C-07

No. 126, Original

In The

Supreme Court of the United States

STATE OF KANSAS,

Plaintiff,

v.

STATE OF NEBRASKA

and

STATE OF COLORADO,

Defendants.

DECLARATION OF JAMES C. SCHNEIDER

JON C. BRUNING
Attorney General of Nebraska
DAVID D. COOKSON
Chief Deputy Attorney General

JUSTIN D. LAVENE
Counsel of Record
Assistant Attorney General
Post Office Box 98920
Lincoln, Nebraska 68509-8920
(402) 471-2682

DONALD G. BLANKENAU
THOMAS R. WILMOTH
Special Assistant Attorneys General
BLANKENAU WILMOTH LLP
206 South 13th Street, Suite 1425
Lincoln, Nebraska 68508-2002
(402) 475-7080

Attorneys for State of Nebraska

May 21, 2012

DECLARATION OF DR. JAMES C. SCHNEIDER

I, DR. JAMES C. SCHNEIDER, am over 18 years of age, having personal knowledge of the matters contained herein, state as follows:

1. Section IV.F. of the Final Settlement Stipulation ("FSS") states:

> Beneficial Consumptive Use of Imported Water Supply shall not count as Computed Beneficial Consumptive Use or Virgin Water Supply. Credit shall be given for any remaining Imported Water Supply that is reflected in increased streamflow, except as provided in Subsection V.B. Determinations of Beneficial Consumptive Use from Imported Water Supply (whether determined expressly or by implication), and any Imported Water Supply Credit shall be calculated in accordance with the RRCA Accounting Procedures and by using the RRCA Groundwater Model.

2. I believe this requires that the RRCA Accounting Procedures reflect that the presence of the Imported Water Supply must provide a credit to Nebraska if such water increases the water supply in the Republican River, and it shall not become a debit that would saddle Nebraska with an additional Compact requirement. I cannot reconcile any other interpretation with my understanding of the RRCA Groundwater Model and the Accounting Procedures.

3. The expert report I prepared for this action dated November 18, 2011 explains the bases for Nebraska's view that the current Republican River Compact Administration ("RRCA") Accounting Procedures (Appendix C to the Final Settlement Stipulation) misrepresent the net effect of Nebraska's groundwater pumping and the Imported Water Supply (or "Mound") in the Swanson—Harlan reach of the Republican River Basin. My report is attached as Exhibit A. In short, the current RRCA Accounting Procedures provide Nebraska with an Imported Water Supply debit.

4. On March 15, 2012, Dr. Willem Schreuder, an expert on behalf of the State of Colorado, submitted an expert report acknowledging that the current RRCA accounting procedures include consumption of imported water. Dr. Schreuder's Report is attached as Exhibit B.

5. Nebraska agrees with Colorado that any accounting method must be consistent with Section IV.F of the FSS.

6. Dr. Schreuder's expert report contains an accounting procedure that is consistent with Section IV.F. See Exhibit B at CO000000405 (equations 3a – 3d). That procedure employs five specific runs of the RRCA Groundwater Model.

7. The accounting procedure identified by Dr. Schreuder is identical to a proposal Nebraska earlier presented to the RRCA when Nebraska first discovered the inconsistency between current Accounting Procedures and Section IV.F. of the FSS. See attached Exhibit C.

8. As Kansas' witness Mr. Steven P. Larson testified during his deposition, the original Nebraska proposal (which included the same five runs suggested by Dr. Schreuder) was presented to the RRCA's Engineering Committee prior to the RRCA annual meeting in 2007. *See* Exhibit D (excerpts of Larson Deposition Transcript at 20-6 and complete copies of Exhibits 3, 4 and 5 thereto).

9. This "five run" proposal was rejected by Kansas. Specifically, Kansas asserted the Accounting Procedures should produce individual results for Mound recharge and groundwater pumping in Colorado, Kansas, and Nebraska that summed to the net impact of these four activities rather than Nebraska's limited concern about Nebraska's activities (Mound recharge and groundwater pumping). *See* Exhibit E (Exhibit 5 to Larson Deposition identifying the "Virgin Water Supply Metric.").

