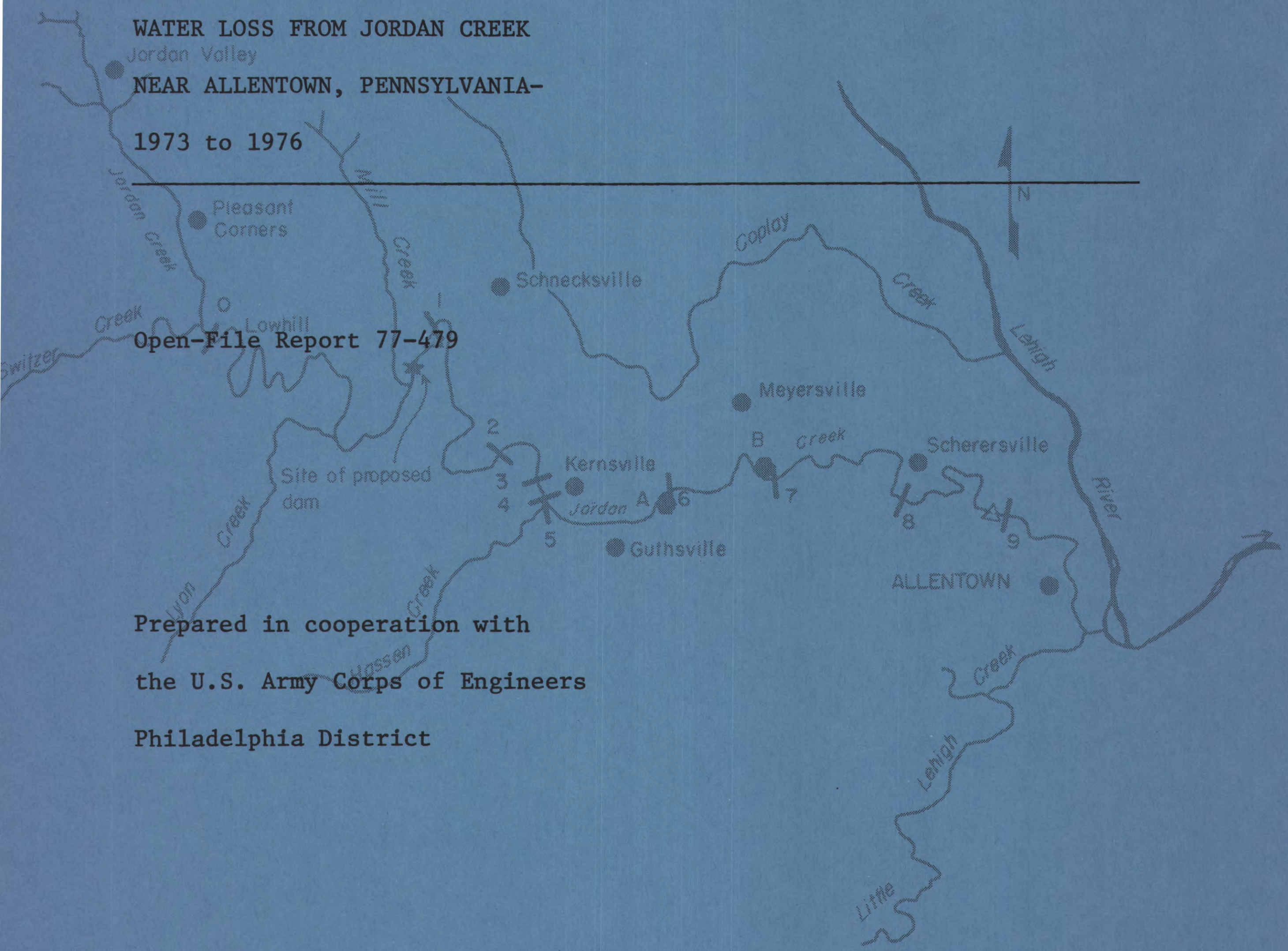
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER LOSS FROM JORDAN CREEK NEAR ALLENTOWN, PENNSYLVANIA— 1973 to 1976



Open-File Report 77-479

Prepared in cooperation with

the U.S. Army Corps of Engineers

Philadelphia District

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CONTENTS

ILLUSTRATIONS

TABLES

FACTORS FOR CONVERTING ENGLISH UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

The following factors may be used to convert the English units published herein to the International System of Units (SI).

Multiply English units	By	To obtain SI units
	Length	
miles (mi)	1.609	kilometers (km)
	Area	
square miles (mi^2)	2.590	square kilometers (km^2)
	Flow	
cubic feet per second (ft^3/s)	.02832	cubic meters per second (m^3/s)

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1973 to 1976

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ABSTRACT

Results of water-loss studies for Jordan Creek near Allentown, Pa. are presented in both tabular and graphical form. The reach studied is approximately 24 miles long and extends from a point near Lowhill, Pa. to a point in Allentown, Pa. The drainage area at Allentown is about 76 square miles. In portions of the study area, Jordan Creek loses considerable parts of its flow to the permeable limestones and dolomites that it traverses.

Seven current-meter measurements were made at each of ten sites along the reach, during the period 1973 to 1976. The results of the above measurements are analyzed and presented in a form suitable for use in planning the operation of a proposed reservoir which may be built near the upstream end of the reach.

Three examples of how the results may be used are presented.

INTRODUCTION

Jordan Creek is in eastern Pennsylvania northeast of Allentown, Pa. Between Schnecksville and Scherersville, Pa. the creek flows over very permeable limestones and dolomites. It loses a considerable portion of its flow to these rocks and in times of drought, certain reaches have gone completely dry. At least part of the missing water flows northeastward through fractures and solution openings in the rock and is discharged to the Lehigh River. The distance to the Lehigh River is approximately four miles. In addition to the above loss from the basin, when sufficient water is available, about eight cubic feet per second flows through the aquifer and reappears as surface flow near the mouth of Jordan Creek. The general situation has been well described by Wood and others (1972, p. 142-158, 210-212).

The U.S. Army Corps of Engineers is planning to construct a dam upstream from the water losing reach. They have, therefore, requested this study as a means of determining the operational controls that may be needed.

