VINCENT

TECHNICAL COMPLETION REPORT

GROUND-WATER MODEL CALIBRATION FOR THE HENRY'S FORK RECHARGE AREA

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Submitted to:
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Purpose

A ground-water flow model of the shallow ground-water system of the Henry's Fork area of southeastern Idaho was initially calibrated by Wytzes (1980). The purpose of this project was to improve the accuracy of the model by recalibration to the data collected by Wytzes (1980) to more closely simulate ground-water levels and gains and losses in the Henry's Fork and Snake rivers.

Procedure

Inaccuracies in model calibration can result from an incorrect concept of the ground-water system or from errors in quantitative estimates in any of the following areas:

1) determination of surface recharge and discharge (surface flux),
2) estimation of leakage parameters,
3) estimation of aquifer transmissivity,
4) establishment of boundaries,
5) determination of initial and calibration (reference) ground-water elevations, or
6) estimation of storage coefficient.

It was determined that for the Henry's Fork - Rigby Fan model conceptual errors or faulty assumptions most likely caused problems apparent during calibration and should receive greatest attention. Evaluation of surface flux was given lowest priority since errors would likely be limited to small areas and would be very difficult to detect.

Conceptual changes in the model were implemented based on physical evidence. Cross-sectional diagrams, prepared from well driller's logs, indicated that the aquifer in the alluvium (modeled aquifer) thins toward the southwest and terminates several miles inside the southwest boundary of the study area. The original boundary was modeled as hydraulically connected (fig. 1) based on the assumption that the shallow system merges with the regional aquifer. The approach was changed to the more representative situation where the aquifer thickness decreases toward the southwest and terminates a few miles inside the original southwest boundary. In this area the bottom of the aquifer was raised, reducing aquifer thickness at some nodes by as much as 100 feet. The southwest model boundary was shifted inward (northeast) several miles to represent the approximate location of termination of the aquifer. This new, impermeable boundary is shown in figure 1.

Initial and reference ground-water elevations were adjusted based on the new concept of the system in the southwest. Head values were adjusted to be representative of the shallow system rather than the combined regional and shallow systems. Adjustments were based on driller's logs and unpublished water level measurements made by Wytzes (1980).

It was anticipated that selection of more appropriate calibration timesteps may improve the results. Ground-water levels from September 9 (timestep 10) were used in place of water levels representing December (timestep 17). This permitted calibration to a time when water levels were at a maximum. The resulting reference timesteps were 4, 10, and 25, representing dates of June 15, September 15, and April 30.

Elevations of hydraulically-connected river reaches were adjusted to be more representative of actual river elevations. The elevations

