

FIRST ANNUAL REPORT

Republican River
Compact
Administration

For the Year 1960



LINCOLN, NEBRASKA
April 4, 1961

c. On November 19, 1959, following consultation with representatives of the several Federal and State agencies interested in the collection of hydrologic data and the development and use of the water resources of the Republican River Basin, the Administration established a "Committee on Procedure for Computation of Annual Virgin Water Supply," consisting of one representative of each of the official members of the Administration, and invited the U. S. Geological Survey, the Bureau of Reclamation, the U. S. Department of Agriculture and the Corps of Engineers to cooperate with the Committee. The Committee was instructed to prepare a separate report with respect to each of the drainage basins set out in Article III of the Republican River Compact.

d. On March 30, 1960, at the Annual Meeting, a progress report, including recommendations for continuing its work, was made by the Committee on Procedure for Computation of Annual Virgin Water Supply and the same was approved by the Administration. A copy of the progress report and recommendations is appended to this report as Appendix A.

e. On March 30, 1960, the Administration amended Rule 9 of the Rules and Regulations to provide that


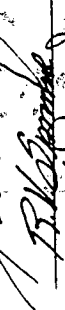

"A regular annual meeting of the Administration shall be held upon the call of the Chairman during the months of March or April each year."

f. On April 4, 1961, the Administration accepted a Progress Report and a report entitled "Formulas for the Computation of Annual Virgin Water Supply, Republican River Basin" prepared by the Committee on Procedure for Computation of Annual Virgin Water Supply which are appended hereto as Exhibits "B" and "C", respectively.

Respectfully submitted

REPUBLICAN RIVER COMPACT ADMINISTRATION

By:

 Colorado Member
 Kansas Member
 Nebraska Member

Minutes of the Annual Meeting

of the

Republican River Compact Administration

Lincoln, Nebraska

March 30, 1960

The meeting was called to order by the Chairman, Dan S. Jones, Jr., at 9:00 o'clock A. M., in the Lawyer's Room, Capitol Building, Lincoln, Nebraska.

Mr. L. T. Burgess was seated as the personal representative of Mr. J. E. Whitten, Colorado member of the Administration, upon presentation of a letter from Mr. Whitten, showing that he had been duly appointed in accordance with the rules and regulations of the Administration. A copy of Mr. Whitten's letter is attached hereto as Exhibit 1 and made a part hereof.

The following were in attendance:

Dan S. Jones, Jr., Chairman, Lincoln, Nebraska

R. V. Sariba, Official Member, Topeka, Kansas

L. T. Burgess, Personal Representative of J. E. Whitten, Denver, Colo.

Harris Mackey, Division of Water Resources, Kansas State

M. E. Bell, Board of Agriculture, Topeka, Kansas

E. C. Reed, Department of Water Resources, Lincoln, Nebr.

University of Nebraska, Conservation & Survey Division, Lincoln, Nebr.

H. E. Engstrom, U. S. Department of Agriculture, Lincoln, Nebr.

Chas F. Keech, District Engineer, Groundwater Branch, U. S. Geological Survey, Lincoln, Nebr.

By unanimous agreement the meeting was declared to be the Annual Meeting of the Administration, the same having not been held on March 1, 1960, although called by the Chairman, because of the absence of a quorum on that date.

The minutes of the last meeting of the Administration which was held on November 19, 1959, were approved as written. It was agreed that the minutes of meetings would be circulated to the members and approved at the next meeting unless circumstances warrant some other procedure.

The Chairman reported that he had appointed M. E. Bell as Chairman of the Committee on Procedure for Computation of Annual Virgin Water Supply pursuant to the action taken at the November meeting; and that the committee would present a progress report as the main item of business.

There were no reports of members.

