UNITS		6.58	6.47	6.43	6.91	6.71
STABILITY INDEX		PH UNITS		6.16	5.93	5.97	6.93	6.52
SATURATION INDEX		PH UNITS		0.42	0.53	0.47	-0.01	0.19
TTL FREE CARBON DIOXIDE		CO2	MG/L	97.24	116.90	131.75	80.95	105.36
NECESSARY FREE CARB. DIOXIDE		CO2	MG/L	256.62	403.24	386.96	78.57	163.31
EXCESS CARBON DIOXIDE		CO2	MG/L	-159.38	-286.34	-255.21	2.38	-57.95
TEMPERATURE OF ANALYSIS		FAHRENHEIT		77.00	77.00	77.00	77.00	77.00
CONDUCTIVITY, MEAS. @ 25C		MICROMHOS/CM		1080.00	*****	*****	739.00	968.00
CONDUCTIVITY, CALC. @ 25C		MICROMHOS/CM		1006.01	1435.15	1228.78	728.12	853.10
CALC. COND./MEAS. COND.				0.9315	0.095	0.091	0.9853	0.8813
IONIC STRENGTH			MOL/L	0.0185	0.0247	0.0224	0.013	0.0152

APPENDIX F. WILSON LAB STANDARD CHEMICAL WATER ANALYSIS FOR THE FOURTH SAMPLING EVENT																											
CATIONS	SAMPLES TAKEN ON:	4/19/91	WELL 1					WELL 2					WELL 3					WELL 4					WELL 5				
			WELL 1					WELL 2					WELL 3					WELL 4					WELL 5				
CATIONS	CALCIUM	CA+2	53.50	83.10	72.70	100.00	100.00	54.50	82.50	72.10	100.00	100.00	54.50	82.50	72.10	100.00	100.00	54.50	82.50	72.10	100.00	100.00	54.50	82.50	72.10	100.00	100.00
	HYDROGEN	H+1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CHLORIDE TOTAL	CL	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	MAGNESIUM	MG+2	13.00	18.90	16.80	24.00	24.00	13.00	18.90	16.80	24.00	24.00	13.00	18.90	16.80	24.00	24.00	13.00	18.90	16.80	24.00	24.00	13.00	18.90	16.80	24.00	24.00
	MANGANESE	MN+2	0.15	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00
	POTASSIUM	K+1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	SODIUM	NA+1	38.00	64.20	70.50	200.00	200.00	38.00	64.20	70.50	200.00	200.00	38.00	64.20	70.50	200.00	200.00	38.00	64.20	70.50	200.00	200.00	38.00	64.20	70.50	200.00	200.00
	BICARBONATE	HCO3-1	349.50	504.75	502.75	1221.90	1221.90	349.50	504.75	502.75	1221.90	1221.90	349.50	504.75	502.75	1221.90	1221.90	349.50	504.75	502.75	1221.90	1221.90	349.50	504.75	502.75	1221.90	1221.90
	CARBONATE	CO3-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	FLUORIDE	F-1	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	HYDROXIDE	OH-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ANIONS	NITRATE	NO3-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	PHOSPHATE	PO4-3	0.31	1.23	0.82	0.82	0.82	0.31	1.23	0.82	0.82	0.82	0.31	1.23	0.82	0.82	0.82	0.31	1.23	0.82	0.82	0.82	0.31	1.23	0.82	0.82	0.82
	SULFATE	SO4-2	51.00	43.00	34.00	37.00	37.00	51.00	43.00	34.00	34.00	37.00	37.00	51.00	43.00	34.00	34.00	51.00	43.00	34.00	34.00	37.00	37.00	51.00	43.00	34.00	34.00
	CATION TOTAL																										
ANION TOTAL																											
ION BALANCE																											
STANDARD DEVIATION																											
SILICA																											
	DRINKING WATER HEAVY METALS																										
	ARSENIC TOTAL	AS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	BARIUM TOTAL	BA	0.22	0.34	0.38	1.12	1.12	0.22	0.34	0.38	1.12	1.12	0.22	0.34	0.38	1.12	1.12	0.22	0.34	0.38	1.12	1.12	0.22	0.34	0.38	1.12	1.12
	CADMIUM TOTAL	CD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHROMIUM TOTAL	CR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

