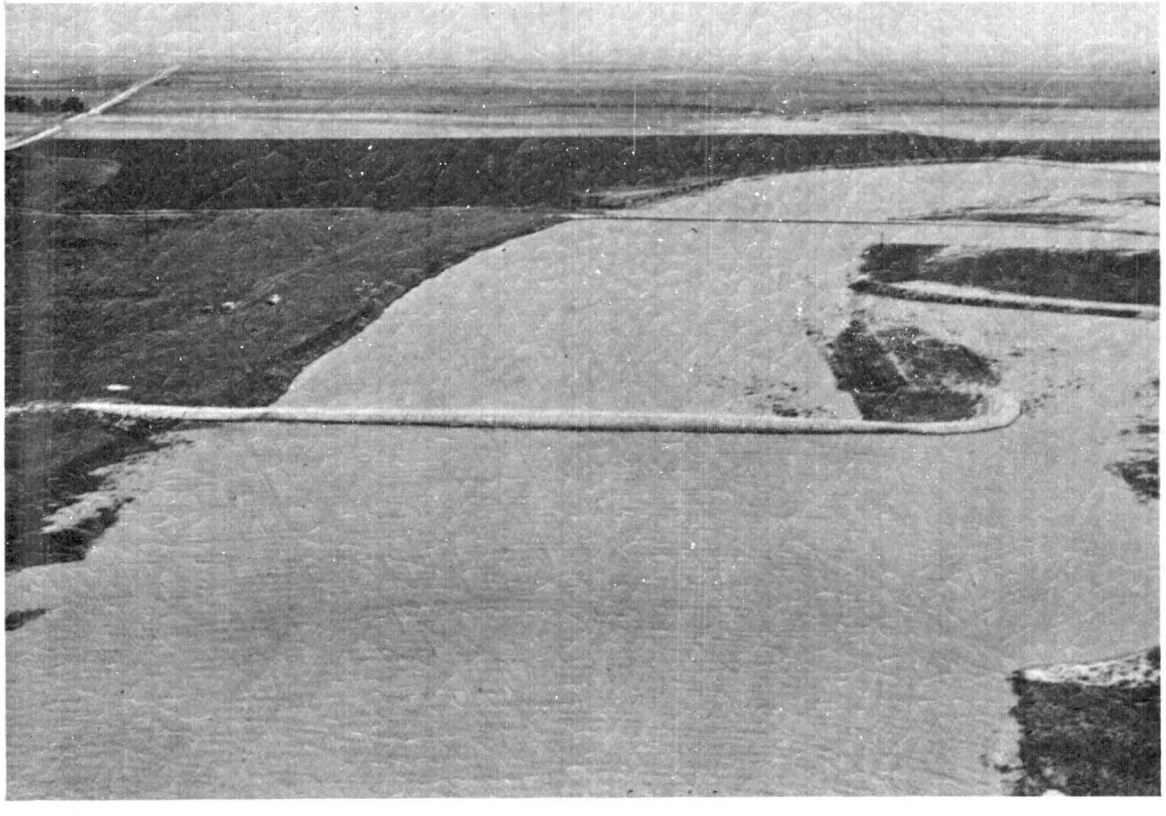
Artificial Ground-Water Recharge On The Arikaree River Near Cope, Colorado



CIVIL ENGINEERING DEPARTMENT

Engineering Research Center

Colorado State University

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Completion Report

ARTIFICIAL GROUND WATER RECHARGE ON THE ARIKAREE RIVER NEAR COPE, COLORADO

by

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INTRODUCTION

This project was initiated July 1, 1964, to study the feasibility of recharging excess or flood waters to an unconfined aquifer. The study included the selection of a site; design, construction, and maintenance of structures; data collection, analysis, and economic evaluation of artificial recharge.

An area on the Arikaree River near Cope, Colorado, was selected for the study. This area has an aquifer of very permeable medium and a large unsaturated thickness. The intermittant stream flows are associated with summer thunderstorm activity resulting in only one or two flows per year. The topography is gently rolling and the climate semi-arid with an annual precipitation of 16 inches. The watershed area above the study site is approximately 582 square miles. Principle irrigated crops near the study area are alfalfa hay, corn, and forage sorghums.

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HISTORY OF PROJECT

Research Sponsors

The 44th General Assembly of Colorado Legislature appropriated $10,000 to the Ground Water Commission for use in fiscal year 1965. These funds were used for construction and instrumentation of the study site. The appropriation was requested by the Ground Water Commission and residents near Cope who asked that the study be located in their area to develop means of supplementing an inadequate irrigation water supply. The Cope Soil Conservation District encouraged the study, offered to act as sub-contracting agency for construction, and pledged support to obtain easements from land owners for the necessary sites.

Contracts for the Study

The Ground Water Commission contracted with the Civil Engineering Department at Colorado State University to select recharge sites, design structures, supervise construction, collect and analyze data, and evaluate the results of the study. The Commission subcontracted with the Cope Soil Conservation District for construction costs. Funds were allocated for three succeeding years to maintain the structures and evaluate the recharge benefits.

Site Selection

Preliminary investigation indicated several possible sites on the Arikaree River near Cope. After brief geologic

investigations, two sites, indicated on Fig. 1, were selected. Site 1 is located on a large curve in the river channel and Site 2 is located below the confluence of the Arikaree River and Gordon Creek. Test holes drilled to bedrock indicated no impermeable layers to prevent vertical movement of water in the aquifer. A thickness of 20 feet between land surface and the water table existed for recharge.

