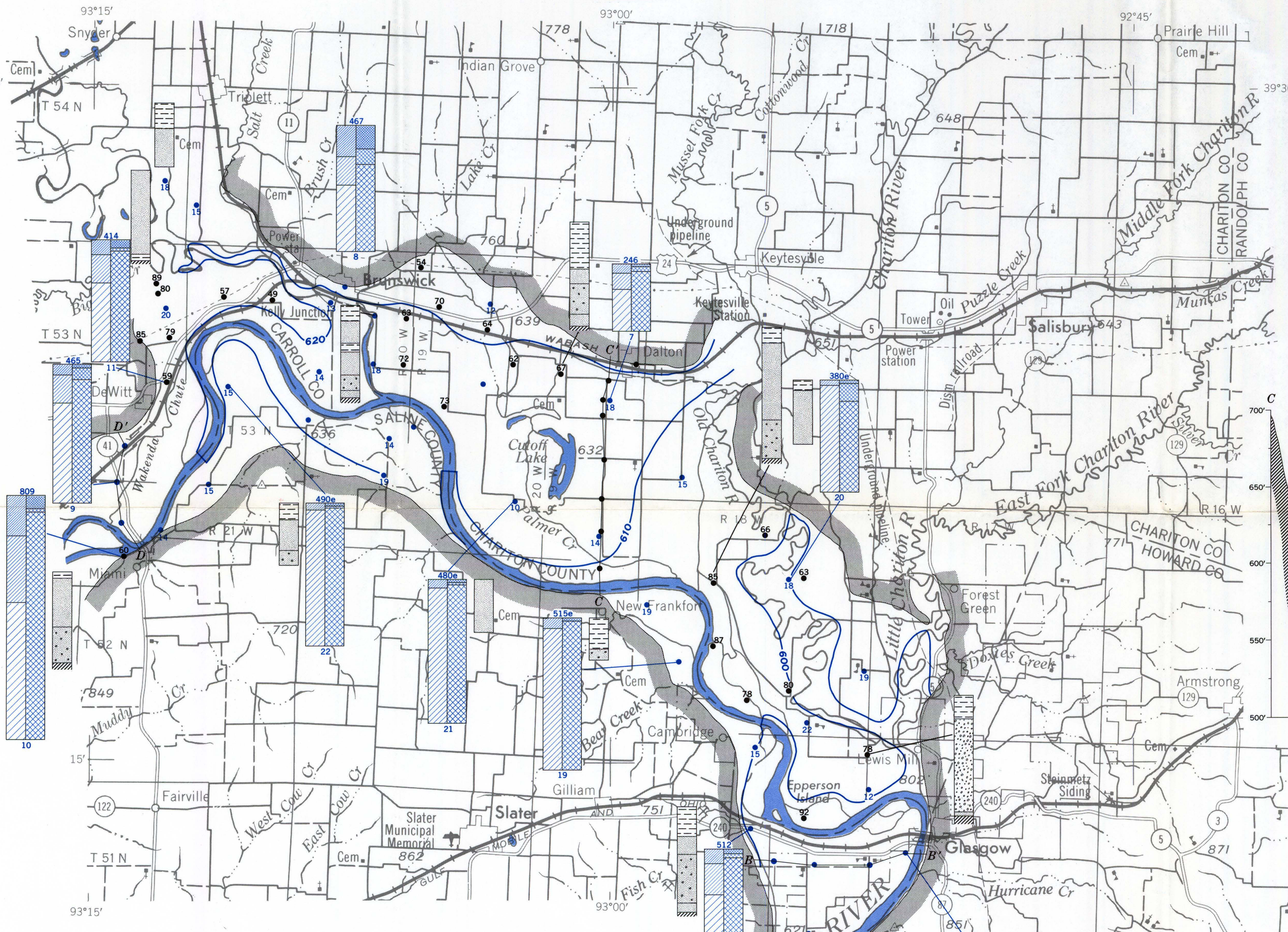
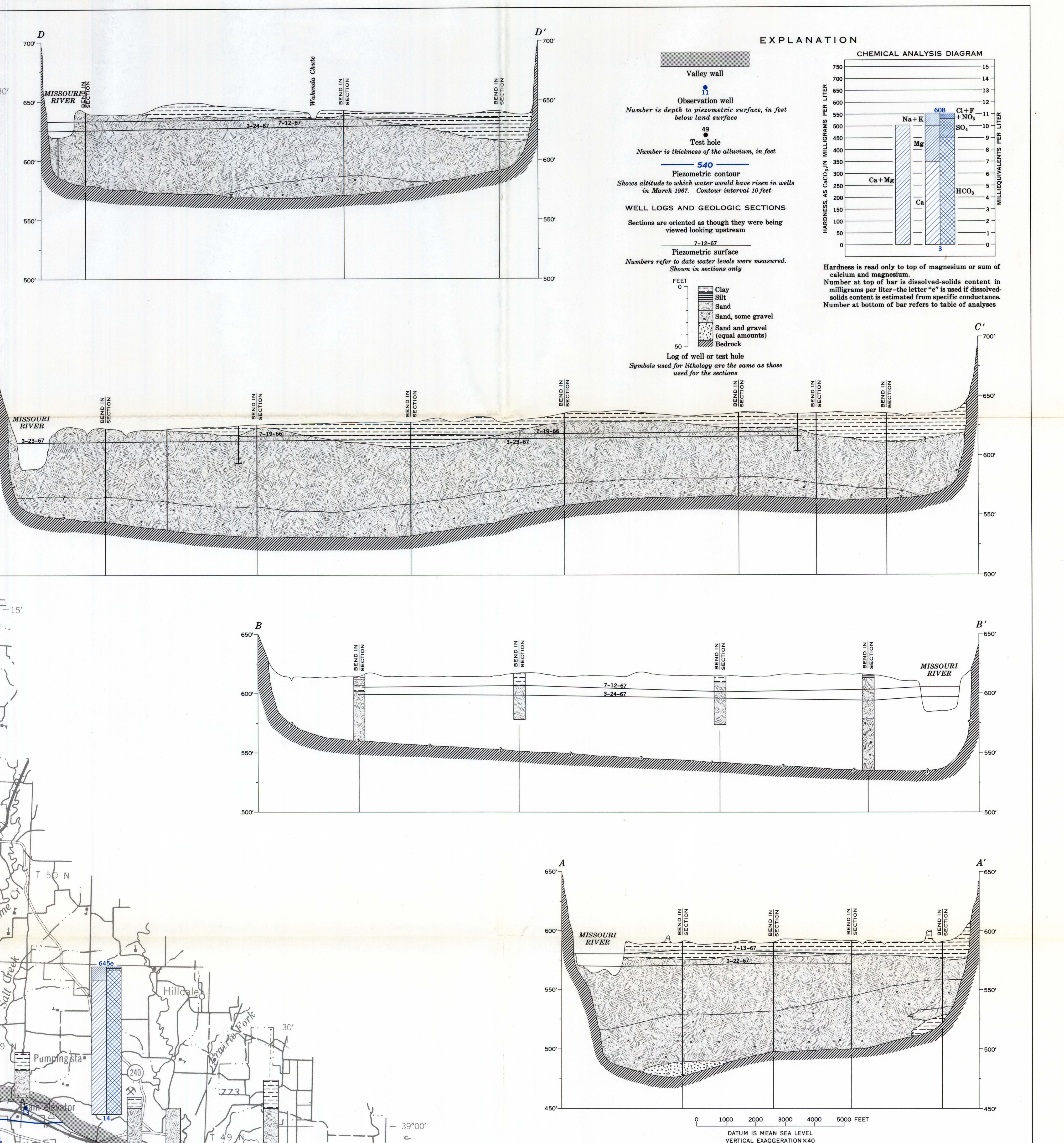
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
WILLIAM T. PECORA, DIRECTOR

