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Hydrosalinity Impacts of Conservation Measures in the Sevier River Basin

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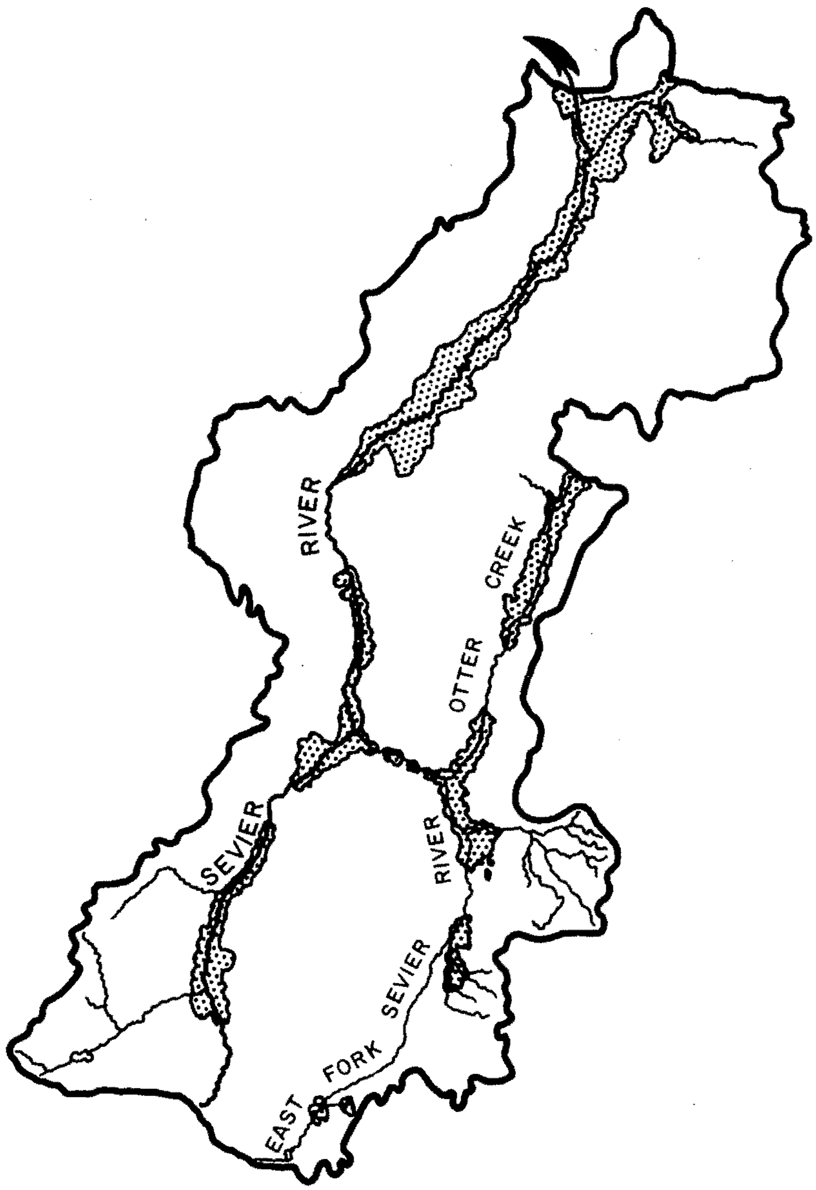

Utah Water Research Laboratory
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Logan, Utah 84322

WATER RESOURCES PLANNING SERIES
UWRL/P-81/07

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Final Report

HYDROSALINITY IMPACTS OF CONSERVATION MEASURES IN THE SEVIER RIVER BASIN

Prepared by

Eugene K. Israelsen

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ABSTRACT

The Sevier River Basin is a water short basin wherein upstream diversions not consumptively used become the water right for downstream users. The diversion-return cycle occurs several times as the stream travels from its mountain source areas to the terminal lake at the lower end of the basin. This study dealt with the proposed implementation of conservation measures which would waste less diverted water and allow for irrigation of additional acres. The objective was to predict the hydrosalinity impacts of the implementation of these measures. The results indicated that increased consumptive use in the upper areas would decrease the water supply but would only increase the salinity by 2-300 mg/l. However, the salinity increase in the lower basins from additional use caused the salinity levels to increase significantly and the water supply to reduce significantly.

The results came from the application of a hydrosalinity model to the upper subbasins. Some problems were encountered while predicting outflows over a 14 year period because the data relationship did not seem to remain constant for that period. Additional investigation of that anomoly would shed more insight to the problem.

ACKNOWLEDGMENTS

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Hydrosalinity Impacts Of Conservation Measures In The Sevier River Basin

INTRODUCTION

Rivers in arid areas are intensively used to supply water for irrigated agriculture. In the water-short Sevier River Basin, the demand for irrigation water is so great that flow is diverted from the stream, used to water crops or pasture, and returned to the stream as many as seven times between its mountain headwaters and its ultimate discharge onto the salt flats of Sevier Lake.

Water conservation is widely advocated to make limited irrigation water go further. Irrigation is made more efficient by reducing nonproductive consumptive use by weeds and phreatophytes, deep percolation, and wastage into areas or aquifers where the water is no longer available for further use. Furthermore, energy is saved as pumping is reduced. According to the conservation ideal, the ultimate conservation would be for every farmer to put all the water he diverted to productive use. Every drop would be applied to crops to supply the water needed for the transpiration that goes with plant growth.

This ideal is of course unachievable. Some water must be applied to replace water that evaporates directly from the soil, and additional water is needed to maintain the soil salt balance by leaching. Furthermore, full conservation is impractical in that many efforts just cannot save enough water to justify their cost.

Other conservation efforts are justified. Canals can be lined, and turnout structures can be made water tight. Methods for more uniform water application can be used to reduce excess percolation at the upstream end of a field or furrow while getting water to the downstream end. Water can be prevented from reaching phreatophyte vegetation, and such vegetation can be removed.

The current trend in irrigation practice in the Sevier River Basin is toward canal lining and sprinkler irrigation to conserve water. Federal money is available to help pay the cost of improved irrigation systems through a program justified on the basis of downstream salinity control benefits. Most farmers also see in these programs an opportunity to expand the acreage they irrigate from their fixed water right and are thereby further motivated to improve their on-farm irrigation efficiency.

The farmer who uses the water saved to irrigate additional land, however, reduces downstream flows. The fact that he returns less water to the stream is in fact appropriating downstream water rights. State water rights administration requires that these rights be protected. In addition, instream flow uses are deprived; and salinity concentrations may be increased by the reduced dilution water.

More detailed examination of the situation will show that some of the water conserved takes directly from the supplies of downstream users while other water does not because it takes from phreatophyte evapotranspiration or other true wastage. To further complicate the situation, the division between the two varies with location in the watershed, time of year, and from year to year at a given place and date.

Equitable water rights management requires differentiation between water saved and water taken from other uses. The farmer should be able to benefit from true savings but not allowed to take water from or otherwise harm others. The technical objective of this study is to work toward a model that can be used for this differentiation.

Specifically, the objective is to predict the response of the Upper Sevier River Basin to farmer water conservation efforts, both their efforts to make more efficient use of diverted water and their attempts to capitalize on these efforts by irrigating additional acreage. River responses of interest include both the quantity and salinity of the water available to downstream users. While this predictive capability is important for both evaluating alternative conservation measures and facilitating water rights administration, the results will not be interpreted for those purposes. Also, this study will not get into implementation of techniques for farm water conservation and their comparative cost effectiveness from the viewpoint of the farm operator.

PROCEDURE

The method used to sort out the relative magnitudes of these impacts of farm water conservation measures by time and place was to construct a water budget model of the Upper Sevier River Basin and calibrate it to match recorded flows and salt concentrations. Specific steps in the procedure were:

1. To divide the river basin into subbasins.
2. To collect the necessary data.
3. To make the required data preparation.
4. To calibrate the model.
5. To use the calibrated model to make predictions.
6. To present and summarize the results.
7. To draw conclusions.

SUBBASINS

The five subbasins used in this study are defined by the location of United States Geological Survey (USGS) gaging stations and are shown in Figure 1. The USGS flow data can be used directly and does not need adjustment to transfer to a subbasin boundary. The Soil Conservation Service (SCS) study (SCS 1974) designated subbasins and subdivided these subbasins into watersheds. The subbasin boundaries selected for this study do not always coincide with the subbasin or watershed boundaries of the SCS study, and, therefore, the flows are not predicted at the same point and cannot be directly compared. Specifically, subbasins 1 and 5 are defined by USGS stream gages 1800 and 2170 respectively and include portions of the SCS designated watersheds (see Table 1).

DATA COLLECTION

The data used in the modeling included flow data, precipitation and temperature data, diversion data, land use data, groundwater data, and salinity data. Since adequate salinity data were not available, additional salinity data were collected as part of this study to supplement existing data to be used in the hydrosalinity model. All of the other data were obtained from information collected by other agencies.

Problems encountered in preparing the data for use in the model included:

1. Extrapolating point data to an area as in the case of precipitation and temperature.

2. Estimating missing data, especially canal diversion data.

3. Estimating subbasin water and salinity exports and imports via irrigation canals and surface and underground drainage.

4. Determining accurate land use for each irrigated area.

5. Determining the proper evapotranspiration rates with the various land uses. This was especially difficult for the phreatophytes.

6. Estimating reservoir inflows where they were not measured.

Because of these six problems, considerable time and effort had to be spent in collecting, preparing and rechecking the data required for the study.

Hydrologic data were initially obtained for three years, 1962-64. More hydrologic and land use data were available for this period than for any other because of an intense study by the SCS. The SCS report also estimated average unmeasured water

Table 1. Subbasin inflow-outflow stations and included SCS designated watersheds.

Subbasin Number	Inflow Station, USGS	Outflow Station, USGS	Name	Included SCS Watersheds
1	10174500	10180000	Circleville	F-1*, F-2, F-3, F-4, F-5
2	10183900	10189000	East Fork	E-1, E-2, E-3, E-4
3	10180000 10189000	10194000	Marysvale	F-1*, D-6, D-7, D-8
4	10194000	10205000	Sigurd	D-1, D-2, D-3, D-4, D-5
5	10205000	10217000	Salina	C-1*, C-2*, C-3, C-4, C-5, C-6

*Only portions of these SCS watersheds were included in the subbasin.

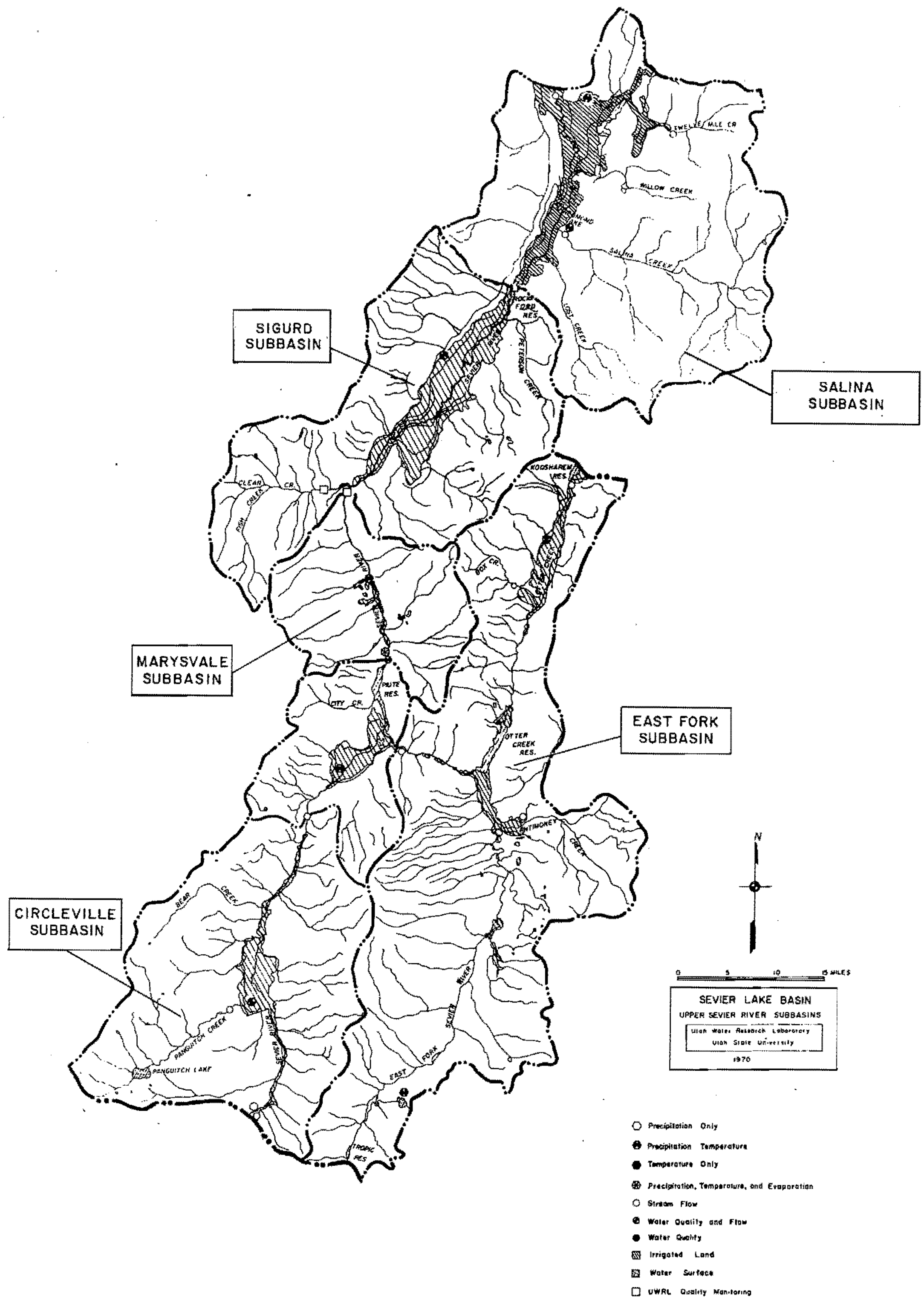

Figure 1. Sevier River subbasins and data stations.

movements during this period, and this, too, was of great assistance in estimating unmeasured data. The SCS study also helped in determining some of the parameter values during model calibration.

Later in the study, hydrologic data were assembled for 11 years, 1965-75. It was found that the data did not always keep the same relationship over the 14-year period (1962-1975). For example, the relationship between total diversions in subbasin 3 and total diversions in subbasin 4 varied considerably. This problem will be discussed futher in the section on model calibration and verification.

Flow Data

Surface flow data, for the five subbasins shown in Table 1, were taken from the USGS Surface Waters of Utah publications (USDA, U.S. Geological Survey 1962 to 1975). The data collection points are shown in Figure 1 where the downstream boundary of each subbasin intersects the Sevier River. The surface flow records at these stations were used in the model without alteration. Unmeasured tributary inflows were estimated during the calibration using gaged stream, precipitation, and snowmelt.

Precipitation and Temperature Data

Precipitation and temperature data were taken from measurements reported in the Utah Climatological Records (USDC 1962-1975) at locations shown in Figure 1. The point measurements were averaged over subbasin areas and multiplied by a coefficient to provide a weighted average for the whole subbasin. Subbasins 1 and 3 required estimation of missing data for a few months, while subbasin 3 required several years of data correlation.

Diversion Data

All the diversions were identified and data on measured diversions were taken from published Commissioners' reports (W. R. Walker et al. 1962-1975) available at the State Engineer's Office. The measured diversions did not include all of the diversions in the subbasin. The selected recorded diversions were adjusted to estimate the total diversions.

Groundwater Data

The use of groundwater is very small compared to the use of surface water in the basin (U.S. Department of Agriculture, Soil Conservation Service 1969). Subbasins 1 and 3 use about 500 acre-feet per year, subbasin 4 uses about 2200 acre-feet per year, and groundwater use in subbasin 5 is insignificant and was set at zero. Groundwater use in these subbasins was assumed to be constant from year to year.

Land Use Data

The land use data were taken from the SCS report (USDA, SCS 1969) and were assumed to remain constant through the simulation period. The SCS land use classifications were irrigated cropland - rotated and nonrotated; nonirrigated lands - wet meadows, dryland, and phreatophytes; and miscellaneous areas - bare ground, water surface, and main reservoirs.

The most difficult part of the land use analysis was to place the phreatophyte groups in the proper use category. The categories were defined with respect to the distance of the water table from the surface. Each category required different evapotranspiration coefficients. These categories were: 1) water within 1 foot of the surface, 2) water from 1 foot to 3 feet from the land surface, and 3) water greater than 3 feet from the surface.

Irrigation diversions have the same problem in that all diversions are not measured, and all of the measurements may not be published. Tributary diversions are least likely to be measured. Irrigation diversions cannot be correlated to natural flows since the needs for irrigation water also vary seasonally. It was assumed that the reported irrigation diversions represented the pattern of total diversions for the subbasin of interest. The sum of these diversions, D, was then multiplied by a coefficient, k, to represent the total diversions, T. The correlation equation would be $T = kD$. The value of the coefficient was initially estimated from data in the SCS report and slightly adjusted during calibration process to improve model results.

Precipitation and temperature data are measured at one or two points in each subbasin. The procedure for extending these measurements to the total valley floor subbasin was to average the total number of measuring stations and assume that the result represented the subbasin. The average values could be adjusted, and sometimes were, by a multiplying coefficient established during the calibration. During the 14-year period of record, some station measurements were not made and so had to be correlated to those of record.

Groundwater data were taken from the SCS report and were assumed to remain constant for the period of interest. The pumped water was usually insignificant when compared to the total water inflow to a subbasin.

The land use data were straightforward except for the phreatophytes and the nonrotated pasture. Considerable effort was spent in trying to separate the phreatophyte areas according to the depth to the water table. The nonrotated pasture was reported by the SCS to get substantial portions of evapotranspiration water from the groundwater system. The portions of these nonrotated pasture areas that received groundwater were included in the phreatophyte area since the phreatophytes also use groundwater, and there is no provision for crops to do so.

Salinity Data

Salinity data were collected at the USGS stations and at some diversions in the Sevier River Basin to be used in this modeling project from August of 1975 through June of 1976. Additional data were assembled from USGS records. The Utah Water Research Laboratory (UWRL) data were collected twice monthly for many of the collection stations while the USGS data were collected from four to eight times per year. The UWRL and USGS concentration data points were plotted against the date and joined by a curve to estimate average monthly salinity levels. These monthly averages were then used in model calibration.

The salinity data for this study were collected by the river commissioners in the Upper Sevier River Basin. Samples were taken at points along the main stem of the river, as well as on tributaries and at points of interest along various canals, and analyzed for total dissolved solids at the UWRL. The water was not always flowing in the canals or at specific points in the river so samples were not available from every point for every sampling run. Collection was made twice each month, once near the beginning and once near the middle of each month. Table 2 lists the data collected and the location of the data stations.

DATA PREPARATION

Unmeasured flows caused a major modeling problem. Partial data required expansion of the measured amounts to estimate total water movement. For example, only the major surface inflows to a given subbasin are measured. The remaining surface inflows had to be estimated by some technique.

One of the most common procedures is to correlate the ungaged flows to some measured surface flow. Since the quantity of the unmeasured flows is unknown, it is not possible to get a direct correlation. This deficiency is overcome during model calibration by adjusting the parameter that multiplies the measured streamflow to the value that causes the best correlation between measured and predicted outflow values. This correlation is linear and forced through the origin so that the intercept, b, goes to zero while the value of the slope, m, is inferred through the match of the outflows. The correlation with precipitation is similar except that a threshold value is established such that monthly precipitation or snowmelt below the chosen levels will not produce any ungaged inflow. Mathematically the correlation with precipitation or snowmelt becomes: $Y=b+mx$ where x is equal to or greater than the threshhold value, t, and b equals zero. The threshhold concept is a quick approximation of infiltration, and depression and interception storage on a monthly basis.

Because the salinity data were lacking, it was sometimes necessary to extend four to eight point measurements to the entire year. This was accomplished by plotting the salinity value against time and drawing a smooth curve connecting all points and then determining the average monthly salinity values from the plots.

The evapotranspiration coefficients were determined from the published data (USDA, SCS 1968, 1969, USDA 1973) and some were modified to reflect the availability of the water to the plants. For example, grass might be classified into three areas depending on the distance of the water table from the surface. The area of grass that was 36 inches or greater from the water table would have a reduced evapotranspiration coefficient. This was done for all phreatophytes where the required information was reported. The data used in the model are listed in Appendix B.

SIMULATION MODELING

The simulation approach to hydrologic modeling represents water movement through the basin with a series of equations. The parameters in the equations are evaluated through a model calibration process that sets values which best match simulated to recorded flows. The more completely the recorded data describe the system, the better is the model one can build and the more precisely it can be calibrated. Once an acceptable model is calibrated, the equations or parameter values can be modified to represent alternative farm water management practices. Changes in simulated flows estimate the consequences of the change in practices. The goal in simulation modeling is to construct the most accurate representation possible of the prototype system consistent with the available data.

THE MODEL AND CALIBRATION

Model

The model used for this study is the Basin Simulation Assessment Model with Salt (BSAMS) developed at the Utah Water Research Laboratory. The hydrology portion of the model is published in a users manual (Huber et al. 1976), and an updated version of the hydrosalinity model was published in a thesis at Utah State University (Sepehr 1980).

The hydrologic model is a descendent or an expanded version of the model described by Riley, Chadwick, and Bagley (1966). The model was subsequently modified by Hyatt (1970), Thomas (1971), Hill (1973), and Huber (1976). Additional adjustments were made during the course of this study. The model is based on the continuity of mass principle and includes a mathematical des-

Table 2. Location of salinity sampling stations and salinity data collected by UWRL, mg/l averaged for the month.

		AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
1	Sevier River near Circleville	264	312	296	259	275	266	216	224	262	195	
2	Sevier River below Piute Reservoir	248	314	298	278	299	317	238	249	260	354	
3	Antimony Creek near Antimony	96	127	134	112	118	143	110	115	124	32	
4	East Fork near Antimony	200	235	240	232	253	252	220	219	218	158	
5	Otter Creek below Koosharem Reservoir	130	189	192	241	256	264	246	208	198	180	
6	Otter Creek Reservoir outlet		232	230	220	224	291	246	247	264	233	
7	East Fork at Kingston	244	268	292	324	346	249	308	282	266	273	
8	Clear Creek above Diversions	138	189	204	138	149	168	124	124	152	96	
9	Sevier River above Clear Creek	248	288	284	283	297	311	288	262	262	235	
10	Sevier Valley Canal west of Rocky Fork Reservoir		294	294	292						234	
11	Sevier River below Rocky Fork Reservoir	688	816	798	681	618	496	764	704	682	830	
12	Vermillion Canal west of Rocky Fork Reservoir	368	590	870	810	866	1,040	1,316	1,301	583	482	
13	Vermillion Canal Dump into Sevier River			802	792	912						
14	Rocky Fork Canal Dump into Sevier River		1,038	876	615	600	492	768	741	702		
15	Lost Creek above Diversions	166	193	284	1,931	3,362	2,318	2,174	1,998	2,526	176	
16	Salina Creek near Salina	286	386	427	392	736	512	700	468	493	160	
17	Willow Creek above Diversions	284	441	567	462	760		696	656	703	286	
18	San Pitch River near Gunnison				1,694	1,636	1,130	1,036	1,029	1,214		
19	Sevier River near Gunnison	1,800	1,742	1,511	1,216	1,210	984	1,102	1,092	1,414	902	
20	Fayette Canal Dump into Sevier Bridge Reservoir				1,382							
21	Sevier Valley Canal Dump into Sevier Bridge Reservoir											
22	Dover Canal Dump into Sevier Bridge Reservoir											
23	West View Canal Dump into Sevier Bridge Reservoir				1,365	1,622						
24	Sevier River below Sevier Bridge Reservoir	1,132	1,228								1,236	
25	12 Mile Creek above Diversions	172	193	250	264	233	256	228			256	
26	Outflow of 9 Mile Reservoir	684	748									
27	Outflow of Gunnison Reservoir	1,048	1,131	1,158								
28	San Pitch River near Manti	822	874	947	950	1,001	850	1,058	1,134	1,422	2,732	
29	Six Mile Creek above Diversions	172	214	221	250	242	256	196	212	140	248	
30	Manti Creek above Diversions	254	283	313	350	340	386	342	358	278	314	
31	San Pitch River near Ephriam	180	237	269	870	850	644	1,008	978	1,378	2,806	
32	San Pitch River at John E. Olsen Diversion	2,946	3,055	894	634				544	634	3,120	
33	Cedar Creek above Diversions			204							190	272
34	San Pitch River at the Wales/Chester Road											
35	Outflow of Wales Reservoir			536							702	795
36	Pleasant Creek and Twin Creeks			222				235			191	199
37	San Pitch River near Fairview											297
38	Cottonwood Creek above Diversions											
	Piute Canal	358	298									
	San Pitch above Mower Ditch			398				373			337	
	Ephraim	1,942		765	290	282	310	240	276	292	286	

cription of flow processes and storage functions that are considered important to the hydrologic system.

The salinity model too has evolved from a series of previous studies. Hyatt (1970) applied the salinity model to the Upper Colorado River Basin. Thomas (1971) modified the model to fit the special case of flow in the soil profile. Hill (1973) expanded on the Hyatt version of the model and applied it to the Bear River Basin. Others have applied the model to other watersheds with success.

This hydrosalinity model assumes that all hydrologic flow processes have an associated salt flow except for precipitation and evapotranspiration. These two processes have an impact on the salt flow but are assumed to not contribute new salt or remove salt from the system. A schematic diagram of the modeled flow system is shown in Figure 2. Processes that are deemed insignificant are set to zero so as not to influence the computed outflows.

Calibration is based on matching predicted to recorded hydrologic and salinity flow and storage amounts. The calibration can be accomplished either by the operator or by the computer, based on instructions given by the operator. The data can be output either in digital or graph form, depending on the hardware available.

BSAMS allows the operator to select from two representations for predicting prototype system responses to the imposed system changes. The model can be operated in either a calibrate or a management mode. The calibrate mode uses historical diversions and/or limits diversions to the calculated water available. The management mode calculates the irrigation diversions required to meet specified soil moisture and crop requirements. If diversions are limited to the available water and the calculated diversions exceed the calculated available water, the diversions are limited to the water available and soil moisture storage decreases below the target level.

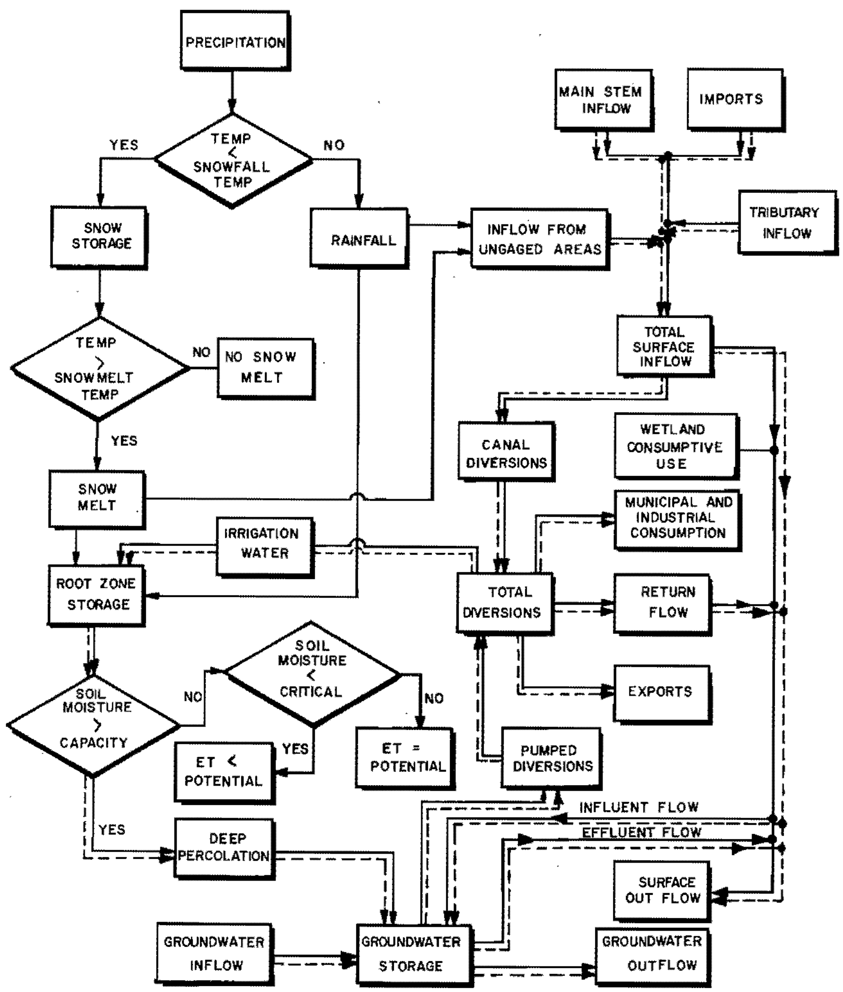

Figure 2. Schematic diagram of hydrosalinity model.

The runs for this study were mostly made in the calibrate mode with diversions limited to the calculated water available. This was considered necessary to reflect the operation of the water rights in each subbasin. If runs were made in the management mode, the water diverted would reflect the needs of the crops and not the operation of the system according to the historical water rights.

It must be understood that the predicted values will not be the same as the measured values because the definition and operation of the system in the model differs from the real system. Actual operation of the system reflects the interjection of the legal water rights or a modification of those rights. The water rights of the modeled system are reflected by the diversions during the calibration period and as such do have some impact on the parameter values that are selected during the calibration of the model. During the management phase, water rights are only reflected to the same degree as the diversions reflected water rights during the calibration of the model. This reflection is incorporated in the established values of the model parameters. It also implies that the reported measured diversions reflect actual diversions and not simply a repeat of water right amounts. The model, using these diversions, will be as accurate as are the recorded diversions.

Calibration

The process of adjusting the model parameters until a measured input generates an output that is within a selected limit of being equal to the corresponding measured output is termed model calibration. Model calibration is an art requiring the judgment of the operator to insure that the selected values of the parameters are within reason. Sometimes the data base is not sufficiently representative of the prototype, and the model parameters must be altered to reflect the operation of the real system. In some basins a particular parameter vector will generate negative flows. This situation, of course, does not occur in the real world, but represents a deviation of the prototype description from the real prototype situation.

The calibration goal was to match measured values within 10 percent in each month and within 10 percent for the year. These criteria are consistent with the reported accuracy of the field data. When using or calibrating a simulation model, it must be kept in mind that many combinations of model parameter values can be used to predict system responses. The process of calibration is to find the parameter set that is most realistic according to the modelers qualitative understanding of how the flows pass through the basin, and gives the system responses most nearly equal to those measured for the real system. The selected parameter set may not provide the best fit and may not be the most realistic but, hopefully, will be the best compromise between the two criteria.

The model was calibrated for the five subbasins for water years 1962, 1963, and 1964. The agreement between the calculated and measured outflows can be seen in Table 3. Four of the five subbasins were later calibrated for the 1974-1976 time period. This was done so that the salinity calibration (covering the period for which salinity data were collected and available) and the water calibration would be for the same period, and the input data relationships would most likely remain constant. The calibration agreement for the 1974-1976 period is shown in Table 4 and Figures 3 to 16.

Table 5 gives a comparison of the difference between predicted and measured values for the two calibrations. Based only on the error term magnitude, the 1962-64 calibration appears best.

OUTPUT DISPARITY

The first test predictions to be made after the 1962-1964 calibration were for the 14 year period 1962-1975. The predictions and the recorded flow values can be seen in Tables 6 to 13. The model was operated using historical irrigation diversions and in the management mode in which diversions are calculated by the model. Subbasins 1, 4, and 5 showed better agreement when the model calculated diversions than when the historical diversion records were used. Though the individual months and years showed some variation, the total period agreement was very close for subbasins 1 and 4. Subbasin 3 showed better agreement with the historical diversion data than with the calculated diversion data. Subbasins 3 and 5 did not have adequate agreement for the total period. Subbasin 4 showed some problem with predicting negative flows, however, the overall agreement for the 14 years was very good. Table 14 shows the difference between predicted and measured outflows for the 14 years.

MODEL PREDICTIONS

The simulation model is not a direct replication of the real system but uses aggregate data to represent how the real system reacts to hydrologic simulation. The input data similarly only represent the simulation. Since all of the data in the early 1960s did not have the same relationship to the system as did data in the 1970s, the final model calibration was made for the period of the salinity data, 1974-1976 except in subbasin 2, East Fork.

After the model is calibrated, the impacts of various conservation measures and patterns of their use among the various subbasins can be predicted by adjusting irrigation efficiencies and phreatophyte and crop acreages in the model to reflect reasonable management choices and using the model to predict the resulting changes in flow and salinity.

Table 3. Calculated and measured monthly outflows from the five subbasins, in acre-feet.

		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
Subbasin #1 Circleville														
Calculated	1962	2,537	3,649	5,500	5,025	10,245	10,474	18,978	18,647	7,987	4,505	4,128	4,449	96,123
Measured	1962	2,920	4,520	5,680	5,060	8,690	11,030	18,370	18,290	7,270	3,230	2,640	3,780	91,480
Calculated	1963	4,075	4,700	6,317	6,362	7,090	4,830	2,620	4,388	3,451	2,365	4,166	2,956	53,319
Measured	1963	5,270	6,330	6,210	4,650	7,100	6,120	3,580	5,350	1,820	1,600	2,710	3,780	54,520
Calculated	1964	2,715	3,048	5,307	5,049	4,431	5,343	5,168	8,955	4,343	2,911	3,039	2,770	53,079
Measured	1964	2,650	4,430	6,210	4,990	4,940	5,180	6,630	9,630	4,730	1,910	2,880	2,100	56,280
Subbasin #2 East Fork														
Calculated	1969	3,765	2,505	1,080	0	526	1,683	11,524	12,550	4,413	5,147	6,538	2,327	52,058
Measured	1969	2,600	1,120	924	956	968	4,960	10,780	13,120	3,450	3,640	7,410	5,050	54,978
Calculated	1970	1,860	1,518	1,536	284	3,727	3,386	2,553	10,225	5,070	6,850	9,140	7,460	53,609
Measured	1970	2,290	1,020	1,090	1,130	4,200	4,070	2,770	8,040	3,400	9,810	10,360	5,130	53,310
Calculated	1971	2,964	4,122	2,478	280	0	1,485	3,035	6,208	8,931	12,523	12,176	2,780	56,980
Measured	1971	1,770	1,130	1,110	744	845	1,280	2,320	5,360	10,950	12,720	12,350	4,130	54,709
Subbasin #3 Marysvale														
Calculated	1962	11,320	4,554	2,315	1,376	3,070	1,715	9,009	21,031	20,706	31,243	23,204	15,328	144,870
Measured	1962	10,520	4,750	1,500	1,560	1,700	1,630	5,580	21,130	22,230	29,570	24,250	14,770	139,190
Calculated	1963	5,673	4,030	1,961	1,004	5,170	10,711	7,381	17,885	7,013	13,962	7,280	4,381	86,450
Measured	1963	5,440	5,570	2,650	615	5,020	12,930	8,180	18,750	7,120	15,310	8,900	3,610	94,095
Calculated	1964	3,870	3,998	1,866	1,056	2,448	5,669	8,634	14,824	8,727	20,204	14,634	4,892	90,823
Measured	1964	5,250	4,050	1,290	952	1,940	5,040	9,100	15,450	8,840	20,590	15,430	5,420	93,352
Subbasin #4 Sigurd														
Calculated	1962	2,102	3,472	3,693	3,628	6,970	2,890	2,378	2,965	4,272	4,227	4,524	5,539	46,660
Measured	1962	1,750	3,190	3,150	3,780	5,630	4,220	1,070	2,390	5,270	3,070	3,190	5,980	42,690
Calculated	1963	1,978	3,727	3,384	3,649	7,884	12,507	4,962	587	-54	-844	718	-121	38,376
Measured	1963	2,860	3,520	3,330	3,150	7,460	10,740	5,520	1,120	564	269	65	54	38,652
Calculated	1964	185	2,201	1,302	1,394	2,223	5,454	6,825	4,958	1,983	696	1,117	163	28,501
Measured	1964	1,440	2,460	2,410	2,790	4,390	5,250	7,120	5,030	729	286	82	123	32,110
Subbasin #5 Salina														
Calculated	1962	5,037	8,191	5,872	7,917	19,321	13,963	9,070	13,291	12,581	5,226	4,797	9,923	115,188
Measured	1962	4,310	6,640	7,390	7,550	18,070	14,690	11,440	11,300	11,170	5,020	6,000	9,120	112,700
Calculated	1963	6,061	7,947	9,855	7,744	15,292	12,997	7,665	4,724	4,097	2,701	2,552	3,112	84,745
Measured	1963	6,520	6,570	9,210	9,270	13,340	13,140	8,840	4,050	3,620	1,880	2,330	3,550	82,320
Calculated	1964	2,180	4,413	4,868	4,873	7,099	10,946	13,048	10,226	4,798	2,678	2,873	2,776	70,778
Measured	1964	3,350	5,120	6,950	7,210	8,710	9,600	9,700	11,400	4,780	1,690	2,350	2,410	73,270

Table 4. Predicted and measured monthly outflow of water (acre-feet) and salt (tons) for 1974-1976 for Circleville, Marysvale, Sigurd, and Salina subbasins.

		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
Circleville														
Water														
Calculated	1974	6,068	8,490	7,920	7,593	8,655	11,261	4,634	3,531	3,362	3,517	2,844	2,583	70,458
Measured	1974	9,350	9,010	10,160	8,730	7,080	9,780	6,740	4,050	2,160	2,970	2,650	2,860	75,540
Calculated	1975	3,140	2,888	3,896	5,344	5,954	6,936	4,092	9,360	16,631	6,646	5,041	3,781	73,709
Measured	1975	4,330	6,180	6,340	5,900	5,680	7,160	4,440	7,180	13,250	5,450	4,160	3,960	74,030
Calculated	1976	4,547	8,617	8,717	7,292	9,389	7,100	4,549	8,346	4,916	4,377	3,115	2,725	73,691
Measured	1976	6,060	7,080	7,120	6,540	6,480	6,910	5,560	9,370	3,950	3,900	2,540	2,780	68,290
Salt														
Calculated	1974	3,330	3,533	2,451	2,330	2,314	3,254	1,638	1,389	1,305	1,327	1,149	1,100	25,120
Measured	1974	3,571	3,257	3,300	2,848	2,406	3,403	2,272	1,349	934	1,223	1,109	1,248	26,918
Calculated	1975	1,429	1,702	2,186	2,376	2,165	2,441	1,658	2,817	4,121	2,059	1,687	1,471	26,112
Measured	1975	1,665	2,343	2,180	1,828	1,613	2,160	1,551	2,293	4,106	2,007	1,645	1,593	24,986
Calculated	1976	2,059	3,339	3,226	2,763	2,459	2,204	1,596	2,340	1,584	1,482	1,152	1,123	25,327
Measured	1976	2,281	2,483	2,516	2,329	2,034	2,254	2,002	3,120	1,224	1,569	1,205	1,345	24,362
Marysvale														
Water														
Calculated	1974	7,604	5,512	3,773	5,896	16,715	8,773	7,807	26,358	21,488	22,645	21,800	5,184	153,555
Measured	1974	9,010	5,060	2,070	3,010	15,020	6,720	2,220	29,970	27,630	26,490	26,060	8,420	161,680
Calculated	1975	3,898	3,331	3,231	2,772	3,560	2,130	8,585	23,969	16,596	29,977	24,457	10,717	133,222
Measured	1975	5,660	4,880	1,940	722	887	1,420	3,770	23,160	14,690	29,460	25,250	11,500	123,339
Calculated	1976	5,476	6,953	4,597	3,887	2,935	3,444	7,326	26,617	17,732	17,890	15,390	6,042	118,290
Measured	1976	4,580	6,050	1,720	906	1,330	1,440	9,500	28,210	23,390	21,000	17,320	4,450	119,896
Salt														
Calculated	1974	1,837	1,320	872	1,772	5,517	2,813	2,218	8,603	7,761	8,491	9,028	2,276	52,507
Measured	1974	2,792	1,864	855	1,137	5,226	2,429	848	11,486	10,777	10,908	9,669	2,632	60,624
Calculated	1975	1,896	1,612	1,435	1,125	1,183	831	2,662	7,238	5,388	9,479	8,507	4,095	45,451
Measured	1975	2,131	1,970	707	254	356	560	1,624	9,159	5,051	10,050	9,128	4,314	45,303
Calculated	1976	2,357	2,970	2,234	1,898	1,462	1,582	2,786	9,238	6,681	7,823	7,380	3,030	49,442
Measured	1976	1,842	2,343	692	362	526	556	3,421	9,316	7,566	7,363	5,979	1,451	41,419
Sigurd														
Water														
Calculated	1974	5,742	8,795	6,772	9,577	19,346	16,580	1,697	1,755	634	140	1,221	2,565	74,823
Measured	1974	7,960	8,040	6,610	7,250	17,460	15,330	6,090	2,020	947	1,590	998	2,760	77,055
Calculated	1975	3,625	6,201	4,647	5,452	4,011	3,653	-1,076	5,814	7,362	6,001	4,244	3,215	53,148
Measured	1975	4,690	4,520	5,570	5,450	5,820	4,350	2,020	3,970	3,460	1,250	1,660	4,410	47,170
Calculated	1976	2,301	5,629	5,034	8,653	7,858	5,634	-498	602	292	-727	-401	-64	34,313
Measured	1976	3,120	4,650	5,270	5,840	6,530	5,320	1,790	803	1,720	369	1,050	1,680	38,142

Table 4. Continued.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
Sigurd (continued)													
Salt													
Calculated 1974	6,420	6,597	4,591	5,204	8,227	5,559	2,334	-4	114	195	869	1,912	42,016
Measured 1974	5,734	6,501	5,884	5,912	12,221	10,105	4,842	1,743	829	1,405	854	2,337	58,366
Calculated 1975	2,094	3,947	4,138	8,438	8,222	5,811	578	5,030	3,673	2,454	2,028	3,026	49,440
Measured 1975	3,742	3,944	5,057	4,852	5,102	4,434	2,128	3,534	2,469	1,021	1,354	4,279	41,914
Calculated 1976	2,749	5,952	5,355	7,766	7,196	5,867	1,414	1,262	1,382	1,723	846	1,204	42,714
Measured 1976	3,193	4,127	4,405	4,619	5,919	4,324	1,593	823	1,587	248	1,067	1,982	33,888
Salina													
Water													
Calculated 1974	15,653	16,797	18,480	18,967	29,392	45,142	18,701	24,314	9,221	6,156	5,710	5,546	214,078
Measured 1974	16,620	17,450	17,640	18,850	29,470	46,190	19,320	26,790	7,370	4,780	5,090	6,460	216,030
Calculated 1975	9,637	14,594	15,945	14,529	16,749	16,588	8,307	20,118	26,921	9,431	4,624	8,034	165,478
Measured 1975	10,090	11,740	13,290	12,910	13,340	15,210	8,850	16,650	32,520	8,410	5,350	8,370	156,730
Calculated 1976	8,434	10,731	13,108	13,995	19,539	14,924	9,230	10,098	9,296	5,352	4,456	5,408	124,571
Measured 1976	10,520	13,720	15,000	15,310	21,710	21,280	7,200	7,700	5,890	3,470	4,220	5,340	131,360
Salt													
Calculated 1974	25,724	28,498	28,966	26,568	32,205	51,509	25,488	31,013	15,334	9,851	11,176	12,465	298,797
Measured 1974	26,540	29,763	29,608	25,106	31,240	55,870	24,419	32,950	13,522	12,863	10,930	11,282	304,093
Calculated 1975	17,630	25,151	26,983	25,719	26,490	26,560	17,199	27,977	37,147	17,218	9,497	16,241	273,810
Measured 1975	17,470	22,338	27,545	26,669	22,300	26,108	15,155	21,610	48,174	20,093	12,957	19,168	279,587
Calculated 1976	18,274	22,167	24,383	27,138	33,304	29,639	18,942	18,070	17,094	10,485	10,128	12,227	241,853
Measured 1976	23,205	24,203	24,545	23,013	31,807	34,300	14,825	11,815	10,246	8,159	10,639	14,261	231,016

