Vertical Hydraulic Conductivity of Soil and Potentiometric Surface of the Missouri River Alluvial Aquifer at Kansas City, Missouri and Kansas—August 1992 and January 1993

By Brian P. Kelly and Dale W. Blevins

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U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

For additional information write to:

District Chief
U.S. Geological Survey
1400 Independence Road
Mail Stop 200
Rolla, Missouri 65401

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
millimeter	3.937	inch
centimeter	0.3937	inch
meter	3.2808	foot
kilometer	0.6215	mile
square kilometer	0.3861	square mile
meter per hour	39.3701	inches per hour
meter per day	3.2808	foot per day
square meter per day	10.7642	square foot per day
cubic meter per day	264.2008	million gallons per day

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

GLOSSARY

Alluvium. The detrital deposits resulting from the actions of rivers. These deposits are composed of clay-, silt-, sand-, gravel-, cobble-, and boulder-size particles.

Aquifer. A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells or springs.

Cone of depression. The depression, approximately conical in shape, produced in a water table or **potentiometric surface** by pumping.

Confined aquifer. An **aquifer** bounded above by **confining units** or an **aquifer** containing confined water.

Confining unit. A body of material with low vertical **hydraulic conductivity** stratigraphically adjacent to one or more **aquifers**.

Evapotranspiration. Water discharge to the atmosphere by evaporation from water surfaces and moist soil and by plant transpiration.

Geographic information system (GIS). A computer data base that processes geographic data in digital form and displays data graphically for efficient data management and analysis.

Ground water. That part of subsurface water that is in the saturated zone.

Hydraulic conductivity. Capacity of material to transmit water under pressure. It is the volume of water per unit of time passing through a unit section of area under a unit **hydraulic gradient** at the existing kinematic viscosity.

Hydraulic gradient. The change in hydraulic head per unit distance of flow in a given direction; synonymous with potentiometric gradient.

Permeability. A measure of the relative ease with which a porous medium can transmit a fluid under a potential gradient.

Potentiometric surface. Surface that represents the static head of water in an **aquifer**; it is defined by the levels to which water will rise in tightly cased wells from a given point in an **aquifer**.

Specific yield. The ratio of the volume of water that an **aquifer** material will yield by gravity drainage to the volume of **aquifer** material.

Storage coefficient. The volume of water an **aquifer** releases from or takes into storage per unit surface area of the **aquifer** per unit change in hydraulic head. In an **unconfined aquifer**, it is essentially equal to the **specific yield.**

Synoptic water-level measurement. The measurement of water levels in wells over a broad area in a defined, relatively short time.

Transmissivity. The volume of water per unit of time that is transmitted through a unit width of an **aquifer** under a unit **hydraulic gradient**. **Transmissivity** is equal to **hydraulic conductivity** multiplied by the **aquifer** saturated thickness.

Unconfined aquifer. An **aquifer** that has a water table; the saturated zone between the water table and the first underlying **confining unit**; synonymous with surficial **aquifer**.

Zone of contribution. The area surrounding a pumped well that encompasses all areas or features that supply recharge to the well.

[Definitions modified from: American Geological Institute (1960); Lohman and others (1972); Heath (1983); Driscoll (1986); U.S. Environmental Protection Agency (1987)].

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Abstract

The Missouri River alluvial aquifer in the Kansas City metropolitan area is the only aquifer in the area capable of supplying large quantities of ground water. Hydrogeologic data for the Missouri River alluvial aquifer at Kansas City, Missouri and Kansas, were compiled from existing data into a regional geographic information system. The vertical hydraulic conductivity of soil was used to identify areas of the aquifer susceptible to surface contamination. The vertical hydraulic conductivity ranges from 0.002 to 0.152 meter per hour. Areas of vertical hydraulic conductivity between 0.023 and 0.043 meter per hour are greatest in extent. Large areas with vertical hydraulic conductivity greater than 0.043 meter per hour occur in conjunction with industrial land use within the Kansas City metropolitan area. Two potentiometric-surface maps of the aquifer were developed from synoptic water-level measurements collected from 187 wells during August 17 to 22, 1992, and from 155 wells during January 18 to 22, 1993. During these periods the Missouri River gained water from the aquifer and ground water flowed away from the valley walls, toward the river, and down the river valley. Under conditions of nearly equal pumping rates at active well fields, induced recharge from the river into the aquifer caused cones of depression at well fields near the river to be smaller than cones of depression around well fields located some distance from the river.

INTRODUCTION

The Missouri River alluvial aquifer in the Kansas City metropolitan area (fig. 1) is the only aquifer in the area capable of supplying large quantities of ground water. Ten public-water-supply well fields were operating and two additional public-water-supply well fields were under development in the area during 1993. Sixty-six municipalities and 23 public-water-supply districts in the Kansas City metropolitan area use water from the aquifer (table 1, at the back of this report). The aquifer supplies all or part of the drinking water for more than 900,000 people in the metropolitan area (Missouri Department of Natural Resources, 1991). Irrigators, printing and publishing companies, chemical manufacturers, primary metal industries, food processors, and other industries also use large quantities of water from the aquifer. The potability and general usability of water from the aquifer in agricultural parts of the flood plain is occasionally limited by large concentrations of nitrate and herbicides from non-point sources (Ziegler and others, 1993). Potential point sources of contamination in the study area include chemical plants, landfills, sewage-treatment plants, sludge disposal sites, and pipelines.