Design of Structures

One principle objective of the study was to develop an inexpensive recharge facility. Use of materials existing at the site for earth fill dams and existing topography and vegetation for erosion control in the spillways provided an inexpensive recharge area.

Figure 2 shows a sketch of structures on Site 1. Dams D-1, D-2, and D-3 divert flow from the original channel and spread the flow over a large area for infiltration. Dikes I-1, I-2, and I-3 control the flow and reduce velocities while forcing a meandering pattern. The dikes prevented development of a new channel and provided some protection for existing irrigation wells.

Construction

Funds for construction of the earth dikes were awarded, by the Ground Water Commission through the Cope Soil Conservation District to a local contractor.

Specifications for the dams were for a 3:1 slope on both faces with a ten foot top width. Dikes were to have a

2:1 up and down slope and a three foot top. Compaction was limited to that which occurred as fill was pushed into place with a bulldozer. A ten percent over-fill was specified to allow for settlement.

Instrumentation

Estimates of the volume of water recharged were computed from the change in ground water levels during and following each recharge period. Data for Site 1 was obtained from ten observation wells and six existing irrigation wells. Ten wells were drilled and cased, seven of which were cased with one and one-fourth inch pipe, and three with five inch pipe. The five-inch wells were equipped with continous water level recorders. Water levels in all wells were measured periodically with a steel tape.

A continuous recorder was placed on a county highway bridge about six miles upstream of the project area. Records on periods of stream flow were collected from May 19 to June 30, 1965. The July 24, 1965, flood destroyed the bridge, recorder, and 24 days of record.

OPERATION OF THE RECHARGE PROJECT

Flow Periods

The continuous recorder six miles upstream of the recharge site recorded flows during May and June 1965. Table 1 shows recorded flow periods and indicates whether water reached the recharge site. Direct measurement of the July

24, 1965, flood was not possible but two slope-area calculations based on high water marks indicated discharge at approximately 18,000 cfs. Flows during the July 25-30, 1965, period were estimated at two different times from 2,000 to 3,000 cfs.

Recharge by Structures

Flows during June 1965 did not exceed the design flows of 1500 to 2000 cfs to significantly damage the structures but did provide a significant amount of water for recharge. The flood of July 1965 did considerable damage to most structures but also removed a considerable amount of accumulated sediment. Flows occurred in August 1966, July 1967, and August 1968. The flow in July 1967 breached dike I-3 which was repaired before the 1968 flow. The total amount of water recharged in the period 1964-1968 was about 1810 acre feet.

EFFECTS ON WATER LEVELS

Water Levels Prior to Recharge

A water table map shown in Fig. 7 was drawn for June 16, 1965, prior to any significant flow. The map shows the water table sloped toward the north-east with no apparent influence from the river. Water levels were declining in all observation wells and pumps on irrigation wells near the project area were breaking suction after short periods of operation.

Effect of Recharge

Water levels were measured several times daily during and immediately after flows occurred in the river. Figure 11 shows six representative water level hydrographs. Note the water levels drop steadily after the peak of recharge indicating lateral spreading and down valley movement. A water table contour map, Fig. 8, drawn for June 28, 1965, shows considerable change from June 16, and sloped sharply downward to the east and northeast. Water table maps drawn for later flows show very similar effects.

Quantity of Water Recharged

After each flow, a change in saturated thickness map was prepared to show the effect of recharge. A planimeter was used to determine the volume of aquifer that was saturated as the water level rose. Assuming a porosity of 20 percent, the estimated volume of recharge was computed. Table 2 gives dates and amounts of water recharged. Cross sections, Figs. 12-16, show the size and shape of the recharge mounds.

PROBLEMS ENCOUNTERED

Design for Large Floods

It is economically not feasible to design earth dikes to safely retain large floods. A complete watershed program, however, consisting of many small recharge facilities placed through the entire drainage might prevent such floods, recharge more water, and prevent massive soil erosion.

Sediment Deposit

Flood waters deposited large volumes of sediment in the recharge area. The coarser material was trapped behind the first structure and finer sediments settled over lower parts of the facility - thus sealing the bed and reducing rates of recharge. Removing these sediment deposits after every flow would be required to maintain high rates of recharge. The flood of July 1965 effectively removed 9-12 inches of sediment, but also removed most of the other structures too.

EVALUATION OF THE STUDY

Demonstrational Purposes

The Cope recharge study has shown that artificial recharge from emphemeral streams with flood flows is possible and practical. The rise in water levels restored nearby irrigation wells to year-around production. The design and construction of the diversion structures was satisfactory; and installation costs were reasonable.

Cost-Benefit Analysis

During the life of the study, 1810 acre feet of water were recharged at a construction and maintenance cost of $13,140.00 or a cost of $7.26 per acre-foot. Assuming a return value of ten dollars per acre-foot, as this water was available to mature a crop, the study was a financial success.

The recharge structures are still effective and the Cope site should provide additional recharge to the aquifer, thereby reducing the cost per acre-foot of recharged water.

SUMMARY AND RECOMMENDATIONS

Inexpensive and expendable structures for artificial recharge were designed and constructed on the Arikaree River near Cope, Colorado, during 1964 and 1965. Flood flows during the study provided approximately 1810 acre-feet of recharged water.

Recharge benefits in this study exceeded the cost of construction and maintenance, and demonstrated that artificial recharge is practical and that similar installations could be constructed in other areas of Colorado to obtain maximum use of water resources. Further study is needed to determine a method of preventing the deposition of sediment and the resulting restricted recharge rates. Water Conservancy and Management Districts, Soil Conservancy Districts, and State Water Commissions should consider artificial recharge as a means of conserving and using all available water supplies.

