SIMULATED INTERACTIONS BETWEEN THE PROPOSED NARROWS RESERVOIR AND THE WATER-TABLE AQUIFER ALONG THE SOUTH PLATTE RIVER, MORGAN COUNTY, COLORADO

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16. Abstract (Limit: 200 words) A computer model, including a ground-water-flow component and a mass-balance reservoir-operations component, was developed to simulate the proposed Narrows Reservoir and the adjacent alluvial aquifer of the South Platte River, Morgan County, Colorado. This model, using a weekly time step, simulated the transient interactions of these two systems for an initial-fill condition, a general-operational condition, and a sensitivity analysis to test the effects of possible data-input errors.

The initial-fill simulation indicated that to fill the reservoir when hydraulic connection between the surface-water system and the aquifer is simulated would take 2 additional years than if no connection were assumed. Simulated ground-water return flow to the river downstream of the proposed dam was about 85 percent of the estimated maximum values, computed under steady-state conditions in an earlier study. The general operational simulation indicated that during the period of lowest reservoir contents the aquifer provided about 80,000 acre-feet of recoverable storage to the reservoir's capacity. Average return flow was only about 70 percent of the estimated maximum values computed in the earlier, steady-state analysis. Monthly ground-water outflow from the reservoir to the aquifer ranged from 55,200 to -10,400 acre-feet.

Parameters tested for sensitivity, in order of decreasing sensitivity, were: Transmissivity, specific yield, hydraulic connection between reservoir and aquifer, local recharge, boundary conditions, and dam permeability. The probable error in the parameters tested would not seem to warrant significant new data collection.

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U.S. DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

Doyle G. Frederick, Acting Director

For additional information write to:

District Chief
U.S. Geological Survey
Box 25046, Mail Stop 415
Denver Federal Center
Lakewood, CO 80225

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METRIC CONVERSION

Inch-pound units used in this report may be converted to metric units by use of the following conversion factors:

Multiply	*By*	*To obtain*
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
mile	1.609	kilometer
acre	4,047	square meter
acre-foot (acre-ft)	1,233	cubic meter
acre-foot per month (acre-ft/mo)	1,233	cubic meter per month
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

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ABSTRACT

A computer model, including a ground-water component and a mass-balance reservoir-operations component, was developed to simulate the proposed Narrows Reservoir and the adjacent alluvial aquifer of the South Platte River, Morgan County, Colorado. This model, using weekly time steps, simulated the transient interactions of these two components for an initial-fill condition and general-operational condition. A sensitivity analysis was made to test the effects of possible errors in the description of aquifer characteristics on the model results.

The initial-fill simulation indicated that to fill the reservoir when hydraulic connection between the surface-water system and the aquifer is simulated would take 2 years more than if no connection were assumed. Simulated ground-water flow to the river downstream from the proposed dam was about 85 percent of the estimated maximum values, computed under steady-state conditions in an earlier study.

The general-operational simulation indicated that during the period of smallest reservoir contents the aquifer would provide about 80,000 acre-feet of recoverable storage to the reservoir. Average flow from the aquifer to the river downstream from the proposed dam would be only about 70 percent of the estimated maximum values computed in the earlier, steady-state analysis. Maximum monthly flow from the reservoir to the aquifer would be 55,200 acre-feet; maximum monthly flow from the aquifer to the reservoir would be 10,400 acre-feet.

Hydrologic characteristics tested for sensitivity, in order of decreasing sensitivity, were: Hydraulic conductivity, specific yield, hydraulic connection between reservoir and aquifer, local recharge, boundary conditions, and dam permeability. The probable error in the hydrologic characteristics tested does not warrant significant new data collection for most analytical purposes.

INTRODUCTION

The proposed Narrows Reservoir is a U.S. Water and Power Resources Service (formerly U.S. Bureau of Reclamation) project to create a multipurpose reservoir in the South Platte River basin. The Narrows Dam would be constructed at Narrows, west of Fort Morgan, Morgan County, Colo. (fig. 1). The reservoir would have a maximum capacity of 1,609,000 acre-ft and inundate a total of 40,813 acres, including pasture, river lowlands, and cropland. The capacity of the reservoir at the top of the joint-use stage would be 498,000 acre-ft. At the base of the dam, the reservoir level could be raised a maximum of 141.5 ft above the current river stage (U.S. Bureau of Reclamation, 1976).

The hydrologic system at this site, as in most of the South Platte River valley in Colorado, is a complex interaction between surface and ground water (Hurr and others, 1975). Water is diverted from the river for irrigation through ditches. Leakage from irrigation ditches and infiltration of water applied on irrigated lands recharges the ground-water system. The ground water then flows downgradient, eventually returning to the river. In some areas, recharge to ground water is exceeded by discharge from ground water by irrigation wells or evapotranspiration.

An earlier study of the proposed reservoir (Burns and Weeks, 1976) considered only the steady-state effects of the reservoir on the adjacent aquifer. That study estimated the maximum water-level changes within the aquifer and the largest flow from the aquifer to the river downstream from the proposed dam. That steady-state analysis did not identify the maximum ground-water inflow to or outflow from the reservoir nor the added storage effects of the aquifer on the reservoir.

PURPOSE AND SCOPE

The purpose of this study was to evaluate the transient interactions between the proposed reservoir and the adjacent aquifer. Specifically, the U.S. Water and Power Resources Service requested that the U.S. Geological Survey estimate flow to and from the proposed reservoir and changes in ground-water discharge to the river downstream from the proposed dam during transient conditions. Also, time estimates for the stream-aquifer system to adjust to the presence and operation of the proposed reservoir were to be made. Finally, the U.S. Geological Survey would provide estimates of the amount of additional storage contributed to the reservoir's capacity by the adjacent aquifer.

The scope of this study included the construction of a digital ground-water model linked to a reservoir-operations model. This combined model was used to consider three general physical and hydrologic conditions. The first condition was to simulate the hydrologic system without the proposed dam (prereservoir). This condition was needed to describe the existing hydrologic system and to provide a basis of comparison for the other conditions. The second condition simulated was with the proposed reservoir assumed to be in place and the hydrologic inflow and operating conditions of the reservoir as being monthly average values (initial fill). The third condition was to simulate stream-aquifer interactions based on 28 years of variable hydrologic inflow and reservoir operations (general operations). In addition to analyzing the above three conditions, a sensitivity analysis of many of the hydrologic characteristics was performed to evaluate possible data deficiencies in the study area.

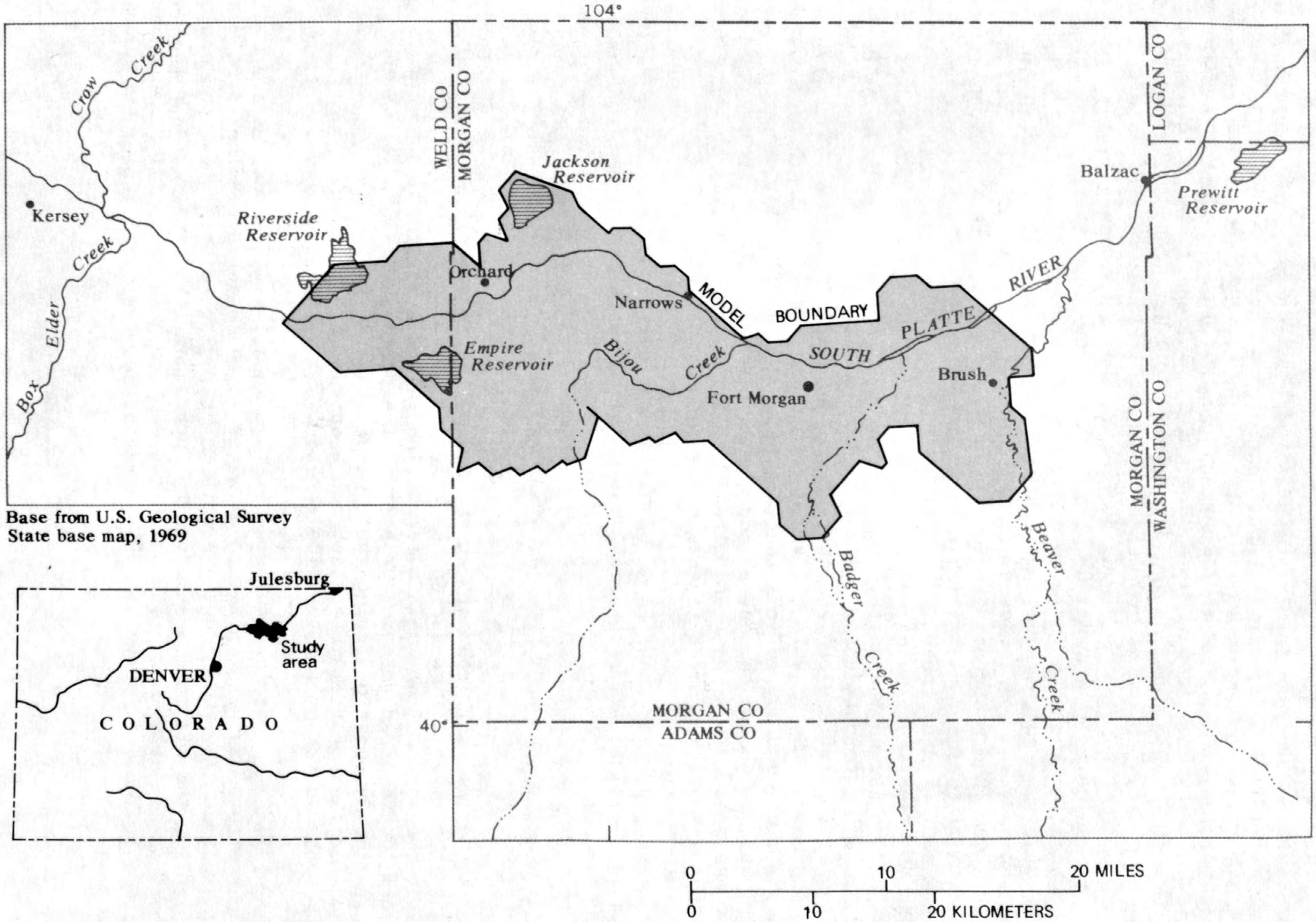

Figure 1.--Location of study area.

DESCRIPTION OF THE MODEL

The digital-computer model used in this study included a ground-water-flow component and a reservoir-operations component. The ground-water-flow component uses an iterative alternating-direction implicit finite-difference ground-water model (Trescott, 1973) modified from one used widely by the U.S. Geological Survey. The input data for the ground-water component included initial altitude of water table, aquifer specific yield, aquifer hydraulic conductivity, altitude of bedrock, altitude of land surface, net areal flux to the aquifer at the phreatic surface, hydraulic characteristics of the connection between the aquifer and the proposed reservoir, a potential evapotranspiration curve, and a definition of model boundaries. The model uses discrete points of data for computation; therefore a grid system was constructed to overlay maps of each of the above-mentioned data. The altitudes of water table and bedrock for this study were determined from reports published by the U.S. Geological Survey (Hurr and others, 1972a; 1972b), and modified slightly based on recent drilling by the U.S. Water and Power Resources Service (Newcomb Bennett, oral commun., 1977). The values of hydraulic conductivity were computed from transmissivity and saturated-thickness maps from the same reports. Altitude of land surface was determined from U.S. Geological Survey topographic maps. Values for specific yield, rate and depth of potential evapotranspiration, and hydraulic connection between aquifer and proposed reservoir were assumed based on general conditions for the South Platte River valley (Bjorklund and Brown, 1957; Hurr and others, 1975). Net areal flux to the aquifer was computed by two independent techniques discussed later.

The reservoir-operations component is a conservation of mass model designed to compute the stage in the reservoir. The model computes the volume in storage by the equation:

$$V_i = V_{i-1} + I_i + R_{i-1} - Q_i - E_i, \quad (1)$$

where

- V is the reservoir contents at the end of the time period;
- I is the river inflow during the time period;
- R is the inflow from the aquifer during the time period;
- Q is the required release during the time period;
- E is the evaporation during the time period and is a function of the average surface area; and
- i is the subscript for the time period i.

Given the volume in storage computed by this equation, the model uses a stage-capacity curve to compute the altitude of water in the reservoir. The input data necessary include river inflow, releases for senior water rights, and project releases. Also, the altitude-area-capacity curves and lake-evaporation rates were needed for the computation of reservoir stage and evaporation. All of these data were provided by the U.S. Water and Power Resources Service (Roger Weidelman, written commun., 1977).

The linkage between the ground-water and reservoir components is the flow of water between the aquifer and the proposed reservoir. The reservoir stage, as computed in the reservoir-operations component, is used as the hydraulic head controlling the flux between the reservoir and the ground-water system. Given this information and the hydraulic properties of the connecting layer, the ground-water-flow component computes the flow entering or leaving the aquifer using the Darcy equation:

$$q_c = A_c \cdot (k/m) \cdot (H_R - h_c), \tag{2}$$

where

q_c is the flow into the aquifer at node c;
A_c is the surface area of node c;
k/m is the leakance of the connecting layer;
H_R is the stage in the reservoir; and,
h_c is the hydraulic head in the aquifer at node c.

Simulated Prereservoir Conditions

Hydrologic conditions in the study area were simulated to provide a description of the existing hydrologic system and a basis for comparing changes resulting from the proposed reservoir. The initial step to model the area was to define all boundary fluxes, including the flux at the phreatic surface. From the previous steady-state analysis of this area (Burns and Weeks, 1976), it was known that the river should be considered a constant hydraulic-head boundary and that evapotranspiration from phreatophytes and the shallow water table should be simulated. In the steady-state analysis (Burns and Weeks, 1976), boundaries along the edge of the valley were modeled as constant hydraulic head, although adjusted to maintain constant fluxes when the effects of the reservoir reached the boundary. The transient analysis used constant-flux boundaries that were computed based on the same March 1968 water-table configuration as used for the steady-state analysis. They were computed in conjunction with the net areal flux.

The net areal flux at the phreatic surface is caused primarily by irrigation applications from surface-water diversions and ground-water pumpage. The net areal flux can be computed using application and pumpage data. Alternatively, the net areal flux can be computed if the water-table configuration is known. The accuracy of the water-table configuration is thought to be better than that for applications and pumpage. Therefore, the net areal flux used for the three simulated conditions was computed using the initial water-table configuration. This initial water-table configuration is based on the March 1968 water levels and appears to be a satisfactory starting point due to the absence of long-term trends in water levels for this area. This value was computed at each grid point by computing a mass balance of flow to and from the neighboring points. If the mass balance is not zero, then the flux necessary to balance the equation is the flux to or from the phreatic surface.

Using the computed net areal flux as input data, the model was used to estimate the steady-state, net ground-water flow to the river upstream and downstream from the proposed dam. The water table computed by the model is shown in figure 2. Ground-water discharge to the river was computed to be 162 ft^3/s upstream from the proposed dam and 65.3 ft^3/s downstream from the proposed dam in the modeled area. Simulated evapotranspiration losses totaled 86.1 ft^3/s for the modeled area. The inflow to the system, 313 ft^3/s, is made up of cross-boundary flow and net areal flux that cannot be identified separately. Because a more refined grid system was used for the transient analysis, the area modeled during the steady-state analysis is different from that used for the transient analysis, and regional inflows and outflows are not the same.

Simulated Initial-Fill Conditions

To simulate the system with the proposed reservoir, the input data were changed to add an impermeable strip to represent the dam in the aquifer. Inflows and releases from the reservoir also were added to the input data. This phase of the study was to consider: (1) The time required to fill the reservoir to the joint-use stage (498,000 acre-ft) under normal conditions assuming hydraulic connection with the aquifer, and (2) the time required before the effects of the reservoir on the aquifer would reach equilibrium. The inflow and release data used were the 12 monthly averages from the U.S. Water and Power Resources Service operations study (table 1) (Roger Weidelman, written commun., 1977). These data were continually cycled through the model for several years to simulate the response of the aquifer system to these reservoir stresses.

For comparison purposes, the reservoir component was simulated first with no hydraulic connection to the aquifer. That is, the reservoir model was run separate from the ground-water model. This simulation corresponds to typical surface-water operational models. With the average inflows and demands (table 1), the reservoir would first fill during May of the 5th year (month 53) when simulated with no hydraulic connection to the aquifer (fig. 3). The reservoir also would reach a cyclic condition (that is, the reservoir contents and other reservoir responses cycled repeatedly thereafter) at the same time (table 2).

The effects of the hydraulic connection between the reservoir and aquifer increase the time required for filling the reservoir and the time until cyclic conditions occur between the aquifer and reservoir. When modeling with hydraulic connection between the surface-water system and aquifer, the reservoir would first fill (fig. 4) during May of the 7th year (month 77). The total system would not reach a cyclic condition, however, until after 15 years of operation. This would be the time required for the flow from the reservoir to the aquifer to balance with the flow from the aquifer to the river downstream from the proposed dam and the change in evapotranspiration, on a yearly basis (table 3).

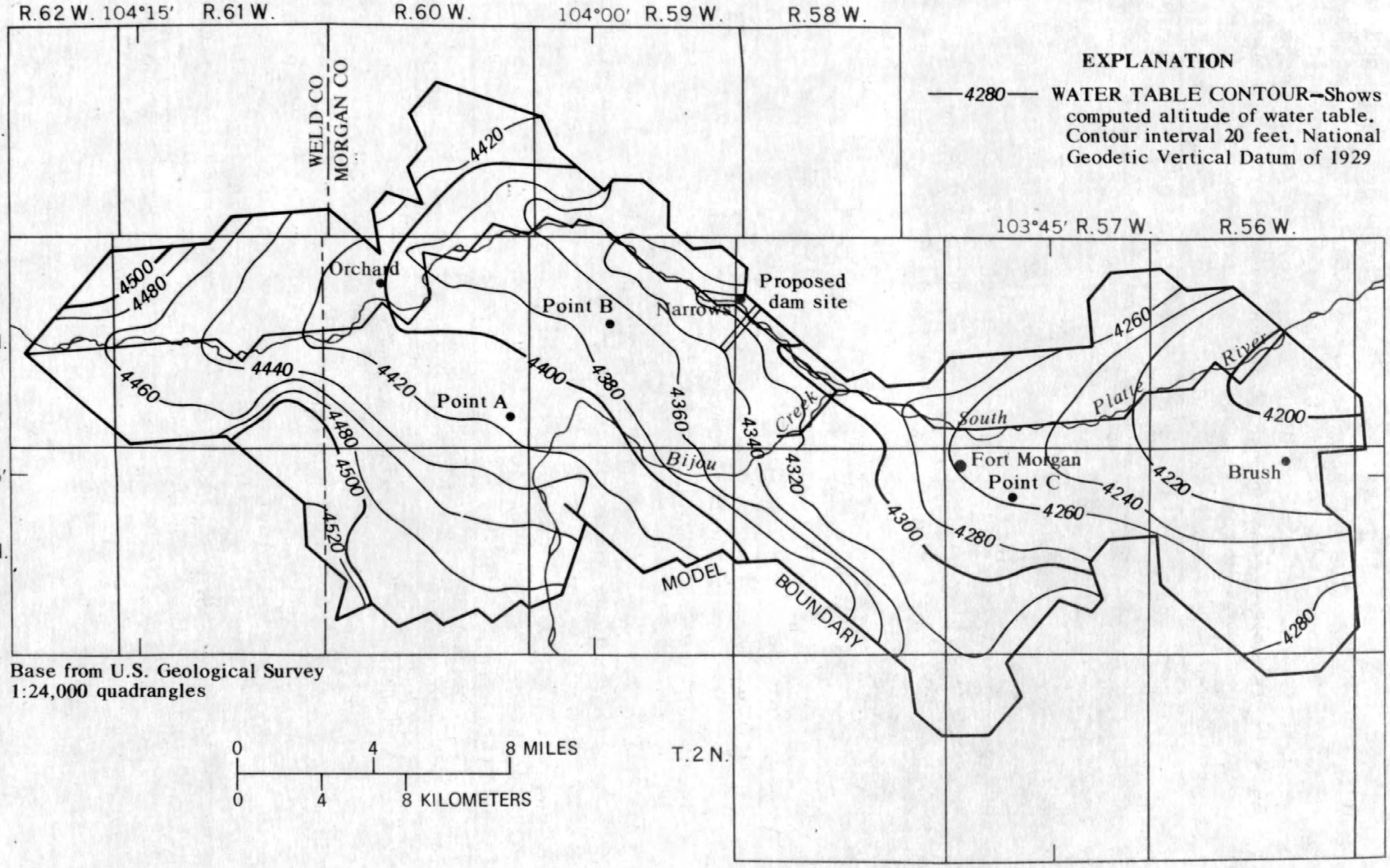

Figure 2. -- Water table computed by the model for prereservoir conditions.

Table 1.--*Monthly average inflow and release data for the proposed Narrows Reservoir*

[In thousands of acre-feet]

Month	Inflow	Required releases	Project releases
January	30.5	11.1	0
February	27.7	8.2	0
March	32.4	10.2	0
April	34.2	12.4	9.4
May	78.7	34.3	4.7
June	112.2	42.5	19.6
July	39.4	33.6	27.4
August	30.5	34.7	19.0
September	30.1	29.1	9.4
October	23.8	21.2	12.5
November	30.5	12.5	0
December	26.8	9.9	0

Table 2.--*Cyclic reservoir stresses with no hydraulic connection to the aquifer*

[In thousands of acre-feet]

Month	End-of-month contents	Inflow	Releases	Spills	Reservoir evaporation
January	463	31	11	0	2
February	481	28	8	0	2
March	498	32	10	2	3
April	498	34	22	7	5
May	498	79	39	33	7
June	498	112	62	42	8
July	468	39	61	0	8
August	439	31	54	0	6
September	426	30	38	0	5
October	413	24	34	0	3
November	429	30	13	0	1
December	445	27	10	0	1

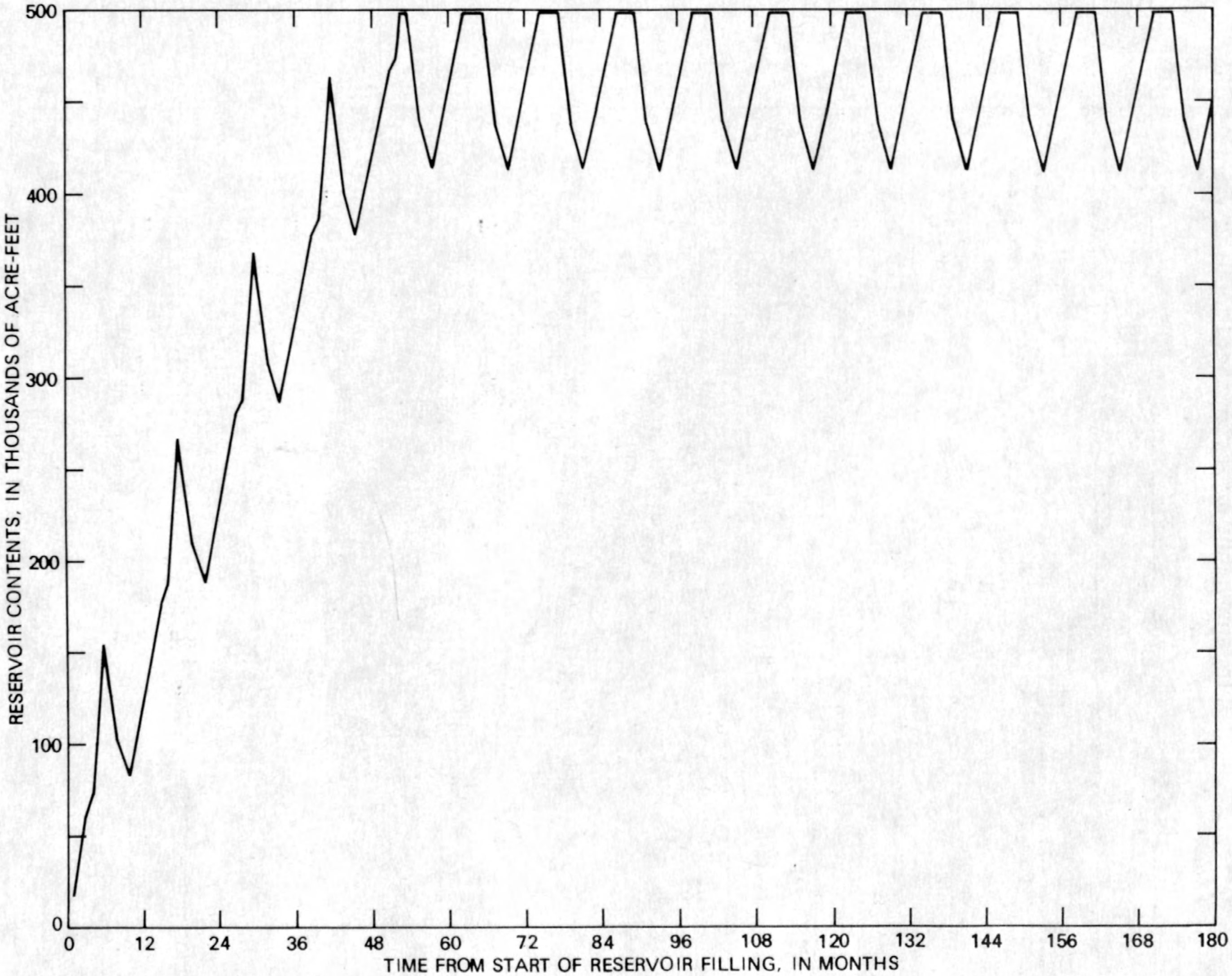

Figure 3. -- Simulated monthly contents of the proposed Narrows Reservoir with average stresses and no hydraulic connection to the aquifer.