10. Nebraska responded to the Kansas Virgin Water Supply Metric by extending Nebraska's original analysis and developing a more elaborate proposal involving sixteen runs of the Model. The original five runs were a subset of the newly proposed sixteen runs. This sixteen run alternative solution which satisfies the "Virgin Water Supply Metric" was first presented to the RRCA in August 2008 and to Arbitrator Dreher in a slightly refined form in January 2009. That extended, sixteen run, solution is the primary subject of my expert report in this litigation.

11. The sixteen run proposal contained in my expert report is merely an extension of the original five run concept Nebraska presented in 2007 and is the same as that presented by Dr. Schreuder in his expert report. This extension was designed to ensure that Kansas' Virgin Water

Supply Metric is fully satisfied in every sub-basin and in every year. In other words, Nebraska's original proposal is a subset of the far more elaborate solution presented in my expert report. This more elaborate solution is entirely the product of Nebraska's additional work to meet the so-called Virgin Water Supply Metric.

12. Nebraska and Colorado have reduced the original five run proposal to a narrative "redline" edit of the existing RRCA Accounting procedures, which is attached to Colorado and Nebraska's Notice of Stipulation filed with this Court on May 16, 2012. Setting aside minor changes in verbiage, it is in all respects identical with (a) Nebraska's original five run proposal; and (b) Dr. Schreuder's five run proposal.

13. To make perfectly clear that the agreement reached by Colorado and Nebraska is merely a subset of Nebraska's sixteen proposal, I have highlighted those portions of Nebraska's Amended Counterclaim (originally filed July 25, 2011) that represent the subset of five runs identified in Exhibit A to Colorado and Nebraska's Notice of Stipulation. *See* Exhibit F.

14. As explained in my report and acknowledged by Dr. Schreuder, the expanded sixteen run approach produces essentially the same quantitative result as Nebraska's original five run proposal where the Mound recharge and groundwater pumping in Nebraska are the two activities of interest (i.e., in the Swanson-Harlan reach). *Compare* Schneider at Appendix D (NE0500094-5) with Schreuder at 24 (third full paragraph, last sentence).

15. As further explained by Dr. Schreuder, and long conceded by Nebraska, the failure of the current RRCA Accounting Procedures to properly represent the net effect of these two activities is the primary cause of overestimating the CBCU for Nebraska. Compare Schneider at Fig. 12 (NE050048) and Fig. 14 (NE0500050) with Schreuder at 4, bullet 7, last sentence, and the following paragraph; 12, second to last full paragraph. While Nebraska's proposed procedures described in my expert report fully address the Virgin Water Supply Metric, the original 2007 proposal addresses most of the harm to Nebraska by eliminating the consumption of imported water in this reach.

16. Nebraska's original proposal, as brought to the RRCA in 2007 and articulated in Dr. Schreuder's report is acceptable to Nebraska because it alleviates the majority of harm accruing to Nebraska by virtue of the present Accounting Procedures.

I declare under penalty of perjury that the foregoing is true and correct.

5-21-12
Date

James C. Schneider

EXHIBIT A

Nebraska Expert Report in Support of Counterclaim and Crossclaim

Nebraska's Proposed Changes to the RRCA Accounting Procedures

James C. Schneider, Ph.D

November 18, 2011

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APPENDICES

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FIGURES

QUALIFICATIONS AND COMPENSATION

I have prepared this expert report on behalf of the State of Nebraska. A true and accurate copy of my curriculum vitae is attached hereto as Appendix A. The opinions contained in this report are made to a reasonable degree of scientific certainty. In preparing this report, I utilized theories and methodologies that are accepted within the scientific community and which have been subject to peer reviewed analysis and publication.

I have prepared this report as a part of my regular duties as an employee of the State of Nebraska and have received no compensation outside of my normal salary and benefits.

James C. Schneider, Ph.D.