ACKNOWLEDGMENTS

Appreciation is expressed to the State of Colorado and the Colorado Ground Water Commission for the financial support that made the study possible. Cooperation by the Cope Soil Conservation District, Ezra Page, Oscar Higgason, Lynn Laybourn, Fred Laybourn, and other residents near Cope was greatly appreciated. Funds provided under the Federal Disaster Act and administered by the Army Corps of Engineers were used to reconstruct the project after the July 1965 flood.

Other publications on the project include:

Longenbaugh, Robert A., PR 170, Progress Report - Artificial Water Recharge on the Arikaree River near Cope, Colorado, July 1965.

Longenbaugh, Robert A., Experiment Station Report CER66RAL35, Artificial Ground Water Recharge on the Arikaree River near Cope, Colorado, June 1966.

TABLE 1 - FLOW PERIODS FOR THE ARIKAREE RIVER IN 1965

Date	Length of flow--hrs	Estimated Peak Discharge-cfs	Water Reached Site No. 1	Water Reached Site No. 2
May 22	14	380	Yes	No
May 26	7	80	No	No
June 4	7	150	No	No
June 5	20	110	No	No
June 13	5	100	No	No
June 16	9	350	Yes	No
June 17	20	1000	Yes	Yes
June 19	10	30	Yes	Yes
June 23	6	290	Yes	No
June 24	20	1600	Yes	Yes
July 24	19	18,000	Yes	Yes
July 25 to July 30	inter-mitt-ent	---	Yes	Yes

TABLE 2 - BEGINNING FLOW DATES AND AMOUNTS OF WATER RECHARGED

Date	Acre-Feet Water Recharged
June 16, 1965	450
July 24, 1965	108
August 18, 1966	391
July 16, 1967	774
August 10, 1968	87
TOTAL	1810

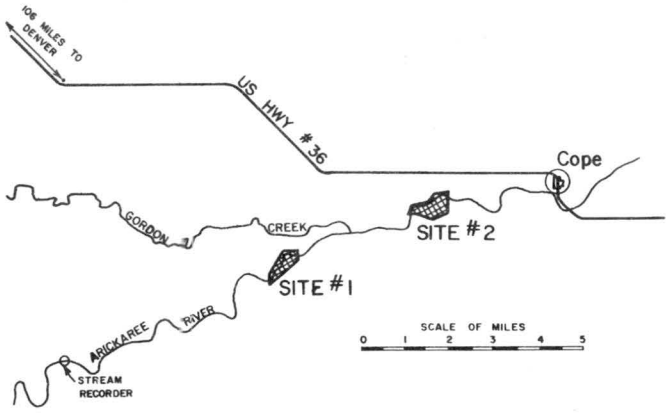

Figure 1.

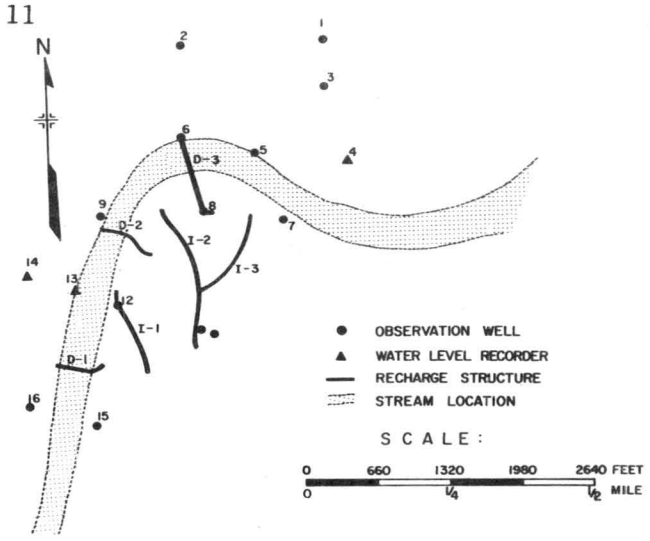

Figure 2.

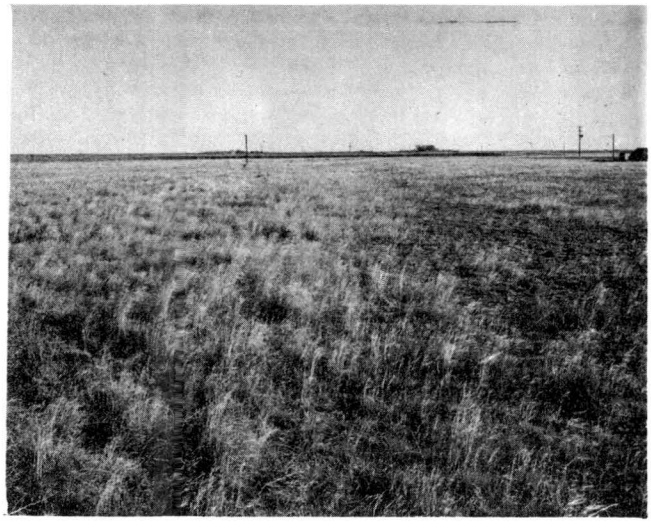

Figure 3.

