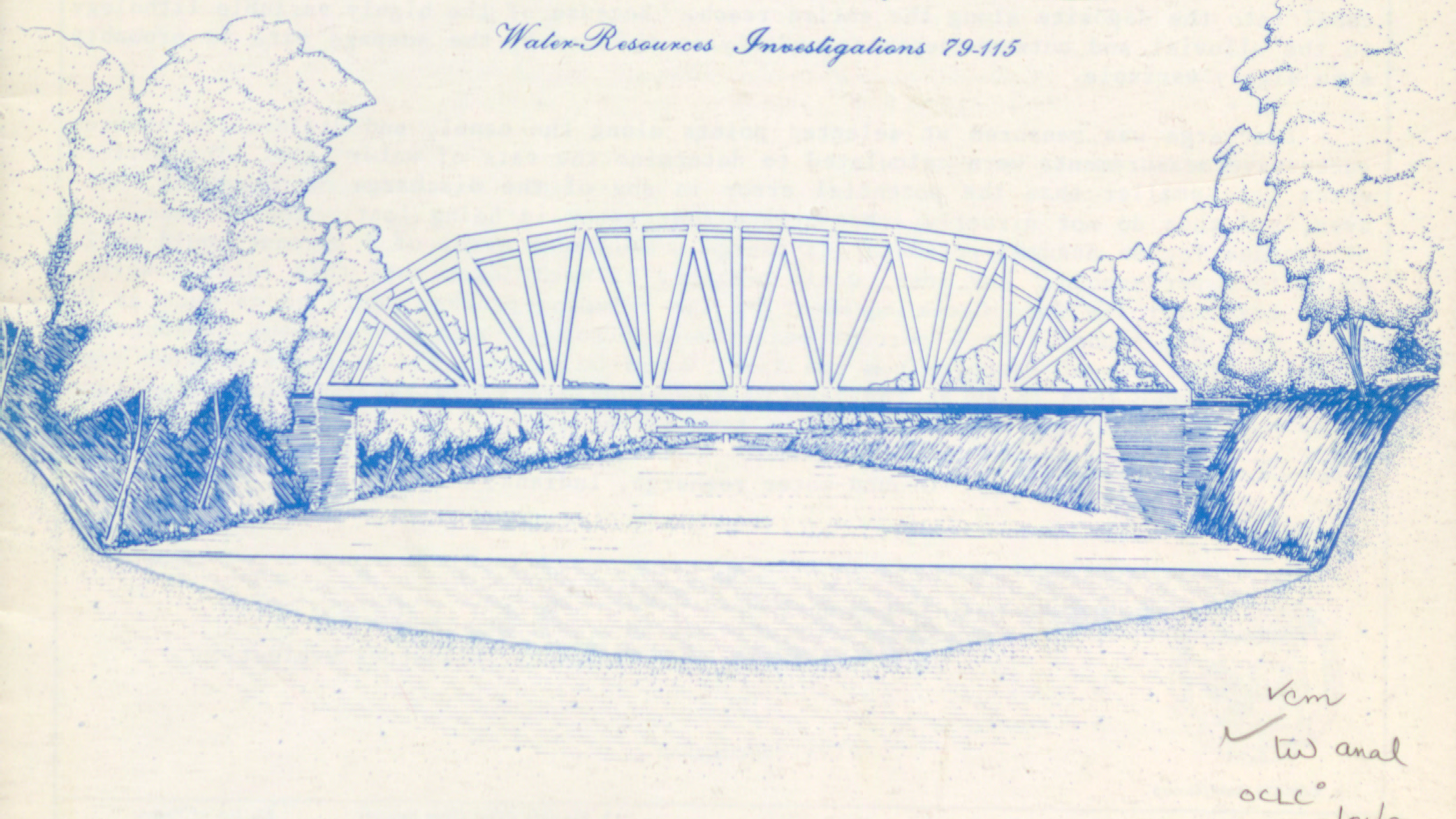
Geohydrologic Setting of and Seepage from a water-supply canal, Indianapolis, Marion County, Indiana

U. S. Geological Survey

Water-Resources Investigations 79-115



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Discharge was measured at selected points along the canal, and differences between successive measurements were calculated to determine the rate of water loss. The differences were smaller than the potential error in any of the discharge measurements, however, and thus do not directly substantiate that water is being lost. The maximum rate of seepage for an assumed potential discharge measurement error of 5 percent would be 21 cubic feet per second. Any loss, would probably be much lower than this rate, however. Water loss over the Fall Creek aqueduct by the skimming process could be as much as 43 cubic feet per second if a 5 percent measurement error at both ends of the aqueduct is assumed. The rate of seepage from the canal would be greater for stages and water temperatures higher than those at the time of the study and would be lower for stages and water temperatures lower than those at the time of the study.

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GEOHYDROLOGIC SETTING OF AND SEEPAGE FROM A WATER-SUPPLY CANAL, INDIANAPOLIS, MARION COUNTY, INDIANA

By William Meyer

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 79-115

Prepared in cooperation with the

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November 1979

UNITED STATES DEPARTMENT OF THE INTERIOR

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METRIC CONVERSION FACTORS

Inch-pound units used in this report can be converted to metric units as follows:

Multiply inch-pound units	By	To obtain metric units
Mile (mi)	1.609	kilometer (km)
cubic feet per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
foot (ft)	0.3048	meter (m)
feet per day (ft/d)	0.3048	meter per day (m/d)

GEOHYDROLOGIC SETTING OF AND SEEPAGE FROM A WATER-SUPPLY CANAL, INDIANAPOLIS, MARION COUNTY, INDIANA

By William Meyer

ABSTRACT

The Indianapolis Water Co. Canal is underlain by alluvial and outwash deposits. The water level in the canal on July 21, 1978, was above the water table along the entire reach of the canal upstream from the Fall Creek aqueduct, which precluded the discharge of ground water into the canal. If the canal sides and bottom can be assumed to be permeable, then water can be assumed to be seeping downward from the canal into these deposits along the entire reach. Because of the highly variable lithology in the deposits underlying the canal, the seepage rate would probably also be highly variable.