The Chairman then called on Mr. Bell to present a progress report for the Committee on Virgin Water Supply which is composed of Mr. Burgess, Mr. Mackey and

Mr. Ball. Mr. Ball presented a written report for his committee which was accepted and ordered made a part of the minutes by unanimous vote. A copy of the committee report is attached hereto as Exhibit 2. Each of the recommendations made in the report was considered and discussed by the Administration, and a summary thereof follows:

No. 1. With respect to the determination of consumptive use of water under canal systems in the Republican River Basin, the Bureau of Reclamation estimates that 35 per cent of the water diverted returns to the stream. It is probable that the return flow from lands irrigated by small pump diversions from streams will be considerably less than for canals. It will be necessary to conduct studies to arrive at a consumptive use factor for such small projects.

No. 2. The Administration generally approved the recommendation that a pilot area be selected where studies would be made to determine actual return flow factors. The matter of financing such studies was considered and each of the Members indicated that they would be agreeable to financing it in connection with their respective cooperative stream gaging programs. Mr. F. F. LeFever, District Engineer, Lincoln District, U.S.G.S., who was scheduled to discuss this proposal, was unable to be present because of the flooding in eastern Nebraska.

No. 3. & No. 4. Discussion of these items was deferred until later in the date to permit Mr. E. C. Reed to be present and participate.

No. 5. In the discussion relative to the making of surveys of reservoirs to determine changes in areas and capacities due to silting, it was the consensus that the owners of the reservoirs will probably make such surveys and revise area-capacity tables when any significant change is evident.

No. 6. The administration concurred in the recommendation that for the present the depletions caused by soil and water conservation works installed in the basin under programs of the U.S. Department of Agriculture, be not considered for the present in computing the Virgin Water Supply. A letter dated March 28, 1960, from S. K. Jackson, containing a tabulation of the surface areas of stock ponds in Colorado, Kansas and Nebraska, and the estimated evaporation therefrom was noted and ordered made a part of the minutes. A copy of the letter is attached as Exhibit 3.

No. 7. This recommendation was concurred in.

The meeting recessed for lunch at 11:45 A. M., and reconvened at 1:30 P. M.

Items No. 3 and No. 4 were discussed jointly. Mr. Ball noted that a study of the Nebraska irrigation well registrations showed that, based on figures supplied by the well owners, there is an average of 96 acres irrigated per well. Mr. Reed and Mr. Keach felt that the average is more probably about 60 acres.

Mr. Reed and Mr. Keach agreed that an observation well program such as recommended by the committee, is needed and they are agreeable to expanding the current cooperative program to include it as financing will permit. Mr. Reed pointed

out that great care must be used in evaluating observation well data, because fluctuations of two to four feet in the bottom land water table is not uncommon without any groundwater withdrawals, while under similar conditions the upland water table fluctuation may be only two-tenths to three-tenths of a foot. Keach and Reed agreed that it will be many years before any depletions from groundwater use in the uplands will be noticeable in the flow of the Republican River.

Mr. Reed discussed a groundwater map of Nebraska relating to water levels in observation wells in the fall of 1959. A copy of the map, identified as Exhibit 4 is attached hereto. Mr. Reed called attention to articles of Luna B. Leopold, Chief, Water Resources Division, U.S.G.S., published in Survey Bulletin, which place the relationship of groundwater and surface water in proper perspective.

Upon motion by Mr. Sarba, seconded by Mr. Jones, the following motion was unanimously adopted:

That the Administration concurs in the recommendations contained in the Progress Report of Committee on Procedure for Computation of Annual Virgin Water Supply.

A brief discussion followed relative to the developing of formulas for each major stream or tributary from which allocations are made in the compact. It was the belief of the committee that the procedures suggested by Kansas in its "1954" maps and charts be followed until revised procedures can be worked out. It was brought out that one of the problems of the committee is to evaluate certain factors which will vary for different sub-basins.

It was the consensus of the Administration and the Committee that the committee should meet as frequently as the accumulation of data for its use will permit.

Under the heading of New Business the following proceedings were had:

1. Upon motion by Mr. Sarba, seconded by Mr. Burgess, Mr. Dan S. Jones, Jr., was re-elected to serve as chairman until the next annual meeting.