DATA COLLECTION

Ten sites for measuring discharge were established. The sites are shown on figure 1 and described in table 1. Seven sets of discharge measurements were made during the period August 25, 1973 to June 14, 1976. Each set included one discharge measurement made at each site on a given day. The measured discharges are listed in table 2.

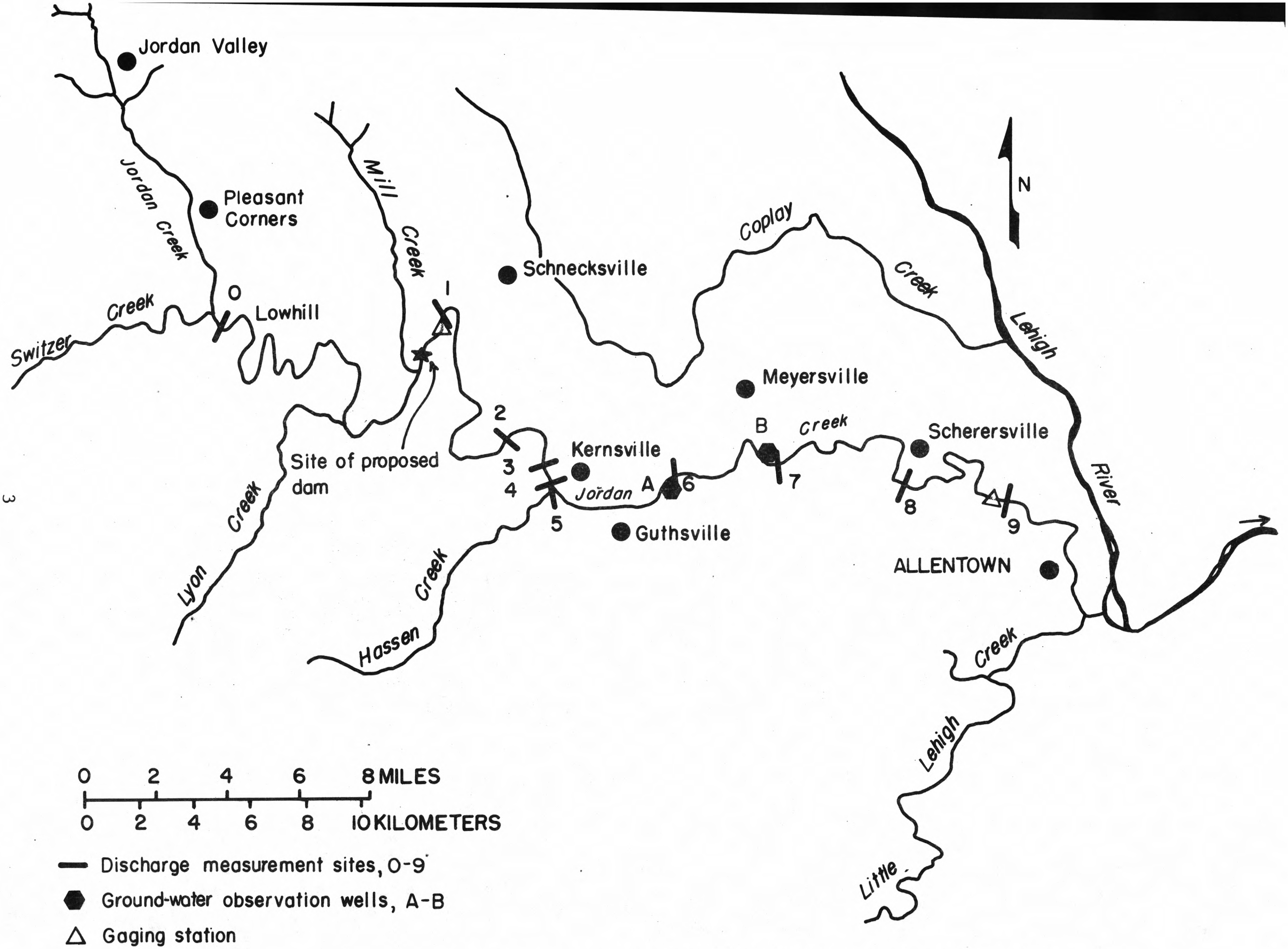

Figure 1 -- Jordan Creek study area and measurement locations

Table 1.--Measurement sites on Jordan Creek

Site No.	U.S.G.S. Station No.	Name and Location
0	01451703	Jordan Creek at Lowhill, Pa. Lat 40°39'27", long 75°41'06", 100 feet upstream from concrete highway (Pa 100) bridge at Lowhill.
1	01451800	Jordan Creek near Schnecksville, Pa. Lat 40°39'42", long 75°37'38", 200 feet downstream from wooden covered bridge at Trexler - Lehigh County Game Preserve. Drainage Area - 53.0 Sq. Mi.
2	01451830	Jordan Creek near Kernsville. Lat 40°38'08", long 75°36'48", 100 feet downstream from wooden covered bridge (Rex's Bridge) 0.7 mile west of Kernsville.
3	01451840	Jordan Creek at Kernsville. Lat 40°37'52", long 75°36'09", 600 ft downstream from bridge at Kernsville.
4	01451850	Jordan Creek above Hassen Creek near Kernsville. Lat 47°37'32", long 75°36'02", 100 feet upstream from Hassen Creek near Kernsville.
5 a/	01451860	Hassen Creek at mouth. Lat 40°37'30", long 75°36'02", 10 feet downstream from bridge near Kernsville.
6	01451870	Jordan Creek near Guthsville. Lat 40°37'39", long 75°34'15", at wooden covered bridge (Wehrs Mill Bridge) 0.9 mile northeast of Guthsville.
7	01451924	Jordan Creek near Meyersville. Lat 40°37'50", long 75°32'31", 400 feet downstream from Reading Railroad bridge, 1.2 miles south of Meyersville.
8	01451952	Jordan Creek at Scherersville. Lat 40°37'32", long 75°30'24", 1,000 feet downstream from highway bridge at Scherersville.
9	01452000	Jordan Creek at Allentown. Lat 40°37'25", long 75°29'00", 200 feet downstream from Seventh Avenue Bridge on State Highway 145, 0.5 mile northwest of Allentown.

a/ This site is on Hassen Creek, the only major tributary to the water losing reach.