Discharge measurements were made at selected points along the canal, and differences between successive measurements were calculated to determine the rate of water loss. The differences were smaller than the potential error in any of the discharge measurements, however, and thus do not directly substantiate that water is being lost. If water is seeping from the canal, the maximum rate of seepage for an assumed potential discharge measurement error of 5 percent would be 21 cubic feet per second. The loss, if it occurs, is probably much lower than this rate, however. The rate of water loss over the Fall Creek aqueduct by the skimming process could be as much as 43 cubic feet per second if a 5 percent potential error for discharge measurements at both ends of the aqueduct is assumed. The difference between the measurements was 25 cubic feet per second. The rate of seepage from the canal would be greater for stages and water temperatures higher than those at the time of the study and would be lower for stages and water temperatures lower than those at the time of the study. Observed ground-water levels were above the canal bottom at three locations along the canal. Lowering these levels below the bottom would increase seepage by approximately 9 cubic feet per second.

INTRODUCTION

A large part of the municipal water supply of Indianapolis is obtained from the White River. This water is diverted into the supply system of the Indianapolis Water Co. by a canal (fig. 1) that begins in Broad Ripple, a northern section of the city. A dam in the river immediately downstream from the canal ensures sufficient flow in the canal. From Broad Ripple downstream to the filtration intakes at approximately 20th Street, a distance of 6.4 mi (miles), the canal roughly parallels the river. It crosses Fall Creek, a major tributary of the river, in an aqueduct.

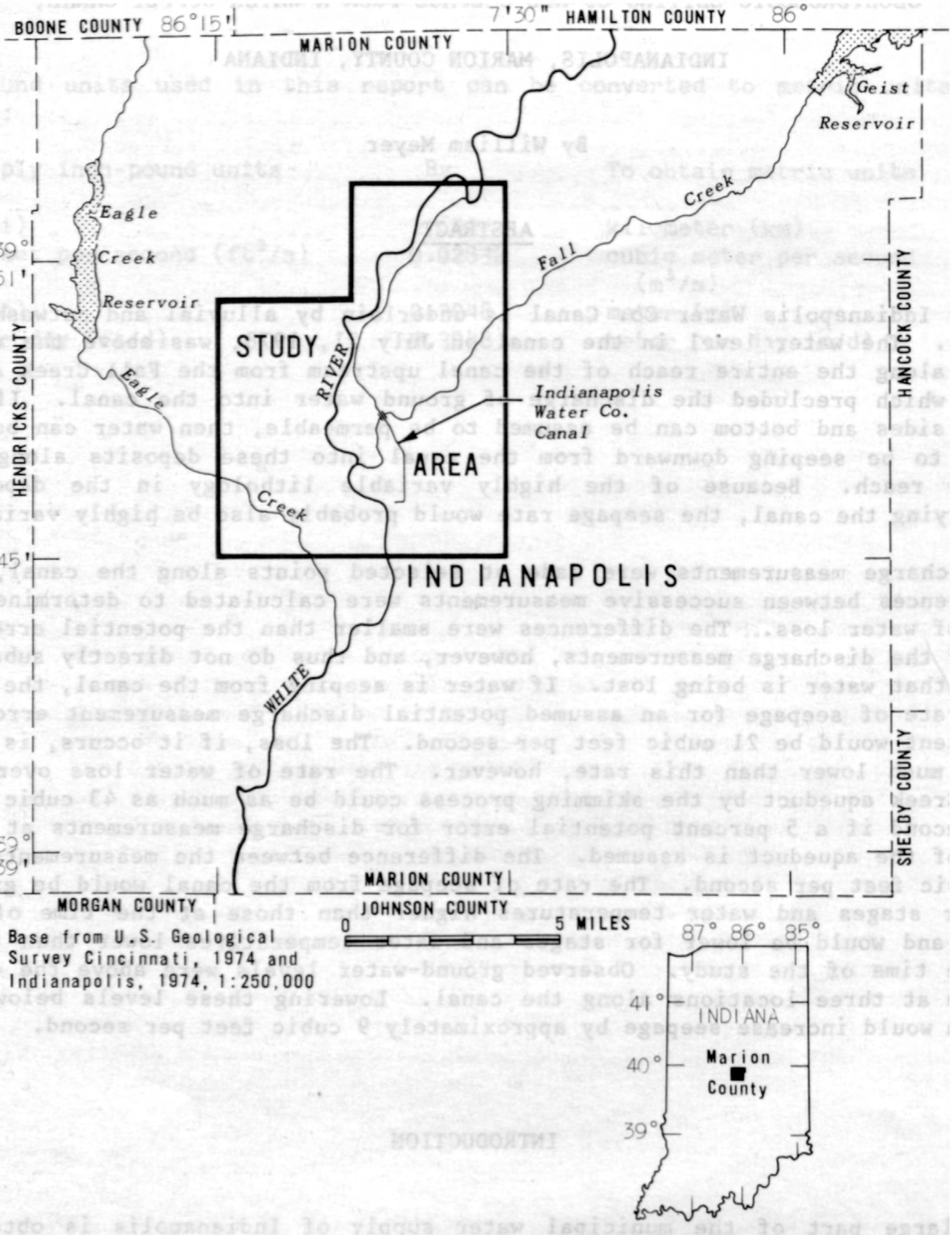

Figure 1.-- Location of the Indianapolis Water Co. Canal, Indianapolis, Marion County, Ind.

From Broad Ripple to the intakes, the canal flows on alluvial deposits, except for a small area at Broad Ripple and another area north of Fall Creek, where it flows over outwash deposits. Because all but 950 ft (feet) of its length is unlined, the canal has the potential for either gaining or losing water.

This report records the results of a study in July 1977 by the U.S. Geological Survey in cooperation with the Indiana Department of Natural Resources to (1) describe the geohydrologic setting of the canal, (2) identify gaining and losing reaches of the canal, (3) determine the rate of water gained or lost in those reaches by discharge measurements, (4) predict the effect of prolonged drought on the above, and (5) determine the amount of water lost over the top of the Fall Creek aqueduct by a skimming process designed to remove material floating in the water. The studied reach begins at Broad Ripple and ends at the aqueduct, a distance of 6.1 mi. The amount of water lost over the aqueduct was calculated by taking the difference between measured discharges on the upstream and downstream ends of the aqueduct.