APPENDIX F

Standard Chemical Water Analysis for
samples taken on 04/19/91

APPENDIX F. WILSON LAB STANDARD CHEMICAL WATER ANALYSIS FOR THE FOURTH SAMPLING EVENT.									
	SAMPLES TAKEN ON:	4/19/91							
				WELL 1	WELL 2	WELL 3	WELL 4	WELL 5	WELL 6
CATIONS									
	CALCIUM	CA + 2	MG/L	59.50	83.10	72.70	160.00	56.90	82.50
	HYDROGEN	H + 1	MG/L	0.00	0.00	0.00	0.00	0.00	0.00
	IRON, TOTAL	FE	MG/L	1.09	9.89	9.59	10.60	3.30	7.80
	MAGNESIUM	MG + 2	MG/L	12.80	18.90	16.60	34.60	11.10	17.10
	MANGANESE	MN + 2	MG/L	0.15	0.48	0.45	0.98	0.08	0.22
	POTASSIUM	K + 1	MG/L	0.00	0.00	0.00	0.00	0.00	0.00
	SODIUM	NA + 1	MG/L	39.30	64.20	70.80	288.00	47.40	34.70
ANIONS									
	BICARBONATE	HCO3-1	MG/L	348.68	504.78	502.28	1321.96	258.30	324.51
	CARBONATE	CO3-2	MG/L	0.05	0.05	0.06	0.16	0.05	0.02
	CHLORIDE	CL-1	MG/L	20.00	6.00	6.00	116.00	42.00	5.00
	FLUORIDE	F-1	MG/L	0.50	0.30	0.30	0.30	0.30	0.20
	HYDROXIDE	OH-1	MG/L	0.00	0.00	0.00	0.00	0.00	0.00
	NITRATE	NO3-1	MG/L	0.00	0.00	0.00	0.00	0.00	0.44
	PHOSPHATE	PO4-3	MG/L	0.31	1.23	0.92	0.92	0.61	0.31
	SULFATE	SO4-2	MG/L	51.00	43.00	34.00	37.00	63.00	144.00
CATION TOTAL			MEQ/L	5.78	8.87	8.43	23.77	5.94	7.32
ANION TOTAL			MEQ/L	7.38	9.41	9.17	25.77	6.78	8.49
ION BALANCE			MEQ/L	-1.61	-0.54	-0.73	-2.00	-0.84	-1.17
STANDARD DEVIATION				7.2703	2.1501	2.9545	3.9456	3.9679	4.9055
SILICA		SIO2	MG/L	31.87	72.94	69.73	76.79	38.07	60.32
DRINKING WATER HEAVY METALS									
	ARSENIC TOTAL	AS	MG/L	0.00	0.00	0.00	0.00	0.00	0.00
	BARIUM TOTAL	BA	MG/L	0.22	0.34	0.38	1.12	0.35	0.46
	CADMIUM TOTAL	CD	MG/L	0.00	0.00	0.00	0.00	0.00	0.00
	CHROMIUM TOTAL	DR	MG/L	0.00	0.03	0.02	0.00	0.04	0.01

APPENDIX F. CONT.									
	SAMPLES TAKEN ON:	4/19/91							
				WELL 1	WELL 2	WELL 3	WELL 4	WELL 5	WELL 6
DRINKING WATER HEAVY METALS CONT.									
	LEAD TOTAL	PB	MG/L	0.00	0.01	0.01	0.01	0.00	0.01
	MERCURY TOTAL	HG	MG/L	0.00	0.00	0.00	0.00	0.00	0.00
	SELENIUM TOTAL	SE	MG/L	0.00	0.00	0.00	0.00	0.00	0.00
	SILVER TOTAL	AG	MG/L	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL DISSOLVED SOLIDS (CALC)			MG/L	388.14	548.50	528.34	1375.74	389.94	512.32
TOTAL ALKALINITY		AS CaCO3	MG/L	286.00	414.00	412.00	1084.00	212.00	266.00
CARBONATE ALKALINITY		AS CaCO3	MG/L	285.91	413.83	411.82	1083.85	211.84	265.96
CALCIUM ALKALINITY		AS CaCO3	MG/L	148.57	207.50	181.53	399.52	142.08	206.00
MAGNESIUM ALKALINITY		AS CaCO3	MG/L	52.68	77.79	68.33	142.41	45.69	59.96
SODIUM ALKALINITY		AS CaCO3	MG/L	82.43	109.93	143.95	521.13	18.00	0.00
TOTAL HARDNESS		AS CaCO3	MG/L	203.48	303.90	267.87	562.72	193.83	290.77
CALCIUM HARDNESS		AS CaCO3	MG/L	148.57	207.50	181.53	399.52	142.08	206.00
MAGNESIUM HARDNESS		AS CaCO3	MG/L	52.68	77.79	68.33	142.41	45.69	70.38
NON-CARB. HARDNESS		AS CaCO3	MG/L	0.00	0.00	0.00	0.00	0.00	24.81
CA NON-CARB. HARDNESS			MG/L	0.00	0.00	0.00	0.00	0.00	0.00
MG NON-CARB. HARDNESS			MG/L	0.00	0.00	0.00	0.00	0.00	10.43
PH		PH UNITS		6.70	6.50	6.60	6.50	6.80	6.20
SATURATION PH		PH UNITS		7.22	6.93	6.98	6.26	7.37	7.12
STABILITY INDEX		PH UNITS		7.73	7.35	7.37	6.03	7.93	8.04
SATURATION INDEX		PH UNITS		-0.52	-0.43	-0.38	0.24	-0.57	-0.92
TTL FREE CARBON DIOXIDE		CO2	MG/L	101.93	230.31	182.63	572.92	60.04	295.72
NECESSARY FREE CARB. DIOXIDE		CO2	MG/L	31.03	86.47	75.67	993.93	16.34	35.60
EXCESS CARBON DIOXIDE		CO2	MG/L	70.88	143.84	106.97	-421.01	43.69	260.11
TEMPERATURE OF ANALYSIS		FAHRENHEIT		77.00	77.00	77.00	77.00	77.00	77.00
CONDUCTIVITY, MEAS. @ 25C		MICROMHOS/CM		646.00	862.00	812.00	2070.00	680.00	692.00
CONDUCTIVITY, CALC. @ 25C		MICROMHOS/CM		557.35	726.01	706.04	1913.33	563.02	647.54
CALC. COND./MEAS. COND.				0.8628	0.8422	0.8695	0.9243	0.828	0.9357
IONIC STRENGTH			MOL/L	0.0092	0.0127	0.0119	0.0308	0.009	0.0123