The Mid-America Regional Council, a planning association of city and county governments in the Kansas City metropolitan area, is developing a comprehensive regional plan for the protection of the Mis-

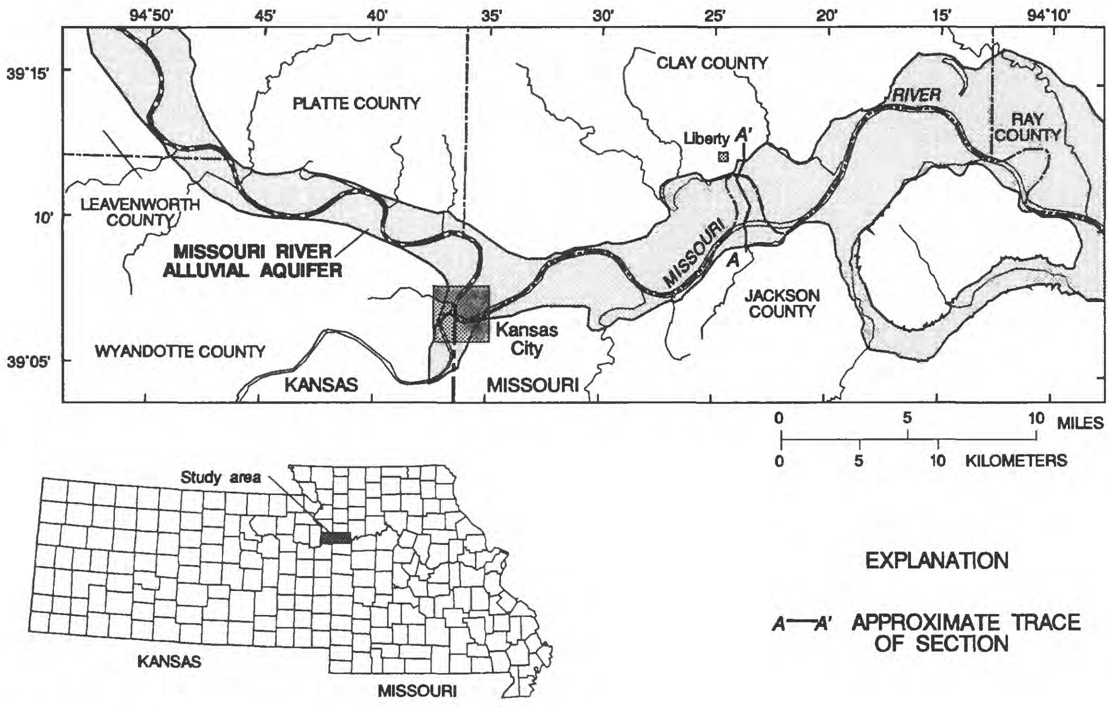

Figure 1. Location of the study area.

souri River alluvial aquifer near Kansas City. In 1991, the U.S. Geological Survey, in cooperation with the Mid-America Regional Council, initiated a study to provide hydrogeologic information to aid in the development of the aquifer protection plan.

Study Area

The approximately 400-square kilometer study area extends from approximately 5 kilometers north of the Leavenworth County-Wyandotte County line in Kansas to the eastern Jackson County line in Missouri and is bounded by the Missouri River alluvial-valley walls on the north and south (fig. 1). Parts of Clay, Jackson, Platte, and Ray Counties in Missouri and Leavenworth and Wyandotte Counties in Kansas lie within the study area. About two-thirds of the study area is row-crop agriculture, and the remaining one-third is urbanized.

Purpose and Scope

This report describes the areal distribution of vertical hydraulic conductivity in soil and shows the potentiometric surface for the Missouri River alluvial aquifer at Kansas City, Missouri and Kansas, at two different seasons and river stages. The vertical hydraulic conductivity in soil within the study area was mapped to identify areas of the aquifer most susceptible to contamination from the land surface. A water-level monitoring network was established for synoptic water-level measurements. Two potentiometric-surface maps of the study area at different seasons and stages of the Missouri River were produced from the synoptic water-level measurements.

Geographic Information System Data Base

Hydrogeologic data have been collected in the study area by public- and private-water suppliers to develop and maintain their well fields, by the U.S. Army Corps of Engineers during levee construction projects, and by various State and local highway departments during road and bridge construction. Additional information has been collected during studies conducted by researchers from local universities and State and Federal agencies. Information also has been collected during remedial investigations of hazardous-waste sites and monitoring of ground water beneath landfills, refineries, chemical plants, and other industries. The information collected from these sources, combined with water-level data collected during the study, was used to develop a regional geographic information system (GIS) data base of ground-water levels and alluvial stratigraphy, including depth to bedrock. Currently (1995), information is available from more than 1,400 locations within the study area. Information available, but not present in the GIS, include aquifer properties, well construction, pumpage, and water quality. Locations of sites for which data are available in the GIS are shown in plate 1.

Land Use

To assess the potential effect of human activity on ground-water quality within the Missouri River alluvial aquifer, a map of land use was developed for the study area from maps provided by the Mid-America Regional Council and is shown in plate 2. Row-crop agriculture is the largest land use in the study area; industrial activity is the second largest. The remaining parts of the study area consist of single- and multiple-family dwellings, commercial activities, undeveloped land, and publicly owned land, such as airports, sewage-treatment plants, and parks.

Agricultural land use may affect ground-water quality in the study area through non-point-source contamination caused by the widespread use of agricultural chemicals and point-source contamination such as feedlots (Ziegler and others, 1993). Types of agricultural chemicals used in the study area include pesticides and fertilizers. Areas of concentrated industrial activity may affect ground-water quality through point-source contamination such as spills and leaks of industrial chemicals. Potential point-source contamination also may occur from spills or leaks along transportation routes that cross the alluvial aquifer.

Acknowledgments

The authors thank the many residents, landowners, and businesses in the study area for their cooperation and assistance with the collection of water-level and other data. The assistance provided by personnel from Kansas City, Independence, North Kansas City, Gladstone, Excelsior Springs, Lake City Army Ammunition Plant, Missouri Cities Water Company, the U.S. Environmental Protection Agency, and various other municipal, county, State, and Federal agencies also is gratefully acknowledged.

HYDROGEOLOGIC SETTING

The flood plain of the Missouri River is underlain by alluvial deposits consisting of clays, silts, sands, gravels, cobbles, and boulders. Generally, the finer clays, silts, and sands are located near the surface of the alluvium and the coarser sands, gravels, cobbles, and boulders are located near the base of the alluvium. A typical cross section of the Missouri River alluvium near Liberty, Missouri, is shown in figure 2. The average thickness of the Missouri River alluvium in the study area is about 30 meters, but some deep bedrock channels are more than 60 meters deep (Hasan and others, 1988). The typical saturated thickness of the aquifer in this area is about 24 meters (Emmett and Jeffery, 1969).