The geology of Marion County, site of the canal, has been described by Harrison (1963), and the county's geohydrologic framework has been described in reports by Roberts and others (1955), Cable and others (1971), and Meyer and others (1975). None of these reports described the geohydrology of the immediate vicinity of the canal in sufficient detail to answer the questions of concern in this study.

DESCRIPTION OF THE CANAL

The geographic setting and the length of the canal are shown in figure 2. The canal, which was built in the late 1830's as part of a statewide transportation system that was never fully completed, continues past the intakes of the Indianapolis Water Co. Water that passes the intakes ultimately returns to the White River through a large underground culvert in downtown Indianapolis. To obtain the necessary geohydrologic data for the study, 13 test holes were drilled on the bank a few feet from the water's edge along the course of the canal. Small-diameter observation wells were installed at each of the test-hole sites. These wells are designated as observation wells A-M in figure 2.

The width, depth, and bottom configuration of the canal cross section, adjacent to observation wells A-M, are presented in figure 3. At these locations, widths ranged from 54 to 78 ft and averaged 66 ft. The maximum depth at any cross section was 6.2 ft, and the average depth at the individual cross sections ranged from 1.8 to 4.7 ft. The composition of the canal bed at each of these sites, which is shown in figure 3, varies from silt and clay to sand and gravel. The composition of the canal bed was determined by shallow probing of the canal bottom when water depths were measured. The canal bed is a veneer of material only a few inches thick and is not necessarily the same lithology as the underlying material.

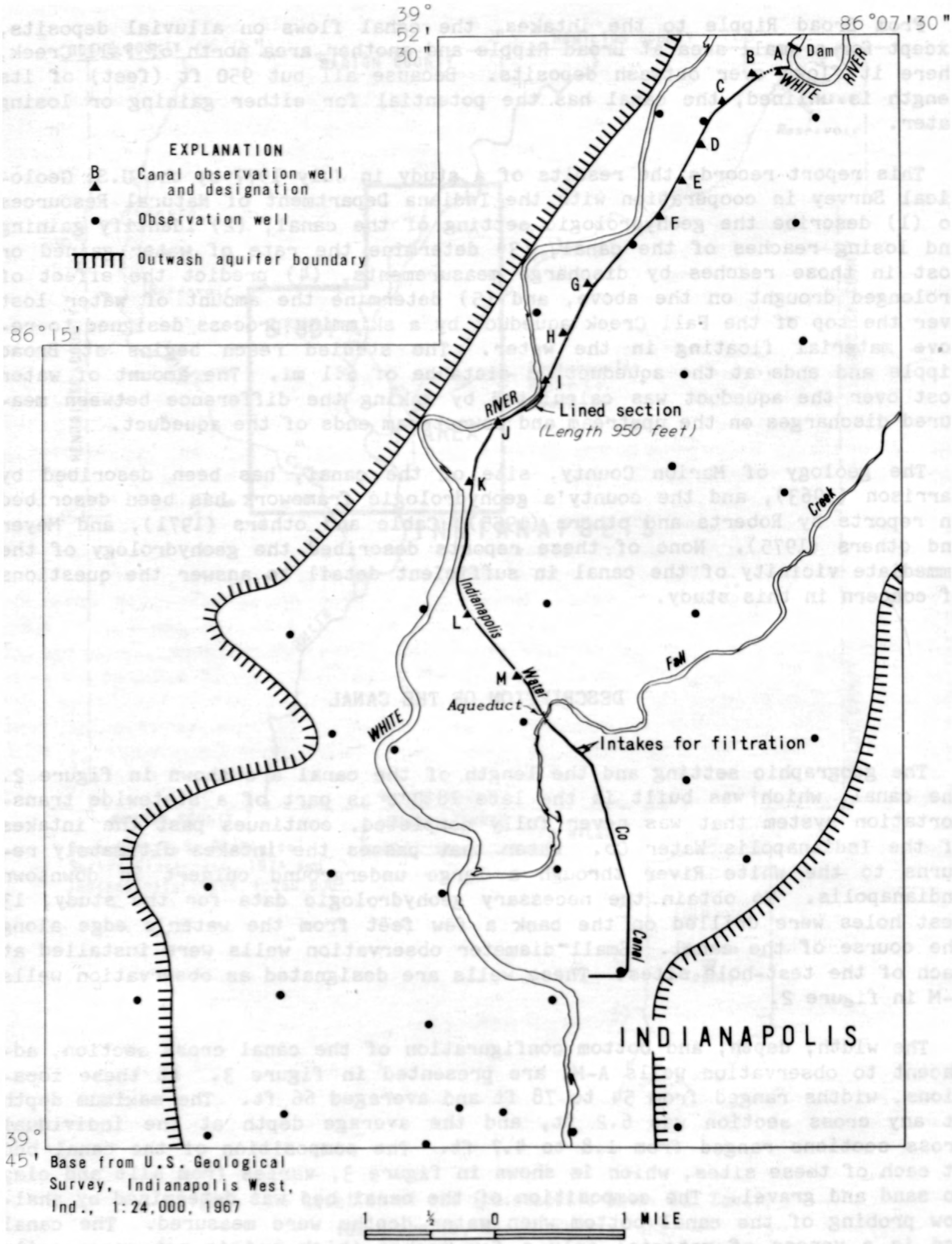

Figure 2.-- Location of observation wells in the study area.