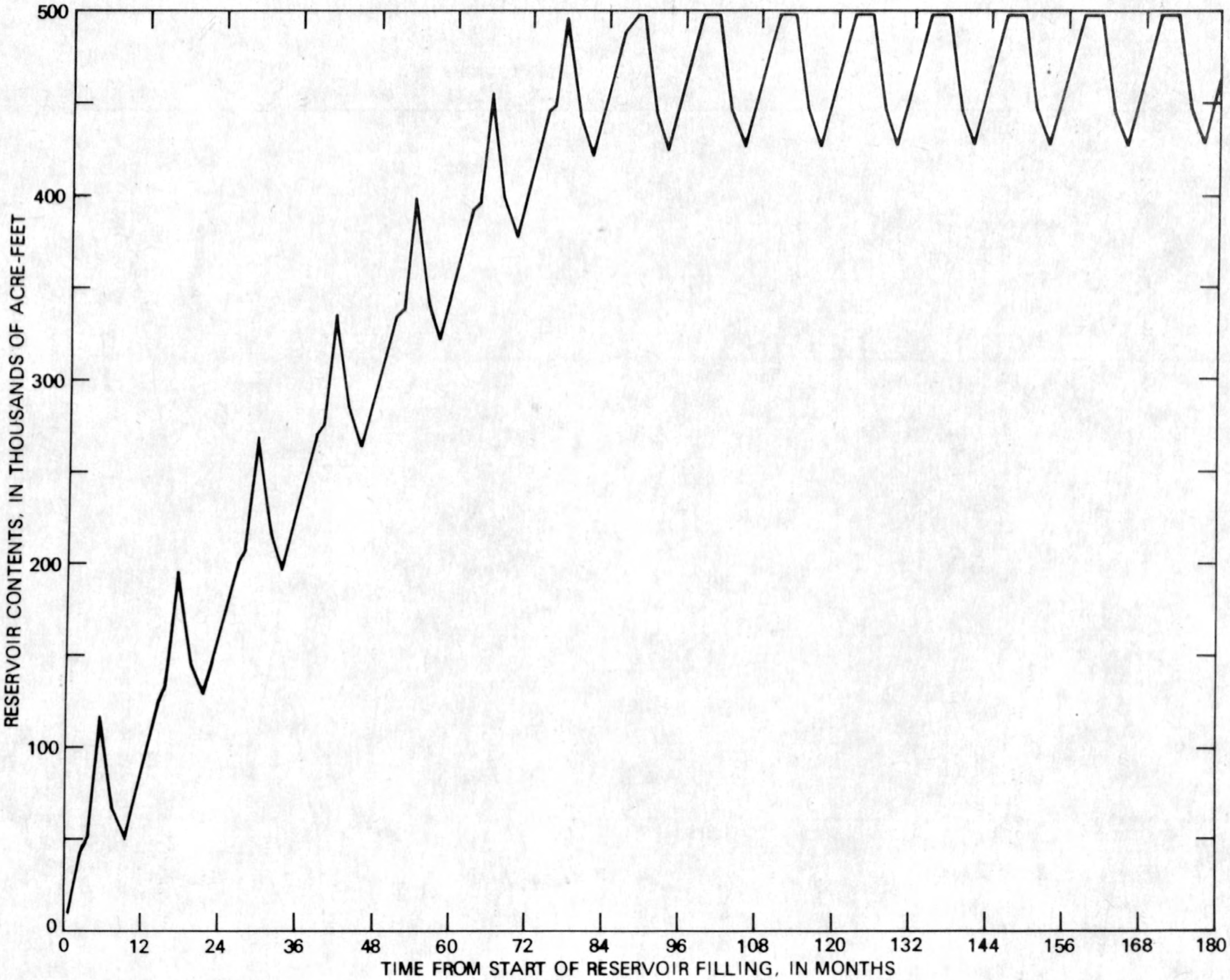

Figure 4. -- Simulated monthly contents of the proposed Narrows Reservoir with average stresses and hydraulic connection to the aquifer.

Table 3.--*Cyclic reservoir stresses after 15 years of average inflow and releases*

[In thousands of acre-feet]

Month	End-of-month contents	Surface-water inflow	Change in flow from the aquifer to the reservoir	Releases[1]	Change in flow from aquifer to river downstream from proposed dam	Spills	Reservoir evaporation	Ground-water evapotranspiration
January----	472	31	-4.8	10	1.2	0	2	5.2
February---	486	28	-5.1	7	1.2	0	2	5.3
March------	498	32	-5.5	9	1.2	2	3	5.3
April------	498	34	-2.8	21	1.2	5	5	5.3
May--------	498	79	-2.4	38	1.2	32	7	5.4
June-------	498	112	-2.2	61	1.2	41	8	5.4
July-------	472	39	2.5	60	1.2	0	8	5.3
August-----	448	31	4.7	53	1.2	0	6	5.3
September--	439	30	3.1	37	1.2	0	5	5.2
October----	430	24	2.1	33	1.2	0	3	5.7
November---	445	30	-2.5	12	1.2	0	1	5.1
December---	457	27	-4.0	9	1.2	0	2	5.2
Totals----------------------			-16.9		14.4		52	63.7

[1]Releases have been reduced to take credit for the flow to the river downstream from the proposed dam caused by the reservoir.

A mass balance indicates the simulation with hydraulic connection between the surface-water system and the aquifer would be almost cyclic after 15 years. The simulation also indicated that annual flow from the reservoir to the aquifer would be 16,900 acre-ft while flow from the aquifer to the river downstream from the proposed dam would be 14,400 acre-ft. Additional evapotranspiration and change in the amount of water stored in the aquifer account for the 2,500-acre-ft difference. The prereservoir analysis simulated ground-water evapotranspiration losses of 86.1 ft^3/s or 62,400 acre-ft/yr. Annual ground-water evapotranspiration for this simulation would be 63,700 acre-ft, an increase of 1,300 acre-ft annually. Reservoir evaporation for the simulated conditions without hydraulic connection between the surface-water system and the aquifer totaled 51,000 acre-ft; the simulation with hydraulic connection indicated 52,000 acre-ft for evaporation.

Comparing the data in tables 2 and 3, the recoverable storage effects of the aquifer can be identified. The minimum reservoir content of 413,000 acre-ft would occur during October when simulated without hydraulic connection to the aquifer. With hydraulic connection, the minimum reservoir content simulated would occur during the same month but would be 430,000 acre-ft. Thus, an additional 17,000 acre-ft of water would be stored in the reservoir due to: (1) Reduced releases because of credits for downstream flow from the aquifer to the river, and (2) water that had flowed to the aquifer from the reservoir during higher stages which then would flow back into the reservoir at lower stages.

The cyclic results of this transient analysis with average inflow and release data compare favorably to results previously published (Burns and Weeks, 1976). Annual flow from the reservoir to the aquifer would total 16,900 acre-ft/yr and flow from the aquifer to the river downstream from the proposed dam would total 14,400 acre-ft/yr. The previous steady-state results (Burns and Weeks, 1976) computed 17,400 acre-ft/yr with the reservoir maintained at a stage of 4,404 ft for both of those values with no change in evapotranspiration. For this transient simulation, the reservoir stage fluctuated between 4,399 and 4,404 ft. The flow from the aquifer to the river downstream from the proposed dam would remain steady at 1,200 acre-ft/mo which is about 80 percent of the maximum rate predicted in the previous steady-state analysis. Maximum flow from the reservoir to the aquifer would be 5,500 acre-ft/mo; maximum flow from the aquifer to the reservoir would be 4,700 acre-ft/mo. Three representative, but randomly chosen, points were selected to illustrate water-level changes throughout the study area. Because different grid systems were used for the transient modeling and the previous steady-state modeling and because the net areal flux was simulated differently, direct comparison of water levels is not possible. By averaging the increase in water levels at certain nodes computed during the steady-state analysis, it was estimated that the modeled increase in water level at point A (see fig. 2 for location) would be 90 percent of the predicted steady-state maximum; at point B 90 percent of the predicted maximum; and at point C only 50 percent of the predicted maximum.

Simulated General-Operational Conditions

The simulation analysis for the general operations was quite similar to that for the initial-fill conditions. Rather than using average monthly inflows and releases, monthly flows and releases from a 28-year (1947-74) operations study conducted by the U.S. Water and Power Resources Service (Roger Weidelman, written commun., 1977) were used. The reservoir was assumed to be empty at the beginning of the simulation and the response of the reservoir by modeling without the ground-water component was first tested (see table 10, Supplemental Information). By comparing these results (fig. 5) with those simulated with the aquifer connected to the surface-water system (see table 11, Supplemental Information), the added storage benefits contributed by the aquifer are quite apparent. Under both instances, the reservoir would have been filled during June 1949 (month 30) due to a very large inflow. However, the volume of water stored in the aquifer would have increased almost 200,000 acre-ft during those first 30 months assuming hydraulic connection between the surface-water system and aquifer. Evidence of the amount of water entering aquifer storage is demonstrated by the spill that would have occurred from the reservoir the first month the reservoir filled. During the simulation without hydraulic connection to the aquifer, 219,000 acre-ft would have spilled. During the simulation with hydraulic connection to the aquifer, only 48,000 acre-ft would have spilled.

Simulated recoverable aquifer storage would have been more than 80,000 acre-ft. The recoverable volume from aquifer storage is illustrated in figure 5 by the low-flow period from 1953 through 1956 (months 73 to 120). When modeling without hydraulic connection to the aquifer, the reservoir contents would have been 12,000 acre-ft during October 1954 (month 94), 15,000 acre-ft during September and October 1955 (months 105 and 106), and 8,000 acre-ft during September and October 1956 (months 117 and 118). However, the reservoir contents during those same periods simulated with hydraulic connection to the aquifer would have been 93,000, 98,000, and 91,000 acre-ft.

The general-operations simulation also was used to compare the hydrologic responses of the idealized steady-state conditions with the hydrologic responses of the more probable transient-operational conditions. The simulated monthly flow from the aquifer to the river downstream from the proposed dam for the 28-year operatons study is shown in figure 6. Transient flow would have equaled the cyclic flow of 1,200 acre-ft/mo (see table 3) only during 5 months of the high-flow period of 1969 thrugh 1974 (months 277 to 330) when the reservoir would have remained nearly full.

Flow from the reservoir to the aquifer would have varied considerably from month to month even for the cyclic conditions. To compare the operational conditions to the cyclic conditions, the annual flow for the operations study is shown in figure 7. These values are compared to the cyclic annual value of 16,900 acre-ft. Monthly cyclic values would range from 5,500 to -4,700 acre-ft (see table 3). Extreme monthly values, based on the general-operations analysis, would have been 55,200 acre-ft during June of 1949 (month 30) when the stage of the reservoir would have risen 21 ft, and -10,400 acre-ft during June of 1954 (month 90) when the stage of the reservoir would have declined 8 ft.

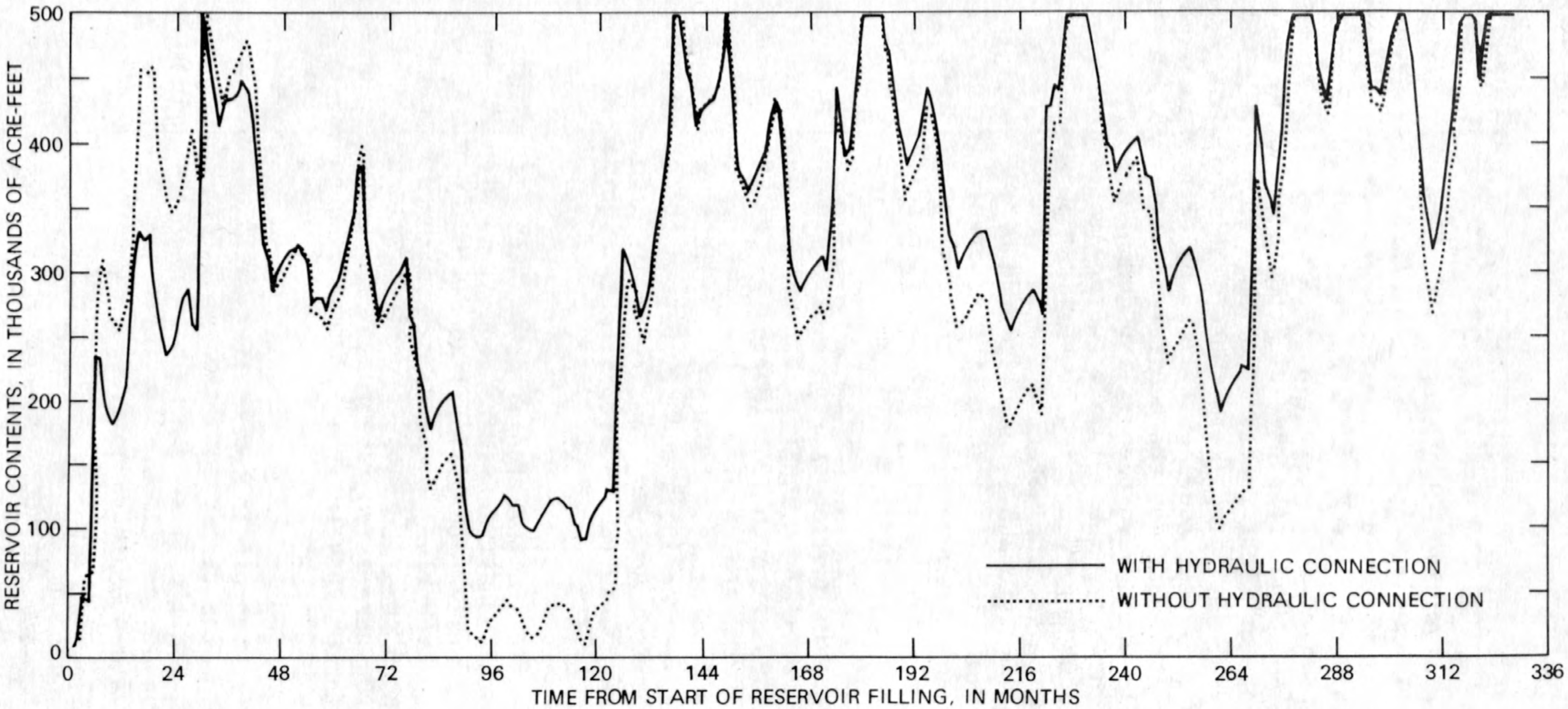

Figure 5. -- Simulated monthly contents of the proposed Narrows Reservoir using 28-year operations-study data, with and without hydraulic connection to the aquifer.

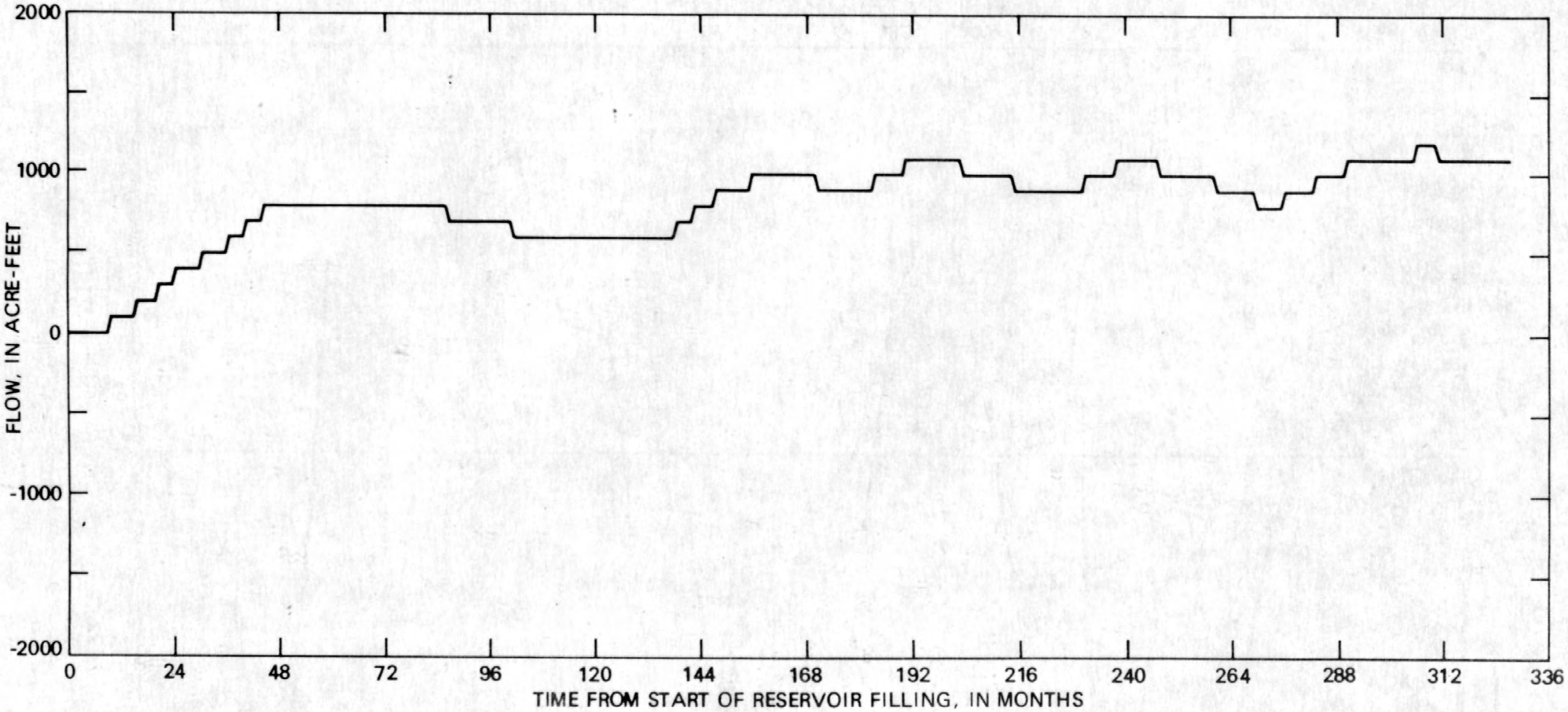

Figure 6. -- Simulated monthly flow from the aquifer to the river downstream from the proposed dam using 28-year operations-study data.

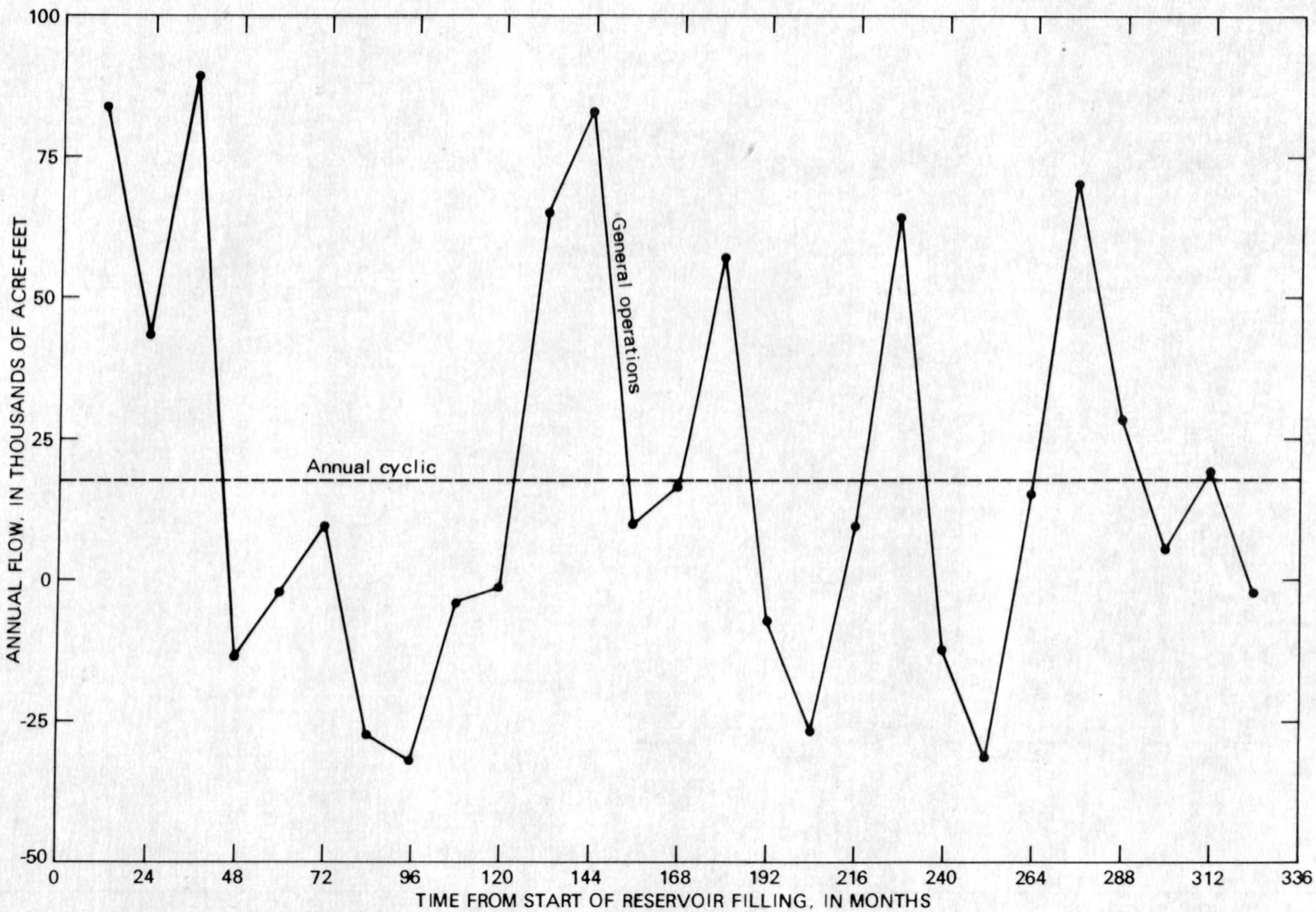

Figure 7. --Simulated annual flow from the reservoir to the aquifer using the 28-year operations-study data.

SENSITIVITY ANALYSIS

Estimates of flow between the reservoir and aquifer, flow from the aquifer to the river downstream from the proposed dam, water-level changes, and recoverable storage effects of the aquifer were discussed in the previous sections. Of additional interest is the accuracy of these estimates relative to the possible errors in the data input. A sensitivity analysis of certain hydrologic characteristics was performed to provide information as to whether additional data collection would be beneficial in refining the above-mentioned estimates.

The input data that could be in error, and that were tested for sensitivity, are: specific yield, hydraulic connection between reservoir and aquifer, dam permeability, aquifer hydraulic conductivity, hydraulic-head values along the boundaries and local-recharge conditions. For each of these hydrologic characteristics, the minimum and maximum probable values were chosen. This range of values represents a subjective attempt to define the minimum and maximum values that could be expected to occur. For example, the specific yield for this area is generally considered to be 0.20. However, it is possible that the real value could be as large as 0.25 or as small as 0.10; thus, those were the extremes tested during the sensitivity analysis. Similar determinations of extremes for each hydrologic characteristic were made based on an evaluation of possible errors for that hydrologic characteristic.

Two simulations were made for each extreme--a prereservoir simulation and a modified initial-fill simulation. The modified initial-fill simulation included 10 years of reservoir operation with monthly average inflows and releases and then an instantaneous emptying of the reservoir. The simulation was continued for 5 additional years to monitor the aquifer's response to emptying the reservoir. The baseline-sensitivity simulation (used for comparisons to all extreme simulations) had one other significant difference from the previous simulations. Because the U.S. Water and Power Resources Service was interested in the accuracy of the data for surface-water applications and ground-water pumpage, the net areal flux was based on this data rather than being computed from the water table.

A detailed discussion of the sensitivity-baseline simulation and all the extreme value simulations can be found in the Supplemental Information. None of the hydrologic characteristics tested appears to cause differences significant enough to justify extensive additional data collection. Variations of the hydraulic conductivity resulted in the greatest ranges in flow from the reservoir to the aquifer and flow from the aquifer to the river downstream from the proposed dam. However, those two components tend to balance one another relative to reservoir operation and aquifer storage so that net differences are small. The estimated recoverable storage is the most affected estimate, ranging from an increase of 13 percent to a decrease of 33 percent. Greatest water-level differences also result from the extreme hydraulic-conductivity values, but these differences are only 12 ft lower or 6 ft higher. Such differences are rather insignificant considering that the water-level data were obtained from a map with a 10-ft contour interval. Variations of the specific yield caused noticeable differences in the change of ground water in storage but caused little difference in water levels.

This storage effect resulted in a 2-year difference in time required to fill the reservoir. Reducing the hydraulic connection between the reservoir and the aquifer has surprisingly small effects. Even if the reservoir were effectively sealed off from the aquifer, ground-water flow to the river upstream from the reservoir and flow to the river downstream from the proposed dam would not change appreciably from the baseline-sensitivity simulation. The major change would be the month-to-month fluctuation of ground-water flow to the reservoir that would be severely reduced.

Extreme-value simulations for the initial boundary hydraulic heads and for the recharge of the net areal flux were different for the prereservoir simulations but had little impact on the reservoir-aquifer interactions. Changes in both caused differences in the average hydraulic-head values, the seasonal fluctuations of hydraulic heads, flow to the river downstream from the proposed dam, and flow to the reservoir from the aquifer. Changing the dam from an impermeable strip to a potentially leaky dam had no effect on simulation results.

CONCLUSIONS

The complex interactions between the surface- and ground-water systems of the South Platte River valley in the vicinity of the proposed Narrows Reservoir have been modeled. The model, which combines a ground-water-flow component and a mass-balance reservoir-operations component, was able to simulate transient ground-water responses to a proposed operating reservoir.

The initial-fill simulation used average hydrologic inflow data with predicted average reservoir releases to determine the effects of the reservoir's hydraulic connection with the aquifer. With these average conditions, the reservoir would be filled after 65 months without hydraulic connection to the aquifer compared to 89 months with hydraulic connection. The aquifer system would almost attain an equilibrium response to the repeated cyclic stresses on the reservoir after 15 years of operation. Total annual flow from the aquifer to the river downstream from the proposed dam would be 14,400 acre-ft compared to the maximum value of 17,400 acre-ft computed in the earlier steady-state study (Burns and Weeks, 1976). Even with the small reservoir-stage fluctuations--from 4,399 to 4,404 ft--within each year, the aquifer would contribute 17,000 acre-ft of reserve storage to the reservoir.

The general-operational simulation used 28 years of variable monthly inflows and reservoir releases. Because of the large monthly inflow that would have occurred during June 1949 (the 30th month simulated), hydraulic connection between the surface-water system and aquifer would have caused no delay in the time required to fill the reservoir. Recoverable volumes of aquifer storage would have added more than 80,000 acre-ft of capacity to the reservoir. Flow to the river downstream from the proposed dam would have been always less than the maximum predicted rates and normally would have been only about 70 percent of the maximum. Maximum monthly rates of flow from the reservoir to the aquifer would have been 55,200 acre-ft; the maximum monthly flow from the aquifer to the reservoir would have been 10,400 acre-ft.