APPENDIX F. CONT.								
	SAMPLES TAKEN ON:	4/19/91						
				WELL 7	WELL 8	WELL 9	WELL 10	WELL 11
CATIONS								
	CALCIUM	CA + 2	MG/L	98.00	151.00	198.00	62.60	105.00
	HYDROGEN	H + 1	MG/L	0.00	0.00	0.00	0.00	0.00
	IRON, TOTAL	FE	MG/L	4.10	8.72	34.30	3.06	1.59
	MAGNESIUM	MG + 2	MG/L	19.40	33.80	37.30	13.20	20.40
	MANGANESE	MN + 2	MG/L	0.30	2.77	2.89	1.37	0.09
	POTASSIUM	K + 1	MG/L	0.00	0.00	5.50	0.00	0.00
	SODIUM	NA + 1	MG/L	94.10	190.00	94.10	41.30	73.70
ANIONS								
	BICARBONATE	HCO3-1	MG/L	690.17	990.14	738.23	404.91	626.93
	CARBONATE	CO3-2	MG/L	0.09	0.11	0.08	0.04	0.07
	CHLORIDE	CL-1	MG/L	19.00	111.00	67.00	23.00	24.00
	FLUORIDE	F-1	MG/L	0.30	0.30	0.30	0.30	0.20
	HYDROXIDE	OH-1	MG/L	0.00	0.00	0.00	0.00	0.00
	NITRATE	NO3-1	MG/L	0.00	0.00	0.00	0.00	0.00
	PHOSPHATE	PO4-3	MG/L	0.61	1.84	7.36	0.31	0.00
	SULFATE	SO4-2	MG/L	25.00	74.00	77.00	26.00	49.00
CATION TOTAL			MEQ/L	10.74	18.99	18.52	6.17	10.18
ANION TOTAL			MEQ/L	12.41	21.00	15.93	7.86	11.99
ION BALANCE			MEQ/L	-1.68	-2.01	2.58	-1.69	-1.80
STANDARD DEVIATION				5.6086	4.644	-7.3077	7.4075	6.1614
SILICA		SIO2	MG/L	44.71	61.39	148.66	35.08	36.58
DRINKING WATER HEAVY METALS								
	ARSENIC TOTAL	AS	MG/L	0.00	0.00	0.00	0.00	0.00
	BARIUM TOTAL	BA	MG/L	0.61	0.30	1.00	0.20	0.42
	CADMIUM TOTAL	CD	MG/L	0.00	0.00	0.01	0.00	0.00
	CHROMIUM TOTAL	DR	MG/L	0.00	0.03	0.07	0.00	0.00