EXECUTIVE SUMMARY

The Republican River Compact Administration (RRCA) administers the Republican River Compact (Compact) through the RRCA Accounting Procedures and Reporting Requirements (Current Accounting Procedures). This involves the use of the RRCA Groundwater Model (Model) to estimate the impact of groundwater pumping by Colorado, Kansas, and Nebraska and to estimate the impact of water imported, by Nebraska, from outside the Republican River Basin (Basin). The Republican River Compact specifies how much water each state is allowed to use, and the Model and the Current Accounting Procedures are used to determine whether a State is in compliance with the Compact. When the Current Accounting Procedures do not represent impacts to the water supply correctly, this determination will fail to properly distribute water supplies as required by the Compact. In other words, an accounting failure results in an unintended redistribution of water supply between the states.

Nebraska's implementation of the Final Settlement Stipulations of 2002 (FSS) resulted in the identification of a significant failure with the Current Accounting Procedures. This failure does not allow for the proper quantification of impacts from groundwater pumping and imported water. These conditions become amplified during years when water supplies are low and Compact compliance is most challenging. If left uncorrected, this problem (i.e., the failure of the Current Accounting Procedures) could deprive Nebraska of up to 800,000 acre feet of water over the next 50 years (roughly twice the annual virgin water supply of the Republican River). It is important to note the problem is not inherent in the Model, but arises from the way in which the Model results are used, through application of the Current Accounting Procedures, to determine the impact of each state's groundwater pumping or importation of water on streamflows.

This report 1) identifies the nature of the problem presented, 2) shows how the failure of the Current Accounting Procedures results in redistribution of water supply, 3) explains Nebraska's proposed solution (Nebraska's Proposed Procedures), and 4) concludes with a discussion of the anticipated impact of the problem on Compact accounting in the future unless the problem is corrected.

The Problem

As discussed in Section 3.3.3, the Model and Current Accounting Procedures are used to estimate impacts of four Target Sets, discussed further below, by calculating the change in baseflow caused by 1) groundwater pumping in Nebraska; 2) groundwater pumping in Colorado; 3) groundwater pumping in Kansas; and 4) Nebraska's mound recharge (the mechanism for importation of water from the Platte River, Figure ES-1. The total impact of groundwater pumping and mound recharge (Total Impact) should be determined by completing a Model run with groundwater pumping and mound recharge present (or "On") and a Model run with these activities not present (or "Off"). The difference between these two Model runs (first conceptualized by Kansas and termed the Virgin Water Supply Metric) is the only direct estimate of the Total Impact. This is a widely accepted scientific practice (e.g., Zume and Tarhule, 2008; Feinstein et al., 2010; Leake and Pool, 2010; Bent et al., 2011; Ely et al., 2011). The Total Impacts are not computed in this manner under the Current Accounting Procedures. The individual impact estimates of the four Target Sets can only be verified by comparing their sum to these Total Impacts.