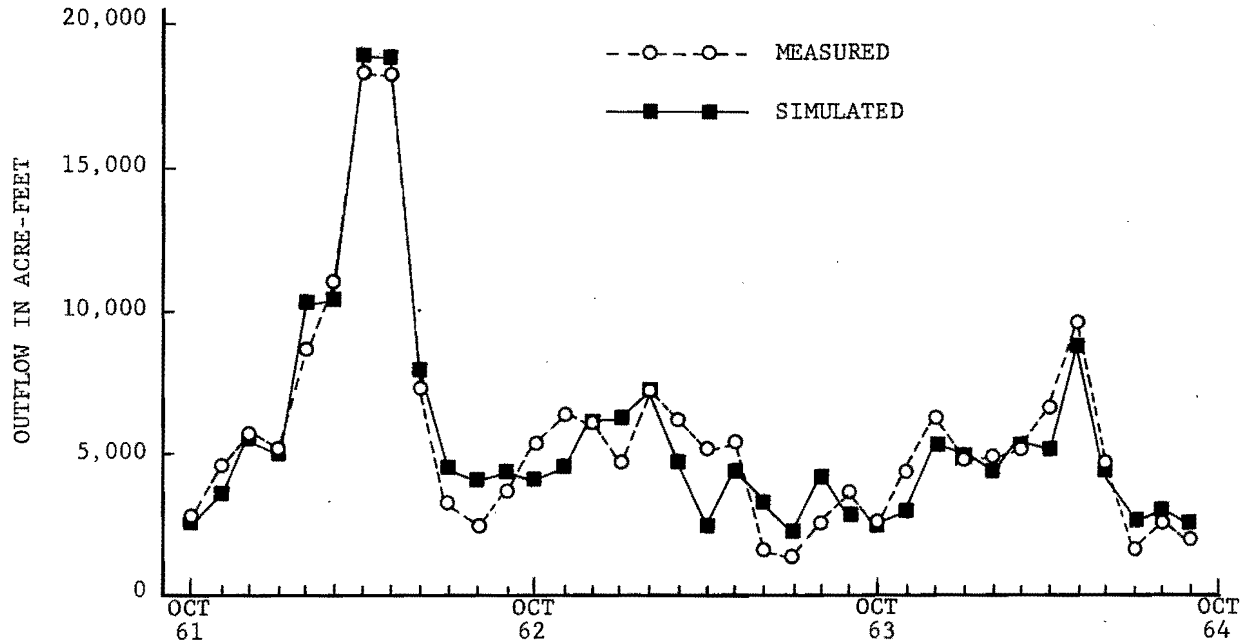

Figure 3. Agreement between measured and simulated surface outflow - Circleville.

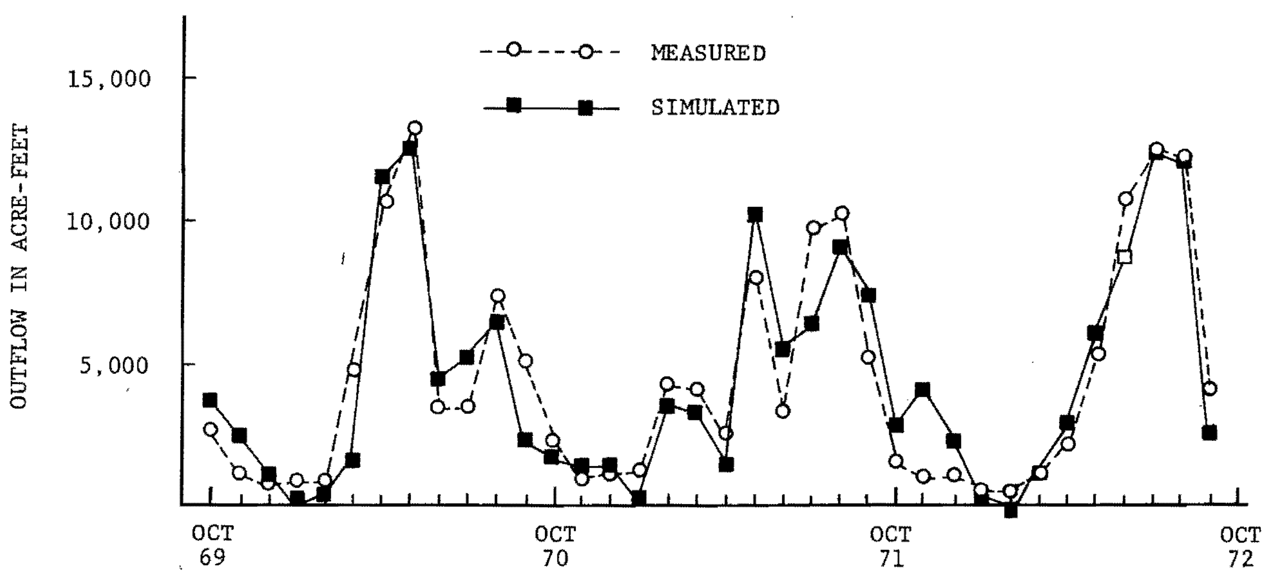

Figure 4. Agreement between measured and simulated surface outflow - East Fork.

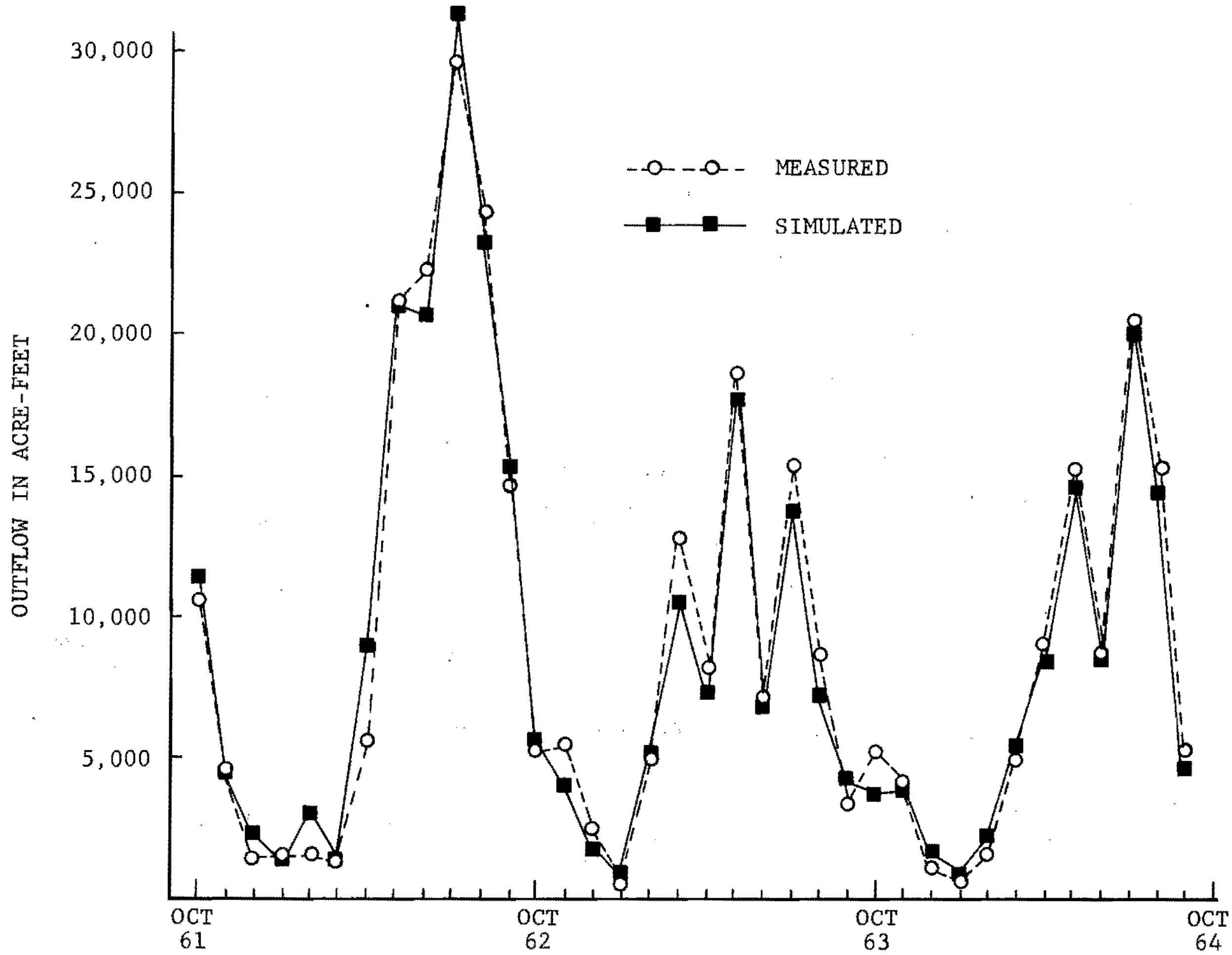

Figure 5. Agreement between measured and simulated surface outflow - Marysvale.

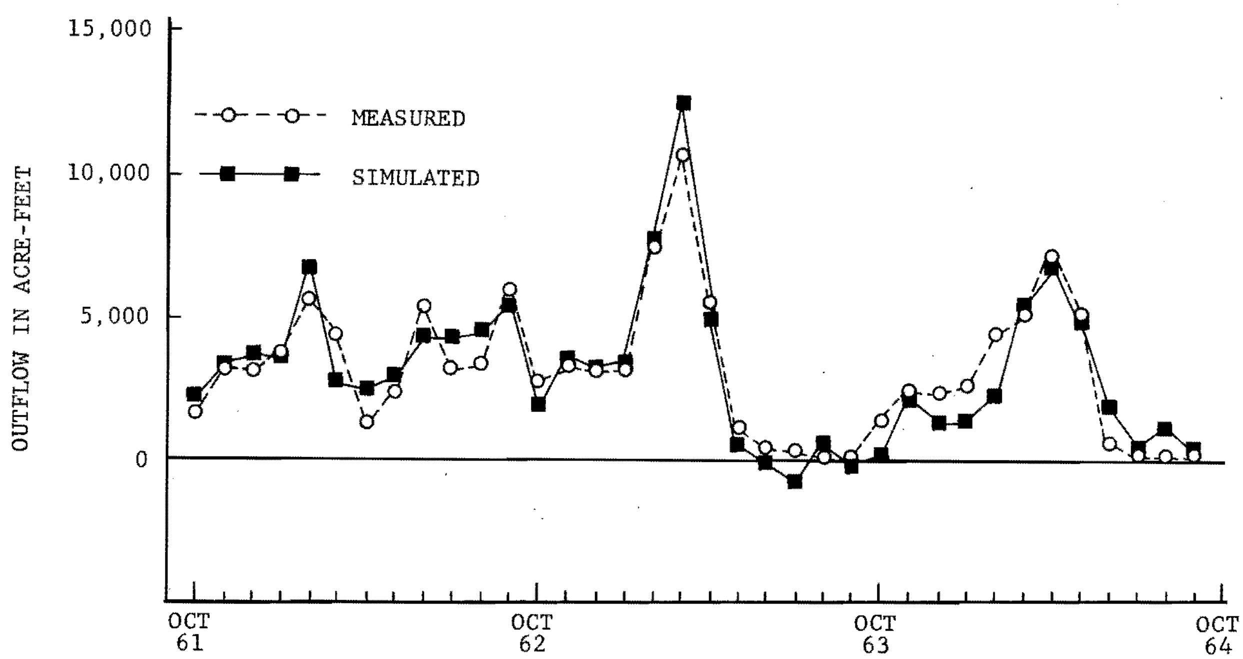

Figure 6. Agreement between measured and simulated surface outflow - Sigurd.

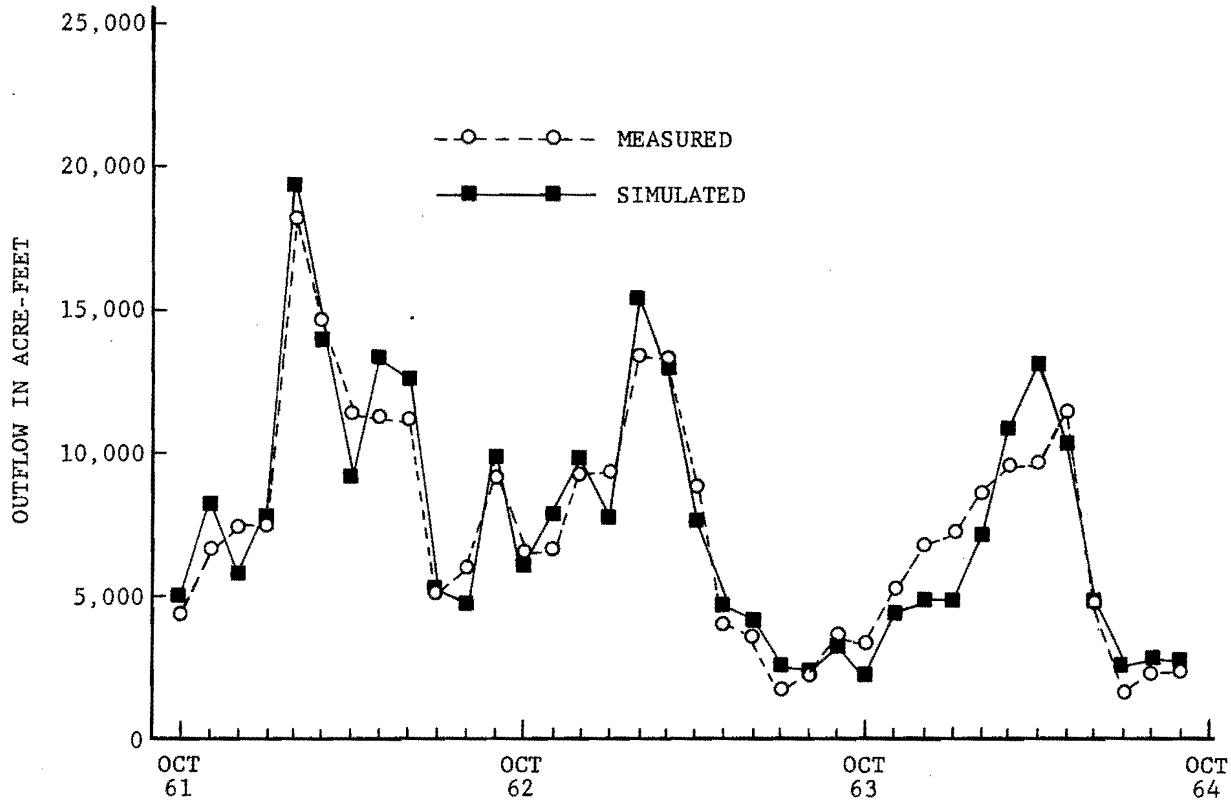

Figure 7. Agreement between measured and simulated surface outflow - Salina.

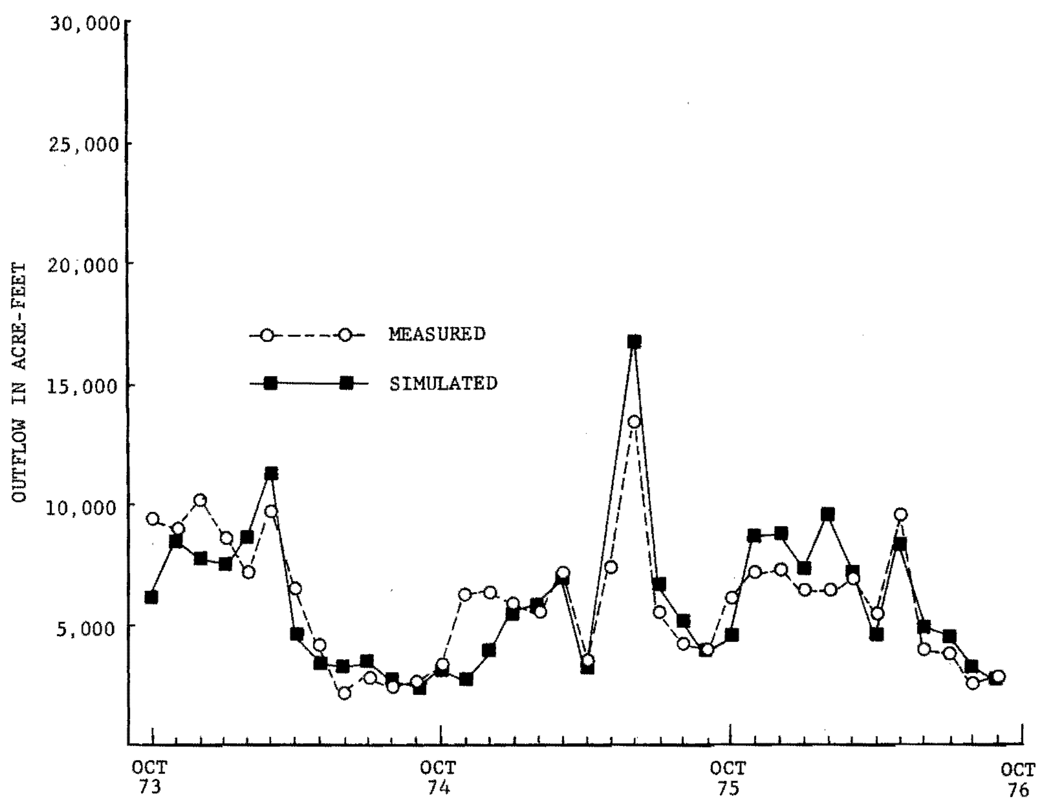

Figure 8. Agreement between measured and simulated surface outflow - Circleville.

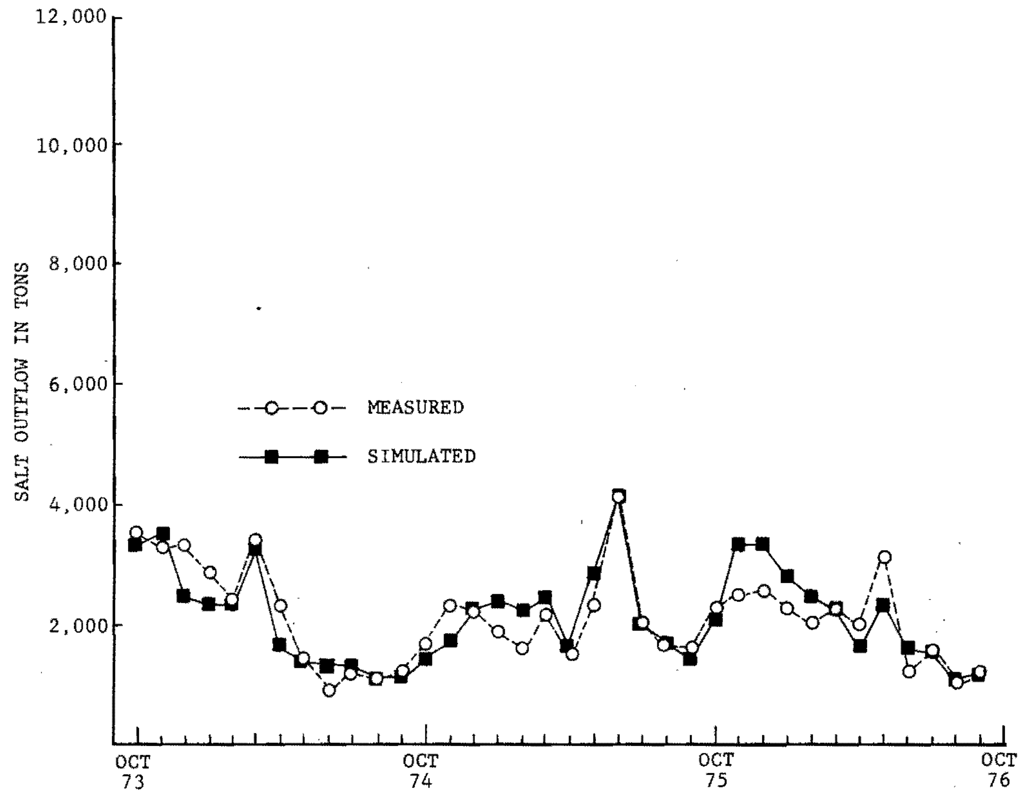

Figure 9. Agreement between measured and simulated salt outflow - Circleville.