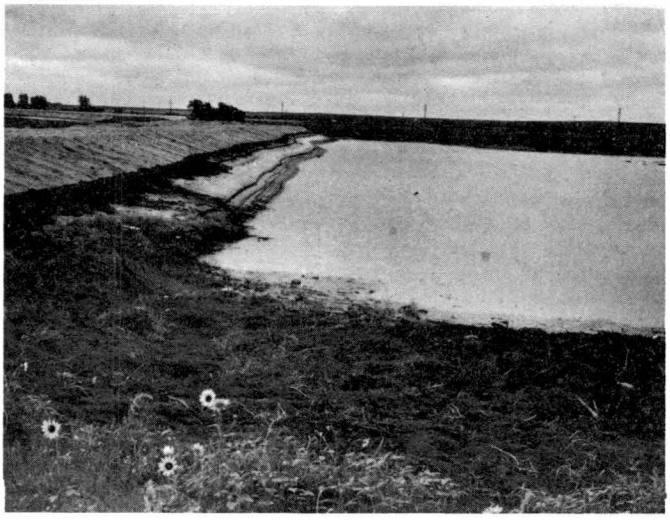

Figure 4.

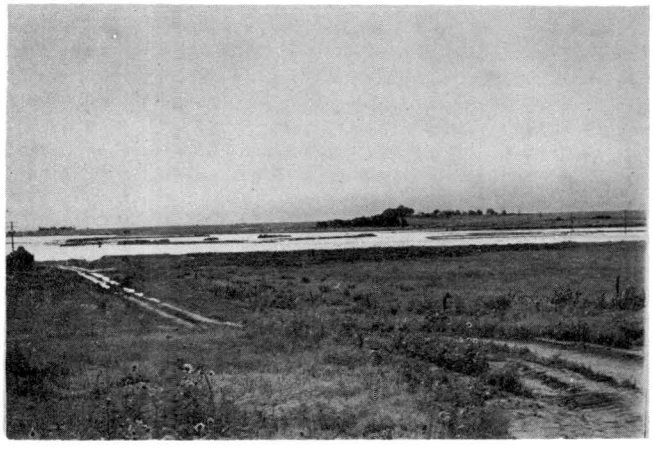

Figure 5.

Figure 1. Location of Cope recharge study area.

Figure 2. Sketch of site No. 1 showing orientation of structures.

Figure 3. View looking northeast across site No. 1 prior to construction.

Figure 4. Water impounded behind dam D-1 site No. 1 after June 18 flow.

Figure 5. Flood flow destroying structures at site No. 1 on July 24, 1965.

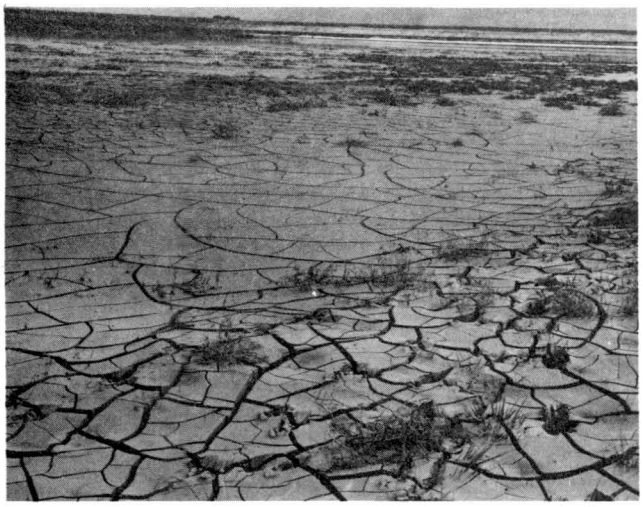

Figure 6.

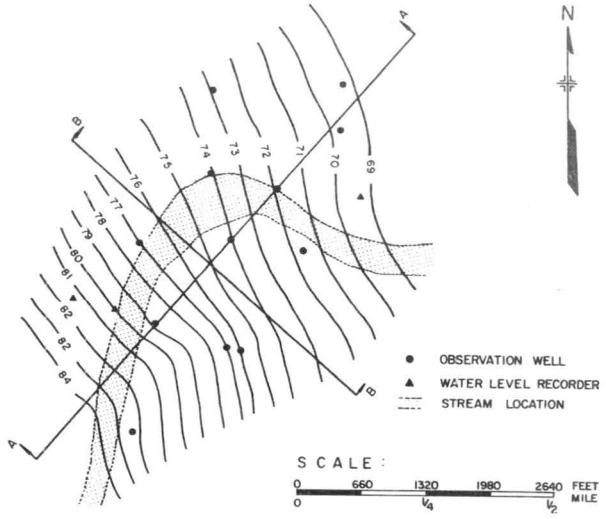

Figure 7.

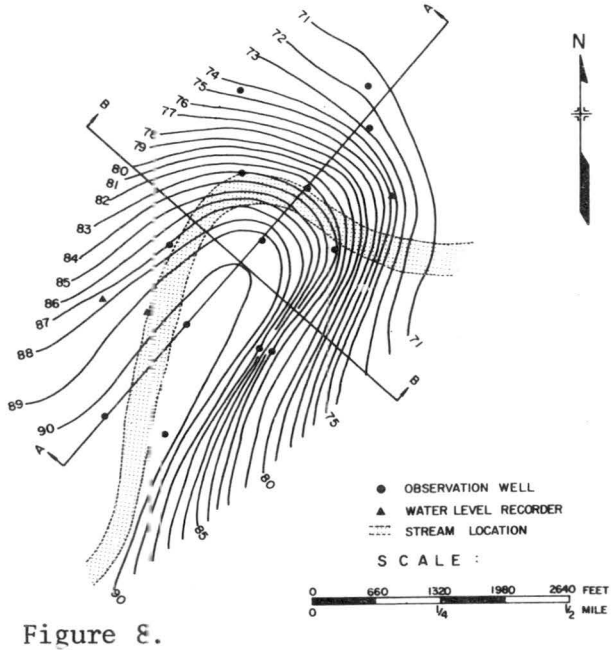

Figure 8.