PREPARED IN COOPERATION WITH THE
MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES
WILLIAM C. HAYES, DIRECTOR AND STATE GEOLOGIST

HYDROLOGIC INVESTIGATIONS
ATLAS HA-340





INTRODUCTION

The report area is the flood plain of the Missouri River from river mile 147, near Jefferson City, Mo., to river mile 263, near Miami, Mo. Flood-plain widths vary from 1.8 to 6.4 miles and have a total surface area of approximately 285 square miles. The flood plain is underlain by alluvium consisting of clay, silt, sand, and gravel which has been deposited by the river. The sand and gravel in the lower part of the alluvium is saturated with water and forms the alluvial aquifer. The water in this aquifer is in hydraulic connection with the Missouri River.

PURPOSE AND SCOPE

This is one of a series of atlases which present data on the ground-water resources of the Missouri River alluvium in Missouri. The purpose of this hydrologic atlas is to describe the thickness, areal extent, and lithology of the alluvial deposits along the Missouri River between Jefferson City, Mo., and Miami, Mo., and to provide information on the occurrence, availability, use, and chemical quality of the water contained in the alluvial aquifer.

PREVIOUS INVESTIGATIONS

Fuller and others (1957) have made a study to determine the possibilities of obtaining water from the glacial drift of Chariton County in which they present chemical analyses of water from wells drilled in the underlying bedrock. They (Fuller and others, 1957, p. 5) conclude for Chariton County that "... wells drilled into the consolidated rock to moderate depths may possibly obtain limited yields of water of marginal quality. The water from "rock" wells in all probabilities will become more mineralized with increased depth of drilling." They also conclude that with proper development wells drilled into the valley fill of the Missouri River in Chariton County may yield as much as 1,000 gpm (gallons per minute).

ACKNOWLEDGMENTS

The assistance and information provided by the staff of the Missouri Geological Survey and Water Resources are gratefully acknowledged. The authors also thank the many residents in the area and the representatives of other State and Federal agencies who provided information and assistance. Thanks are also due Mr. W. B. Russell and other officials of the Layne-Western Co., for making available pertinent records concerning wells and test holes drilled by their company.

GEOLOGIC SETTING

ALLUVIUM

The river that carved the Missouri Valley also partially filled the trough with sand, gravel, silt, and clay. In general, the lower part of the alluvium is made up of coarse sand and gravel, while the upper part is frequently composed of fine sand, silt, or clay. Thickness of the alluvium is controlled by irregularities in the bedrock surface. Based on available test-hole data the maximum alluvial thickness in this reach is about 95 feet and the average thickness is about 80 feet. The average saturated thickness is about 60 feet.

Lithologic character and thickness of the alluvium are shown on the accompanying map by strip logs and geologic sections. Information pertaining to geologic logs of wells and test holes shown on the map but not accompanied by a strip log can be obtained from the Missouri Geological Survey and Water Resources, Rolla, Mo.

GLACIAL DRIFT AND LOESS

The bedrock bordering the Missouri River flood plain is covered in some places by glacial drift and loess. The glacial drift is a heterogeneous mixture of clay, sand, gravel, and boulders. Where sand and gravel are present the deposits may be water bearing. Loess on the other hand is a homogeneous deposit of silt-sized particles, which though quite porous, yields little water. In places these materials obscure the bedrock-alluvium contact at the valley wall and make it difficult to determine whether the alluvium is in hydraulic connection with the glacial drift and loess or is contained by a relatively impermeable bedrock barrier. A more detailed study would be needed to determine this relationship in certain areas.

BEDROCK

The bluffs and rounded hills which border the Missouri River flood plain between Jefferson City, Mo., and Miami, Mo., are composed predominantly of limestone with lesser amounts of dolomite, shale, and sandstone. The same type of rocks also underlie the alluvium and form the bedrock (the rock surface upon which the sand and gravel rests). Areal distribution of the bedrock is shown on the geologic map of Missouri (McCracken and others, 1961). A description of each formation can be found in Howe and Koenig (1961). Well yield and quality of water from bedrock formations in Missouri are shown on maps by Robertson (1962), Fuller (1962), and Knight (1962).

GROUND-WATER HYDROLOGY

Ground water available to wells occurs in the openings between individual sand and gravel particles making up the alluvium. Some of this water comes from the streams, either from overbank flooding or sustained high-river stage; some comes from direct penetration by downward percolation of rainfall. A still smaller amount may be due to underflow from bedrock aquifers.

The main ground-water discharge is effluent seepage into the Missouri River. Other discharge may be attributed to evapotranspiration, downward movement of water into the bedrock, and pumping from wells.