A part of the ancestral Missouri River valley now occupied by the Little Blue River and Fire Prairie Creek is included in the eastern part of the study area (pl. 1). At one time the Little Blue River flowed eastward through the Lake City Army Ammunition Plant and Buckner, Missouri, areas. However, the ancestral Missouri River was diverted southward into the Little Blue River by continental glaciation, and a deeper channel was created in the Little Blue River valley during that time. After glacial retreat, the Missouri River returned to its previous course and the Little Blue River flowed to the north and west of its previous course. The deep channel created by the diversion of the Missouri River filled with alluvium and is hydrologically connected to the main part of the aquifer (Fischel and others, 1953).

Most water in the aquifer is derived from direct recharge from precipitation, seepage of water from adjacent geologic formations into the aquifer, and inflow from the Missouri River and its tributaries during flooding and sustained high-river stage. Sources of discharge from the aquifer include flow from the aquifer into the Missouri River, evapotranspiration, and pumping from public and private wells (Emmett and Jeffery, 1970).

Hydraulic properties of the alluvium in the study area have been determined by several investigators (Emmett and Jeffery, 1969, 1970; Layne Western Co., written commun., 1981; W.C. Walton, Geraghty

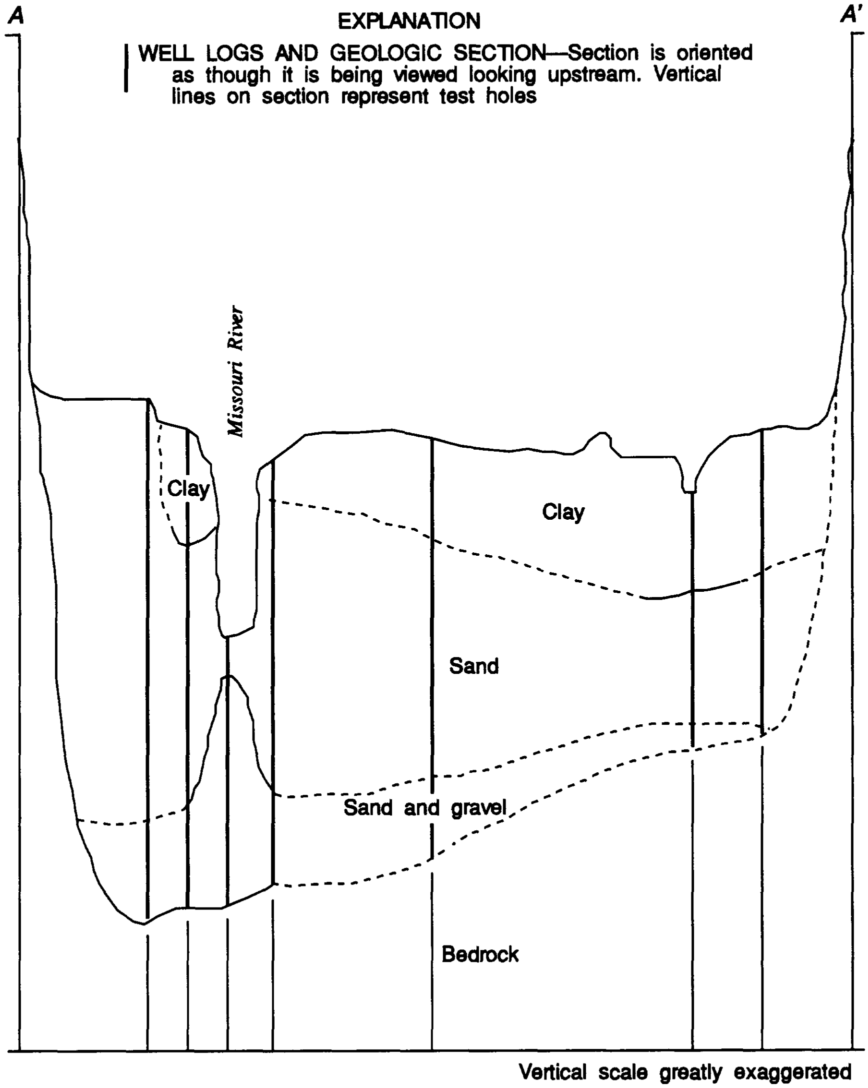

Figure 2. Generalized geologic cross section through the Missouri River alluvium near Liberty, Missouri (modified from Emmett and Jeffery, 1970; location of section is shown in fig. 1).

and Miller, written commun., 1982); much of the hydraulic properties data in this report were obtained from those reports. Reported hydraulic conductivity values for the Missouri River alluvial aquifer in the study area range from 126.3 to 326 meters per day. Transmissivity values range from 2,700 to 6,200 meters squared per day. Estimated values of the coefficient of storage in the study area average about 0.2 and indicate an unconfined aquifer (Crabtree and Older, 1985). Typical coefficient of storage values (specific yield) for unconfined aquifers range from 0.01 to 0.3. Coefficient of storage values (storativity) for confined aquifers range from 0.00005 to 0.005 (Freeze and Cherry, 1979). In some locations within the study area, the top of the aquifer is overlain by a layer of clay and clay-rich soil. The aquifer may be confined or semiconfined in these areas.

VERTICAL HYDRAULIC CONDUCTIVITY OF SOIL

Parts of the study area are covered with soil deposits characterized by low vertical hydraulic conductivity clays and silty clays that provide the alluvial aquifer with some protection from surface contamination. However, in other areas, sandy soil with greater vertical hydraulic conductivity is present at the land surface (fig. 2). In these areas, the aquifer is most susceptible to surface contamination because of rapid recharge to ground water. The vertical hydraulic conductivity of the soil in the study area is mapped on plate 3.

The map showing vertical hydraulic conductivity of soils in the study area was developed by digitizing the areal extent of 31 classified soil types from 1:20,000 and 1:24,000 Soil Conservation Service soil survey maps. The vertical hydraulic conductivity of each of these soils was described by the Soil Conservation Service from land surface to depths of 1.5 to 1.8 meters (Zavesky, 1977; Preston, 1984, 1985, 1986). Soils with similar vertical hydraulic conductivity values were grouped, resulting in five vertical hydraulic conductivity classes. A sixth (unknown) class of vertical hydraulic conductivity was assigned to fill material and urban land covered by roads, parking lots, and buildings. The areas where these materials and structures are present can have vertical hydraulic conductivities that may vary greatly in short distances. Soil name, Soil Conservation Service soil number, soil location, and vertical hydraulic conductivity for each soil are listed in table 2, at the back of this report.