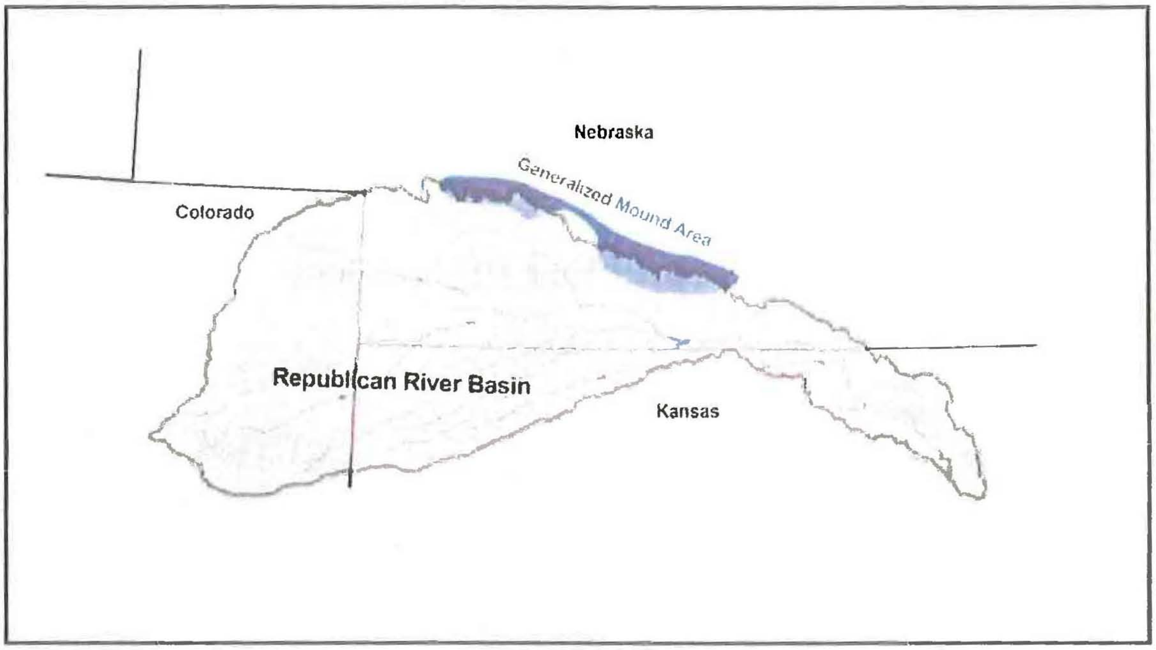

Figure ES-1. The groundwater mound recharge as contribution to the Republican River basin water supply.

The sum of the individual impacts (e.g. Colorado groundwater pumping, Kansas groundwater pumping, etc), as calculated under the Current Accounting Procedures, does not add to the Total Impact and thus fails to meet the Virgin Water Supply Metric. In other words, the sum of the parts does not equal the whole. For the purposes of determining Compact compliance, these "Unaccounted Impacts" are lost in the calculus. It is as if to say that the Current Accounting Procedures would calculate two plus two equals three. This is an unreasonable result that should not exist in any accounting exercise.

The difficulties generated by this problem manifest themselves in multiple ways, but a glaring example is presented in Section 4.4.2. In a hydrologic system, higher groundwater levels increase discharge to streams. This is the practical effect of the mound recharge in the Republican River Basin. Therefore, mound recharge can have only a positive impact to stream baseflow; no negative impact is associated with it. The mound recharge is supplied in Nebraska by water imported from the Platte River. Thus, any positive impact to stream baseflow in the Republican River Basin should accrue as a benefit to Nebraska in the accounting. The Kansas projected future scenario (Kansas Petition, C20) is analyzed as an example for this report, using the Current Accounting Procedures, to determine the positive impact to stream baseflow that should result from the mound recharge over the long term. The Current Accounting Procedures produce the results shown in figure ES-2. These results indicate that continuation of mound recharge will ***reduce*** stream baseflows over the long term. This result makes no sense and demonstrates the absurdity inherent in the Current Accounting Procedures. It is rather difficult from a scientific perspective to reconcile the paradoxical notion that adding imported water to the system, which should be a "credit" to the importer state, results in just the opposite, a "debit".