Ground water in the alluvial aquifer occurs under water table (unconfined) and artesian (confined) conditions. These conditions vary geographically and in time. Consequently, in referring to the map, reference will be made to the piezometric surface (the surface to which water in the aquifer will rise under its full head) rather than the water table (the upper surface of the zone of saturation).

The contour lines on the accompanying map show the general shape of the piezometric surface for March 1967. Arrows drawn at right angles to the contour lines and pointing in the direction of decreasing altitude would show the direction of movement of the ground water. At this particular time (March 1967) the river was acting as a drain throughout most of its length. At other times, such as during periods of prolonged high-river stage, the direction of movement may be reversed, especially in the area close to the river and the aquifer will be recharged by the river.

The geologic sections show the maximum amount of fluctuation in the piezometric surface observed over a one-year period. In general, the greatest amount of fluctuation occurs closest to the river.

GROUND WATER USE

Ground water withdrawal by wells from the alluvium bordering this reach of the Missouri River represents a small fraction of the water available to wells. Negligible amounts of ground water are used for rural household and stock water throughout the area. A small amount is pumped sporadically from a few irrigation wells in Howard, Cooper, and Saline Counties. For Howard County it is estimated that in 1965 about 6.5 million gallons were pumped for irrigation. This is about 18,000 gpd (gallons per day). Figures are not available for Cooper and Saline Counties but it is probable that they would be about the same or less. The largest amount of water pumped in this area is for municipal use. Five towns pump a combined total of about 430,000 gpd, or about 300 gpm. Combined irrigation, municipal, rural, domestic, and stock use amounts to less than 500 gpm of continuous pumping.

WELL YIELDS

Several irrigation wells in the Boonville area and one in Boone County have reported yields of 1,000 gpm. The wells penetrate 60 to 70 feet of saturated sand and gravel. Municipal wells in this reach of the valley, while generally capable of greater yields are pumped at rates of less than 300 gpm. Reported specific capacities of five municipal wells range from 25 to 65 gallons per minute per foot of drawdown.

Test drilling indicates the alluvial aquifer is sufficiently thick and well sorted throughout much of this reach (see geologic sections and strip logs) to yield 1,000 gpm to wells properly located and constructed.

QUALITY OF THE WATER

Water from alluvial deposits in this reach of the Missouri River is characterized by a high hardness and iron content. The dissolved-solids content of the water ranges from 246 to 819 mg/l (milligrams per liter) and consists principally of calcium and bicarbonate with significant, but variable, amounts of magnesium, sulfate, sodium, and chloride. Variations in the dissolved-solids content and chemical character of the water are caused principally by differences in the chemical composition of the aquifer material and the length of time the water has been in contact with them.

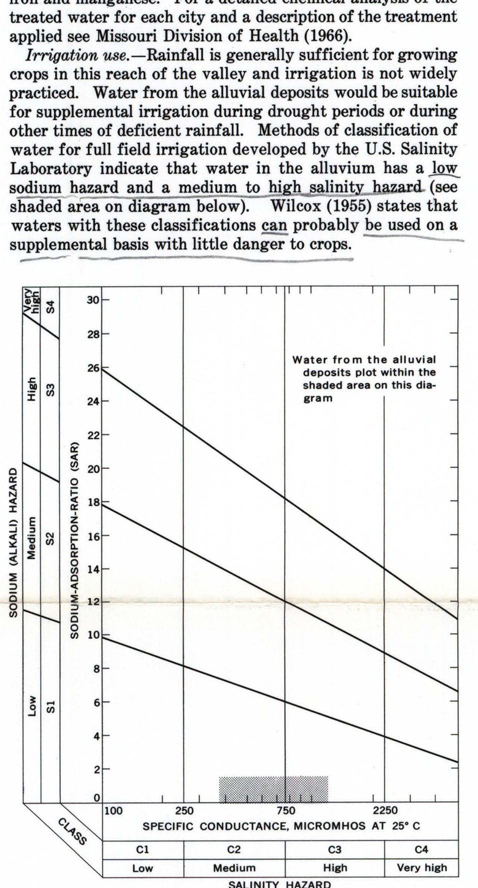
Areal variations in the dissolved-solids content and in the chemical characteristics of the water are shown graphically on the map. Chemical analyses of water from selected wells, along with the maximum, minimum, and median values based on all of the available analyses, and the recommended limits for drinking water, are shown in a table below. Bacterial content of the ground water was not evaluated during the present study. Thus, the remarks pertaining to suitability, given below, are restricted to an evaluation of chemical data and do not indicate the sanitary condition of the water.