The vertical hydraulic conductivity of soils in the study area ranges from 0.002 to 0.152 meter per hour. The areal extent of soils characterized by a range of vertical hydraulic conductivity between 0.023 and 0.043 meter per hour is the largest in the study area. Soils with vertical hydraulic conductivities less than 0.043 meter per hour occur over one-half of the study area. The smallest hydraulic conductivities are located in the eastern one-half of the study area and are associated with lower lying areas of the alluvium, where more clay-rich soils have developed. The larger vertical hydraulic conductivities (greater than 0.043 meter per hour) are more common in the central and western part of the study area near urban and industrial areas of the Kansas City metropolitan area.

POTENTIOMETRIC SURFACE

Several public well fields in the study area are adjacent to industrial and agricultural areas in the Missouri River alluvial valley. To assess the potential for activities in these areas to adversely affect ground-water quality, it is necessary to know the contributing area relative to each well field. Potentiometric-surface maps show the characteristics of the alluvial-aquifer potentiometric surface and, where a cone of depression has developed, provide an estimate of at least part of the area contributing water to wells or well fields. However, the area contributing to a well field may be substantially larger than the cone of depression.

Methods of Measurement

Water levels were measured in 187 wells from August 17 to 22, 1992, and in 155 wells from January 18 to 22, 1993, to determine the potentiometric surface of the aquifer. Most water-level measurements were made with a steel tape or an electric water-level measuring tape and are accurate to the nearest 3 millimeters. Water levels in public-water-supply wells were measured with an air line by water-company personnel to an accuracy of 0.33 meter.

Measuring-Point Altitude

Measuring-point altitudes of the wells in the water-level monitoring network were obtained using several methods. The measuring-point altitude or the altitude of the land surface plus the distance of the measurement point above land surface was used at wells for which associated documentation showed a surveyed altitude. The measuring-point altitudes for 18 wells with no altitude information were determined with a global positioning system (Brenda Groskinsky and Dan Harris, U.S. Environmental Protection Agency, written commun., 1992). The estimated accuracy of this method is 0.15 meter. The remaining measuring-point altitudes were determined to the nearest 0.01 meter using conventional surveying methods with a transit and level rod.

River-Stage Measurement

The stage of the Missouri River strongly affects water levels in the aquifer. River stage was measured during synoptic ground-water measurements at six locations on the Missouri River: the Kansas City, Kansas, Board of Public Utilities Nearman Power Plant; the Kansas City, Missouri, water-treatment plant; the U.S. Geological Survey gaging station at the Hannibal Bridge in Kansas City, Missouri; the Kansas City Power and Light Company Hawthorne Power Plant; the Missouri Public Services Sibley Power Plant; and the U.S. Army Corps of Engineers gaging station at

Napoleon, Missouri, about 4.5 kilometers east of the study area (pl. 4). River stage was measured on the Kansas River at the 23rd Street Bridge. River stage was interpolated along the midline of each river between known measuring points to help determine the potentiometric surface for each synoptic water-level measurement.

Ground-Water Movement

Generally, ground water flows away from the valley walls, toward the Missouri River, which drains the alluvial aquifer, and down the river valley. However, changes in river stage can temporarily reverse the usual pattern of ground-water flow. When the river stage increases rapidly or remains higher than water levels in the surrounding aquifer for extended periods, water flows from the river into the aquifer.

The effect of pumped wells on the potentiometric surface is indicated by cones of depression. A cone of depression in the potentiometric surface generally has the shape of an inverted cone and develops around a well from which water is being withdrawn. Cones of depression around individual wells and major well fields indicate a part of the area around each well field that supplied water to wells during a water-level measurement. However, the actual zone of contribution for each well field typically extends for some distance upgradient from the cone of depression. Because much of the water supplied to wells near the Missouri River is captured from the river, the extent of the cone of depression is less for these wells than for wells pumped at some distance from the river. Other factors that affect the extent of the cone of depression around a well or well field are the rate of pumping, aquifer transmissivity, aquifer storativity, sources of recharge to the aquifer, and the distance to impermeable or low-permeability boundaries, such as the alluvial-valley walls. The areal extent of the cones of depression at the Independence and Kansas City well fields (pls. 4, 5) is limited by the proximity to the river and the alluvial-valley walls. Conversely, the Liberty well field has a large cone of depression partially because of a lack of nearby hydraulic boundaries.

Non-point source ground-water contamination is typically associated with agricultural activities. Point-source ground-water contamination occurs more frequently in industrial areas and in the vicinity of transportation routes. Therefore, a comparison of land use in the study area with the part of the area of contribution defined by the cones of depression for each public-water-supply well field can indicate whether non-point source or point-source ground-water contamination is more likely to occur for each well field. Public-water-supply well fields located in areas of agricultural activity include the Missouri Cities Water Company well field; the Independence well field; the Liberty well field; the Excelsior Springs well field; and the Ray County Public Water Supply District Number 2 well field (pls. 4, 5). Because these well fields also are located near transportation routes, potential ground-water contamination may result from non-point or point sources. Public-water-supply well fields located in areas of industrial activity include the Gladstone well field, the Kansas City well field, and the North Kansas City well field (pls. 4, 5). These well fields are all near industrial activity and major transportation routes, and potential ground-water contamination can result from point sources.

The potentiometric-surface maps can be used to determine the directions of ground-water flow that existed around each well field and the area of contribution at the times the water levels were measured. Equipotential lines connect points of equal hydraulic head and represent the potentiometric surface of the aquifer at the time that water levels were measured. Ground water from areas of high potential to areas of low potential is assumed to move along flow lines at right angles to equipotential lines. Therefore, to determine the direction of ground-water flow from a map of the potentiometric surface, a flow line is drawn from an area of higher ground-water potential to an area of lower ground-water potential so that the flow line crosses each equipotential line at a right angle. An unlimited number of flow lines can be drawn on a potentiometric-surface map. However, the general pattern of ground-water flow can be ascertained from relatively few flow lines.