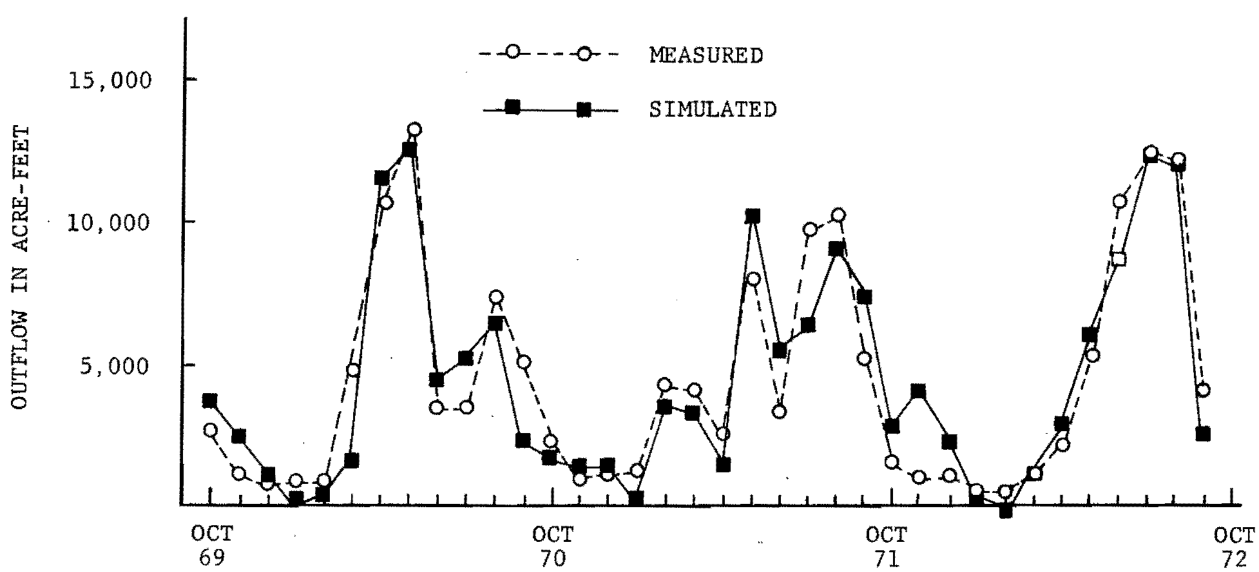

Figure 10. Agreement between measured and simulated surface outflow - East Fork.

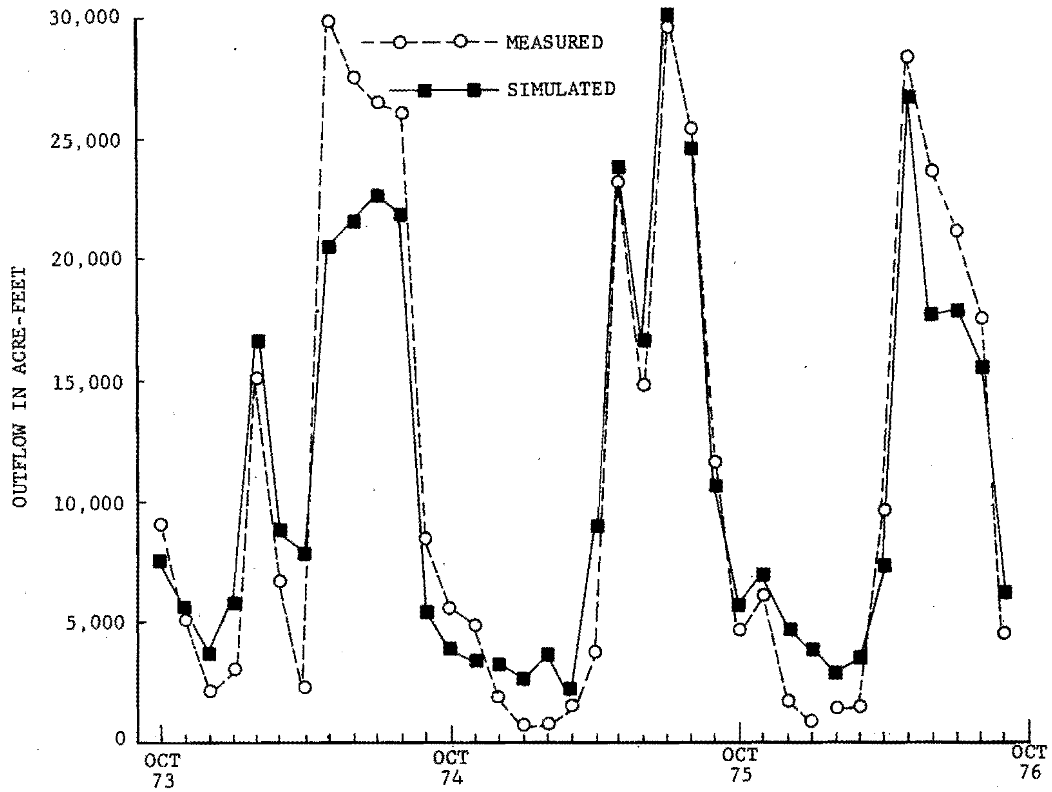

Figure 11. Agreement between measured and simulated surface outflow - Marysvale.

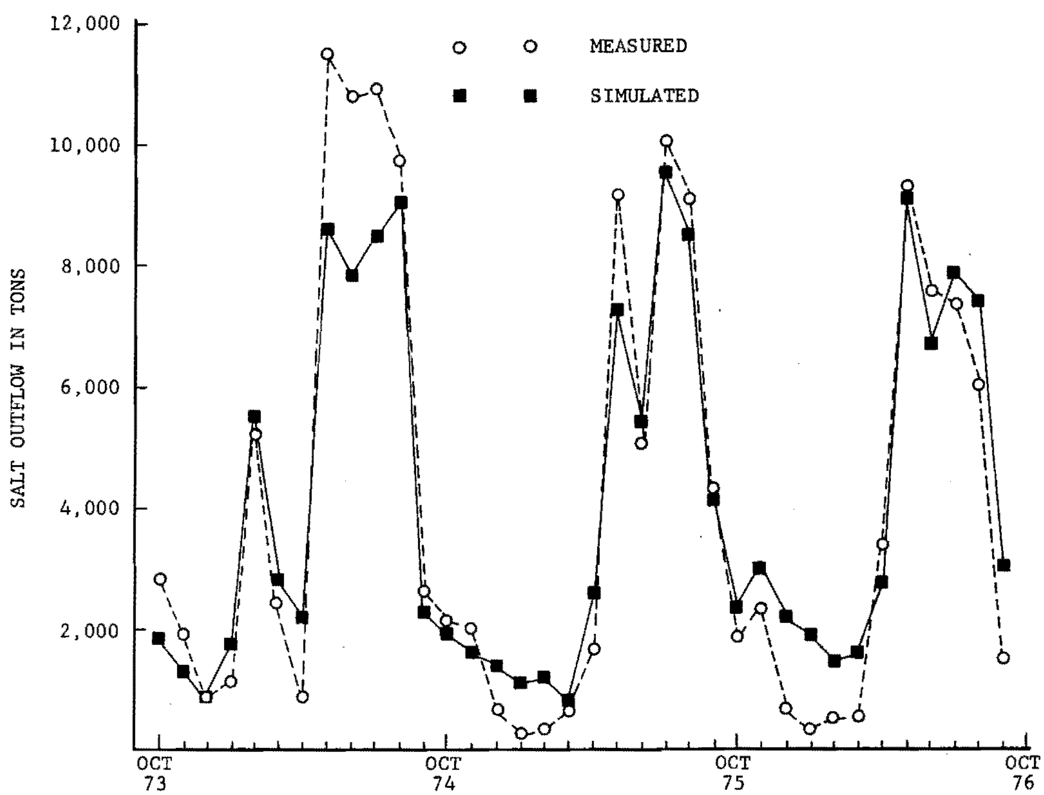

Figure 12. Agreement between measured and simulated salt outflow - Marysvale.

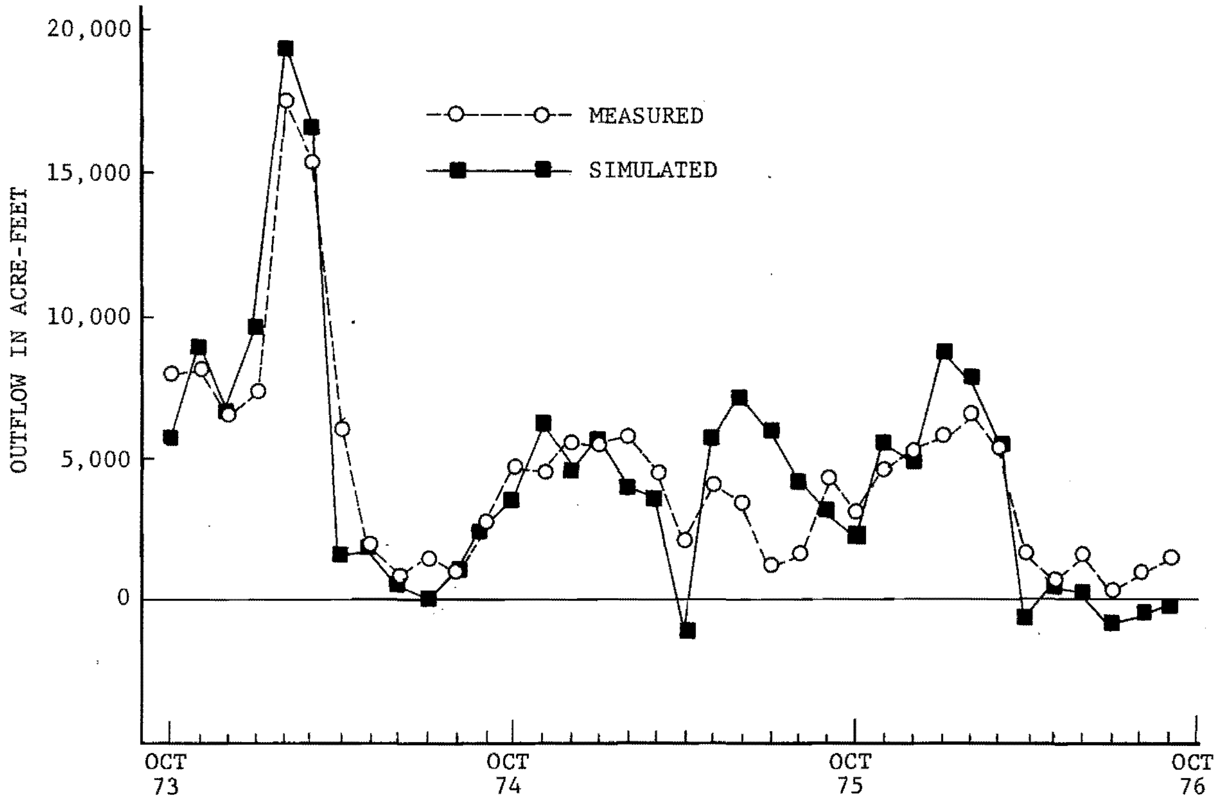

Figure 13. Agreement between measured and simulated surface outflow - Sigurd.

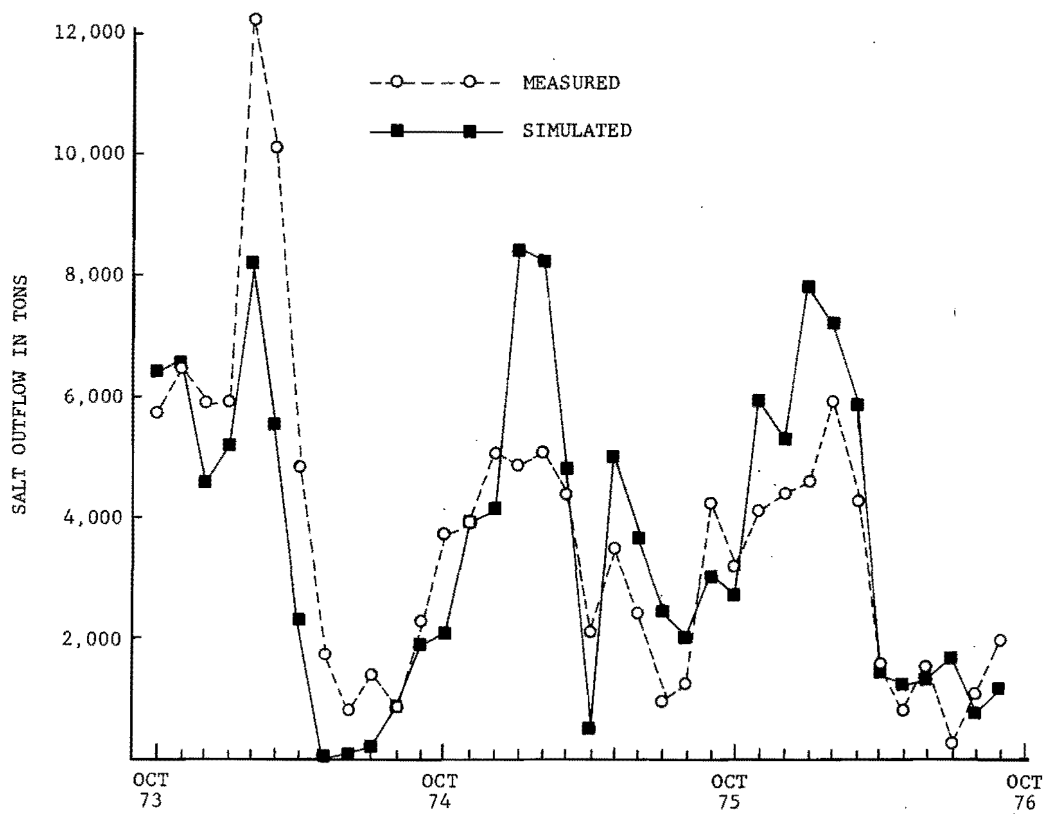

Figure 14. Agreement between measured and simulated salt outflow - Sigurd.

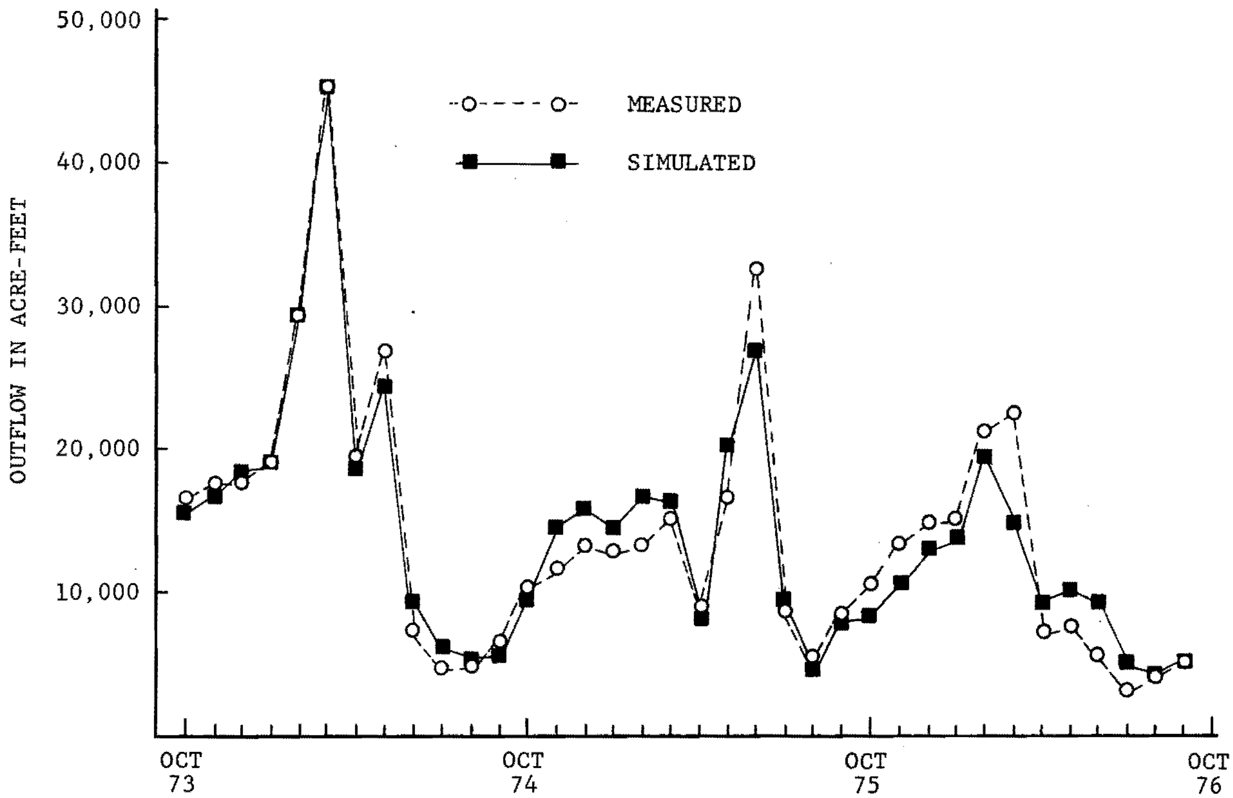

Figure 15. Agreement between measured and simulated surface outflow - Salina.

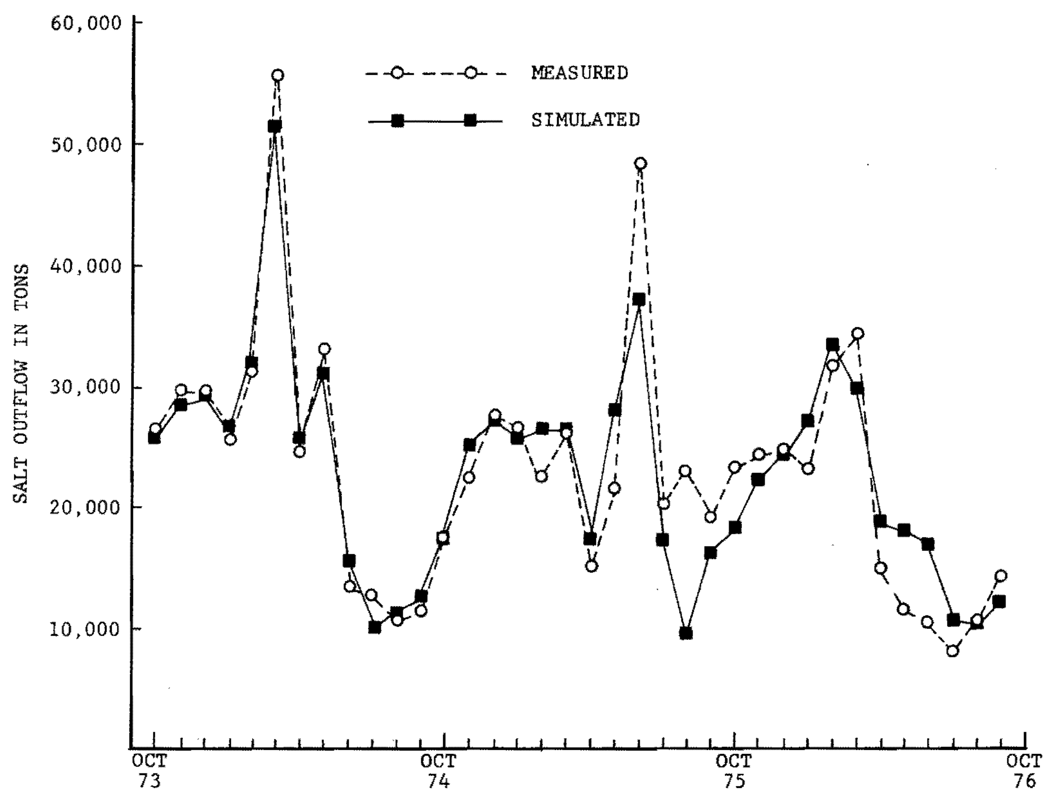

Figure 16. Agreement between measured and simulated salt outflow - Salina.

Table 5. Comparison of error between predicted and measured outflow.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
<u>Circleville</u>													
1962	-383	-871	-180	-35	1,555	-556	608	357	717	1,275	1,488	669	4,643
1974	-3,282	-520	-2,240	-1,137	1,575	1,481	-2,106	-519	1,202	547	194	-277	-5,082
1963	-1,195	-1,630	107	1,712	-10	-1,290	-960	-962	1,631	765	1,456	-824	-1,201
1975	-1,190	-3,292	-2,444	-556	274	-224	-348	2,180	3,381	1,196	881	-179	-321
1964	65	-1,382	-903	59	-509	163	-1,462	-675	-387	1,001	-841	670	-3,201
1976	-1,513	1,537	1,597	752	2,909	190	-1,011	-1,024	966	477	575	-55	5,401
<u>Marysvale</u>													
1962	800	-196	815	-184	1,370	85	3,429	-99	-1,524	1,673	-1,046	558	5,680
1974	-1,406	452	1,703	2,886	1,695	2,053	5,587	-3,612	-6,147	-3,845	-4,260	-3,236	-8,125
1963	233	-1,540	-689	389	150	-2,219	-799	-865	-107	-1,348	-1,620	771	-7,645
1975	-1,762	-1,549	1,291	2,050	2,673	710	4,815	809	1,906	517	-793	-783	9,883
1964	-1,380	-52	576	104	508	629	-466	-626	-113	-386	-796	528	-2,529
1976	896	903	2,877	2,981	1,605	2,004	-2,174	-1,593	-5,658	-3,110	-1,930	1,592	-1,606
<u>Sigurd</u>													
1962	352	282	543	-152	1,340	-1,330	1,308	575	-998	1,157	1,334	-441	3,970
1974	-2,218	755	162	2,327	1,886	1,250	-4,393	-265	-313	-1,450	233	-195	-2,232
1963	-882	207	54	499	424	1,767	-558	-533	-618	-1,113	653	-175	-276
1975	-1,065	1,681	-923	2	-1,809	-697	-3,096	1,844	3,902	4,751	2,584	-1,195	5,978
1964	-1,255	-259	-1,108	-1,396	-2,167	204	-295	-72	1,254	410	1,035	40	-3,609
1976	-819	979	-236	2,813	1,328	314	-2,288	-201	-1,428	-1,096	-1,451	-1,744	-3,829
<u>Salina</u>													
1962	727	1,551	-1,518	367	1,251	-727	-2,370	1,991	1,411	206	-1,203	803	2,488
1974	-967	-653	840	117	-78	-1,048	-619	-2,476	1,851	1,376	620	-914	-1,952
1963	-459	1,477	645	-1,526	1,952	-143	-1,175	674	477	821	222	-438	2,425
1975	-453	2,854	2,655	1,619	3,409	1,378	-543	3,468	-5,599	1,021	-726	-336	8,748
1964	-1,170	-707	-2,082	-2,337	-1,611	1,346	3,348	-1,174	18	988	523	366	-2,492
1976	-2,086	-2,989	-1,892	-1,315	-2,171	-4,661	2,030	2,398	3,406	1,882	236	68	-6,789

Table 6. Comparison of simulated and measured outflow, 1962-1975, using historical diversions - Circleville.