Domestic and municipal use.—In this reach of the valley, water from the alluvium is used for farm supplies and by six communities for municipal water supplies. A comparison of the median values with the recommended limits for drinking water indicates that the iron and manganese content of water in the alluvium is generally excessive for domestic and municipal use, and treatment for iron and manganese removal is desirable.

The minimum value of 190 mg/l for hardness indicates that in this reach of the valley the water is very hard and could be profitably softened for many domestic uses. Although hardness of water is not considered in the drinking water standards, a high hardness is undesirable in water for domestic uses because it forms a scale in hot water pipes and in other vessels in which water is boiled, and it also consumes an excessive amount of soap and detergent during the washing process.

All water pumped from the Missouri River alluvium for municipal use is disinfected at the treatment plants. Some plants also have provision for water softening and removal of iron and manganese. For a detailed chemical analysis of the treated water for each city and a description of the treatment applied see Missouri Division of Health (1966).

Irrigation use.—Rainfall is generally sufficient for growing crops in this reach of the valley and irrigation is not widely practiced. Water from the alluvial deposits would be suitable for supplemental irrigation during drought periods or during other times of deficient rainfall. Methods of classification of water for full field irrigation developed by the U.S. Salinity Laboratory indicate that water in the alluvium has a low sodium hazard and a medium to high salinity hazard (see shaded area on diagram below). Wilcox (1955) states that waters with these classifications can probably be used on a supplemental basis with little danger to crops.



Classification of water for irrigation use.

DEVELOPMENT OF THE GROUND-WATER SUPPLY

POTENTIAL YIELDS

The alluvial aquifer receives a large but undetermined amount of recharge from the river during overbank flooding and during sustained high-river stage. In addition to recharge from the river it is assumed that an average of 6 inches of the 38 inches of annual precipitation recharges the aquifer. This amounts to about 81 mgd (million gallons per day). The average saturated thickness of 60 feet and average effective porosity of 15 percent indicates that approximately 530 billion gallons of water are in storage at all times. When the average recharge from precipitation of 81 mgd and the large but undetermined amount of recharge from the river plus the 530 billion gallons of water in storage is contrasted with the 0.45 mgd that is withdrawn from the aquifer it is obvious that only a small fraction of the available water is being utilized.

The amount of water available from natural storage in the aquifer can be increased in some areas by locating a well so it induces recharge from the river. The amount induced from the river will depend upon the distance of the well from the river, the rate at which water can move through the aquifer, rate of pumping, amount of natural recharge to the aquifer, direction of natural ground-water movement, river stage, temperature of the river water, and vertical permeability of the streambed.

The chief advantages of a water supply developed through streambed percolation over a supply directly from the stream are a more nearly uniform chemical quality, a temperature range less than that of a stream, and the apparent removal or dilution of most objectionable odors and tastes (Rorabaugh, 1963, p. 52, 55–56).

The advantages of an induced infiltration supply over a conventional ground-water supply are the availability of more water, with less drawdown and consequent reduced pumping costs.

Rorabaugh (1963, p. 5) states that "...the planning of a water supply that is to be dependent on induced percolation through a streambed requires extensive knowledge of not only the hydrology of the basin, but also the geologic and ground water conditions in the vicinity of the proposed installation."

POTENTIAL PROBLEMS IN DEVELOPING A WELL OR WELL FIELD

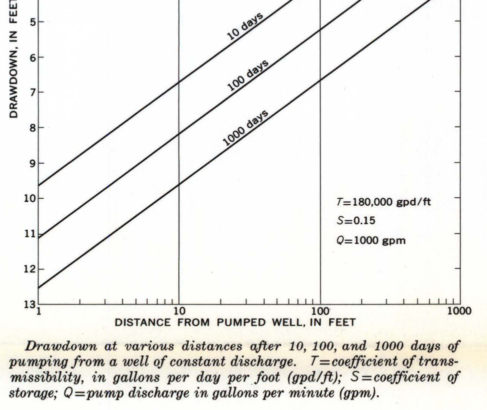
The chief problems which may be encountered in developing a well or well field in the alluvial aquifer are encrustation of well screens and excessive drawdowns caused by placing wells too close to each other.