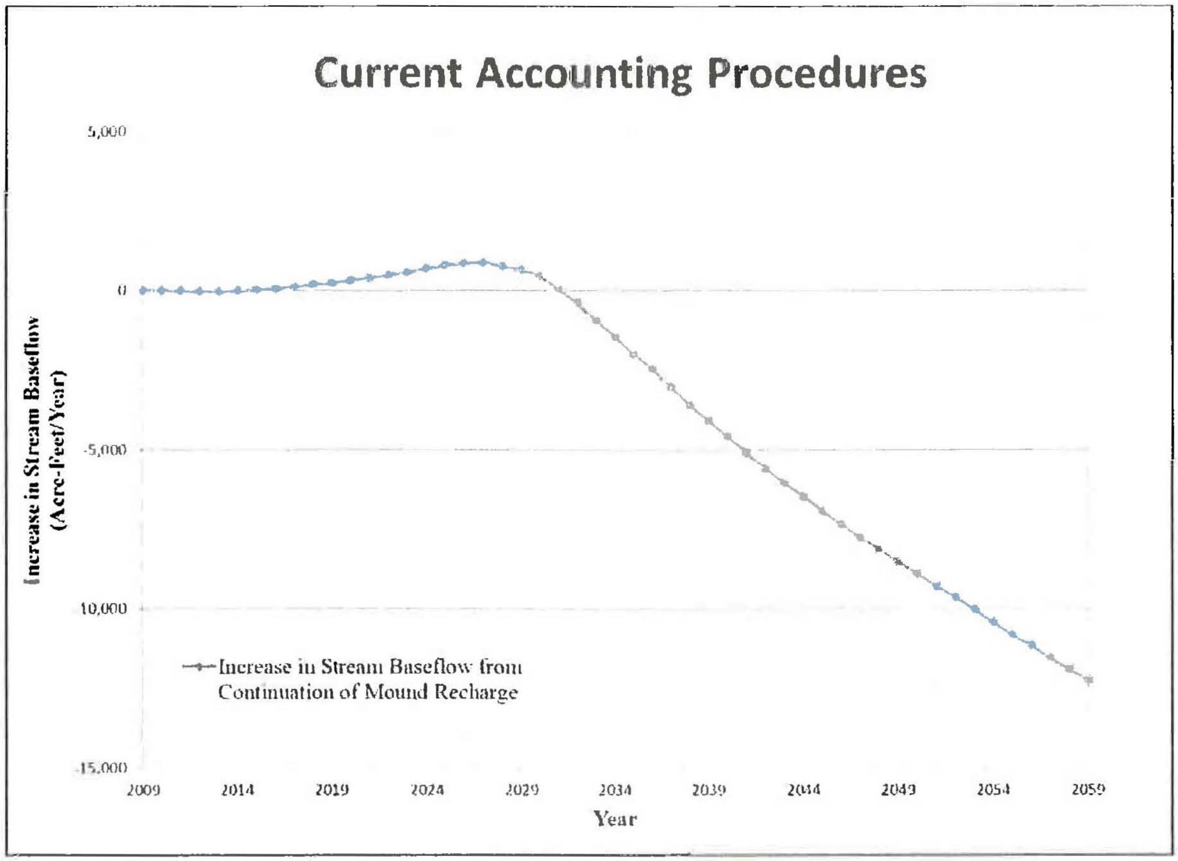

Figure ES-2. The increase in stream baseflow that results from the continuation of mound recharge as determined by the Current Accounting Procedures. These results indicate that continuation of mound recharge will ***reduce*** stream baseflows over the long term.

Section 4 presents an analogy to the Model using a scale and two people whose combined weight exceeds the capacity of the scale. Under the Current Accounting Procedures there are Unaccounted Impacts, and this analogy serves as a simple demonstration of how these Unaccounted Impacts occur. The Current Accounting Procedures do not address these Unaccounted Impacts. These Unaccounted Impacts are eliminated using the existing Model and Nebraska's Proposed Procedures.

Nebraska raised this problem with the RRCA in 2007, but it was not resolved at that time. Nebraska, therefore, presented the problem and Nebraska's Proposed Procedures to an arbitrator in 2009 pursuant to the dispute resolution procedures outlined in the FSS. In acknowledging the problem presented by the Current Accounting Procedures, the arbitrator concluded that Nebraska's approach to estimate the Total Impacts of pumping and mound recharge was more consistent with the Compact and admonished the States to work toward a thorough solution. Kansas and Colorado, however, currently benefit from this failure of the Current Accounting Procedures.

The Solution

To rectify this failure of the Current Accounting Procedures (the problem), Nebraska proposes a solution that complies with the following criteria:

1) The sum of the individually derived impacts equals the Total Impacts.

2) The results obtained from Nebraska's Proposed Procedures are identical to those obtained with the Current Accounting Procedures in the cases in which the latter already satisfy the principle in number (1) above.

3) The Unaccounted Impacts are not distributed among the states arbitrarily, but rather they are applied in a manner related to each state's ability to cause Unaccounted Impacts.