The area contributing to a pumped well or well field can be estimated by constructing flow lines on a potentiometric-surface map as described above. However, to determine the flow of ground water to a particular well or well field, flow lines must be drawn outward from the pumped well and toward areas of higher potential. This is necessary to ensure that the flow line represents water that is moving directly toward the pumped well. In addition, several flow lines must be drawn in different directions from the pumped well to describe the entire area contributing water to the well. Most of the hachured areas shown on plates 4 and 5 represent cones of depression around wells or well fields and also represent minimum contributing areas.

To estimate larger contributing areas, each flow line is drawn outward from the well or well field so that the flow line crosses equipotential lines at a right angle and until a boundary to ground-water flow is encountered. In the Missouri River alluvial aquifer in the study area, the major flow boundaries are the Missouri River, the Kansas River, the Blue River, the Little Blue River, the Fishing River, and the alluvial-valley walls (pl. 1). Smaller streams on the Missouri River alluvial valley may affect ground-water flow, but these effects, if present, are not well known. When several flow lines have been constructed, the contributing area of the well or well field can be estimated by connecting the ends of each flow line at the point where the flow line reached a flow boundary. The resulting area is the area of contribution at the time when water levels used to construct the potentiometric-surface map were measured.

The direction of ground-water movement and the areas of contribution estimated using the above method can be extremely useful, but some limitations exist with this approach that must be understood. These limitations are as follows:

1. The estimated areas of contribution are valid only for the period when water levels were measured.
2. The effects of vertical flow cannot be assessed.
3. The rate of flow cannot be determined without knowledge of the hydraulic conductivity of the aquifer material.

Potentiometric Surface—August 1992

During the August 17 to 22, 1992, synoptic water-level measurements, the river stage was decreasing, the general direction of flow in the aquifer was toward the river and downstream, and the Missouri River gained water from the aquifer along most of its length in the study area. However, near Parkville, North Kansas City, and Sugar Creek, induced recharge from the river into the aquifer occurred where pumped wells were located near the river. During the week of the synoptic measurement, the altitude of the Missouri River at the U.S. Geological Survey gaging station at the Hannibal Bridge in Kansas City decreased 1.32 meters from 221.17 meters on August 17 to 219.85 meters on August 22 (fig. 3; Reed and others, 1993).

Pumped wells and differences in local recharge caused the potentiometric surface for August 1992 to have numerous cones of depression and ground-water mounds within the study area. Cones of depression surround all public-water-supply well fields indicated on plate 4. Also, several additional cones of depression caused by industrial pumped wells were present; the largest of which is beneath intensely industrialized areas of North Kansas City, Missouri. Industrial wells are present in the river bend north of the junction of the Kansas and Missouri Rivers in Kansas City, Kansas. These wells have produced a broad but relatively shallow cone of depression in the southeastern one-half of the river bend. Near the Lake City Army Ammunition Plant in the eastern part of the study area, wells were pumped, but a well-defined cone of depression was not present.

Other areas where the potentiometric surface was low were not caused by pumped wells but rather from the effects on the potentiometric surface of variations in local recharge and previous changes in river stage. One such area of low potentiometric-surface altitude is south of Birmingham, Missouri (pl. 4). There were no pumped wells in this area, and the low potentiometric surface probably was caused by a combination of low recharge and the incomplete adjustment of water levels within the aquifer to the August river stage. Similar areas of relatively low potentiometric-surface altitudes but no local pumped wells were located south of Missouri City, Missouri. Both of these areas are characterized by extensive agricultural activity, and the lower recharge rates may have been caused by higher evapotranspiration rates associated with crop production.

Two ground-water mounds were present south of Parkville, Missouri, near the south alluvial-valley wall in Kansas and south of Missouri City, Missouri, near the south alluvial-valley wall next to the Little Blue River (pl. 4). These mounds probably are the result of local recharge to the aquifer from the surrounding highlands or from direct infiltration of precipitation.

The highest altitude of the potentiometric surface was 228 meters near the alluvial-valley walls in the northwestern part of the study area. The lowest altitudes, below 211 meters, were within the cones of depression surrounding the Independence, Liberty,

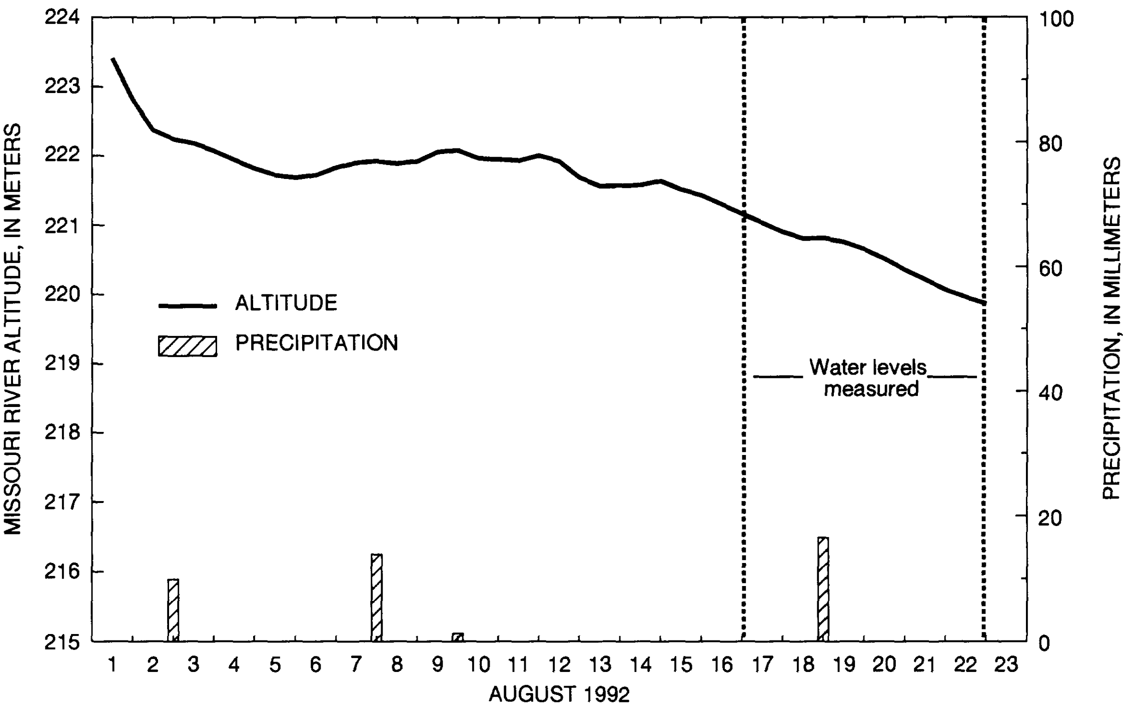

Figure 3. Altitude of the Missouri River at the U.S. Geological Survey gaging station at the Hannibal Bridge and precipitation at Kansas City Municipal Airport, Kansas City, Missouri—August 1 to August 22, 1992 (precipitation data from the National Oceanic and Atmospheric Administration, 1992).

