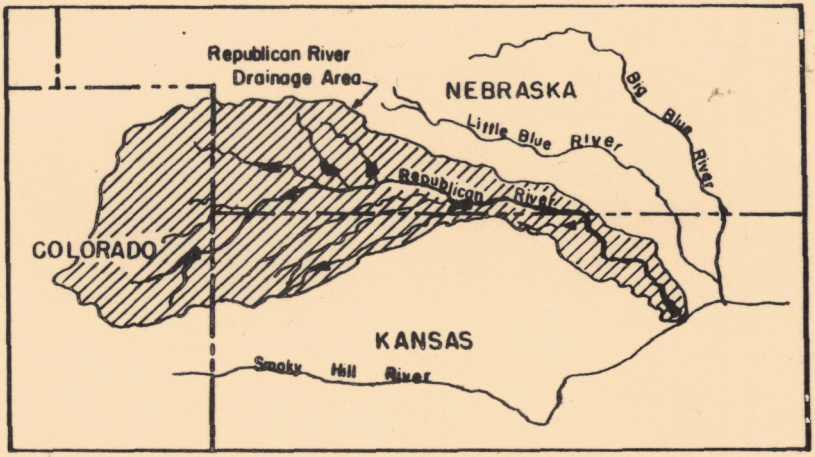
Thompson

REPUBLICAN RIVER COMPACT ADMINISTRATION

TWENTY-SEVENTH ANNUAL REPORT



For The Year 1986

Junction City, Kansas
July 9, 1987

REPUBLICAN RIVER COMPACT ADMINISTRATION

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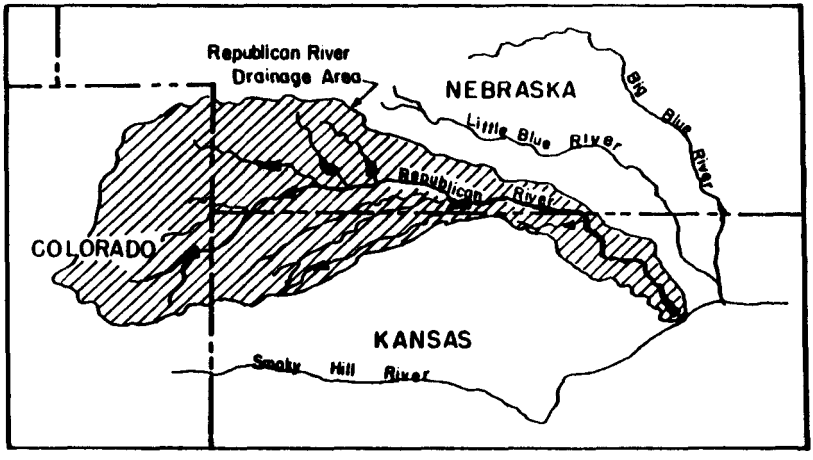

For The Year 1986

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TWENTY-SEVENTH ANNUAL REPORT

REPUBLICAN RIVER COMPACT ADMINISTRATION

In conformity with the Rules and Regulations of the Republican River Compact Administration, the Twenty-Seventh Annual report is submitted as follows:

1. Pursuant to Rule 12, as amended, this report covers the period from July 10, 1986 to July 9, 1987.

2. Members of the Republican River Compact Administration are the officials of each of the states who are charged with the duty of administering the public water supplies, and are as follows:

   Jeris A. Danielson, State Engineer, Colorado

   Michael Jess, Director, Department of Water Resources, Nebraska

   David L. Pope, Chief Engineer-Director, Division of Water Resources, State Board of Agriculture, Kansas

3. The Twenty-Eighth Annual Meeting of the Administration was held on July 9, 1987, at Junction City, Kansas. The minutes of the meeting are included in this report.

4. During the period covered by this report, two meetings of the Engineering committee were held. A report from that committee together with summary tabulations of the computed annual water supply and consumptive use for the 1986 water year in the Republican River Basin were presented and accepted by the Administration and are included in this report.

5. Reports were received from the Bureau of Reclamation on operation and administration of their projects in the basin of the Republican River.

6. David Pope, Kansas member of the Administration, will serve as Chairman for 1987 and 1988.

MINUTES
28th ANNUAL MEETING
REPUBLICAN RIVER COMPACT ADMINISTRATION

The meeting was called to order by Chairman David L. Pope at 8:45 a.m. on July 9, 1987, in the Harvest Inn Motel, Junction City, Kansas. Those in attendance were:

Name	Agency	Location
David L. Pope	Kansas Commissioner	Topeka, Kansas
Jeris A. Danielson	Colorado Commissioner	Denver, Colorado
Michael Jess	Nebraska Commissioner	Lincoln, Nebraska
Hal Simpson	Engineer Advisor	Denver, Colorado
Jerry Hilmes	Engineer Advisor	Topeka, Kansas
Bob Bishop	Engineer Advisor	Lincoln, Nebraska
H. Lee Becker	Engineer Advisor	Lincoln, Nebraska
James Bagley	Div. of Water Resources	Topeka, Kansas
Tom Stiles	Kansas Water Office	Topeka, Kansas
Dale Mahan	Div. of Water Resources	Topeka, Kansas
Matt Scherer	Div. of Water Resources	Topeka, Kansas
Russ Oaklund	Dept. of Water Resources	Cambridge, Nebraska
Bob Kutz	U.S. Bureau of Reclamation	Grand Island, NE
Dennis Allacher	U.S. Bureau of Reclamation	McCook, Nebraska
Alan Berryman	Div. of Water Resources	Denver, Colorado
Lee Rolfs	Div. of Water Resources	Topeka, Kansas
Wayland Anderson	Div. of Water Resources	Topeka, Kansas

Chairman Pope asked for introductions of staff members and persons in the audience.

Approval of Minutes

A motion was made by Commissioner Pope and seconded by Commissioner Danielson that minutes of the 27th Annual Meeting as previously circulated and approved be adopted. The motion passed.

Report of Chairman

Chairman Pope reported on water-related activities that occurred in Kansas during the year. Pope advised that approximately 25 bills were introduced during the last legislative session with about 14 of those dealing with the State Water Plan. Bills passed under the plan dealt primarily with the implementation of the fish, wildlife, and recreation section of the State Water Plan.

Senate Bill 40 enacted an environmental coordination act which imposes an interagency review process on water related projects. The Division of Water Resources administers 3 statutes that will be affected by the act. They are construction of dams and channel modifications, construction of levees, and approval of general plans for organized watershed districts.

A second bill that passed dealt with the adoption of additional minimum desirable streamflow standards. Nine additional streams and rivers were added to the program which now includes a total of 18 in the State. The Republican is one of those rivers.

Pope reported on the proposed organization of a water assurance district in the Kansas River valley and indicated a transfer of water from Milford Reservoir to south central Kansas is still being considered by municipal interests.

Commissioners Report

Commissioner Danielson reported that legislation was enacted in 1987 that increased well permit fees and funds from the fee increase will be used for

groundwater management programs. He said that priority would be given to expansion of their monitoring network and groundwater recharge studies.

Danielson advised that a full time water commissioner had been re-established at Wray, Colorado, and that he would be administering all of the compact streams in the area on a full time basis. A bill was also passed dealing with chemigation in Colorado. It provides for permitting and licensing wells that will be using any kind of chemical application.

The State of Colorado submitted proposals on four sites under the U.S. Bureau of Reclamation's groundwater recharge demonstration program.

Commissioner Jess reported that very few water resource matters were passed by the Nebraska legislature this session. He noted there had been no significant changes in the Upper Republican Natural Resource District which is in charge of groundwater use management in that area. The district has regulations mandating water meters and there are spacing requirements on newly constructed wells.

There is a proposal for diversion of South Platte River water into the high plains area of eastern Colorado and southwest Nebraska. Several Local districts in Colorado and Nebraska have signed an agreement with the Bureau of Reclamation to proceed with the first stages of the study.

The so-called Enders Project is a proposal to transport water from the South Platte River near the Nebraska-Colorado border to Enders Reservoir for a supplemental supply to users in Nebraska. The proposal was denied by state officials and is now under appeal to the Supreme Court.

Jess also reported briefly on an instream flow application submitted by the Nebraska Game Parks Commission, consolidation of natural resource agencies, and adjudication proceedings for Frenchman Creek water appropriations.

Bureau of Reclamation Report

Bob Kutz, Project Manager, gave a report on recent Bureau activities within the Republican Basin. Kutz noted that some planning funds may be cut back but was hopeful congress would keep them at about two-thirds of that requested. The Frenchman diversion study has been approved and there will be a 50-50 cost sharing on that project. Three groundwater districts in Colorado and 3 irrigation districts in Nebraska will be involved in the project.

The Bureau is cooperating with the State of Kansas on several studies related to water management in the Kansas River Basin. They are gathering and supplying data for a model study that Kansas is completing.

Starting in 1984 irrigation districts were required to pay a portion of the maintenance and operation costs for Harlan County Dam. An attempt has been made to start the collection process but the districts have taken the matter to court.

The Bureau is in the process of renegotiating contracts for repayment by irrigation districts in Kansas. This has been brought about because of water shortages in several reservoirs which supply water for irrigation purposes. Under the new contracts the district's existing obligation to the United States will probably be cancelled and changed to a water service type contract.

Frenchman-Cambridge irrigation district is continuing the program to change all of their open ditch laterals into a buried pipeline distribution system.

Dennis Allacher reported on 1986 operations in the basin. This was the first year since 1980 that all irrigation districts in the basin received reservoir stored water. Allacher noted that most of the reservoirs contain about the same amount or slightly more water than last year. Kirwin and Webster reservoirs in Kansas are at their highest level since 1976.