APPENDIX F. CONT.								
	SAMPLES TAKEN ON:	4/19/91						
				WELL 7	WELL 8	WELL 9	WELL 10	WELL 11
DRINKING WATER HEAVY METALS CONT.								
	LEAD TOTAL	PB	MG/L	0.00	0.01	0.05	0.00	0.00
	MERCURY TOTAL	HG	MG/L	0.00	0.00	0.00	0.00	0.00
	SELENIUM TOTAL	SE	MG/L	0.00	0.00	0.00	0.00	0.00
	SILVER TOTAL	AG	MG/L	0.00	0.00	0.00	0.00	0.00
TOTAL DISSOLVED SOLIDS (CALC)			MG/L	645.17	1122.08	1006.86	405.49	619.06
TOTAL ALKALINITY			AS CaCO3 MG/L	566.00	812.00	606.00	332.00	514.00
CARBONATE ALKALINITY			AS CaCO3 MG/L	565.88	811.78	605.24	331.94	513.97
CALCIUM ALKALINITY			AS CaCO3 MG/L	244.71	377.05	494.41	156.31	262.19
MAGNESIUM ALKALINITY			AS CaCO3 MG/L	79.85	139.12	110.84	54.33	83.97
SODIUM ALKALINITY			AS CaCO3 MG/L	233.44	274.94	0.00	113.32	164.81
TOTAL HARDNESS			AS CaCO3 MG/L	332.45	536.84	714.66	218.62	349.16
CALCIUM HARDNESS			AS CaCO3 MG/L	244.71	377.05	494.41	156.31	262.19
MAGNESIUM HARDNESS			AS CaCO3 MG/L	79.85	139.12	153.53	54.33	83.97
NON-CARB. HARDNESS			AS CaCO3 MG/L	0.00	0.00	109.42	0.00	0.00
CA NON-CARB. HARDNESS			MG/L	0.00	0.00	0.00	0.00	0.00
MG NON-CARB. HARDNESS			MG/L	0.00	0.00	42.69	0.00	0.00
PH		PH UNITS		6.60	6.50	6.50	6.50	6.50
SATURATION PH		PH UNITS		6.73	6.41	6.42	7.13	6.74
STABILITY INDEX		PH UNITS		6.86	6.32	6.33	7.76	6.98
SATURATION INDEX		PH UNITS		-0.13	0.09	0.08	-0.63	-0.24
TTL FREE CARBON DIOXIDE		CO2 MG/L		247.86	433.68	324.00	187.25	283.49
NECESSARY FREE CARB. DIOXIDE		CO2 MG/L		185.39	539.69	395.35	43.78	164.01
EXCESS CARBON DIOXIDE		CO2 MG/L		62.47	-106.01	-71.36	143.46	119.48
TEMPERATURE OF ANALYSIS		FAHRENHEIT		77.00	77.00	77.00	77.00	77.00
CONDUCTIVITY, MEAS. @ 25C		MICROMHOS/CM		1032.00	1820.00	1280.00	655.00	1110.00
CONDUCTIVITY, CALC. @ 25C		MICROMHOS/CM		914.89	1564.30	1279.78	585.62	880.35
CALC. COND./MEAS. COND.				0.8865	0.8595	0.9998	0.8941	0.7931
IONIC STRENGTH		MOL/L		0.0152	0.0262	0.0254	0.0095	0.0151

APPENDIX G

Standard Chemical Water Analysis for
samples taken on 11/22/91

APPENDIX G. WILSON LAB STANDARD CHEMICAL WATER ANALYSIS FOR THE SIXTH SAMPLING EVENT									
DATE: 11/22/91		WELL 1		WELL 2		WELL 3		WELL 4	
ANALYST: JESSE CHEN		11/22/91		11/22/91		11/22/91		11/22/91	
CA + 2		MGA		MGA		MGA		MGA	
H + 1		MGA		MGA		MGA		MGA	
FE		MGA		MGA		MGA		MGA	
MG + 2		MGA		MGA		MGA		MGA	
NH + 3		MGA		MGA		MGA		MGA	
K + 1		MGA		MGA		MGA		MGA	
Na + 1		MGA		MGA		MGA		MGA	
CL - 1		MGA		MGA		MGA		MGA	
SO4 - 2		MGA		MGA		MGA		MGA	
NO3 - 3		MGA		MGA		MGA		MGA	
CO3 - 2		MGA		MGA		MGA		MGA	
HCO3 - 3		MGA		MGA		MGA		MGA	
CATION TOTAL		MGA		MGA		MGA		MGA	
ANION TOTAL		MGA		MGA		MGA		MGA	
ION BALANCE		MGA		MGA		MGA		MGA	
STANDARD DEVIATION		MGA		MGA		MGA		MGA	
SILICA		MGA		MGA		MGA		MGA	
DRINKING WATER HEAVY METALS		MGA		MGA		MGA		MGA	
ARSENIC TOTAL		MGA		MGA		MGA		MGA	
BARIUM TOTAL		MGA		MGA		MGA		MGA	
CADMIUM TOTAL		MGA		MGA		MGA		MGA	
CHROMIUM TOTAL		MGA		MGA		MGA		MGA	