The sensitivity of these simulated results to possible errors in the hydrologic-aquifer characteristics data was tested. Simulated reservoir responses were most sensitive to changes in specific yield and hydraulic conductivity, and to a lesser degree to changes in hydraulic connection between reservoir and aquifer. Less sensitivity was recorded for changes in net areal flux and boundary conditions. Modeling results were insensitive to variations of the dam permeability.

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SUPPLEMENTAL INFORMATION

SENSITIVITY ANALYSIS

An important phase of this study was to evaluate the effects of possible errors in input data on simulated results. To accomplish this, a sensitivity analysis was performed on the following data: Specific yield, hydrologic connection between reservoir and aquifer, dam permeability, aquifer hydraulic conductivity, hydraulic-head values along the boundaries, and local recharge conditions.

A prereservoir condition and modified initial-fill condition were simulated for each of the data tested. An initial set of data similar to that used for the previous simulations was created with only two changes. First, the model was run for only 10 years of reservoir inflows and releases. After 10 years, the hydrologic system would be nearing cyclic conditions and additional years of simulation would add little new information. Then the reservoir was assumed to empty instantaneously and the response of the aquifer to the empty reservoir was simulated for another 5 years. This choice of periods was arbitrary; allowing the reservoir to empty was done only to see the sensitivity effects during more than just stable conditions, without the costly longer time frame used in the general-operational simulations.

The second modification from previous data input was the computation of net areal flux. As discussed earlier, the net areal flux was computed using the historic water table. Of interest to the U.S. Water and Power Resources Service (Richard Ribbens, written commun., 1976) because of questions relating to total water management, however, is the accuracy of surface-water applications and pumpage data. Thus, the net areal flux was computed independently of the water table by considering the areal distribution of surface-water applications and ground-water pumpage in the area. From unpublished data for irrigated acreage, surface-water diversions, individual well pumpage (R. T. Hurr and A. W. Burns, U.S. Geological Survey, written commun., 1978), and precipitation data, the average annual net applications were computed for each node in the model grid system. The net areal flux was computed for each node, assuming that 30 percent of the applied water recharges the aquifer. The value of 30 percent is the average value computed from a model study of the South Platte River basin (R. T. Hurr and A. W. Burns, written commun., 1978). Although the value varies seasonally and annually, depending on the actual applications, using the average with average applications and pumpage should give good results. The change in water table between that computed for steady state using this input data and the historic water table is shown in figure 8. The sum of the net areal flux plus the boundary inflow was about 410 ft^3/s using this technique as compared to 310 ft^3/s using the computation with the water-table configuration. The data in figure 8 illustrates that this difference of recharge does not greatly affect the regional ground-water system.

The application of irrigation water on agricultural lands does not occur at a steady rate throughout the year. Therefore, the net areal flux is not constant throughout the year. A constant net areal flux was used for all previous simulations because the flux was derived from water-level data for which there was no monthly information. For this analysis, however, the net areal flux was assumed to follow the same monthly distribution as the potential evapotranspiration curve computed for this area (Hurr and others, 1975). The variations in monthly net areal flux caused monthly changes throughout the hydrologic system, as shown for the initial simulation under prereservoir conditions (table 4).

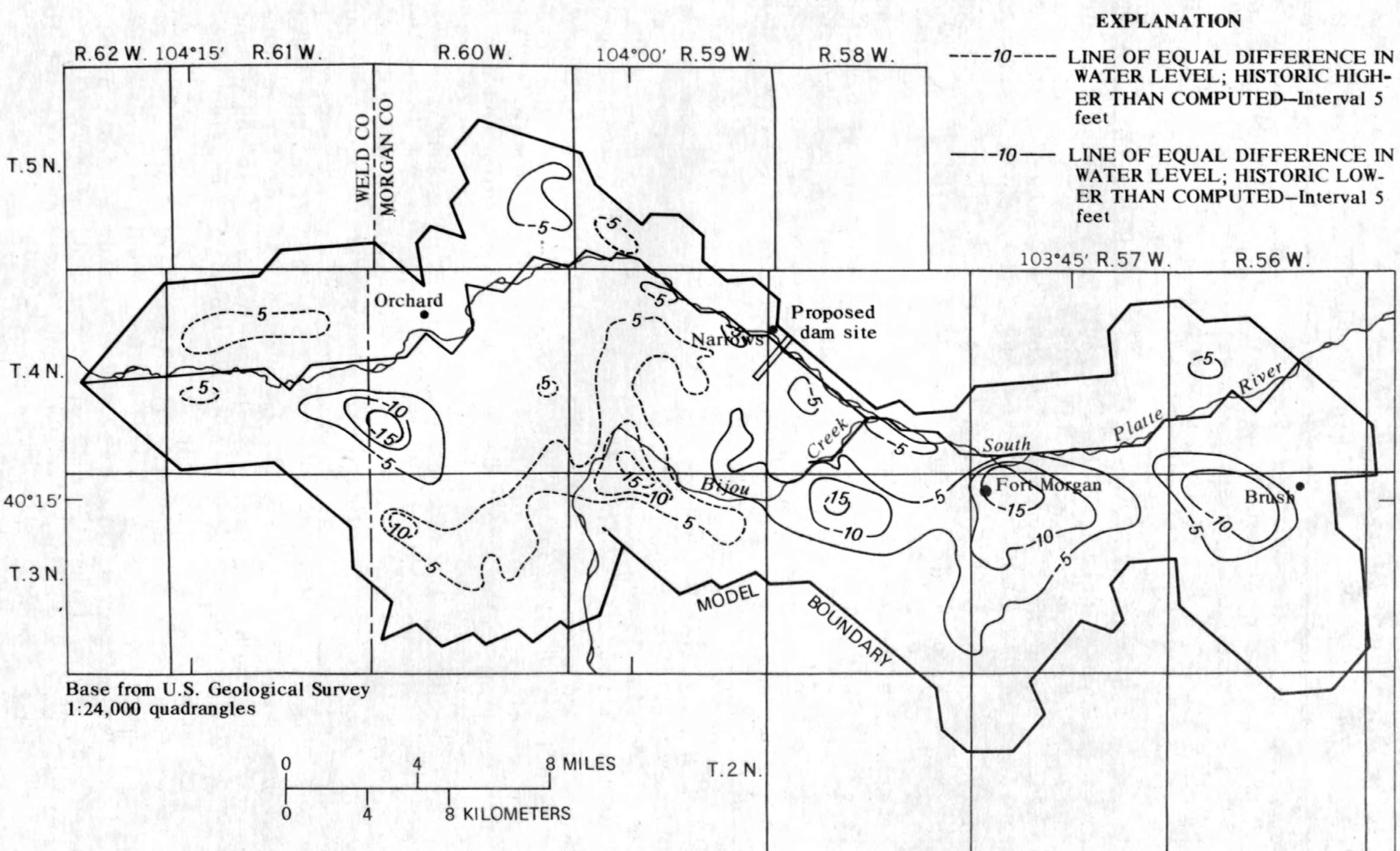


Figure 8. -- Difference in water table between that computed using agricultural applications and that based on historic data.

Table 4.--*Monthly hydrologic responses to monthly changes of net areal flux for the baseline-sensitivity simulation under prereservoir conditions*

Month	Percent of annual potential evapotran- spiration	Water level at point A[1] (feet)	Water level at point B[1] (feet)	Water level at point C[1] (feet)	Change in flow from aquifer to river from average conditions (acre-feet)	
					Upstream from pro- posed dam	Downstream from pro- posed dam
January----	0	4,409.0	4,366.8	4,269.8	-200	-100
February---	.1	4,409.4	4,366.5	4,269.5	-400	-100
March------	.2	4,409.8	4,366.2	4,269.2	-400	-200
April------	2.6	4,410.0	4,366.1	4,269.0	-500	-300
May--------	10.3	4,409.6	4,366.4	4,269.4	-400	-300
June-------	19.9	4,408.6	4,367.0	4,270.2	-100	-100
July-------	27.3	4,407.2	4,367.9	4,271.4	200	0
August-----	23.1	4,406.4	4,368.3	4,272.0	600	400
September--	13.5	4,406.4	4,368.4	4,272.0	700	500
October----	2.8	4,407.2	4,367.9	4,271.4	500	500
November---	.2	4,407.9	4,367.5	4,270.8	100	300
December---	0	4,408.5	4,367.1	4,270.3	-100	100

[1]See figure 2 for location.

The contents of the proposed reservoir under the initial-fill conditions used for the baseline-sensitivity simulation are shown in figure 9. The reservoir contents were almost identical to those of the initial-fill simulation (fig. 4). The flow from the aquifer to the river downstream from the proposed dam varied within the annual cycle, but followed the same trend as the initial-fill simulation (fig. 10). The trend of the flow changes when the proposed reservoir was emptied (month 120), but there were no abrupt changes. The flow from the reservoir to the aquifer responded rapidly to the empty reservoir, however (fig. 11). About 65,000 acre-ft flowed from the aquifer into the reservoir reach during the first 4 months that the reservoir was empty. The cumulative change in aquifer storage (defined as the amount of flow entering the aquifer from the reservoir less the flow leaving the aquifer downstream from the proposed dam) reached a maximum of 290,000 acre-ft during the 10-year filling period and was 80,000 acre-ft at the end of the simulation, 5 years after the reservoir emptied (fig. 12). Maximum water level at point A (see fig. 2 for location) was 4,422.7 ft, a rise of 12.7 ft, and the water level at the end of the simulation was 4,413.3 ft. Maximum water level at point B was 4,407.0 ft, a rise of 38.6 ft, and the water level at the end of the simulation was 4,370.2 ft. Maximum water level at point C was 4,271.9 ft, a rise of 0.2 ft, and the water level at the end of simulation was 4,270.2 ft. Those maximum rises compare to the steady-state estimates of 16.8 ft for point A, 41.3 ft for point B, and 0.6 ft for point C.

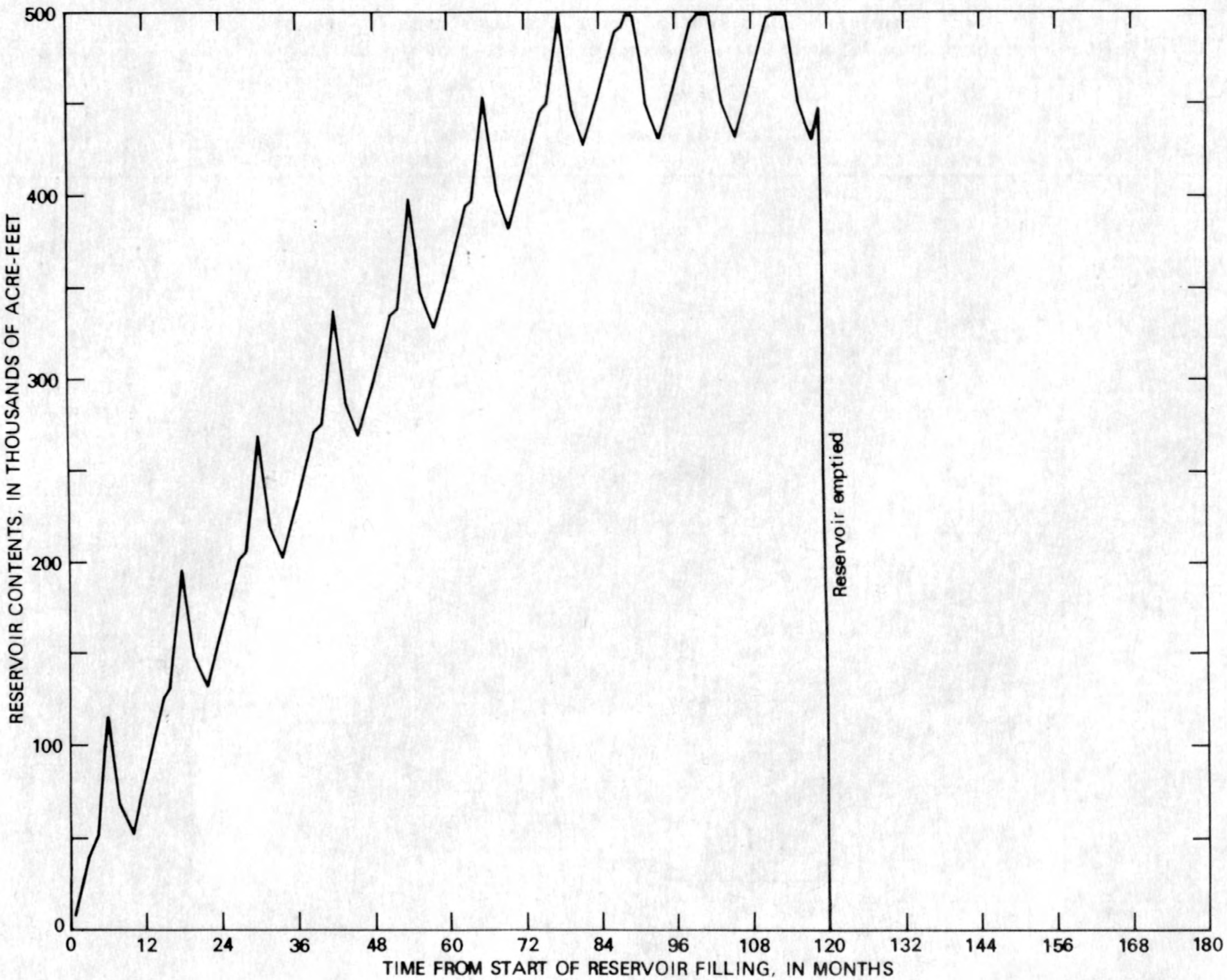


Figure 9. -- Monthly contents of the proposed Narrows Reservoir used for the baseline-sensitivity simulation.

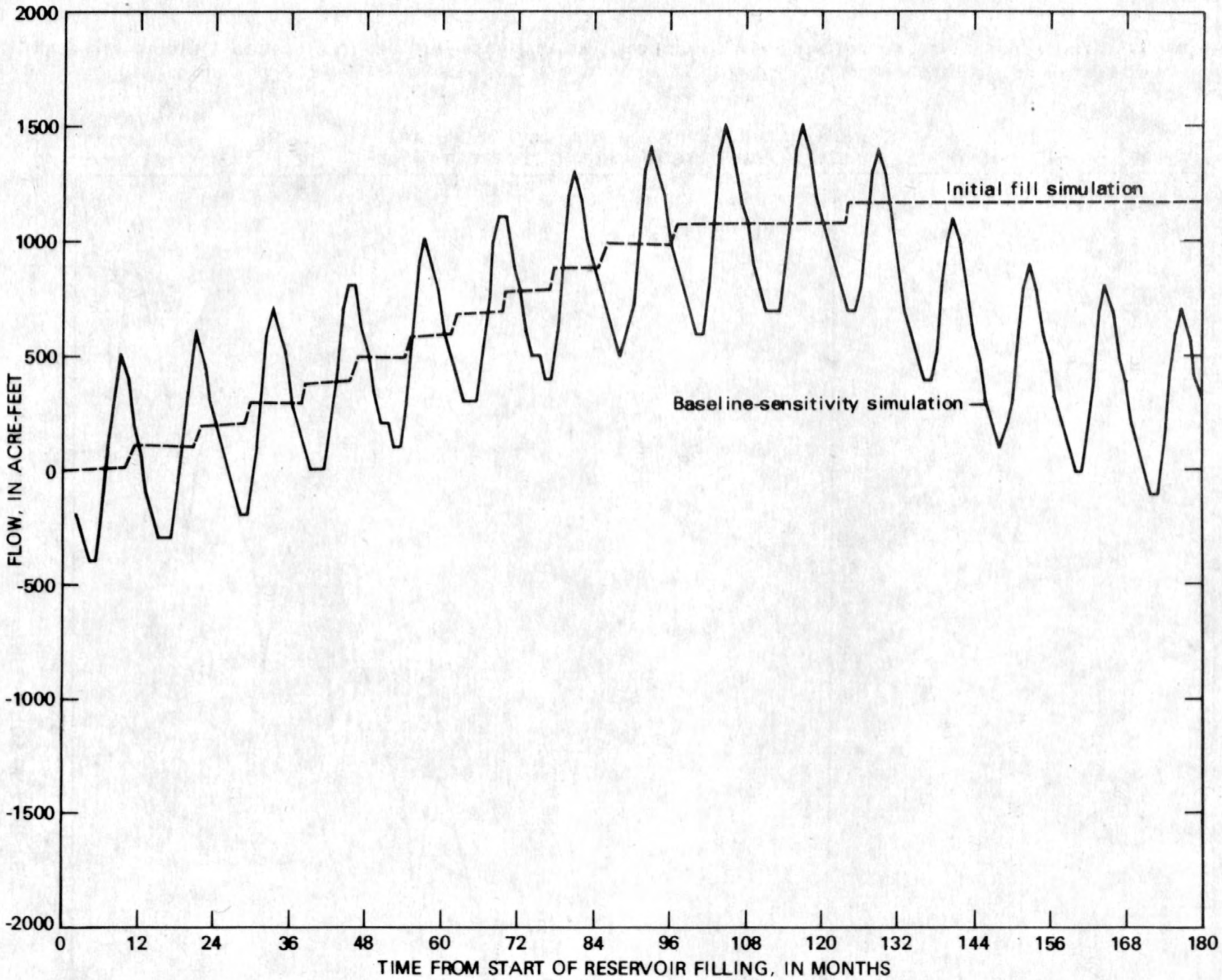


Figure 10. --Monthly flow from the aquifer to the river downstream from the proposed dam used for the initial-fill simulation and baseline-sensitivity simulation.

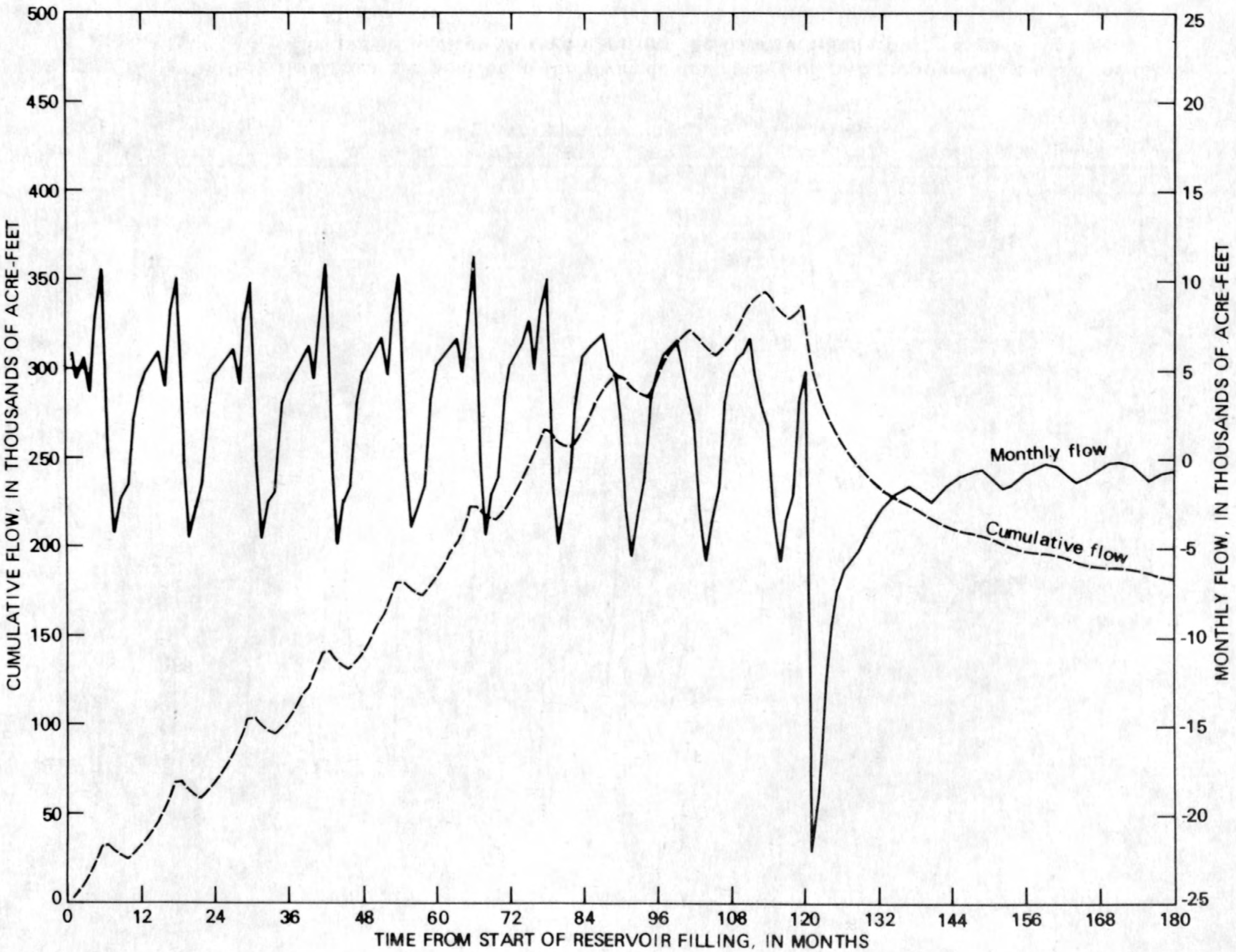


Figure 11. -- **Flow from the reservoir to the aquifer used for the baseline-sensitivity simulation.**

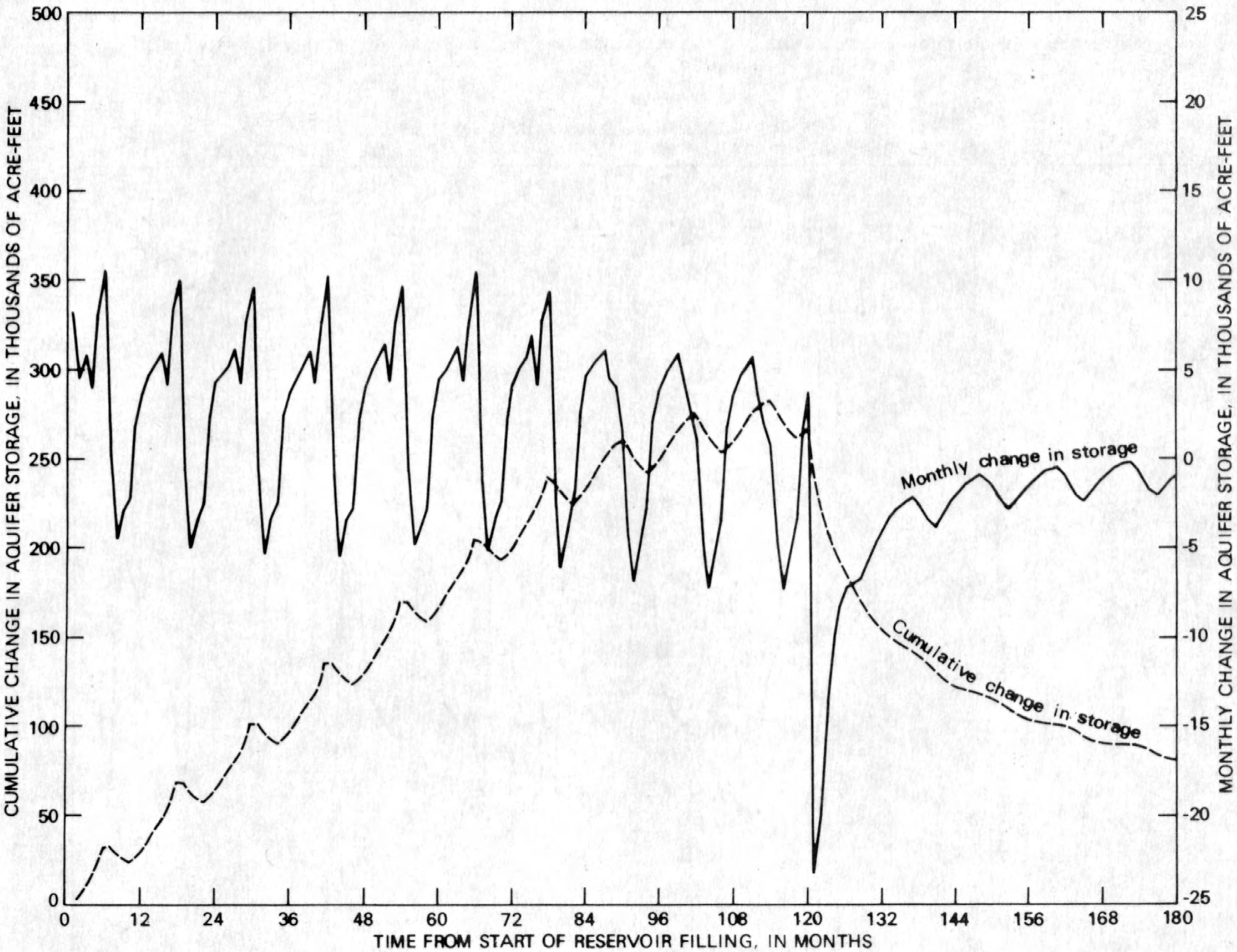


Figure 12. -- Change in aquifer storage used for the baseline-sensitivity simulation.

Specific Yield

For the initial-fill, general-operations, and sensitivity-baseline simulations, a specific yield of 0.20 was used. This value was reported by both Hurr (Hurr and others, 1975) and Bjorklund (Bjorklund and Brown, 1957). A range of the probable value is from 0.10 to 0.25. Two additional hydrologic settings were simulated identical to the sensitivity-baseline conditions, except that one assumed a specific yield of 0.25 and the other assumed a value of 0.10.

The simulation using the specific yield of 0.25 decreased the cyclic fluctuations of water levels, flow to the river upstream from the proposed dam, and flow to the river downstream from the proposed dam by about 17 percent (fig. 13) for prereservoir conditions. Increases in the cyclic fluctuations were about 64 percent when a specific yield of 0.10 was used in the model.