Report of the Engineering Committee

Mr. Hal Simpson, member of the Committee, presented the report and a copy is included in the 27th Annual Report. Mr. Simpson advised that the committee had met twice during the past year to complete assignments given by the Administration. He discussed recommendations of the Committee and Tables 1 and 2 which show the computed annual virgin water supply, consumptive use, and adjusted allocations for water year 1986 for each of the sub-basins.

Commissioner Jess expressed concern about those cases where the virgin water supply originates in a sub-basin and is consumed in another. This situation occurs in Red Willow and Medicine Creek and Commissioner Jess indicated this was deceiving and gives the impression that the consumptive use in the respective sub-basins far exceeds the computed virgin water supply. Commssioner Jess moved that the Engineering Committee study this matter and report back to the Administration at the next annual meeting. It was agreed to defer action on this motion until assignments were given to the Engineering Committee.

Commissioner Danielson recommended that the Committee look at the matter of whether or not including changes in groundwater storage is within the compact definition of virgin water supply.

The Commissioners reviewed Tables I & II of the Engineering Committee Report which show computed virgin water supply, adjusted allocations and consumptive use for water year 1986. They also reviewed several other tables which show various comparison's of virgin water supply and consumptive use for 28 years of records. The tables are shown on pages 41-47 of the 27th Annual Report.

Committee member Bishop recommended that all municipal and industrial uses be included in virgin water supply, adjusted allocations and consumptive use computations. Current procedure includes only those municipal & industrial

entities using more than 50 acre feet per year. It was agreed to deal with this matter in the assignments to the Engineering Committee.

Chairman Pope requested the study on change in groundwater storage be extended into Nebraska in the Beaver Creek sub-basin. Commissioner Jess requested that the engineering committee include computed consumptive use for the lower portion of the Republican Main Stem basin down-stream from the Nebraska-Kansas stateline to the confluence of the Kansas River. This to be done for water year 1987.

Commissioner Jess moved that the Engineering Committee Report be accepted and Commissioner Danielson seconded. The motion passed.

New Business

A lengthy discussion was had on assignments to the Engineering Committee for the 1987 water year. Commissioner Pope then suggested the Administration assign the committee the following items:

1. Carry out the normal computations that have been done from year to year on calculating virgin water supply, adjusted allocations, consumptive use, and related matters.
2. Develop formulas and procedures that would be necessary to include change in groundwater storage in the computations and to then do so for the Beaver Creek Sub-basin for both Kansas and Nebraska which would provide the Administration an example to look at next year.
3. Assess the availability of existing data and what additional data would be necessary to implement a procedure for including change in groundwater storage in the computations.
4. Analyze the computations of virgin water supply versus the location of use as requested by Commissioner Jess and make recommendations back to

the Administration regarding any suggested changes necessary for the sub-basins that would be affected.

5. Research the historical evolution of the methods used to compute the adjusted allocations and report the findings at the next annual meeting.

6. Analyze and report back to the Administration on those steps that would be necessary to include the area below the Kansas-Nebraska state line for the purpose of assessing the task at hand.

Upon completing his suggestions, Chairman Pope asked for any comments by the Administration and from the Engineering Committee. Commissioner Jess clarified item number 6 to be, computation of consumptive use below the state line for water year 1987. There being no further comments Pope moved that the 6 suggested items be considered assignments to the Engineering Committee for the 1987 water year.

Colorado voted, yes. Nebraska voted, No. Kansas voted, yes. Motion failed.

After discussion and suggested changes to Pope's motion, Commissioner Danielson moved that the Engineering Committee complete the following assignments prior to the next annual meeting:

1. Perform normal computations of virgin water supply, consumptive use, and adjusted allocations for water year 1987.

2. Evaluate how allocations and usage will be affected in those cases where virgin water supply originates in a sub-basin and is consumed in another.

3. Research the issue of how annual adjusted allocations were determined.

4. Provide computed consumptive use for water year 1987 for the Main Stem

Republican drainage basin in Kansas below the Hardy gaging station located near the Kansas-Nebraska state line.

5. Expand the study on Beaver Creek Basin into Nebraska to explore what data is available and needed for the inclusion of change in groundwater storage in the virgin water supply computations. Assess how the inclusion of change in groundwater storage in the entire Beaver Creek basin would affect the computed virgin water supply.

Commissioner Jess seconded the motion.

Motion passed.

Commissioner Danielson and Jess extended appreciation to Chairman Pope for hosting the meeting in Junction City. The next annual meeting will be held in Kansas and the date was tentatively set for July 14, 1988.

The meeting was adjourned at 2:30 pm.

DAVID L. POPE
KANSAS MEMBER (CHAIRMAN)

J. MICHAEL JESS
NEBRASKA MEMBER

JERIS A. DANIELSON
COLORADO MEMBER

REPORT OF THE ENGINEERING COMMITTEE TO THE
REPUBLICAN RIVER COMPACT ADMINISTRATION
FOR THE 1986 WATER YEAR

The Engineering Committee met twice to address the work assigned by the Compact Administration at its annual meeting on July 10, 1986. The work assigned included the following:

1. Computation of virgin water supply and consumptive use by basin for each state for the 1986 water year using the previously approved procedures.

2. Estimate consumptive uses caused by Soil Conservation Service (SCS) watershed treatment (conservation measures) and by ground water pumping in the entire basin.

3. Evaluate how to include ground water in the virgin water supply computation.

4. Calculate new allocations based on the past record and not just the annual record and compare with the original allocations.

5. Compare the methods of each state for computing ground water consumptive use.

The Engineering Committee held its first meeting on October 13-15, 1986, in Denver, Colorado. The second meeting was held on May 5-7, 1987, in McCook, Nebraska.

The Engineering Committee consists of representatives from the three signatory states of the compact and are appointed by the members of the Compact Administration. The Engineering Committee members are:

Gerald E. Hilmes, Kansas Division of Water Resources

James O. Bagley, Kansas Division of Water Resources

H. Lee Becker, Nebraska Department of Water Resources

Robert F. Bishop, Nebraska Department of Water Resources

Harold D. Simpson, Colorado State Engineer's Office

COMPUTATION OF VIRGIN WATER SUPPLIES AND CONSUMPTIVE USES

The computation of virgin water supply and consumptive use for each basin was accomplished using the previously approved procedures. Allocations of consumptive use were adjusted in accordance with procedures set forth in the compact. The formulas necessary to compute these values were used along with a computer program developed by Nebraska.

Shown in Table 1 is the 1986 computed virgin water supply by ground water and surface water components and the original computed virgin water supply and the original allocations to each state by sub-basin along with the 1986 adjusted allocations. Adjusted allocations for each state were computed for each sub-basin. A state's allocation is adjusted when the computed annual virgin water supply varies "more than ten percent from the virgin water supply" as set forth originally in the Compact. The allocations made from

such a source are "increased or decreased in the relative proportions that the future computed virgin water supply of such source bears to the computed virgin water supply" as originally set forth in the Compact.

The 1986 consumptive use computations were made for each state and for each sub-basin. Table 2 summarizes those quantities. Annual consumptive use was computed for diversions from surface and ground water sources. Both measured and estimated data were utilized. Allowance was made for reservoir evaporation, return flow, and other losses. Attachments to this report are Tables 1 and 2 and the computer printouts of the calculations.

ADDITIONAL WORK ASSIGNMENTS

The Engineering Committee met on October 13-15, 1986 to begin work on the additional assignments given it by the Compact Administration which are item nos. 2-5 above. Work on these items was continued at the May 5-7, 1987 meeting.

Assignment No. 2

With respect to assignment no. 2, the Engineering Committee reviewed at length the 1985 Republican River Basin Water Management Study and Appendices as prepared by the U. S. Bureau of Reclamation (USBR). This study not only provides much useful basic data, but also attempted to estimate the depletions caused by SCS conservation measures and basin-wide ground water pumping upon the streamflows of the basin.

Careful analysis of the application of the Glover technique used by the USBR to estimate stream depletion resulting from pumping by Ogallala and alluvial wells indicates that the depletion is overstated due primarily to the assumptions necessary to use the Glover technique.

The Engineering Committee agreed that the best method to estimate stream depletions caused by basin-wide well pumping would be a computer model using a finite difference solution technique. The ground water model recently developed by the U. S. Geological Survey, often referred to as the McDonald-Harbaugh Model, would be appropriate. The data necessary to operate the model may be available but it would take considerable effort and expense to obtain this data, construct the model, and calibrate it. This effort would be beyond the capabilities of the Engineering Committee and would require the support of the U. S. Geological Survey or a consultant.

The technique used by the USBR to estimate stream depletion caused by SCS conservation measures is based upon a computer model developed by Kansas State University and is data intensive. It requires data that is not readily available since the SCS does not maintain its data for longer than seven years before it discards the data. Discussions with former USBR engineers that worked on this study indicate that much of the missing data had to be estimated in order to compute the depletions caused by these conservation measures in each basin over the study period.

It may be possible that the computer models could be used to estimate the depletions caused by the SCS conservation measures by assuming that there were

none or very little measures in place at the time of the compact enactment and obtain the latest data available from SCS land use maps and data bases. This computer model then would estimate the depletions caused by these conservation measures based upon the annual precipitation data. Unfortunately, the computer model and data developed by the USBR cannot be located so it would require considerable additional effort by the Engineering Committee or others to develop a new model of the basin and obtain the necessary data.