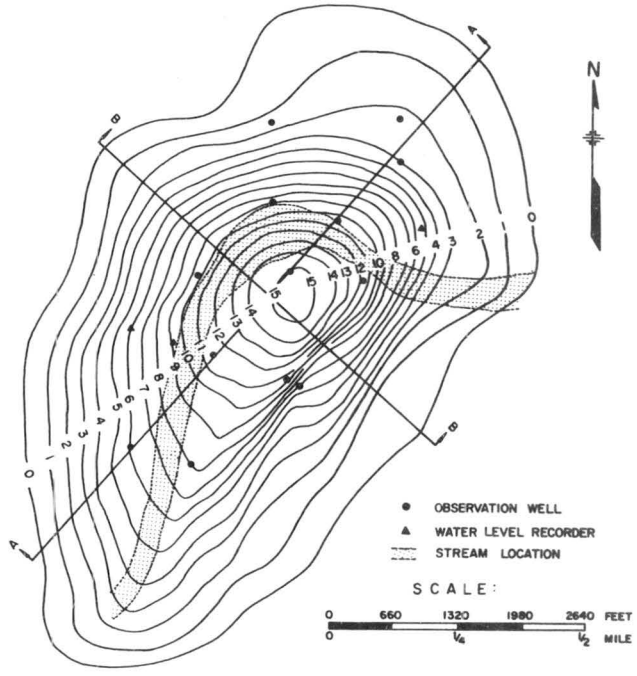

Figure 9.

Figure 10.

Figure 6. View across site No. 1 showing deposit of fine clay sediment.

Figure 7. Water table contour map prior to flow in the river.

Figure 8. Water table contour map on June 28 after flows in the river on June 16 and 26, 1965

Figure 9. Map showing the rise in water level between June 16 and June 28, 1965

Figure 10. Aerial view of site No. 1 on June 18, 1965

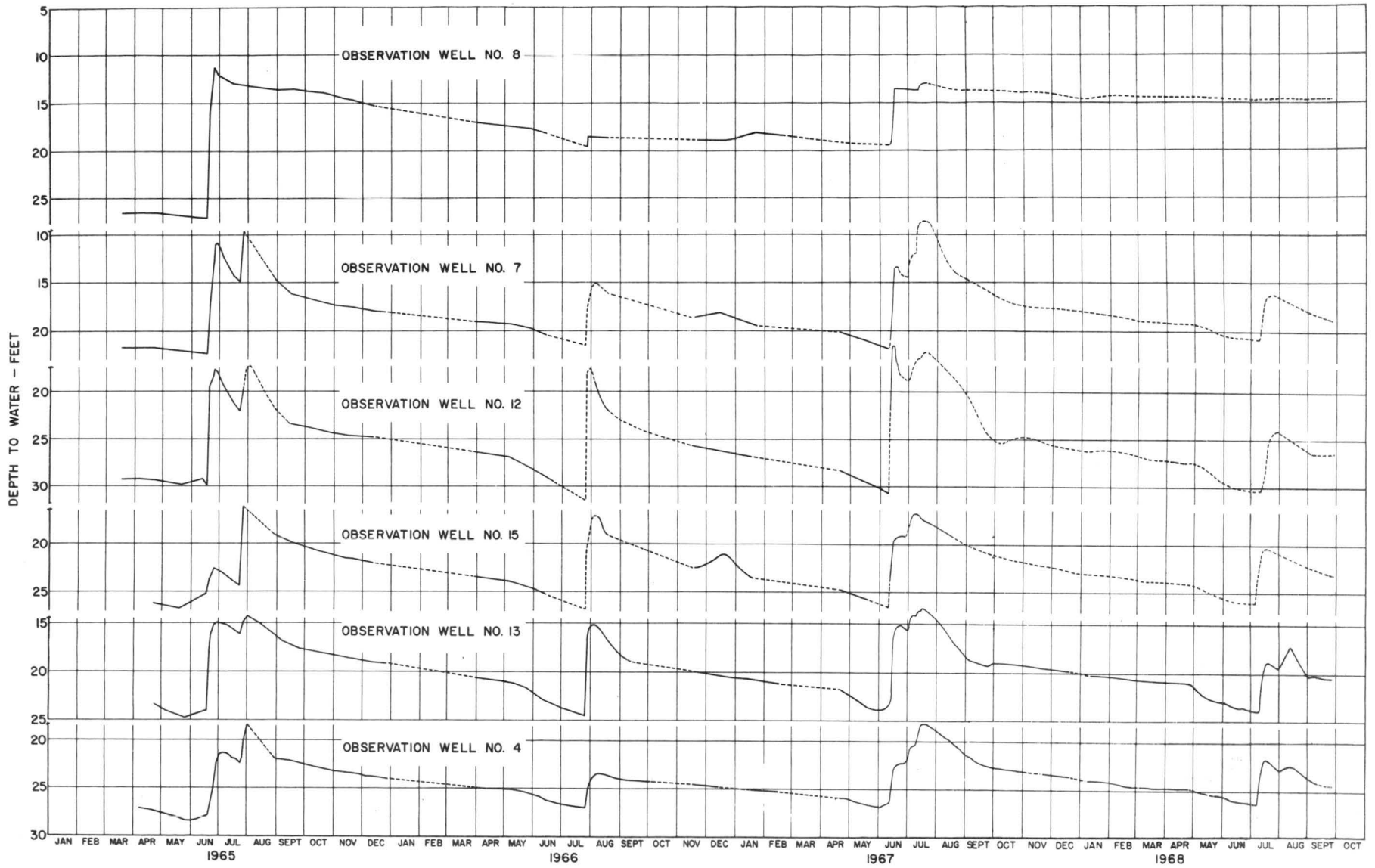

Figure 11. Representative well hydrographs for six observation wells at site No. 1.