APPENDIX G. WILSON LAB STANDARD CHEMICAL WATER ANALYSIS FOR THE SIXTH SAMPLING EVENT.									
	SAMPLES TAKEN ON:	11/22/91							
				WELL 1	WELL 2	WELL 3	WELL 4	WELL 5	WELL 6
CATIONS									
	CALCIUM	CA + 2	MG/L	78.40	131.00	79.10	204.00	107.00	205.00
	HYDROGEN	H + 1	MG/L	0.00	0.00	0.00	0.00	0.00	0.00
	IRON, TOTAL	FE	MG/L	0.61	8.48	15.10	7.34	32.80	147.00
	MAGNESIUM	MG + 2	MG/L	15.20	24.30	19.30	40.70	27.20	58.70
	MANGANESE	MN + 2	MG/L	0.17	0.62	0.66	0.53	1.10	2.88
	POTASSIUM	K + 1	MG/L	0.00	0.00	0.00	0.00	5.10	20.50
	SODIUM	NA + 1	MG/L	40.40	86.70	95.20	324.00	47.90	177.00
ANIONS									
	BICARBONATE	HCO3-1	MG/L	387.87	507.13	1195.36	1551.35	318.77	609.04
	CARBONATE	CO3-2	MG/L	0.03	0.04	0.09	0.17	0.06	0.15
	CHLORIDE	CL-1	MG/L	27.00	7.00	4.00	216.00	40.00	15.00
	FLUORIDE	F-1	MG/L	0.20	0.30	0.30	0.20	0.30	0.30
	HYDROXIDE	OH-1	MG/L	0.00	0.00	0.00	0.00	0.00	0.00
	NITRATE	NO3-1	MG/L	0.00	3.54	0.00	0.00	16.38	6.64
	PHOSPHATE	PO4-3	MG/L	0.31	2.76	0.61	0.61	2.45	1.23
	SULFATE	SO4-2	MG/L	2.00	55.00	230.00	3.00	60.00	54.00
CATION TOTAL			MEQ/L	6.95	12.63	10.24	27.91	11.01	28.65
ANION TOTAL			MEQ/L	7.19	9.85	24.54	31.63	7.99	11.71
ION BALANCE			MEQ/L	-0.24	2.79	-14.30	-3.72	3.01	16.94
STANDARD DEVIATION				1.0863	-10.7488	29.3665	6.2348	-13.0706	-58.8128
SILICA		SIO2	MG/L	36.36	120.00	116.58	92.40	157.22	367.91
DRINKING WATER HEAVY METALS									
	ARSENIC TOTAL	AS	MG/L	0.00	0.00	0.00	0.00	0.01	0.06
	BARIUM TOTAL	BA	MG/L	0.20	0.37	0.50	1.06	1.00	1.93
	CADMIUM TOTAL	CD	MG/L	0.00	0.00	0.00	0.00	0.00	0.02
	CHROMIUM TOTAL	DR	MG/L	0.00	0.03	0.00	0.00	0.07	0.12