In light of the above discussion, the Engineering Committee decided to study one basin using less complex methods to attempt to estimate the depletions caused by basin-wide well pumping and SCS conservation measures. It was decided to select a basin that is consistently over-allocated and evaluate historic data for possible trends and simplified procedures for estimating depletions caused by the above.

At the meeting in October of 1986, Lee Becker used his portable computer and data provided by Hal Simpson on a floppy disk to analyze streamflow data for the Beaver Creek basin. Baseflow was estimated by using the November to February streamflows and multiplying by 3. This annual baseflow estimate for the period 1939 through 1984 was accumulated and a single mass curve was plotted. This curve indicated a sharp decline beginning in 1966 and essentially going to nearly zero thereafter. The Engineering Committee decided to pursue this analysis further by using a more accurate technique for separating baseflow from the annual hydrograph of daily mean flows for the Beaver Creek basin.

The Engineering Committee recognized that this procedure would not provide a quantitative procedure for estimating the depletions caused by ground water pumping and SCS watershed treatment, but it may provide some general indication of the impacts of these factors after known consumptive uses of surface water and alluvial ground water within the basin are considered.

The Engineering Committee's investigation of changes in baseflow and surface runoff over the period of record was directed at attempting to identify changes, if any, in these two components of the annual streamflow. The thought was that changes in baseflow would indicate impacts of ground water pumping and changes in surface runoff would indicate impacts of SCS watershed treatment. A key issue is whether ground water levels in alluvium drop below the streambed elevation. If the ground water elevation drops below the streambed causing separation of the aquifer from the stream, then this proposed method of analysis may not be appropriate.

The annual hydrographs for the period of 1938 to 1986 were plotted in May of 1987 using USGS WATSTOR data and the baseflow was separated using techniques suggested in the literature. Hal Simpson and his staff then determined the volume of baseflow for each year as well as the volume of surface water flow. This data is shown on Table 3 along with accumulated volumes. This data was then plotted as single mass curves and are shown on Figures 1 thru 4.

As can be observed, the single mass curves of streamflow indicate a sharp decline in flow in 1966 that does not appear to correlate directly with

precipitation conditions in the basin. An illustration of this poor correlation is shown on Figures 5 and 6 which are precipitation mass diagrams for two stations near the Beaver Creek basin, St. Francis, and Colby. A study for the USBR by Kansas State University in 1983 entitled, "Assessment of Changes in Precipitation Regime of the Republican River Basin", indicates that precipitation alone does not explain the decline in runoff but that precipitation intensity when combined with SCS soil and water conservation practices explain the decline in surface runoff in the upper part of the Republican River basin. A conclusion of the study on page 68 is that "Man-made changes in the Basin appear to overshadow effects of precipitation on inflows. These changes are decreasing the responsiveness of the Basin to fluctuations in precipitation."

The following table, Table 4, contains a summary of pre-1967 and post-1967 averages derived from Table 3.

TABLE 4
Streamflow Comparisons - Beaver Creek

Period	Total Streamflow AF	Surface Component AF	Baseflow AF
1938-1966 Average	25489	21122	4367
1967-86 Average	3281	2635	646
Change in Average	22208	18487	3721

Table 5 contains the computed consumptive use of ground water and surface water in the basin for the period of record of the Compact Administration, 1959-1986. This data is provided to allow comparison of the streamflow declines with increased consumptive use in the basin. As can be seen, the increase in consumptive use does not fully explain the decline in streamflow.

The impacts of SCS watershed treatment and ground water pumping outside the alluvium in the Ogallala appear to be evident especially when change in storage in the alluvium is considered.

Gerry Hilmes obtained in early 1987 ground water level data for Beaver and Sappa Creeks and plotted this data as a profile along the streams. This profile indicates that the ground water table was above the streambed in 1950. The overall decline in the water table was about 7.5 feet throughout the basin for the 1950-1980 period and indicated that the available water supply was declining. This decline resulted not only from increased consumptive use within the basin, but apparently from the reduced runoff due to SCS watershed treatment and from pumping of the Ogallala formation. Figure 7 illustrates the changes in water level and storage.

This profile also indicates that the water table levels were near the streambed elevation throughout most of the basin in 1966 and approximately 5 feet below in 1980. Thus, it appears that separation of the aquifer from the stream occurred around 1966 and that streamflow has declined sharply since a portion of the surface runoff is percolating through the streambed into the alluvium to replace water lost from pumping.

To further illustrate the complexity of the hydrologic system, a series of cross-sections (6) across Beaver and Sappa Creeks were constructed by Gerry Hilmes to compare the water table elevations in the Ogallala formation with the land surface elevations. The cross-sections indicate that the Ogallala formation was contributing to baseflow in 1950 throughout most of the Beaver Creek basin approximately downstream of Goodland, Kansas. By 1966, the water

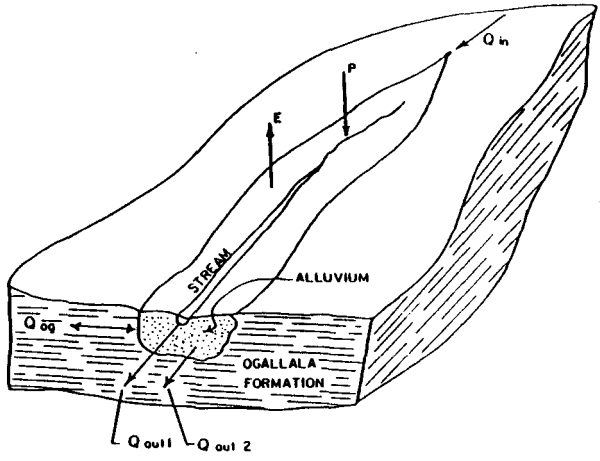
table elevations had declined by 4 to 8 feet with the larger declines in the upper basin. By 1980, the water elevations had declined 8 to 20 feet and the Ogalalla contribution area had moved downstream about 30 miles.

Both of the exhibits prepared by Gerry Hilmes are on 24x36 inch drawings which are too large to attach to this report. These exhibits will be provided at the compact meeting on July 9, 1987. Table 6 contains data on annual changes in ground water storage in Kansas.

The Engineering Committee concludes that it cannot readily determine the annual depletions caused separately by SCS watershed treatment and ground water pumping unless computer models are utilized and these may not be practical due to the data required to properly utilize the models as well as costs.

Assignment No. 3

The Engineering Committee reviewed the present procedure for computing the virgin water supply and agreed that it may result in an over-estimate of the virgin water supply because of pumping from storage. Figure No. 8 shows how the present procedure overstates the virgin water supply for the Beaver Creek basin. The Engineering Committee agreed that the virgin water supply computation should at least consider the change in storage of water in the alluvial aquifer. A mass balance equation of the various factors in the hydrologic system shown in Figure 9 can be written. The stream channel and contiguous alluvium can be treated as one system. The Ogallala Formation would be a boundary of the system. Figure 9 could represent the Beaver Creek basin above the Beaver City gage.



Representative Stream-Alluvium System

Figure 9

The mass balance equation is:

$$Q_{in} + Q_{og} + P - Q_{out1} - Q_{out2} - E = \Delta V \quad \text{- - - - - - - - - - - (1)}$$

where

Q_{in} = annual surface inflow from areas outside system

Q_{og} = annual inflow or outflow from Ogallala formation

P = annual precipitation on stream-aquifer system

Q_{out1} = annual surface outflow of gage

Q_{out2} = annual subsurface outflow at gage

E = annual evapotranspiration losses from the system

ΔV = annual change in storage volume of water in alluvium and surface reservoirs

Since equation 1 is in general terms, it would be desirable to expand the parameters into components. The evapotranspiration loss parameter, E, includes all evapotranspiration losses from the system which include consumptive use loss, phreatophyte loss, and evaporative losses from streams, ditches, reservoirs and the bare soil surface. Therefore,

$$E = CU_{sw} + CU_{gw} + CU_p + E_{ph} + E_R + E_D + E_S + E_B \quad \text{- - - - - - - - - (2)}$$

where

CU_{sw} = consumptive use of surface water irrigation

CU_{gw} = consumptive use of ground water irrigation

CU_p = consumptive use of precipitation

E_{ph} = evapotranspiration by phreatophytes

E_R = surface evaporation from reservoirs

E_D = surface evaporation from ditches

E_S = surface evaporation from streams

E_B = surface evaporation from bare soil

Substituting equation 2 into equation 1 and rearranging parameters into those that represent inflow to the system on one side of the equation results in:

$$Q_{in}+Q_{og}+(P-CU_p) = Q_{out1}+Q_{out2}+CU_{sw}+CU_{gw}+E_{ph}+E_R+E_D+E_S+E_B+\Delta V$$

The terms on the left side of the equation represent the inflow to the system and could be considered a definition of the virgin water supply for the alluvial system. The terms on the right side of the equation can be estimated with various degrees of accuracy or disregarded as not having significance in the total water budget.

Q_{out1} is annual gaged streamflow. Q_{out2} is subsurface outflow and, if deemed significant, can be estimated using Darcy's law and test well data or data from existing wells.

CU_{sw} and CU_{gw} have been computed annually by the Engineering Committee since 1959. The computation of CU_{gw} varies among the states but each state's method appears reasonable. This issue is discussed in assignment no. 5.

E_{ph} can be estimated if phreatophytes are considered to be significant in the basin. Aerial photos or Landsat photos can be used to map areas of phreatophytes. Also, the USBR Republican River Basin Water Management Study estimated phreatophyte areas in each subbasin in acres (Table 19, pg. 77 of Special Report) for 1978. The report estimated that the consumptive use is 4.1 acre-feet per acre.

