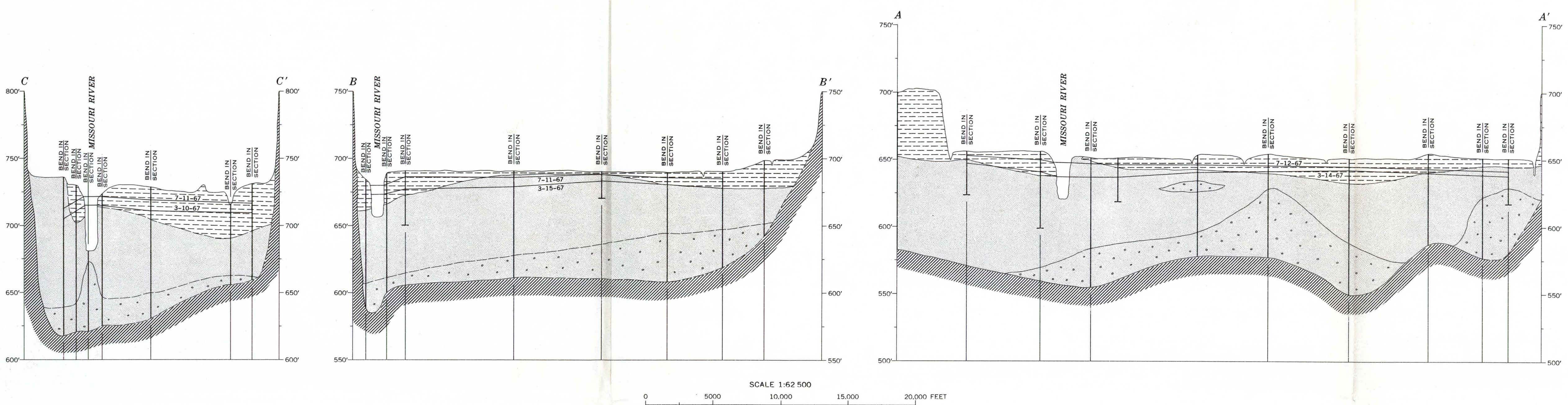
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
WILLIAM T. PECORA, DIRECTOR