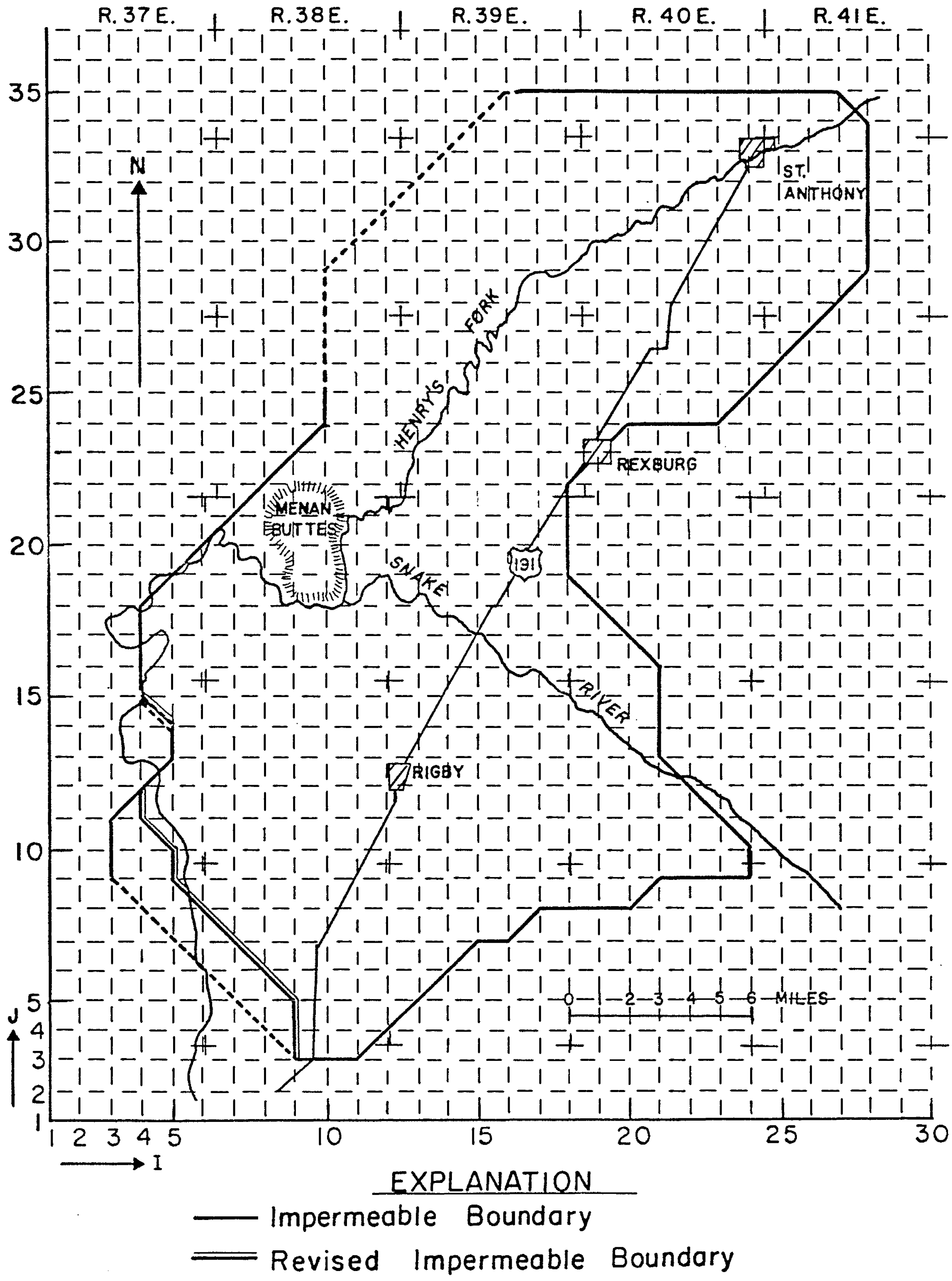


Figure 1. Model Boundary Modifications.

had previously been manipulated by Wytzes (1980) to attempt to match historic river gains and losses. Revised elevations were taken from U. S. Geological Survey river profiles and topographic maps. Elevations were adjusted to represent the center of each cell (node point).

Leakage parameters were evaluated and adjusted to be representative of the new concept of the interaction between the local and regional aquifers. Leakage parameters adjusted during calibration by Wytzes were replaced by values based solely on physical data. The head difference between the modeled aquifer and the regional system was increased in some areas by tens of feet. Head difference can be estimated reasonably well from basic data and generally should not be subject to calibration. The leakage term, FAC, related to vertical hydraulic conductivity between the aquifers, was decreased by as much as an order of magnitude in some places. The changes were based on thickness of the confining bed and typical values of vertical hydraulic conductivity for materials reported in driller's logs (Morris and Johnson, 1962). Uncertainty of FAC estimates make it a candidate for calibration adjustment.

The model was run with the previously mentioned changes to calibrate hydraulic conductivity, leakage factor, and storage coefficient. Despite repeated attempts, the differences between simulated and measured head values could not be significantly reduced from the version calibrated by Wytzes (1980), indicating additional changes were necessary.

Henry's Fork and the Snake River were previously treated as hydraulically connected to the shallow aquifer. Although this situation may exist in reality, modeling hydraulically-connected rivers may produce unrealistic gains and losses unless the model is accurately calibrated. For this reason the rivers were removed from the hydraulically-connected mode, and gains and losses were included in the surface flux input, Q. River gains and losses were calculated for each node and timestep using a subroutine "MAIN2" temporarily linked to the model. In MAIN2, the gains and losses are calculated in a manner similar to that employed by the model except simulated ground-water elevations in nodes adjacent to river nodes are replaced by values interpolated from measured heads. The gains and losses of each river node are calculated as the product of aquifer transmissivity times the hydraulic gradient between the river and aquifer at surrounding nodes. The aquifer head at each timestep (at nodes adjacent to river nodes) is linearly interpolated from head values at reference timesteps. Hydraulic conductivities in nodes immediately adjacent to rivers are adjusted by trial and error until the gains and losses approximately match the measured values from Wytzes (1980) as shown in table 1.