E_R is included in the computations for virgin water supply for on-stream reservoirs. Smaller off-stream reservoirs on the alluvium could be included if necessary. E_D would be expected to be minimal and could be disregarded in most basins but it also can be computed without difficulty. E_S can be computed by estimating the surface area of the stream and using

the nearest evaporation data. E_B is evaporation from bare soil and only occurs when the water table is within 24 inches of the soil surface. This would probably apply to the stream channel where no vegetation exists and can be estimated from aerial photos and using the nearest evaporation data.

The change in storage volume of the alluvial aquifer is the term that would require the most effort to obtain. The change in storage is a significant term in the water budget in most basins. A declining water table as is the case in the Beaver Creek basin would reduce the virgin water supply. The change in water table elevations would have to be obtained using data available from existing and new monitoring wells. In addition, a monitoring network using irrigation wells measured at the same time every year, such as January or February, could be established to provide additional data points so that the water table elevations could be contoured from year to year to obtain a change in volume of saturated material. With recent advances of computer technology, programs are available for desk-top computers that would plot water table elevation data, contour the data, and compute the change in volume. The specific yield of the alluvium could be estimated from pump tests or obtained from published reports. The annual change in volume of saturated material multiplied by the specific yield would provide the annual change in storage of water in the alluvium. The change in storage of surface reservoirs is computed by the Engineering Committee now for existing large on-stream reservoirs. Smaller reservoirs in the alluvium could be included without much additional effort.

The Engineering Committee believes that this method offers the most reasonable and most effective procedure to compute the annual virgin water supply in each basin. This method would compute the combined effects of all activities of man as well as rainfall. The funds spent improving and expanding ground water monitoring networks in each state would be better spent than on funds for sophisticated computer models. The overall costs for data collection should be considerably less than costs for computer model development and operation. Furthermore, the Engineering Committee can accomplish the work without relying upon federal agencies or consultants.

Assignment No. 4

The Engineering Committee, using the historic data base on the Nebraska computer, has computed a long-term average virgin water supply for each basin and adjusted the allocation, if necessary. These values are shown in Table 7.

Assignment No. 5

The Engineering Committee was directed to review the method used by each state to estimate ground water pumping. Each state uses a different method suitable to the nature of ground water use in the individual state.

Colorado, which has the least ground water use (12,770 acre-feet in 1986) uses an average value of 159 acre-feet per well. This average is based upon a well survey done by the U. S. Geological Survey several years ago. With the restoration of the water commissioner position in Wray, Colorado will obtain additional data on ground water use to update this average.

Kansas, which used 46,290 acre-feet in 1986, utilizes water user reports to estimate total ground water use. The reported volume pumped is divided by the permitted pumping volume for the reported wells and this fraction is multiplied by the total permitted pumping.

Nebraska, which used 178,430 acre-feet in 1986, estimates ground water pumping by multiplying acres irrigated by the irrigation water requirement.

In all cases, the estimates are for pumping from the alluvium only and does not include pumping from the Ogallala.

The Engineering Committee, at this time, believes the method used by each state is reasonable. Each state should review its procedures to determine if the input data can be refined to improve the accuracy of the ground water pumping estimates.

Harold D. Simpson

Robert F. Bishop

H. Lee Becker

Gerald E. Hilmes

James O. Bagley

TABLE 3

BEAVER CREEK ANNUAL FLOW DATA IN ACRE FEET

YEAR	QTOTAL	QBASE	QRUNOFF	CUMQT	CUMQB	CUMQR
38	16321	1176.7	15144	16321	1177	15144
39	13842	1003.2	12839	30163	2180	27983
40	9035	344.3	8691	39198	2524	36674
41	34934	1779.1	33155	74132	4303	69829
42	40058	8659.6	31398	114190	12963	101227
43	9744	4343.7	5400	123934	17307	106627
44	45743	4234.6	41508	169677	21541	148136
45	17047	8444.4	8603	186724	29986	156738
46	8592	1226.8	7365	195316	31213	164103
47	60936	4645.4	56291	256252	35858	220394
48	21821	2773.3	19048	278073	38631	239442
49	42250	5197.8	37052	320323	43829	276494
50	32414	6674.7	25739	352737	50504	302233
51	84118	9680.9	74437	436855	60185	376670
52	25595	13507.3	12088	462450	73692	388758
53	4515	1595.8	2919	466965	75288	391677
54	2929	264.4	2665	469894	75552	394342
55	285	66.6	218	470179	75619	394560
56	1692	70.4	1622	471871	75689	396182
57	33775	1964.8	31810	505646	77654	427992
58	20164	7364.3	12800	525810	85018	440792
59	7505	2590.4	4915	533315	87609	445706
60	41775	3870.2	37905	575090	91479	483611
61	14447	1861.5	12585	589537	93340	496197
62	37192	5057.6	32134	626729	98398	528331
63	17636	5516.6	12119	644365	103914	540451
64	15259	3545.8	11713	659624	107460	552164
65	43144	5699.9	37444	702768	113160	589608
66	36405	13474.0	22931	739173	126634	612539
67	8801	2955.7	5845	747974	129590	618384
68	2689	1111.3	1578	750663	130701	619962
69	6092	1096.5	4995	756755	131798	624957
70	2434	922.3	1512	759189	132720	626469
71	2397	514.6	1882	761586	133235	628351
72	1821	559.0	1262	763407	133794	629613
73	1234	363.3	871	764641	134157	630484
74	2944	418.7	2525	767585	134576	633009
75	5069	430.4	4639	772654	135006	637648
76	677	469.0	208	773331	135475	637856
77	1520	206.4	1314	774851	135681	639170
78	363	261.3	102	775214	135943	639271
79	1309	139.8	1169	776523	136083	640440
80	418	280.2	138	776941	136363	640578
81	545	126.4	419	777486	136489	640997
82	493	358.1	135	777979	136847	641132
83	22723	592.2	22131	800702	137440	663262
84	1659	877.6	781	802361	138317	664044
85	873	594.8	278	803234	138912	664322
86	1571	649.8	921	804805	139562	665243

TABLE 5

BEAVER CREEK BASIN
COMPUTED CONSUMPTIVE USE
Acre-Feet

Year	Total CU	GW CU	SW CU
1959	9140	4177	4963
1960	9200	7610	1590
1961	7420	6230	1190
1962	5510	3590	1920
1963	13480	11380	2100
1964	10980	9220	1760
1965	8040	6240	1800
1966	10100	7920	2180
1967	11580	8660	2920
1968	12940	10250	2690
1969	13600	10780	2820
1970	12970	11710	1260
1971	16290	12490	3800
1972	17710	14020	3690
1973	17450	12160	5290
1974	20810	15870	4940
1975	27450	22460	4990
1976	33340	27380	5960
1977	27810	21910	5900
1978	40240	33380	6860
1979	16420	15120	1300
1980	19980	19940	40
1981	13950	13120	830
1982	15370	15180	190
1983	15550	15130	420
1984	18020	17790	230
1985	14880	14630	250
1986	18070	17800	270

TABLE 6
BEAVER CREEK BASIN - KANSAS
CHANGE IN STORAGE

Year[1]	Change in Storage
1965	22905
1966	-8451
1967	-6468
1968	-9199
1969	358
1970	-8150
1971	-346
1972	622
1973	9457
1974	-5904
1975	-2680
1976	-8540
1977	7661
1978	-16341
1979	-2224
1980	-5191
1981	15577
1982	15444
1983	-1590
1984	2619
1985	-421

[1]Accurate data not available before 1965.

Table 7

Virgin Water Supply 28 Year Average 1959-86
Original and Adjusted Allocations based on 28 Year Average
using same percentage as from Original Supply

Sub-basin and the Original Compact Virgin Water Supply		Virgin Water Supply Republican River Basin 28 Year Average (Acre-Feet)			Comparison of Original Compact Allocations and Adjusted Allocations (Acre-Feet)							
					Colorado		Kansas		Nebraska		Total Basin	
		Ground Water	Surface Water	Total Basin	Compact Alloc.	Adj. Alloc.	Compact Alloc.	Adj. Alloc.	Compact Alloc.	Adj. Alloc.	Compact Alloc.	Adj. Alloc.
Prairie Dog Cr.	27,600	10,110	14,920	25,030			12,600	11,410	2,100	1,900	14,700	13,310
Sappa Cr.	21,400	14,750	18,100	32,850			8,800	13,500	8,800	13,500	17,600	27,000
Beaver Cr.	16,500	13,910	11,450	25,360	3,300	5,070	6,400	9,840	6,700	10,300	16,400	25,210
Medicine Cr.	50,800	6,450	46,250	52,750					4,600	4,800	4,600	4,800
Red Willow Cr.	21,900	2,950	22,800	25,750					4,200	4,940	4,200	4,940
Driftwood Cr.	7,300	850	3,850	4,750			500	320	1,200	780	1,700	1,100
Frenchman Rv.	98,500	34,830	83,320	118,150					52,800	63,330	52,800	63,330
South Fork of the Republican Rv.	57,200	6,450	32,800	39,250	25,400	17,430	23,000	15,780	800	550	49,200	33,760
Rock Cr.	11,000	50	9,700	9,750					4,400	3,900	4,400	3,900
Buffalo Cr.	7,890	150	5,400	5,550					2,600	1,830	2,600	1,830
Arikaree Rv.	19,610	2,450	11,190	13,640	15,400	10,710	1,000	700	3,300	2,290	19,700	13,700
N.F. Republican Rv. in Colorado	44,700	250	45,600	45,850	10,000	10,270			11,000	11,280	21,000	21,550
*N.F. and Main Stem of Republican Rv. incl. Blackwood Cr. in Nebraska	94,500	57,850	167,800	225,650			138,000	209,460	132,000	200,440	270,000	409,900
TOTALS	478,900	151,050	473,180	624,330	54,100	43,480	190,300	261,010	234,500	319,840	478,900	624,330

*Main Stem 87,700
Blackwood Creek 6,800

Values underlined are less than original allocations.