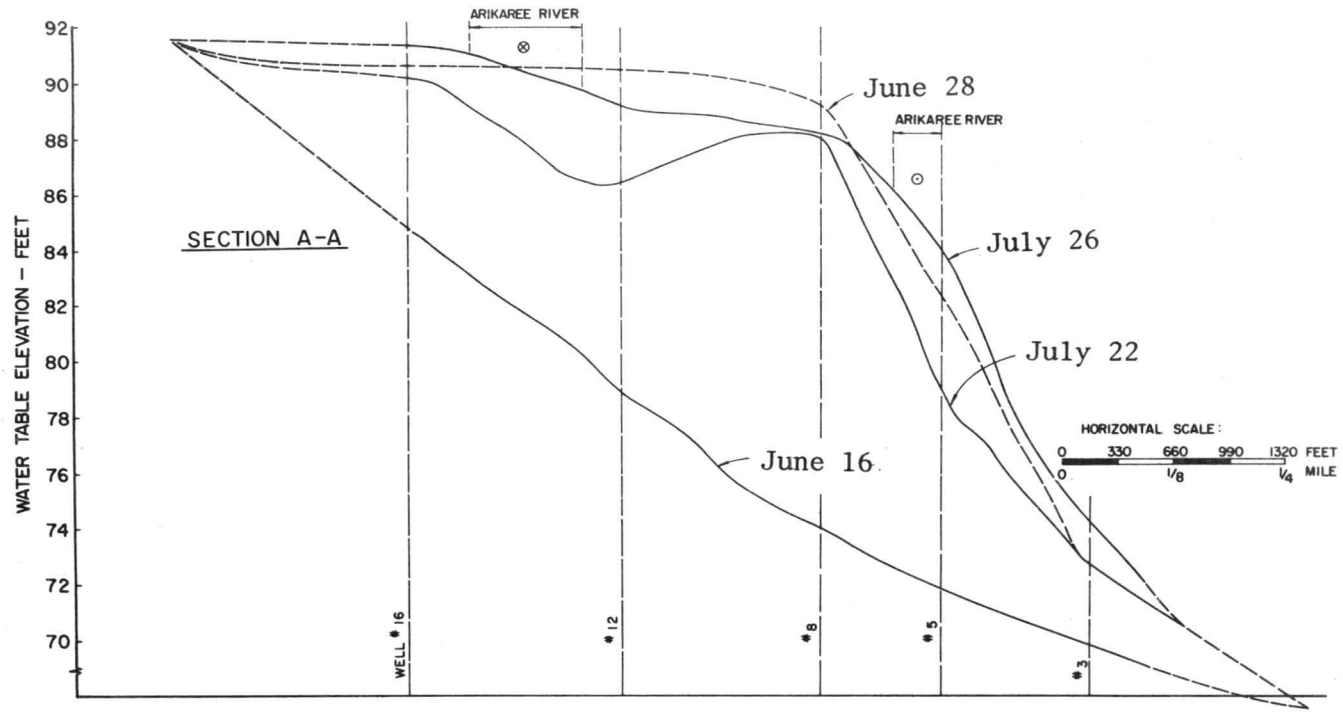

Figure 12. Cross sections for June 16, 28, July 22, 26, 1965.