APPENDIX G. CONT.									
	SAMPLES TAKEN ON:	11/22/91							
				WELL 1	WELL 2	WELL 3	WELL 4	WELL 5	WELL 6
DRINKING WATER HEAVY METALS CONT.									
	LEAD TOTAL	PB	MG/L	0.00	0.01	0.01	0.01	0.10	0.23
	MERCURY TOTAL	HG	MG/L	0.00	0.00	0.00	0.00	0.00	0
	SELENIUM TOTAL	SE	MG/L	0.00	0.00	0.00	0.00	0.00	0
	SILVER TOTAL	AG	MG/L	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL DISSOLVED SOLIDS (CALC)			MG/L	391.53	689.09	1149.12	1652.22	616.99	1107.87
TOTAL ALKALINITY			AS CaCO3 MG/L	318.00	416.00	980.00	1272.00	262.00	500.00
CARBONATE ALKALINITY			AS CaCO3 MG/L	317.95	415.71	979.88	1271.88	261.43	499.59
CALCIUM ALKALINITY			AS CaCO3 MG/L	195.76	327.11	197.51	509.39	261.43	499.59
MAGNESIUM ALKALINITY			AS CaCO3 MG/L	62.56	88.61	79.44	167.52	0.00	0.00
SODIUM ALKALINITY			AS CaCO3 MG/L	58.21	0.00	674.67	580.84	0.00	0.00
TOTAL HARDNESS			AS CaCO3 MG/L	259.74	443.46	305.21	691.04	439.92	1022.17
CALCIUM HARDNESS			AS CaCO3 MG/L	195.76	327.11	197.21	509.39	267.18	511.89
MAGNESIUM HARDNESS			AS CaCO3 MG/L	62.56	100.02	79.44	167.52	111.96	241.61
NON-CARB. HARDNESS			AS CaCO3 MG/L	0.00	27.75	0.00	0.00	178.48	522.58
CA NON-CARB. HARDNESS			MG/L	0.00	0.00	0.00	0.00	5.74	12.3
MG NON-CARB. HARDNESS			MG/L	0.00	11.41	0.00	0.00	111.96	241.61
PH		PH UNITS		6.44	6.40	6.35	6.45	6.78	6.81
SATURATION PH		PH UNITS		7.05	6.74	6.60	6.10	7.02	6.49
STABILITY INDEX		PH UNITS		7.67	7.08	6.85	5.74	7.27	6.18
SATURATION INDEX		PH UNITS		-0.61	-0.34	-0.25	0.35	-0.24	0.32
TTL FREE CARBON DIOXIDE			CO2 MG/L	205.72	287.47	745.72	745.29	75.81	129.29
NECESSARY FREE CARB. DIOXIDE			CO2 MG/L	50.14	132.24	420.79	1698.73	43.47	270.32
EXCESS CARBON DIOXIDE			CO2 MG/L	155.58	155.23	324.93	-953.44	32.34	-141.03
TEMPERATURE OF ANALYSIS			FAHRENHEIT	77.00	77.00	77.00	77.00	77.00	77.00
CONDUCTIVITY, MEAS. @ 25C			MICROMHOS/CM	919.00	1100.00	1120.00	3250.00	1100.00	1600.00
CONDUCTIVITY, CALC. @ 25C			MICROMHOS/CM	585.10	866.59	1333.26	2306.98	764.99	1404.92
CALC. COND./MEAS. COND.				0.6367	0.7878	1.1904	0.7098	0.6954	0.8781
IONIC STRENGTH			MOL/L	0.0097	0.0163	0.0229	0.0367	0.0146	0.031

APPENDIX G. CONT.								
	SAMPLES TAKEN ON:	11/22/91						
				WELL 7	WELL 8	WELL 9	WELL 10	WELL 11
CATIONS								
	CALCIUM	CA + 2	MG/L	167.00	177.00	217.00	87.30	134.00
	HYDROGEN	H + 1	MG/L	0.00	0.00	0.00	0.00	0.00
	IRON, TOTAL	FE	MG/L	45.10	9.86	4.08	5.87	2.53
	MAGNESIUM	MG + 2	MG/L	33.80	39.00	41.70	18.90	21.80
	MANGANESE	MN + 2	MG/L	1.34	2.46	2.73	2.46	0.07
	POTASSIUM	K + 1	MG/L	8.30	0.00	9.70	0.00	0.00
	SODIUM	NA + 1	MG/L	117.00	215.00	152.00	44.00	57.90
ANIONS								
	BICARBONATE	HCO3-1	MG/L	658.16	1067.73	1062.92	414.67	609.89
	CARBONATE	CO3-2	MG/L	0.12	0.20	0.16	0.03	0.05
	CHLORIDE	CL-1	MG/L	14.00	131.00	125.00	32.00	21.00
	FLUORIDE	F-1	MG/L	0.30	0.30	0.20	0.30	0.20
	HYDROXIDE	OH-1	MG/L	0.00	0.00	0.00	0.00	0.00
	NITRATE	NO3-1	MG/L	0.00	0.00	0.00	0.44	2.66
	PHOSPHATE	PO4-3	MG/L	0.61	1.53	3.07	1.23	0.00
	SULFATE	SO4-2	MG/L	16.00	47.00	6.00	44.00	22.00
CATION TOTAL			MEQ/L	18.08	21.84	21.37	8.13	11.09
ANION TOTAL			MEQ/L	11.56	22.27	21.22	8.69	11.10
ION BALANCE			MEQ/L	6.52	-0.43	0.14	-0.57	-0.01
STANDARD DEVIATION				-22.8135	0.9487	-0.3244	2.348	0.032
SILICA		SIO2	MG/L	194.65	102.67	75.72	82.78	71.01
DRINKING WATER HEAVY METALS								
	ARSENIC TOTAL	AS	MG/L	0.02	0.00	0.00	0.00	0.00
	BARIUM TOTAL	BA	MG/L	1.20	0.36	0.40	0.33	0.48
	CADMIUM TOTAL	CD	MG/L	0.00	0.00	0.00	0.00	0.00
	CHROMIUM TOTAL	DR	MG/L	0.05	0.02	0.02	0.00	0.00