BEAVER CREEK FLOWS

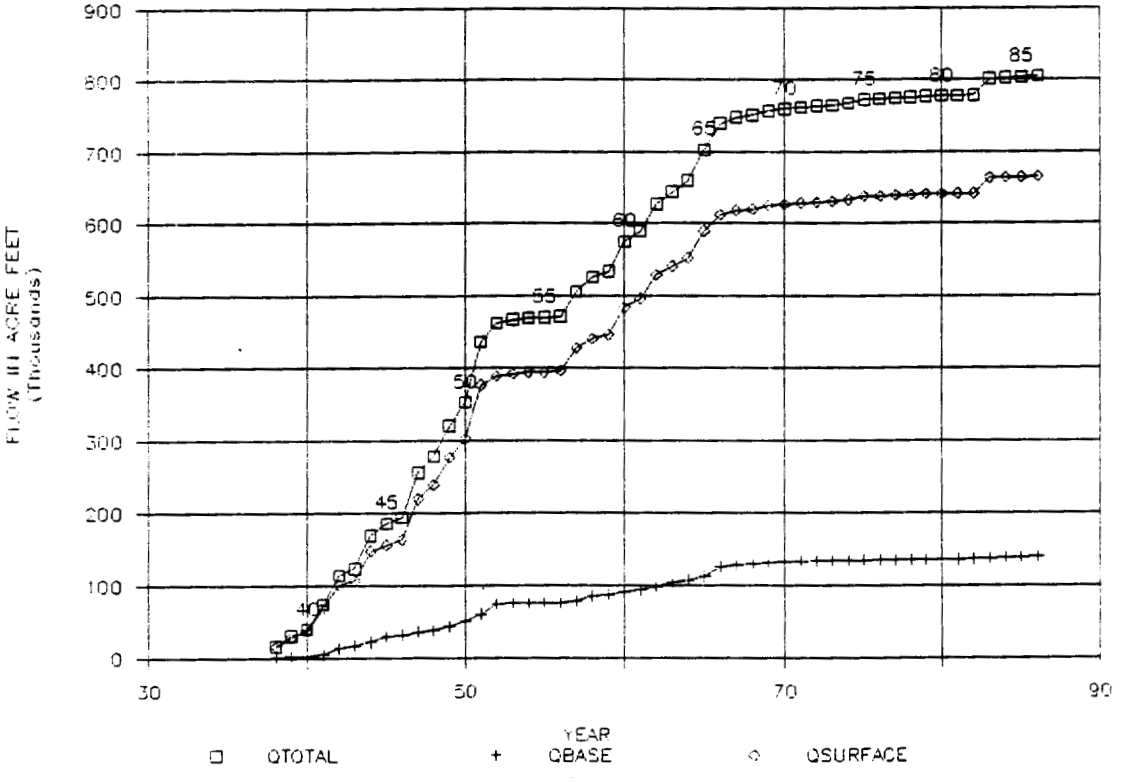


FIGURE 1

BEAVER CREEK TOTAL RUNOFF

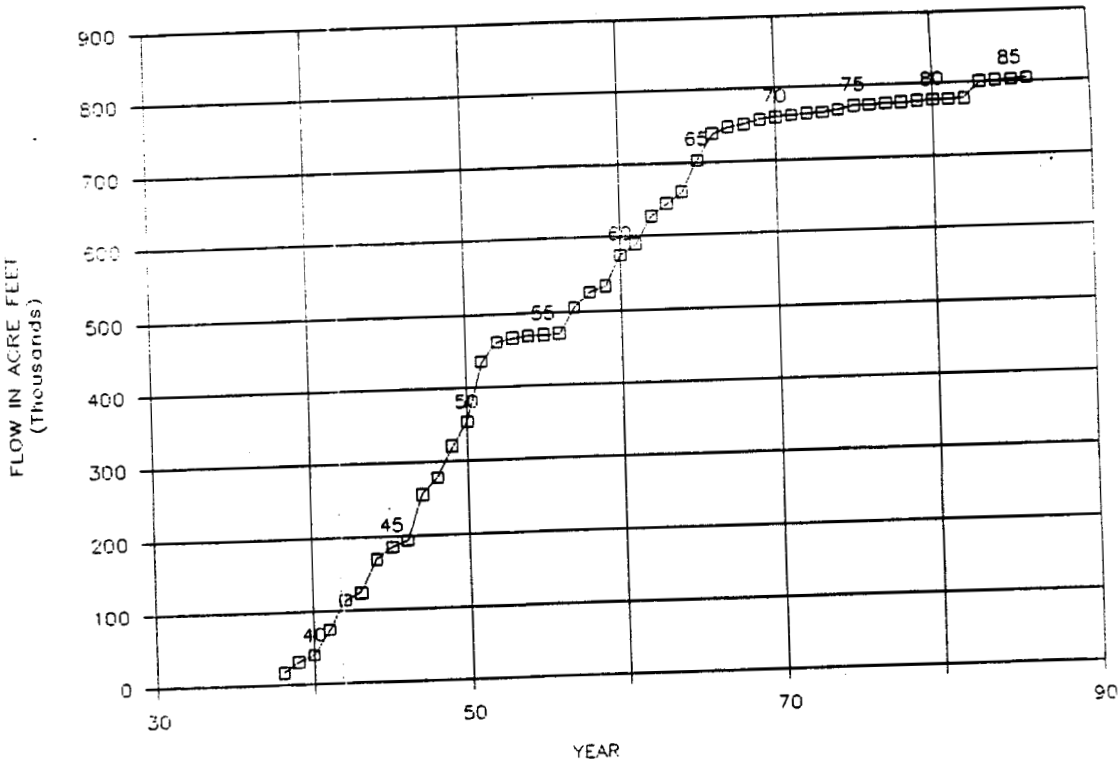


FIGURE 2

BEAVER CREEK BASE RUNOFF

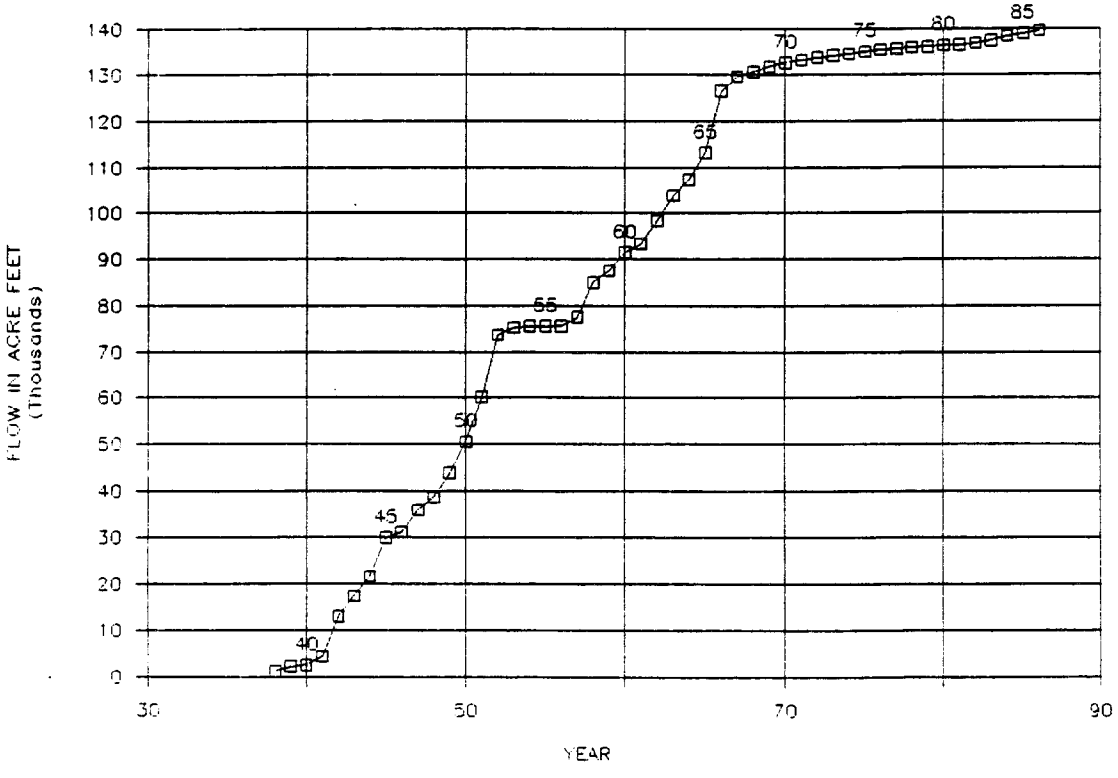


FIGURE 3

BEAVER CREEK SURFACE RUNOFF

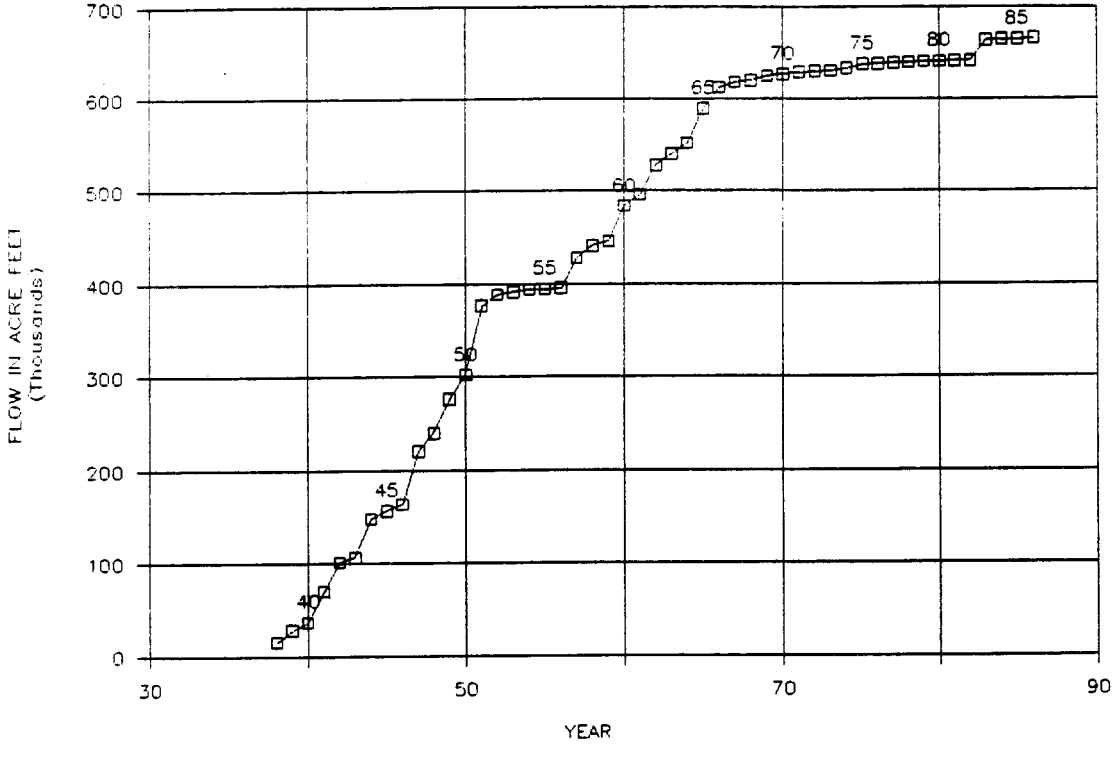


FIGURE 4

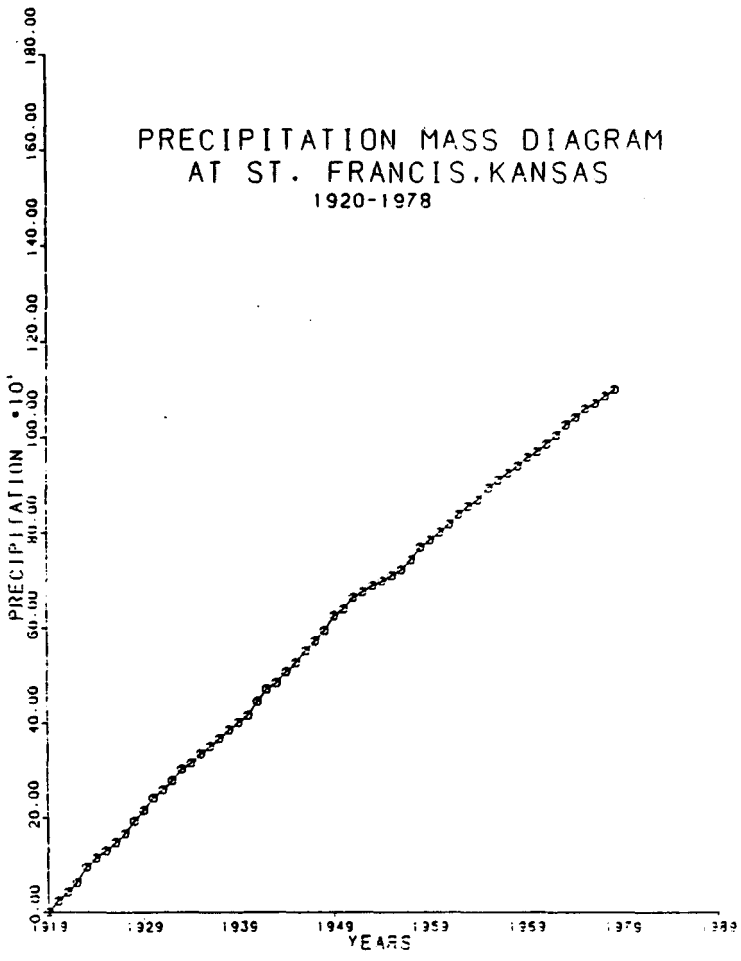


Figure 5. Precipitation mass diagram for St. Francis, Kansas, 1920-78.

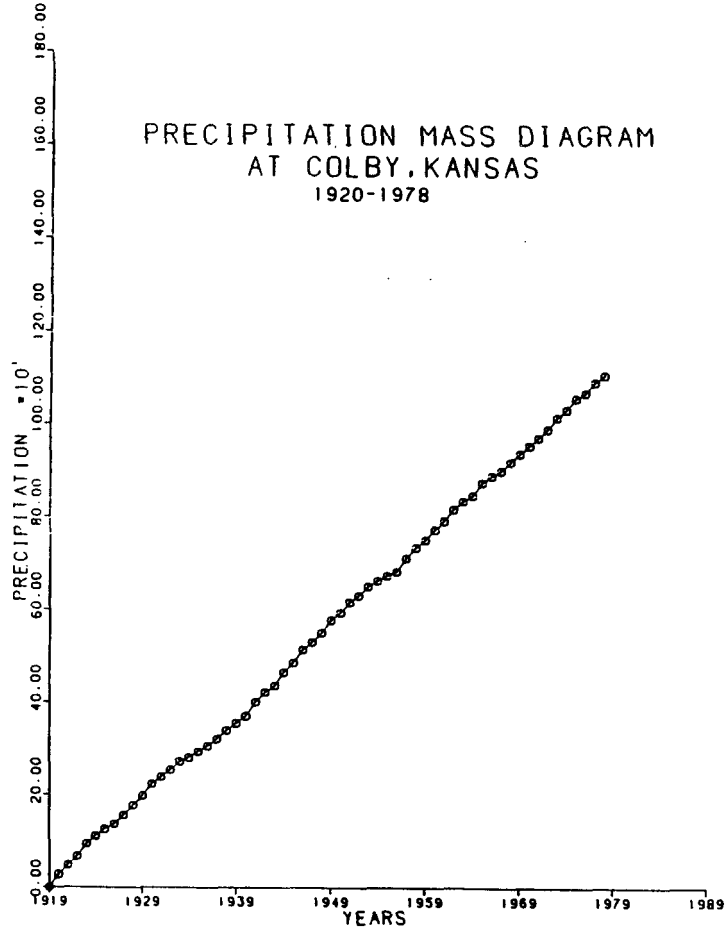


Figure 6. Precipitation mass diagram for Colby, Kansas, 1920-78.

USBR-KSU 1983

ILLUSTRATION

FOR