and Ray County Public Water Supply District Number 2 well fields (pl. 4).

Potentiometric Surface—January 1993

During the synoptic water-level measurements of January 18 to 22, 1993, the river stage was lower than it was in August 1992, but slowly increased during the week of the measurement. The general direction of flow in the aquifer was toward the river and downstream, and the Missouri River gained water from the aquifer in the study area except where pumped wells were located near the river. Fairly constant river stage and little precipitation preceding and during the week of the synoptic water-level measurements maintained a constant relation between ground-water levels, flow direction, and river stage. The potentiometric surface of January 18 to 22, 1993, is more indicative of a steady-state ground-water-flow regime for this system than the potentiometric surface of August 1992. During the week of the measurement, the altitude of the Missouri River at the U.S. Geological Survey gaging station at the Hannibal Bridge in Kansas City ranged from 218.46 meters on January 18 to 218.62 meters on January 22 (fig. 4; Reed and others, 1993).

In January 1993, cones of depression surround all public-water-supply well fields indicated on plate 5. Other cones of depression were around industrial well fields in North Kansas City, Missouri, and in Kansas City, Kansas, as noted previously for the August 1992 potentiometric surface. While variations in local recharge and previous changes in river stage have affected the potentiometric surface, their effect was much less than for the August 1992 potentiometric surface as illustrated by the regular spacing of potentiometric contours in areas not affected by pumped wells. Areas of low potentiometric surface caused by low recharge rates are not evident for January 1993. This is probably due to the low evapotranspiration rates associated with the winter months.

Ground-water mounds are present south of Parkville, Missouri, in Kansas near the south alluvial-valley wall; in Kansas City, Missouri, east of North Kansas City, Missouri, and west of Interstate 435 near the south alluvial-valley wall; east of the Liberty well

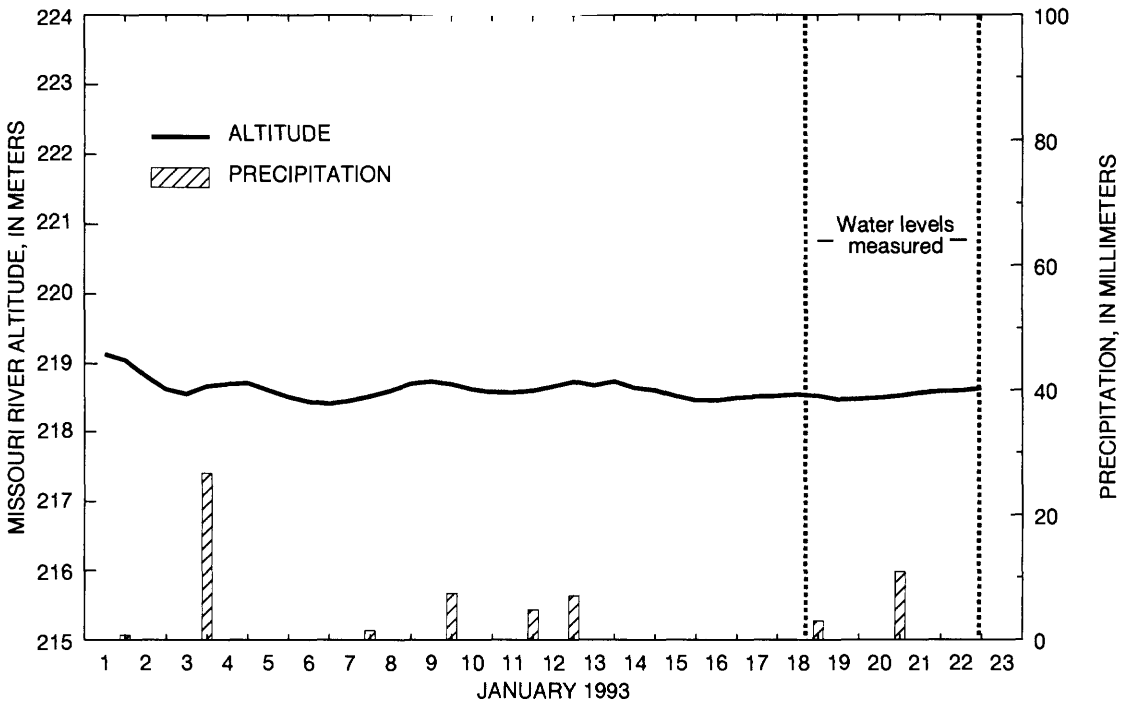

Figure 4. Altitude of the Missouri River at the U.S. Geological Survey gaging station at the Hannibal Bridge and precipitation at Kansas City Municipal Airport, Kansas City, Missouri—January 1 to January 22, 1993 (precipitation data from the National Oceanic and Atmospheric Administration, 1993).

field and west of Missouri City, Missouri, near the north alluvial-valley wall; and south of Missouri City, Missouri, near the south alluvial-valley wall next to the Little Blue River. These ground-water mounds are the result of local recharge from the highlands and increased amounts of infiltration caused by decreased evapotranspiration rates in the winter months.

The potentiometric-surface altitude ranged from 228 meters near the alluvial-valley wall in the northwestern part of the study area to 211 meters within the cones of depression surrounding the Independence and Ray County Public Water Supply District Number 2 well fields and near the Missouri River in the eastern part of the study area. This range is similar to that for August 1992. However, the average altitude of the potentiometric surface for January 1993 was approximately 0.42 meter lower than in August 1992 because Missouri River stages were lower in January 1993 than in August 1992.