2. It was unanimously agreed that the "report covering a summary of Administration transactions and proceedings for the preceding calendar year," as provided by Paragraph 12 of the Rules and Regulations, would be dispensed with because of the fact that the Administration was not formally set up until late in Calendar year 1959, and it was felt that the summary for that period could well be included with the summary for 1960.

3. The following motion relative to the amendment of Rules was adopted upon motion by Mr. Sarba, seconded by Mr. Burgess:

That the first sentence in Rule No. 9 of the Rules and Regulations constituting

the Republican River Compact Administration, as adopted on July 15, 1959, be amended to read as follows:

"A regular annual meeting of the Administration shall be held upon the call of the Chairman during the months of March or April each year."

4. It was decided that the chairman should send copies of approved minutes of meetings to the principal representatives of the following Federal agencies: Corps of Engineers, Bureau of Reclamation, Geological Survey and Department of Agriculture.

5. Mr. Smith reported that officials of St. Francis, Kansas, had complained to his office that the use of the waters of the South Fork of the Republican River by users in Colorado has been drying up the river and causing the water in the City's wells to drop four to five feet during July and August. He referred to another letter from a landowner along the South Fork complaining that Colorado water users are damming the river in the summer, causing it to go dry in Kansas. Both complainants said they had been let to believe that low flow conditions would be improved with the new water projects.

No action was taken on the matter. However, Mr. Burgess said that he would look into it.

The meeting adjourned at 4:15 P. M.

David Burgess, Chairman

The Committee held its first meeting February 25 and 26, 1960, at Lincoln, Nebraska assisted by representatives of the U. S. Geological Survey, The U. S. Bureau of Reclamation, The U. S. Dept. of Agriculture, The Corps of Engineers and The University of Nebraska. Copies of Minutes of the Meeting were prepared and furnished to members of the "Administration," the Committee, and to persons designated by the Federal Agencies as their representatives to act as consultants to the Committee.

After detailed discussions concerning all the items involved in the Computation of Virgin Water Supply the following recommendations were adopted by the Committee for consideration by the "Administration."

No. 1 That, the "Consumptive Use" for U. S. B. R. Canals be determined by the formula "Recorded Diversions Minus the Return Flow."

No. 2 That, the Surface Water Branch of the U. S. Geological Survey pick a Pilot Area in the Republican River Basin to determine actual return flow factors.

No. 3 That, only the wells in the valley floor of the main Republican River and of its tributaries be considered as depleting the water supply of the Republican River, for present use in the Virgin Flow Formula.

No. 4 That, a minimum ground water Observation Well Program be established for determining the effect of "Table-Land" wells on the flow of the Republican River to indicate the change in the surface of the ground water table, and that stream gaging stations be established on selected north side tributaries of the Republican River between Harlan County Dam and Superior, Nebraska for the purpose of determining the effect of the Tri-County project and the "Table-Land" wells in Gosper, Phelps, Kearney, Franklin, Webster, and Nuckolls counties, on the flow of the north side tributaries and the Republican River.

No. 5 That, the necessity for Reservoir Sediment Surveys and the resultant change in area capacity curves and tables be hinged on the occurrence of floods.

No. 6 That, the depletions due to erosion control practices of the Department of Agriculture not be considered at the present time in computing the Virgin Water Supply for the Republican River Basin.

No. 7 That, no factor be adopted at the present for increase in consumptive use of water in river channels below reservoirs due to changes in the river channel caused by the change in the regimen of river flow below reservoirs.

The discussions pertaining to the recommendations which were presented in the Minutes are not herein repeated since each member of the "Administration" received copies of the Minutes of the Meeting. Recommendations numbered 2 and 4 are the only recommendations pertaining to programs of the federal agencies which would require additional funds. These two recommendations would require studies and field work by the Geological Survey. No requests were made by the Committee to the Geological Survey for any studies or work which involve extra funds for it was considered that such requests should be left to the discretion of the "Administration." Mr. Floyd LeFever said that considerable study and possibly a field reconnaissance would be required to select a return flow study area, and he agreed to make preliminary estimates of costs of the studies and work, and that he would be prepared to discuss the recommendations at the March 30th meeting of the Administration.