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

HYDROLOGIC INVESTIGATIONS
ATLAS HA-344



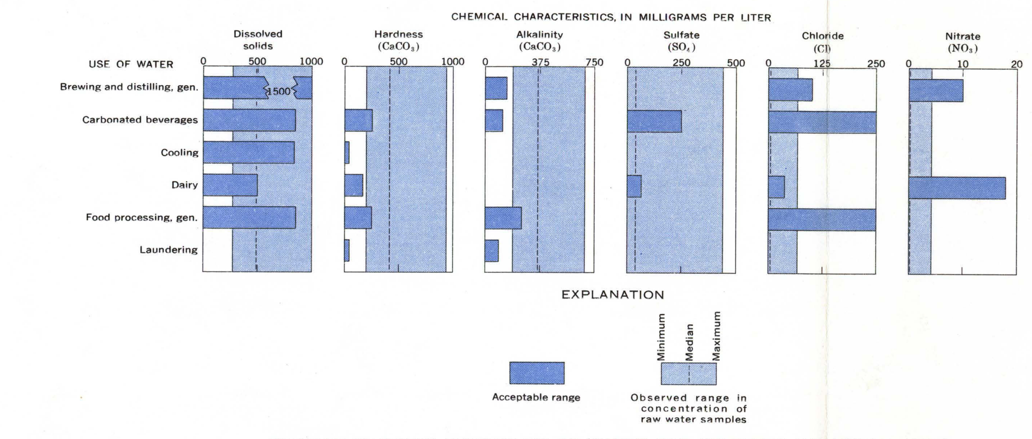
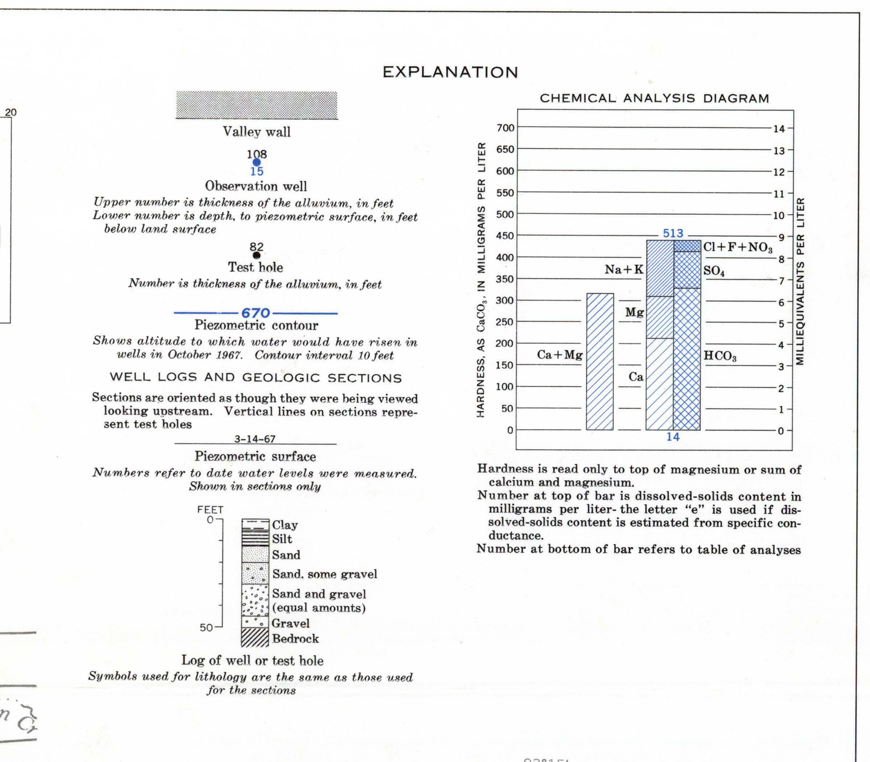
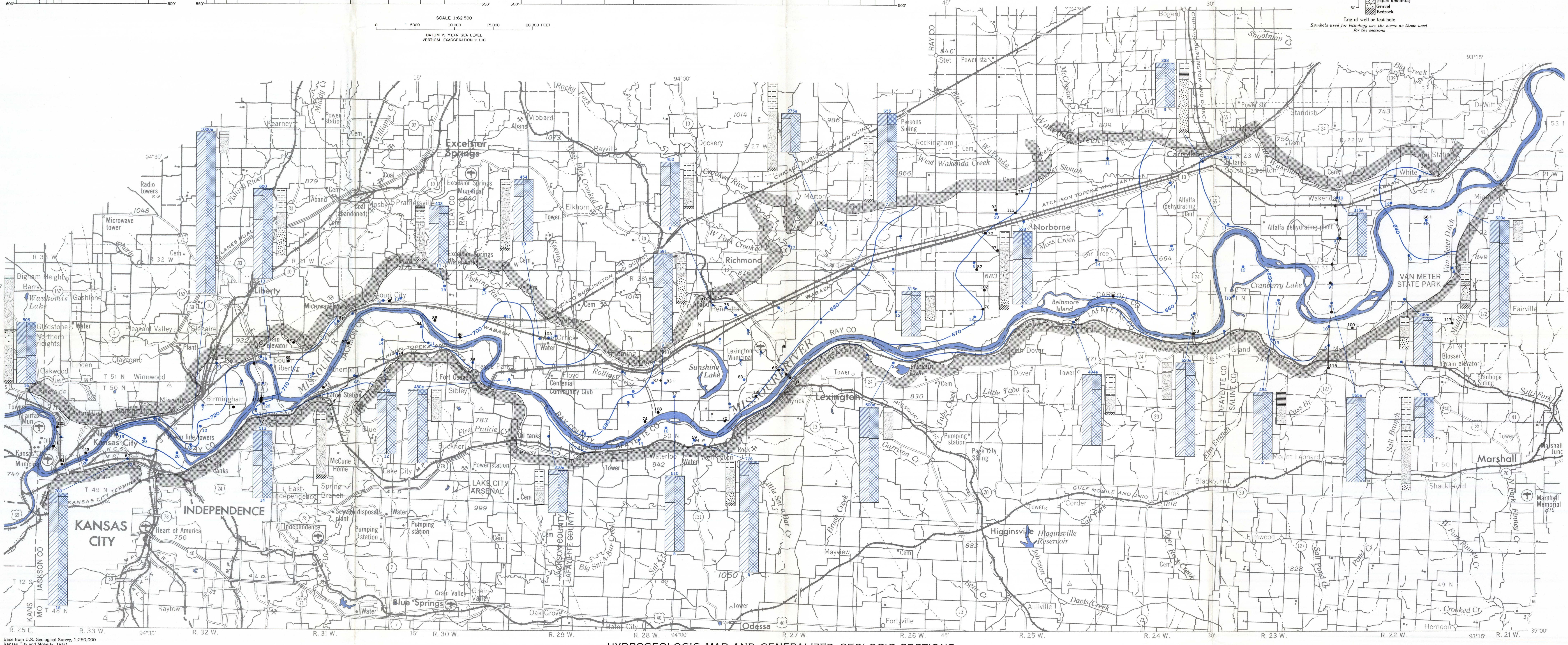