Table 2.--Discharge measurements and drainage areas above measurement sites

	Site Number									
	0	1	2	3	4	5 c/	6	7	8	9
Drainage Area, mi^2	23.0	53.0	55.4	57.2	57.4	7.70	68.8	71.8	74.2	75.8
Date	Discharge, in cubic feet per second									
10-16-73	5.15	13.9	15.5	14.7	14.3	1.55	10.3	6.28	6.56	14.1
8-25-73	5.22 a/	13.6	14.1	14.0	14.0	1.68	10.3	8.01	9.00	16.8
7-31-74	5.21	13.1	17.7	10.6	12.2	0.98	7.83	5.18	5.90	26.5 b/
6-14-76	7.24	14.9	16.3	15.6	15.6	1.63	11.1	8.82	9.79	17.2
7- 8-75	19.0	47.9	53.8	46.4	48.5	4.6 a/	46.9	45.3	50.4	55.1
3-13-74	39.7	148	151	151	147	20.6	165	145	136	173
4-17-74	95.4	209	216	214	215	13.7	189	185	211	204

a/ Estimated.
b/ Affected by precipitation on lower basin.
c/ This site is on Hassen Creek, the only major tributary to the water losing reach.

ANALYSIS

This report has two objectives: first, to document the conditions existing prior to construction of the proposed dam, and second, to organize the gain-loss relations in such a way that it is possible to predict the results that will be obtained by operation of the proposed dam and reservoir.

The first objective was achieved by preparing individual graphs for sites 0, 2, 3, 4, 6, 7, 8 and 9 in order to develop the relation of their respective discharges to the discharges at site 1 (the site nearest to the location proposed for the dam). Figures 2 and 3 are illustrative examples of these graphs. Table 3 is a summary of these relations. Figure 4 presents graphs of selected flows listed in table 3. The magnitude and location of the water loss are evident.

The second objective was realized by considering the water input and the water loss from the system separately. Water input consists of the flow passing the damsite and water, both surface and ground, draining from the basin downstream from the dam. The water loss for any point downstream from the damsite is defined as the difference between the total flow that would be expected if there were no water loss and the surface flow that is observed. The surface flow for a given condition is then calculated by the algebraic summation of the water input and water loss for that condition.

The system is demonstrated by the three examples in the following section.

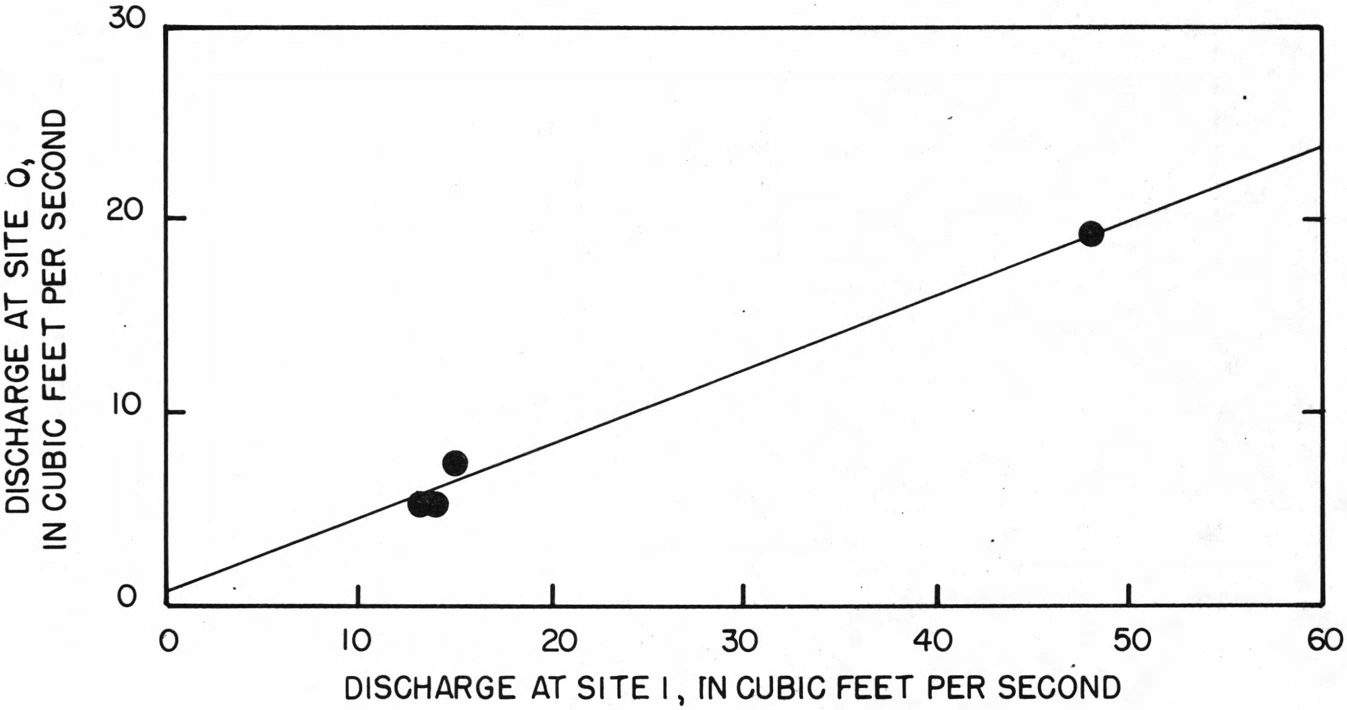

Figure 2.--Relation between discharge at site 1 and discharge at site 0.