Three simulations were made for different specific-yield values using the modified initial-fill conditions. The effects of those different specific-yield values on reservoir contents are shown in figure 14. A specific yield of 0.25 resulted in the proposed reservoir requiring an additional year to be filled because the aquifer is capable of storing more water. Alternatively, less water can be stored in the aquifer with a specific yield of 0.10, and the reservoir was first filled 1 year earlier than for the sensitivity-baseline simulation. The trends in flow from the aquifer to the river downstream from the proposed dam were similar for all three simulations, with the magnitudes of the within-year fluctuations varying about as for prereservoir conditions. Flow from the reservoir to the aquifer varied considerably for the three specific-yield values (table 5).

Maximum cumulative flow simulated with a specific yield of 0.25 exceeded that simulated with a value of 0.10 by 70 percent. When the reservoir first emptied, the aquifer released more water from storage with a larger specific yield. This is evidenced by the 70-percent larger loss during the first 4 months after the reservoir was emptied. The cumulative change in aquifer storage for the three specific-yield values (fig. 15) reflected these differences in flow from the aquifer to the reservoir. A specific yield of 0.25 caused a final simulated increase in aquifer storage of about 40 percent more than the baseline simulation. A specific yield of 0.10 generated a final change in storage of about 60 percent less than for the baseline simulation. Water levels were similar for each of the three simulations.

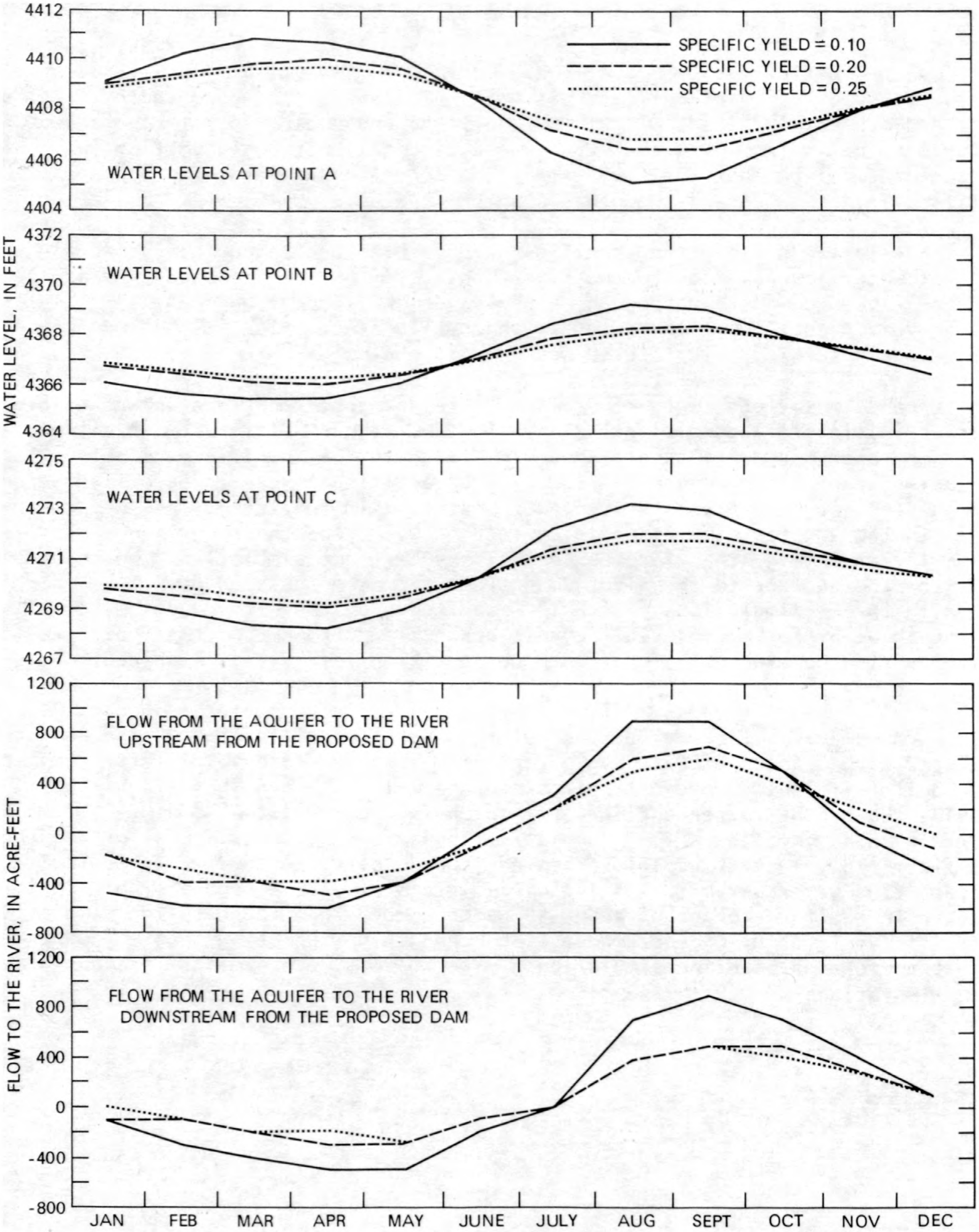


Figure 13. -- Monthly hydrologic responses under prereservoir conditions for three assumed values of specific yield.

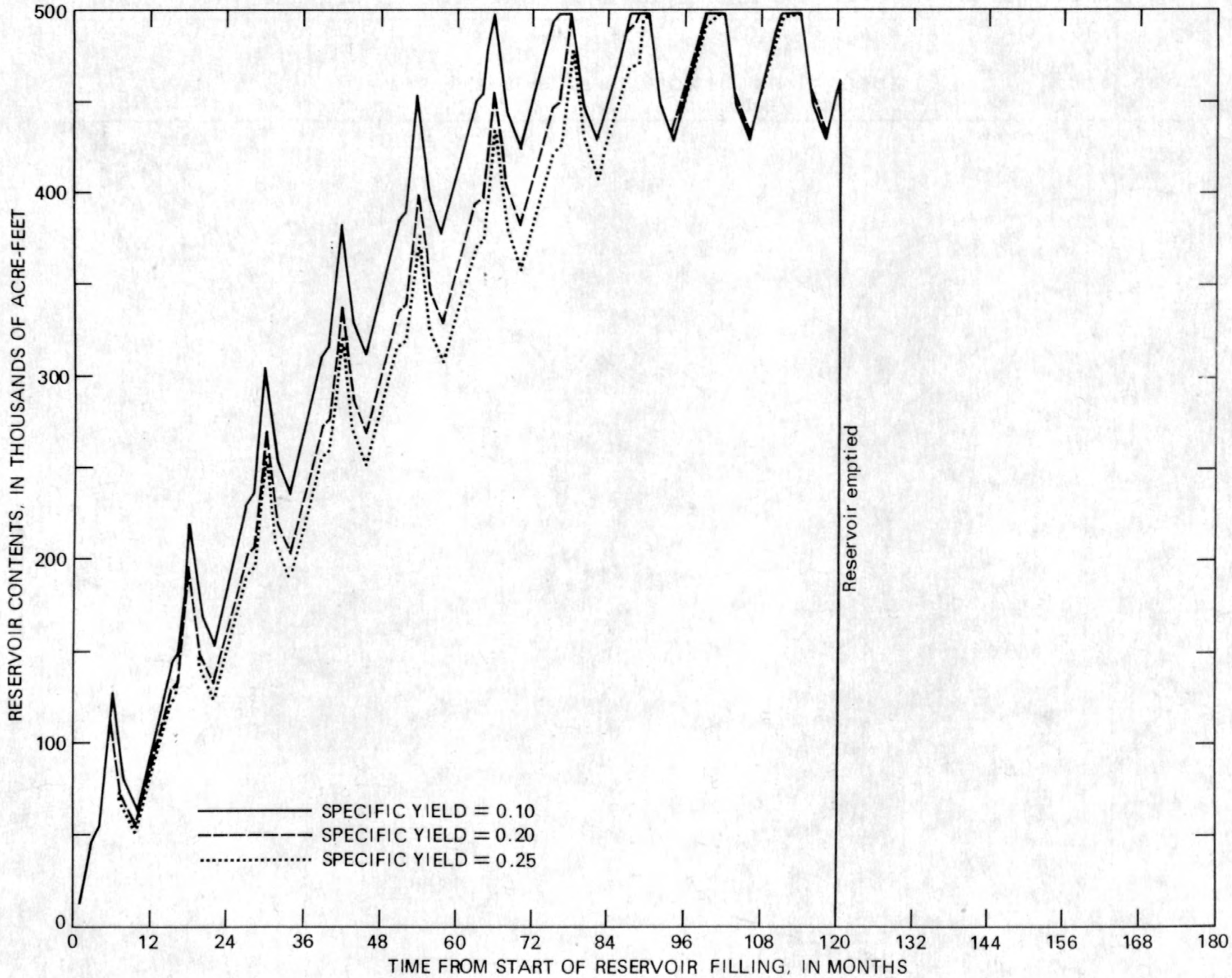


Figure 14.--Monthly contents of the proposed Narrows Reservoir for three assumed values of specific yield.

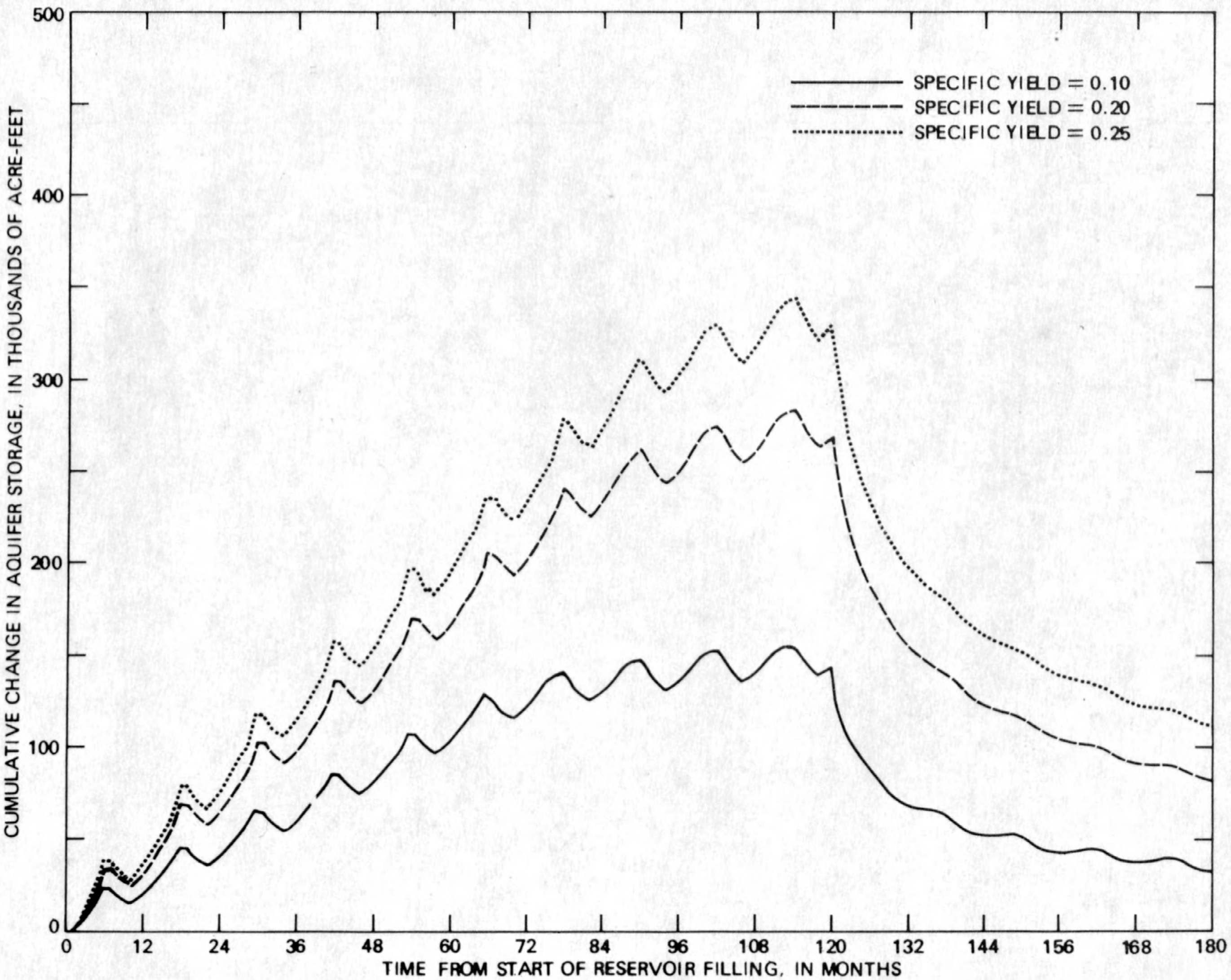


Figure 15. -- Cumulative change in aquifer storage for three assumed values of specific yield.

Table 5.--*Hydrologic responses to three assumed values of specific yield*

Simulated interaction	Hydrologic responses at specific-yield values of		
	0.10	0.20	0.25
Maximum cumulative flow from reservoir to aquifer, in acre-feet----------------	230,000	350,000	390,000
Maximum cumulative change in aquifer storage, in acre-feet-------------------	150,000	290,000	350,000
Final cumulative change in aquifer storage, in acre-feet-------------------	30,000	80,000	110,000
Maximum water level at point A, in feet---	4,426.2	4,422.7	4,420.8
Final water level at point A, in feet-----	4,411.5	4,413.3	4,414.0
Maximum water level at point B, in feet---	4,408.8	4,407.3	4,406.1
Final water level at point B, in feet-----	4,367.6	4,370.2	4,371.1

Hydraulic Connection between Reservoir and Aquifer

The effects of the proposed reservoir on the adjacent aquifer were modeled by considering the bottom and sides of the reservoir to be a leaky confining layer. The difference in hydraulic head between the reservoir and aquifer and the leakance (the vertical hydraulic conductivity divided by the thickness) of this confining layer control the flux through this layer. The determination of leakance is difficult even under ideal hydrologic settings. Thus, estimates for a proposed reservoir can vary considerably. The value of leakance used for the initial-fill, general-operations, and baseline-sensitivity simulations was set equal to the hydraulic conductivity of the aquifer at each node. This was considered a reasonable estimate considering the relatively large permeability of the aquifer throughout the vertical section. Original sensitivity estimates reduced leakance by 10^{-2} and 10^{-4}. However, these reductions did not measurably affect modeling results. Therefore, the final sensitivity analysis was made using leakance values reduced by 10^{-6} and 10^{-10}.

Two additional modified initial-fill simulations were made to test the effects of changes in leakance. The smaller leakance values caused the interaction between reservoir and aquifer to decrease and the annual cyclic benefits from aquifer storage were lost. However, the time required to fill the reservoir did not change. There was little change in flow to the river from the aquifer downstream from the proposed dam using the different leakance simulations. Flow decreased just slightly with the decrease of leakance values. However, flow from the reservoir to the aquifer changed significantly among the different simulations. For the baseline simulation, monthly flow from the reservoir to the aquifer ranged from 11,000 to -5,700 acre-ft during the reservoir-filling period. For the model simulation with leakance reduced by 10^{-6}, the fluctuation was reduced to between 4,700 and 1,700 acre-ft. Until the reservoir emptied, the flow occurred only from the reservoir to the aquifer. The fluctuations were reduced further when simulating with leakance reduced by 10^{-10}. The range of monthly flow to the aquifer from the reservoir was from 4,200 to 2,600 acre-ft until the reservoir emptied. The simulations with leakance reduced 10^{-10} indicate that the reservoir was virtually sealed off from the aquifer. This simulation differed from the previously discussed no-hydraulic-connection simulations where both the river and reservoir were unconnected from the aquifer in that only the reservoir was sealed off during this simulation. The sum of these monthly flows is shown in figure 16. Note the change in the trend of each line at about month 84, when the reservoir filled. The apparent increase in flow to the aquifer from the reservoir for the smaller leakance values was caused by increased impedance of flow that normally would be entering the river in the reservoir reach. The cumulative change in aquifer storage reflects the differences in the ground-water outflow results. Final cumulative change in aquifer storage was 80,000 acre-ft for baseline sensitivity, 130,000 acre-ft for leakance reduced by 10^{-6}, and 150,000 acre-ft for leakance reduced by 10^{-10}. Hydraulic heads in the aquifer tended to be lower when simulated with a smaller leakance until the reservoir first filled (fig. 17). Then the hydraulic heads simulated with the smaller leakance became higher, with the reservoir acting as an impermeable boundary with the smallest leakance values.

Dam Permeability

For the initial-fill, general-operations, and baseline-sensitivity simulations, the proposed dam was modeled as an impermeable barrier. This is a reasonable assumption because much of the proposed dam foundation will be in contact with the Cretaceous Pierre Shale, which is the bedrock boundary for the alluvial aquifer. Where the foundation will not reach the shale, a slurry trench is planned. The modeled dam extended south only as far as the proposed slurry trench would be in contact with the shale. The sensitivity of the regional ground-water-flow system was tested to observe the effects if the dam were not totally impermeable. Two simulations were made by assigning hydraulic-conductivity values of 0.001 and 0.1 ft/d to the proposed dam. Neither of these simulations showed any differences from the baseline conditions. For the purpose of sensitivity, assumed hydraulic-conductivity values of 1 and 10 ft/d were simulated. It is realized that these values represent hydraulic properties more typically related to poor aquifers than to proposed dams (Todd, 1959). These values compare to the range of hydraulic conductivities in the modeled area of about 100 to about 2,000 ft/d.

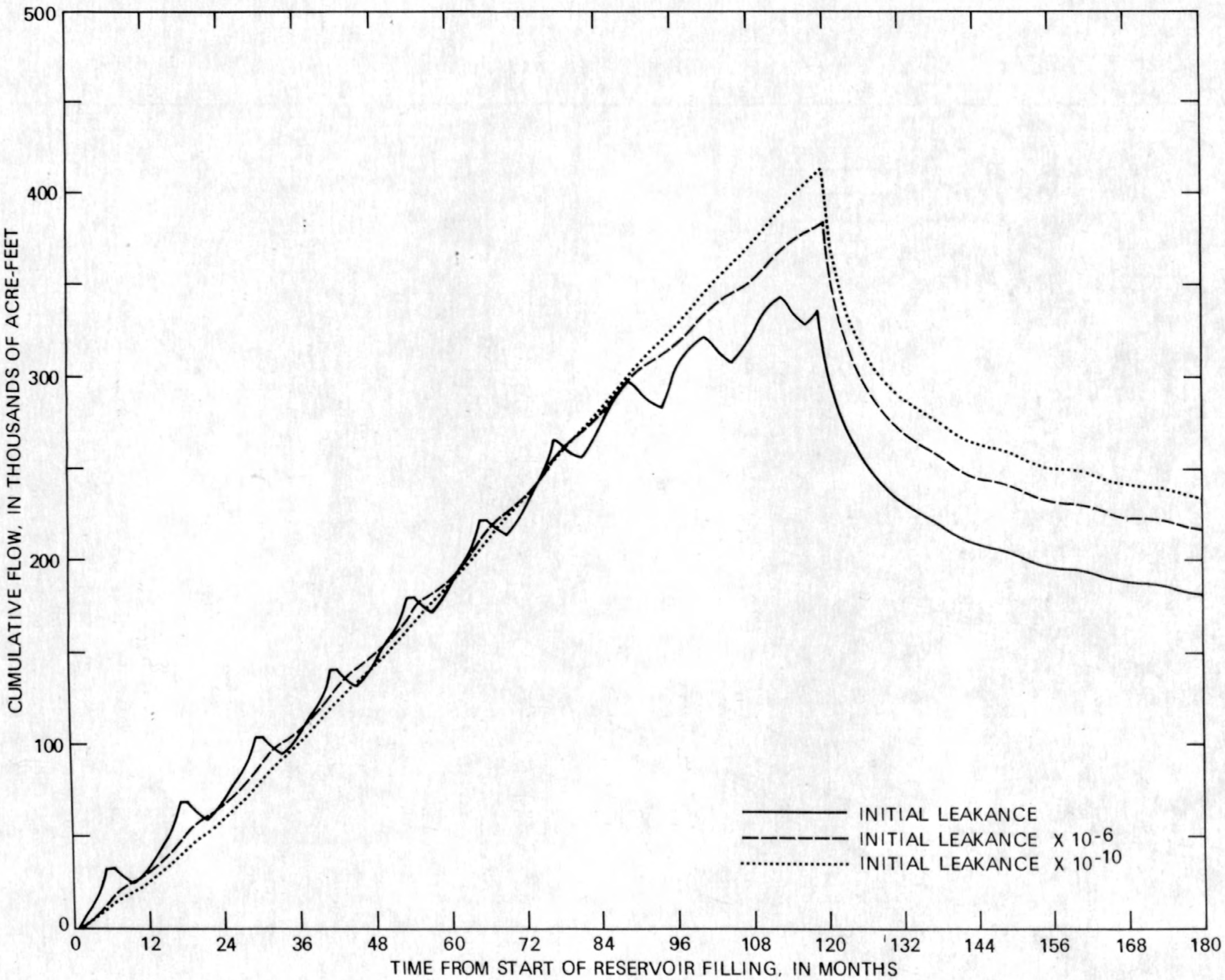


Figure 16. -- Cumulative flow from the reservoir to the aquifer for three assumed leakance values.

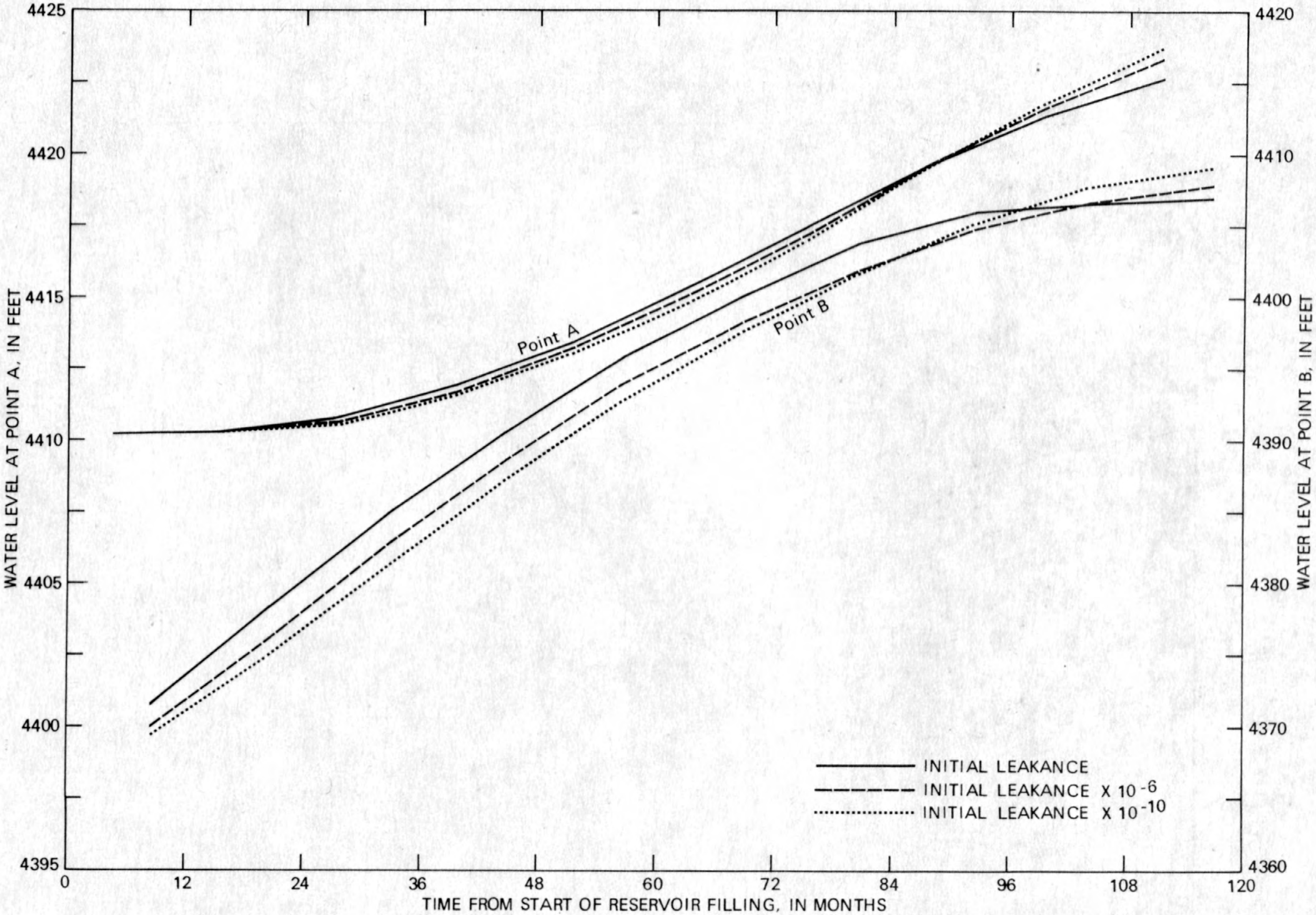


Figure 17. -- Water levels for three assumed leakance values.

The effects of assigning a hydraulic conductivity of 10 ft/d to the proposed dam were minor. Reservoir contents and change in aquifer storage changed negligibly from the baseline-sensitivity simulation. The small increase in flow from aquifer to the river downstream from the proposed dam was approximately balanced by the increase in flow from the reservoir to the aquifer. The maximum monthly flow downstream from the proposed dam for the baseline-sensitivity simulation was 1,500 acre-ft which occurred in 2 separate months. Similar flows occurred during the 1-ft/d simulation, but there were 6 months of 1,500 acre-ft flow and 3 months of 1,600 acre-ft flow modeled with a dam permeability of 10 ft/d. Water levels at points A, B, and C did not change for any of the simulations. The maximum water level at the first node of the aquifer at the south end of the proposed dam rose 0.1 ft for the 1-ft/d simulation and 0.4 ft for the 10-ft/d simulation from the baseline water levels. Water levels within the dam were the major differences in the simulation results. For the baseline simulation, the initial water level of 4,306.0 ft could not change as water levels in the reservoir rose because the proposed dam was impermeable. When assuming a permeability of 1 ft/d, the water level rose to 4,329.7 ft directly above the river. A maximum level of 4,356.9 ft was modeled for a hydraulic conductivity value of 10 ft/d. These water levels were caused by an average stage in the reservoir of about 4,400 ft.