DIAGRAM SHOWING SUITABILITY OF WATER FOR SELECTED INDUSTRIAL USES

(From California State Water Quality Control Board publication no. 3-A, 2d ed.)





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

HYDROGEOLOGIC MAP AND GENERALIZED GEOLOGIC SECTIONS

SCALE 1:125 000

DATUM IS MEAN SEA LEVEL

1969 MAGNETIC DECLINATION FROM TRUE NORTH FOR THIS SHEET VARIES FROM 6½° EASTERLY FOR THE EAST EDGE TO 7½° EASTERLY FOR THE WEST EDGE

AREA OF THIS REPORT

INTRODUCTION

The report area is the flood plain of the Missouri River from river mile 263 near Miami to river mile 372 near Kansas City. Flood-plain width varies from 2 to 10 miles, and has a total surface area of approximately 440 square miles. Underlying the flood plain are clay, silt, sand, and gravel deposited by the river. The saturated sand and gravel, which is hydraulically connected with the river, constitutes a large and productive aquifer, which for the most part is presently underdeveloped.

PURPOSE AND SCOPE

The purpose of this hydrologic atlas is to describe the thickness, areal extent, and lithology of the alluvial deposits along the Missouri River between Miami and Kansas City, Mo., and to provide information on the occurrence, availability, use, and chemical quality of the water contained in the alluvial aquifer.

PREVIOUS INVESTIGATIONS

Fishel, Searcy, and Rainwater (1953) in a water-resources study of the Kansas City area found that the average yield for wells in that area was about 980 gpm (gallons per minute) and the average specific capacity about 60 gpm per foot of drawdown. They also report the results of two pumping tests that indicate the water-bearing alluvial deposits have a coefficient of permeability of about 3,000 gallons per day per square foot.

The area adjacent to this reach of the Missouri River flood plain is in what the Missouri Geological Survey refers to as the saline ground-water province. Fuller and others (1967, p. 295) define this province "...as that area in which the total dissolved solids exceed 1,000 parts per million in consolidated aquifers capable of yielding adequate water volumes to municipalities or industries. This does not preclude the existence at shallower depths of fresh ground water in sufficient volume to meet municipal, industrial, and domestic needs from the alluvium and glacial drift. Supplies of 5 to 10 gallons per minute can usually be obtained in this area from Pennsylvanian sandstone and Mississippian limestone at depths ranging from 250 to 400 feet."

ACKNOWLEDGMENTS

The assistance and information provided by the staff of the Missouri Division of 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. They also thank Mr. W. B. Russell and other officials of the Layne-Western Co. for providing information on some of the wells drilled by the company.