As shown in figure ES-3, Nebraska's Proposed Procedures solve the problem previously illustrated in figure ES-2. The results from the Current Accounting Procedures indicate that continuation of mound recharge will reduce stream baseflows. The results from Nebraska's Proposed Procedures indicate that continuation of mound recharge will increase stream baseflows. Recharging water into the ground cannot by itself ***reduce*** stream baseflow, but it can ***increase*** stream baseflow. Therefore, ***Nebraska's Proposed Procedures produce realistic results, whereas the Current Accounting Procedures do not.***

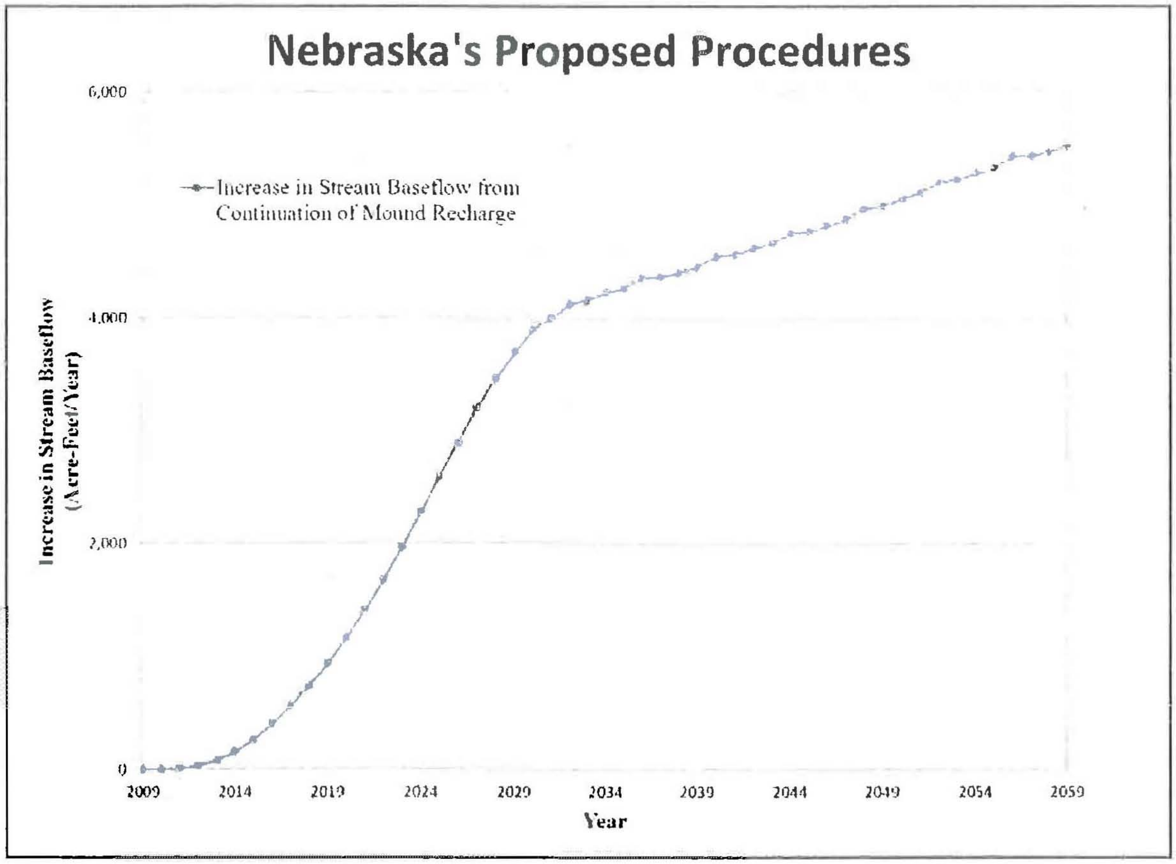

Figure ES-3. The increase in stream baseflow that results from the continuation of mound recharge as determined by Nebraska's Proposed Procedures. These results indicate that continuation of mound recharge will ***increase*** stream baseflows over the long term.