Aquifer Hydraulic Conductivity

The transmissivity of the modeled alluvium was determined from maps by Hurr and others (1972a; 1972b). Values computed from additional data collected by the U.S. Water and Power Resources Service (Newcomb Bennett, oral commun., 1977) corresponded with those maps. Under water-table conditions, transmissivity is a function of both the permeability characteristics of the aquifer material and the saturated thickness. Because the presence of the proposed reservoir would affect the saturated thickness, transmissivity could not be used directly in the model. Hydraulic conductivity was computed at each node of the modeled area by dividing the transmissivity by the saturated thickness in that area. That computed value of hydraulic conductivity was assumed to be representative of the entire column of aquifer material from bedrock to land surface. Probable values for hydraulic conductivity could range from one-half to twice the input values due to possible errors in the transmissivity and saturated-thickness maps or the assumption of uniform hydraulic conductivity throughout the column. Two additional hydrologic settings were simulated identical to the baseline-sensitivity conditions, except that one simulation assumed all hydraulic-conductivity values were halved and the other assumed all values were doubled.

The effects of different hydraulic-conductivity values on simulated prereservoir conditions were distinct (fig. 18). Doubling the values of hydraulic conductivity increased the simulated cyclic fluctuations of flow to and from the aquifer by about 50 percent but reduced the water-level fluctuations about 20 percent. Halving the values of hydraulic conductivity decreased the simulated cyclic fluctuations of flow by about 40 percent but increased water-level fluctuations about 10 percent.

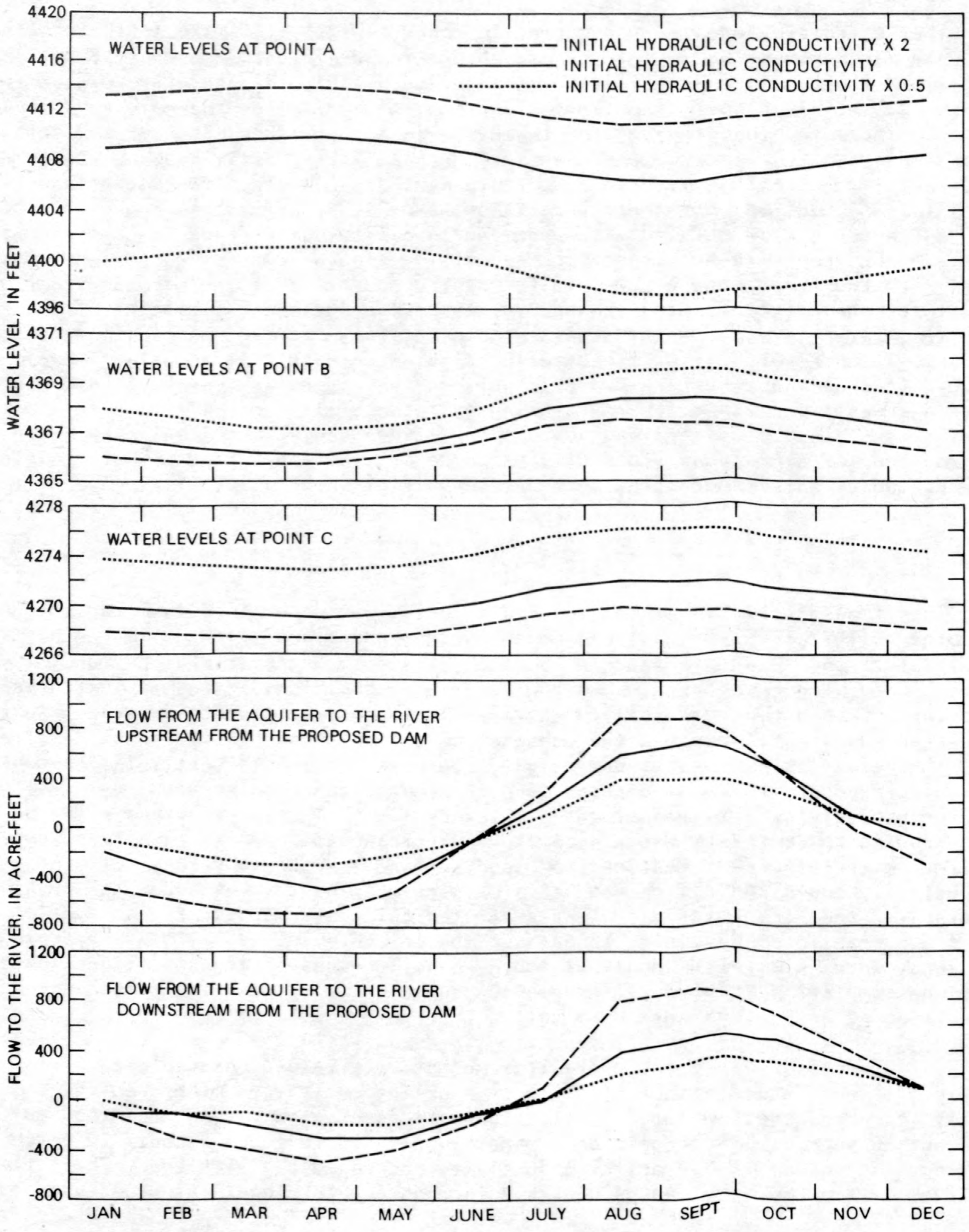


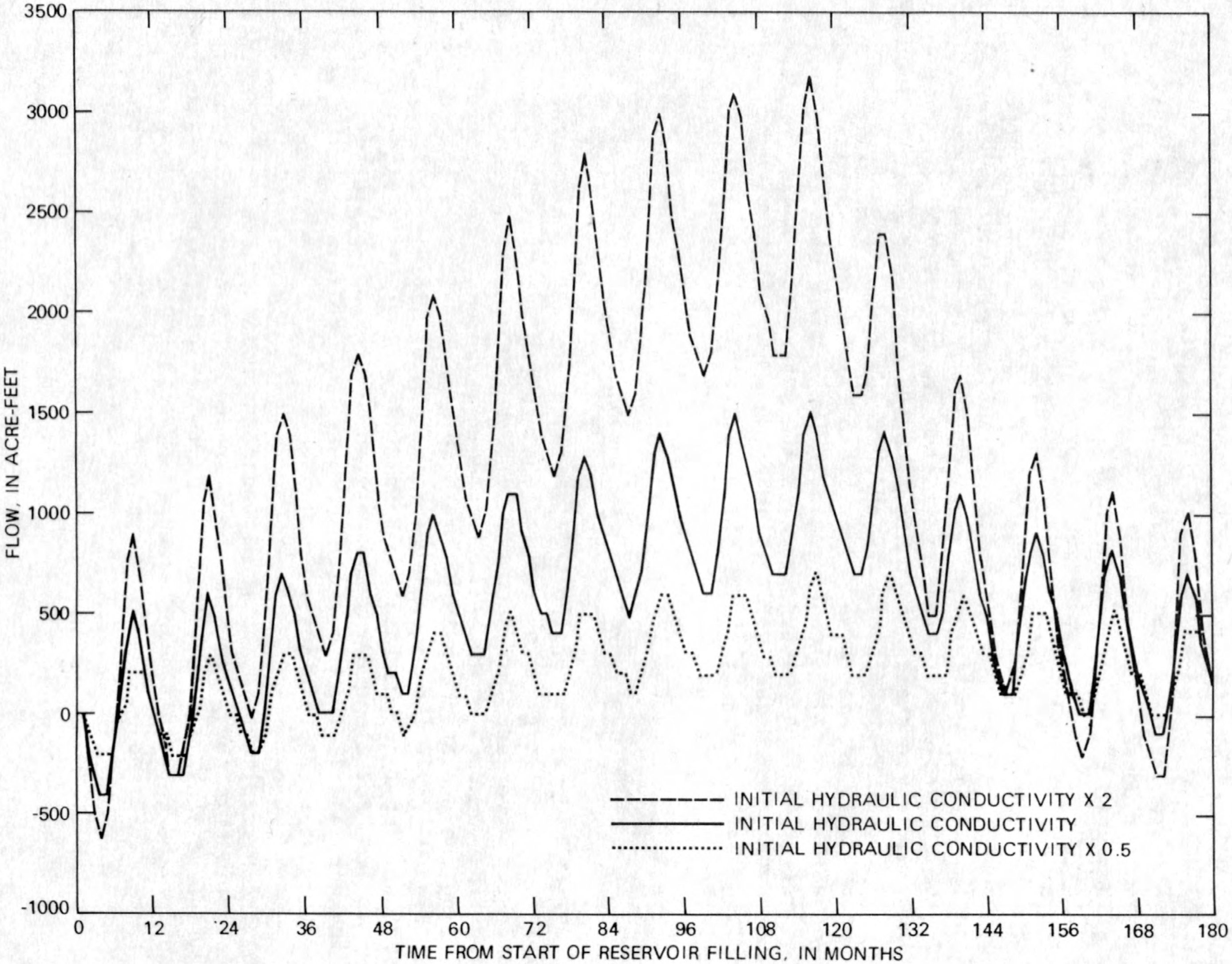
Figure 18. -- Monthly hydrologic responses under prereservoir conditions for three assumed hydraulic-conductivity conditions.

Varying the hydraulic conductivities had relatively small effects on the reservoir contents but had major effects on flow to the river downstream from the proposed dam (fig. 19 and table 6). Maximum monthly flow to the river downstream from the proposed dam about doubled for the doubled hydraulic-conductivity simulation and likewise about halved for the halved hydraulic-conductivity simulation. Similar results were recorded for the cumulative flows. Offsetting the effects of flow from the aquifer downstream from the proposed dam under different hydraulic-conductivity values were the corresponding effects on flow from the reservoir to the aquifer (fig. 20). Maximum cumulative flow was about 40 percent greater when simulated with the greater hydraulic conductivity and about 20 percent less when simulated with the lesser hydraulic conductivity. In a situation opposite from the effects of specific yield, the increased hydraulic conductivity, which caused more flow into the aquifer while the reservoir filled, also caused the aquifer to drain faster. The simulation with the hydraulic conductivity doubled had the largest maximum cumulative change in aquifer storage but the smallest final cumulative change (fig. 21). Water levels varied widely among the three cnditions. The maximum water level at point A was almost 20 ft higher when simulated with the increased hydraulic conductivities compared to the simulation with the decreased hydraulic conductivities. At point B, the maximum water level also occurred for the increased hydraulic-conductivities simulation although the final water level for that condition was the lowest of the three. Water levels at point C rose only 0.1 ft for all three simulations.

Boundary Hydraulic-Head Conditions

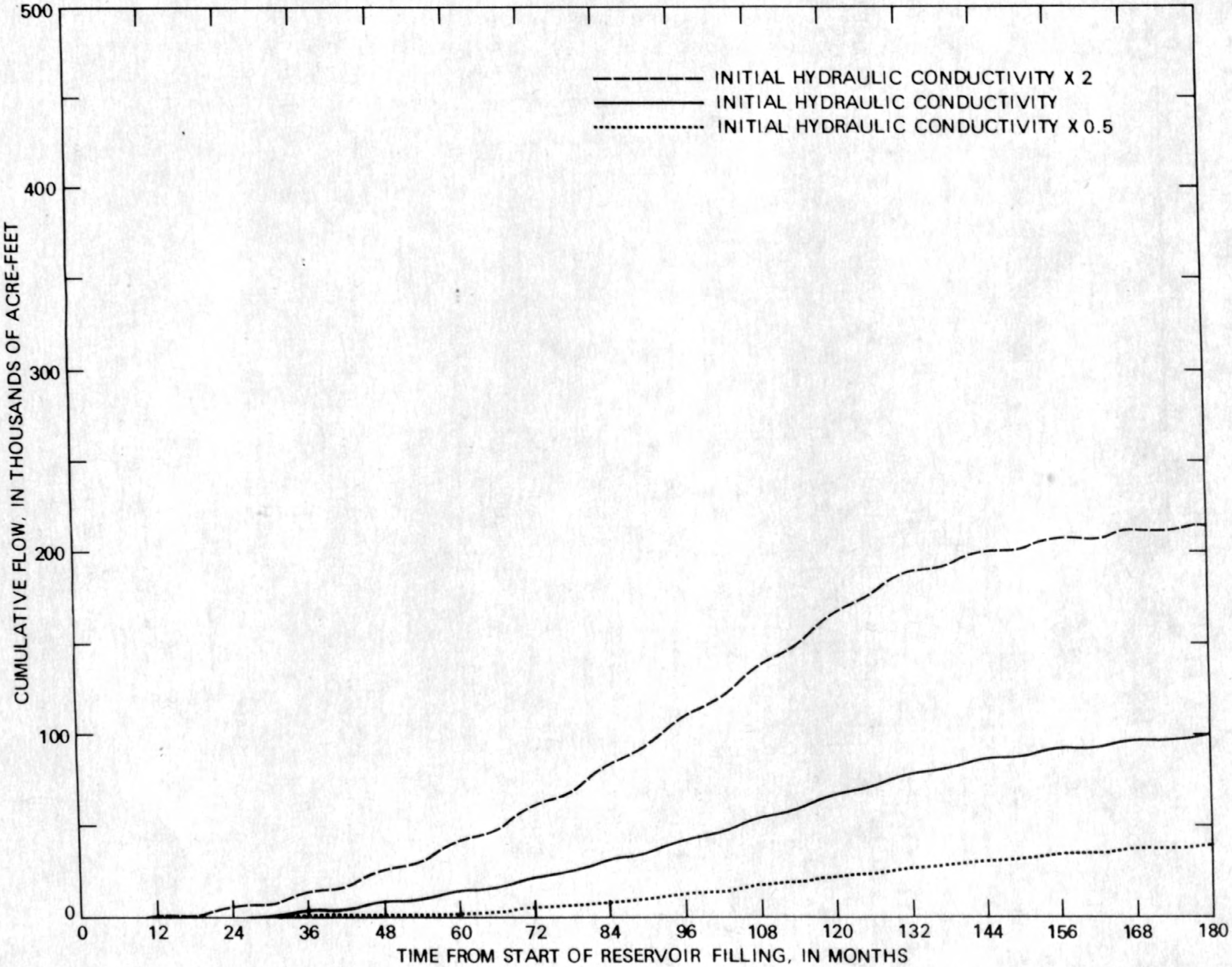
The hydraulic-head values for the model were determined from Hurr and others (1972a; 1972b) for water-level data measured during March 1968. The water levels in the South Platte River area are known to vary both seasonally and annually. However, along the boundary of the alluvial aquifer there has been no perceptible trend, justifying the use of those 1968 water-table maps. To test the sensitivity due to possible errors in the water-level data, two sensitivity simulations were made with identical input to the baseline-sensitivity simulation, except that in one the hydraulic heads along every boundary were increased by 20 percent of the saturated thickness, and in the other all boundary water levels were decreased 20 percent of the saturated thickness.

Changing the hydraulic heads at the boundaries caused no measurable change in the flow fluctuations to and from the aquifer under prereservoir conditions. Water-level fluctuations did not differ, although the average hydraulic-head values varied for the three different simulations (table 7). Average water levels varied about 6 ft at points A and C from baseline conditions and about 1 ft at point B.



A. MONTHLY FLOW

Figure 19.--Flow from the aquifer to the river downstream from the proposed dam for three assumed hydraulic-conductivity conditions.



B. CUMULATIVE FLOW

Figure 19. -- Flow from the aquifer to the river downstream from the proposed dam for three assumed hydraulic-conductivity conditions --Continued.

Table 6.--*Hydrologic responses to three assumed transmissivity conditions*

Simulated interactions	Percent of calculated hydraulic conductivity		
	50	100	200
Maximum monthly flow to the river downstream from the proposed dam, in acre-feet	700	1,500	3,200
Total cumulative flow to the river downstream from the proposed dam, in acre-feet	40,000	100,000	220,000
Maximum cumulative flow from the reservoir to the aquifer, in acre-feet	270,000	350,000	470,000
Final cumulative flow from the reservoir to the aquifer, in acre-feet	140,000	180,000	280,000
Flow from the aquifer to the reservoir during first 4 months of empty reservoir, in acre-feet	40,000	65,000	91,000
Maximum cumulative change in aquifer storage, in acre-feet	240,000	290,000	330,000
Final cumulative change in aquifer storage, in acre-feet	100,000	80,000	70,000
Maximum water level at point A, in feet	4,410.6	4,422.7	4,428.4
Water-level rise at point A, in feet	9.4	12.7	14.4
Final water level at point A, in feet	4,406.9	4,413.3	4,415.2
Maximum water level at point B, in feet	4,406.1	4,407.3	4,407.8
Water-level rise at point B, in feet	36.5	38.6	40.3
Final water level at point B, in feet	4,374.6	4,370.2	4,367.5

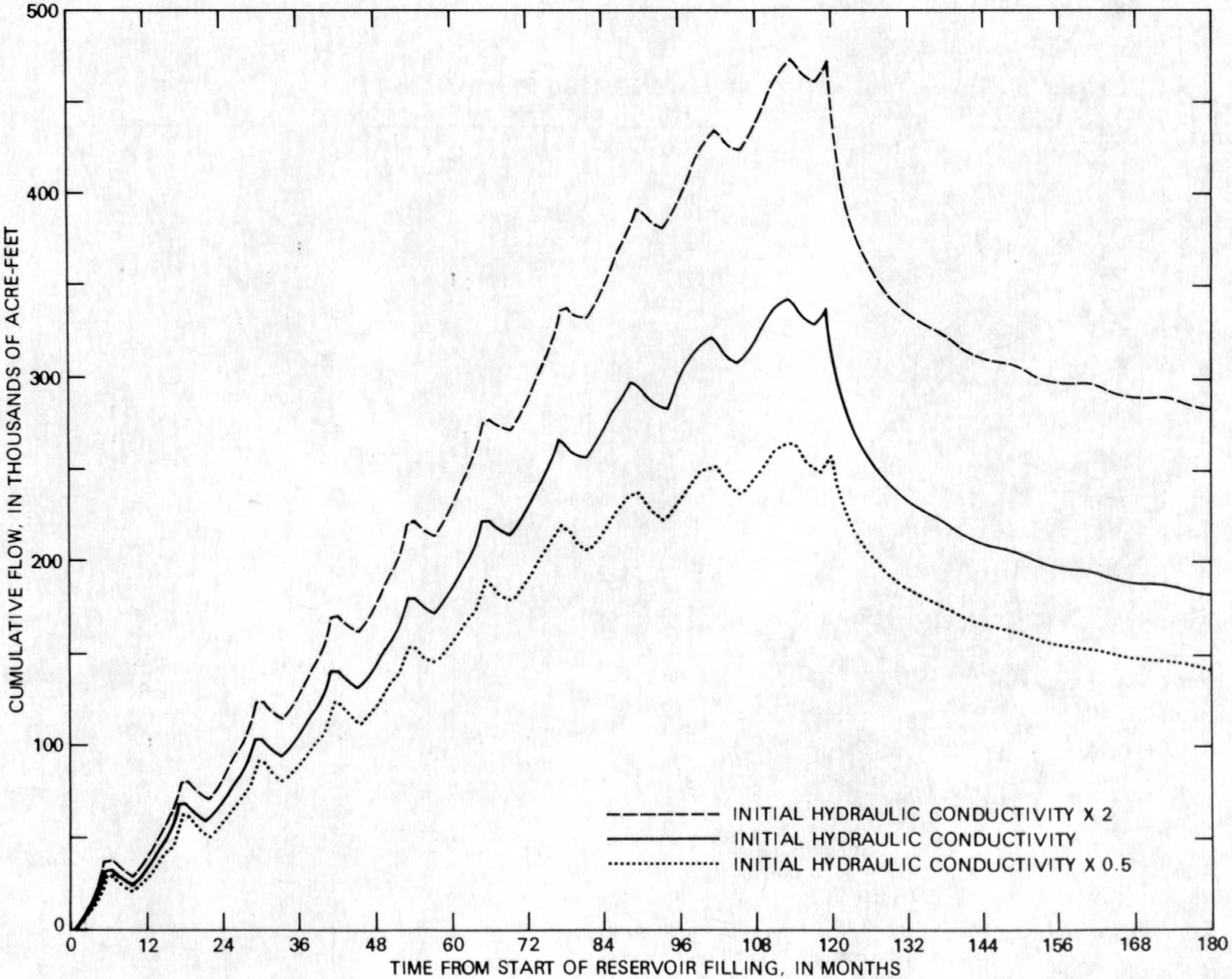


Figure 20. -- Cumulative flow from the reservoir to the aquifer for three assumed hydraulic-conductivity conditions.

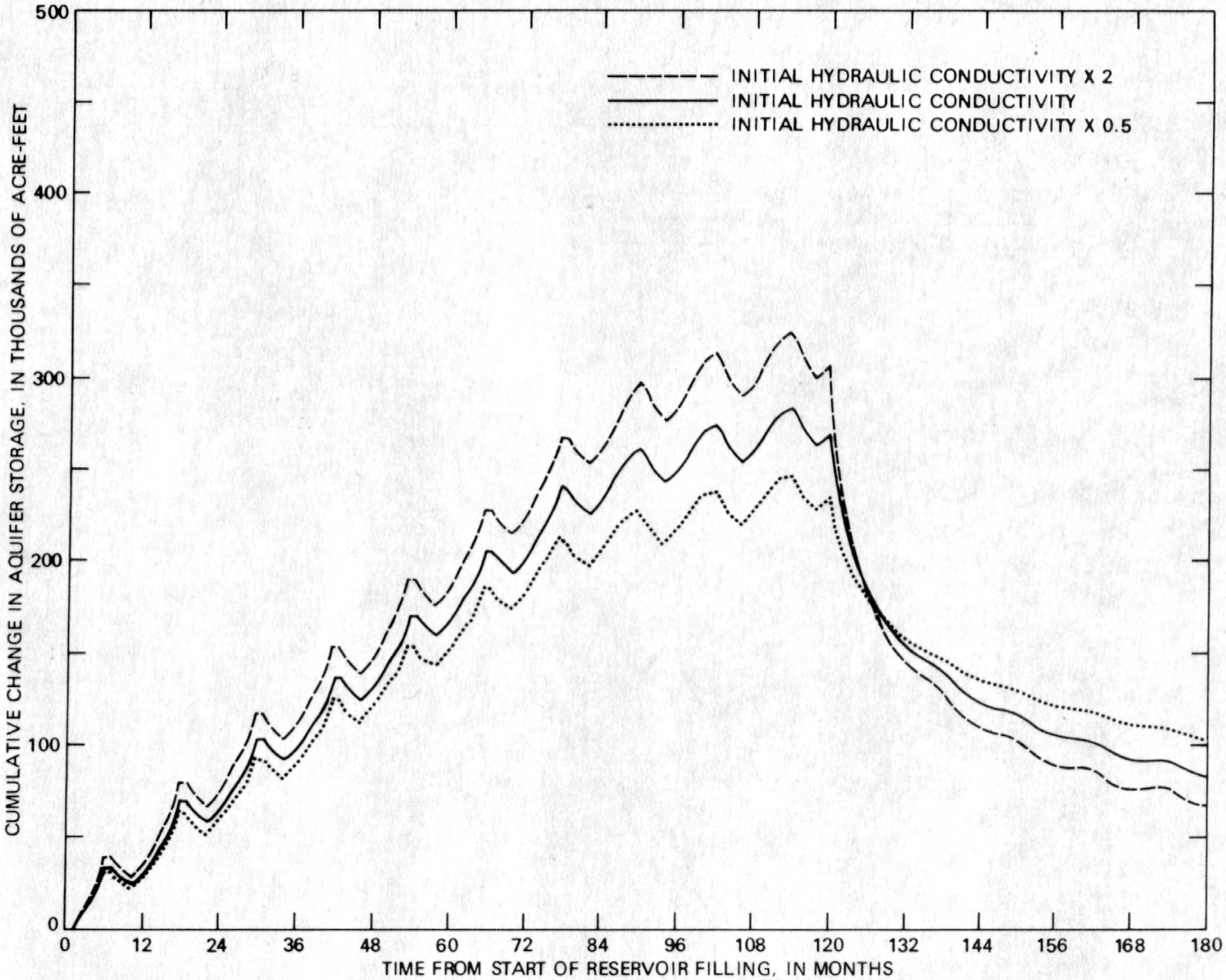


Figure 21. -- Cumulative change in aquifer storage for three assumed hydraulic-conductivity conditions.

Table 7.--*Water levels for prereservoir simulation of three assumed boundary conditions*

Simulated interaction	Boundary condition: Initial less 20 percent saturated thickness, in feet	Initial, in feet	Initial plus 20 percent saturated thickness, in feet
Average water level at point A--------	4,403.0	4,408.6	4,414.4
Average water level at point B--------	4,366.1	4,367.1	4,368.1
Average water level at point C--------	4,264.3	4,270.2	4,276.3

Two additional simulations were made with the modified initial-fill conditions. There were no changes in the reservoir contents due to changing the hydraulic head at the boundaries. There was a small increase in the monthly flow to the river downstream from the proposed dam when the simulated hydraulic heads along the boundary decreased and a corresponding slight increase in the total cumulative flow (table 8). The opposite was true for the simulation with increased hydraulic heads at the boundaries. Cumulative flow from the reservoir to the aquifer responded similarly, resulting in minimal net effect on change in aquifer storage. The higher hydraulic-head simulation had a total cumulative change in aquifer storage of 20,000 acre-ft less than the baseline simulation, and the simulation with lower hydraulic heads at the boundaries had a total of 10,000 acre-ft greater than the baseline simulation. Changes in water levels were similar for all boundary conditions, although the average levels were quite different, as was the case for the prereservoir condition.

Net Areal Flux

The net areal flux at the phreatic surface is primarily caused by the agricultural activities at the land surface. For the baseline simulation, water applications on the land surface included precipitation, surface-water diversions, and ground-water pumpage. Thirty percent of the applied water was assumed to recharge the ground-water system, based on work done in the South Platte River basin (R. T. Hurr and A. W. Burns, U.S. Geological Survey, written commun., 1978). However, this percent of recharge varies throughout the year and is probably a function of the crop potential evapotranspiration and the amount of applications (Luckey and others, 1978). On an annual basis, it is unlikely that this value exceeds 50 percent. For the sensitivity analysis, two additional simulations were made with conditions identical to the baseline-sensitivity analysis, except that one simulation assumed 50 percent of the applications was recharged to the aquifer and the other assumed 10 percent of the applications was recharged.