GEOLOGIC SETTING

ALLUVIUM

The river that carved the Missouri Valley also partially filled the trough with alluvium consisting of sand, gravel, silt, and clay. In general, the lower part of the alluvium is made up of coarse sand and gravel; the upper part is frequently composed of fine sand, silt, or clay. Variations in thickness of the alluvium are controlled by irregularities in the bedrock surface. Based on available test-hole data the maximum alluvial thickness in this reach is 143 feet, and the average thickness is about 85–90 feet. The average saturated thickness is about 70 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 that are located on the map but not accompanied by a strip log may be obtained from the Missouri Geological Survey and Water Resources, Rolla, Mo.

BURIED VALLEYS

Heim and Howe (1962) show the location of several buried valleys along this reach of the Missouri River. These filled valleys, which are potential sources of ground water, apparently are in hydraulic connection with the Missouri River alluvium.

TERRACE DEPOSITS

The Teteseau terrace is in the northwestern part of Saline County. Its northwest-facing scarp is 50 to 60 feet high and is sharply outlined by Missouri River undercutting. Bretz (1965) believes the terrace "...undoubtedly was constructed by Missouri Valley water flowing down Salt Fork either before the Dewitt-Miami narrows existed or when they were blocked by glacial ice. The undissected surface suggests the latter date." Whatever the origin of the terrace it appears that the sand and gravel underlying it is in hydraulic connection with the sand and gravel underlying the flood plain (see geologic section A–A′). Although gravel is not present in this section (A–A′), it has been reported from wells drilled in the terrace. One city, Marshall, obtains its water supply from wells drilled in the terrace deposit. This old channel is clearly shown on the map by Heim and Howe (1962).

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. Loess on the other hand is a homogeneous deposit of silt-size particles. 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 or is contained by a relatively impermeable bedrock barrier. A more detailed study would be needed to determine this in certain areas.

BEDROCK

The bluffs and rounded hills which border the Missouri River flood plain between Miami and Kansas City, Mo., are composed of shale, limestone, and sandstone. The same types of rocks also underlie the alluvium and form the rock surface upon which the alluvial 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 Fuller (1962) and Knight (1962). A map by Heim and Howe (1962) shows by contours the configuration of the bedrock surface of northwestern Missouri.

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 streams, either from overbank flooding or sustained high-river stage; some comes from direct penetration of rainfall. A still smaller amount may be underflow from bedrock aquifers.

The main ground-water discharge is effluent seepage into the Missouri River. Other discharge may be attributed to evapotranspiration 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 (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 piezometric contours on the accompanying map show the general shape of the piezometric surface for October 1967. Arrows drawn at right angles to the contours and pointing in the direction of decreasing altitude would show the direction of movement of the ground water. At this particular time 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. The aquifer would then be recharged by the river. The geologic sections show the maximum amount of fluctuation in the piezometric surface observed over a 1-year period. In general, the greatest amount of fluctuation occurs nearest to the river.

GROUND-WATER USE

Eleven cities pump approximately 13.6 million gallons of water per day from the alluvial aquifer in this reach of the river. Industrial use of ground water is confined to the Kansas City area and amounts to about 13 mgd (million gallons per day). A rough approximation of water used for irrigation is about 1.25 mgd. Combined municipal, industrial, and irrigation use amounts to about 28 mgd; 85 percent of this is pumped from the alluvium between Kansas City and Independence.

WELL YIELDS

Municipal wells in this area are pumped at rates of less than several hundred gallons per minute (some are pumped at less than 100 gpm) but generally are capable of much greater yields. For example a well in the Liberty, Mo., well field reportedly was pumped at a rate of 1,250 gpm for 6 hours resulting in a drawdown of 15.3 feet. This gives a specific capacity of about 80 gpm per foot of drawdown for this well. Irrigation wells in the area have reported pumping rates of around 1,000 gpm, and specific capacities ranging from 50 to 150 gpm per foot of drawdown.