Table 1. River gains and losses.

Reach Name	Net Gains and Losses (af/yr)		
	Measured[1]	Wytzes (1980) Simulated[2]	Model Input Non-Hyd. Connected
Henry's Fork, St Anthy to Rexb	83,600	179,200	62,735
Snake River, Heise to Lorenzo	-253,000	total -95,000	-266,244
Snake River, Lorz to Rbts Brdg	158,000		145,202

[1] Wytzes (1980, p. 29)
[2] Wytzes (1980, p. 174)

Hydraulic conductivity, leakage factor and storage coefficient were calibrated in the absence of hydraulically-connected rivers. The leakage factor was calibrated to the last timesteps (25), minimizing errors induced by inaccurate estimates of the storage coefficient.

Results

Accuracy of model calibration can be measured by differences between simulated and measured heads, and by a comparison of simulated to actual river gains and losses. These statistics, however, can be misleading. Differences between simulated and reference heads can often be reduced by introducing unrealistic values of other parameters, or by changing parameters which should remain fixed. The result is a model which will simulate the aquifer response during the calibration period but may not accuratly simulated the response to other input conditions.

Only three parameters were adjusted during the model calibration: 1) hydraulic conductivity, 2) leakage factor, and 3) storage coefficient. Adjustments to other parameters such as head, boundary conditions, leakage head difference, and river elevations were based on physical data, not on improvements in simulation accuracy. Resulting parameter values should therefore be more representative than the original values.

The sum of squares of deviations and mean difference between simulated and reference heads for three simulations is presented in table 2. Table 2 compares the final calibration given by Wytzes (1980) to final calibration results of this project, both with and without hydraulically-connected rivers. The statistics are distorted, however, due to changes made in the model. The model calibrated by Wytzes contained several more nodes, tending to increase the sum of squares of the differences. Wytzes also calibrated to a December timestep in which heads were generally closer to initial and final values and therefore easier to duplicate than the September calibration timestep used in this project.

Table 2. Statistical summary of calibration results.

Simulation	Calibration Timestep No.	Calibration Timestep Date	Sum of Squares (ft^2)	Mean Error (ft)
Wytzes	4	6-15	$1.407x10^{4}$	3.9
(1980, p.155)	17	12-15	$7.337x10^{3}$	2.5
	25	5-1	$2.095x10^{4}$	4.7
		Total	$4.236x10^{4}$	
Recalibrated,	4	6-15	$1.155x19^{4}$	3.5
no hydraulically	10	9-15	$3.246x10^{4}$	5.9
connected rivers	25	5-1	$1.240x10^{4}$	3.6
		Total	$5.642x10^{4}$	
Recalibrated,	4	6-15	$1.103x10^{4}$	3.3
with hydraulically	10	9-15	$3.105x10^{4}$	5.5
connected rivers	25	5-1	$1.027x10^{4}$	3.1
		Total	$5.235x10^{4}$	

A water balance of the aquifer would indicate that, for the calibration period, leakage out of the aquifer should approximately equal the sum of the surface flux, river gains and losses and flow across boundaries. This relationship will hold best for the simulation where gains and losses from rivers are input, that is, they are not hydraulically connected. The recalibrated simulation with no hydraulically-connected rivers produced a water balance shown in table 3. Since final water levels approximately equal initial water levels the change in storage over the length of the study period is relatively minor. Leakage simulated by the recalibrated model is much greater than that determined by Wytzes (1980, p. 153), however, this is justified by the conceptual changes in the aquifer in the southwest part of the study area. Eliminating hydraulically-connected rivers and calibrating to the final timestep improves the accuracy of the individual components of the water balance and results in leakage values of greater credibility.