Apparently the determination of the effect of pumping by "table-land" wells on the flow of the streams in the Republican River Basin must await considerable more research and data regarding the character of the groundwater aquifer and the behavior of groundwater flow before even approximate information is available as to the monthly or annual effects on stream flow. The groundwater representatives of the Geological Survey and the University of Nebraska reported that the effect of pumping of "table-land" wells is not subject to an exact determination and that it is possible that the table-land wells may not appreciably deplete stream flows. Recommendation number 4 is, therefore, for the purpose of observing the trend of the effect of such wells.

The Committee is not prepared at this time to present detailed Virgin Flow formulas for any of the tributaries of the Republican River. Additional study is required by each member of the Committee to analyze the diversion records and records of well registrations before the Committee can be prepared to agree on the various numerical factors for use in the formulas.

The Committee respectfully requests the concurrence of the "Administration" in the recommendations heretofore listed and recommends further that the Administration request the U. S. Geological Survey to initiate studies required for selecting a pilot area for a return flow study and to select gaging stations on the north side tributaries of the Republican River between Harlan County Dam and Hardy, Nebraska, in accordance with recommendations 2 and 4.

M. S. Ball

James F. Mackay
M. J. Burgard

PROGRESS REPORT OF
COMMITTEE ON PROCEDURE FOR COMPUTATION
OF ANNUAL VIRGIN WATER SUPPLY

TO
THE REPUBLICAN RIVER COMPACT ADMINISTRATION

April 4, 1961

The Committee has concluded the preparation of a report entitled Formulas for the Computation of Annual Virgin Water Supply, Republican River Basin which is presented herewith. The formulas do not contain the numerical factors necessary for making the computations. The report does however contain a paragraph on the general procedures to be followed in making the computation including an evaluation of factors to be used at present in the formulas. The numerical factors recommended by the committee for use in formulas were adopted after considerable research and consultation with the various federal and state agencies. Many of the factors are estimates based on meager information and are thus subject to change as additional information is obtained.

Many questions have arisen during the drafting of the formulas which have been tentatively agreed upon by the Committee in the preparation of the formulas. The decisions affect the formulas, therefore these questions need to be resolved by the administration. The questions are as follows:

1. The drainage area between the gaging station and the confluence of each tributary with the Republican River is included as a part of the main area of the Republican River. The gaging stations on Prairie Dog, Sappa, Medicine and Driftwood Creeks, and the North Fork of the Republican River are located several miles above the mouth of these tributaries. Therefore, the flow as measured at the gaging station does not reflect all of the depletions or stream flow at the mouth of the tributary. It would be preferable if the gaging stations were located just above the