QUALITY OF THE WATER

Water in alluvium in this reach of the valley is a calcium bicarbonate type, characterized by a high hardness and high iron content. The dissolved-solids content, ranging from about 275 to about 1,000 mg/l (milligrams per liter), is variable over the area, and the amounts are controlled primarily by the length of time the water has been in the aquifer and the solubility of the aquifer material through which the water has moved. Calcium and bicarbonate are the principal constituents dissolved in the water, but magnesium and, at most locations, sulfate are also a significant part of the dissolved solids. The amounts of sodium, potassium, chloride, fluoride, and nitrate are small but at a few places sodium is as much as 33 percent of the cations. Occasionally the higher sodium content is accompanied by a decrease in silica content indicating a different mineralogical environment.

Bar diagrams showing areal variations in chemical characteristics are shown on the map. Representative chemical analyses of water in this stretch of the alluvium are shown in the table along with the maximum, minimum, and median values for the area. Also shown on the table are the maximum concentrations recommended by the U.S. Public Health Service for potable water. These standards serve as criteria for evaluating the water for municipal and domestic uses.

Bacterial quality of the ground water was not evaluated during the present study. Thus, the following remarks pertaining to suitability of the water are restricted to an evaluation of chemical data and do not indicate the sanitary condition of the water.

Domestic and Municipal Use.—A comparison of the maximum, minimum, and median concentrations of constituents dissolved in water in the alluvial deposits with the maximum limits recommended by the U.S. Public Health Service for drinking water shows that the concentration of most constituents are within the recommended maximum limit. The iron and manganese content of the water exceeds the maximum limit and treatment to effect the removal of the ions would be desirable. The maximum sulfate content also exceeds the maximum recommended limit but the median value of 36 mg/l indicates that the sulfate content is generally below this level.

Hardness of water, although not considered in the drinking water standards, is an important characteristic to domestic and municipal users. The minimum value for hardness indicates that water in the alluvium is very hard. Nordell (1961) states that excessive hardness in the water may scale up water heaters and hot water piping, causing reduced flows and eventually such serious clogging and burnouts that expensive repairs and replacements are required. Also, hardness wastes large amounts of the soap used in laundering and deposits insoluble calcium and magnesium soap curds in the laundered materials. These curds prevent thorough cleansing resulting in "tattletale gray" and rancid odors on standing. They also tender and embrittle the fibers thus greatly shortening the fibers useful life.

Industrial Use.—The cool and fairly uniform temperature, about 13 to 16 degrees Celsius, of the water makes it especially desirable for cooling uses in industrial operations. However, calculations of the Langlier saturation index (Nordell, 1961) indicates that the water has a tendency to precipitate calcium carbonate, and an increase in the water temperature would increase this tendency, so that some treatment might be necessary depending upon the type of cooling system. Because the quality requirements for industrial process water vary greatly between industries and between plants within the same industry, it is generally impractical to evaluate water quality for a specific industrial use. The illustration comparing the water-quality requirements for selected industries with the quality of water from the alluvial aquifer is indicative of the degree of treatment necessary to make the water suitable for some industrial uses.

Irrigation Use.—Rainfall is generally adequate to supply the moisture needed for growing crops in the area, but some supplemental irrigation, utilizing water from the alluvium, is practiced during short periods of deficient rainfall. Based on indices developed by the U.S. Salinity Laboratory Staff, 1954, (see diagram below) water from the alluvium has a low sodium hazard and a medium to high salinity hazard. Wilcox (1955) states that water of these classifications can be used for supplemental irrigation with little danger to any but the most salt-sensitive crops. Corn, alfalfa, and soybeans, which are the principal crops grown in the area, are moderately tolerant to salinity, and supplemental irrigation of these crops with water from the alluvium would be satisfactory.