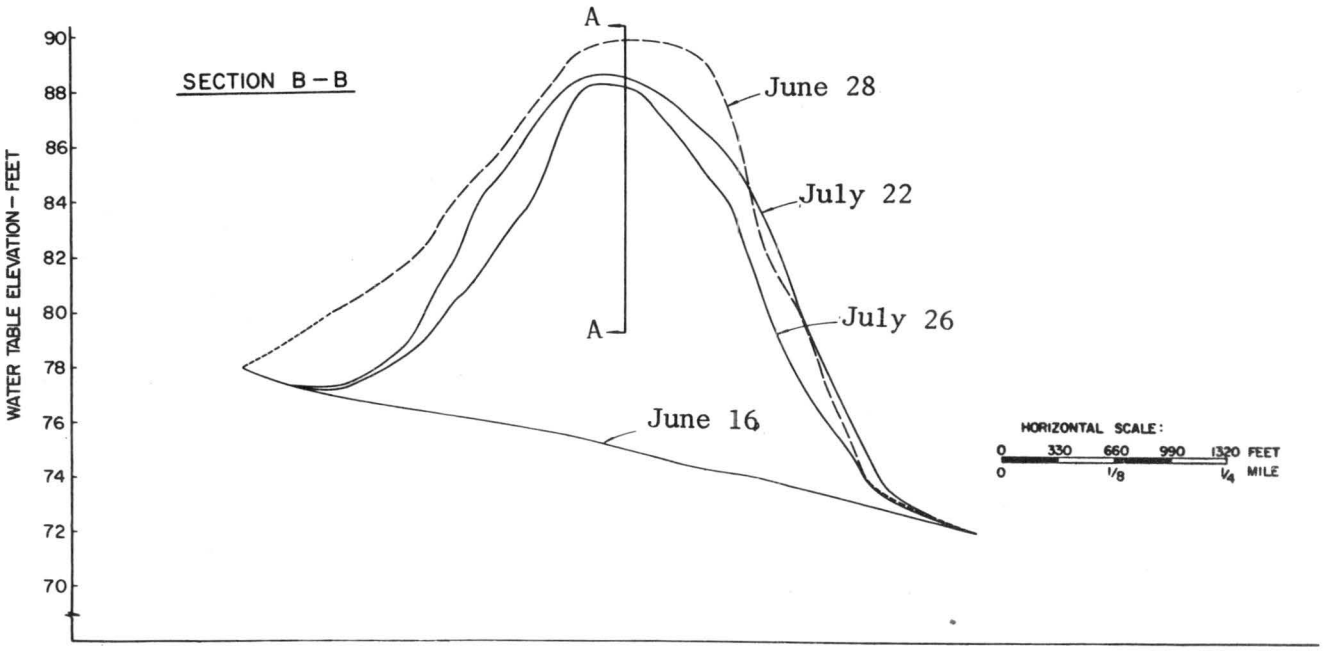

Figure 13. Cross sections for June 16, 28, July 22, 26, 1965

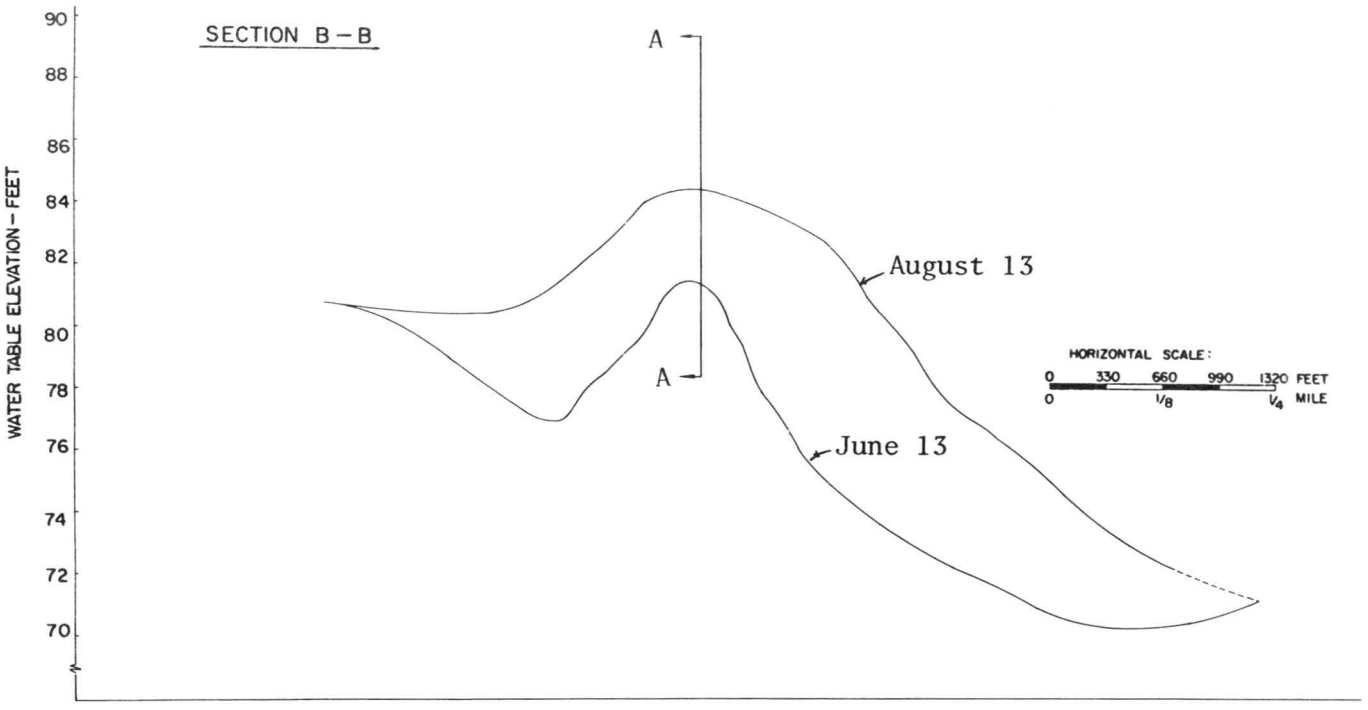

Figure 14. Cross sections for June 13 and August 13, 1966.