SUMMARY

Hydrogeologic data for the Missouri River alluvial aquifer at Kansas City, Missouri and Kansas, were obtained from public- and private-water suppliers, the U.S. Army Corps of Engineers, State and local highway departments, other State and Federal agencies, local universities, and various hydrogeologic reports. Additional data were collected from ground-water monitoring of hazardous-waste sites, landfills, refineries, chemical plants, and other industries. The information collected from these sources, combined with water-level and other data collected during a study by the U.S. Geological Survey, was compiled into a geographic information system data base of the Missouri River alluvial aquifer. This information will be used by the Mid-America Regional Council, a planning association of city and county governments in the Kansas City metropolitan area, to develop a comprehensive ground-water protection plan for the aquifer.

A map of the areal distribution of vertical hydraulic conductivity of soil was prepared to help identify areas of the aquifer most susceptible to contamination from the land surface. Six vertical hydraulic conductivity classes were assigned to 31 soils in the study area. The vertical hydraulic conductivity ranges from 0.002 to 0.152 meter per hour. Soils with vertical hydraulic conductivity between 0.023 and 0.043 meter per hour have the largest areal extent. The soils with the lowest vertical hydraulic conductivity are associated with lower lying areas of the alluvium in the eastern one-half of the study area. Higher vertical are more common in the central and western parts of the study area and large areas of higher vertical hydraulic conductivity are present in urban and industrial areas of the alluvial valley.

Potentiometric surfaces of the aquifer were determined from synoptic water-level measurements of 187 wells during August 17 to 22, 1992, and of 155 wells during January 18 to 22, 1993. The Missouri River was gaining water from the aquifer when both potentiometric surfaces were determined, and ground water was moving away from the valley walls, toward the river, and down the river valley except where pumped wells were located near the river. Because much of the water supplied to wells close to the Missouri River is captured from the river, the extent of the cone of depression is less in these areas than for areas where pumped wells are located some distance from the river when pumping rates are nearly equal between well fields.

In August 1992 and in January 1993 cones of depression were present around all public-water-supply well fields and several industrial wells and well fields, and the altitude of the potentiometric surface in the study area was between 228 and 211 meters. The highest altitude was in the northwestern part of the study area. The lowest altitudes in August 1992 were within cones of depression in the vicinity of well fields in the eastern part of the study area. The lowest altitudes in January 1993 were in the eastern part of the study area within cones of depression in the vicinity of well fields and near the Missouri River. Areas of relatively low potentiometric-surface altitude due to decreased recharge caused by high rates of evapotranspiration were present in agricultural areas where no local wells were pumped during August 1992. These low potentiometric-surface areas were not present in January 1993 because recharge is not reduced by evapotranspiration during the winter. Two prominent ground-water mounds caused by recharge from the highlands and local recharge from infiltrating precipitation were present in August 1992 and four prominent ground-water mounds were present in January 1993.

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TABLES

Table 1. Users and sources of drinking water from the Missouri River alluvial aquifer in the Kansas City metropolitan area

[Data from Missouri Department of Natural Resources, 1991; PWSD, public water supply district; --, data not available]

Ground-water user	Source of water	Total daily use (cubic meters per day)	People served	Percentage of water use from ground water	Ground-water use (cubic meters per day)
Excelsior Springs	Alluvium	4,540	14,700	100	4,540
Mosby	Excelsior Springs	102	337	100	102
Ray County PWSD 1	Excelsior Springs	95	2,000	100	95
Elmira	Ray County PWSD 1	--	109	100	--
Woods Heights	Excelsior Springs	140	729	100	140
Gladstone	Alluvium	7,650	25,000	100	7,650
Independence	Alluvium	38,800	125,000	100	38,800
Blue Springs	Independence	15,600	37,000	100	15,600
Buckner	Independence	757	3,040	100	757
Levasy	Buckner	86	276	100	86
Sibley	Buckner	87	550	100	87
Grain Valley	Independence	511	1,850	100	511
Jackson County PWSD 15	Independence	2,044	3,500	100	2,044
Jackson County PWSD 17	Jackson County PWSD 15	492	1,600	100	492
Lake Lotawana	Jackson County PWSD 15	--	1,875	100	--
Lafayette County PWSD 1	Independence	1,480	6,106	100	1,480
Napoleon	Lafayette County PWSD 1	--	271	100	--
Bates City	Lafayette County PWSD 1	61	290	100	61
Lake Tapawingo	Independence	390	1,200	100	390
Lee's Summit	Kansas City Independence	25,800	43,000	81.5	21,000
Cass County PWSD 3	Lee's Summit	3,560	900	81.5	2,900
Cass County PWSD 6	Lee's Summit	443	2,000	81.5	361
Greenwood	Lee's Summit	--	1,315	81.5	--
Jackson County PWSD 12	Lee's Summit	14,800	1,680	81.5	12,100
Jackson County PWSD 13	Lee's Summit Jackson County PWSD 15	931	3,000	81.5	759
Tarsney	Jackson County PWSD 13	--	--	81.5	--
Jackson County PWSD 14	Lee's Summit	--	430	81.5	--

Table 1. Users and sources of drinking water from the Missouri River alluvial aquifer in the Kansas City metropolitan area—Continued