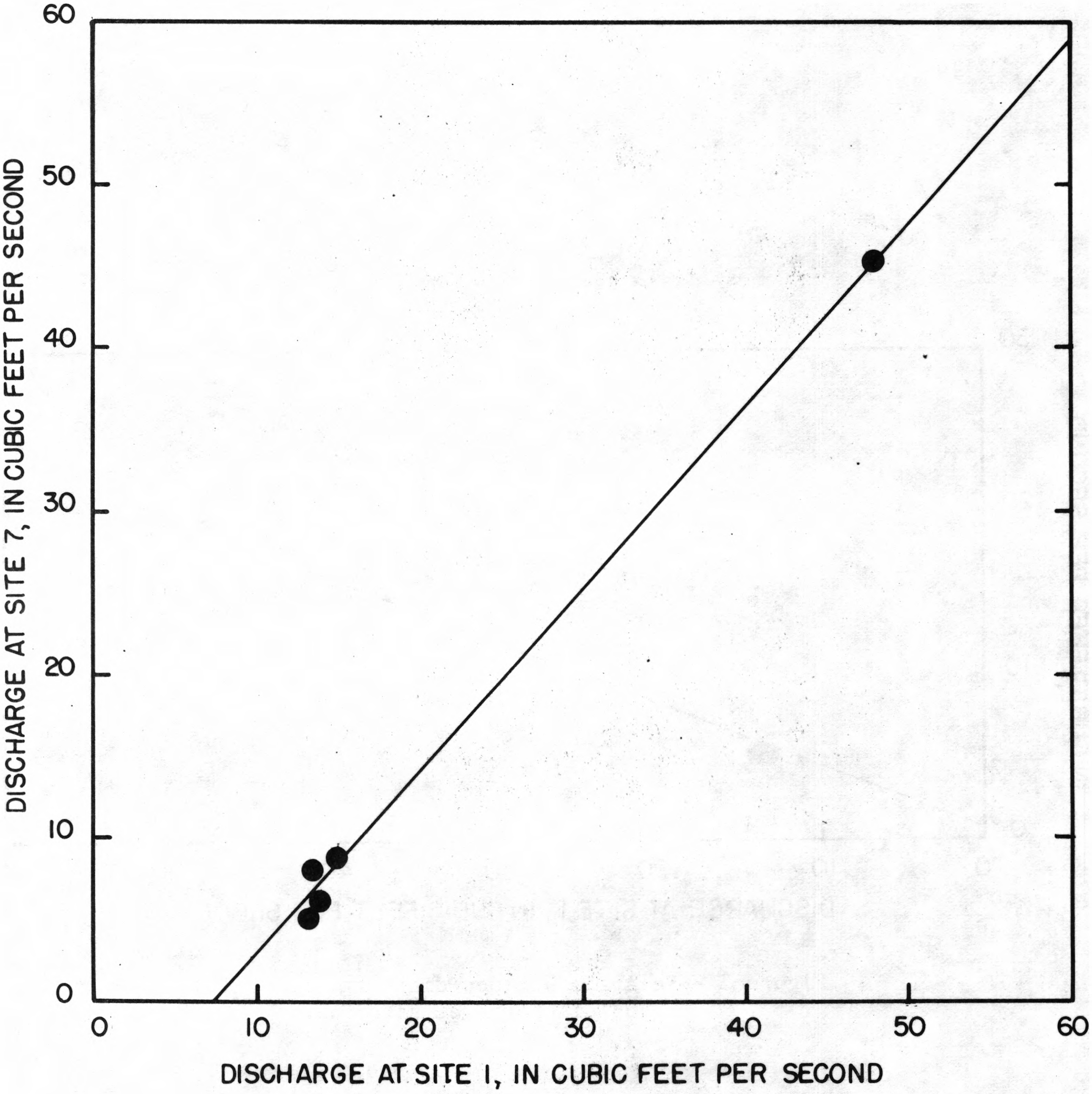

Figure 3.--Relation between discharge at site 1 and discharge at site 7.

Table 3.--Relation between discharge at site 1 and discharge at other sites

Site Number 1	0	2	3	4	6	7	8	9
Assumed Discharge ft^3/s	Discharge from graphical relations, in cubic feet per second							
0	0.6	0.3	0.8	0	0	0	0	0.3
1	1.0	1.5	1.6	1.0	0	0	0	1.5
2	1.3	2.5	2.5	2.0	0	0	0	2.6
3	1.8	3.7	3.5	3.0	0	0	0	3.7
4	2.1	4.8	4.5	4.0	0	0	0	4.8
5	2.5	6.0	5.4	5.0	0.2	0	0	6.0
6	2.9	7.0	6.4	6.0	1.5	0	0	7.2
7	3.3	8.1	7.3	7.0	2.6	0	0	8.3
8	3.7	9.3	8.2	8.0	3.7	0.9	0.5	9.5
9	4.0	10.4	9.2	9.0	4.7	2.0	1.9	10.7
10	4.4	11.5	10.1	10.0	5.7	3.0	3.0	11.8
15	6.3	17.0	15.0	15.1	11.0	8.7	9.4	17.5
20	8.2	22.5	19.7	20.1	16.5	14.0	15.5	23.2
30	12.1	33.5	29.0	30.1	27.4	25.2	28.0	34.6
40	16.0	44.8	38.7	40.2	38.2	36.4	40.4	46.0
50	20.0	56.0	48.2	50.3	49.2	47.7	52.8	57.6