(1) Continued

- mouth of the tributary for ease in making the computations pertaining to virgin water supply and conservative use. It may not, however, be possible to move the gaging stations further downstream. The quantity of land and water which is involved is small, but its inclusion with the tributary could affect the virgin flow computations.
 - It is recognized that the flow of Frenchman Creek crossing the Colorado-Nebraska stateline should be eliminated from the computation of virgin water supply. Normally there is no surface flow in Frenchman Creek at the stateline. The groundwater flow crossing the stateline has not been determined up to the present time and has not been considered in the present formulas. The diversions from groundwater in the Frenchman Creek basin in Colorado are considered to be tableland diversions.
 - The Pioneer Irrigation Company diverts via the Haigler Canal above the Colorado-Nebraska stateline, and lands are irrigated in both Colorado and Nebraska. Mr. Burgess stated that lands in Colorado under the Haigler Canal are presently irrigated entirely by wells. The canal is not provided with an automatic recorder, therefore, a record of diversions has not been obtained. The Committee recommends that an automatic recorder be installed near the point of diversion to obtain a record of that diversion. An additional gaging station on the canal at the stateline would also be desirable.
 - The Committee agreed that the evaporation for reservoirs should include the winter evaporation. The net evaporation would be the gross evaporation in acre-feet computed by the Corps of Engineers as shown on the monthly reservoir operation reports minus the total monthly precipitation on the reservoir surface in acre-feet.
 - A formula was not prepared for the Blackwood Creek Basin since there are no specific allocations made from that source. The Blackwood Creek drainage was considered to be a part of the main stem of the Republican River.
 - The Committee agreed that for the present the reservoir bank-storage is not pertinent to the determination of virgin water supply on an annual basis. All of the reservoirs reached a stable condition within a one or two year period after storage commenced. If the virgin water supply is to be computed for the years when storage was first initiated, the bank-storage would have to be taken into account in those years.
7. One problem encountered in connection with the preparation of the formulas was whether the computations should be made on a water year, calendar year, or some other year basis. Availability of data that would be needed in an annual report in March or April of each year indicated that the water year ending on September 30 should be used. It appears that with present data collection and publication procedure, that the calendar year might leave too little time prior to the annual meeting to compile the necessary data to be used in the formulas. The matter of return flows is also an important element in this consideration. According to the Bureau of Reclamation, 80 percent of the return flows reach the stream the same calendar year as the diversions, 58 percent during the water year and 71 percent during a November to October year. The new H. & R. W. District lands will be some distance from the river and return flows will be delayed more than for other districts near the river. The delay of return flows would also be an important consideration if depletions by tableland wells were to be taken into consideration in the future.
- Any accurate determination of the virgin water supply in the Republican River Basin is dependent upon a considerable improvement in obtaining data for diversions by stream pumps and by pumping of groundwater from wells. Colorado has made good progress toward the installation of Parshall flumes with stage recorders on small diversions with 75 percent coverage on the Arikaree River in 1959 and an expected 100 percent in 1961. It is also expected that the same type of installation would begin along the South Fork of the Republican River in the next two or three years. A diversion rate of 1.6 acre-feet per acre has been recommended for the small diversions and for the wells based on diversion rates reported in 1959 in Kansas. There is some feeling that this rate may be too high where a large number of wells are involved. Additional data needs to be obtained. The Committee in its report to the administration on March 30, 1960, made specific recommendations for obtaining additional return flow data in the Republican River Basin. Apparently nothing

further has been done since that recommendation has been made. The Committee urges that return flow investigations be initiated at an early date.

The Committee is not officially presenting computations of virgin water supply as a part of this progress report due to the necessity for the resolution of some questions by the administration. A tentative tabulation has been prepared, however, for the 1959 water year based on assumptions adopted by the Committee. This tabulation is for illustrative purposes only.

M. E. Ball

Harold L. Mackay

REPORT
to the
REPUBLICAN RIVER COMPACT ADMINISTRATION

FORMULAS FOR THE COMPUTATION
OF
ANNUAL VIRGIN WATER SUPPLY
REPUBLICAN RIVER BASIN

Committee on Procedure for Computation of
Annual Virgin Water Supply

April 4, 1961

Computation of Virgin Water Supply
 Republican River Compact Administration

INTRODUCTION

Article III of the Republican River Compact designates the drainage basins, or parts thereof, from which specific allocations are made to the States of Colorado, Kansas and Nebraska.

The annual virgin water supply for each of those designated drainage basins shall be computed by the formulas given herein.