A METHOD TO DETERMINE CHANGE IN GROUNDWATER STORAGE

BEAVER CREEK BASIN IN KANSAS

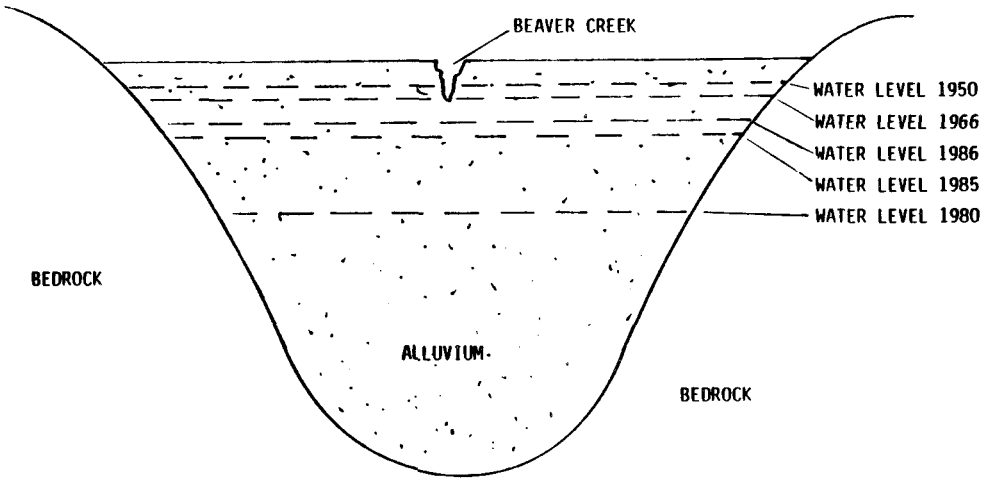


FIG. 7 - TYPICAL VALLEY CROSS - SECTION (not to scale)

ALLUVIUM AQUIFER DATA:

LENGTH = 60 MILES
AV. WIDTH = 1.2 MILES
SP. YIELD = .15

1/ CHANGE IN WATER LEVEL:

1950 - 1980 = -7.5 ft
1966 - 1980 = -6.7 ft
1966 - 1986 = -3.5 ft
1985 - 1986 = +.04 ft

CHANGE IN STORAGE, AF = ACRES x WATER-LEVEL CHANGE x 0.15

1950 - 1980 = -51840 AF or -1730 AF/yr
1966 - 1980 = -46310 AF or -3310 AF/yr
1966 - 1986 = -24190 AF or -1210 AF/yr
1985 - 1986 = +280 AF