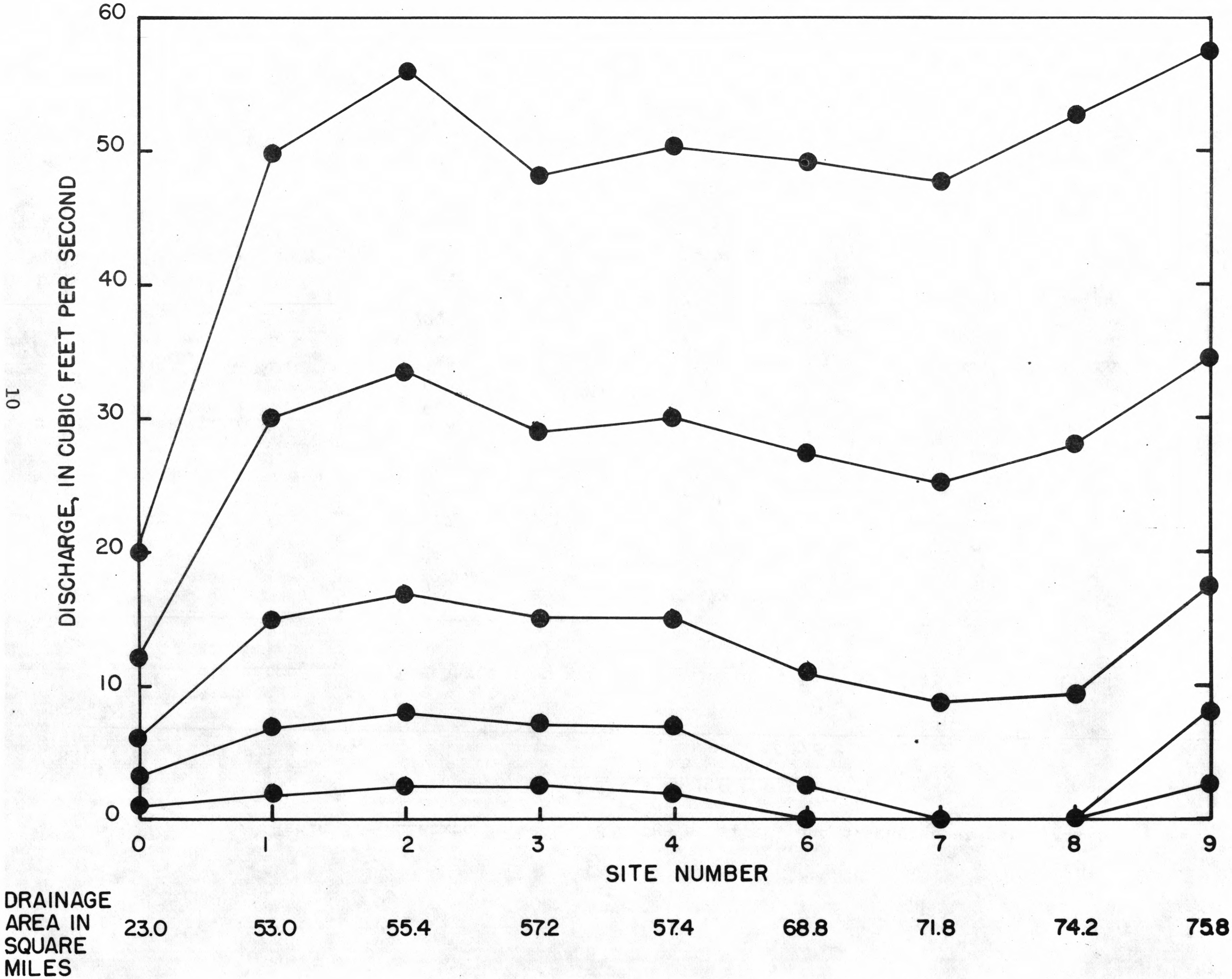

Figure 4.--Variation of discharge along Jordan Creek

APPLICATION

In this section, three examples are presented which show how the relations previously developed may be used to solve typical problems involving operation of the proposed reservoir.

Example 1

<u>Problem</u>.--Suppose that a decision has been made to maintain a minimum release of 6 ft^3/s from the proposed reservoir. What will the surface flow at site 7 be for a selection of natural flow conditions. The required calculations are shown in table 4 and are described below.

<u>Solution</u>.--

Table 4 Column	Operation
1.	Assumed natural flow at site 1.
2.	Divide figures in column 1 by 53.0, which is the drainage area in square miles at site 1.
3.	Calculate total flow that would be expected at site 7 if there were no loss of water. This is column 2 figure times drainage area at site 7 (71.8 mi^2).
4.	Site 7 surface flow obtained from table 3.
5.	Subtract column 4 figures from column 3 figures. This is the water loss between site 1 and site 7.
6.	Calculate expected yield, both surface and underground from the 18.8 square miles of drainage area between site 1 and site 7. This is done by multiplying the figures in column 2 by 18.8.

Table 4.--Calculations for Example 1

1	2	3	4	5	6	7	8	9
Natural flow of site 1	Discharge per square mile (col. 1 ÷ 53.0)	Calculated total flow at site 7 (col. 2 x 71.8)	Surface flow at site 7 (from table 3)	Water loss between site 1 and site 7 (col. 3 - col 4)	Calculated total flow from drainage area between sites 1 and 7 (col. 2 x 18.8)	Calculated total flow at site 7 if 6 ft^3/s released from reservoir (col. 6 + 6 ft^3/s)	Water loss between sites 1 and 7 (from fig. 5)	Calculated surface flow at site 7 (col. 7 - col. 8)
ft^3/s	$(ft^3/s)/mi^2$	ft^3/s	ft^3/s	ft^3/s	ft^3/s	ft^3/s	ft^3/s	ft^3/s
0	0	0	0	0	0	6.0	6.0	0
1	.019	1.4	0	1.4	.4	6.4	6.4	0
2	.038	2.7	0	2.7	.7	6.7	6.7	0
3	.057	4.1	0	4.1	1.1	7.1	7.1	0
4	.075	5.4	0	5.4	1.4	7.4	7.4	0
5	.094	6.7	0	6.7	1.8	7.8	7.8	0
6	.113	8.1	0	8.1	2.1	8.1	8.1	0
7	.132	9.5	0	9.5	2.5	8.5	8.5	0
8	.151	10.8	0.9	9.9	2.8	8.8	8.8	0
9	.170	12.2	2.0	10.2	3.2	9.2	9.2	0
10	.189	13.6	3.0	10.6	3.6	9.6	9.6	0
15	.283	20.3	8.7	11.6	5.3	11.3	10.1	1.2
20	.377	27.0	14.0	13.0	7.1	13.1	10.7	2.4
30	.566	40.6	25.2	15.4	10.6	16.6	11.4	5.2
40	.755	54.2	36.4	17.8	14.2	20.2	12.1	8.1
50	.943	67.7	47.7	20.0	17.7	23.7	12.8	10.9

7. Calculate total flow that would be expected at site 7 if there were no water loss and if the proposed reservoir were to maintain a release of 6 ft^3/s. These figures are the sum of the column 6 figure and 6 ft^3/s.

8. List the water loss between site 1 and site 7. The water loss is assumed to be a function of the total flow at site 7. The relationship is shown on figure 5, which is a plot of column 3 versus column 5. At flows less than about 10 ft^3/s this relation has a 45 degree slope. This indicates that the aquifer is able to absorb all available water at total flows less than this amount. At total flows greater than about 10 ft^3/s there is some surface flow at site 7.

9. Calculate surface flow at site 7 that might be expected for various natural runoff conditions if a release of 6 ft^3/s is maintained by the proposed reservoir. The figures are obtained by subtracting the figures in colunn 8 from the figures in column 7.