Table 8.--*Hydrologic responses to three assumed boundary conditions*

Simulated interaction	Boundary condition: Initial less 20 percent saturated thickness, in feet	Initial, in feet	Initial plus 20 percent saturated thickness, in feet
Total cumulative flow to the river downstream from the proposed dam, in acre-feet	110,000	100,000	90,000
Maximum cumulative flow from the reservoir to the aquifer, in acre-feet	370,000	350,000	320,000
Final cumulative flow from the reservoir to the aquifer, in acre-feet	200,000	180,000	150,000
Final cumulative change in aquifer storage, in acre-feet	90,000	80,000	60,000
Water-level increase at point A, in feet	13.0	12.7	12.3
Water-level increase at point B, in feet	39.0	38.6	38.3

The effects of the different recharge rates were quite distinctive for the prereservoir condition (fig. 22). For increased recharge, flow to the river downstream from the proposed dam increased 160 percent from the baseline simulation and flow to the river upstream from the proposed dam increased 60 percent. Average water levels rose from 3 to 5 ft at points A, B, and C. The deviations from the historic water table for the simulation recharging 50 percent of the applications are shown in figure 23. Water-level fluctuations increased 90 percent over the baseline simulation at point C and 50 percent at point B, although fluctuations decreased 35 percent at point A. For the decreased recharge, the simulated flow to the river below the proposed dam decreased 50 percent from the baseline simulation and became out-of-phase with other fluctuations. Flow to the river upstream from the proposed dam decreased 60 percent. Average water levels declined 3 to 5 ft at points A, B, and C. The deviations from the historic water table for the simulation recharging 10 percent of the applications are shown in figure 24. Water-level fluctuations at point C decreased 90 percent from the baseline simulation and 60 percent at point B, while fluctuations increased 35 percent at point A.

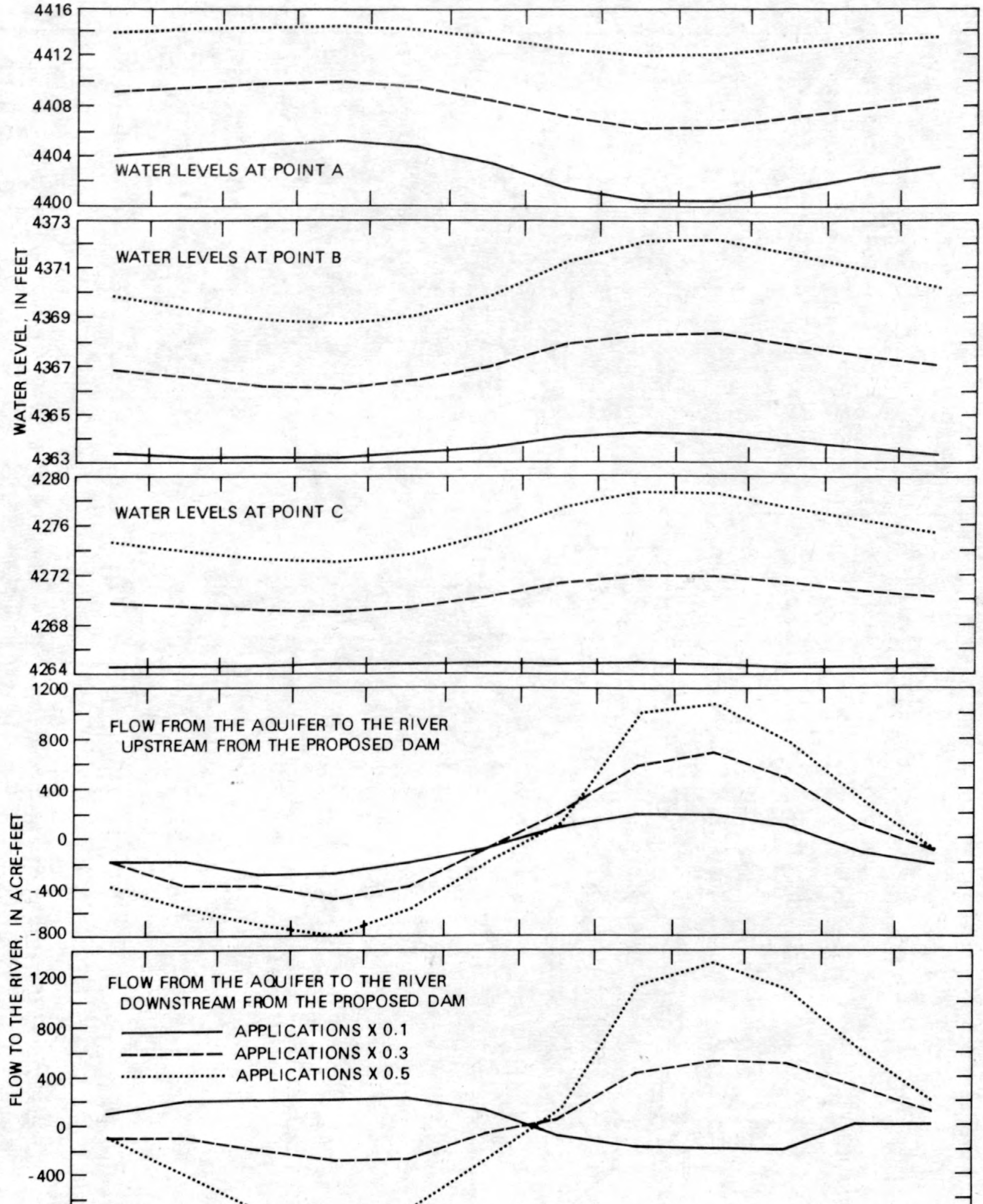


Figure 22. --Monthly hydrologic responses under prereservoir conditions for three assumed local recharge conditions.

EXPLANATION

----*10*---- LINE OF EQUAL DIFFERENCE IN WATER LEVEL; HISTORIC HIGHER THAN COMPUTED--Interval 5 feet

——*10*—— LINE OF EQUAL DIFFERENCE IN WATER LEVEL; HISTORIC LOWER THAN COMPUTED--Interval 5 feet

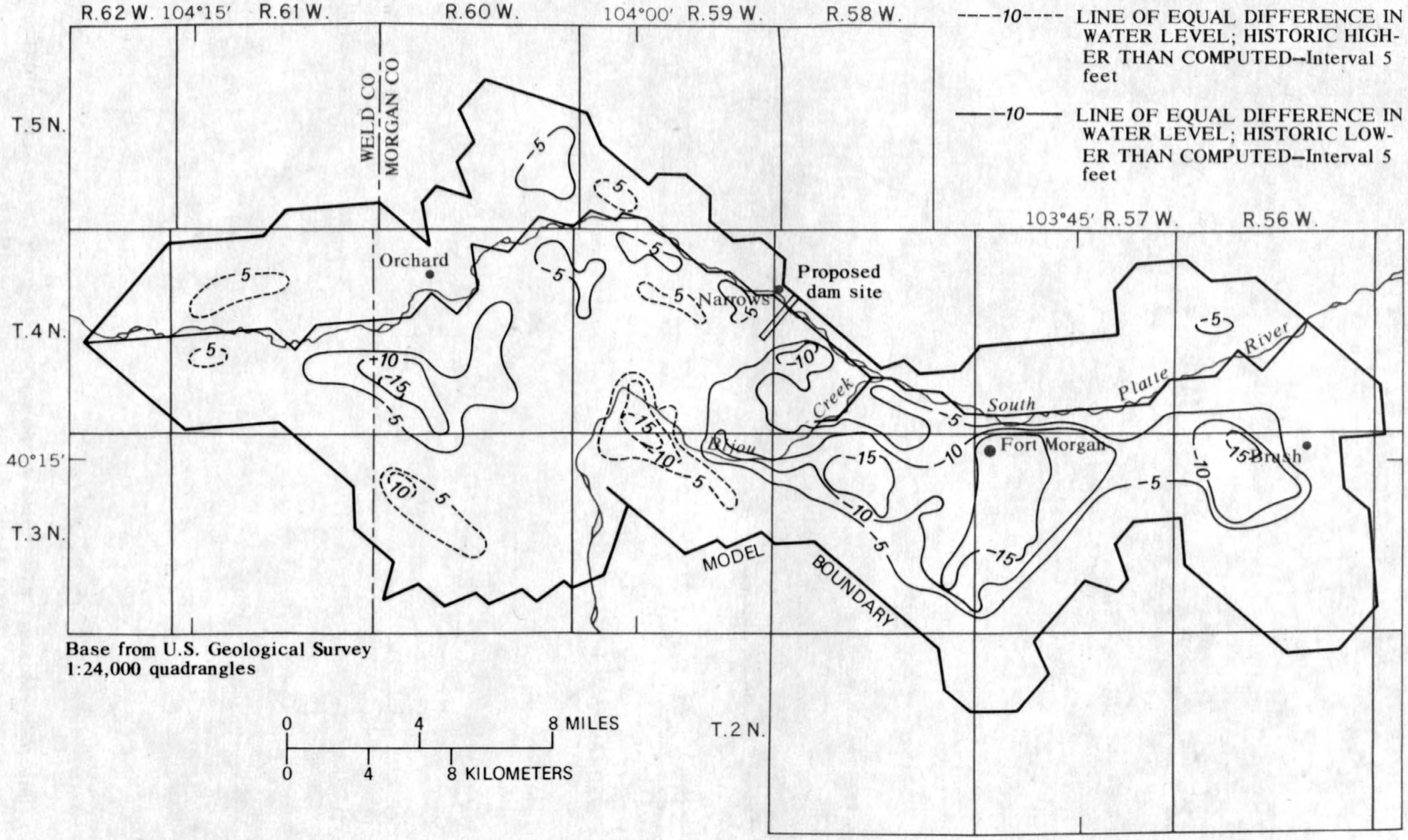


Figure 23. --Difference in water table between that computed using recharge of 0.5 of applications and that based on historic data.

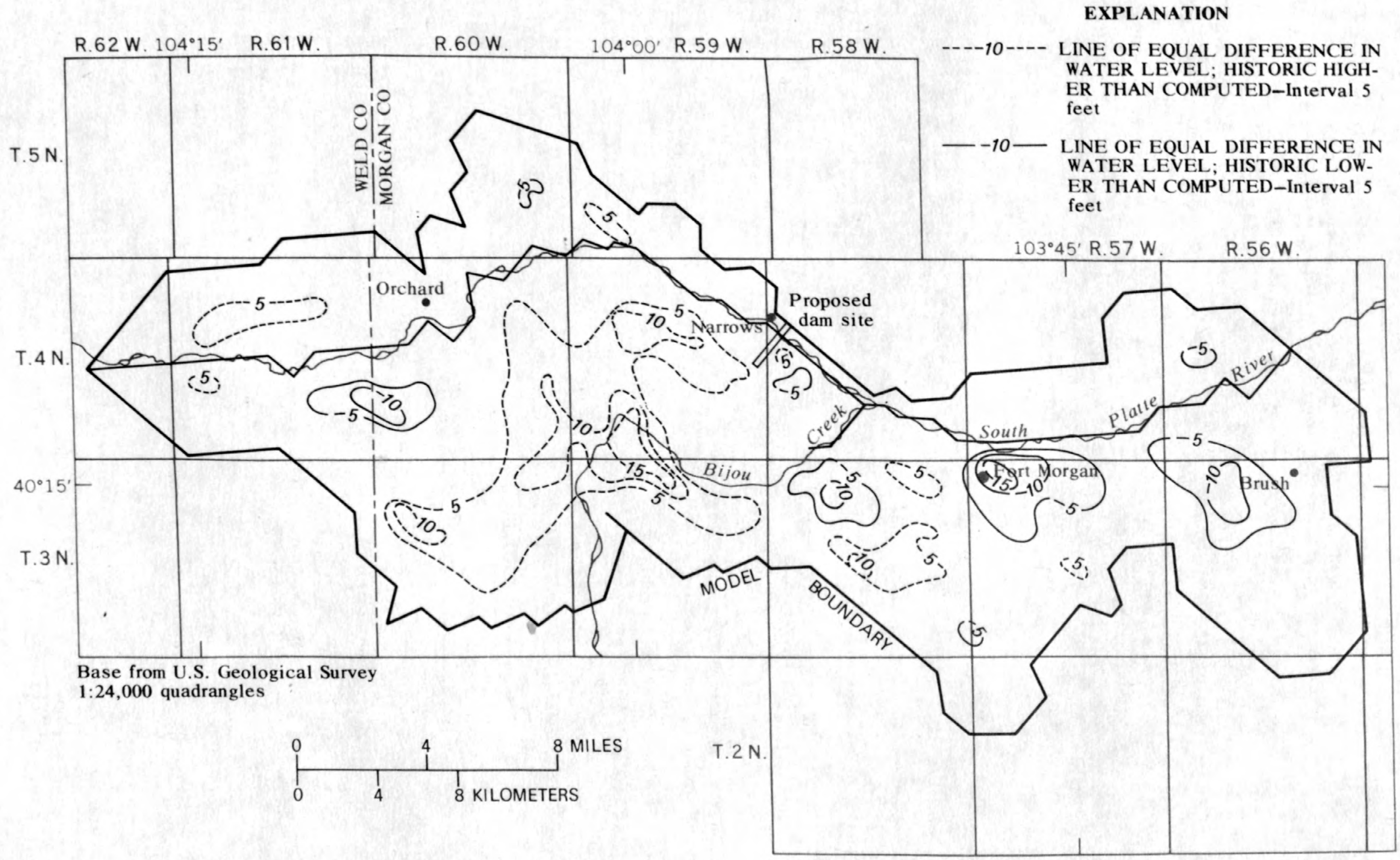


Figure 24. -- Difference in water table between that computed using recharge of 0.1 of applications and that based on historic data.

In spite of the major differences among the three recharge conditions in the prereservoir-simulation results, reservoir contents were the same for all three simulations. Monthly flow to the river downstream from the proposed dam varied considerably (table 9) and, as with the prereservoir simulation, was out of phase during the decreased recharge simulation. However, total cumulative flow was quite similar for all three simulations. Monthly flow from the reservoir to the aquifer did not change appreciably among the three simulations with a corresponding minor difference among the simulated cumulative flow from the reservoir to the aquifer. The net result was a similar change in aquifer storage for all three simulated conditions. There were small differences in water-level fluctuations at points A and B among the three simulations. Water-level rises at point C were 0.2 ft or less for all three simulations.

Table 9.--*Hydrologic responses to three assumed recharge conditions*

Simulated interaction	Percent of applications recharged		
	10	30	50
Maximum monthly flow to the river downstream from the proposed dam, in acre-feet---------	1,300	1,500	2,200
Total cumulative flow to the river downstream from the proposed dam, in acre-feet---------	110,000	100,000	90,000
Maximum cumulative flow from the reservoir to the aquifer, in acre-feet-------------------	360,000	350,000	330,000
Final cumulative flow from the reservoir to the aquifer, in acre-feet-------------------	200,000	180,000	170,000
Final cumulative change in aquifer storage, in acre-feet--------------------------------	90,000	80,000	80,000
Maximum water level at point A, in feet-------	4,418.5	4,422.7	4,426.6
Water-level rise at point A, in feet----------	12.8	12.7	12.1
Maximum water level at point B, in feet-------	4,404.5	4,407.0	4,409.5
Water-level rise at point B, in feet----------	40.2	38.6	37.3

Table 10.--*Monthly reservoir stresses for the 28-year operations-study data with no hydraulic connection to the aquifer*

[All stresses except end-of-month elevation are in thousands of acre-feet]

Month	End-of-month: Elevation (feet)	End-of-month: Contents	Reservoir inflow: River flow	Reservoir inflow: Aquifer flow	Reservoir releases: Required	Reservoir releases: Project	Reservoir releases: Spill	Reservoir releases: Aquifer flow to river	Reservoir evaporation
1	4334.7	11.	25.	0.0	14.0	0.0	0.0	0.0	.09
2	4339.5	20.	22.	0.0	12.4	0.0	0.0	0.0	.18
3	4351.6	53.	48.	0.0	14.2	0.0	0.0	0.0	.68
4	4354.4	64.	19.	0.0	6.9	0.0	0.0	0.0	1.37
5	4354.3	63.	68.	0.0	66.8	0.0	0.0	0.0	1.84
6	4387.2	291.	313.	0.0	62.2	18.5	0.0	0.0	3.90
7	4389.1	310.	109.	0.0	34.2	50.5	0.0	0.0	5.52
8	4385.7	276.	33.	0.0	41.1	21.3	0.0	0.0	4.62
9	4384.4	264.	33.	0.0	36.8	4.8	0.0	0.0	3.42
10	4383.5	254.	26.	0.0	26.7	7.0	0.0	0.0	2.20
11	4384.4	264.	28.	0.0	17.5	0.0	0.0	0.0	1.02
12	4385.9	278.	34.	0.0	18.6	0.0	0.0	0.0	1.05
13	4387.7	297.	41.	0.0	21.2	0.0	0.0	0.0	1.09
14	4393.0	350.	56.	0.0	2.1	0.0	0.0	0.0	1.17
15	4399.4	431.	85.	0.0	1.2	0.0	0.0	0.0	2.88
16	4401.4	456.	65.	0.0	18.5	16.7	0.0	0.0	4.81
17	4401.2	454.	67.	0.0	60.4	2.5	0.0	0.0	6.31
18	4401.6	460.	71.	0.0	52.6	5.1	0.0	0.0	7.45
19	4397.9	412.	20.	0.0	29.4	31.5	0.0	0.0	7.18
20	4396.0	387.	19.	0.0	28.4	9.6	0.0	0.0	5.71
21	4394.4	367.	19.	0.0	24.9	10.5	0.0	0.0	4.26
22	4392.6	346.	15.	0.0	18.8	14.5	0.0	0.0	2.69
23	4393.0	349.	12.	0.0	7.3	0.0	0.0	0.0	1.23
24	4393.5	356.	18.	0.0	10.7	0.0	0.0	0.0	1.24
25	4395.5	382.	27.	0.0	0.0	0.0	0.0	0.0	1.28
26	4397.1	402.	21.	0.0	0.0	0.0	0.0	0.0	1.34
27	4397.7	409.	20.	0.0	9.2	0.0	0.0	0.0	2.96
28	4395.4	380.	23.	0.0	17.4	29.3	0.0	0.0	4.40
29	4394.8	372.	22.	0.0	25.1	.2	0.0	0.0	5.46
30	4404.3	498.	476.	0.0	96.3	27.1	219.0	0.0	7.64
31	4404.0	493.	61.	0.0	37.7	20.8	0.0	0.0	7.93
32	4402.0	464.	23.	0.0	37.7	6.8	0.0	0.0	6.56
33	4400.1	441.	22.	0.0	27.6	12.9	0.0	0.0	4.89
34	4398.9	425.	9.	0.0	15.7	6.0	0.0	0.0	3.11
35	4400.6	446.	42.	0.0	19.0	0.0	0.0	0.0	1.46
36	4401.2	454.	19.	0.0	9.7	0.0	0.0	0.0	1.49
37	4401.5	458.	17.	0.0	11.0	0.0	0.0	0.0	1.51
38	4402.0	465.	15.	0.0	7.2	0.0	0.0	0.0	1.52
39	4403.0	478.	18.	0.0	.8	0.0	0.0	0.0	3.33
40	4402.8	476.	19.	0.0	10.3	5.5	0.0	0.0	5.10
41	4401.7	460.	18.	0.0	26.8	0.0	0.0	0.0	6.45
42	4398.2	416.	32.	0.0	37.0	32.1	0.0	0.0	7.21
43	4394.5	370.	21.	0.0	29.3	31.2	0.0	0.0	6.63
44	4390.9	329.	17.	0.0	26.1	26.0	0.0	0.0	5.17
45	4389.5	315.	20.	0.0	20.7	9.9	0.0	0.0	3.81
46	4386.4	284.	6.	0.0	15.0	20.1	0.0	0.0	2.40
47	4387.5	295.	18.	0.0	5.7	0.0	0.0	0.0	1.09
48	4388.1	301.	12.	0.0	5.3	0.0	0.0	0.0	1.11
49	4388.9	309.	17.	0.0	8.6	0.0	0.0	0.0	1.13
50	4389.6	315.	15.	0.0	7.2	0.0	0.0	0.0	1.15
51	4389.7	317.	13.	0.0	9.4	0.0	0.0	0.0	2.48
52	4390.1	321.	14.	0.0	6.4	0.0	0.0	0.0	3.79
53	4389.2	312.	17.	0.0	20.9	0.0	0.0	0.0	4.84
54	4388.6	305.	44.	0.0	40.2	4.4	0.0	0.0	5.61
55	4384.8	267.	31.	0.0	36.1	27.7	0.0	0.0	5.35
56	4384.8	268.	66.	0.0	49.3	11.9	0.0	0.0	4.37
57	4384.6	266.	28.	0.0	23.7	2.8	0.0	0.0	3.40
58	4383.7	256.	7.	0.0	14.4	0.0	0.0	0.0	2.21
59	4384.9	269.	21.	0.0	7.2	0.0	0.0	0.0	1.03
60	4385.7	276.	24.	0.0	15.0	0.0	0.0	0.0	1.06

Table 10.--*Monthly reservoir stresses for the 28-year operations-study data with no hydraulic connection to the aquifer*--Continued

Month	End-of-month		Reservoir inflow		Reservoir releases				Reservoir evaporation
	Elevation (feet)	Contents	River flow	Aquifer flow	Required	Project	Spill	Aquifer flow to river	
61	4386.4	283.	28.	0.0	19.9	0.0	0.0	0.0	1.07
62	4388.4	304.	29.	0.0	7.5	0.0	0.0	0.0	1.10
63	4390.5	324.	23.	0.0	0.0	0.0	0.0	0.0	2.47
64	4392.2	341.	37.	0.0	16.3	0.0	0.0	0.0	3.90
65	4396.1	389.	86.	0.0	33.4	0.0	0.0	0.0	5.34
66	4396.5	396.	97.	0.0	61.5	21.8	0.0	0.0	5.63
67	4391.4	333.	28.	0.0	36.4	47.6	0.0	0.0	5.28
68	4388.2	301.	26.	0.0	36.6	16.3	0.0	0.0	4.85
69	4386.9	289.	26.	0.0	30.6	4.3	0.0	0.0	3.61
70	4383.7	256.	11.	0.0	17.5	23.3	0.0	0.0	2.27
71	4384.7	266.	19.	0.0	7.8	0.0	0.0	0.0	1.03
72	4385.3	273.	14.	0.0	6.3	0.0	0.0	0.0	1.05
73	4386.0	280.	18.	0.0	9.6	0.0	0.0	0.0	1.06
74	4386.7	286.	16.	0.0	8.7	0.0	0.0	0.0	1.08
75	4387.2	291.	23.	0.0	15.8	0.0	0.0	0.0	2.35
76	4388.2	301.	19.	0.0	5.3	.2	0.0	0.0	3.62
77	4383.5	254.	12.	0.0	17.8	36.4	0.0	0.0	4.47
78	4382.0	239.	34.	0.0	34.9	8.9	0.0	0.0	4.90
79	4376.9	196.	23.	0.0	33.9	27.9	0.0	0.0	4.54
80	4374.6	178.	27.	0.0	33.7	8.2	0.0	0.0	3.43
81	4370.2	147.	17.	0.0	24.6	21.2	0.0	0.0	2.46
82	4367.3	130.	10.	0.0	16.9	9.0	0.0	0.0	1.46
83	4369.3	142.	20.	0.0	7.6	0.0	0.0	0.0	.67
84	4370.3	147.	14.	0.0	7.1	0.0	0.0	0.0	.70
85	4371.2	153.	16.	0.0	9.8	0.0	0.0	0.0	.72
86	4371.9	157.	13.	0.0	7.7	0.0	0.0	0.0	.73
87	4372.1	158.	12.	0.0	9.4	0.0	0.0	0.0	1.59
88	4367.5	131.	12.	0.0	12.1	24.3	0.0	0.0	2.28
89	4364.1	110.	7.	0.0	19.0	6.0	0.0	0.0	2.62
90	4351.4	52.	14.	0.0	20.2	49.4	0.0	0.0	2.46
91	4341.7	24.	13.	0.0	17.0	22.6	0.0	0.0	1.62
92	4338.0	17.	16.	0.0	21.6	0.0	0.0	0.0	.93
93	4336.3	14.	13.	0.0	14.8	1.1	0.0	0.0	.59
94	4335.3	12.	11.	0.0	12.2	0.0	0.0	0.0	.35
95	4339.2	20.	21.	0.0	13.1	0.0	0.0	0.0	.18
96	4344.5	29.	17.	0.0	7.2	0.0	0.0	0.0	.25
97	4345.7	33.	20.	0.0	15.7	0.0	0.0	0.0	.30
98	4347.0	38.	16.	0.0	11.0	0.0	0.0	0.0	.32
99	4349.1	45.	17.	0.0	9.1	0.0	0.0	0.0	.74
100	4348.7	44.	16.	0.0	15.4	1.3	0.0	0.0	1.17
101	4346.7	37.	8.	0.0	13.1	0.0	0.0	0.0	1.42
102	4346.6	37.	13.	0.0	9.0	2.4	0.0	0.0	1.59
103	4341.3	24.	10.	0.0	20.6	.8	0.0	0.0	1.42
104	4338.1	17.	18.	0.0	23.4	0.0	0.0	0.0	.92
105	4336.9	15.	15.	0.0	16.8	0.0	0.0	0.0	.61
106	4336.8	15.	17.	0.0	15.4	1.0	0.0	0.0	.38
107	4340.4	22.	12.	0.0	5.4	0.0	0.0	0.0	.20
108	4344.4	29.	14.	0.0	6.1	0.0	0.0	0.0	.26
109	4346.2	35.	14.	0.0	8.3	0.0	0.0	0.0	.30
110	4347.9	41.	14.	0.0	8.0	0.0	0.0	0.0	.33
111	4348.5	43.	12.	0.0	9.3	0.0	0.0	0.0	.75
112	4348.3	42.	13.	0.0	12.8	0.0	0.0	0.0	1.14
113	4346.7	37.	20.	0.0	23.8	0.0	0.0	0.0	1.40
114	4345.9	34.	25.	0.0	25.8	.5	0.0	0.0	1.56
115	4341.9	25.	15.	0.0	21.0	1.7	0.0	0.0	1.40
116	4339.0	19.	18.	0.0	21.9	.4	0.0	0.0	.96
117	4332.6	8.	7.	0.0	17.2	.3	0.0	0.0	.54
118	4332.4	8.	14.	0.0	14.2	0.0	0.0	0.0	.26
119	4341.8	24.	24.	0.0	7.8	0.0	0.0	0.0	.19
120	4345.3	32.	15.	0.0	7.2	0.0	0.0	0.0	.28