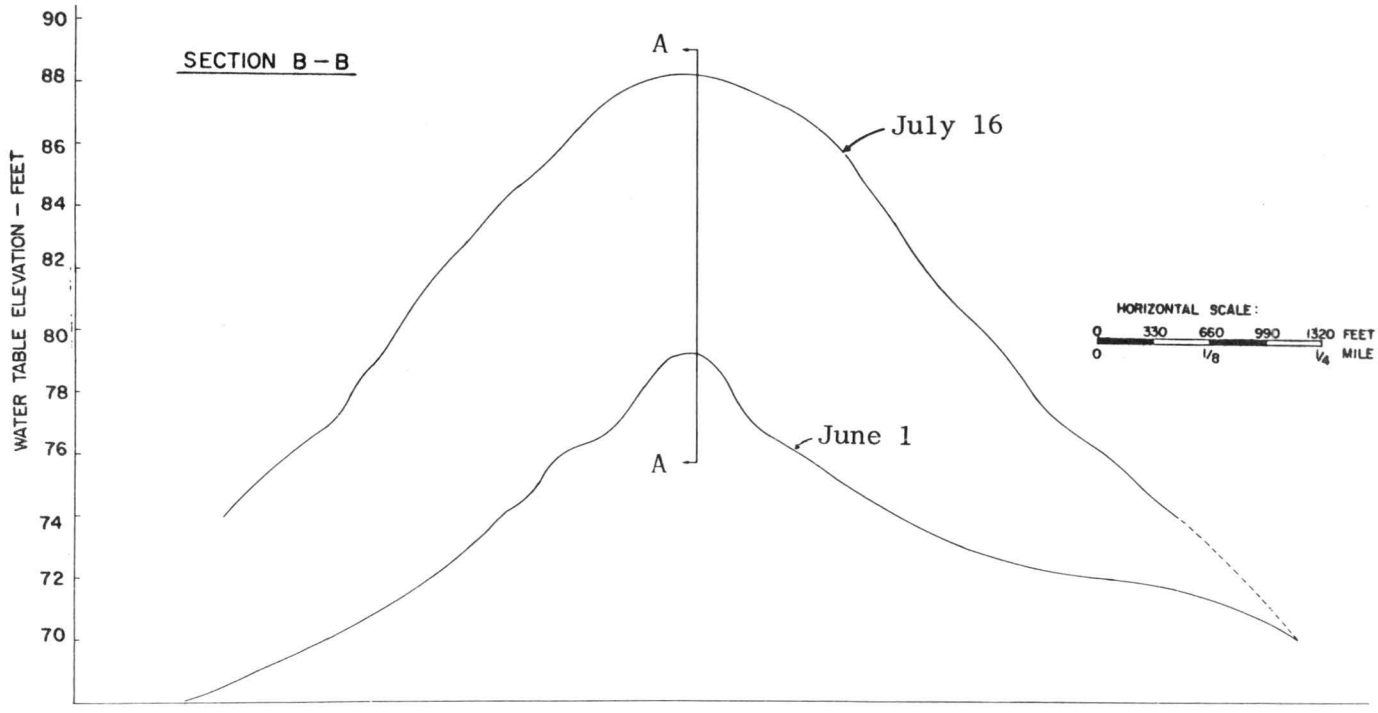

Figure 15. Cross sections for June 1 and July 16, 1967.

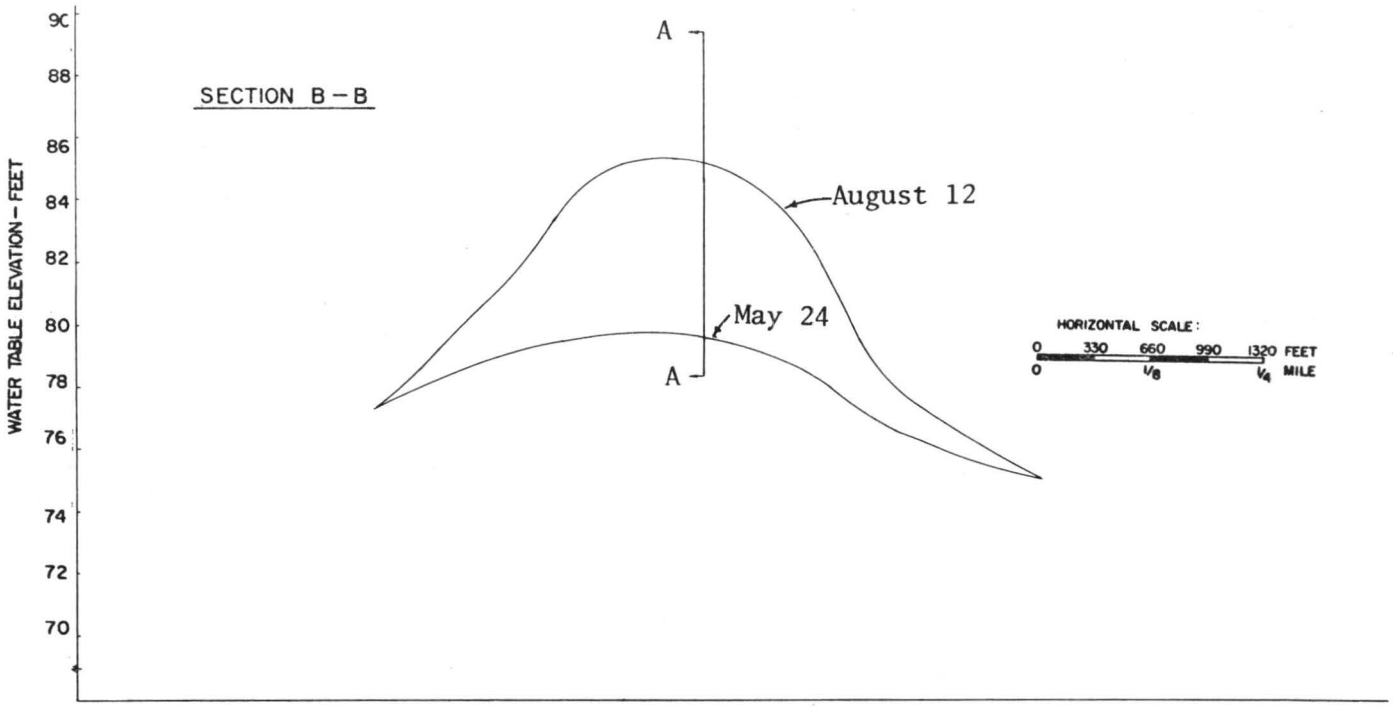

Figure 16. Cross sections for May 24 and August 12, 1968