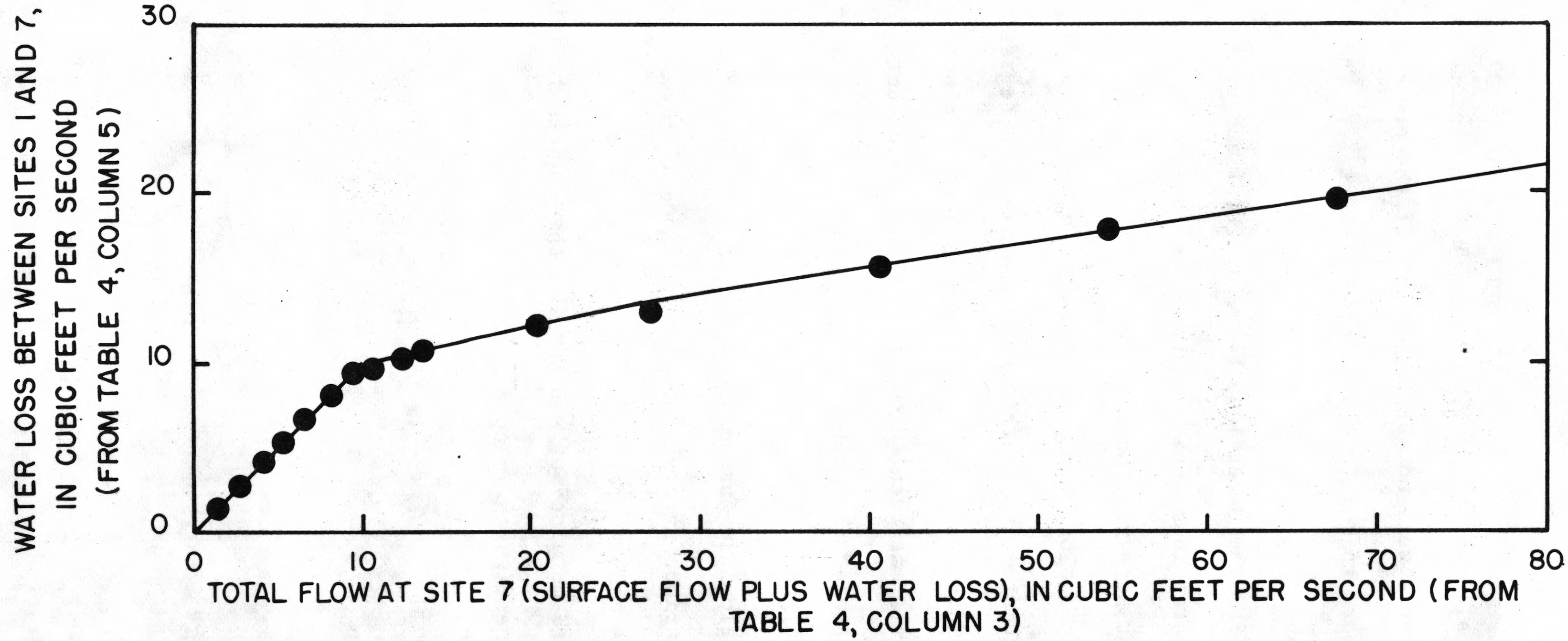

Figure 5.--Calculated water loss between sites 1 and 7 versus total calculated flow at site 7

Example 2

Problem.--What release would be required from the proposed reservoir if a surface flow of 2 ft^3/s is desired at site 7 at a time when the natural runoff is at the 7-day, 10-year level. (The lowest mean flow for seven consecutive days in a climatic year which could be expected on an average of once in ten years).

Solution.--

Step

1. From table 5, the 7-day, 10-year natural flow at site 1 is 1.6 ft^3/s.

2. Compute the runoff per square mile for this flow

$$\frac{1.6\ ft^3/s}{53.0\ mi2} = 0.03\ (ft^3/s)/mi^2$$

3. Compute expected runoff between sites 1 and 7.

$$0.03\ (ft^3/s)/mi^2 \times 18.8\ mi^2 = 0.6\ ft^3/s$$

4. In this case water loss between sites 1 and 7 is needed as a function of surface flow at site 7. Figure 6 defines this relation. The plotted values are from columns 4 and 5 of table 4. For this example, the surface flow at site 7 is 2 ft^3/s. Figure 6 indicates a corresponding water loss between sites 1 and 7 of 10.1 ft^3/s:

Table 5.--Low-flow frequency and flow duration data for Site 1

Magnitude and frequency of annual low flow.-- Period: 1967-72

Period of Consecutive days	Discharge, in cubic feet per second, for indicated recurrence interval in years. 2	5	10
7	5.4	2.5	1.6
14	6.6	2.7	1.7
30	8.4	3.1	1.9

Basis of estimate.-- Correlated with Jordan Creek at Allentown and Little Schuylkill River at Tamaqua concurrent low-flow discharges for the period 1967-72.

Duration table of daily flow.-- Period: 1967-72

Discharge, in cubic feet per second, which was equaled or exceeded for indicated percent of time

percent	2	5	10	20	30	40	50	60	70	80	90	95	98
ft^3/s	440	265	180	112	77	58	45	34	26	18	10.6	7.2	5.8