APPENDIX G. CONT.								
	SAMPLES TAKEN ON:	11/22/91						
				WELL 7	WELL 8	WELL 9	WELL 10	WELL 11
DRINKING WATER HEAVY METALS CONT.								
	LEAD TOTAL	PB	MG/L	0.06	0.00	0.00	0.01	0.00
	MERCURY TOTAL	HG	MG/L	0.00	0.00	0.00	0.00	0.00
	SELENIUM TOTAL	SE	MG/L	0.00	0.00	0.00	0.00	0.00
	SILVER TOTAL	AG	MG/L	0.00	0.00	0.00	0.00	0.00
TOTAL DISSOLVED SOLIDS (CALC)			MG/L	847.21	1251.40	1160.32	523.40	633.33
TOTAL ALKALINITY			AS CaCO3 MG/L	540.00	876.00	872.00	340.00	500.00
CARBONATE ALKALINITY			AS CaCO3 MG/L	539.74	875.66	871.58	339.88	499.95
CALCIUM ALKALINITY			AS CaCO3 MG/L	417.00	441.97	541.85	217.99	334.60
MAGNESIUM ALKALINITY			AS CaCO3 MG/L	122.74	160.52	171.64	77.79	89.73
SODIUM ALKALINITY			AS CaCO3 MG/L	0.00	251.01	145.81	29.10	70.96
TOTAL HARDNESS			AS CaCO3 MG/L	639.38	624.64	725.77	310.78	428.99
CALCIUM HARDNESS			AS CaCO3 MG/L	417.00	441.97	541.85	217.99	334.60
MAGNESIUM HARDNESS			AS CaCO3 MG/L	139.12	160.52	171.64	77.79	89.73
NON-CARB. HARDNESS			AS CaCO3 MG/L	99.64	0.00	0.00	0.00	0.00
CA NON-CARB. HARDNESS			MG/L	0.00	0.00	0.00	0.00	0.00
MG NON-CARB. HARDNESS			MG/L	16.38	0.00	0.00	0.00	0.00
PH		PH UNITS		6.71	6.70	6.61	6.30	6.40
SATURATION PH		PH UNITS		6.53	6.31	6.22	6.99	6.65
STABILITY INDEX		PH UNITS		6.36	5.92	5.84	7.68	6.89
SATURATION INDEX		PH UNITS		0.18	0.39	0.39	-0.69	-0.25
TTL FREE CARBON DIOXIDE			CO2 MG/L	180.01	293.34	359.32	300.56	346.53
NECESSARY FREE CARB. DIOXIDE			CO2 MG/L	272.35	725.14	881.39	61.77	196.99
EXCESS CARBON DIOXIDE			CO2 MG/L	-92.34	-431.79	-522.07	238.79	149.55
TEMPERATURE OF ANALYSIS			FAHRENHEIT	77.00	77.00	77.00	77.00	77.00
CONDUCTIVITY, MEAS. @ 25C			MICROMHOS/CM	1400.00	2500.00	3000.00	1089.00	1440.00
CONDUCTIVITY, CALC. @ 25C			MICROMHOS/CM	1099.36	1707.81	1621.88	688.61	863.02
CALC. COND./MEAS. COND.				0.7853	0.6831	0.5406	0.6323	0.5993
IONIC STRENGTH			MOL/L	0.0214	0.0288	0.0287	0.012	0.0156