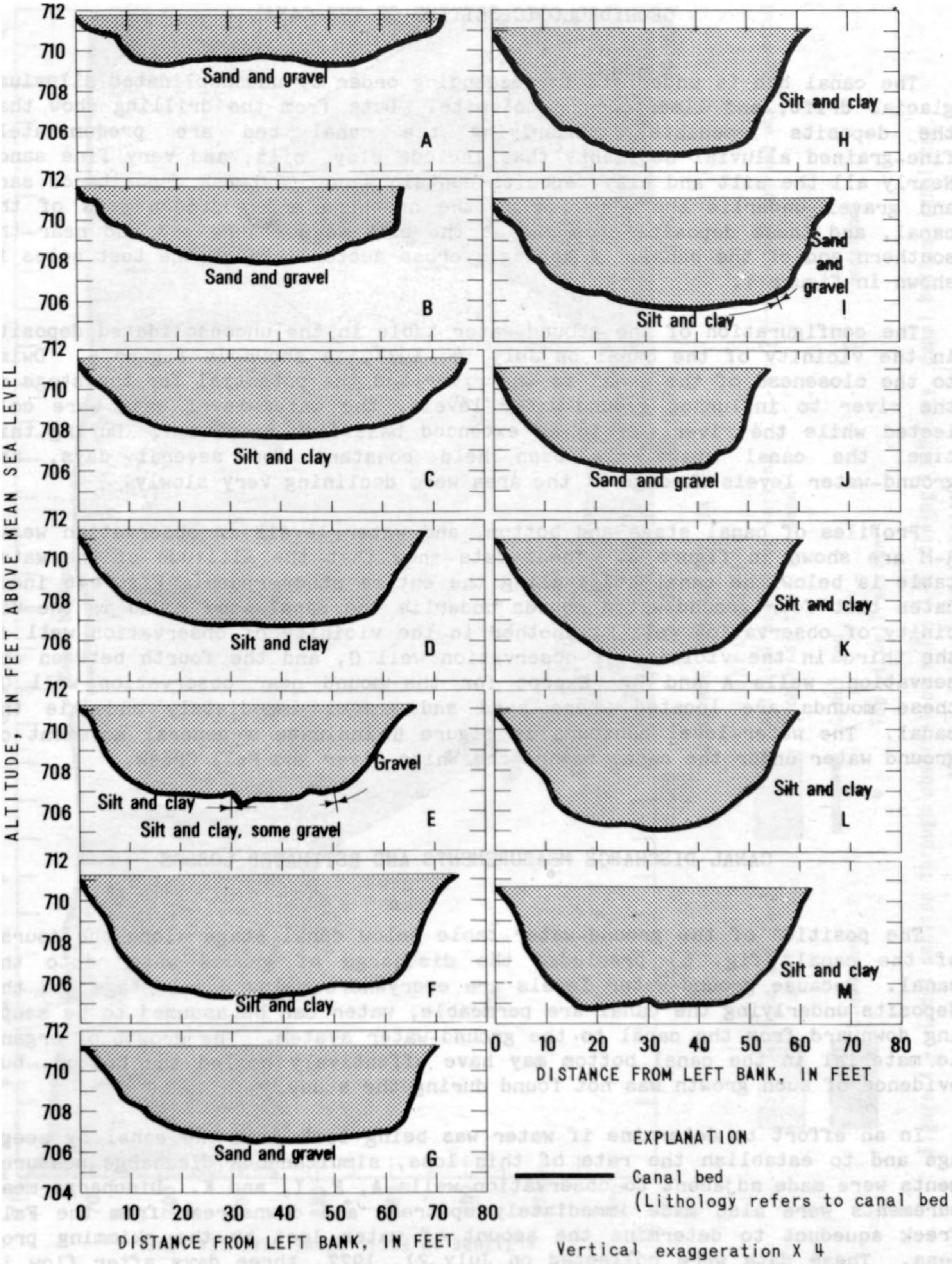

Figure 3.-- Cross sections of the Indianapolis Water Co. Canal at observation-well sites A-M showing the composition of the canal bed.

GEOHYDROLOGIC SETTING OF THE CANAL

The canal bed is underlain in descending order by unconsolidated alluvium, glacial drift, and limestone or dolomite. Data from the drilling show that the deposits immediately underlying the canal bed are predominately fine-grained alluvial sediments that include clay, silt, and very fine sand. Nearly all the silt and clay deposits contain sand. Outwash deposits of sand and gravel underlie the alluvium at the northern and southern ends of the canal, and these deposits crop out at the extreme northern end and near the southern end of the canal. A geologic cross secton through the test holes is shown in figure 4.

The configuration of the ground-water table in the unconsolidated deposits in the vicinity of the canal on July 19, 1977, is shown in figure 5. Owing to the closeness of the canal to the river and the potential for the stage of the river to influence ground-water levels, the water-level data were collected while the river was in an extended base-flow recession. During this time, the canal stage had been held constant for several days, and ground-water levels throughout the area were declining very slowly.

Profiles of canal stage and bottom, and water levels in observation wells A-M are shown in figure 6. These data show that the altitude of the water table is below the canal stage along the entire study reach. Figure 6 indicates that four ground-water mounds underlie the canal--one mound in the vicinity of observation well L, another in the vicinity of observation well J, the third in the vicinity of observation well G, and the fourth between observation wells A and B. Except for the mound near observation well G, these mounds are located where sand and gravel immediately underlie the canal. The water-level contours in figure 5 indicate a general movement of ground water under the canal toward the White River and Fall Creek.

CANAL DISCHARGE MEASUREMENTS AND ESTIMATED LOSSES

The position of the ground-water table below canal stage along the course of the canal (fig. 6) precluded the discharge of ground water into the canal. Because ground-water levels are everywhere below canal stage and the deposits underlying the canal are permeable, water can be assumed to be seeping downward from the canal to the ground-water system. The growth of organic material in the canal bottom may have effectively sealed the bottom, but evidence of such growth was not found during the study.