Effect of Problem if Left Unresolved

The Basin wide effect of the failure of the Current Accounting Procedures on Nebraska's annual Compact accounting balances was approximately 10,000 acre-feet per year in 2005 and 2006 (the years subject to the Kansas Complaint). These are example years in which Nebraska's water supply was relatively small. The effect on Nebraska's annual Compact accounting balances may exceed 20,000 acre-feet per year in the future (or approximately 10% of an average Nebraska allocation). The effect, moreover, is cumulative, and unless corrected, will continue to grow into the future depriving Nebraska of a substantial portion of its Compact entitlement (a cumulative total of as much as 800,000 acre-feet over 50 years).

If the problem remains uncorrected, Nebraska will be required to consume less water than it is entitled to under the Compact. This is tantamount to a redistribution of the states' Allocations specified in the Compact.

1.0 INTRODUCTION

In 1943 the United States and the States of Kansas, Nebraska, and Colorado entered into the Republican River Compact (Compact). A primary purpose of the Compact was "to provide for the equitable division" (Compact, 1943) of the streamflow of the Republican River Basin (Basin). Streamflow originates in all three states under the physical processes described in Section 2. The streamflow has been altered by activities of man over time; some of these activities reduce streamflow, some of these activities increase streamflow. In order to provide for the equitable division of water as envisioned in the Compact, a proper quantification of the impacts of man's activities on streamflow is required.

The Republican River Compact Administration (RRCA), a committee with a representative from each of the three states, administers the Compact. The RRCA Accounting Procedures and Reporting Requirements contain procedures for the quantification of streamflows and the impacts to streamflows attributable to man's activities in each state. These are included as Appendix C to the Final Settlement Stipulations (FSS) of 2002; these will be called the Current Accounting Procedures in this report. The Current Accounting Procedures have been changed multiple times since 2003, most recently in 2010.

One of the activities of man that has had a large impact on streamflow in the Basin is the irrigation of crops with water pumped from the ground. Groundwater pumping intercepts water that might otherwise have discharged to the stream; the impact of this practice cannot be directly measured. Another activity of man that has significantly impacted streamflow in the Basin is the importation of water from the Platte River. This process provides additional water in the ground, increasing the amount of groundwater that can eventually discharge to the stream. This impact also cannot be directly measured. Therefore, the RRCA Groundwater Model (Model) was developed to quantify the impact of these activities. The Model and the Current Accounting Procedures are discussed in greater detail in Section 3.

A conventional way to estimate the impact of a set of activities on a system is to look at the behavior of the system with and without those activities occurring. The difference observed in the system is assumed to be a reasonable estimate of the impacts of those activities. The Model can be utilized to test the impact of groundwater pumping and mound recharge on streamflow in the Basin by running the Model first with both of these activities and running the Model again without these activities. This is a generally accepted scientific practice (e.g., Zume and Tarhule, 2008; Feinstein et al., 2010; Leake and Pool, 2010; Bent et al., 2011; Ely et al., 2011). The difference in streamflow values produced by the Model will be termed the Total Impact in this report.

For the Current Accounting Procedures to be valid, the sum of the impacts attributable to the states, as calculated using these procedures, must equal the Total Impacts. Application of the Current Accounting Procedures fails to accomplish this; rather these procedures produce unreasonable results and provide Kansas and Colorado with an unwarranted benefit. This failure is demonstrated in Section 4. This section also contains a discussion of an analogy intended to illustrate the physical and mathematical reasons for the failure of the Current Accounting Procedures.

In the cases in which the Current Accounting Procedures fail to account for the Total Impacts, a refined approach that overcomes these failures is needed. The best approach to this, termed Nebraska's Proposed Procedures, is presented in Section 5. Application of Nebraska's Proposed Procedures produces realistic results that fully account for the Total Impacts. Section 6 demonstrates the magnitude of the failure of the Current Accounting Procedures to accomplish the equitable division of waters.