GAGING STATIONS

The stream-gaging stations necessary to the virgin water supply formulas are described in U. S. Geological Survey Water-Supply Papers, Part 6-B, and are listed below:

Station Number	Station Name
68-8215.00	Arikaree River at Raigler, Nebr.
68-8230.00	North Fork Republican River at Colorado-Nebraska State line
68-8235.00	Buffalo Creek near Raigler, Nebr.
68-8240.00	Rock Creek at Parke, Nebr.
68-8275.00	South Fork Republican River near Benkelman, Nebr.
68-8355.00	Frenchman Creek at Culbertson, Nebr.
68-8365.00	Driftwood Creek near McCook, Nebr.
68-8380.00	Red Willow Creek near Red Willow, Nebr.
68-8425.00	Medicine Creek below Harry Strunk Lake, Nebr.
68-8470.00	Beaver Creek near Beaver City, Nebr.
68-8475.00	Sappa Creek near Stamford, Nebr.
68-8485.00	Prairie Dog Creek near Woodruff, Kans.
68-8525.00	Courtland Canal at Nebraska-Kansas State line
68-8535.00	Republican River near Hardy, Nebr.

DRAINAGE BASINS

The drainage basins designated in Article III, Republican River Compact, are defined for use in the formulas as those drainage areas above the gaging stations at or near the mouths of the streams, with the following exceptions:

Prairie Dog Creek drainage basin is that drainage area above the gaging station near Woodruff;

Sappa Creek drainage basin is that drainage area above the gaging station, Sappa Creek near Stamford, and below the gaging station, Beaver Creek near Beaver City;

Beaver Creek drainage basin is that drainage area above the gaging station near Beaver City;

Medicine Creek drainage basin is that drainage area above the gaging station below Harry Strunk Lake;

The main stem of the Republican River is that area between the junction of the North Fork and the Arikaree River and the gaging station near Hardy and includes (1) those areas below the gaging stations of the designated drainage basins and (2) all of Blackwood Creek drainage basin.

BASIC DATA

Basic data for use in the formulas shall be obtained from the following sources:

1. Stream discharges from surface water records as compiled by the U. S. Geological Survey;
2. Total reservoir evaporation records as computed by the U. S. Corps of Engineers;
3. Precipitation records as compiled by the U. S. Weather Bureau;
4. Reservoir elevations, surface areas and storage contents from records as compiled by the operating agency;
5. Irrigation diversions or irrigated acreages from records as compiled by each State.

GENERAL PROCEDURES

Reservoir evaporation shall be the total evaporation corrected for the precipitation upon the reservoir surface area.

Average monthly reservoir surface areas shall be computed by applying the average of the mean daily reservoir elevations to the most recent area-capacity tables.

Depletions of stream flows due to erosion control practices and stock-water ponds have not been included in the present virgin water supply formulas. Representatives of the U. S. Department of Agriculture have indicated there has been no success in isolating the effect of such practices on stream flow.

Irrigation diversions from ground water shall be limited to those by wells pumping from the alluvium along the stream channels. The determination of the effect of pumping by "table-land" wells on the flows of the streams in the Republican River Basin must await considerably more research and data regarding the character of the ground-water aquifers and the behavior of ground-water flow before even approximate information is available as to the monthly or annual effects on stream flows. The ground-water representatives of the Geological Survey and the University of Nebraska reported that the effect of pumping by "table-land" wells is not subject to an exact determination and that it is possible those wells may not appreciably deplete stream flows. The wells in the Frenchman Creek drainage basin in Colorado have been considered as "table-land" wells.

Irrigation diversions by canals, stream pumps and wells for which recorded diversions are not available shall be computed by applying an average annual diversion rate to the irrigated acreages.

Return flows from the lands irrigated by major project developments flowing into two or more designated drainage basins shall be divided in the ratio of the irrigated lands from which the water returns to each drainage basin.

Return flows are considered to be reflected in stream discharge records during the same year the irrigation diversions are made.