The precipitation of calcium and iron carbonates probably is the major cause of well-screen encrustation problems in the area. The water in the alluvium has a tendency to precipitate carbonates, and, where well-screen encrustation is a problem, it is likely that the drop in pressure which occurs around the well screen during pumping causes some carbon dioxide to leave solution, thus permitting some carbonates to precipitate. The accumulation of these precipitates eventually lessens the well yield.

Although well encrustation cannot be completely eliminated its effects can be delayed or minimized by controlling the methods of well operation. Since the decrease in pressure drop as water moves into the well is indirectly the principal cause of encrustation, well operating practices which cause the least pressure drop will delay the rate of encrustant accumulation. These practices are (1) developing the well to its maximum capacity, then pumping it at a rate somewhat less than its developed capacity (2) reducing the pumping rate and pumping more continuously or, (3) increasing the number of wells pumped and pumping them at a lower rate.

Wells that are farther apart are more efficient owing to less interference between wells. However, where more than one well is to be used in a single well field the cost of the connecting pipeline and electrical installation is less when the wells are closer together. The optimum spacing of wells in a multiple well field is largely an economic problem and outside the scope of this report. For information on the optimum spacing of wells the reader is referred to Theis (1963, p. 113–117). Where pumping costs are the sole or major economic factor it may be desirable to space wells so there is a minimum of interference between wells.

The graph below shows the various drawdowns at different distances from a well pumping 1,000 gpm in an aquifer having a coefficient of transmissibility of 180,000 gallons per day per foot and a storage coefficient of 0.15.



Drawdown at various distances after 10, 100, and 1000 days of pumping from a well of constant discharge. T=coefficient of transmissibility, in gallons per day per foot (gpd/ft); S=coefficient of storage; Q=pump discharge in gallons per minute (gpm).

A pumping test was not run in this area, however the values used for the coefficient of transmissibility and the coefficient of storage in the preparation of the graph are based on tests run elsewhere in the Missouri River alluvium. The coefficient of transmissibility used here is based on a permeability of 3,000 gallons per day per square foot and an average saturated thickness of 60 feet. For an explanation of aquifer test theory and the assumptions upon which they are based see Ferris, and others, 1962.

It should also be noted where wells are closely spaced and pumped more or less continuously it is possible to lower the water level in the aquifer below the bottom of nearby shallower wells causing them, at least temporarily, to go dry.