Table 10.--*Monthly reservoir stresses for the 28-year operations-study data with no hydraulic connection to the aquifer*--Continued

Month	End-of-month		Reservoir inflow		Reservoir releases				Reser-voir evapo-ration
	Elevation (feet)	Contents	River flow	Aquifer flow	Required	Project	Spill	Aquifer flow to river	
121	4347.1	38.	12.	0.0	5.5	0.0	0.0	0.0	.32
122	4348.7	44.	13.	0.0	7.2	0.0	0.0	0.0	.34
123	4351.6	53.	19.	0.0	8.5	0.0	0.0	0.0	.81
124	4351.6	53.	14.	0.0	12.4	0.0	0.0	0.0	1.30
125	4376.5	194.	215.	0.0	72.2	0.0	0.0	0.0	2.65
126	4386.6	285.	188.	0.0	75.3	16.5	0.0	0.0	4.80
127	4386.9	289.	90.	0.0	71.1	10.2	0.0	0.0	5.36
128	4386.1	281.	59.	0.0	59.7	2.2	0.0	0.0	4.54
129	4384.4	263.	30.	0.0	32.5	11.4	0.0	0.0	3.44
130	4382.4	243.	14.	0.0	18.6	13.4	0.0	0.0	2.17
131	4383.4	254.	26.	0.0	15.1	0.0	0.0	0.0	1.00
132	4385.3	272.	53.	0.0	33.2	0.0	0.0	0.0	1.03
133	4389.6	316.	45.	0.0	0.0	0.0	0.0	0.0	1.11
134	4392.6	345.	33.	0.0	2.0	0.0	0.0	0.0	1.19
135	4395.3	379.	36.	0.0	0.0	0.0	0.0	0.0	2.72
136	4398.9	424.	57.	0.0	7.2	0.0	0.0	0.0	4.46
137	4404.3	498.	310.	0.0	65.1	25.1	139.6	0.0	6.61
138	4404.3	498.	106.	0.0	27.1	4.8	66.1	0.0	7.96
139	4403.7	489.	32.	0.0	27.9	5.5	0.0	0.0	7.90
140	4401.3	455.	25.	0.0	36.3	15.7	0.0	0.0	6.49
141	4400.4	444.	23.	0.0	27.4	1.9	0.0	0.0	4.87
142	4397.9	412.	20.	0.0	23.4	25.4	0.0	0.0	3.09
143	4398.7	423.	24.	0.0	12.2	0.0	0.0	0.0	1.41
144	4399.3	430.	18.	0.0	8.9	0.0	0.0	0.0	1.43
145	4399.8	436.	17.	0.0	8.9	0.0	0.0	0.0	1.45
146	4400.1	440.	15.	0.0	9.4	0.0	0.0	0.0	1.46
147	4401.2	454.	29.	0.0	11.7	0.0	0.0	0.0	3.19
148	4402.7	474.	55.	0.0	0.0	30.1	0.0	0.0	4.99
149	4404.3	498.	45.	0.0	2.3	0.0	12.2	0.0	6.68
150	4402.4	469.	41.	0.0	36.4	25.6	0.0	0.0	7.78
151	4398.0	414.	24.	0.0	32.9	40.0	0.0	0.0	7.25
152	4394.9	373.	25.	0.0	34.0	25.1	0.0	0.0	5.64
153	4393.9	361.	26.	0.0	30.8	3.0	0.0	0.0	4.18
154	4392.8	347.	9.	0.0	16.7	3.9	0.0	0.0	2.68
155	4393.6	357.	21.	0.0	9.5	0.0	0.0	0.0	1.24
156	4394.3	366.	19.	0.0	8.4	0.0	0.0	0.0	1.27
157	4395.0	375.	28.	0.0	18.4	0.0	0.0	0.0	1.29
158	4395.8	385.	37.	0.0	25.4	0.0	0.0	0.0	1.31
159	4398.5	419.	63.	0.0	26.9	0.0	0.0	0.0	2.94
160	4399.8	435.	37.	0.0	6.3	8.5	0.0	0.0	4.68
161	4399.2	429.	42.	0.0	37.6	5.7	0.0	0.0	6.06
162	4395.3	379.	40.	0.0	36.3	46.5	0.0	0.0	6.78
163	4392.0	340.	25.	0.0	32.8	26.0	0.0	0.0	6.21
164	4386.8	287.	16.	0.0	24.5	38.7	0.0	0.0	4.81
165	4384.5	264.	22.	0.0	26.8	14.0	0.0	0.0	3.46
166	4383.1	250.	12.	0.0	18.1	6.4	0.0	0.0	2.19
167	4383.5	255.	14.	0.0	8.0	0.0	0.0	0.0	1.01
168	4384.1	260.	14.	0.0	8.0	0.0	0.0	0.0	1.02
169	4384.6	266.	16.	0.0	9.0	0.0	0.0	0.0	1.03
170	4385.1	270.	18.	0.0	12.3	0.0	0.0	0.0	1.04
171	4385.5	274.	39.	0.0	32.9	0.0	0.0	0.0	2.27
172	4384.5	264.	20.	0.0	13.3	13.8	0.0	0.0	3.41
173	4387.9	299.	74.	0.0	35.1	0.0	0.0	0.0	4.50
174	4399.0	426.	203.	0.0	26.8	42.0	0.0	0.0	6.26
175	4398.0	414.	31.	0.0	34.5	2.1	0.0	0.0	6.98
176	4395.4	379.	30.	0.0	38.1	20.3	0.0	0.0	5.68
177	4395.8	385.	63.	0.0	49.7	3.3	0.0	0.0	4.30
178	4398.2	416.	102.	0.0	34.6	33.1	0.0	0.0	2.94
179	4403.2	482.	89.	0.0	22.3	0.0	0.0	0.0	1.49
180	4404.3	498.	59.	0.0	0.0	0.0	41.4	0.0	1.61

Table 10.--*Monthly reservoir stresses for the 28-year operations-study data with no hydraulic connection to the aquifer*--Continued

Month	End-of-month		Reservoir inflow		Reservoir releases				Reservoir evaporation
	Elevation (feet)	Contents	River flow	Aquifer flow	Required	Project	Spill	Aquifer flow to river	
181	4404.3	498.	58.	0.0	1.5	0.0	54.4	0.0	1.62
182	4404.3	498.	75.	0.0	1.9	0.0	71.5	0.0	1.62
183	4404.3	498.	73.	0.0	10.9	0.0	58.1	0.0	3.47
184	4404.3	498.	53.	0.0	24.2	11.7	11.5	0.0	5.27
185	4403.1	480.	21.	0.0	25.5	5.9	0.0	0.0	6.67
186	4402.4	469.	50.	0.0	26.3	26.6	0.0	0.0	7.67
187	4399.4	431.	48.	0.0	44.4	33.7	0.0	0.0	7.36
188	4397.3	404.	36.	0.0	34.2	23.1	0.0	0.0	5.91
189	4395.7	384.	31.	0.0	34.7	11.6	0.0	0.0	4.40
190	4393.7	359.	12.	0.0	19.0	15.6	0.0	0.0	2.78
191	4394.4	367.	19.	0.0	9.2	0.0	0.0	0.0	1.27
192	4395.0	375.	19.	0.0	10.7	0.0	0.0	0.0	1.29
193	4395.7	383.	28.	0.0	17.8	0.0	0.0	0.0	1.31
194	4397.3	404.	32.	0.0	10.0	0.0	0.0	0.0	1.35
195	4399.2	428.	29.	0.0	1.3	0.0	0.0	0.0	3.02
196	4398.1	415.	15.	0.0	13.4	10.5	0.0	0.0	4.63
197	4396.5	394.	10.	0.0	19.9	5.0	0.0	0.0	5.76
198	4394.1	364.	32.	0.0	32.1	23.5	0.0	0.0	6.46
199	4390.3	322.	23.	0.0	28.9	29.7	0.0	0.0	6.01
200	4386.9	289.	23.	0.0	30.9	20.2	0.0	0.0	4.74
201	4385.6	275.	26.	0.0	25.7	10.2	0.0	0.0	3.51
202	4383.4	254.	3.	0.0	8.6	13.9	0.0	0.0	2.23
203	4384.3	263.	17.	0.0	7.4	0.0	0.0	0.0	1.02
204	4385.1	270.	17.	0.0	8.6	0.0	0.0	0.0	1.04
205	4385.6	275.	13.	0.0	7.2	0.0	0.0	0.0	1.06
206	4386.0	279.	13.	0.0	8.1	0.0	0.0	0.0	1.07
207	4386.3	282.	16.	0.0	11.1	0.0	0.0	0.0	2.31
208	4386.1	280.	23.	0.0	17.2	4.0	0.0	0.0	3.50
209	4384.4	263.	13.	0.0	23.2	2.3	0.0	0.0	4.41
210	4382.9	249.	33.	0.0	33.7	9.3	0.0	0.0	5.01
211	4380.7	226.	25.	0.0	31.2	11.7	0.0	0.0	4.79
212	4378.2	206.	23.	0.0	31.8	8.3	0.0	0.0	3.85
213	4376.7	194.	18.	0.0	23.0	4.2	0.0	0.0	2.84
214	4374.8	179.	10.	0.0	17.7	5.3	0.0	0.0	1.78
215	4375.9	188.	19.	0.0	9.2	0.0	0.0	0.0	.82
216	4376.8	195.	14.	0.0	6.2	0.0	0.0	0.0	.84
217	4377.5	200.	11.	0.0	4.4	0.0	0.0	0.0	.86
218	4378.1	205.	14.	0.0	8.7	0.0	0.0	0.0	.88
219	4378.6	209.	18.	0.0	12.1	0.0	0.0	0.0	1.92
220	4377.5	200.	20.	0.0	18.3	7.4	0.0	0.0	2.88
221	4375.8	187.	18.	0.0	27.9	0.0	0.0	0.0	3.56
222	4394.9	374.	213.	0.0	20.0	.1	0.0	0.0	5.28
223	4396.2	390.	79.	0.0	27.1	29.7	0.0	0.0	6.50
224	4398.0	413.	84.	0.0	41.7	13.2	0.0	0.0	5.73
225	4398.1	415.	47.	0.0	33.6	6.5	0.0	0.0	4.57
226	4400.9	451.	83.	0.0	34.4	9.9	0.0	0.0	3.11
227	4404.3	498.	62.	0.0	11.0	0.0	2.5	0.0	1.56
228	4404.3	498.	38.	0.0	1.0	0.0	34.9	0.0	1.62
229	4404.3	498.	43.	0.0	13.8	0.0	27.1	0.0	1.62
230	4404.3	498.	43.	0.0	15.9	0.0	25.9	0.0	1.62
231	4404.3	498.	20.	0.0	10.4	0.0	6.4	0.0	3.47
232	4403.5	487.	11.	0.0	7.5	9.2	0.0	0.0	5.22
233	4402.4	470.	8.	0.0	14.4	4.0	0.0	0.0	6.56
234	4400.5	445.	25.	0.0	22.1	20.4	0.0	0.0	7.45
235	4397.8	411.	25.	0.0	26.6	25.9	0.0	0.0	7.08
236	4395.6	383.	24.	0.0	29.7	17.2	0.0	0.0	5.68
237	4394.9	374.	22.	0.0	18.1	8.6	0.0	0.0	4.27
238	4393.3	354.	10.	0.0	15.0	12.3	0.0	0.0	2.73
239	4394.0	363.	17.	0.0	6.9	0.0	0.0	0.0	1.26
240	4394.6	370.	16.	0.0	7.1	0.0	0.0	0.0	1.28

Table 10.--*Monthly reservoir stresses for the 28-year operations-study data with no hydraulic connection to the aquifer*--Continued

Month	End-of-month		Reservoir inflow		Reservoir releases				Reservoir evaporation
	Elevation (feet)	Contents	River flow	Aquifer flow	Required	Project	Spill	Aquifer flow to river	
241	4395.0	375.	19.	0.0	12.1	0.0	0.0	0.0	1.29
242	4395.3	379.	18.	0.0	12.6	0.0	0.0	0.0	1.31
243	4395.7	384.	16.	0.0	7.8	0.0	0.0	0.0	2.83
244	4394.4	367.	19.	0.0	15.1	16.5	0.0	0.0	4.24
245	4392.9	348.	10.	0.0	14.9	9.3	0.0	0.0	5.26
246	4392.5	345.	80.	0.0	39.2	38.3	0.0	0.0	6.05
247	4390.8	327.	83.	0.0	46.5	48.4	0.0	0.0	5.93
248	4386.4	283.	25.	0.0	30.6	34.3	0.0	0.0	4.74
249	4384.0	260.	18.	0.0	20.7	17.3	0.0	0.0	3.43
250	4381.0	230.	5.	0.0	10.8	22.1	0.0	0.0	2.13
251	4382.0	239.	17.	0.0	6.6	0.0	0.0	0.0	.97
252	4382.8	248.	28.	0.0	18.2	0.0	0.0	0.0	.99
253	4383.4	253.	34.	0.0	27.0	0.0	0.0	0.0	1.00
254	4383.8	257.	20.	0.0	15.3	0.0	0.0	0.0	1.02
255	4384.3	262.	29.	0.0	21.7	0.0	0.0	0.0	2.20
256	4383.2	251.	19.	0.0	16.0	10.6	0.0	0.0	3.32
257	4381.4	234.	13.	0.0	21.1	5.1	0.0	0.0	4.12
258	4378.2	206.	27.	0.0	26.4	23.8	0.0	0.0	4.57
259	4373.2	167.	27.	0.0	31.2	30.1	0.0	0.0	4.08
260	4368.4	136.	24.	0.0	31.5	20.5	0.0	0.0	3.02
261	4365.7	120.	22.	0.0	25.3	10.3	0.0	0.0	2.11
262	4361.8	98.	8.	0.0	15.3	14.1	0.0	0.0	1.26
263	4363.5	107.	17.	0.0	7.4	0.0	0.0	0.0	.57
264	4364.7	114.	16.	0.0	7.8	0.0	0.0	0.0	.59
265	4365.8	121.	16.	0.0	8.5	0.0	0.0	0.0	.61
266	4366.6	125.	13.	0.0	8.0	0.0	0.0	0.0	.63
267	4367.4	130.	26.	0.0	20.1	0.0	0.0	0.0	1.39
268	4367.0	128.	19.	0.0	11.8	7.5	0.0	0.0	2.12
269	4379.4	215.	145.	0.0	51.2	2.8	0.0	0.0	3.28
270	4394.7	371.	257.	0.0	94.6	1.6	0.0	0.0	5.43
271	4393.2	352.	33.	0.0	18.1	27.0	0.0	0.0	6.23
272	4390.1	320.	25.	0.0	30.5	21.3	0.0	0.0	5.04
273	4388.8	307.	22.	0.0	24.6	6.5	0.0	0.0	3.75
274	4387.2	291.	38.	0.0	42.0	9.9	0.0	0.0	2.40
275	4391.5	335.	69.	0.0	23.8	0.0	0.0	0.0	1.15
276	4396.0	388.	74.	0.0	19.5	0.0	0.0	0.0	1.27
277	4401.4	457.	71.	0.0	1.0	0.0	0.0	0.0	1.42
278	4404.3	498.	50.	0.0	.6	0.0	6.4	0.0	1.57
279	4404.3	498.	36.	0.0	5.4	0.0	25.9	0.0	3.47
280	4404.3	498.	102.	0.0	2.2	0.0	94.1	0.0	5.27
281	4404.3	498.	136.	0.0	38.4	0.0	91.2	0.0	6.76
282	4404.3	498.	310.	0.0	84.6	0.0	217.4	0.0	7.96
283	4403.6	487.	64.	0.0	34.2	32.3	0.0	0.0	7.90
284	4400.9	451.	34.	0.0	38.5	25.1	0.0	0.0	6.46
285	4399.7	434.	49.	0.0	42.2	18.4	0.0	0.0	4.81
286	4398.8	423.	37.	0.0	35.9	9.9	0.0	0.0	3.09
287	4401.4	457.	55.	0.0	19.7	0.0	0.0	0.0	1.47
288	4404.0	493.	49.	0.0	11.0	0.0	0.0	0.0	1.56
289	4404.3	498.	65.	0.0	19.4	0.0	39.1	0.0	1.61
290	4404.3	498.	46.	0.0	.6	0.0	43.6	0.0	1.62
291	4404.3	498.	53.	0.0	5.3	0.0	44.5	0.0	3.47
292	4404.3	498.	87.	0.0	33.9	7.5	40.7	0.0	5.27
293	4404.3	498.	203.	0.0	16.9	0.0	179.7	0.0	6.76
294	4404.3	498.	88.	0.0	34.9	5.7	39.4	0.0	7.96
295	4401.8	462.	37.	0.0	37.8	27.2	0.0	0.0	7.73
296	4399.2	429.	34.	0.0	40.5	19.9	0.0	0.0	6.20
297	4399.1	428.	75.	0.0	61.9	9.8	0.0	0.0	4.69
298	4398.7	422.	51.	0.0	43.1	9.9	0.0	0.0	3.07
299	4399.9	438.	35.	0.0	17.6	0.0	0.0	0.0	1.44
300	4401.7	460.	31.	0.0	7.3	0.0	0.0	0.0	1.49

Table 10.--*Monthly reservoir stresses for the 28-year operations-study data with no hydraulic connection to the aquifer*--Continued

Month	End-of-month		Reservoir inflow		Reservoir releases				Reservoir evaporation
	Elevation (feet)	Contents	River flow	Aquifer flow	Required	Project	Spill	Aquifer flow to river	
301	4403.4	484.	47.	0.0	21.1	0.0	0.0	0.0	1.55
302	4404.3	498.	30.	0.0	9.8	0.0	5.1	0.0	1.60
303	4404.3	498.	27.	0.0	10.2	0.0	13.7	0.0	3.47
304	4403.4	484.	17.	0.0	8.9	16.8	0.0	0.0	5.21
305	4401.9	463.	12.	0.0	16.3	9.7	0.0	0.0	6.51
306	4398.8	423.	43.	0.0	36.5	39.3	0.0	0.0	7.27
307	4394.1	363.	26.	0.0	30.2	49.7	0.0	0.0	6.64
308	4389.7	317.	32.	0.0	37.8	35.1	0.0	0.0	5.08
309	4387.6	296.	23.	0.0	22.8	17.8	0.0	0.0	3.70
310	4384.8	267.	17.	0.0	20.0	22.6	0.0	0.0	2.31
311	4385.9	278.	26.	0.0	13.9	0.0	0.0	0.0	1.06
312	4388.1	301.	34.	0.0	10.6	0.0	0.0	0.0	1.09
313	4391.9	338.	55.	0.0	16.0	0.0	0.0	0.0	1.16
314	4395.2	378.	50.	0.0	9.1	0.0	0.0	0.0	1.26
315	4398.4	418.	54.	0.0	11.5	0.0	0.0	0.0	2.92
316	4402.9	478.	83.	0.0	10.8	7.5	0.0	0.0	4.85
317	4404.3	498.	571.	0.0	136.6	0.0	407.3	0.0	6.74
318	4404.3	498.	235.	0.0	56.1	0.0	171.0	0.0	7.96
319	4404.2	497.	65.	0.0	50.0	7.9	0.0	0.0	7.95
320	4400.5	445.	39.	0.0	39.5	44.1	0.0	0.0	6.48
321	4402.3	468.	75.	0.0	32.0	15.3	0.0	0.0	4.93
322	4404.3	498.	83.	0.0	27.0	9.9	13.5	0.0	3.42
323	4404.3	498.	79.	0.0	33.6	0.0	44.2	0.0	1.62
324	4404.3	498.	40.	0.0	3.7	0.0	34.2	0.0	1.62
325	4404.3	498.	56.	0.0	1.0	0.0	53.0	0.0	1.62
326	4404.3	498.	38.	0.0	.6	0.0	35.7	0.0	1.62
327	4404.3	498.	53.	0.0	.6	0.0	48.7	0.0	3.47
328	4404.3	498.	69.	0.0	7.5	11.0	44.8	0.0	5.27
329	4403.4	485.	33.	0.0	33.5	5.3	0.0	0.0	6.70
330	4401.8	462.	52.	0.0	42.3	24.7	0.0	0.0	7.66
331	4398.5	420.	35.	0.0	38.8	31.2	0.0	0.0	7.24
332	4395.9	386.	36.	0.0	43.1	21.2	0.0	0.0	5.74
333	4395.2	378.	52.	0.0	44.8	10.6	0.0	0.0	4.30
334	4393.9	361.	27.	0.0	26.2	14.6	0.0	0.0	2.76
335	4394.9	374.	31.	0.0	17.2	0.0	0.0	0.0	1.28
336	4396.1	389.	32.	0.0	14.7	0.0	0.0	0.0	1.32

Table 11.--*Monthly reservoir stresses for the 28-year operations-study data*

[All stresses except end-of-month elevation are in thousands of acre-feet]

Month	End-of-month		Reservoir inflow		Reservoir releases				Reservoir evaporation
	Elevation (feet)	Contents	River flow	Aquifer flow	Required	Project	Spill	Aquifer flow to river	
1	4331.0	7.	25.	-4.3	14.0	0.0	0.0	-1.0	.05
2	4335.6	13.	22.	-2.8	12.4	0.0	0.0	.0	.13
3	4347.4	39.	48.	-6.7	14.2	0.0	0.0	.0	.56
4	4349.3	46.	19.	-4.2	6.9	0.0	0.0	.0	1.14
5	4348.8	44.	68.	-1.9	66.8	0.0	0.0	.0	1.50
6	4381.4	234.	313.	-38.7	62.2	18.5	0.0	.0	3.42
7	4381.5	234.	109.	-19.2	34.2	50.5	0.0	.0	4.71
8	4377.5	200.	33.	-.6	41.1	21.3	0.0	.0	3.85
9	4376.1	190.	33.	.8	36.8	4.8	0.0	.0	2.79
10	4375.0	181.	26.	.3	26.7	7.0	0.0	.1	1.77
11	4376.0	188.	28.	-2.4	17.5	0.0	0.0	.1	.82
12	4377.4	199.	34.	-4.2	18.6	0.0	0.0	.1	.85
13	4379.1	212.	41.	-5.3	21.2	0.0	0.0	.1	.89
14	4383.5	255.	56.	-10.8	2.1	0.0	0.0	.1	.96
15	4390.0	319.	85.	-17.5	1.2	0.0	0.0	.1	2.34
16	4391.3	332.	65.	-12.9	18.5	16.7	0.0	.2	3.84
17	4390.7	326.	67.	-5.5	60.4	2.5	0.0	.2	4.97
18	4391.0	329.	71.	-4.7	52.6	5.1	0.0	.2	5.84
19	4386.8	287.	20.	3.8	29.4	31.5	0.0	.2	5.60
20	4384.9	268.	19.	4.1	28.4	9.6	0.0	.2	4.47
21	4383.2	251.	19.	2.8	24.9	10.5	0.0	.3	3.34
22	4381.5	235.	15.	3.3	18.8	14.5	0.0	.3	2.12
23	4382.0	239.	12.	.2	7.3	0.0	0.0	.3	.97
24	4382.5	245.	18.	-1.5	10.7	0.0	0.0	.3	.98
25	4384.7	266.	27.	-4.8	0.0	0.0	0.0	.4	1.02
26	4386.1	281.	21.	-5.2	0.0	0.0	0.0	.4	1.06
27	4386.6	286.	20.	-3.7	9.2	0.0	0.0	.4	2.32
28	4384.1	260.	23.	2.1	17.4	29.3	0.0	.4	3.44
29	4383.5	255.	22.	1.3	25.1	.2	0.0	.4	4.27
30	4404.3	498.	476.	-55.2	96.3	27.1	48.2	.4	6.76
31	4403.2	481.	61.	-12.1	37.7	20.8	0.0	.5	7.83
32	4401.0	451.	23.	-1.8	37.7	6.8	0.0	.5	6.42
33	4399.2	429.	22.	.6	27.6	12.9	0.0	.5	4.79
34	4398.0	414.	9.	-.1	15.7	6.0	0.0	.5	3.05
35	4399.3	430.	42.	-5.1	19.0	0.0	0.0	.5	1.42
36	4399.6	434.	19.	-5.1	9.7	0.0	0.0	.5	1.45
37	4399.7	435.	17.	-4.1	11.0	0.0	0.0	.6	1.45
38	4399.9	438.	15.	-4.2	7.2	0.0	0.0	.6	1.46
39	4400.6	447.	18.	-5.4	.8	0.0	0.0	.6	3.17
40	4400.3	442.	19.	-2.9	10.3	5.5	0.0	.6	4.82
41	4399.1	427.	18.	-.3	26.8	0.0	0.0	.7	6.08
42	4396.1	388.	32.	4.9	37.0	32.1	0.0	.7	6.82
43	4393.1	350.	21.	7.1	29.3	31.2	0.0	.7	6.34
44	4390.0	319.	17.	8.3	26.1	26.0	0.0	.7	5.02
45	4389.1	310.	20.	4.5	20.7	9.9	0.0	.8	3.76
46	4386.6	286.	6.	6.0	15.0	20.1	0.0	.8	2.39
47	4387.9	299.	18.	.7	5.7	0.0	0.0	.8	1.10
48	4388.5	304.	12.	-1.0	5.3	0.0	0.0	.8	1.12
49	4389.2	311.	17.	-1.5	8.6	0.0	0.0	.8	1.14
50	4389.8	317.	15.	-1.8	7.2	0.0	0.0	.8	1.15
51	4389.9	318.	13.	-1.2	9.4	0.0	0.0	.8	2.49
52	4390.2	321.	14.	-1.5	6.4	0.0	0.0	.8	3.80
53	4389.4	313.	17.	.5	20.9	0.0	0.0	.8	4.85
54	4388.9	309.	44.	.8	40.2	4.4	0.0	.8	5.64
55	4385.7	277.	31.	5.7	36.1	27.7	0.0	.8	5.42
56	4386.1	280.	66.	2.1	49.3	11.9	0.0	.8	4.48
57	4386.0	280.	28.	.6	23.7	2.8	0.0	.8	3.50
58	4385.3	273.	7.	1.7	14.4	0.0	0.0	.8	2.28
59	4386.5	285.	21.	-1.2	7.2	0.0	0.0	.8	1.07
60	4387.2	291.	24.	-1.9	15.0	0.0	0.0	.8	1.09
61	4387.7	297.	28.	-1.8	19.9	0.0	0.0	.8	1.11
62	4389.4	314.	29.	-4.1	7.5	0.0	0.0	.8	1.13
63	4391.0	329.	23.	-5.4	0.0	0.0	0.0	.8	2.51
64	4392.2	342.	37.	-5.3	16.3	0.0	0.0	.8	3.92
65	4395.4	380.	86.	-9.6	33.4	0.0	0.0	.8	5.30
66	4395.6	382.	97.	-5.5	61.5	21.8	0.0	.8	6.48
67	4390.8	327.	28.	6.0	36.4	47.6	0.0	.8	6.14
68	4388.3	303.	26.	7.2	36.6	16.3	0.0	.8	4.84
69	4387.5	295.	26.	3.6	30.6	4.3	0.0	.8	3.64
70	4384.9	269.	11.	5.8	17.5	23.3	0.0	.8	2.31