EVALUATION OF FACTORS

Present computations of virgin water supply by the formulas have been based upon the following factors:

1. The irrigation diversions by canals, stream pumps and wells for which recorded diversions are not available shall be computed by applying a diversion rate of 1.6 acre-feet per acre per year to the irrigated acreages. Selection of this rate of diversion was based upon the average of rates reported in 1959 by water users in the Republican River Basin in Kansas. This diversion rate may vary from year to year as weather conditions change, operating procedures are modified, and additional information is made available.
2. Return flows from the lands irrigated by small canals, stream pumps and wells shall be computed as 25 per cent of the annual diversions. Irrigation diversions for these lands apparently average less than 2 acre-feet per acre and it was thought the return flow would be less than for the major projects and was selected as approximately 25 per cent.
3. Return flows from the lands irrigated by major project development shall be computed as per cent of annual diversions based on information furnished the Committee by the U. S. Bureau of Reclamation. The percentages of annual diversions to be used at the present time are given in the following table, and shall be adjusted each year on basis of additional information to be furnished by the U. S. Bureau of Reclamation.

Frenchman Creek Drainage Basin in Nebraska

Annual Virgin Water Supply equals

the recorded discharge at Culbertson;
plus, the evaporation from Enders Reservoir;
plus, or minus, the change in storage in Enders Reservoir;
plus, the diversions by the Culbertson Canal;
plus, the other irrigation diversions of surface water in Nebraska;
plus, the irrigation diversions from ground water in Nebraska;
minus, the return flows from the lands within the Frenchman Creek drainage basin served by the Culbertson Canal;
minus, the return flows from the lands irrigated by the other diversions from surface water in Nebraska;
minus, the return flows from the lands irrigated by ground water diversions in Nebraska.

South Fork of the Republican River Drainage Basin

Annual Virgin Water Supply equals

the recorded discharge near Benkelman;
plus, the evaporation from Bonny Reservoir;
plus, or minus, the change in storage in Bonny Reservoir;
plus, the diversions by the Hale Ditch;
plus, the other irrigation diversions of surface water in Colorado, Kansas and Nebraska;
minus, the irrigation diversions from ground water in Colorado, Kansas and Nebraska;
minus, the return flows from the lands irrigated by the Hale Ditch;
minus, the return flows from the lands irrigated by the other diversions from surface water;
minus, the return flows from the lands irrigated by diversions from ground water.

Rock Creek Drainage Basin

Annual Virgin Water Supply equals

the recorded discharge at Parks;
plus, the irrigation diversions of surface water;
plus, the irrigation diversions from ground water;
minus, the return flows from the lands irrigated by the diversions from surface water;
minus, the return flows from the lands irrigated by diversions from ground water.

Buffalo Creek Drainage Basin

Annual Virgin Water Supply equals

the recorded discharge near Haigler;
plus, the irrigation diversions of surface water;
plus, the irrigation diversions from ground water;
minus, the return flows from the lands irrigated by the diversions from surface water;
minus, the return flows from the lands irrigated by diversions from ground water.

Arikaree River Drainage Basin

Annual Virgin Water Supply equals

the recorded discharge at Haigler;

plus, the irrigation diversions of surface water in Colorado, Kansas and Nebraska;

plus, the diversions from ground water in Colorado, Kansas and Nebraska;

minus, the return flows from the lands irrigated by the diversions from surface water;

minus, the return flows from the lands irrigated by the diversions from ground water.

North Fork of the Republican River Drainage Basin in Colorado

Annual Virgin Water Supply equals

the recorded discharge at the Colorado-Nebraska state line;

plus, the diversions by the Haigler Canal;

plus, the other irrigation diversions of surface water in Colorado;

plus, the irrigation diversions from ground water in Colorado;

minus, the return flows from the lands within the North Fork of the Republican River drainage basin in Colorado that are irrigated by the Haigler Canal;

minus, the return flows from the lands irrigated by the other diversions from surface water in Colorado;

minus, the return flows from the lands irrigated by diversions from ground water in Colorado.

The North Fork of the Republican River in Nebraska and the main stem of the Republican River between the junction of the North Fork and the Arikaree River and the lowest crossing of the river at the Nebraska-Kansas state line and the small tributaries thereof.