		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
Calculated	1962	2,537	3,649	5,500	5,025	10,245	10,474	18,978	18,647	7,987	4,505	4,128	4,449	96,123
Recorded	1962	2,920	4,520	5,680	5,060	8,690	11,030	18,370	18,290	7,270	3,230	2,640	3,780	91,480
Calculated	1963	4,075	4,700	6,317	6,362	7,090	4,830	2,620	4,388	3,451	2,365	4,166	2,956	53,319
Recorded	1963	5,270	6,330	6,210	4,650	7,100	6,120	3,580	5,350	1,820	1,600	2,710	3,780	54,520
Calculated	1964	2,715	3,048	5,307	5,049	4,431	5,343	5,168	8,955	4,343	2,911	3,039	2,770	53,079
Recorded	1964	2,650	4,430	6,210	4,990	4,940	5,180	6,630	9,630	4,730	1,910	2,880	2,100	56,280
Calculated	1965	2,430	3,256	5,711	5,127	4,827	5,896	3,386	12,438	23,745	6,296	4,994	5,261	83,367
Recorded	1965	3,030	4,360	6,420	5,530	5,630	5,720	5,240	11,930	19,900	7,940	3,970	5,240	84,910
Calculated	1966	4,405	9,026	9,757	7,758	6,719	9,797	11,400	14,707	5,611	3,827	4,107	3,813	90,928
Recorded	1966	5,190	7,660	7,900	6,480	5,770	12,240	9,850	13,670	3,860	2,910	3,240	3,690	82,460
Calculated	1967	4,972	6,785	8,918	7,045	6,044	7,382	3,502	14,291	22,401	9,575	6,232	11,920	110,006
Recorded	1967	6,520	7,050	8,540	6,970	6,800	7,850	4,520	11,220	19,480	8,370	5,070	11,220	103,610
Calculated	1968	6,986	7,462	7,173	6,861	8,944	7,649	9,567	19,148	14,140	5,967	6,201	5,521	105,619
Recorded	1968	8,800	6,380	6,350	5,260	5,120	5,000	9,130	17,910	15,750	7,290	8,300	5,150	100,440
Calculated	1969	5,166	7,110	8,942	8,521	7,176	3,965	17,790	52,461	29,850	11,499	9,687	9,378	171,547
Recorded	1969	7,080	7,910	6,980	7,120	6,780	7,340	13,680	41,940	26,810	10,790	9,860	8,870	155,160
Calculated	1970	6,786	6,871	10,808	11,028	9,786	8,918	3,798	5,592	6,128	5,333	5,135	5,883	86,066
Recorded	1970	8,780	10,300	9,620	8,840	7,850	7,670	5,120	4,450	4,050	3,580	4,180	4,290	78,730
Calculated	1971	5,952	9,152	6,548	5,928	5,469	5,945	2,468	4,115	6,033	3,646	4,783	3,390	63,428
Recorded	1971	5,170	7,350	7,090	6,820	5,120	6,770	3,710	4,490	5,820	2,640	6,070	4,550	65,600
Calculated	1972	4,422	6,720	9,765	7,201	6,459	5,853	2,459	4,085	4,846	3,327	3,768	3,525	62,432
Recorded	1972	5,080	7,630	12,110	6,820	6,770	6,390	3,400	5,410	3,990	2,400	2,830	4,010	66,840
Calculated	1973	7,160	7,771	6,155	5,021	5,992	6,623	11,704	48,643	34,932	9,650	7,635	7,578	158,863
Recorded	1973	7,350	7,820	6,150	6,940	7,040	8,820	12,730	38,890	31,440	9,600	8,130	7,220	152,130
Calculated	1974	6,016	7,717	8,917	7,057	6,712	7,987	4,029	3,866	3,243	3,253	2,721	2,618	64,136
Recorded	1974	9,350	9,010	10,160	8,730	7,080	9,780	6,740	4,050	2,160	2,970	2,650	2,860	75,540
Calculated	1975	2,983	2,872	3,717	5,094	4,519	5,632	3,308	7,935	14,925	5,293	5,865	3,975	65,119
Recorded	1975	4,330	6,180	6,340	5,900	5,680	7,160	4,440	7,180	13,250	5,450	4,160	3,960	74,030

Table 7. Comparison of simulated and measured outflow, 1962-1975, using model calculated diversions - Circleville.

		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
Calculated	1962	2,537	5,847	5,399	4,915	4,396	9,587	16,429	20,198	6,393	5,041	4,653	4,999	90,392
Recorded	1962	2,920	4,520	5,680	5,060	8,690	11,030	18,370	18,290	7,270	3,230	2,640	3,780	91,480
Calculated	1963	4,600	8,389	7,645	6,521	3,364	3,146	3,082	4,737	3,727	2,606	3,981	3,239	54,938
Recorded	1963	5,270	6,330	6,210	4,650	7,100	6,120	3,580	5,350	1,820	1,600	2,710	3,780	54,520
Calculated	1964	2,978	6,323	5,423	4,921	2,081	2,476	3,376	5,926	5,089	3,520	3,565	3,263	48,941
Recorded	1964	2,650	4,430	6,210	4,990	4,940	5,180	6,630	9,630	4,730	1,910	2,880	2,100	56,280
Calculated	1965	2,948	6,211	6,033	5,318	2,337	2,747	3,139	16,379	20,678	5,757	5,478	5,722	82,746
Recorded	1965	3,030	4,360	6,420	5,530	5,630	5,720	5,240	11,930	19,990	7,940	3,970	5,240	84,910
Calculated	1966	4,770	11,750	9,900	7,901	3,528	4,631	7,947	14,458	5,992	4,666	4,926	4,664	84,133
Recorded	1966	5,190	7,660	7,900	6,480	5,770	12,240	9,850	13,670	3,860	2,910	3,240	3,690	82,460
Calculated	1967	4,880	8,793	9,739	7,693	3,121	3,555	3,689	16,028	21,288	6,827	6,333	11,697	103,643
Recorded	1967	6,520	7,050	8,540	6,970	6,800	7,850	4,520	11,220	19,480	8,370	5,070	11,220	103,610
Calculated	1968	5,484	10,556	8,344	7,825	5,878	7,235	8,571	23,481	9,324	6,947	7,094	6,340	108,082
Recorded	1968	8,800	6,380	6,350	5,260	5,120	5,000	9,130	17,910	15,750	7,290	8,300	5,150	100,440
Calculated	1969	5,844	10,633	9,282	10,167	4,221	5,826	18,118	52,999	31,088	8,590	8,309	7,731	172,807
Recorded	1969	7,080	7,910	6,980	7,120	6,780	7,340	13,680	41,940	26,810	10,790	9,860	8,870	155,160
Calculated	1970	7,161	13,687	11,971	10,503	4,809	4,902	4,344	5,940	6,339	5,537	5,406	5,224	85,825
Recorded	1970	8,780	10,300	9,620	8,840	7,850	7,670	5,120	4,450	4,050	3,580	4,180	4,290	78,730
Calculated	1971	4,641	10,346	7,606	6,610	3,046	3,164	3,115	4,642	5,639	4,105	5,217	3,836	61,967
Recorded	1971	5,170	7,350	7,090	6,820	5,120	6,770	3,710	4,490	5,820	2,640	6,070	4,550	65,600
Calculated	1972	4,826	7,974	10,399	7,362	3,034	3,230	3,069	4,560	5,216	3,682	4,155	3,913	61,419
Recorded	1972	5,080	7,630	12,110	6,820	6,770	6,390	3,400	5,410	3,990	2,400	2,830	4,010	66,840
Calculated	1973	4,999	8,917	6,633	5,696	2,966	5,271	9,811	49,199	32,211	7,541	7,258	6,827	147,329
Recorded	1973	7,350	7,820	6,150	6,940	7,040	8,820	12,730	38,890	31,440	9,600	8,130	7,220	152,130
Calculated	1974	6,077	12,500	10,534	7,784	3,916	4,293	3,934	4,827	4,007	3,916	3,379	3,268	68,435
Recorded	1974	9,350	9,010	10,160	8,730	7,080	9,780	6,740	4,050	2,160	2,970	2,650	2,860	75,540
Calculated	1975	3,602	6,463	5,606	4,972	2,090	2,517	2,812	5,680	10,495	6,188	5,640	4,661	60,724
Recorded	1975	4,330	6,180	6,340	5,900	5,680	7,160	4,440	7,180	13,250	5,450	4,160	3,960	74,030

Table 8. Comparison of simulated and measured outflow, 1962-1975, using historical diversions - Marysvale.

		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
Calculated	1962	11,320	4,554	2,315	1,376	3,070	1,715	9,009	21,031	20,706	31,243	23,204	15,328	144,870
Measured	1962	10,520	4,750	1,500	1,560	1,700	1,630	5,580	21,130	22,230	29,570	24,250	14,770	139,190
Calculated	1963	5,673	4,030	1,961	1,004	5,170	10,711	7,381	17,885	7,013	13,962	7,280	4,381	86,450
Measured	1963	5,440	5,570	2,650	615	5,020	12,930	8,180	18,750	7,120	15,310	8,900	3,610	94,095
Calculated	1964	3,870	3,998	1,866	1,056	2,448	5,669	8,634	14,824	8,727	20,204	14,634	4,892	90,823
Measured	1964	5,250	4,050	1,290	952	1,940	5,040	9,100	15,450	8,840	20,590	15,430	5,420	93,352
Calculated	1965	4,081	3,224	1,609	793	2,615	7,411	14,589	15,506	10,245	21,569	12,453	17,848	111,944
Measured	1965	5,010	3,330	1,180	1,100	2,990	7,920	15,180	15,630	12,030	22,560	12,860	17,050	116,840
Calculated	1966	8,634	5,930	3,030	1,515	819	2,001	12,452	21,439	18,954	21,021	18,401	5,310	119,595
Measured	1966	10,910	5,680	1,750	1,220	1,270	1,270	13,530	23,010	21,730	23,030	18,460	5,890	127,750
Calculated	1967	4,989	3,652	5,482	2,327	4,312	8,695	7,977	20,699	9,645	24,752	19,065	9,021	120,616
Measured	1967	5,980	5,090	1,930	1,290	4,500	10,480	7,730	21,040	12,490	26,480	22,090	10,620	129,720
Calculated	1968	9,703	2,481	1,747	1,502	2,819	6,546	3,767	25,027	17,479	31,883	11,065	22,712	136,730
Measured	1968	8,680	6,240	1,830	1,550	7,570	11,490	1,730	28,750	20,190	31,720	15,530	23,650	158,930
Calculated	1969	6,005	3,980	2,061	1,101	4,876	13,066	22,515	46,088	32,268	31,371	27,773	14,637	205,740
Measured	1969	9,120	5,680	2,380	1,700	5,900	15,590	25,720	44,850	39,020	37,650	30,640	18,390	236,640
Calculated	1970	7,445	5,304	2,993	8,614	9,167	9,982	14,599	24,855	15,208	28,287	22,067	11,466	159,986
Measured	1970	9,350	5,430	3,520	8,500	11,140	10,430	16,370	28,840	20,910	29,570	25,840	16,750	186,650
Calculated	1971	6,438	3,371	1,608	830	546	240	8,564	26,714	16,675	26,405	18,489	5,179	115,059
Measured	1971	8,900	4,710	1,630	1,220	1,110	1,210	9,340	26,200	21,440	30,130	21,530	6,470	133,890
Calculated	1972	5,228	2,559	2,362	745	287	1,761	10,635	25,189	16,129	24,885	13,456	3,520	106,757
Measured	1972	4,600	3,540	2,320	1,820	1,660	2,180	13,690	26,440	19,220	27,780	20,120	5,440	128,810
Calculated	1973	3,985	2,780	1,069	1,054	1,235	996	11,496	58,741	56,138	30,872	28,651	17,633	214,648
Measured	1973	4,940	3,500	1,540	1,710	1,520	1,830	8,470	50,570	57,200	35,060	30,440	20,110	216,890
Calculated	1974	7,595	4,778	2,322	3,404	14,001	5,962	4,829	28,464	22,897	22,476	20,672	3,806	141,205
Measured	1974	9,010	5,060	2,070	3,010	15,020	6,720	2,220	29,970	27,630	26,490	26,060	8,420	161,680
Calculated	1975	2,049	1,938	1,768	699	5,038	379	5,983	24,589	15,226	26,278	24,803	7,388	116,136
Measured	1975	5,660	4,880	1,940	722	887	1,420	3,770	23,160	14,690	29,460	25,250	11,500	123,339

Table 9. Comparison of simulated and measured outflow, 1962-1975, using model calculated diversions - Marysvale.

		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
Calculated	1962	7,737	7,577	2,273	1,756	1,988	1,744	9,787	22,624	14,108	20,066	19,051	16,760	125,471
Measured	1962	10,520	4,750	1,500	1,560	1,700	1,630	5,580	21,130	22,230	29,570	24,250	14,770	139,190
Calculated	1963	10,793	9,305	3,194	1,433	3,167	9,493	10,473	13,203	7,919	9,394	8,333	6,493	93,199
Measured	1963	5,440	5,570	2,650	615	5,020	12,930	8,180	18,750	7,120	15,310	8,900	3,610	94,095
Calculated	1964	5,170	7,280	1,325	988	1,199	3,213	13,376	14,790	7,651	11,784	12,229	7,940	86,844
Measured	1964	5,250	4,050	1,290	952	1,940	5,040	9,100	15,450	8,840	20,590	15,430	5,420	93,352
Calculated	1965	5,885	5,996	1,720	703	1,316	386	12,903	20,394	10,331	15,748	12,993	15,539	107,388
Measured	1965	5,010	3,330	1,180	1,100	2,990	7,920	15,180	15,630	12,030	22,560	12,860	17,050	116,840
Calculated	1966	11,233	9,457	3,064	1,620	883	1,346	8,497	20,093	14,444	15,869	16,568	10,323	113,396
Measured	1966	10,910	5,680	1,750	1,220	1,270	1,270	13,530	23,010	21,730	23,030	18,460	5,890	127,750
Calculated	1967	7,820	7,333	6,046	2,369	2,140	5,394	8,830	22,439	10,187	16,424	16,403	12,775	118,161
Measured	1967	5,980	5,090	1,930	1,290	4,500	10,480	7,730	21,040	12,490	26,480	22,090	10,620	129,720
Calculated	1968	8,702	6,077	2,960	2,977	1,630	3,649	4,183	27,320	13,658	24,009	14,181	17,371	126,718
Measured	1968	8,680	6,240	1,830	1,550	7,570	11,490	1,730	28,750	20,190	31,720	15,530	23,650	158,930
Calculated	1969	10,401	7,603	2,838	1,548	3,372	10,890	23,322	47,292	29,796	23,011	21,807	16,970	198,850
Measured	1969	9,120	5,680	2,380	1,700	5,900	15,590	25,720	44,850	39,020	37,650	30,640	18,390	236,640
Calculated	1970	11,937	10,399	4,457	9,084	4,775	8,266	16,994	22,203	12,679	19,209	19,183	15,212	154,397
Measured	1970	9,350	5,430	3,520	8,500	11,140	10,430	16,370	28,840	20,910	29,570	25,840	16,750	186,650
Calculated	1971	10,800	6,663	2,713	1,386	854	449	5,821	22,649	13,736	17,776	18,076	10,549	111,473
Measured	1971	8,900	4,710	1,630	1,220	1,110	1,210	9,340	26,200	21,440	30,130	21,530	6,470	133,890
Calculated	1972	8,390	4,411	3,358	1,085	459	1,003	6,935	19,978	13,970	17,132	14,558	8,434	99,711
Measured	1972	4,600	3,540	3,320	1,820	1,660	2,180	13,690	26,440	19,220	27,780	20,120	5,440	128,810
Calculated	1973	6,913	5,124	1,545	1,478	970	1,281	9,533	60,635	51,466	23,968	24,816	18,919	206,649
Measured	1973	4,940	3,500	1,540	1,710	1,520	1,830	8,470	50,570	57,200	35,060	30,440	20,110	216,890
Calculated	1974	11,595	8,772	3,421	4,108	7,289	5,558	5,435	23,107	15,962	12,827	17,983	11,134	132,190
Measured	1974	9,010	5,060	2,070	3,010	15,020	6,720	2,220	29,970	27,630	26,490	26,060	8,420	161,680
Calculated	1975	6,077	5,770	2,964	616	2,410	1,233	4,548	22,372	13,274	18,697	19,691	13,225	110,877
Measured	1975	5,660	4,880	1,940	722	887	1,420	3,770	23,160	14,690	29,460	25,250	11,500	123,339

Table 10. Comparison of simulated and measured outflow, 1962-1975, using historical diversions - Sigurd.

		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
Calculated	1962	2,102	3,472	3,693	3,628	6,870	2,890	2,378	2,965	4,272	4,227	4,524	5,539	46,660
Measured	1962	1,750	3,190	3,150	3,780	5,630	4,220	1,070	2,390	5,270	3,070	3,190	5,980	42,690
Calculated	1963	1,978	3,727	3,384	3,649	7,884	12,507	4,962	587	-54	-844	718	-121	38,376
Measured	1963	2,860	3,520	3,330	3,150	7,460	10,740	5,520	1,120	564	269	65	54	38,652
Calculated	1964	185	2,201	1,302	1,394	2,223	5,454	6,825	4,958	1,983	696	1,117	163	28,501
Measured	1964	1,440	2,460	2,410	2,790	4,390	5,250	7,120	5,030	729	286	82	123	32,110
Calculated	1965	625	1,948	4,447	1,810	3,373	7,335	6,079	3,460	5,023	3,968	3,301	3,246	44,616
Measured	1965	1,500	2,600	3,050	2,970	4,420	7,010	7,200	1,840	2,880	2,630	1,260	3,040	40,400
Calculated	1966	3,612	3,759	4,310	3,376	3,330	5,257	-515	1,215	348	410	409	146	25,657
Measured	1966	3,980	4,020	4,520	4,350	4,170	4,190	290	759	262	186	272	1,050	28,049
Calculated	1967	1,337	2,507	4,649	4,080	7,764	10,659	2,565	5,315	6,045	1,537	3,413	5,475	55,346
Measured	1967	2,210	3,030	4,460	4,760	6,970	10,070	3,860	4,170	5,000	2,140	2,760	3,590	53,020
Calculated	1968	2,877	3,126	4,435	4,953	12,629	14,834	2,543	9,219	4,226	2,670	3,125	1,558	66,194
Measured	1968	4,040	3,900	5,370	5,900	10,470	13,900	2,930	3,830	3,660	1,730	3,410	1,570	60,710
Calculated	1969	2,467	4,212	4,268	7,483	10,510	19,894	17,145	22,899	25,186	4,419	4,230	9,970	132,685
Measured	1969	4,500	5,210	6,810	6,660	8,630	17,500	15,380	15,150	22,130	3,900	3,630	7,400	116,900
Calculated	1970	8,826	10,810	10,477	15,356	16,575	13,870	5,097	4,919	6,648	-1,254	196	815	92,334
Measured	1970	8,640	8,810	10,100	12,990	17,280	13,530	8,480	4,500	5,010	2,190	2,250	4,360	98,140
Calculated	1971	5,240	6,759	2,716	6,146	5,268	7,005	1,137	238	257	-1,253	245	1,450	35,209
Measured	1971	8,050	8,180	7,500	7,880	6,930	7,300	3,000	1,200	1,200	552	2,280	3,490	57,562
Calculated	1972	2,807	3,730	5,570	5,136	5,259	3,373	1,500	3,204	2,730	2,048	3,611	2,864	41,833
Measured	1972	3,730	6,120	6,570	6,960	6,150	4,120	264	587	832	110	1,490	2,200	39,133
Calculated	1973	3,359	3,455	2,980	4,219	4,100	4,692	19,971	44,603	29,125	-1,347	234	3,427	118,817
Measured	1973	3,350	3,320	3,480	4,770	6,510	4,930	12,870	32,240	32,770	1,710	5,130	6,460	117,540
Calculated	1974	2,463	6,406	6,837	9,547	19,833	14,552	493	868	-983	-877	630	1,465	61,234
Measured	1974	7,960	8,040	6,610	7,250	17,460	15,330	6,090	2,020	947	1,590	998	2,760	77,055
Calculated	1975	3,209	5,730	3,213	4,092	3,570	3,794	-232	13,577	14,135	7,903	3,661	2,440	65,092
Measured	1975	9,690	4,520	5,570	5,450	5,820	4,350	2,020	3,970	3,460	1,250	1,660	4,410	47,170

Table 11. Comparison of simulated and measured outflow, 1962-1975, using model calculated diversions - Sigurd.