In an effort to determine if water was being lost from the canal by seepage and to establish the rate of this loss, simultaneous discharge measurements were made adjacent to observation wells A, F, I, and K. Discharge measurements were also made immediately upstream and downstream from the Fall Creek aqueduct to determine the amount of water lost by the skimming process. These data were collected on July 21, 1977, three days after flow in the canal had been stablized. Measurements and changes between successive measurements are shown in table 1. If the potential error in the discharge

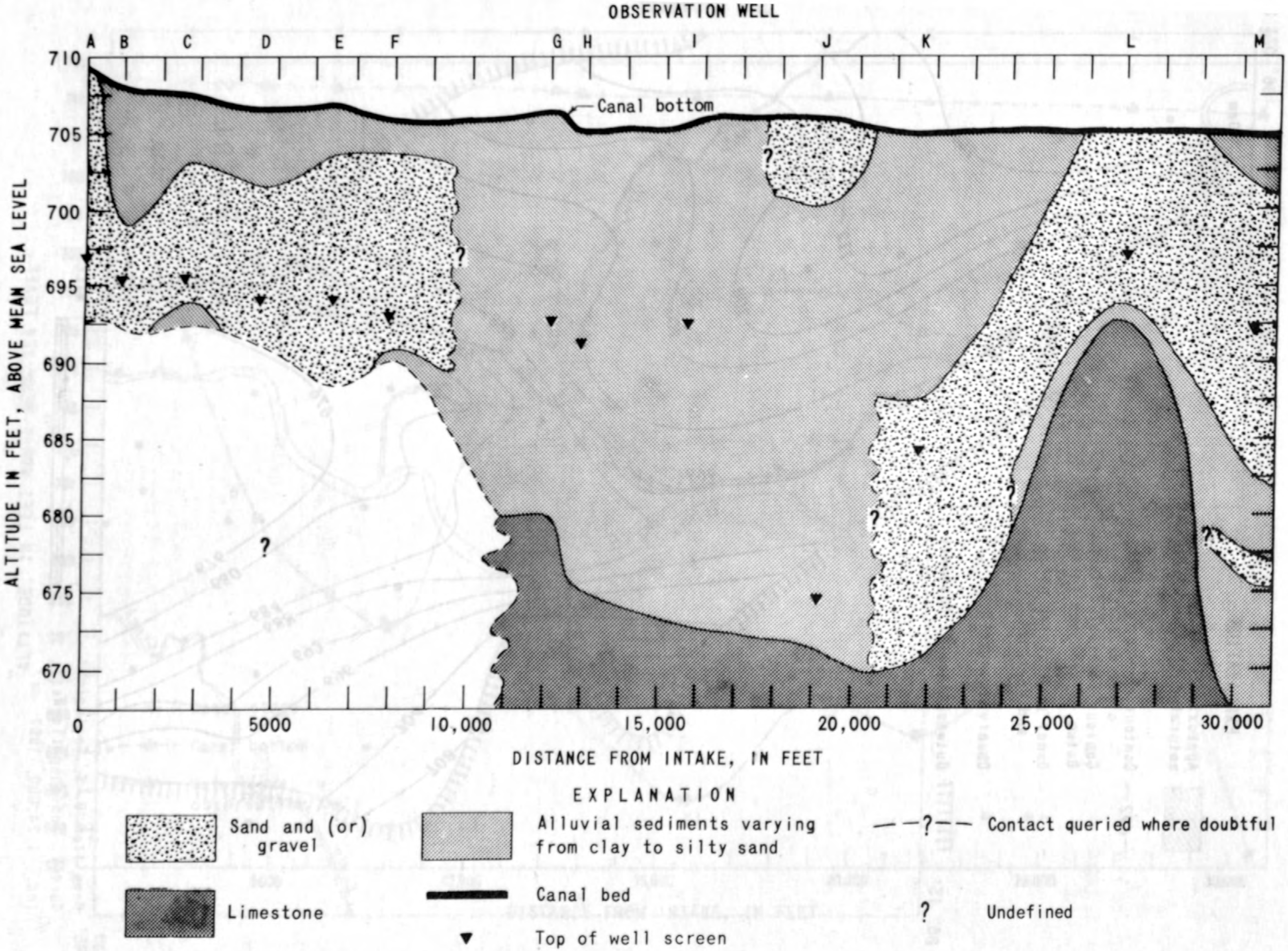

Figure 4.-- Cross section through observation wells A-M showing lithology, canal bottom, canal bed, and altitude of well screens.