Table 11.--*Monthly reservoir stresses for the 28-year operations-study data*--Continued

Month	End-of-month Elevation (feet)	End-of-month Contents	Reservoir inflow River flow	Reservoir inflow Aquifer flow	Reservoir releases Required	Reservoir releases Project	Reservoir releases Spill	Reservoir releases Aquifer flow to river	Reservoir evaporation
71	4386.1	280.	19.	.7	7.8	0.0	0.0	.8	1.06
72	4386.7	286.	14.	-1.0	6.3	0.0	0.0	.8	1.08
73	4387.3	293.	18.	-1.4	9.6	0.0	0.0	.8	1.10
74	4387.9	298.	16.	-1.6	8.7	0.0	0.0	.8	1.11
75	4388.3	302.	23.	-1.6	15.8	0.0	0.0	.8	2.41
76	4389.1	311.	19.	-2.4	5.3	.2	0.0	.8	3.70
77	4385.1	270.	12.	5.8	17.8	36.4	0.0	.8	4.58
78	4384.1	260.	34.	4.3	34.9	8.9	0.0	.8	5.12
79	4380.5	225.	23.	7.5	33.9	27.9	0.0	.8	4.85
80	4379.1	213.	27.	5.5	33.7	8.2	0.0	.8	3.89
81	4376.0	189.	17.	6.6	24.6	21.2	0.0	.8	2.84
82	4374.5	177.	10.	5.2	16.9	9.0	0.0	.8	1.76
83	4376.2	190.	20.	.2	7.6	0.0	0.0	.8	.82
84	4376.9	196.	14.	-.9	7.1	0.0	0.0	.8	.85
85	4377.5	201.	16.	-.9	9.8	0.0	0.0	.8	.86
86	4378.1	204.	13.	-.9	7.7	0.0	0.0	.8	.88
87	4378.2	206.	12.	-.5	9.4	0.0	0.0	.7	1.90
88	4375.3	183.	12.	4.2	12.1	24.3	0.0	.7	2.78
89	4373.2	167.	7.	4.6	19.0	6.0	0.0	.7	3.33
90	4365.5	119.	14.	10.4	20.2	49.4	0.0	.7	3.41
91	4361.9	98.	13.	7.6	17.0	22.6	0.0	.7	2.90
92	4361.1	94.	16.	4.2	21.6	0.0	0.0	.7	2.30
93	4360.9	93.	13.	2.5	14.8	1.1	0.0	.7	1.76
94	4360.8	93.	11.	1.8	12.2	0.0	0.0	.7	1.15
95	4362.5	101.	21.	-.1	13.1	0.0	0.0	.7	.55
96	4364.0	110.	17.	-1.1	7.2	0.0	0.0	.7	.58
97	4364.5	114.	20.	-.7	15.7	0.0	0.0	.7	.60
98	4365.4	118.	16.	-.2	11.0	0.0	0.0	.7	.61
99	4366.5	124.	17.	-.9	9.1	0.0	0.0	.7	1.35
100	4366.2	123.	16.	.2	15.4	1.3	0.0	.7	2.07
101	4365.2	117.	8.	1.5	13.1	0.0	0.0	.7	2.60
102	4365.2	117.	13.	.9	9.0	2.4	0.0	.6	3.02
103	4363.2	105.	10.	1.8	20.6	.8	0.0	.6	2.92
104	4362.3	100.	18.	1.7	23.4	0.0	0.0	.6	2.38
105	4361.9	98.	15.	1.2	16.8	0.0	0.0	.6	1.81
106	4362.0	98.	17.	.6	15.4	1.0	0.0	.6	1.19
107	4363.2	105.	12.	-.7	5.4	0.0	0.0	.6	.56
108	4364.3	111.	14.	-1.2	6.1	0.0	0.0	.6	.59
109	4365.1	116.	14.	-1.3	8.3	0.0	0.0	.6	.60
110	4366.0	122.	14.	-.7	8.0	0.0	0.0	.6	.62
111	4366.2	123.	12.	-.5	9.3	0.0	0.0	.6	1.35
112	4366.0	122.	13.	.1	12.8	0.0	0.0	.6	2.05
113	4365.2	117.	20.	1.0	23.8	0.0	0.0	.6	2.60
114	4364.7	114.	25.	.8	25.8	.5	0.0	.6	3.00
115	4363.3	105.	15.	1.3	21.0	1.7	0.0	.6	2.91
116	4362.4	100.	18.	1.4	21.9	.4	0.0	.6	2.38
117	4360.4	91.	7.	2.4	17.2	.3	0.0	.6	1.78
118	4360.5	92.	14.	1.1	14.2	0.0	0.0	.6	1.14
119	4363.4	106.	24.	-2.2	7.8	0.0	0.0	.6	.56
120	4364.4	112.	15.	-1.9	7.2	0.0	0.0	.6	.59
121	4365.3	118.	12.	-1.1	5.5	0.0	0.0	.6	.61
122	4366.0	122.	13.	-1.2	7.2	0.0	0.0	.6	.62
123	4367.3	130.	19.	-1.8	8.5	0.0	0.0	.6	1.38
124	4367.2	129.	14.	-.7	12.4	0.0	0.0	.6	2.12
125	4382.7	246.	215.	-22.7	72.2	0.0	0.0	.6	3.51
126	4389.6	316.	188.	-22.5	75.3	16.5	0.0	.6	5.29
127	4389.1	310.	90.	-9.0	71.1	10.2	0.0	.6	5.65
128	4388.1	300.	59.	-2.5	59.7	2.2	0.0	.6	4.73
129	4386.4	284.	30.	.4	32.5	11.4	0.0	.6	3.58
130	4384.7	266.	14.	2.2	18.6	13.4	0.0	.6	2.28
131	4385.6	275.	26.	-1.7	15.1	0.0	0.0	.6	1.05
132	4387.1	290.	53.	-4.4	33.2	0.0	0.0	.6	1.08
133	4390.5	325.	45.	-8.9	0.0	0.0	0.0	.6	1.14
134	4392.6	345.	33.	-9.7	2.0	0.0	0.0	.6	1.20
135	4394.5	370.	36.	-9.2	0.0	0.0	0.0	.6	2.70
136	4397.3	404.	57.	-11.1	7.2	0.0	0.0	.6	4.34
137	4404.3	498.	310.	-30.4	65.1	25.1	90.2	.6	6.52
138	4404.3	498.	106.	-8.0	27.1	4.8	58.8	.6	7.96
139	4403.4	485.	32.	-4.2	27.9	5.5	0.0	.7	7.88
140	4401.2	454.	25.	1.1	36.3	15.7	0.0	.7	6.46

Table 11.--*Monthly reservoir stresses for the 28-year operations-study data*--Continued

Month	End-of-month Elevation (feet)	End-of-month Contents	Reservoir inflow River flow	Reservoir inflow Aquifer flow	Reservoir releases Required	Reservoir releases Project	Reservoir releases Spill	Reservoir releases Aquifer flow to river	Reservoir evaporation
141	4400.4	444.	23.	.5	27.4	1.9	0.0	.7	4.86
142	4398.1	415.	20.	2.6	23.4	25.4	0.0	.7	3.09
143	4398.9	424.	24.	-1.9	12.2	0.0	0.0	.8	1.42
144	4399.2	429.	18.	-3.5	8.9	0.0	0.0	.8	1.43
145	4399.5	433.	17.	-3.5	8.9	0.0	0.0	.8	1.44
146	4399.6	434.	15.	-3.1	9.4	0.0	0.0	.8	1.45
147	4400.4	444.	29.	-4.7	11.7	0.0	0.0	.8	3.15
148	4401.6	459.	55.	-6.1	0.0	30.1	0.0	.9	4.89
149	4403.6	487.	45.	-8.9	2.3	0.0	0.0	.9	6.50
150	4401.6	459.	41.	-.6	36.4	25.6	0.0	.9	7.64
151	4397.9	412.	24.	7.3	32.9	40.0	0.0	.9	7.17
152	4395.4	380.	25.	7.2	34.0	25.1	0.0	.9	5.67
153	4394.7	372.	26.	3.3	30.8	3.0	0.0	.9	4.25
154	4393.9	361.	9.	2.2	16.7	3.9	0.0	.9	2.74
155	4394.6	370.	21.	-.9	9.5	0.0	0.0	.9	1.28
156	4395.3	379.	19.	-2.1	8.4	0.0	0.0	1.0	1.30
157	4395.8	386.	28.	-2.5	18.4	0.0	0.0	1.0	1.32
158	4396.5	394.	37.	-3.0	25.4	0.0	0.0	1.0	1.34
159	4398.7	422.	63.	-6.7	26.9	0.0	0.0	1.0	2.98
160	4399.6	434.	37.	-6.1	6.3	8.5	0.0	1.0	4.68
161	4399.0	425.	42.	-2.2	37.6	5.7	0.0	1.0	6.03
162	4395.6	382.	40.	5.4	36.3	46.5	0.0	1.0	6.76
163	4393.0	350.	25.	6.7	32.8	26.0	0.0	1.0	6.30
164	4388.9	308.	16.	10.1	24.5	38.7	0.0	1.0	4.97
165	4387.4	294.	22.	7.0	26.8	14.0	0.0	1.0	3.66
166	4386.5	285.	12.	4.7	18.1	6.4	0.0	1.0	2.35
167	4387.2	292.	14.	1.3	8.0	0.0	0.0	1.0	1.09
168	4387.8	298.	14.	-.2	8.0	0.0	0.0	1.0	1.11
169	4388.4	303.	16.	-.7	9.0	0.0	0.0	1.0	1.12
170	4388.9	308.	18.	-.9	12.3	0.0	0.0	1.0	1.13
171	4389.2	312.	39.	-1.0	32.9	0.0	0.0	.9	2.46
172	4388.4	303.	20.	1.1	13.3	13.8	0.0	.9	3.70
173	4391.4	333.	74.	-5.2	35.1	0.0	0.0	.9	4.87
174	4400.1	440.	203.	-21.2	26.8	42.0	0.0	.9	6.58
175	4398.5	420.	31.	-8.4	34.5	2.1	0.0	.9	7.07
176	4396.1	389.	30.	2.5	38.1	20.3	0.0	.9	5.76
177	4396.6	395.	63.	-1.1	49.7	3.3	0.0	.9	4.39
178	4398.6	420.	102.	-6.4	34.6	33.1	0.0	.9	2.98
179	4402.6	472.	89.	-14.1	22.3	0.0	0.0	.9	1.49
180	4404.3	498.	59.	-13.2	0.0	0.0	19.0	.9	1.60
181	4404.3	498.	58.	-4.9	1.5	0.0	50.4	.9	1.62
182	4404.3	498.	75.	-4.2	1.9	0.0	68.3	.9	1.62
183	4404.3	498.	73.	-3.7	10.9	0.0	55.4	.9	3.47
184	4404.3	498.	53.	-3.4	24.2	11.7	9.1	1.0	5.27
185	4403.1	481.	21.	-.3	25.5	5.9	0.0	1.0	6.67
186	4402.5	471.	50.	.2	26.3	26.6	0.0	1.0	7.69
187	4400.0	439.	48.	4.8	44.4	33.7	0.0	1.0	7.42
188	4398.3	417.	36.	4.6	34.2	23.1	0.0	1.0	6.02
189	4397.1	402.	31.	3.5	34.7	11.6	0.0	1.0	4.53
190	4395.5	382.	12.	4.2	19.0	15.6	0.0	1.0	2.89
191	4396.3	391.	19.	-.1	9.2	0.0	0.0	1.1	1.33
192	4396.8	397.	19.	-1.8	10.7	0.0	0.0	1.1	1.35
193	4397.3	405.	28.	-2.3	17.8	0.0	0.0	1.1	1.37
194	4398.7	422.	32.	-4.4	10.0	0.0	0.0	1.1	1.40
195	4400.2	441.	29.	-6.0	1.3	0.0	0.0	1.1	3.11
196	4399.1	427.	15.	-1.6	13.4	10.5	0.0	1.1	4.73
197	4397.7	410.	10.	2.0	19.9	5.0	0.0	1.1	5.91
198	4395.7	384.	32.	4.3	32.1	23.5	0.0	1.1	6.68
199	4393.1	350.	23.	6.7	28.9	29.7	0.0	1.1	6.31
200	4390.6	325.	23.	7.6	30.9	20.2	0.0	1.1	5.05
201	4389.8	317.	26.	4.9	25.7	10.2	0.0	1.1	3.81
202	4388.2	302.	3.	4.9	8.6	13.9	0.0	1.1	2.45
203	4389.3	312.	17.	.8	7.4	0.0	0.0	1.1	1.14
204	4390.0	320.	17.	-.9	8.6	0.0	0.0	1.0	1.16
205	4390.5	325.	13.	-1.0	7.2	0.0	0.0	1.0	1.17
206	4390.9	329.	13.	-1.0	8.1	0.0	0.0	1.0	1.18
207	4391.2	331.	16.	-.9	11.1	0.0	0.0	1.0	2.56
208	4391.0	330.	23.	-.1	17.2	4.0	0.0	1.0	3.88
209	4389.7	317.	13.	2.6	23.2	2.3	0.0	1.0	4.91
210	4388.6	305.	33.	3.1	33.7	9.3	0.0	1.0	5.62

Table 11.--*Monthly reservoir stresses for the 28-year operations-study data*--Continued

Month	End-of-month		Reservoir inflow		Reservoir releases				Reser-voir evapo-ration
	Elevation (feet)	Contents	River flow	Aquifer flow	Required	Project	Spill	Aquifer flow to river	
210	4388.6	305.	33.	3.1	33.7	9.3	0.0	1.0	5.64
211	4386.8	288.	25.	4.6	31.2	11.7	0.0	1.0	5.47
212	4385.3	273.	23.	5.0	31.8	8.3	0.0	1.0	4.49
213	4384.5	265.	18.	3.6	23.0	4.2	0.0	1.0	3.41
214	4383.5	254.	10.	3.6	17.7	5.3	0.0	1.0	2.20
215	4384.5	264.	19.	.4	9.2	0.0	0.0	1.0	1.02
216	4385.2	271.	14.	-.8	6.2	0.0	0.0	.9	1.04
217	4385.7	277.	11.	-.5	4.4	0.0	0.0	.9	1.06
218	4386.2	281.	14.	-.7	8.7	0.0	0.0	.9	1.07
219	4386.5	285.	18.	-.7	12.1	0.0	0.0	.9	2.32
220	4385.8	278.	20.	1.1	18.3	7.4	0.0	.9	3.50
221	4384.8	267.	18.	2.7	27.9	0.0	0.0	.9	4.41
222	4399.1	427.	213.	-27.6	20.0	.1	0.0	.9	6.12
223	4399.2	429.	79.	-14.3	27.1	29.7	0.0	.9	7.04
224	4400.3	443.	84.	-9.3	41.7	13.2	0.0	.9	6.10
225	4400.2	441.	47.	-4.6	33.6	6.5	0.0	.9	4.80
226	4402.3	469.	83.	-8.9	34.4	9.9	0.0	.9	3.24
227	4404.3	498.	62.	-12.3	11.0	0.0	9.1	.9	1.59
228	4404.3	498.	38.	-5.1	1.0	0.0	30.7	.9	1.62
229	4404.3	498.	43.	-4.3	13.8	0.0	23.7	.9	1.62
230	4404.3	498.	43.	-3.8	15.9	0.0	23.0	.9	1.62
231	4404.3	498.	20.	-3.5	10.4	0.0	3.9	.9	3.47
232	4403.5	486.	11.	-1.3	7.5	9.2	0.0	1.0	5.22
233	4402.5	471.	8.	.6	14.4	4.0	0.0	1.0	6.56
234	4400.9	450.	25.	2.8	22.1	20.4	0.0	1.0	7.49
235	4398.7	422.	25.	5.0	26.6	25.9	0.0	1.0	7.18
236	4396.9	399.	24.	4.9	29.7	17.2	0.0	1.0	5.63
237	4396.5	394.	22.	2.3	18.1	8.6	0.0	1.0	4.42
238	4395.2	378.	10.	3.1	15.0	12.3	0.0	1.0	2.85
239	4396.0	387.	17.	-.4	6.9	0.0	0.0	1.1	1.32
240	4396.4	393.	16.	-1.8	7.1	0.0	0.0	1.1	1.34
241	4396.8	398.	19.	-1.8	12.1	0.0	0.0	1.1	1.35
242	4397.0	401.	18.	-1.8	12.6	0.0	0.0	1.1	1.36
243	4397.3	405.	16.	-1.9	7.8	0.0	0.0	1.1	2.95
244	4396.2	390.	19.	1.0	15.1	16.5	0.0	1.1	4.43
245	4395.0	374.	10.	2.8	14.9	9.3	0.0	1.1	5.52
246	4394.8	373.	80.	.7	39.2	38.3	0.0	1.1	6.39
247	4393.7	358.	83.	2.1	46.5	48.4	0.0	1.1	6.28
248	4390.3	322.	25.	7.6	30.6	34.3	0.0	1.1	5.07
249	4388.7	306.	18.	6.5	20.7	17.3	0.0	1.0	3.76
250	4386.4	284.	5.	6.8	10.8	22.1	0.0	1.0	2.38
251	4387.6	295.	17.	1.5	6.6	0.0	0.0	1.0	1.10
252	4388.5	304.	28.	-.8	18.2	0.0	0.0	1.0	1.12
253	4389.0	310.	34.	-.9	27.0	0.0	0.0	1.0	1.14
254	4389.4	314.	20.	-.8	15.3	0.0	0.0	1.0	1.15
255	4389.9	318.	29.	-1.0	21.7	0.0	0.0	1.0	2.49
256	4389.0	309.	19.	1.2	16.0	10.6	0.0	1.0	3.75
257	4387.6	295.	13.	3.3	21.1	5.1	0.0	1.0	4.70
258	4385.4	273.	27.	5.6	26.4	23.8	0.0	1.0	5.33
259	4382.3	242.	27.	7.8	31.2	30.1	0.0	1.0	5.02
260	4380.0	219.	24.	7.9	31.5	20.5	0.0	1.0	4.01
261	4378.6	208.	22.	4.9	25.3	10.3	0.0	1.0	2.98
262	4376.4	192.	8.	5.6	15.3	14.1	0.0	.9	1.87
263	4377.8	202.	17.	.9	7.4	0.0	0.0	.9	.86
264	4378.7	210.	16.	-.9	7.8	0.0	0.0	.9	.89
265	4379.5	216.	16.	-1.0	8.5	0.0	0.0	.9	.91
266	4380.0	220.	13.	-1.0	8.0	0.0	0.0	.9	.93
267	4380.6	226.	26.	.7	20.1	0.0	0.0	.9	2.02
268	4380.5	224.	19.	1.0	11.8	7.5	0.0	.9	3.08
269	4388.0	299.	145.	-12.0	51.2	2.8	0.0	.9	4.33
270	4399.0	426.	257.	-29.1	94.6	1.6	0.0	.9	6.28
271	4396.9	399.	33.	-8.7	18.1	27.0	0.0	.8	6.85
272	4394.5	369.	25.	1.7	30.5	21.3	0.0	.8	5.54
273	4393.6	357.	22.	.7	24.6	6.5	0.0	.8	4.14
274	4392.3	343.	38.	1.4	42.0	9.9	0.0	.8	2.66
275	4395.5	381.	69.	-6.5	23.8	0.0	0.0	.8	1.27
276	4398.8	423.	74.	-11.3	19.5	0.0	0.0	.8	1.37
277	4402.8	476.	71.	-16.7	1.0	0.0	0.0	.9	1.49
278	4404.3	498.	50.	-13.2	.6	0.0	13.5	.9	1.60
279	4404.3	498.	36.	-5.4	5.4	0.0	22.4	.9	3.47
280	4404.3	498.	102.	-4.5	2.2	0.0	90.5	.9	5.27

Table 11.--*Monthly reservoir stresses for the 28-year operations-study data*--Continued

Month	End-of-month Elevation (feet)	End-of-month Contents	Reservoir inflow River flow	Reservoir inflow Aquifer flow	Reservoir releases Required	Reservoir releases Project	Reservoir releases Spill	Reservoir releases Aquifer flow to river	Reservoir evaporation
281	4404.3	498.	136.	-4.0	38.4	0.0	88.1	.9	6.76
282	4404.3	498.	310.	-3.7	84.6	0.0	214.7	.9	7.96
283	4403.5	487.	64.	-1.5	34.2	32.3	0.0	.9	7.89
284	4401.2	455.	34.	3.4	38.5	25.1	0.0	1.0	6.47
285	4400.3	442.	49.	3.0	42.2	18.4	0.0	1.0	4.86
286	4399.5	433.	37.	1.3	35.9	9.9	0.0	1.0	3.14
287	4401.8	462.	55.	-5.9	19.7	0.0	0.0	1.0	1.49
288	4403.8	490.	49.	-8.7	11.0	0.0	0.0	1.0	1.56
289	4404.3	498.	65.	-6.6	19.4	0.0	30.9	1.0	1.61
290	4404.3	498.	46.	-3.2	.6	0.0	40.9	1.0	1.62
291	4404.3	498.	53.	-2.9	5.3	0.0	42.7	1.1	3.47
292	4404.3	498.	87.	-2.7	33.9	7.5	39.1	1.1	5.27
293	4404.3	498.	203.	-2.6	16.9	0.0	178.2	1.1	6.76
294	4404.3	498.	88.	-2.5	34.9	5.7	38.0	1.1	7.96
295	4402.1	466.	37.	3.1	37.8	27.2	0.0	1.1	7.75
296	4400.1	440.	34.	5.7	40.5	19.9	0.0	1.1	6.28
297	4400.2	441.	75.	1.3	61.9	9.8	0.0	1.1	4.79
298	4399.8	437.	51.	.1	43.1	9.9	0.0	1.1	3.15
299	4400.9	450.	35.	-3.0	17.6	0.0	0.0	1.1	1.48
300	4402.3	468.	31.	-5.5	7.3	0.0	0.0	1.1	1.52
301	4403.6	487.	47.	-6.2	21.1	0.0	0.0	1.1	1.56
302	4404.3	498.	30.	-6.0	9.8	0.0	3.1	1.1	1.61
303	4404.3	498.	27.	-3.0	10.2	0.0	11.9	1.1	3.47
304	4403.4	485.	17.	-.3	8.9	16.8	0.0	1.1	5.21
305	4402.2	467.	12.	1.9	16.3	9.7	0.0	1.1	6.53
306	4399.6	434.	43.	6.2	36.5	39.3	0.0	1.1	7.36
307	4395.8	385.	26.	9.8	30.2	49.7	0.0	1.2	6.84
308	4393.0	349.	32.	9.6	37.8	35.1	0.0	1.2	5.36
309	4391.6	335.	23.	6.7	22.8	17.8	0.0	1.2	3.97
310	4389.6	315.	17.	7.2	20.0	22.6	0.0	1.2	2.53
311	4390.9	328.	26.	1.2	13.9	0.0	0.0	1.2	1.17
312	4392.9	348.	34.	-3.3	10.6	0.0	0.0	1.1	1.21
313	4395.5	381.	55.	-6.3	16.0	0.0	0.0	1.1	1.27
314	4398.0	413.	50.	-8.1	9.1	0.0	0.0	1.1	1.36
315	4400.5	445.	54.	-9.3	11.5	0.0	0.0	1.1	3.09
316	4403.9	492.	83.	-14.1	10.8	7.5	0.0	1.1	5.02
317	4404.3	498.	571.	-8.4	136.6	0.0	413.8	1.1	6.75
318	4404.3	498.	235.	-3.9	56.1	0.0	168.2	1.1	7.96
319	4404.1	495.	65.	-2.9	50.0	7.9	0.0	1.1	7.94
320	4400.9	450.	39.	5.2	39.5	44.1	0.0	1.1	6.48
321	4402.5	472.	75.	-2.4	32.0	15.3	0.0	1.1	4.97
322	4404.3	498.	83.	-8.8	27.0	9.9	9.0	1.1	3.42
323	4404.3	498.	79.	-3.1	33.6	0.0	42.2	1.1	1.62
324	4404.3	498.	40.	-2.7	3.7	0.0	32.6	1.1	1.62
325	4404.3	498.	56.	-2.5	1.0	0.0	51.5	1.1	1.62
326	4404.3	498.	38.	-2.4	.6	0.0	33.9	1.1	1.62
327	4404.3	498.	53.	-2.3	.6	0.0	47.1	1.1	3.47
328	4404.3	498.	69.	-2.2	7.5	11.0	43.8	1.1	5.27

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