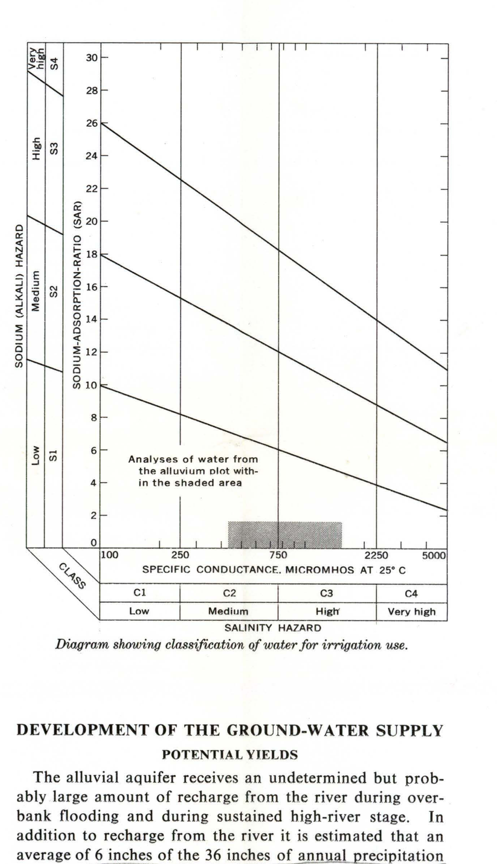


Diagram showing classification of water for irrigation use.

DEVELOPMENT OF THE GROUND-WATER SUPPLY

POTENTIAL YIELDS

The alluvial aquifer receives an undetermined but probably large amount of recharge from the river during overbank flooding and during sustained high-river stage. In addition to recharge from the river it is estimated that an average of 6 inches of the 36 inches of annual precipitation recharges the aquifer. This amounts to about 126 mgd. The average saturated thickness of 70 feet and average effective porosity of 15 percent indicates that approximately 1,000 billion gallons of water is in storage at all times. When the average recharge from precipitation and the large but undetermined amount of recharge from the river, plus the water in storage is contrasted with the 28 mgd withdrawn from the aquifer, it is obvious only a small fraction of the available water is being utilized.

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

The advantages are numerous for a ground-water supply developed through streambed infiltration over a supply pumped directly from a stream. The infiltrated water will have a more nearly uniform chemical quality and temperature than that of surface water. Objectionable odors and tastes will be removed and water will generally be free of bacterial contamination and turbidity (Rorabaugh, 1963, p. 52, 55–56, 61).

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

Rorabaugh (1963, p. 51) lists 17 facts that need to be known in planning an infiltrated water supply and 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."

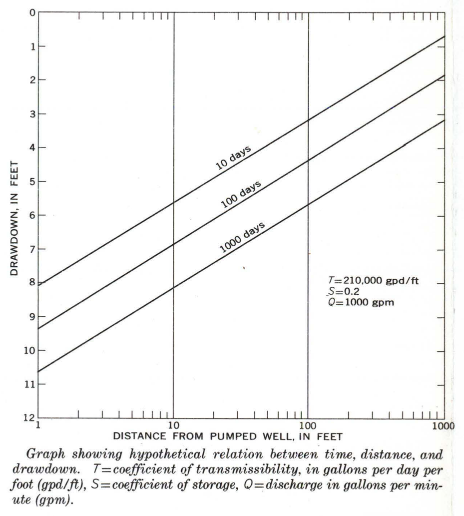
POTENTIAL PROBLEMS IN DEVELOPING A WELL OR WELL FIELD

The chief problems that 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. Calculations of the Langlier carbonate saturation index (Nordell, 1961) indicate that 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 that 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. Because the decrease in pressure as water moves into the well is indirectly the principal cause of encrustation, well-operating practices that 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.

The accompanying graph shows the time-distance-drawdown relation for a discharge of 1,000 gpm from an aquifer having a coefficient of transmissibility of 210,000 gpd (gallons per day) per foot and a storage coefficient of 0.2.



Graph showing hypothetical relation between time, distance, and drawdown. T=coefficient of transmissibility, in gallons per day per foot (gpd/ft), S=coefficient of storage, Q=discharge in gallons per minute (gpm).

An aquifer test was not run in this area; 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 coefficient of permeability of 3,000 gallons per day per square foot and an average saturated thickness of 70 feet.