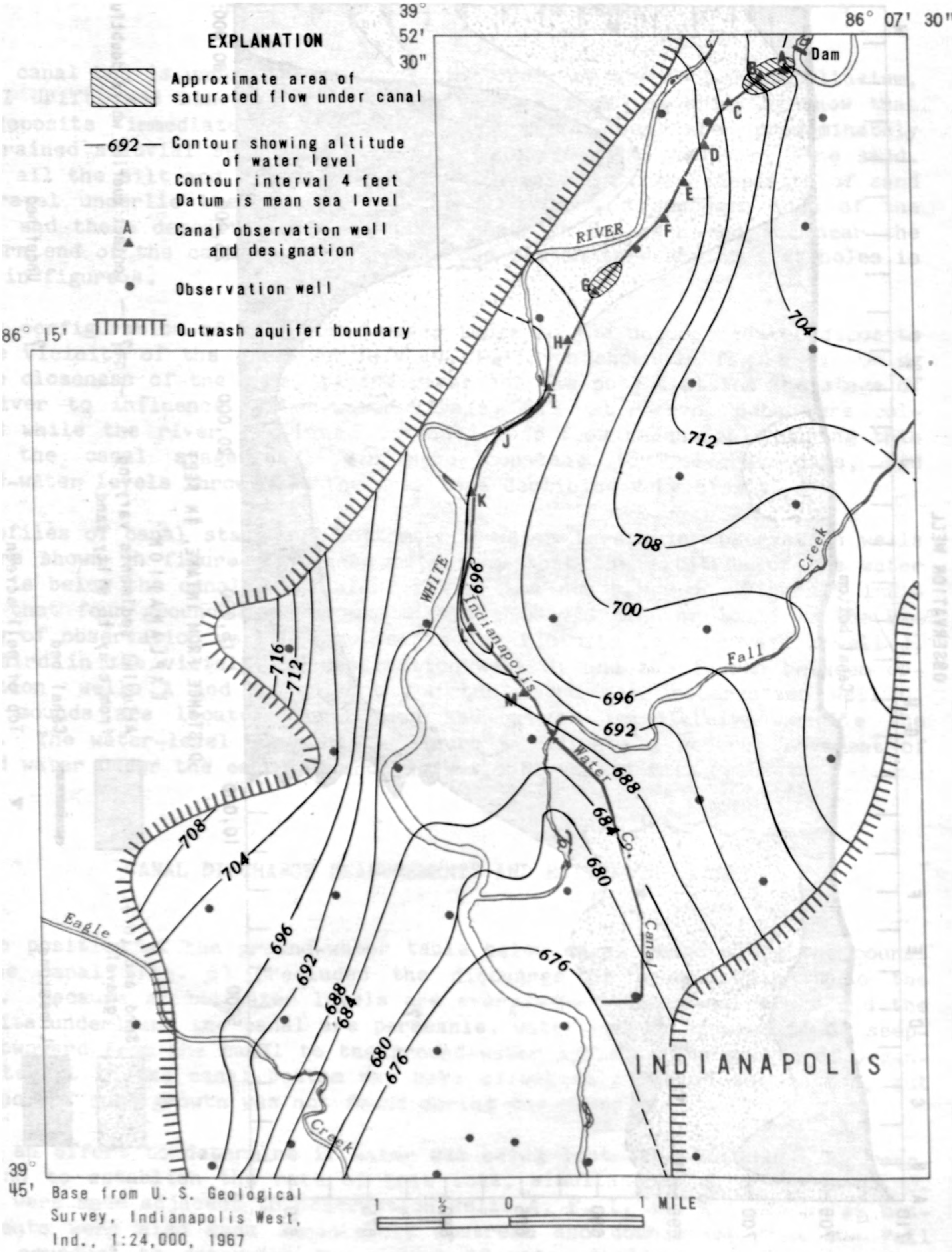

Figure 5.-- Water levels in the outwash aquifer, July 19, 1977.

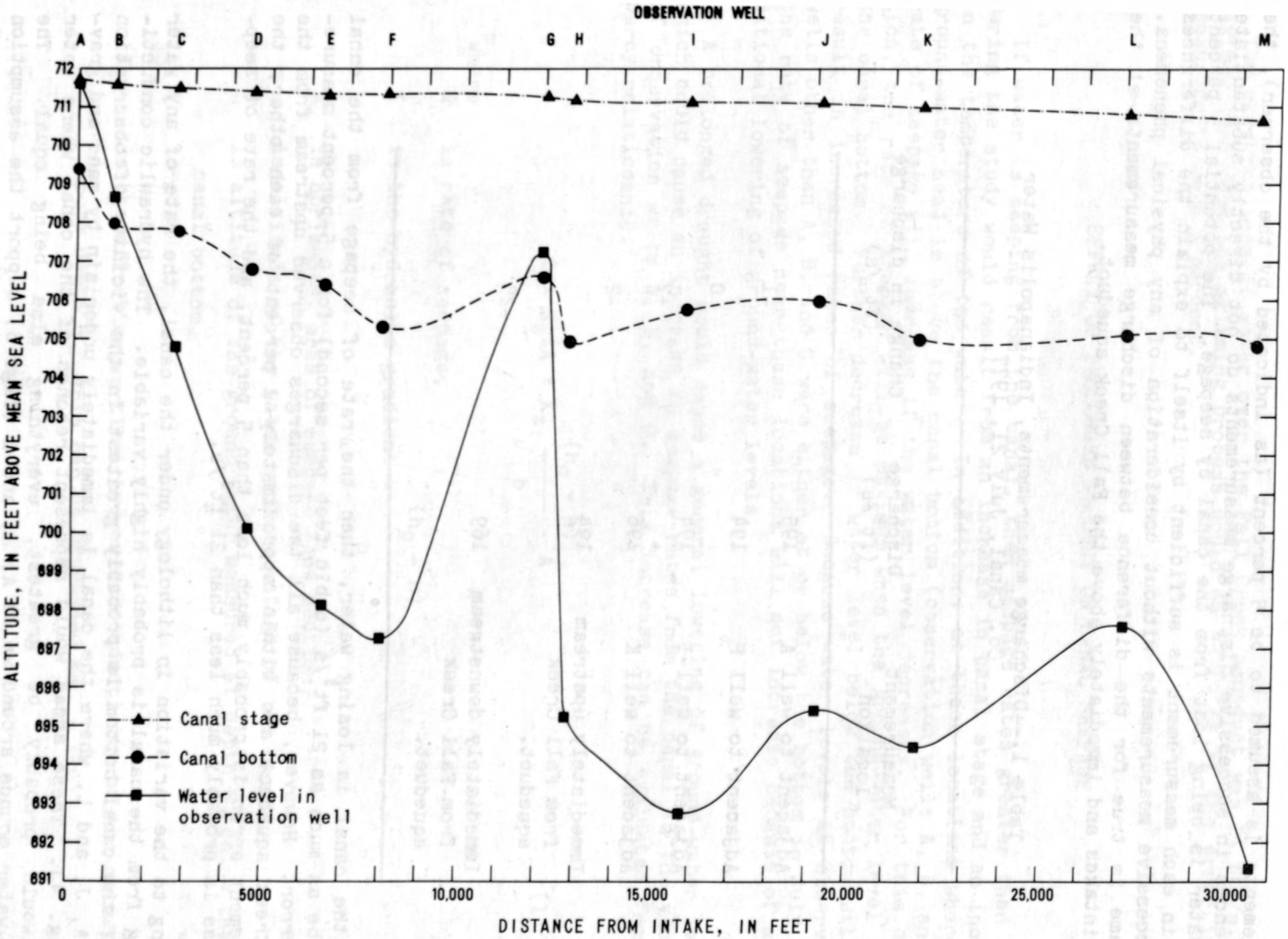

Figure 6.-- Profiles of canal stage, canal bottom, and water levels in observation wells A-M, July 21, 1977.

measurements is assumed to be 5 percent (as indicated by the observer), the differences in successive discharge measurements do not directly substantiate that water is being lost from the canal by seepage. The potential 5 percent error in each measurement is sufficient by itself to explain the differences in successive measurements without consideration of any physical phenomena. The same is true for the difference between discharge measurements at the canal intakes and immediately above the Fall Creek aqueduct.