		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
Calculated	1962	2,102	8,071	4,910	4,229	2,540	1,693	2,101	8,070	3,856	3,882	4,303	4,833	50,591
Measured	1962	1,750	3,190	3,150	3,780	5,630	4,220	1,070	2,390	5,270	3,070	3,190	5,980	42,690
Calculated	1963	1,988	8,516	5,780	3,619	3,441	6,539	1,827	687	-223	-1,130	459	-163	31,339
Measured	1963	2,860	3,520	3,330	3,150	7,460	10,740	5,520	1,120	564	269	65	54	38,652
Calculated	1964	364	6,470	2,715	2,078	918	2,246	2,833	3,780	2,268	862	1,214	166	25,916
Measured	1964	1,440	2,460	2,410	2,790	4,390	5,250	7,120	5,030	729	286	82	123	32,110
Calculated	1965	724	5,864	6,047	3,096	1,363	3,042	2,810	10,170	4,058	3,628	3,001	3,124	46,926
Measured	1965	1,500	2,600	3,050	2,970	4,420	7,010	7,200	1,840	2,880	2,630	1,260	3,040	40,400
Calculated	1966	3,702	9,900	5,529	3,783	1,687	2,499	-450	1,037	2	-31	-17	-166	27,474
Measured	1966	3,980	4,020	4,520	4,350	4,170	4,190	290	759	262	186	272	1,050	28,049
Calculated	1967	1,098	6,544	6,438	4,168	2,782	5,048	759	13,198	3,457	1,431	3,318	2,917	51,157
Measured	1967	2,210	3,030	4,460	4,760	6,970	10,070	3,860	4,170	5,000	2,140	2,760	3,590	53,020
Calculated	1968	3,297	8,926	5,393	4,801	5,155	8,875	6,220	18,659	3,686	2,242	3,017	1,830	72,101
Measured	1968	4,040	3,900	5,370	5,900	10,470	13,900	2,930	3,830	3,660	1,730	3,410	1,570	60,710
Calculated	1969	2,826	9,290	6,107	7,669	5,817	17,267	23,189	36,167	26,120	3,275	3,205	5,976	146,917
Measured	1969	4,500	5,210	6,810	6,660	8,630	17,500	15,380	15,150	22,130	3,900	3,630	7,400	116,900
Calculated	1970	4,998	10,580	8,308	13,019	8,347	14,395	10,074	10,255	2,094	-1,543	158	336	81,019
Measured	1970	8,640	8,810	10,100	12,990	17,280	13,530	8,480	4,500	5,010	2,190	2,250	4,360	98,140
Calculated	1971	2,943	9,270	4,513	5,243	2,670	2,936	496	5,814	-520	-1,545	44	676	32,540
Measured	1971	8,050	8,180	7,500	7,880	6,930	7,300	3,000	1,200	1,200	552	2,280	3,490	57,562
Calculated	1972	1,664	6,706	6,236	5,391	2,962	2,325	1,420	3,224	2,666	1,929	3,538	1,987	40,046
Measured	1972	3,730	6,120	6,570	6,960	6,150	4,120	264	587	832	110	1,490	2,200	39,133
Calculated	1973	2,749	6,554	4,781	4,000	1,564	1,517	15,192	57,142	33,846	-1,020	-211	1,417	127,532
Measured	1973	3,350	3,320	3,480	4,770	6,510	4,930	12,870	32,240	32,770	1,710	5,130	6,460	117,450
Calculated	1974	2,422	9,802	6,797	7,795	10,069	14,797	570	6,122	-1,903	-1,543	404	1,780	57,111
Measured	1974	7,960	8,040	6,610	7,250	17,460	15,330	6,090	2,020	947	1,590	998	2,760	77,055
Calculated	1975	3,050	9,008	5,384	3,505	1,640	1,030	-790	9,086	8,400	9,315	3,682	2,241	55,553
Measured	1975	4,690	4,520	5,570	5,450	5,820	4,350	2,020	3,970	3,460	1,250	1,660	4,410	47,170

Table 12. Comparison of simulated and measured outflow, 1962-1975, using historical diversions - Salina.

		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
Calculated	1962	5,037	8,191	5,872	7,917	19,321	13,963	9,070	13,291	12,581	5,226	4,797	9,923	115,188
Measured	1962	4,310	6,640	7,390	7,550	18,070	14,690	11,440	11,300	11,170	5,020	6,000	9,120	112,700
Calculated	1963	6,061	7,947	9,855	7,744	15,292	12,997	7,665	4,724	4,097	2,701	2,552	3,112	84,745
Measured	1963	6,520	6,570	9,210	9,270	13,340	13,140	8,840	4,050	3,620	1,880	2,330	3,550	82,320
Calculated	1964	2,180	4,413	4,868	4,873	7,099	10,946	13,048	10,226	4,798	2,678	2,873	2,776	70,778
Measured	1964	3,350	5,120	6,950	7,210	8,710	9,600	9,700	11,400	4,780	1,690	2,350	2,410	73,270
Calculated	1965	2,265	7,952	9,976	6,373	8,547	8,700	8,644	10,387	15,762	7,439	5,319	8,530	99,896
Measured	1965	3,340	5,230	8,780	8,850	9,500	9,850	10,010	14,400	21,380	7,650	6,330	8,030	113,450
Calculated	1966	6,783	11,112	12,283	10,499	9,727	6,925	6,948	7,784	6,932	6,280	6,219	6,036	97,530
Measured	1966	9,990	12,840	19,580	17,250	14,500	20,990	4,210	5,300	3,190	2,140	2,760	4,320	117,070
Calculated	1967	8,368	13,551	23,200	14,078	16,815	16,979	21,373	24,585	34,509	36,503	29,583	29,786	269,331
Measured	1967	5,970	6,500	10,210	9,940	12,430	13,420	8,280	8,210	9,870	3,750	4,650	7,030	100,260
Calculated	1968	36,346	37,415	43,699	38,037	37,412	33,780	22,011	21,196	18,478	12,410	12,401	11,785	324,970
Measured	1968	7,670	8,400	10,660	11,720	15,500	21,630	9,020	16,370	17,590	3,850	7,900	4,930	135,240
Calculated	1969	16,394	17,977	18,369	18,457	17,704	23,019	21,026	29,805	35,966	11,897	10,588	16,629	237,829
Measured	1969	10,220	12,070	14,720	21,420	24,010	39,160	25,230	33,540	37,660	11,860	8,930	12,430	251,250
Calculated	1970	22,664	20,327	22,750	23,405	24,500	22,937	13,313	10,600	15,008	9,887	9,889	10,144	205,424
Measured	1970	17,490	18,500	21,280	27,760	32,980	26,340	14,390	23,530	19,690	7,140	7,960	11,160	228,220
Calculated	1971	21,577	19,181	18,312	17,163	15,966	15,535	9,539	9,575	9,215	7,687	8,085	8,139	159,974
Measured	1971	16,740	18,380	17,390	20,230	22,810	21,600	10,730	14,230	11,210	3,720	6,000	9,000	172,040
Calculated	1972	8,424	8,355	15,803	10,668	7,873	6,658	6,964	6,689	6,564	5,820	6,604	5,906	96,329
Measured	1972	11,460	16,060	16,370	15,990	17,350	14,720	4,910	4,370	4,700	2,830	4,620	6,480	119,860
Calculated	1973	5,980	6,003	5,764	5,479	17,093	14,212	8,691	17,006	19,105	12,430	11,946	12,045	135,754
Measured	1973	8,870	11,480	12,360	13,180	14,350	16,700	24,570	63,810	60,580	7,850	7,490	11,050	252,290
Calculated	1974	25,870	35,122	27,488	19,398	28,220	29,498	14,434	11,276	9,363	8,717	8,727	10,153	228,265
Measured	1974	16,620	17,450	17,640	18,850	29,470	46,190	19,320	26,790	7,370	4,780	5,090	6,460	216,030
Calculated	1975	12,462	13,874	14,045	12,126	14,195	12,518	5,526	10,761	10,408	7,400	5,578	6,428	125,321
Measured	1975	10,090	11,740	13,290	12,910	13,340	15,210	8,850	16,650	32,520	8,410	5,350	8,370	156,730

Table 13. Comparison of simulated and measured outflow, 1962-1975, using model calculated diversions - Salina.

		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
Calculated	1962	3,391	11,564	7,874	9,890	20,765	15,056	9,350	16,367	6,740	4,941	4,422	5,698	116,059
Measured	1962	4,310	6,640	7,390	7,550	18,070	14,690	11,440	11,300	11,170	5,020	6,000	9,120	112,700
Calculated	1963	4,708	11,719	11,620	9,420	5,376	4,175	4,585	5,438	4,804	3,358	3,169	3,738	72,110
Measured	1963	6,520	6,570	9,210	9,270	13,340	13,140	8,840	4,050	3,620	1,880	2,330	3,550	82,320
Calculated	1964	2,791	9,195	7,785	7,275	3,048	3,525	4,348	5,928	4,934	3,638	3,758	3,589	59,813
Measured	1964	3,350	5,120	6,950	7,210	8,710	9,600	9,700	11,400	4,780	1,690	2,350	2,410	73,270
Calculated	1965	3,060	12,923	13,067	9,157	3,610	3,067	7,470	17,117	8,142	7,127	5,755	7,519	98,016
Measured	1965	3,440	5,230	8,780	8,850	9,500	9,850	10,010	14,400	21,380	7,650	6,330	8,030	113,450
Calculated	1966	6,941	17,408	22,629	18,884	5,999	6,350	6,414	7,255	6,375	5,683	5,666	5,515	115,117
Measured	1966	9,990	18,840	19,580	17,250	14,500	20,990	4,210	5,300	3,190	2,140	2,760	4,320	117,070
Calculated	1967	5,568	60,579	104,770	32,811	21,679	37,909	56,410	57,440	63,274	57,083	13,452	16,792	527,768
Measured	1967	5,970	6,500	10,210	9,940	12,430	13,420	8,280	8,210	9,870	3,750	4,650	7,030	100,260
Calculated	1968	9,375	18,295	17,805	18,007	21,086	29,328	25,437	26,252	10,344	7,403	8,159	7,840	199,331
Measured	1968	7,670	8,400	10,660	11,720	15,500	21,630	9,020	16,370	17,590	3,850	7,900	4,930	135,240
Calculated	1969	7,099	17,268	17,949	26,161	8,074	33,132	30,344	31,907	31,350	9,934	8,875	9,203	231,296
Measured	1969	10,220	12,070	14,720	21,420	24,010	39,160	25,230	33,540	37,660	11,860	8,930	12,430	251,250
Calculated	1970	9,242	22,463	24,892	30,079	10,126	31,484	28,638	10,769	10,296	8,923	9,138	9,411	205,461
Measured	1970	17,490	18,500	21,280	27,760	32,980	26,340	14,390	23,530	19,690	7,140	7,960	11,160	228,220
Calculated	1971	9,440	23,238	21,558	21,830	8,842	16,808	18,081	12,795	8,442	6,903	7,408	7,530	162,875
Measured	1971	16,740	18,380	17,390	20,230	22,810	21,600	10,730	14,230	11,210	3,720	6,000	9,000	172,040
Calculated	1972	7,636	18,471	16,251	16,814	6,655	5,522	5,936	5,690	5,646	4,931	5,786	5,156	104,495
Measured	1972	11,460	16,060	16,370	15,990	17,350	14,720	4,910	4,370	4,700	2,830	4,620	6,480	119,860
Calculated	1973	5,298	13,840	9,819	9,867	5,346	16,526	33,976	64,611	35,933	7,856	7,590	7,994	218,655
Measured	1973	8,870	11,480	12,360	13,180	14,350	16,700	24,570	63,810	60,580	7,850	7,490	11,050	252,290
Calculated	1974	7,852	23,785	21,069	17,112	11,734	49,388	20,600	8,782	7,090	6,695	7,079	6,630	187,817
Measured	1974	16,620	17,450	17,640	18,850	29,470	46,190	19,320	26,790	7,370	4,780	5,090	6,460	216,030
Calculated	1975	6,413	15,641	14,981	12,842	5,676	5,820	5,369	14,196	10,597	7,293	5,511	6,435	110,774
Measured	1975	10,090	11,740	13,290	12,910	13,340	15,210	8,850	16,650	32,520	8,410	5,350	8,370	156,730

Table 14. Error for 14 years.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
Circleville													
1962	-383	-871	-180	-35	1,555	-556	608	357	717	1,275	1,488	669	4,643
1963	-1,195	-1,630	107	1,712	-10	-1,290	-960	-962	1,631	765	1,456	-824	-1,201
1964	65	-1,382	-903	59	-509	163	-1,462	-675	-387	1,001	-841	670	-3,201
1965	-600	-1,104	-709	-403	-803	176	-1,854	508	3,845	-1,644	1,024	21	-1,543
1966	-785	1,366	1,857	1,278	949	-2,443	1,550	1,037	1,751	917	867	123	8,468
1967	-1,548	-265	378	75	-756	-468	-1,018	3,071	2,921	1,205	1,162	700	6,396
1968	-1,814	1,082	823	1,601	3,824	2,649	437	1,238	-1,610	-1,323	-2,099	371	5,179
1969	-1,914	-800	1,962	1,401	396	-3,375	4,110	10,521	3,040	709	-173	508	16,387
1970	-1,994	-3,429	1,188	2,188	1,936	1,248	-1,322	1,142	2,078	1,753	955	1,593	7,336
1971	782	1,802	-542	-892	349	-825	-1,242	-375	213	1,006	-1,287	-1,160	-2,172
1972	-658	-910	-2,345	381	-311	-537	-941	-1,325	856	927	938	-485	-4,408
1973	-190	-49	5	-1,919	-1,048	-2,197	-1,026	9,753	3,492	50	-495	358	6,733
1974	-3,334	-1,293	-1,243	-1,673	-368	-1,793	-2,711	-184	1,083	283	71	-242	-11,404
1975	-1,347	-3,308	-2,623	-806	-1,161	-1,528	-1,132	755	1,675	-157	1,705	15	-8,911
Marysvale													
1962	800	-196	815	-184	1,370	85	3,429	-99	-1,524	1,673	-1,046	558	5,680
1963	233	-1,540	-689	389	150	-2,219	-799	-865	-107	-1,348	-1,620	771	-7,645
1964	-1,380	-52	576	104	508	629	-466	-626	-113	-386	-796	528	-2,429
1965	-929	-106	429	-307	-375	-509	-591	-124	-1,785	-991	-407	798	-4,896
1966	-2,276	250	1,280	295	-451	731	-1,078	-1,571	-2,776	-2,009	-59	-580	-8,155
1967	-991	-1,438	3,552	1,037	-188	-1,785	247	-341	-2,845	-1,728	-3,025	-1,599	-9,104
1968	1,023	-3,759	-83	-48	-4,751	-4,944	2,037	-3,723	-2,711	163	-4,465	-938	-22,200
1969	-3,115	-1,700	-319	-599	-1,024	-2,524	-3,205	1,238	-6,752	-6,279	-2,867	-3,753	-30,900
1970	-1,905	-126	-527	114	-1,973	-448	-1,771	-3,985	-5,702	-1,283	-3,773	-5,284	-26,664
1971	-2,462	-1,339	-22	-390	-564	-970	-776	514	-4,765	-3,725	-3,041	-1,291	-18,831
1972	628	-981	42	-1,075	-1,373	-419	-3,055	-1,251	-3,091	-2,895	-6,664	-1,920	-22,053
1973	-955	-720	-471	-656	-285	-834	3,026	8,171	-1,062	-4,188	-1,789	-2,477	-2,242
1974	-1,415	-282	252	394	-1,019	-758	2,609	-1,506	-4,733	-4,014	-5,388	-4,614	-20,475
1975	-3,611	-2,942	-172	-23	4,151	-1,041	2,213	1,429	536	3,182	-447	-4,112	-7,203
Sigurd													
1962	352	282	543	-152	1,340	-1,330	1,308	575	-998	1,157	1,334	-441	3,970
1963	-882	207	54	499	424	1,767	-558	-533	-618	-1,113	653	-175	-276
1964	-1,255	-259	-1,108	-1,396	-2,167	204	-295	-72	1,254	410	1,035	40	-3,609
1965	-875	-652	1,397	-1,160	-1,047	325	-1,121	1,620	2,143	1,338	2,041	206	4,216
1966	-368	-261	-210	-974	-840	1,067	-805	456	86	224	137	-904	-2,392
1967	-873	-523	189	-680	794	589	-1,295	1,145	1,045	-603	653	1,885	2,326
1968	-1,163	-774	-935	-947	2,159	934	-387	5,389	566	940	-285	-12	5,484
1969	-2,033	-998	-2,542	823	1,880	2,394	1,765	7,749	3,056	519	660	2,570	15,785
1970	186	2,000	377	2,366	-705	340	-3,383	419	1,638	-3,444	-2,054	-3,545	-5,806
1971	-2,810	-1,421	-4,784	-1,734	-1,662	-295	-1,863	-962	-943	-1,805	-2,035	-2,040	-22,353
1972	-923	-2,390	-1,000	-1,824	-891	-747	1,236	2,617	1,898	1,938	2,121	664	2,700
1973	9	135	-500	-551	-2,410	-238	7,101	12,363	-3,645	-3,057	-4,896	-3,033	1,277
1974	-5,497	-1,634	227	2,297	2,373	-778	-5,597	-1,152	-1,930	-2,467	-368	-1,295	-15,821
1975	-6,481	1,210	-2,357	-1,358	-2,250	-556	-2,252	9,607	10,675	6,653	2,001	-1,970	17,922

Table 14. Continued.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
Salina													
1962	727	1,551	-1,518	367	1,251	-727	-2,370	1,991	1,411	206	-1,203	803	2,488
1963	-459	1,477	645	-1,526	1,952	-143	-1,175	674	477	821	222	-438	2,425
1964	-1,170	-707	-2,082	-2,337	-1,611	1,346	3,348	-1,174	18	988	523	366	-2,492
1965	-1,075	2,722	1,196	-2,477	-953	-1,150	-1,366	-4,013	-5,618	-211	-1,011	500	-13,554
1966	-3,207	-1,728	-7,297	-6,751	-4,773	-14,065	2,738	2,484	3,742	4,140	3,459	1,716	-19,540
1967	2,398	7,051	12,990	4,138	4,385	3,559	13,093	16,375	24,639	32,753	24,933	22,756	169,071
1968	28,676	29,015	33,039	26,317	21,912	12,150	12,991	4,826	888	8,560	4,501	6,855	189,730
1969	6,174	5,907	3,649	-2,963	-6,306	-16,141	-4,204	-3,735	-1,694	127	1,658	4,199	-13,421
1970	5,174	1,827	1,470	-4,355	-8,480	-3,403	-1,077	-12,930	-4,682	2,747	1,929	-1,016	-19,796
1971	4,837	801	922	-3,067	-6,844	-6,065	-1,191	-4,655	-1,995	3,967	2,085	-861	-12,066
1972	-3,036	-7,705	-567	-5,322	-9,477	-8,062	2,054	2,319	1,864	2,990	1,984	-574	-23,531
1973	-2,890	-5,477	-6,596	-7,701	2,743	-2,488	-15,879	-46,804	-41,475	4,580	4,456	995	-116,563
1974	9,250	17,672	9,848	548	-1,250	-16,692	-4,886	-15,514	1,993	3,937	3,637	3,693	12,235
1975	2,372	2,134	755	-784	855	-2,692	-3,324	-5,889	-22,112	-1,010	228	-1,942	-31,409

After the 1962-1964 calibration, 14 years of data were used in a model run. In subbasin 3 it appeared that the accuracy of prediction decreased after about 1967 or 1968 while the accuracy of prediction in subbasin 4 seemed to remain quite constant. As a result of this observation, several comparisons of data from subbasin 3 and subbasin 4 were made. After the comparisons of subbasin 3 and 4 data, it was decided to recalibrate for the 1974-1976 time period because the salinity data were collected after the diversion data relationship change.

Input data consistency needs to be checked before modeling begins. The double mass curve is commonly used to determine when relationships among variables change and is accomplished by plotting the variable being tested against a base data set. Since the relationship between diversion records in subbasins 3 and 4 seemed to change over the 14-year period of record, a double mass plot of the sum of diversions in subbasin 3 and subbasin 4 was plotted. It was obvious that the relationship changed in 1967 or 1968 from the double mass plot, Figure 17. During operation of the model, the predicted outflows, based on the model as calibrated to match 1964 flows, agreed quite well with the measured outflows until 1967. It would seem that the inability of the model to continue accurate prediction was due to a change in the relationship between systems of the collected diversion data. It is unfortunate that the double mass plot cannot also give the reason for the change in the relationship between the two variables. It was interesting, however, that the relationship seemed to remain quite constant on either side of the change. Since the model had no way of predicting the change in relationship, it could not make proper predictions for the record after the change.