For an explanation of aquifer test theories and the assumptions upon which they are based see Ferris, and others, 1962.

It should also be noted that in some areas where wells are closely spaced and extensively pumped it is possible to lower the water level in the aquifer below the bottom of shallow wells causing them, at least temporarily, to go dry.

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CHEMICAL ANALYSES OF WATER FROM SELECTED WELLS

Well number	Depth, feet	Date of collection	Temperature, °C	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
				Milligrams per liter																			
1	95	4/10/67	—	33	1.7	0.38	54	16	25	2.4	240	36	20	0.3	0.8	293	201	4	21	0.8	432	7.5	11
2	42	4/10/67	14	34	2.7	.38	119	28	4.3	6.5	520	1.4	.5	.5	1.1	454	412	0	2	.1	752	7.7	10
3	75	4/13/67	—	35	1.9	.32	74	17	17	3.7	301	31	10	.4	.2	338	255	8	12	.5	539	7.9	5
4	87	4/13/67	—	26	2.2	.42	116	25	33	3.7	360	74	70	.3	.1	528	393	98	15	.7	879	7.9	4
5	77	4/12/67	14	36	4.2	.24	128	30	14	5.4	580	3.6	2.9	.2	.1	510	443	0	6	.3	830	7.6	6
6	53	4/11/67	—	27	4.0	3.7	157	56	41	7.4	836	2.6	13	.3	2.5	726	623	0	12	.7	1,270	7.6	11
7	71	4/13/67	—	30	2.2	.39	140	33	30	5.0	463	107	53	.1	.3	655	485	106	12	.6	1,010	7.9	7
8	54	4/13/67	—	27	2.0	.57	106	28	11	3.3	417	64	1.4	.2	1.5	452	380	38	6	.2	723	7.9	8
9	80	4/12/67	—	26	2.3	.97	142	35	31	4.7	672	14	3.6	.2	.6	591	498	0	12	.6	967	7.8	8
10	88	4/12/67	—	28	2.4	.28	113	21	9.1	3.5	390	71	2.6	.4	.6	454	369	49	5	.2	704	8.1	9
11	54	4/12/67	—	28	.12	.55	102	22	7.7	5.3	405	34	2.5	.3	.3	403	345	13	4	.2	662	7.8	9
12	80	4/11/67	—	26	3.8	.82	108	20	21	5.7	460	16	3.2	.2	.3	432	352	0	11	.5	754	7.8	8
13	76	4/12/67	—	29	.34	.86	153	38	18	5.9	668	23	2.5	.2	.6	600	538	0	6	.3	980	7.6	7
14	—	4/11/67	—	18	.59	.44	85	23	55	5.7	337	130	16	.3	.2	513	307	30	28	1.4	814	7.7	9
15	30	4/11/67	—	30	3.8	5.6	190	45	23	9.1	790	52	16	.2	.2	780	660	12	7	.4	1,300	7.6	10
16	—	4/12/67	—	16	.22	.30	70	20	60	6.1	219	180	21	.4	.1	505	257	77	33	1.6	776	7.7	8
Maximum for area				36	4.2	5.6	190	56	60	9.1	836	442	70	0.5	4.1	1,000[e]	978	410	—	—	1,620	8.1	11
Minimum for area				16	.12	.24	54	16	4.3	2.4	219	1.4	.2	.1	.0	275[e]	201	0	—	—	432	7.5	4
Median for area				28	2.5	.56	114	26	22	5.4	451	36	3.2	.3	.2	497	402	7	—	—	796	7.7	8
Recommended limits, drinking water standards[1]					.3	.05	—	—	—	—	—	250	250	[2]1.7	45	500	—	—	—	—	—	—	20

[1] U.S. Public Health Service, Drinking Water Standards, revised 1962
[2] Varies with the annual average of maximum daily air temperatures and ranges downward from 1.7 mg/l at 10° C to 0.8 mg/l at 32.1° C. The optimum concentration is from 1.2 to 0.7 mg/l.
[e] Estimated from specific conductance

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1970—W69150

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

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

1970

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