SELECTED BIBLIOGRAPHY

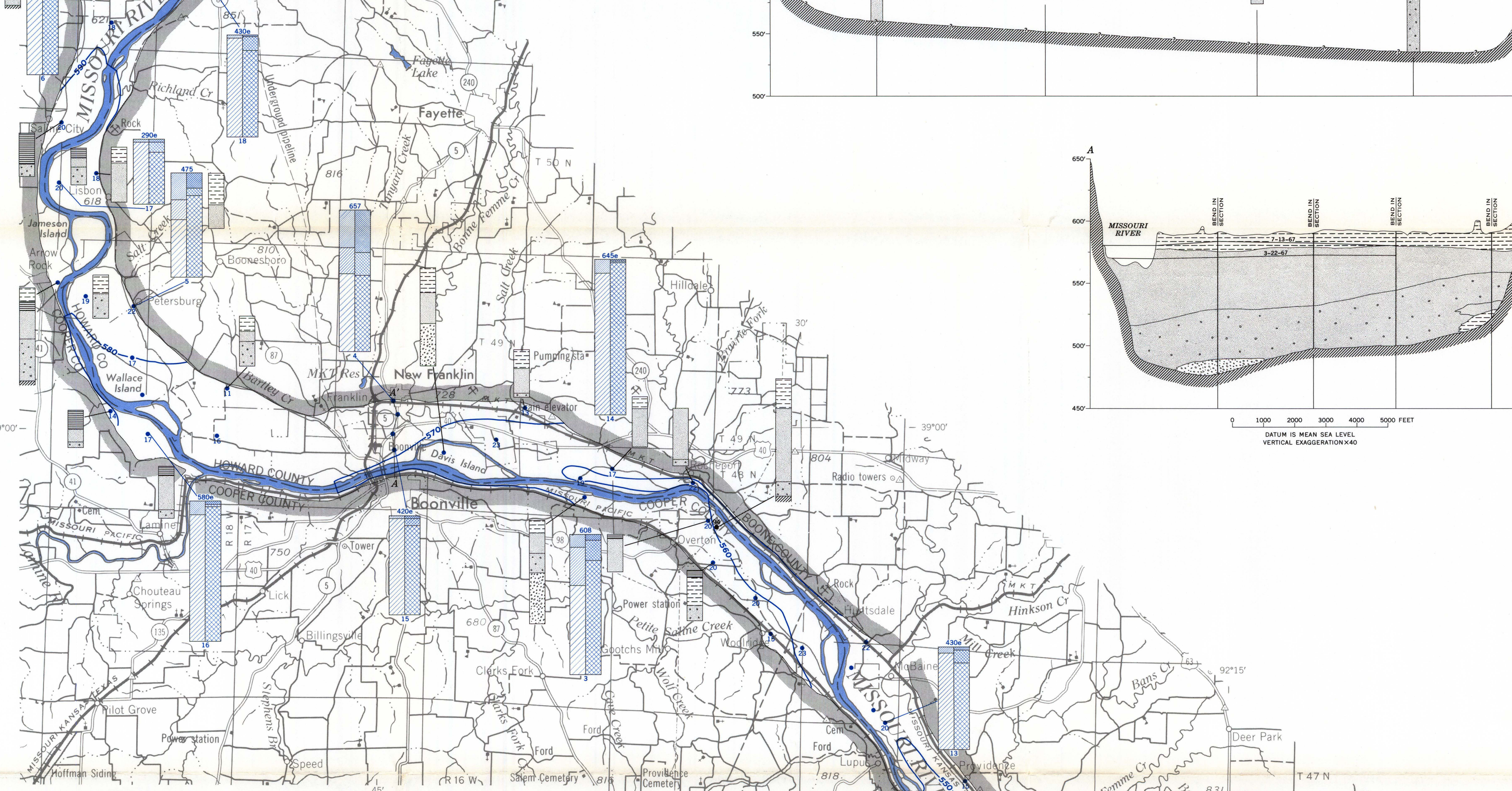
Ferris, J. G., and others, 1962, Theory of aquifer tests: U.S. Geological Survey Water-Supply Paper 1536-E, 174 p.
Fuller, D. L., and others, 1957, Water possibilities from the glacial drift of Chariton County: Missouri Geol. Survey and Water Resources, Water Resources Report no. 12, 14 p., 3 pls.
Fuller, D. L., 1962, Groundwater quality map of deep aquifers in Missouri *in* Groundwater maps of Missouri, 1963: Missouri Geol. Survey and Water Resources.
Howe, W. B., and Koenig, J. W., 1961, The stratigraphic succession in Missouri: Missouri Geol. Survey and Water Resources, 2d ser., v. 40, 185 p.
Knight, R. D., 1962, Groundwater areas in Missouri *in* Groundwater maps of Missouri, 1963: Missouri Geol. Survey and Water Resources.
McCracken, Mary H., and others, 1961, compilers, Geologic map of Missouri: Missouri Geol. Survey and Water Resources.
Missouri Division of Health, 1966, Census of Public Water Supplies in Missouri: Missouri Division of Health, 127 p.
Robertson, C. E., 1962, Water well yield map of Missouri, *in* Groundwater maps of Missouri, 1963: Missouri Geol. Survey and Water Resources.
Rorabaugh, M. I., 1963, Streambed percolation in development of water supplies, *in* Bentall, Ray, Methods of collecting and interpreting ground-water data: U.S. Geol. Survey Water-Supply Paper 1544-H, p. 47-62.
Schict, R. J., 1965, Ground-Water Development in East St. Louis Area, Illinois: Illinois State Water Survey Report of Investigation no. 51, 70 p.
Theis, C. V., 1963, Spacing of wells, *in* Bentall, Ray, Shortcuts and special problems in aquifer tests: U.S. Geol. Survey Water-Supply Paper 1545-C, p. 113-117.
U.S. Public Health Service, 1962, Drinking water standards: U.S. Public Health Service publication 956, 61 p.
U.S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U.S. Dept. Agriculture, Agriculture Handbook no. 60, 160 p.
Wilcox, L. V., 1955, Classification and use of irrigation waters: U.S. Dept. Agriculture Circ. 969, 19 p.