Ground-water user	Source of water	Total daily use (cubic meters per day)	People served	Percentage of water use from ground water	Ground-water use (cubic meters per day)
Lake Winnebago	Lee's Summit	190	609	81.5	155
Pleasant Hill	Lee's Summit	1,700	3,480	81.5	1,390
Cass County PWSD 1	Pleasant Hill	95	574	81.5	77
Strasburg	Cass County PWSD 1	--	170	81.5	--
Cass County PWSD 5	Pleasant Hill	379	650	81.5	309
Baldwin Park	Cass County PWSD 5	--	126	81.5	--
Oak Grove	Independence	1,510	4,065	100	1,510
Sugar Creek	Independence	905	2,500	100	905
Unity Village	Lee's Summit Two lakes	568	600	--	--
Kansas City	River Alluvium	325,000	450,000	5-10	24,400
Avondale	Kansas City	--	612	5-10	--
Belton	Kansas City	3,740	18,000	5-10	284
Cass County PWSD 2	Belton	1,020	2,613	5-10	77
Cass County PWSD 8	Belton	72	250	5-10	5
Loch Lloyd	Belton	--	9	5-10	--
Birmingham	Kansas City	45	240	5-10	3
Claycomo	Kansas City	--	1,671	5-10	--
Clay County PWSD 2	Kansas City	1,440	3,050	5-10	108
Pleasant Valley	Clay County PWSD 2	--	1,545	5-10	--
Clay County PWSD 6	Kansas City	787	2,400	5-10	59
Clay County PWSD 9	Kansas City	23	1,200	5-10	1.7
Ferrelview	Kansas City	--	447	5-10	--
Jackson County PWSD 1	Kansas City	8,860	22,368	5-10	665
Grandview	Jackson County PWSD 1	--	24,561	5-10	--
Northmoor	Kansas City	136	560	5-10	10
Oaks	Kansas City	--	126	5-10	--
Oakview	Kansas City	--	497	5-10	--
Oakwood	Kansas City	--	227	5-10	--
Oakwood Manor	Kansas City	--	137	5-10	--
Oakwood Park	Kansas City	--	231	5-10	--

Table 1. Users and sources of drinking water from the Missouri River alluvial aquifer in the Kansas City metropolitan area—Continued

Ground-water user	Source of water	Total daily use (cubic meters per day)	People served	Percentage of water use from ground water	Ground-water use (cubic meters per day)
Randolph	Kansas City	--	91	5-10	--
Raymore	Kansas City	1,820	5,569	5-10	137
Raytown	Kansas City	1,890	25,000	5-10	142
Weatherby Lake	Kansas City	606	1,500	5-10	45
Lake City Army Ammunition Plant	Alluvium	4,920	2,000	100	4,920
Liberty	Alluvium	8,250	20,600	100	8,250
Clay County PWSD 4	Liberty	632	1,000	100	632
Clay County PWSD 7	Clay County PWSD 4	61	160	100	61
Missouri City	Clay County PWSD 4	61	325	100	61
Prathersville	Clay County PWSD 4	--	141	100	--
Stockdale	Clay County PWSD 4	--	--	100	--
Clay County PWSD 5	Liberty	303	1,000	100	303
Nebo	Clay County PWSD 5	--	--	100	--
South Liberty	Clay County PWSD 5	--	--	100	--
North Kansas City	Alluvium	13,200	5,000	100	13,200
Orrick	Alluvium	340	650	100	340
Parkville	Alluvium	5,180	18,000	100	5,180
Houston Lake	Parkville	--	280	100	--
Lake Waukomis	Parkville	568	1,100	100	568
Platte Woods	Parkville	--	467	100	--
Platte County PWSD 6	Parkville	594	1,800	100	594
Riverside	Parkville	--	3,206	100	--
Ray County PWSD 2	Alluvium	2,460	10,200	100	2,460
Albany	Ray County PWSD 2	--	--	100	--
Camden	Ray County PWSD 2	--	219	100	--
Dockery	Ray County PWSD 2	--	--	100	--
Elkhorn	Ray County PWSD 2	--	--	100	--

Table 1. Users and sources of drinking water from the Missouri River alluvial aquifer in the Kansas City metropolitan area—Continued

Ground-water user	Source of water	Total daily use (cubic meters per day)	People served	Percentage of water use from ground water	Ground-water use (cubic meters per day)
Fleming	Ray County PWSD 2	--	144	100	--
Knoxville	Ray County PWSD 2	--	55	100	--
Lawson	Ray County PWSD 2 and one lake	693	2,100	100	--
Ray County PWSD 3	Ray County PWSD 2	337	1,143	100	--
Rayville	Ray County PWSD 2	--	197	100	--
Vibbard	Ray County PWSD 2	--	89	100	--

Table 2. Vertical hydraulic conductivity of soils in the Missouri River alluvial valley at Kansas City, Missouri and Kansas

[SCS, Soil Conservation Service; All, all counties in study area]

Soil name	SCS soil number	County and state	Vertical hydraulic conductivity (meter per hour)
Booker	35	Clay and Ray, Mo.	0.002
Bremer	36	Clay, Jackson, Platte, and Ray, Mo.	.015
Cotter	92	Jackson, Mo.	.033
Dockery	72	Clay and Ray, Mo.	.033
Eudora (overwash)	Eu	Leavenworth and Wyandotte, Kans.	.077
Fill	102	All	Unknown
Gilliam	88	Clay, Jackson, and Ray, Mo.	.033
Haynie	83	Clay, Jackson, and Ray, Mo.	.033
Haynie	83	Leavenworth and Wyandotte, Kans.	.072
Haynie	84	Platte, Mo.	.030
Kennebec	30	Jackson and Platte, Mo. Leavenworth and Wyandotte, Kans.	.033
Landes	80	Clay and Ray, Mo.	.064
Leta	73	Clay and Ray, Mo.	.015
Leta	73	Jackson and Platte, Mo.	.022
Levasy	74	Clay and Ray, Mo.	.017
Modale	87	Clay and Ray, Mo.	.013
Modale	87	Jackson, Mo.	.017
Myrick	78	Clay and Ray, Mo.	.027
Napier	91A	Jackson, Mo.	.033
Nodaway	39	Clay and Ray, Mo.	.033
Norborne	75	Clay and Ray, Mo.	.033
Onawa	On	Leavenworth and Wyandotte, Kans.	.021
Onawa (overwash)	Oo	Leavenworth and Wyandotte, Kans.	.024
Parkville	82	Jackson, Mo.	.055
Parkville	82	Clay, Platte, and Ray, Mo.	.025
Sarpy	89	All	.152
Urban	69A	All	Unknown
Waldron	81	Clay, Platte, and Ray, Mo.	.004
Wabash	90	Clay, Jackson, and Ray, Mo.	.002
Wiota	38	Clay, Jackson, Platte, and Ray, Mo.	.033
Zook	33	Clay, Jackson, and Ray, Mo.	.007

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