1/ CHANGE IN WATER LEVEL IS AVERAGE OF 12 OBSERVATION WELLS

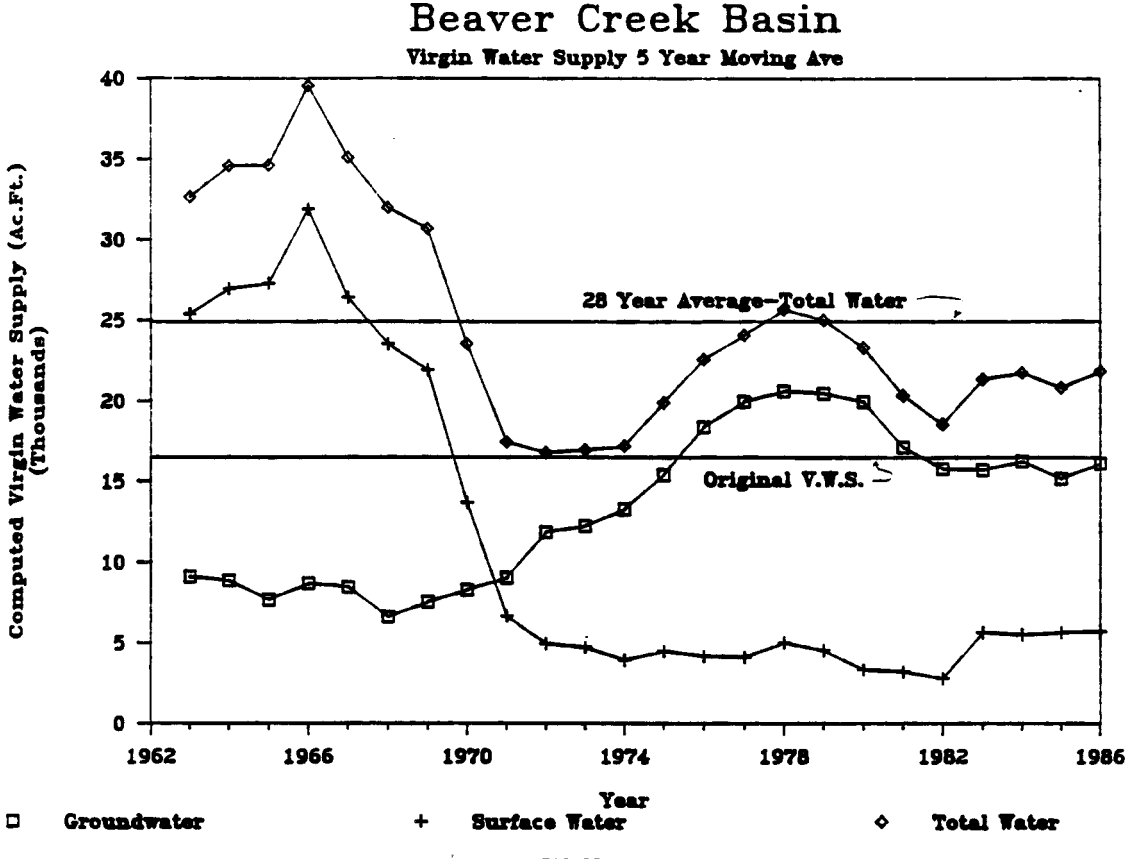

Beaver Creek Basin
Virgin Water Supply 5 Year Moving Ave
Computed Virgin Water Supply (Ac.Ft.)
(Thousands)
40
35
30
25
20
15
10
5
0
28 Year Average--Total Water
Original V.W.S.
1962
1966
1970
1974
1978
1982
1986
Year
Groundwater
Surface Water
Total Water

FIGURE 8

Table 8

Virgin Water Supply
28 Year Average 1959-86
and Original Allocations

Sub-basin and the Original Compact Virgin Water Supply		Virgin Water Supply Republican River Basin 28 Year Average (Acre Feet)			Original Compact Allocations							
					Colorado		Kansas		Nebraska		Total Basin	
		Ground Water	Surface Water	Total Basin	Compact Alloc.	Adj. Alloc.	Compact Alloc.	Adj. Alloc.	Compact Alloc.	Adj. Alloc.	Compact Alloc.	Adj. Alloc.
Prairie Dog Cr.	27,600	10,110	14,920	25,030			12,600		2,100		14,700	
Sappa Cr.	21,400	14,750	18,100	32,850			8,800		8,800		17,600	
Beaver Cr.	16,500	13,910	11,450	25,360	3,300		6,400		6,700		16,400	
Medicine Cr.	50,800	6,450	46,250	52,750					4,600		4,600	
Red Willow Cr.	21,900	2,950	22,800	25,750					4,200		4,200	
Driftwood Cr.	7,300	850	3,850	4,750			500		1,200		1,700	
Frenchman Rv.	98,500	34,830	83,320	118,150					52,800		52,800	
South Fork of the Republican Rv.	57,200	6,450	32,800	39,250	25,400		23,000		800		49,200	
Rock Cr.	11,000	50	9,700	9,750					4,400		4,400	
Buffalo Cr.	7,890	150	5,400	5,550					2,600		2,600	
Arikaree Rv.	19,610	2,450	11,190	13,640	15,400		1,000		3,300		19,700	
N.F. Republican Rv. in Colorado	44,700	250	45,600	45,850	10,000				11,000		21,000	
*N.F. and Main Stem of Republican Rv. incl. Blackwood Cr. in Nebraska	94,500	57,850	167,800	225,650			138,000		132,000		270,000	
TOTALS	478,900	151,050	473,180	624,330	54,100		190,300		234,500		478,900	

*Main Stem 87,700
Blackwood Creek 6,800

Table 9

Virgin Water Supply 28 Year Average 1959-86
Original and Adjusted Allocations based on 28 Year Average
using same percentage as from Original Supply

Sub-basin and the Original Compact Virgin Water Supply		Virgin Water Supply Republican River Basin 28 Year Average (Acre-Feet)			Comparison of Original Compact Allocations and Adjusted Allocations (Acre-Feet) Surface Water Only							
					Colorado		Kansas		Nebraska		Total Basin	
		Ground Water	Surface Water	Total Basin	Compact Alloc.	Adj. Alloc.	Compact Alloc.	Adj. Alloc.	Compact Alloc.	Adj. Alloc.	Compact Alloc.	Adj. Alloc.
Prairie Dog Cr.	27,600	10,110	14,920	25,030			12,600	6,800	2,100	1,130	14,700	7,930
Sappa Cr.	21,400	14,750	18,100	32,850			8,800	7,440	8,800	7,440	17,600	14,880
Beaver Cr.	16,500	13,910	11,450	25,360	3,300	2,290	6,400	4,440	6,700	4,650	16,400	11,380
Medicine Cr.	50,800	6,450	46,250	52,750					4,600	4,210	4,600	4,210
Red Willow Cr.	21,900	2,950	22,800	25,750					4,200	4,380	4,200	4,380
Driftwood Cr.	7,300	850	3,850	4,750			500	260	1,200	630	1,700	890
Frenchman Rv.	98,500	34,830	83,320	118,150					52,800	44,650	52,800	44,650
South Fork of the Republican Rv.	57,200	6,450	32,800	39,250	25,400	14,560	23,000	13,190	800	460	49,200	28,210
Rock Cr.	11,000	50	9,700	9,750					4,400	3,880	4,400	3,880
Buffalo Cr.	7,890	150	5,400	5,550					2,600	1,780	2,600	1,780
Arikaree Rv.	19,610	2,450	11,190	13,640	15,400	8,780	1,000	570	3,300	1,880	19,700	11,230
N.F. Republican Rv. in Colorado	44,700	250	45,600	45,850	10,000	10,210			11,000	11,220	21,000	21,430
*N.F. and Main Stem of Republican Rv. incl. Blackwood Cr. in Nebraska	94,500	57,850	167,800	225,650			138,000	162,670	132,000	155,660	270,000	318,330
TOTALS	478,900	151,050	473,180	624,330	54,100	35,840	190,300	195,370	234,500	241,970	478,900	473,180

*Main Stem 87,700
Blackwood Creek 6,800

Values underlined are less than original allocations.

Table 10

Virgin Water Supply 28 Year Average 1959-86
Original and Adjusted Allocations based on 28 Year Average
using same percentage as from Original Supply

Sub-basin and the Original Compact Virgin Water Supply		Virgin Water Supply Republican River Basin 28 Year Average (Acre-Feet)			Comparison of Original Compact Allocations and Adjusted Allocations (Acre-Feet)							
					Colorado		Kansas		Nebraska		Total Basin	
		Ground Water	Surface Water	Total Basin	Compact Alloc.	Adj. Alloc.	Compact Alloc.	Adj. Alloc.	Compact Alloc.	Adj. Alloc.	Compact Alloc.	Adj. Alloc.
Prairie Dog Cr.	27,600	10,110	14,920	25,030			12,600	11,410	2,100	1,900	14,700	13,310
Sappa Cr.	21,400	14,750	18,100	32,850			8,800	13,500	8,800	13,500	17,600	27,000
Beaver Cr.	16,500	13,910	11,450	25,360	3,300	5,070	6,400	9,840	6,700	10,300	16,400	25,210
Medicine Cr.	50,800	6,450	46,250	52,750					4,600	4,800	4,600	4,800
Red Willow Cr.	21,900	2,950	22,800	25,750					4,200	4,940	4,200	4,940
Driftwood Cr.	7,300	850	3,850	4,750			500	320	1,200	780	1,700	1,100
Frenchman Rv.	98,500	34,830	83,320	118,150					52,800	63,330	52,800	63,330
South Fork of the Republican Rv.	57,200	6,450	32,800	39,250	25,400	17,430	23,000	15,780	800	550	49,200	33,760
Rock Cr.	11,000	50	9,700	9,750					4,400	3,900	4,400	3,900
Buffalo Cr.	7,890	150	5,400	5,550					2,600	1,830	2,600	1,830
Arikaree Rv.	19,610	2,450	11,190	13,640	15,400	10,710	1,000	700	3,300	2,290	19,700	13,700
N.F. Republican Rv. in Colorado	44,700	250	45,600	45,850	10,000	10,270			11,000	11,280	21,000	21,550
*N.F. and Main Stem of Republican Rv. incl. Blackwood Cr. in Nebraska	94,500	57,850	167,800	225,650			138,000	209,460	132,000	200,440	270,000	409,900
TOTALS	478,900	151,050	473,180	624,330	54,100	43,480	190,300	261,010	234,500	319,840	478,900	624,330

*Main Stem 87,700
Blackwood Creek 6,800

Values underlined are less than original allocations.