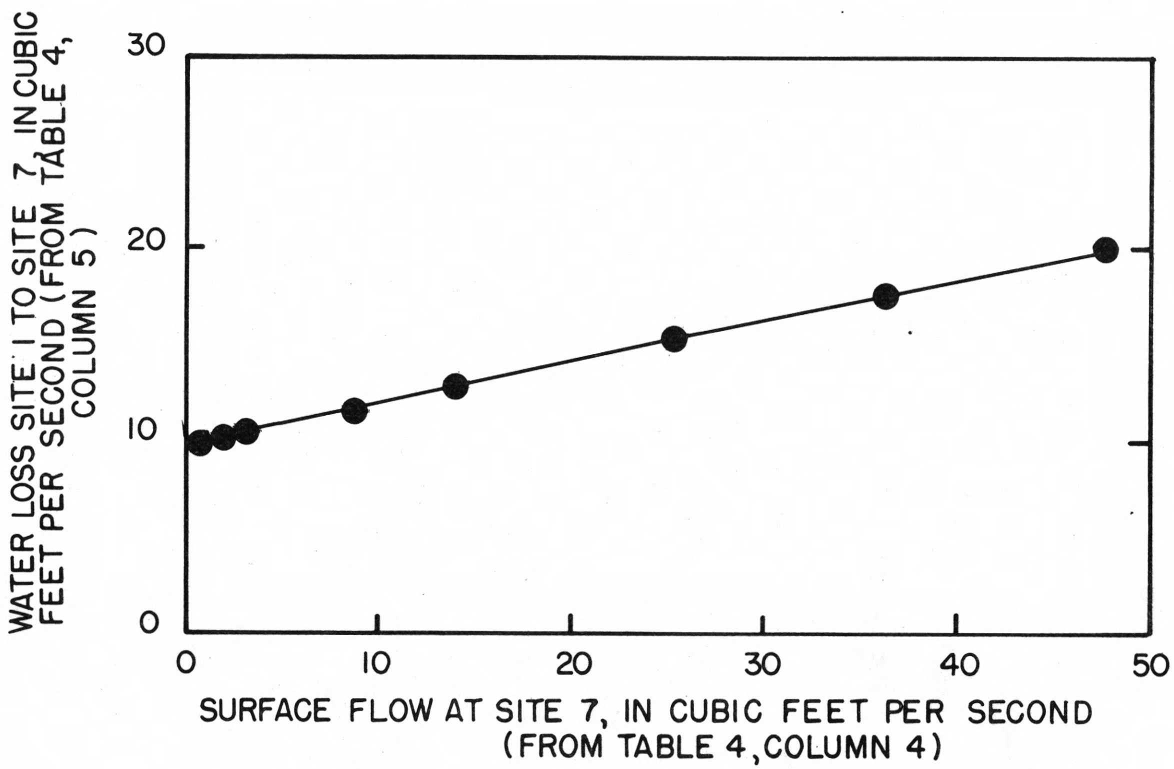

Figure 6.--Calculated water loss between sites 1 and 7 versus surface flow at site 7.

5. Required release + inflow - water loss = surface flow at site 7, or required release + 0.6 ft^3/s - 10.1 ft^3/s = 2.0 ft^3/s, or

Required release = -0.6 + 10.1 + 2.0

= 11.5 ft^3/s

Example 3

Problem.--What release from the proposed reservoir would be required to maintain a surface flow at the Allentown gage (site 9) equal to the unregulated 95 percent duration flow at that location.

Solution.--

Step

1. Table 6 gives a discharge of 5.2 ft^3/s at site 9 for the 95 percent duration flow.

2. Because the solution to this problem will vary with natural flow conditions, table 7 was developed. Table 7 is similar to table 4 for columns 1 to 6. The negative values in the first two lines of column 5 indicate that the surface flow is slightly more than would be expected if runoff were uniform.

3. In this example water loss between sites 1 and 9 is assumed to be a function of surface flow at site 9. Figure 7 defines this relation. Values from table 7, column 4 were plotted against those in column 5. For this example the surface flow at site 9 is 5.2 ft^3/s and from figure 7 the water loss between sites 1 and 9 is 1.0 ft^3/s.

Table 6.--Low-flow frequency and flow duration data for Site 9

Magnitude and frequency of annual low flow.--

Period: 1946-72

Period of consecutive days	Discharge, in cubic feet per second, for indicated recurrence intervals in years: 2	5	10	20	30
7	10.0	3.5	1.5	0.60	0.35
14	10	3.8	1.9	1.0	.70
30	11	4.8	2.8	1.8	1.3
60	17	7.1	4.2	2.6	2.0
120	28	11	6.6	4.1	3.1

Duration table of daily flow.--

Period: 1945-72

Discharge, in cubic feet per second, which was equaled or exceeded for indicated percent of time

percent	2	5	10	20	30	40	50	60	70	80	90	95	98
ft^3/s	550	340	240	150	100	79	58	42	31	20	9.0	5.2	3.5

Table 7.--Calculations for Example 3

1	2	3	4	5	6	7
Natural flow at site 1	Discharge per square mile (col. 1 ÷ 53.0)	Calculated total flow at site 9 (col. 2 x 75.8)	Surface flow at site 9 (from table 3)	Water loss between site 1 and site 9 (col. 3 - col 4)	Calculated total flow from drainage area between sites 1 and 9 (col. 2 x 22.8)	Reservoir release required to provide 5.2 ft^3/s at site 9 (5.2 ft^3/s - col. 6 + 1.0 ft^3/s)
ft^3/s	$(ft^3/s)/mi^2$	ft^3/s	ft^3/s	ft^3/s	ft^3/s	ft^3/s
0	0	0	0.3	-0.3	0	6.2
1	.019	1.4	1.5	-0.1	0.4	5.8
2	.038	2.9	2.6	+0.3	0.9	5.3
3	.057	4.3	3.7	0.6	1.3	4.9
4	.075	5.7	4.8	0.9	1.7	4.5
5	.094	7.1	6.0	1.1	2.1	4.1
6	.113	8.6	7.2	1.4	2.6	3.6
7	.132	10.0	8.3	1.7	3.0	3.2
8	.151	11.4	9.5	1.9	3.4	2.8
9	.170	12.9	10.7	2.2	3.9	2.3
10	.189	14.3	11.8	2.5	4.3	1.9
15	.283	21.5	17.5	4.0	6.5	0
20	.377	28.6	23.2	5.4	8.6	0
30	.566	42.9	34.6	8.3	12.9	0
40	.755	57.2	46.0	11.2	17.2	0
50	.943	71.5	57.6	13.9	21.5	0