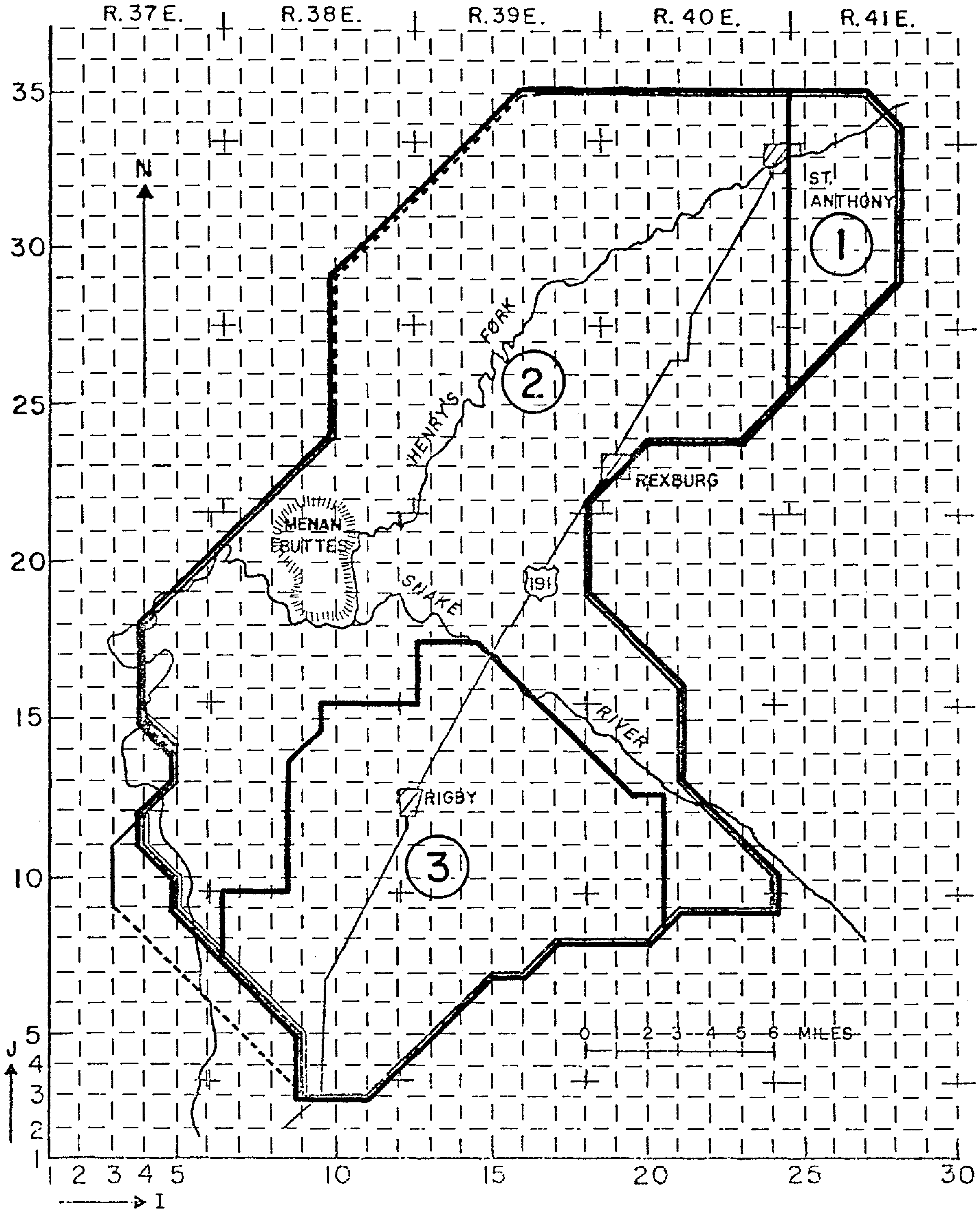
Table 3. Water balance for the calibration period, 5-1-77 through 4-30-78.

Simulation	Surface (af)	Outflows[1] (af)	Storage (af)	Leakage (af)
Wytzes (1980, p.153)	-1,674,351	407,700	147,113	1,058,000
Recalibrated, no. hyd. conn. rivers	-1,585,637	26,490	-1,089	1,558,396
Recalibrated with hyd. conn. rivers	-1,572,608	47,660	61,198	1,473,725

[1] Gains or losses in hydrualically connected nodes.

Two areas were recognized where nearly all nodes within the areas exhibited similar differences between simulated and reference heads. These areas are identified as areas #1 and #3 in figure 2. The greatest differences are apparent in the northeast area (#1), near the Henry's Fork and Teton River. Simulated heads at some nodes in this area varied more than 30 feet from the reference water level. The problem area in the southern part of the study area (#3) had simulated water levels which were generally lower than the reference water levels. No consistent errors were apparent in area #2.