APPENDIX H. RADIOLOGICAL SURVEY OF MONITORING WELLS AT THE KSU LANDFILL			
APPENDIX H			
Radiological survey of monitoring wells			
SAMPLES TAKEN ON: 7/18/90 AND ANALYZED ON: 8/2/90			
WELL	TRITIUM	CARBON-14	PHOSPHORUS-32
8	25.50	18.60	27.30
1	28.90	17.30	28.60
2	163.20	28.10	31.80
3	41.20	20.90	27.90
4	43.00	29.50	34.00
5	25.60	22.90	29.20
SAMPLES TAKEN ON: 4/19/91 AND ANALYZED ON: 4/20/90			
WELL	TRITIUM	CARBON-14	PHOSPHORUS-32
1	0.00	1.21	0.08
2	37.87	0.09	4.07
3	16.96	0.00	0.00
4	202.35	3.13	0.00
5	0.49	1.44	5.72
6	0.00	0.00	0.00
7	0.00	0.00	0.00
8	104.06	0.00	0.00
9	34.43	2.36	0.48
10	0.35	0.00	0.00
11	0.01	0.00	0.00
SAMPLES TAKEN ON: 5/1/91 AND ANALYZED ON: 6/5/91			
WELL	TRITIUM	CARBON-14	PHOSPHORUS-32
4	283.77	7.31	1.10
7	0.00	1.49	0.62
8	107.50	3.43	1.78
9	42.76	11.84	15.01
SAMPLES TAKEN ON: 7/16/91 AND ANALYZED ON: 7/24/91			
WELL	TRITIUM	CARBON-14	PHOSPHORUS-32
1	0.10	0.00	0.00
2	19.48	0.00	0.00
3	3.40	0.00	0.34
4	219.00	4.66	1.20
5	0.00	1.81	1.63
6	0.00	1.54	3.77
7	0.32	0.00	0.00
8	86.49	1.11	1.31
9	58.00	2.89	0.78
10	0.00	0.00	0.00
11	0.00	0.00	0.11

APPENDIX H. RADIOLOGICAL SURVEY OF MONITORING WELLS AT THE KSU LANDFILL.				
	SAMPLES TAKEN ON: 7/16/90		AND ANALYZED ON: 8/2/90	
WELL	TRITIUM	CARBON-14	PHOSPHORUS-32	
B	23.60	18.60	27.20	
1	28.90	17.30	28.60	
2	163.20	28.10	31.80	
3	41.20	20.90	27.90	
4	43.60	28.50	34.00	
5	25.60	22.90	29.20	
	SAMPLES TAKEN ON: 4/19/91		AND ANALYZED ON: 4/20/90	
WELL	TRITIUM	CARBON-14	PHOSPHORUS-32	
1	0.00	1.31	0.08	
2	37.87	0.09	4.07	
3	16.96	0.00	0.00	
4	202.35	3.13	0.00	
5	0.49	1.44	5.72	
6	0.00	0.00	0.00	
7	0.00	0.00	0.00	
8	104.06	0.00	0.00	
9	34.43	2.36	0.48	
10	0.35	0.00	0.00	
11	0.01	0.00	0.00	
	SAMPLES TAKEN ON: 5/1/91		AND ANALYZED ON: 6/5/91	
WELL	TRITIUM	CARBON-14	PHOSPHORUS-32	
4	205.77	7.31	1.10	
7	0.00	1.49	0.62	
8	107.50	3.43	1.78	
9	42.76	11.84	15.01	
	SAMPLES TAKEN ON: 7/16/91		AND ANALYZED ON: 7/24/91	
WELL	TRITIUM	CARBON-14	PHOSPHORUS-32	
1	0.10	0.00	0.00	
2	19.48	0.00	0.00	
3	3.40	0.00	0.34	
4	219.00	4.66	1.20	
5	0.00	1.81	1.63	
6	0.00	1.54	3.77	
7	0.32	0.00	0.00	
8	86.49	1.11	1.31	
9	58.00	2.89	0.78	
10	0.00	0.00	0.00	
11	0.00	0.00	0.11	

APPENDIX H. CONT. RADIOLOGICAL SURVEY OF MONITORING WELLS.				
	SAMPLES TAKEN ON: 11/22/91		AND ANALYZED ON: 11/26/91	
WELL	TRITIUM	CARBON-14	PHOSPHORUS-32	
1	0.69	0.43	1.15	
2	25.23	6.67	3.83	
3	4.02	0.00	2.96	
4	290.32	6.35	2.17	
5	0.00	0.29	5.32	
6	0.00	0.00	4.43	
7	0.00	0.54	1.33	
8	98.86	4.20	1.82	
9	95.06	3.28	0.00	
10	2.97	0.00	6.87	
11	0.00	0.00	0.00	
RESULTS OF ANALYSIS ARE GIVEN IN DISINTEGRATIONS PER MINUTE.				
6600 DISINTEGRATIONS PER MINUTE ARE ALLOWED BY KDHE IN THE				
EFFLUENT (6600 DPM = KANSAS NOTIFICATION LEVEL).				
WELL "B" FROM ANALYSIS PERFORMED ON 8/2/90 REFERS TO A BACKGROUND				
STANDARD WHICH IS CONSIDERED NORMAL BACKGROUND.				
WATER SAMPLES WERE SURVEYED BY COMBINING ONE MILLILITER OF SAMPLE WITH				
TEN MILLILITERS OF SCINTILLATION FLUID AND ANALYZED ON A BECKMAN LIQUID				
SCINTILLATION COUNTER, MODEL 1801.				