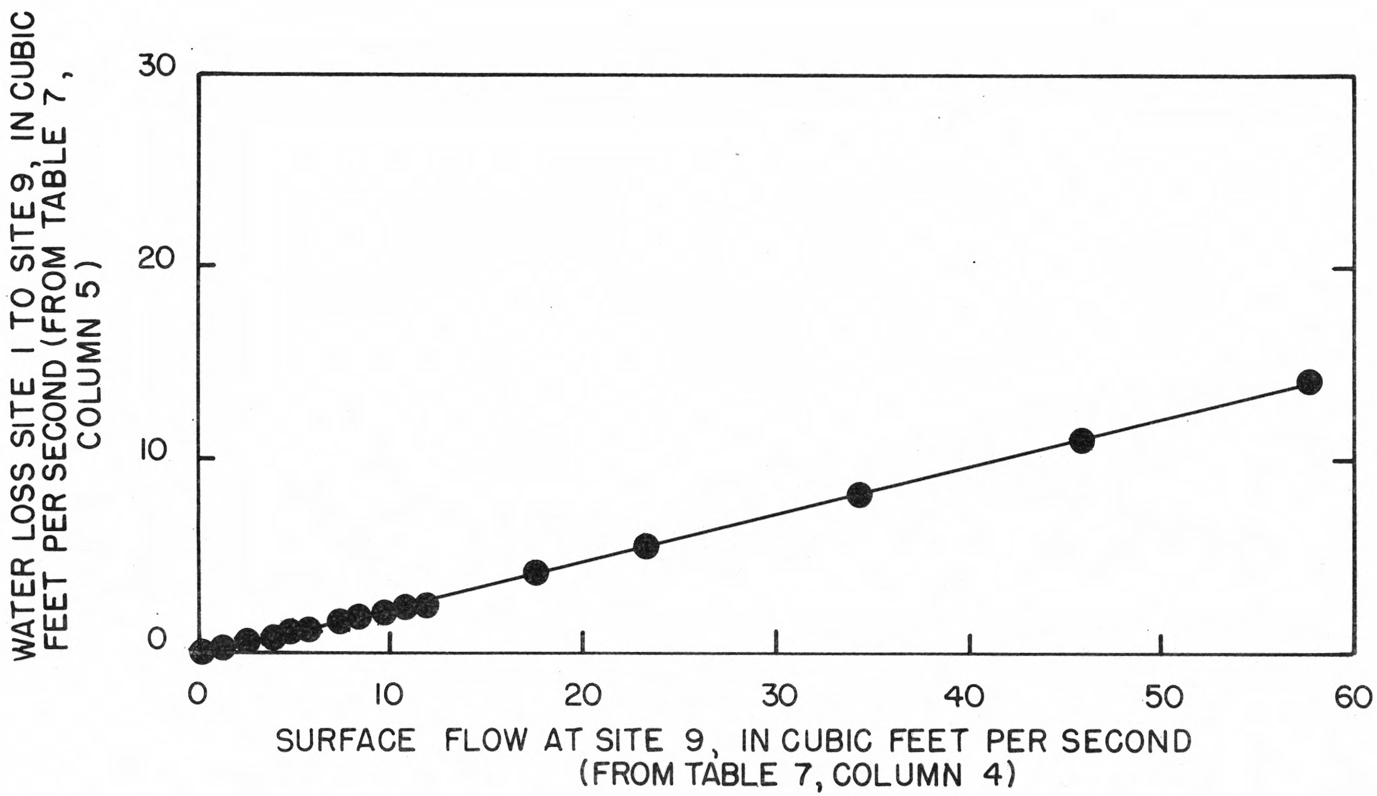

Figure 7.--Calculated water loss between site 1 and site 9 versus surface flow at site 9.

4. Required release + inflow - water loss = required flow at site 9, or

Required release + column 6 of table 7 $-1.0\ ft^3/s$ = $5.2\ ft^3/s$, or

Required release = $5.2\ ft^3/s$ - column 6 of table 7 + $1.0\ ft^3/s$.

The results of these computations for a selection of natural flow conditions are shown in column 7 of table 7.

GROUND WATER

U.S. Army Corps of Engineers plans for operation of the proposed dam and reservoir include diverting water from the reservoir by pipeline to serve domestic needs outside the Jordan Creek basin. This storage and diversion will have the effect of reducing the mean annual flow and the magnitude of peak flows in Jordan Creek downstream from the dam. The reservoir probably will be used to provide a small augmentation of extreme low flows. This section is an assessment of how this change in the hydrologic regime will affect the availability of ground water in the Jordan Creek basin downstream from the proposed dam.

Wood and others (1972, p. 142) made an exhaustive study of the ground-water resources of the Jordan Creek basin and the following material is based largely on that study.

From a short distance downstream from the proposed damsite to its mouth, Jordan Creek flows through a limestone valley that is about ten miles wide. The limestone aquifer is quite permeable and discharges considerable quantities of ground water to the Lehigh River. Sources of this ground water are precipitation, losses from Jordan Creek, and losses from Coplay Creek, which also drains the shale highlands to the north of the limestone valley.

The elevation of Jordan Creek in the vicinity of site 7 is about 300 feet above mean sea level. The low-water elevation of the Lehigh River in the area where the limestone aquifer discharges is about 260 feet above mean sea level. Therefore, even if the aquifer could transmit water with no loss in head, the water table in the vicinity of site 7 could not lie more than about 40 feet below the stream bed. Actually the water table could be expected to be much higher because of the head required to move the water about four miles to the Lehigh River, and because of the availability of water from sources other than Jordan Creek.

Ground-water levels in a given area could be depressed significantly locally by excessive withdrawals from wells owing to the fact that a pumped well will develop a cone of depression of sufficient size to convey the quantity of water that is being withdrawn. Such local ground-water-level problems could be alleviated by limiting the pumpage in specific areas or by releasing additional water from the proposed reservoir.

From the above discussion, it can be seen that the reduced flows in Jordan Creek that may result from the operation of the proposed reservoir would have little or no effect on the yield of drilled wells of adequate depth. There are very few shallow dug wells in the affected area. Those that are still in use may go dry at times.

SUMMARY

The available data indicate that the Jordan Creek flow system follows a rather predictable pattern, losing considerable parts of its flow to the underlying permeable limestones and dolomites. The relations between the flow variables have been defined in tables and figures.

Because the criteria for design and operation of the proposed reservoir may be changed from time to time as the plans for the reservoir progress, no attempt was made to cover all possible situations. Three illustrative examples are given to provide a guide for any additional computations that may be required.

Ground-water levels in the vicinity of Jordan Creek would not be lowered drastically by the operation of the proposed reservoir.

REFERENCE

Wood, C. R., Flippo, H. N., Jr., Lescinsky, J. B., and Barker, J. L., 1972, Water resources of Lehigh County, Pennsylvania: Pennsylvania Geol. Survey Water Resource Rept. 31, 4th ser., 263 p.