Table 1.--Discharge measurements, Indianapolis Water Co. Canal, July 21, 1977

Measurement location	Discharge (ft^3/s)	Change in discharge (ft^3/s)
Adjacent to well A	195	
		-1
Adjacent to well F	194	
		0
Adjacent to well I	194	
		+2
Adjacent to well K	196	
		-2
Immediately upstream from Fall Creek aqueduct.	194	
		-25
Immediately downstream from Fall Creek aqueduct.	169	

If the canal is losing water, then the rate of seepage from the canal could be as much as 21 ft^3/s (cubic feet per second) for a 5-percent measurement error. However, because all the discharges observed upstream from the Fall Creek aqueduct are within approximately 1 percent of each other, the measurement error is probably much less than 5 percent, and the rate of seepage loss is probably much less than 21 ft^3/s.

Owing to the variation in lithology under the canal, the rate of any water seeping from the canal is probably highly variable. The hydraulic conductivity of the canal bottom is probably greatest in the vicinity of observation wells A, J, and L, where the canal is immediately underlain by sand and gravel (fig. 4). These areas would represent reaches of the canal where water loss would probably be greatest, everything else being equal. The ground-water mounds around wells A, J, and L (fig. 6) support the assumption that the canal is losing water.

The measured loss of water over the Fall Creek aqueduct was 25 ft^3/s. The maximum loss from the skimming process would be 43 ft^3/s if the error in the measurements were 5 percent.

EFFECT OF PROLONGED DROUGHT ON CANAL SEEPAGE

If water is seeping from the canal, then seepage rates greater than those during the study would result from an increase in canal stage and an increase in the temperature of the water. In addition, at those locations where the ground-water head is above the canal bottom (observation wells A, B, and G), rate of seepage will increase if the water level decreases. For this condition, the rate of seepage will be maximum when the ground-water level is at the canal bottom. Further decrease in water level below the bottom will not result in increased rates of seepage. Because water levels at observation wells other than A, B, and G were either at or below the bottom in July 1977, the rate of seepage near these locations will not increase because of an additional lowering of ground-water levels.

A prolonged drought would cause a general lowering of ground-water levels, which could cause an increase in seepage rates from the canal in the vicinity of observation wells A, B, and G. This increase can be evaluated from the Darcy relationship.

$$Q = K_z IA = K_z \frac{(h_c - h)}{b} A \qquad (1)$$

where

Q is rate of seepage,

I is the hydraulic gradient = $\frac{(h_c - h)}{b}$

A is horizontal area of seepage flow section,

h_c is altitude of the water surface (stage of the canal),

h is altitude of the ground water measured at depth b, below the canal bottom,

and

K_z is the effective vertical hydraulic conductivity of the material above depth b. This can be expressed as

$$K_z = \frac{b}{\Sigma_i b_i/K_i} \qquad (2)$$

where

b is the total thickness below the canal bottom where h is measured,

b_i is the thickness of individual layers within b,

and

K_i is the vertical hydraulic conductivity of these individual layers.

Use of equation 1 requires knowledge of K_z, which was not measured during the study. In a previous study the author (Meyer and others, 1975) established for K_z an average value of 24 ft/d (feet per day) for the outwash deposits and a range from 10^{-4} to 7×10^{-2} ft/d for the silt and clay deposits in Marion County. The hydraulic connection between a stream or canal overlying outwash deposits is often less than the vertical hydraulic conductivity of the outwash because of clogging of the streambed. In another study, the author (Meyer, 1978) established a hydraulic conductivity of the White River streambed of 7.2 ft/d at a location where the river flows over outwash deposits in the southern part of Marion County.

The potential increase in seepage from the canal in the vicinity of observation wells A, B, and G was estimated for a decrease in ground-water levels for a vertical hydraulic connection of 7.2 ft/d between the canal and outwash deposits in the vicinity of observation well A and a vertical connection of 7×10^{-2} ft/d between the canal and the silt and clay deposits in the vicinity of observation wells B and G. Selection of the latter value would tend to maximize the rates obtained. For the calculation of seepage, the area of canal bottom was determined for canal reaches defined as follows: For observation well A, the reach extended from the beginning of the canal to a point half way between wells A and B. For observation wells B and G, the reaches were defined by points half the distance between each of these wells and the nearest upstream and downstream wells.

Seepage rates would increase approximately 8.9, 0.11, and 0.04 ft^3/s in reaches A, B, and G, respectively, if the canal stage remained constant and the ground-water levels decreased to the bottom of the canal.

The previously mentioned values of K_z were also used to estimate approximate seepage losses of 0.60, 0.24, and 0.68 ft^3/s for reaches defined for observation wells A, B, and G at the time of the study. The sum of these losses, 1.5 ft^3/s, is the same order of magnitude as the difference between discharge measurements (table 1) and is much less than the measurement error attributed to the discharge measurements in the canal.

EFFECT OF CHANGES IN WATER TEMPERATURE

Although not directly drought related, the effect of temperature on canal seepage rates was considered because a prolonged drought would tend to extend through more than one season.

The effect of temperature of the water on the rate of seepage can be seen by expressing K_z in terms of the hydraulic properties of the unconsolidated deposits underlying the canal and the properties of the canal water by the relationship:

$$K_z = k \frac{\rho g}{\mu} \qquad (3)$$

where

k is hydraulic properties of the unconsolidated deposits,

g is acceleration due to gravity,

ρ is fluid density,

and

μ is dynamic viscosity.

Both fluid density and dynamic viscosity are functions of temperature. Thus, large variations in water temperature can affect the hydraulic conductivity of the canal bottom and the rate of seepage. The minimum and maximum temperatures recorded for the White River at the Nora gaging station, 0° and 32°C (Celsius), just upstream from the canal intake, are based on the continuous measurements at the gage from June 1954 to May 1960 and from October 1962 to April 1972 (U.S. Geological Survey, 1973, p. 166). The variation in K_z resulting from this variation in temperature is shown in figure 7. The graph indicates a variation in the value of K_z of 56 percent for the historical variation in canal water temperature. This variation in K_z would cause a similar change in the rate of seepage for the canal, everything else being equal. Water temperature in the canal at the time of the study (30.5°C) indicates that the value of K_z was near maximum.