Base from U.S. Geological Survey, 1:250,000 Jefferson City, 1959 and Moberly, 1960

CHEMICAL ANALYSES OF WATER FROM SELECTED WELLS IN THE MISSOURI RIVER ALLUVIUM

Well number	Depth, feet	Date of collection	Temperature, °C	Milligrams per liter: Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180° C)	Hardness as $CaCO_3$: Calcium Magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos at 25° C)	pH	Color
1	37	3-3-67	14	22	3.2	0.56	163	40	6.8	3.6	596	102	7.2	0.0	0.0	639	572	82	2.6	0.1	1,030	7.5	0
2	42	3-3-67	17	25	6.2	2.8	196	48	22	6.1	740	122	23	.1	.4	819	687	80	6.4	.4	1,290	7.4	5
3	28	2-28-67	16	21	.25	.54	143	36	12	4.8	552	79	3.1	.2	18	608	506	52	4.8	.2	981	7.5	0
4	63	3-3-67	13	26	3.5	.56	123	25	71	4.2	366	94	113	.2	1.0	657	410	110	27	1.5	1,070	7.4	0
5	45	3-2-67	—	38	3.4	.61	93	20	40	6.6	400	27	45	.1	.0	475	314	0	21	1.0	781	7.5	0
6	57	3-1-67	13	31	4.9	.75	133	26	14	4.7	557	16	6.7	.2	.5	512	439	0	6.4	.3	839	7.6	0
7	32	3-2-67	16	31	2.0	.16	53	14	5.5	3.0	236	17	.7	.2	.1	246	190	0	5.8	.2	392	7.7	5
8	60	3-2-67	12	26	4.6	.50	86	22	42	3.0	337	49	58	.2	.1	467	305	29	23	1.0	768	7.7	0
9	40	3-1-67	14	28	5.0	1.0	127	22	8.4	4.0	476	36	1.9	.2	.1	465	408	18	4.2	.2	747	7.6	0
10	—	3-1-67	14	24	6.1	2.5	178	51	57	7.1	900	5.6	32	.2	2.9	809	655	0	16	.9	1,330	7.5	5
11	—	4-14-67	—	33	1.3	.57	101	22	17	4.0	432	3.0	20	.1	.0	414	343	0	9.4	.4	692	7.7	7
Maximum for area			18	38	6.2	2.8	196	51	71	7.1	900	122	113	0.2	18	819	687	110	—	—	1,330	8.0	12
Minimum for area			12	21	.12	.16	53	14	5.5	3.0	236	.2	.7	.0	.0	246	190	0	—	—	392	7.4	0
Median for area			14	26	2.0	.57	127	25	17	4.2	513	32	4.8	.2	.4	485	421	20	—	—	788	7.6	2
Recommended limits, drinking water standards[1]					0.30	0.05	—	—	—	—	—	250	[2]250	1.7	45	500	—	—	—	—	—	—	20

[1] U.S. Public Health Service, Drinking Water Standards, revised, 1962.
[2] Varies with annual average of maximum daily air temperatures and ranges downward from 1.7 mg/l (ppm) at 10.0° C (50° F) to 0.8 mg/l (ppm) at 32.1° C (90.5° F). The optimum concentration is from 1.2 to 0.7 mg/l (ppm).



HYDROGEOLOGIC MAP AND GENERALIZED GEOLOGIC SECTIONS

SCALE 1:125 000

DATUM IS MEAN SEA LEVEL

RECONNAISSANCE OF THE GROUND-WATER RESOURCES OF THE MISSOURI RIVER ALLUVIUM BETWEEN JEFFERSON CITY AND MIAMI, MISSOURI

By
L. F. Emmett and H. G. Jeffery

1969

For sale by U.S. Geological Survey, price 50 cents