An individual water balance was determined for each problem area and the components of the balance are plotted against time. The plots for the northeast area (#1) are shown in figure 3, the plots for the southern area (#3) are shown in figure 4, and the plots for the rest of the study area (#2) are shown in figure 5. Each graph is cummulative.



EXPLANATION

Boundary of Calibration Problem Area

(2) Problem Area Identification Number

Figure 2. Extent of Problem Areas Assigned for Calibration Evaluation.

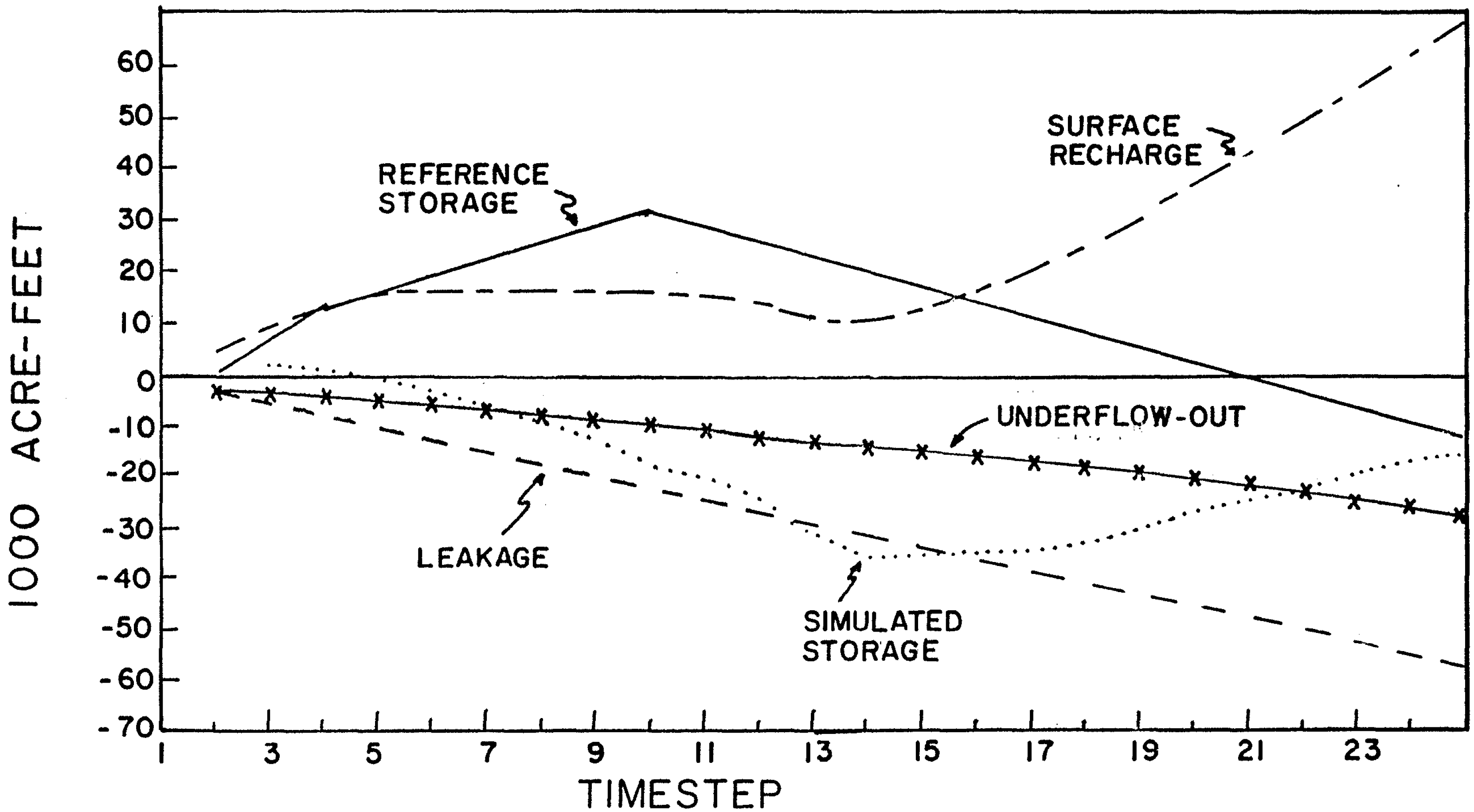


Figure 3. Cummulative Water Balance Components for Problem Area # 1 during the Calibration Period.