Annual Virgin Water Supply equals

the recorded discharge of the Republican River near Hardy;

plus, the diversions by the Courtland Canal;

minus, the return flows from the lands in Kansas above Hardy irrigated by the Courtland Canal;

minus, the return flows from the lands in Nebraska irrigated by the Courtland Canal;

plus, the diversions by the Superior Canal;

minus, the return flows from the lands irrigated by the Superior Canal;

plus, the diversions by the Franklin Pump Canal;

minus, the return flows from the lands irrigated by the Franklin Pump Canal;

plus, the diversions by the Franklin Canal;

minus, the return flows from the lands irrigated by the Franklin Canal;

plus, the diversions by the Neponsee Canal;

minus, the return flows from the lands irrigated by the Neponsee Canal;

plus, the evaporation from Harlan County Reservoir;

plus, or minus, the change in storage in Harlan County Reservoir;

minus, the recorded discharge of Prairie Dog Creek near Woodruff;

plus, the irrigation diversions of surface water from Prairie Dog Creek in Nebraska;

minus, the return flows from the lands irrigated from surface water of Prairie Dog Creek in Nebraska;

plus, the irrigation diversions from ground water along Prairie Dog Creek in Nebraska;

minus, the return flows from the lands irrigated from ground water along Prairie Dog Creek in Nebraska;

The North Fork of the Republican River in Nebraska
and the main stem of the Republican River
(concluded)

minus, the return flows to the Republican River from the lands irrigated by the Meeker-Driftwood Canal;

minus, the return flows to the Republican River from the lands irrigated by the Culbertson Canal;

minus, the recorded discharge of Franchman Creek at Culbertson; plus, the evaporation from Swanson Lake;

plus, or minus, the change in storage in Swanson Lake;

minus, the recorded discharge of the South Fork of the Republican River near Benkelman;

minus, the recorded discharge of Rock Creek at Parke;

minus, the recorded discharge of Buffalo Creek near Haigler;

minus, the recorded discharge of the Arikaree River at Haigler;

minus, the return flows to the North Fork of the Republican River in Nebraska from the lands irrigated by the Haigler Canal;

minus, the recorded discharge of the North Fork of the Republican River at the Colorado-Nebraska state line;

plus, the other irrigation diversions of surface water in Nebraska and Kansas above the gaging station near Hardy;

minus, the return flows from the lands irrigated by the other diversions from surface water in Nebraska and Kansas above the gaging station near Hardy;

plus, the irrigation diversions from ground water in Nebraska and Kansas above the gaging station near Hardy;

minus, the return flows from the lands irrigated by diversions from ground water in Nebraska and Kansas above the gaging station near Hardy.

The North Fork of the Republican River in Nebraska
and the main stem of the Republican River
(continued)

minus, the recorded discharge of Sappa Creek near Stamford;

plus, the irrigation diversions of surface water from Sappa Creek downstream from the gaging station near Stamford;

minus, the return flows from the lands irrigated from surface water downstream from the gaging station near Stamford;

plus, the irrigation diversions from ground water along Sappa Creek downstream from the gaging station near Stamford;

minus, the return flows from the lands irrigated from ground water along Sappa Creek downstream from the gaging station near Stamford;

plus, the diversions by the Cambridge Canal;

minus, the return flows from the lands irrigated by the Cambridge Canal;

minus, the recorded discharge of Medicine Creek below Harry Strunk Lake;

plus, the irrigation diversions of surface water from Medicine Creek downstream from Harry Strunk Lake;

minus, the return flows from the lands irrigated from surface water downstream from Harry Strunk Lake;

plus, the irrigation diversions from ground water along Medicine Creek downstream from Harry Strunk Lake;

minus, the return flows from the lands irrigated from ground water along Medicine Creek downstream from Harry Strunk Lake;

plus, the diversions by the Bartley Canal;

minus, the return flows from the lands irrigated by the Bartley Canal;

minus, the return flows to the Republican River from the lands irrigated by the Red Willow Canal;

minus, the recorded discharge of Red Willow Creek near Red Willow;

minus, the recorded discharge of Driftwood Creek near McCook;

plus, the diversions by the Meeker-Driftwood Canal;