Figure 18 is a double mass plot of the temperature data in subbasins 3 and 4. This plot shows that the temperature relationship between these two subbasins remains constant throughout the 14-year period. Plots of inflow vs diversions in subbasin 3 and precipitation in subbasin 3 vs precipitation in subbasin 4 are shown in Figures 19 and 20. The purpose of these plots was to determine whether or not the relationship between the data groups plotted remains constant

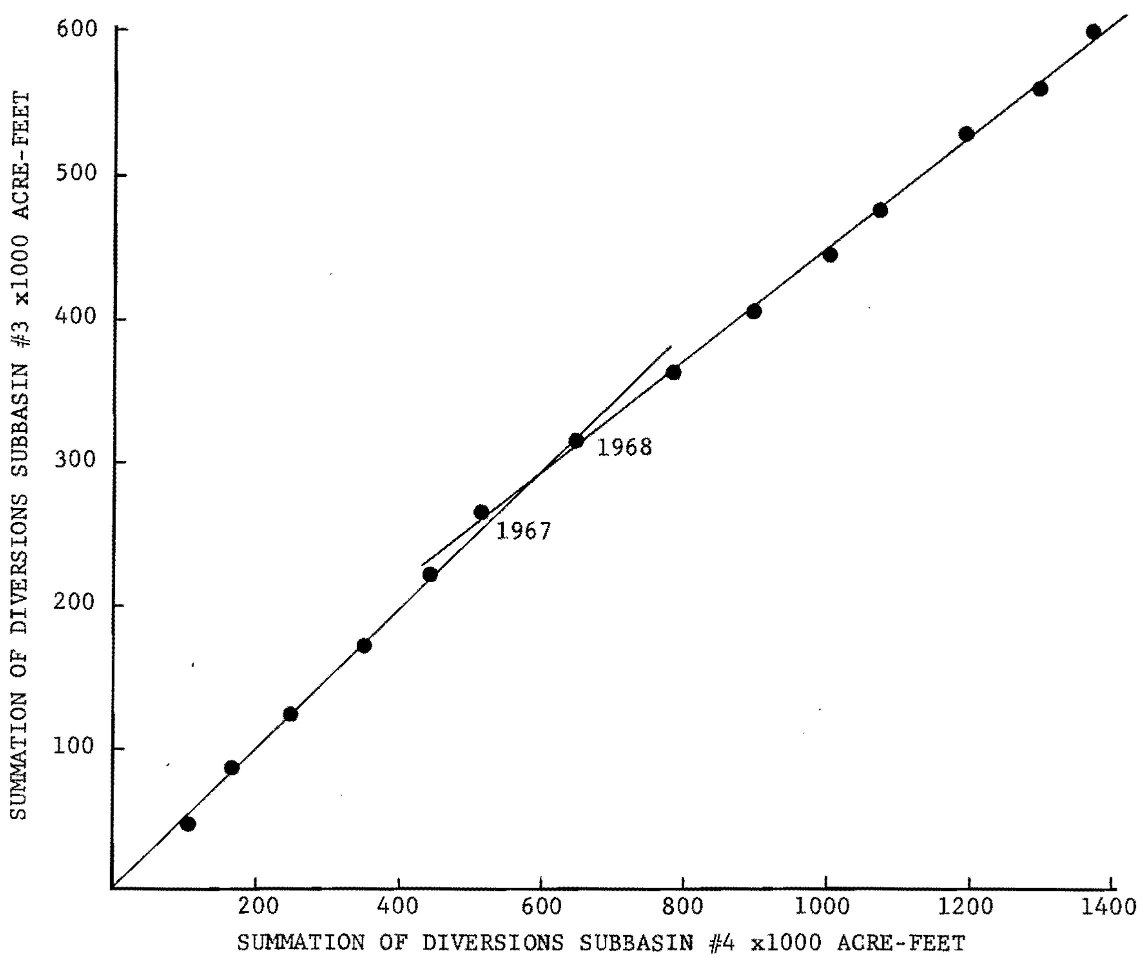

Figure 17. Relationship between diversions of Marysvale and Sigurd, 1962 to 1975.

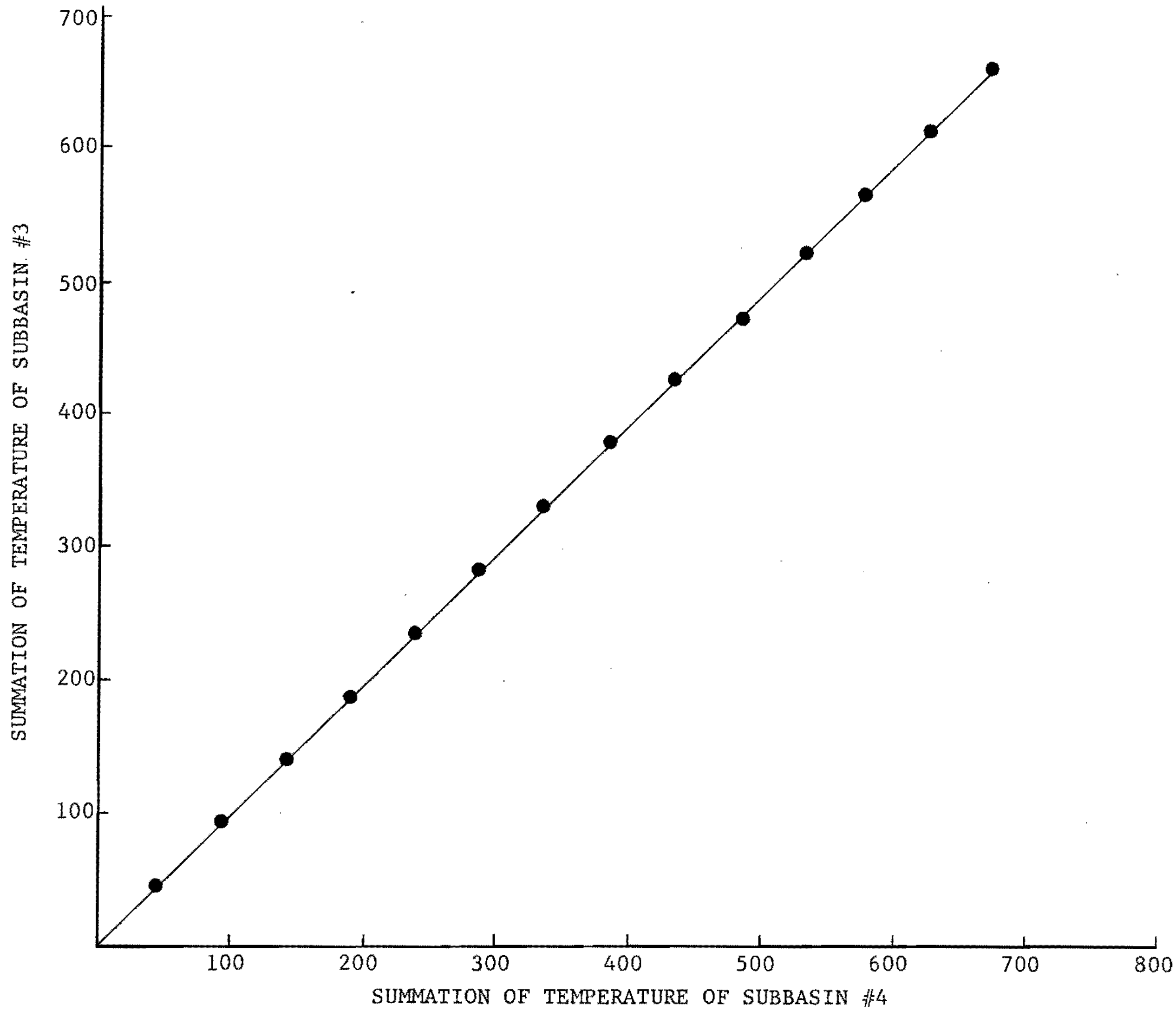

Figure 18. Temperature relationship between Marysvale and Sigurd, 1962-1975.

through the 14-year simulation period. The most obvious results are the temperature which remained the same and the diversions which changed once.

In subbasin 1 the average predicted outflow for the 14 years was 1.8 percent high. For subbasin 3, the predicted output was 8.6 percent low. Subbasin 4 predicted outflow was 0.4 percent below the measured total. The difference between predicted and measured outflows from subbasin 5 was a plus 40 percent. This of course is too high. The data comparisons were made between subbasin 3 and subbasin 4 because the difference in the degree of accuracy was first noticed between these two subbasins. The same type of comparison could be made for the subbasin 3 and subbasin 5 data. However, this was not done, but the subbasins were recalibrated for the 1974-1976 data period. Fourteen-year predictions were not made for subbasin 2 since insufficient data were available to provide input for the model.

As discussed earlier, local water conservation can be accomplished through more efficient water transport systems, elimination of tailwater at the farm, reduction of phreatophyte use, and more efficient application of the water to the crops. However, the individual farmer may feel that the water saved should then be available for application to additional land. Increased use efficiency on the farm could be achieved through lined ditches, improved control structures, and sprinkler systems.

Model estimation of the effects of these measures on downstream flow and salinity were based on the calibrations for 1974-1976. These estimates should be considered as

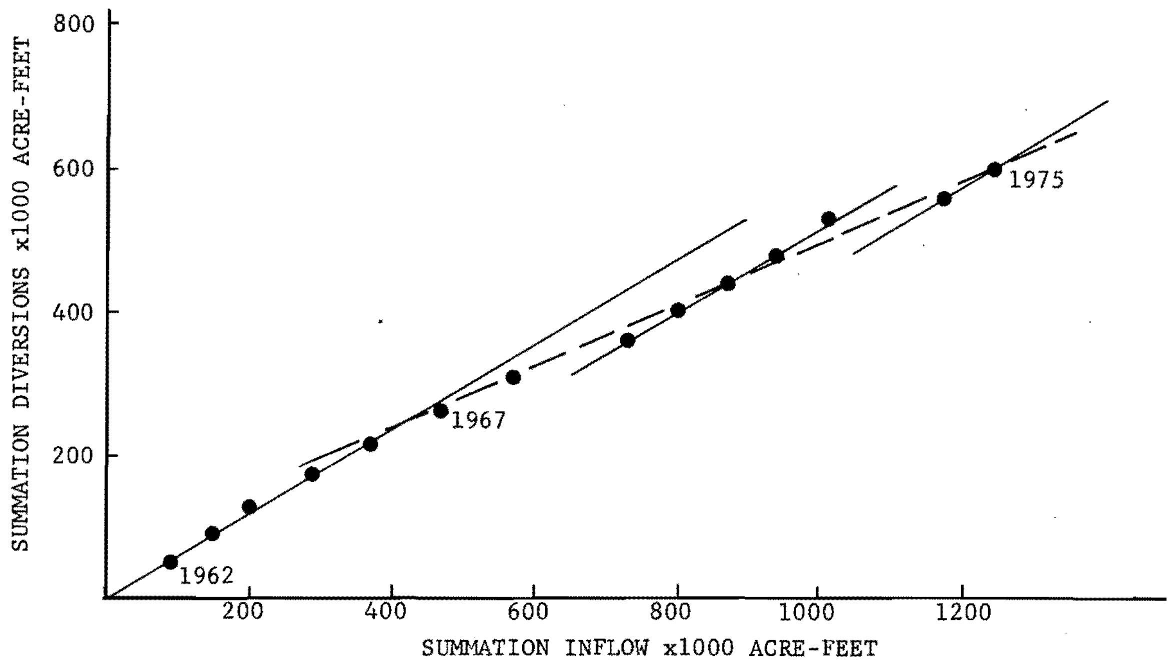

Figure 19. Relationship between inflow and diversions - Marysvale, 1962-1975.

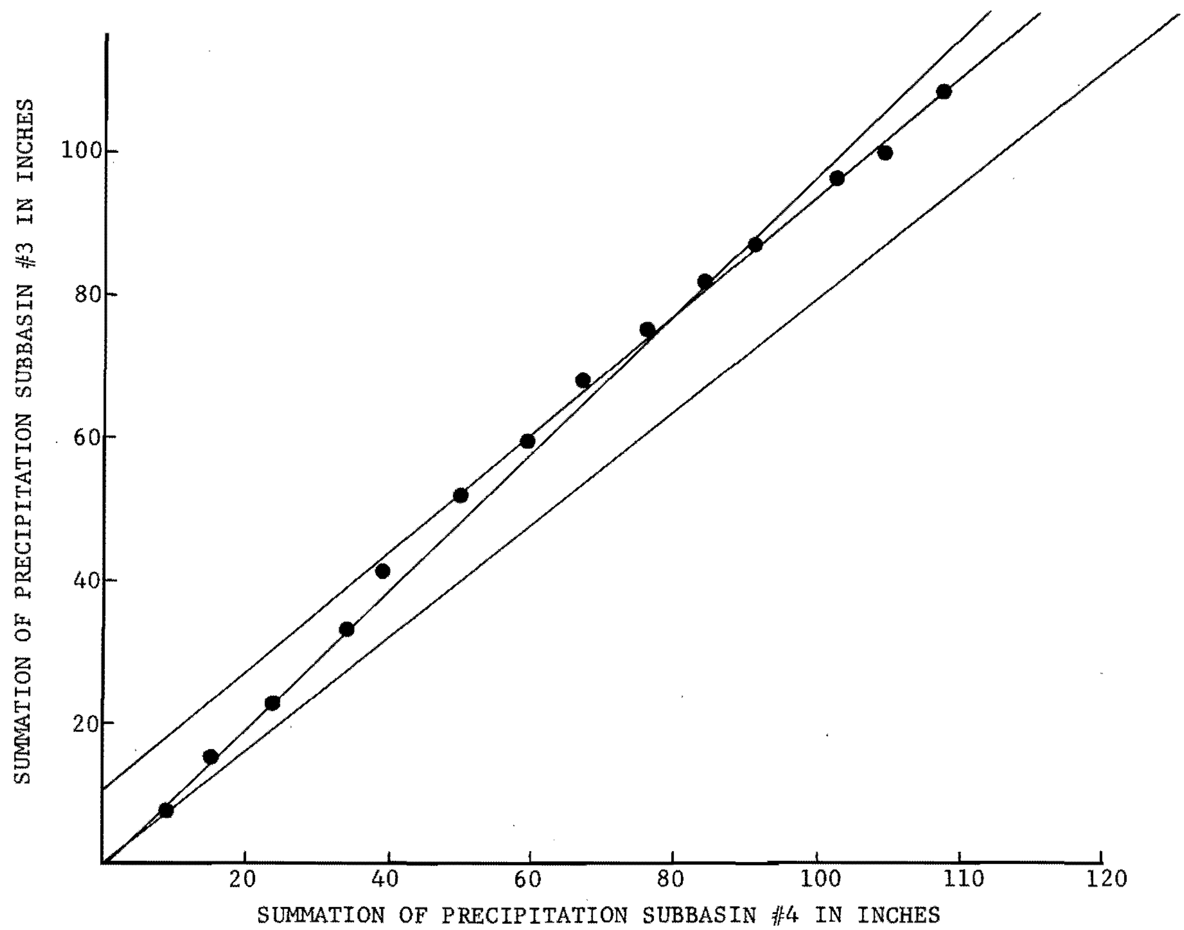

Figure 20. Relationship between precipitation of Marysvale and Sigurd, 1962-1975.

indicative of the results to be expected from the prototype changes. They are, however, associated with some degree of variance, just as the calibration process demonstrated variance.

The parameters that were varied to estimate the consequences of water conservation efforts were canal spills (18), canal conveyance efficiency (19), the canal diversion coefficient (32), and the irrigated land consumptive use (36). These parameters were selected to approximate the activities of the local farmers in implementing the conservation measures. For example, canal spills represent the degree of efficiency of the irrigation control structures. Canal conveyance efficiency represents lining of canals and ditches or installation of pipe delivery systems. Application efficiencies cannot be directly controlled in the model, so reduction of canal diversions approximates an increase in application efficiency by supplying about the same amount of water for crop use but reducing the amount of water that percolates from the root zone. The change in irrigated land consumptive use approximates changes in irrigated acreage. These changes can be made much faster than can changes in the actual crop acreage; though some error may exist in this technique. Table 15 shows combinations of values used for these parameters and the resulting model predictions summed or averaged for the 3 years as applicable.

Parameters 19, 32, and 36 were used because they represent adjusting factors for canal conveyance efficiency, canal diversions, and irrigated land consumptive use. Increased irrigation efficiency includes reducing losses so less water needs to be diverted to deliver a specified amount to the farm, and increasing acreage increases consumptive use. Parameters 19 and 32 represent better transportation and application efficiences, while parameter 36 represents an increase in irrigated acres.

Two periods of flow pattern change will occur. One flow pattern change occurs during the irrigation diversions season and appears in the surface flows. Greater delivery and on-farm efficiencies require less diversions for the same use by the crops so more surface water flows from the subbasin. The second change occurs during the return flow period. If less water reaches the groundwater system, less return flow will be seen as a result of increased efficiencies or other measures. Increased acreage and consumptive use will reduce surface outflow and, depending on efficiency values used, increase the return flow from the groundwater system. The resulting changes from the changes in these three parameters are not linear since there are feedbacks and interrelationships with other parameters.

In the computer runs, one parameter was changed each run. This was done to get some idea of the magnitude of individual parameter influence. The combinations of changes may or may not be achievable in the real world. However, the final run with all three parameters changed approximates conditions achievable in the real world.

Circleville

The model as calibrated for the Circleville subbasin calculated outflows essentially summing to the measured 3-year total. The calibrated salt outflow was just under 300 tons too large, and the outflow salinity concentration was 259 mg/l. The actual evapotranspiration was 87,521 acre-feet which is about 700 acre-feet or 1 percent less than potential.

The first test run consisted of a 41 percent reduction in the canal diversions. The total water outflow increased 2.8 percent, and the 0.6-percent reduction in total salt load resulted in a 3.5 percent reduction in the average TDS for the 3-year period to an average of 250 mg/l. The reduced diversions caused 1.6 percent decrease in evapotranspiration which was within 2.4 percent of the potential evapotranspiration. The reduction in diversions would be made possible by a reduction of tailwater or an increase of 9.2 percent in the application efficiency which in effect reduced the excess percolation from the root zone. The results of this run show actual ET within 2 percent of potential. It seems that to divert and apply such an amount of water through flood irrigation would require excess irrigation for each turn. A similar pattern exists in other high basins where the water is set and allowed to run for many hours, and the infiltration exceeds the water holding capacity of the root zone. A more efficient timing of water settings would reduce the diversion requirement. Single settings may currently be overirrigated and should be carefully checked. This increase in application efficiency might be reached without installing sprinkler systems, but on-farm testing would be necessary to assure that the required leaching would be achieved if such a reduction were imposed. Necessary diversions could also be reduced by an increase in the canal conveyance efficiency; however, this combination was not run.

The two other runs both reduced the total water outflow for the 3-year period. Although the salinity concentration was increased with the increase in irrigated area, none of the concentrations were sufficiently high to hinder agricultural production. Several extra runs were made on this subbasin involving combinations of canal conveyance efficiency and total diversions and will be discussed later.

East Fork

The East Fork subbasin had insufficient diversion data during the 1974-1976 period to calibrate a reliable hydrology model or subsequently a salinity model so only the

Table 15. Summary of 3-year model runs to indicate system response to management alternatives.

PARAMETER VALUES				WATER OUTFLOW	SALT OUTFLOW	OUTFLOW TDS	APPLICATION EFFICIENCY	ACTUAL ET	POTENTIAL ET
18	19	32	36	Acre Feet	Tons	mg/ℓ		Acre Feet	Acre Feet
Circleville									
*0	.54	1.7	1.0	217,858	76,559	259	75.7	87,521	88,225
0	.54	1.0	1.0	224,247	76,080	250	82.7	86,104	88,225
0	1.0	1.28	1.0	203,622	71,446	258	58.0	88,226	88,225
0	.54	1.7	1.3	207,006	75,333	268	83.3	105,201	114,693
Marysvale									
.15	.6	2.1	1.3	395,369	142,777	266	71.3	80,678	96,061
0	.6	2.1	1.3	384,379	144,911	277	66.0	89,112	96,061
* .15	.6	2.1	1.0	405,065	147,400	268	67.0	69,052	73,894
0	1.0	2.1	1.3	366,862	158,421	318	49.3	96,061	96,061
0	1.0	1.58	1.3	375,697	152,619	299	59.0	94,448	96,061
0	1.0	1.58	1.0	391,769	158,495	298	49.7	73,894	73,894
.15	.6	1.58	1.0	413,242	145,909	260	70.7	64,330	73,894
Sigurd									
* .01	.77	2.1	1.0	162,284	134,170	608	65.3	231,854	247,116
.01	.77	2.1	1.3	144,345	187,411	955	69.3	256,753	320,909
0	.77	2.1	1.3	142,103	179,028	927	69.3	258,697	320,909
0	1.0	2.1	1.3	118,217	119,212	742	69.3	283,120	320,909
0	1.0	1.58	1.3	122,455	128,842	774	69.3	280.037	320,909
0	1.0	1.26	1.3	128,873	246,836	1,409	70.0	274,851	320,909
Salina									
* .063	.71	1.5	1.0	504,127	814,460	1,189	51.6	228,407	258,057
.063	.71	1.5	1.3	491,123	839,592	1,258	54.3	253,625	335,474
0	.71	1.5	1.3	476,241	817,338	1,263	54.0	264,877	335,474
0	1.0	1.5	1.3	473,856	913,085	1,418	47.7	286,226	335,474
0	1.0	1.25	1.3	485,193	678,526	1,029	52.0	281,959	395,474

*Indicates the calibrated parameter values.

18 - Canal spills
19 - Canal conveyance efficiency
32 - Adjusting coefficient for canal diversions
36 - Adjusting coefficient for irrigated land consumptive use

hydrologic model results based on 1970-1972 data are presented. With increased efficiencies and 25 percent additional acreage imposed on the East Fork system, the model predicted a decrease in the surface outflow of about 7820 acre-feet per year. About 5430 acre-feet of that amount is from increased evapotranspiration, about 800 acre-feet from groundwater storage, which would logically seem to be short term change and stabilize about 600 acre-feet from increased soil moisture storage. It should also be noted that the model predicts an additional 4258 acre-feet per year of water could be saved if one half of the phreatophytes could be eliminated.