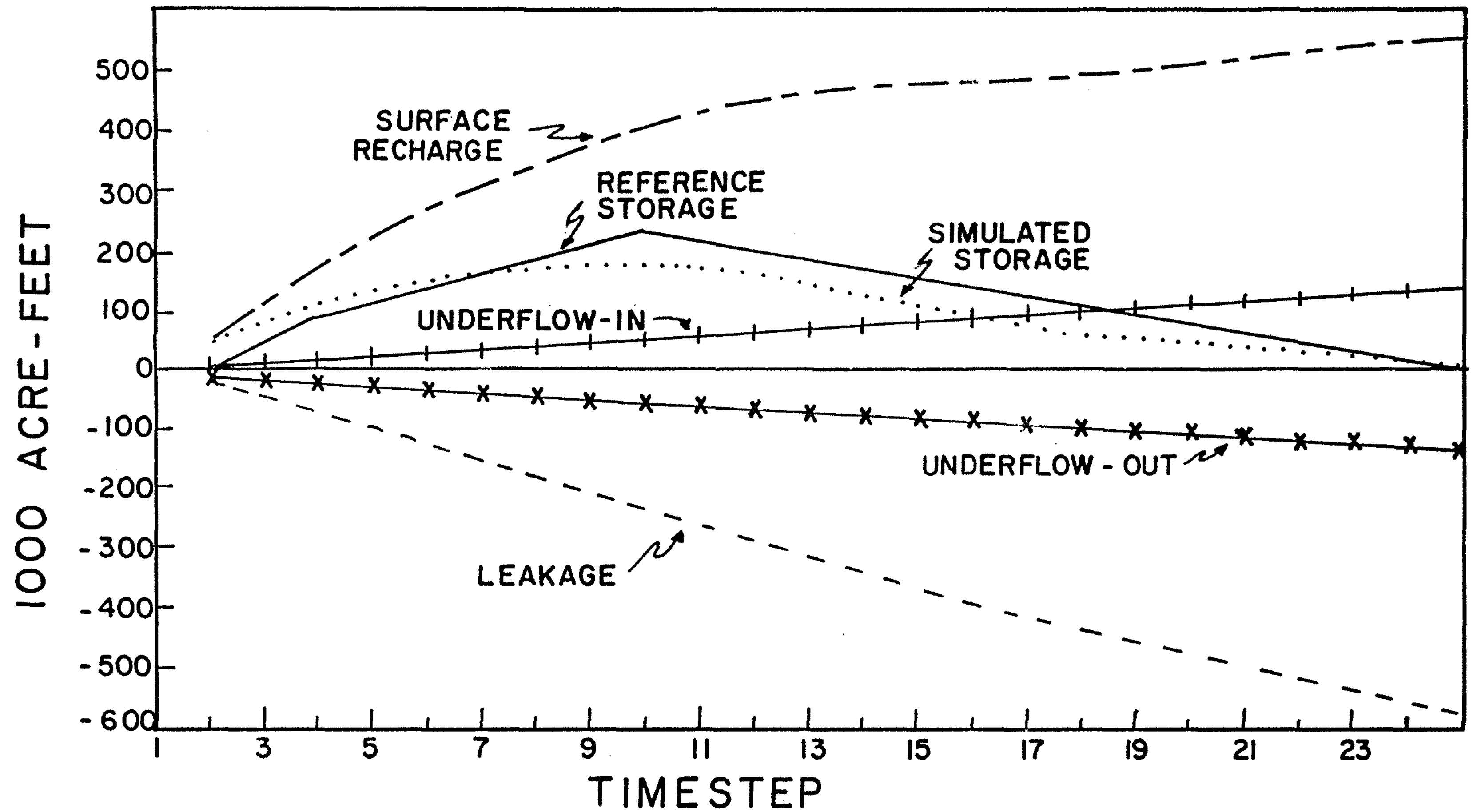


Figure 4. Cummulative Water Balance Components for Problem Area # 3 during the Calibration Period.