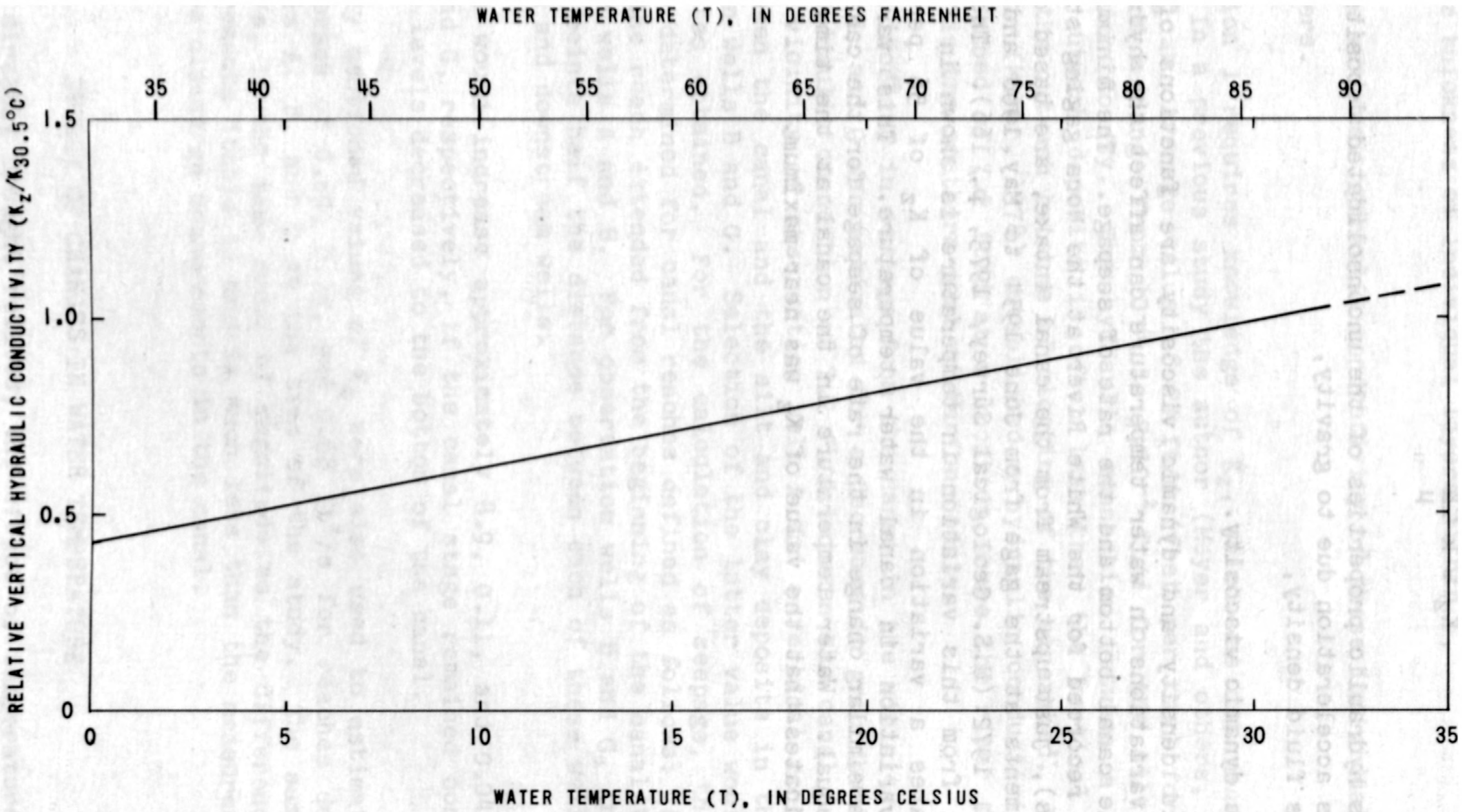

Figure 7. -- Effect of water temperature (T) on effective vertical hydraulic conductivity ($K_z/K_{30.5}$ C°), Indianapolis Water Co. Canal.

SUMMARY

The Indianapolis Water Co. Canal is underlain by unconsolidated deposits of predominantly fine-grained alluvial sediments that include clay, silt, and very fine sand. Outwash deposits of sand and gravel underlie the alluvium at the northern and southern reaches and crop out at the extreme northern end and near the southern end of the study reach.

The altitude of the water table was everywhere below the water level in the canal, a fact that precluded the discharge of ground water into the canal. If the canal sides and bottom are assumed to be permeable, then water was seeping from the canal. This assumption is supported by the fact that four ground-water mounds underlie the canal. The areal configuration of ground-water levels during the study indicated that ground water is moving under the canal and discharging into the White River and Fall Creek. Canal flow was stabilized, and simultaneous discharge measurements were then made at selected points along the canal to determine if the canal was losing water and the rate of loss. The differences between successive discharge measurements were calculated; all differences were smaller than the potential error that had been assigned to the measurements by the observer. Thus the discharge measurements did not directly substantiate that water was being lost from the canal. If water was seeping from the canal and the error attributed to the measurement was maximum, the rate of water lost from the canal could be 21 ft^3/s. Because all the discharge measurements were within approximately 1 percent of each other, the rate of seepage was probably much less than 21 ft^3/s.

If water is seeping from the canal, then seepage rates greater than those during the study would result from an increase in canal stage, an increase in the density, and a decrease in the viscosity of the canal water, or a decrease in ground-water levels at sites A, B, and G.

A decrease in ground-water levels to the bottom of the canal bed in the vicinity of observation wells A, B, and G would increase seepage by rates estimated to be equal to 8.9, 0.11, and 0.04 ft^3/s if the canal stage remained constant. These values were obtained by using values of the vertical hydraulic conductivity for the deposits underlying the canal that have been established for these deposits in other areas in Marion County.

The ranges in canal water temperature from June 1954 to May 1960 and from October 1962 to April 1972 indicate that the vertical hydraulic conductivity of the canal bottom can vary by approximately 56 percent. This variation would cause seepage from the canal to vary accordingly, everything else being equal.

The calculated rate of water loss over the Fall Creek aqueduct was 25 ft^3/s, and the calculated maximum loss was 43 ft^3/s. These rates will probably not decrease substantially without a significant decrease in canal stage.

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