Marysvale

The 3-year summary of the runs made on the Marysvale subbasin are shown in Table 15. A 25 percent diversion reduction resulted in a 2 percent increase in outflow, or an additional outflow of 8015 acre-feet during the 3-year period. Total salt load decreased by 1 percent or 1491 tons. The average salinity concentration decreased 3 percent to 260 mg/l. The associated application efficiency increased 4.7 percent to 70.7 percent, but the actual evapotranspiration decreased 6.8 percent to 12.9 percent below potential. A decrease in spills without an accompanying reduction in total diversions provides additional water for application to the fields which reduces the total outflow and the application efficiency since more water percolates to groundwater. The greatest increase in salinity loading occurred with eliminating spills, increasing canal conveyance efficiency to 100 percent, and increasing the irrigated acreage. This combination increased the salinity concentration to 318 mg/l, and reduced the total outflow by 9.4 percent or 38,200 acre-feet. The application efficiency dropped to 49.3 percent while evapotranspiration increased to the potential. The salinity predictions for this subbasin in the cases of increased land use may be as much as 5 percent low. In those cases where the irrigated acreage is unchanged the prediction should be within the model accuracies.

None of the changes will make the salinity sufficiently high to impact agricultural production in this subbasin. However, these changes would obviously be transported downstream in the real system. The area of most immediate concern is the water quantity. Some consideration needs to be given to the impacts of reduced water supplied to the crop and the resulting production loss as opposed to the increased water for downstream users.

Sigurd

The average calculated and measured salinity concentrations for the Sigurd subbasin were 608 mg/l which is about 350 mg/l higher than the upper subbasins. The measured outflow for the 3-year period was 162,367 acre-feet. A 30 percent increase in acreage caused the salinity concentration to jump to 955 mg/l and the outflow to drop to 144,345 acre-feet. This represents a 12 percent drop in water outflow and a 57 percent increase in salinity concentration with a 24,900 acre-feet increase in consumptive use. The potential consumptive use rose 73,894 acre-feet to 320,909 acre-feet for the period. With the added acreage, the actual consumptive use drops to about 80 percent of the potential which probably has significant impacts on agricultural production. The most effective measure in reducing the salinity concentration was to increase the canal conveyance efficiency. A 23-percent increase in the canal conveyance efficiency from 77 to 100 percent reduced the average salinity concentration from 927 mg/l to 742 mg/l for the 3-year period. A 40 percent reduction in canal diversions increased the average salinity concentration to 1409 mg/l.

Reduced salinity concentration and increased water outflow would be obtained by elimination of canal spills, maximum increase of canal conveyance efficiency, and about 15-20 percent reduction in canal diversions. The water savings achieved by efficiency increases would be sent downstream by reducing the diversions by the same amount. Irrigated land should not be increased in this subbasin. The application efficiencies seem to remain quite constant for all of the changes that were made in this subbasin.

Salina

The calibrated and measured average salinity concentration for the period of calibration were the same at 1189 mg/l. The salinity levels in this subbasin are sufficiently high under present conditions that additional salinity inputs are undesirable if not intolerable. The 30 percent increase of irrigated land use increases the salinity concentration from 1189 to 1258 mg/l. The water outflow from the subbasin is reduced by 13,000 acre-feet for the 3-year period, a 2.6 percent reduction. The combination of eliminating canal spills and increasing the canal conveyance efficiency to 100 percent reduces the subbasin outflow and increases the average salinity concentration. This occurs if the saved water is not removed from the total diversions. However, both of these water saving actions increase the actual evapotranspiration. This would mean that production or phreatophytes use is enhanced. A 16.7 percent reduction in canal diversions and 100 percent canal conveyance efficiency reduced the salinity level to 1029 mg/l and increased the water outflow by 234,500 acre-feet. The calibration run showed actual evapotranspiration to currently be about 88.5 percent of the potential. Addition of new land reduced the ratio of actual to potential evapotranspiration to 75.6 percent. Elimination of spills raised it to 79 percent, and assigning 100 percent canal conveyance efficiency raised the ratio to 85 percent. Reduction in canal diversions by 17 percent reduced the actual to potential consumptive use ratio to 84 percent.

These runs indicate that irrigation of additional land, even in conjunction with water saving measures, would reduce the outflow but the combination would not worsen the long term salinity concentration level. The procedure to maximize water outflow and minimize salinity concentration would be to eliminate spills, improve the canal conveyance efficiency to the maximum, and reduce the canal diversions to correspond with the savings plus maybe 10 percent additional. Additional acreage should not be irrigated.

The canal spills return to the river and add directly to subbasin outflow. If canal spills are eliminated, the water delivered to the farm increases by that amount and evapotranspiration may increase correspondingly. To maintain the same farm deliveries, canal diversions must be reduced to equal the spill reductions. The same process occurs with the improvement in canal conveyance efficiency; if the diversions are not reduced equally to the savings, the extra water reaching the fields will add to evapotranspiration and deep percolation. Increased efficiencies, spill elimination, decreased diversions, and tailwater control must occur in combinations to maintain current field conditions and increase the water supply to downstream users.

The seasonal pattern of salt outflow was not consistent. A look at Table 4 shows that for Circleville subbasin the highest and lowest salt outflow occurred in the month of June for the calibration period. Generally the highest salt production occurred in the summer high runoff period. However, there are exceptions to this statement too. The seasonal effects were not considered in detail.

Another factor that was not included in the management variations was the accumulative effects from one subbasin to the next. The numbers given refer to the increase or decrease for the specific subbasin and not for the accumulation from the first to the subbasin under consideration. Additional studies could determine the accumulative effects for the whole Sevier River Basin above Gunnison.

ADDITIONAL RUNS

Additional runs were made on the Circleville subbasin using changes in parameters 19, 20, and 32 (canal conveyance efficiency, target application efficiency, and canal diversion adjustment). The resulting outflows and salinity levels are shown in Table 14. The outflow varies from 199,411 to 222,242 acre-feet for the 3-year total while the dissolved solids vary from 246 to 263 mg/l average for the 3 years. The salinity level corresponding to the maximum outflow for these tests was 252 mg/l. This is below the present salinity level, however, the worst case was only 4 mg/l above the present level as represented by the calibrated model. These additional runs support the conclusion that changes in irrigation practice in this subbasin will not have serious impacts on the salinity levels. The water savings do not need to reduce the evapotranspiration from the irrigated areas. It appears that phreatophyte removal is one of the more promising water conservation possibilities.

Twenty sensitivity runs were made using the Circleville subbasin data while varying the canal conveyance efficiency, the target application efficiency, and the canal diversions. When these runs were made, it was anticipated that the model would be the final version, but the target application efficiency was later deleted from the model, because the application efficiency could not be directly controlled. All other parameters remained the same, except for a slight change in the definition of the application efficiency. This slight change made no difference in the model output for the calibration runs as shown by a comparison of Tables 13 and 14. However, since it was feasible that the target application efficiency could cause a small difference if set at values other than 0.6, only those runs with parameter value equal to 0.6 were used for plotting the figures and deriving the equations.

Table 16 shows the parameter values and the system responses for the 20 runs. Figure 21 shows the relationship between application efficiency, canal conveyance efficiency, and canal diversions to water outflow. The top solid line represents all runs with a parameter 20 value of 0.6, and should be used if making predictions. The lower solid line is parallel to the top line but drawn through a set of points whose parameter 20 value was not 0.6. The dashed line represents all points. These two lines are only for information to indicate the variance of using all points. It can generally be said that the most significant parameter indicating the water outflow for this subbasin is the application efficiency. As application efficiency in the Circleville subbasin increases, the outflow increases. Application efficiency results from the operation of several processes and cannot be controlled by setting one parameter.

Figure 22 shows the relationship of application and canal efficiency to the salinity concentration of the outflow. The salinity concentration was found to be more affected than was total salt load. The lines and equations were made using the runs with parameter 20 equal to 0.6, plotted as circles. The other points are included for reference only. Canal conveyance efficiency and application efficiency are important when considering salinity concentration. This is significant since concentration levels impact crop production, but total salt load has no significance unless compared to the total flow.

Table 16. Parameter value and system responses for Circleville subbasin.

Parameter Values				Water Outflow Acre feet	Salt Outflow Tons	TDS mg/ℓ	Actual Application Efficiency	Actual ET Acre feet	Potential ET Acre feet
18	19	20	32						
0	.75	.85	1.7	217,439	73,715	249	81	88,226	88,226
0	.75	.60	1.7	213,599	73,808	254	73	88,226	88,226
0	.95	.60	1.7	211,141	71,991	251	71	88,226	88,226
0	.75	.75	1.7	216,450	73,609	250	81	88,226	88,226
0	.95	.75	1.7	215,404	72,166	247	80	88,226	88,226
0	.95	.85	1.7	216,544	72,326	246	82	88,226	88,226
0	.54	.75	1.7	219,608	76,351	256	83	87,924	88,226
0	.54	.85	1.7	220,522	76,394	255	84	87,779	88,226
*0	.54	.60	1.7	217,858	76,559	259	52	87,521	88,226
0	.75	.60	1.7	207,802	74,034	262	62	88,226	88,226
0	.95	.60	1.7	199,411	71,256	263	52	88,226	88,226
0	.54	.60	1.53	219,555	76,198	255	79	87,215	88,226
0	.75	.60	1.53	209,289	73,887	260	65	88,226	88,226
0	.95	.60	1.53	201,263	71,384	261	55	88,226	88,226
0	.54	.60	1.36	222,242	75,978	252	82	86,645	88,226
0	.75	.60	1.36	211,801	73,874	257	70	88,266	88,226
0	.95	.60	1.36	203,958	71,701	259	59	88,266	88,226
0	.54	.60	1.45	220,670	76,069	254	81	87,000	88,226
0	.75	.60	1.45	210,444	73,886	258	67	88,226	88,226
0	.95	.60	1.45	202,259	71,467	260	56	88,226	88,226

*Calibrate run.

19 - Canal conveyance efficiency
20 - Target application efficiency
32 Adjusting coefficient for canal diversions

In general for this subbasin, as canal conveyance and/or application efficiency increase, average salinity decreases. Water outflow increases as the application efficiency increases. Conveyance efficiency increases do not significantly alter the water available.

SUMMARY

The objective of this study was to predict the impacts on water quantity and the salinity of the flow available to downstream users in the Upper Sevier River Basin from implementation of measures for more efficient water transport and application and from increases in irrigated acreage. Data were collected and prepared to calibrate a hydrosalinity model for four of the five subbasins. The East Fork subbasin data would not support the hydrologic model for 1974-1976 data. As a check on the validity of the model calibration, a test run was made for the 14 years after the 1962-1964 calibration period. Because of apparent discontinuities in the relationships of the collected data for the 14-year period for one or two subbasins and because the salinity data were better for the 1974-1976 period, the model was recalibrated for the new period. The model parameters were changed to reflect the implementation of the conservation measures and the addition of irrigated areas, and the model predicted the response of the system to these changes.

In summary, the model predicted that water conservation measures in the two upper subbasins would not significantly affect the salinity levels, but the flows available for downstream use would be reduced by the increased evapotranspiration. Implementation of the conservation measures in the Salina and Sigurd areas would reduce the water availability and increase the salinity level significantly. All water flow paths are potential salinity loading routes. During model calibration, portions of the salt loading are assigned to each flow path. Management measures that reduce flow and salt pickup along the major pickup routes will reduce the total salt loading and, conversely, management measures which increase the flow and salt pickup along the major pickup routes will increase the total salt outflow. Dilution and increased evaporation or concentration also have an effect. The lower basins seem to have more salt formations and sources to supply salt increases than do the upper basins. In all four subbasins, the additional evapotranspiration caused by a 25 to 30 percent increase in irrigated area could be offset by reduction in the consumptive use by phreatophytes. These nonproductive plants include salt grass, willows, tules and cattails, and cottonwoods and are concentrated along canals and ditches, and in wet areas along the stream.

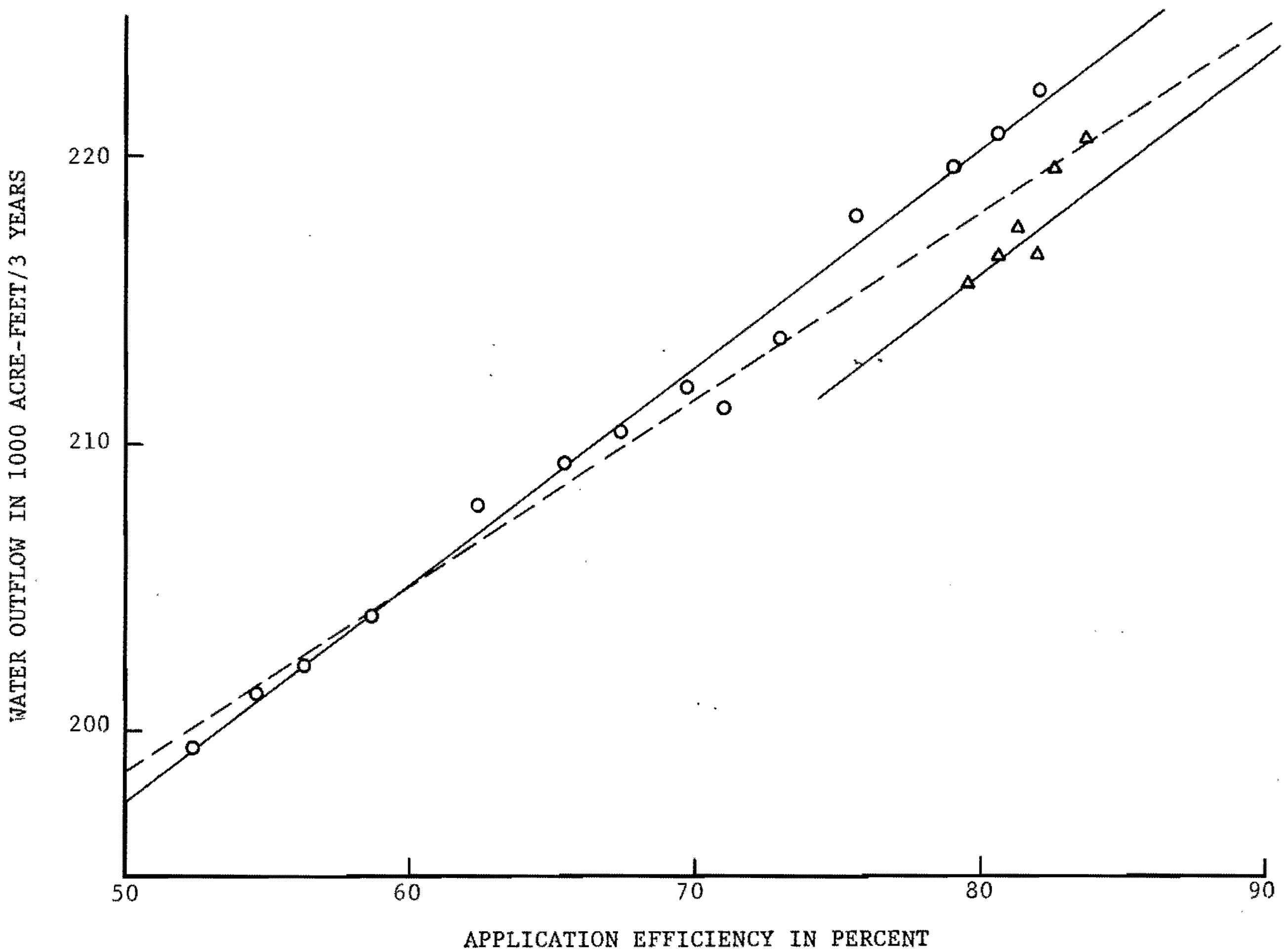

Figure 21. Relationship between application efficiency, canal conveyance efficiency, and canal diversions to water outflow for Circleville subbasin.

CONCLUSIONS

The effects of on-farm water conservation measures and irrigated acreage changes on downstream flows and salinity estimated in this study have significant implications for water management in the Upper Sevier River Basin. These conclusions are:

1. Data consistency is extremely important for model calibration and application. Consistency is required among the data and between the data and physical relationships occurring within the watershed. Consistency checks should be made before using raw data.

2. Consistency is often a problem for data collected over long time periods by various people or agencies. Hydrologic and climatologic data are generally collected by standard methods. This reduces inconsistency problems, and double mass curve and other techniques can be used to check doubtful data. Salinity and diversion data are less standardized and the total collection network is much less satisfactory as a data base for consistency checking. Sensitivity checking provides an initial step for evaluating the consequences of various degrees of data inconsistency and inaccuracy.

3. Conservation measures in the upper subbasins (Circleville and Marysvale) would not seriously affect the quality of water delivered to downstream users but would cause a reduction in quantity which may have an inverse impact on salinity production within the subbasin.

4. Conservation measures in the lower subbasins (Sigurd and Salina) would increase the salinity levels sufficiently in each subbasin such that an adverse effect on agriculture would result.

5. The computed and potential evapotranspiration rates in the Circleville

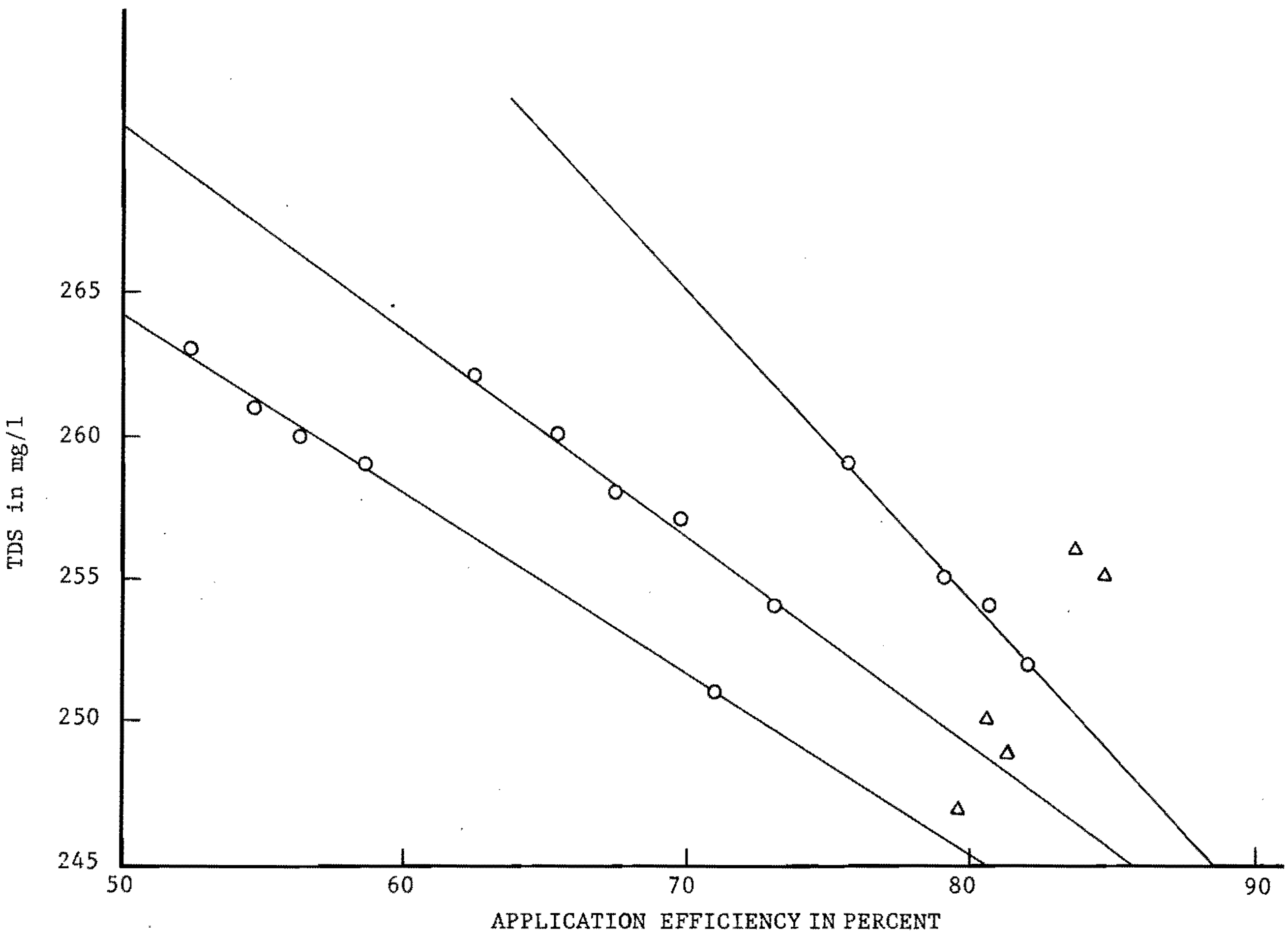

Figure 22. Salinity concentration response to changes in the application efficiency and the canal conveyance efficiency - Circleville.

subbasin and perhaps in the East Fork and Marysvale subbasins suggest that excess water is being applied. The low irrigation efficiencies and close to potential ET rates indicate that these areas are receiving more water than the crops need. However, since salt pickup in these areas is small, these subbasins are probably providing a 'low salt added' groundwater storage.

6. Additional computations and analysis are needed to establish the sensitivities of flows and salinities to imposed measures and to demonstrate the interrelationship between transportation and application efficiencies and other processes in the field, such as tailwater, percolation, and evapotranspiration.

7. Additional effort should be spent in determining the amount of water that could be saved and used for irrigation by eliminating or denying access to the water by phreatophytes. The feasibility of effective phreatophyte control in the basin needs to be explored before formulating such a program.

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