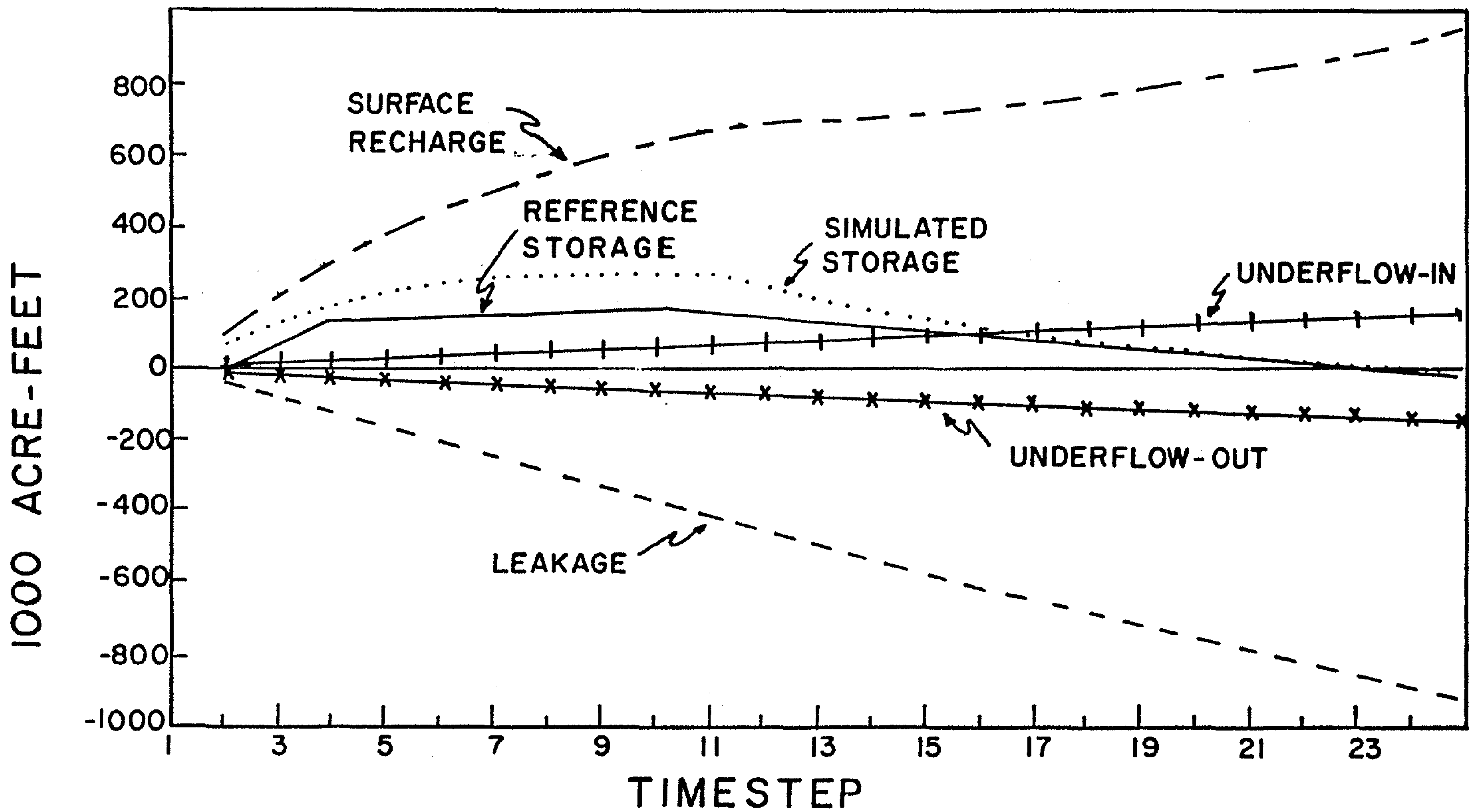


Figure 5. Cummulative Water Balance Components for Problem Area # 2 during the Calibration Period.

These plots allow comparison of the relative magnitude and timing of each of the water balance components and can be used to detect the source of the problem. The "simulated storage" line represents the simulated change in storage (or head) from initial conditions for the entire area. Similarly the "reference storage" line indicates the reference change in storage from initial conditions. Calibration accuracy within the area is indicated by the closeness of the simulated and reference storage lines.