Table 11

Virgin Water Supply
28 Year Average 1959-86
Original and Adjusted Allocations

Sub-basin and the Original Compact Virgin Water Supply		Virgin Water Supply Republican River Basin 28 Year Average (Acre Feet)			Original and Adjusted Allocations on Basis of Consumptive Use of both Surface and Ground Water, 28 Year Average							
					Colorado		Kansas		Nebraska		Total Basin	
		Ground Water	Surface Water	Total Basin	Compact Alloc.	Adj. Alloc.	Compact Alloc.	Adj. Alloc.	Compact Alloc.	Adj. Alloc.	Compact Alloc.	Adj. Alloc.
Prairie Dog Cr.	27,600	10,110	14,920	25,030			12,600	14,750	2,100	550	14,700	15,300
Sappa Cr.	21,400	14,750	18,100	32,850			8,800	6,350	8,800	10,050	17,600	16,400
Beaver Cr.	16,500	13,910	11,450	25,360	3,300	0	6,400	7,050	6,700	9,370	16,400	16,420
Medicine Cr.	50,800	6,450	46,250	52,750					4,600	17,500	4,600	17,500
Red Willow Cr.	21,900	2,950	22,800	25,750					4,200	10,150	4,200	10,150
Driftwood Cr.	7,300	850	3,850	4,750			500	50	1,200	800	1,700	850
Frenchman Rv.	98,500	34,830	83,320	118,150					52,800	51,650	52,800	51,650
South Fork of the Republican Rv.	57,200	6,450	32,800	39,250	25,400	9,850	23,000	5,850	800	180	49,200	15,880
Rock Cr.	11,000	50	9,700	9,750					4,400	150	4,400	150
Buffalo Cr.	7,890	150	5,400	5,550					2,600	850	2,600	850
Arikaree Rv.	19,610	2,450	11,190	13,640	15,400	2,030	1,000	220	3,300	200	19,700	2,450
N.F. Republican Rv. in Colorado	44,700	250	45,600	45,850	10,000	5,850			11,000	4,600	21,000	10,450
*N.F. and Main Stem of Republican Rv. incl. Blackwood Cr. in Nebraska	94,500	57,850	167,800	225,650			138,000	48,750	132,000	154,500	270,000	203,250
TOTALS	478,900	151,050	473,180	624,330	54,100	17,730	190,300	83,020	234,500	260,550	478,900	361,300

*Main Stem 87,700
Blackwood Creek 6,800

Values underlined are less than original allocations.

Table 12

Virgin Water Supply
28 Year Average 1959-86
Original and Adjusted Allocations

Sub-basin and the Original Compact Virgin Water Supply		Virgin Water Supply Republican River Basin 28 Year Average (Acre-Feet)			Original and Adjusted Allocations on Basis of Consumptive Use of Surface Water only, 28 Year Average							
					Colorado		Kansas		Nebraska		Total Basin	
		Ground Water	Surface Water	Total Basin	Compact Alloc.	Adj. Alloc.	Compact Alloc.	Adj. Alloc.	Compact Alloc.	Adj. Alloc.	Compact Alloc.	Adj. Alloc.
Prairie Dog Cr.	27,600	10,110	14,920	25,030			12,600	4,640	2,100	50	14,700	4,690
Sappa Cr.	21,400	14,750	18,100	32,850			8,800	130	8,800	220	17,600	350
Beaver Cr.	16,500	13,910	11,450	25,360	3,300	0	6,400	610	6,700	1,940	16,400	2,550
Medicine Cr.	50,800	6,450	46,250	52,750					4,600	10,550	4,600	10,550
Red Willow Cr.	21,900	2,950	22,800	25,750					4,200	7,200	4,200	7,200
Driftwood Cr.	7,300	850	3,850	4,750			500	50	1,200	50	1,700	100
Frenchman Rv.	98,500	34,830	83,320	118,150					52,800	29,100	52,800	29,100
South Fork of the Republican Rv.	57,200	6,450	32,800	39,250	25,400	8,950	23,000	490	800	180	49,200	9,620
Rock Cr.	11,000	50	9,700	9,750					4,400	100	4,400	100
Buffalo Cr.	7,890	150	5,400	5,550					2,600	600	2,600	600
Arikaree Rv.	19,610	2,450	11,190	13,640	15,400	0	1,000	0	3,300	0	19,700	0
N.F. Republican Rv. in Colorado	44,700	250	45,600	45,850	10,000	5,650			11,000	4,600	21,000	10,250
*N.F. and Main Stem of Republican Rv. incl. Blackwood Cr. in Nebraska	94,500	57,850	167,800	225,650			138,000	48,600	132,000	95,810	270,000	144,410
TOTALS	478,900	151,050	473,180	624,330	54,100	14,600	190,300	54,520	234,500	150,400	478,900	219,520

*Main Stem 87,700
Blackwood Creek 6,800

Values underlined are less than original allocations.

Table 1

1986 Computed Annual Virgin Water Supply and
Original and Annual Adjusted Allocations

Sub-basin and the Original Compact Virgin Water Supply	Computed Annual Virgin Water Supply Republican River Basin 1986 (Acre Feet)				Comparison of Original Compact Allocations and 1986 Adjusted Allocation (Acre Feet)							
					Colorado		Kansas		Nebraska		Total Basin	
		Ground Water	Surface Water	Total Basin	Compact Alloc.	Adj. Alloc.	Compact Alloc.	Adj. Alloc.	Compact Alloc.	Adj. Alloc.	Compact Alloc.	Adj. Alloc.
Prairie Dog Cr.	27600	19660	4620	24280			12600	11090	2100	1850	14700	12940
Sappa Cr.	21400	27510	5870	33380			8800	13730	8800	13730	17600	27460
Beaver Cr.	16500	17800	1840	19640	3300	3930	6400	7620	6700	7970	16400	19520
Medicine Cr.	50800	12310	35370	47680					4600	4600	4600	4600
Red Willow Cr.	21900	4720	16460	21180					4200	4200	4200	4200
Driftwood Cr.	7300	1300	1410	2710			500	190	1200	450	1700	640
Frenchman Rv.	98500	34830	57420	92250					52800	52800	52800	52800
South Fork of the Republican Rv.	57200	11980	20700	32680	25400	14500	23000	13130	800	460	49200	28090
Rock Cr.	11000	100	8550	8650					4400	3460	4400	3460
Buffalo Cr.	7890	700	4920	5620					2600	1850	2600	1850
Arikaree Rv.	19610	5220	6920	12140	15400	9530	1000	620	3300	2040	19700	12190
N.F. Republican Rv in Colorado	44700	380	40280	40660	10000	10000			11000	11000	21000	21000
N.F. and Main Stem of Republican Rv. incl. Blackwood Cr. in Nebraska[1]	94500	95180	149130	244310			138000	202180	132000	194250	270000	396430
TOTALS	478900	231690	353490	585180	54100	37960	190300	248560	234500	298660	478900	585180

[1] Main Stem 87,700
Blackwood Creek 6,800

Table 2

1986 Computed Consumptive Use within the Republican River Basin (Acre Feet)

Sub-basin	Colorado Ground Water	Colorado Surface Water	Colorado Total	Kansas Ground Water	Kansas Surface Water	Kansas Total	Nebraska Ground Water	Nebraska Surface Water	Nebraska Total	Total Basin Ground Water	Total Basin Surface Water	Total Basin Total
Prairie Dog Cr.				19660	4270	23930	1390	0	1390	21050	4270	25320
Sappa Cr.				8240	90	8330	20570	150	20720	28810	240	29050
Beaver Cr.	0	0	0	8370	170	8540	9430	100	9530	17800	270	18070
Medicine Cr.							13310	4190	17500	13310	4190	17500
Red Willow Cr.							4720	8320	13040	4720	8320	13040
Driftwood Cr.				0	0	0	1300	0	1300	1300	0	1300
Frenchman Rv.							34830	17170	52000	34830	17170	52000
South Fork of the Republican Rv.	2530	8430	10960	9450	270	9720	0	0	0	11980	8700	20680
Rock Cr.							100	150	250	100	150	250
Buffalo Cr.							700	750	1450	700	750	1450
Arikaree Rv.	4060	0	4060	460	0	460	700	0	700	5220	0	5220
N.F. Republican Rv in Colorado	380	4340	4720				0	2930	2930	380	7270	7650
N.F. and Main Stem of Republican Rv. incl. Blackwood Cr. in Nebraska*				110	37980	38090	91380	98900	190280	91490	136880	228370
TOTALS	6970	12770	19740	46290	42780	89070	178430	132660	311090	231690	188210	419900

* Evaporation from Harlan County Reservoir -- Kansas 48 percent 9300 Acre Feet
Nebraska 52 percent 10070 Acre Feet