Dramatic differences exist between reference and simulated heads in the area surrounding the Teton River and Henry's Fork as shown in figure 3 (problem area #1). The simulated storage line is equal to the sum of all other lines on the graph except the reference storage. The simulated storage graph is strongly influenced by the surface flux and shows no resemblence to the reference storage line in problem area #1. This indicates that errors probably exist in either the surface flux or the reference head values in this area. The surface flux is related primarily to gains and losses in the Teton and Henry's Fork rivers. Errors may exist in the reference water levels since few wells are available for determination of the water table. These uncertainties prompted a closer evaluation of surface flux, boundary conditions, and reference water-level altitudes in the northeast area.

The gains and losses in the Teton River above the apex of the South and North Forks were analyzed first, since they are the largest single factor affecting surface flux. A lack of measured inflow and outflow data prevents accurate determination of gains and losses in this reach. Conversations with personnel from the U. S. Geological Survey and Idaho Department of Water Resources supported the inflow and outflow estimates used by Wytzes (1980) as the most reliable values available. Therefore, the Teton River gains and losses above the apex were left unchanged.

Underflow across the extreme northeast study boundary was also examined. Possible sources of water which may contribute to underflow include the Henry's Fork, the Fall's River, the Teton River, several irrigation canals, and excess irrigation application, all outside the model boundary. The total volume of water available for underflow from these sources was calculated to be approximately 155,000 acre feet during the calibration period. Approximately 108,000 acre feet of this is derived from losses in the Henry's Fork between Ashton and St. Anthony gaging stations. The direction of ground-water movement beneath the river is primarily from east to west, so most of the losses from Henry's Fork and Fall's River move parallel to the northern study boundary, and do not contribute to underflow. However, since the Henry's Fork at St. Anthony gaging station is inside the model boundary, a percentage of the losses (and gains) occurs within the model. Losses also occur from a portion of the Henry's Fork which lies directly east of the study area. These losses contribute to ground-water underflow.

Approximately 16 percent of the length of the Ashton to St. Anthony reach of the Henry's Fork lies within the model, so 16 percent of the gains and losses in this reach were distributed within the model (these gains and losses were not accounted for by Wytzes). Approximately 14 percent of the same reach lies east of the model boundary, so 14 percent of the losses were applied to two boundary nodes as underflow. Additional underflow was added to boundary nodes as a result of canal seepage and irrigation application east of the model. The Teton River does not lose water in its course outside of the study area. The total volume of water added within the model was approximately 18,500 acre feet. The total volume of water added as underflow was approximately 18,700 acre feet.

This addition of more than 37,000 acre feet of water in the calibration period did not cause any significant improvement in the results. Further analysis of surface flux or underflow would involve significant field data collection and is beyond the scope of this project.

The reference water levels were evaluated and no changes were made to the existing data.

Cumulative plots of the water balance components for the southern part of the study area (#3) are shown in figure 4 and do not indicate any specific problems. The simulated storage plot nearly follows the reference storage line. The graphs deviate at both the first and second calibration timesteps, but are similar in shape.

Conclusions and Recommendations

Model changes which were made should make it more representative of the real system. The changes include moving the southwest boundary and changing it from fixed head to impermeable, changing leakage parameters, returning rivers to approximately the actual elevations, and adjusting head values to exclude the regional system in the southwest part of the study area. Parameter values resulting from the new calibration will be more representative because of the changes employed and additional restraints applied in calibration.

Changes were also made in the surface flux in the extreme northeastern part of the study area. These included adding gains and losses in the Henry's Fork between the St. Anthony gaging station and the model boundary, and adding underflow representing river and canal losses and irrigation application east of the study area to boundary nodes. The net gains and losses within the study area from the Henry's Fork amounted to approximately 18,500 acre feet of water lost from the river to the ground water during the calibration period. Approximately 18,700 acre feet of water was also added to boundary nodes from underflow during the period. These changes made no significant improvement in the results.

The recalibrated model is acceptable for predicting major water table changes resulting from dramatic changes in recharge and/or discharge. It is not sufficiently refined to demonstrate the effects of stress on river gains and losses. In future simulations the Henry's Fork and Snake Rivers should be modeled as hydraulicaly connected to impose their stabilizing influence on the water table. The gains and losses predicted by the model, however, do not approach real values and should not be used in a predictive capacity.

Cited References

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