2.0 PHYSICAL SYSTEM

This section begins with a brief overview of important general hydrologic principles (Chin, 2006; Dingman, 2002; Fetter, 2001; Schwartz and Zhang, 2003). These generally accepted scientific principles are then related to the specific physical conditions of the Republican River Basin. Throughout this report, volumes of water are discussed in units of acre-feet and rates are discussed in units of acre-feet per year. An acre-foot of water is the volume of water that would cover an area of one acre to a depth of one foot. It is equal to 325,851 gallons. By way of comparison, the public water supply required for an average American city of 100,000 people would be approximately 20,000 acre-feet per year[1] (Hutson et al., 2004).

Important physical features of the Republican River Basin are the land surface and stream network that constitute the surface water drainage basin and the underlying geologic materials that constitute the hydrologically connected aquifer. This system is further complicated by various activities of man, who utilizes the water supply and other resources of the Basin. This entire system can be understood in terms of a total water budget for the Basin. The water budget approach is conceptually similar to maintaining a checkbook; money in and out of the account is recorded, thereby tracking the balance of funds in the account.

2.1 Surface Water Hydrology and the Republican River Basin

The following general discussion of surface water hydrology is a distillation of numerous standard references on the subject, including Dingman (2002). A surface water basin such as the Republican River Basin is characterized on the land surface by a network of streams. A section of a stream is known as a stream reach. Those portions of a stream network that do not continually carry water are generally found in the upper reaches of the networks and are known as intermittent streams. The remaining stream reaches that generally carry flowing water throughout the year are the larger, more centralized portion of the stream network and are known as perennial reaches. Generally speaking, streamflow derives from one of two processes, overland runoff and stream baseflow. Overland runoff occurs during large rainfall events when rainfall rates exceed the capacity of the soils to absorb the water, causing the water to run off the land, generally gather in the nearest drainage (stream reach) and flow down that reach of the stream network. Runoff can enter the stream network through both intermittent reaches and perennial reaches. During periods between rainfall events, streamflow is maintained

[1] More specifically, water for the City of Portland, Maine is supplied by the Portland Water District. This District serves 200,000 people delivering approximately 21 million gallons of water per day or about 23,500 acre-feet per year.

in the perennial reaches by stream baseflow from the aquifer, which is discussed further in the next section.

A drainage basin is defined as the land area that drains to a given location in a stream network. The areal extent of a drainage basin is determined by the topography; the line that may be drawn on a map to separate the locations from which water would flow into one drainage basin versus an adjoining drainage basin is known as the basin divide. A well-known basin divide is the Continental Divide, which divides the North American continent into the area that drains to the Pacific Ocean and the area that drain to the Atlantic Ocean. A given drainage basin can be sub-divided into a number of component sub-basins, which can be further sub-divided. Generally, a stream basin will be characterized by a single "main stem" which constitutes the primary stream that drains to the end, or "outlet" of the basin, and tributary streams that flow into this main stem from "sub-basins". For example, the Mississippi River is the main stem of the Mississippi River Basin, with its outlet near New Orleans where it drains into the Gulf of Mexico; the Missouri River, with its own sub-basin, is a tributary of the Mississippi River.

In the Republican River Basin, the Republican River Compact recognizes twelve (12) sub-basins that are accounted for separately from the remaining tributaries and the main stem reaches, all of which are collectively called the Main Stem of the Republican River, or simply "Main Stem" (figure 1). The Main Stem begins at the confluence of the North Fork of the Republican River and the Arikaree River at Haigler, Nebraska. These two sub-basins begin in eastern Colorado. Four other sub-basins originate in eastern Colorado: 1) the South Fork of the Republican River, which flows from Colorado through Kansas to join the Main Stem at Benkelman, Nebraska; 2) Frenchman Creek and 3) Buffalo Creek flow directly from Colorado into Nebraska; and 4) Beaver Creek, which flows from Colorado into Kansas and then into Nebraska where it joins Sappa Creek. Driftwood Creek, Sappa Creek and Prairie Dog Creek all rise in Kansas and flow into Nebraska where they join the Republican River. Rock Creek, Red Willow Creek and Medicine Creek rise in Nebraska. The Lower Republican River, consisting of the main stem and tributaries downstream of Hardy, Nebraska, is not included as part of the Main Stem or Compact accounting.

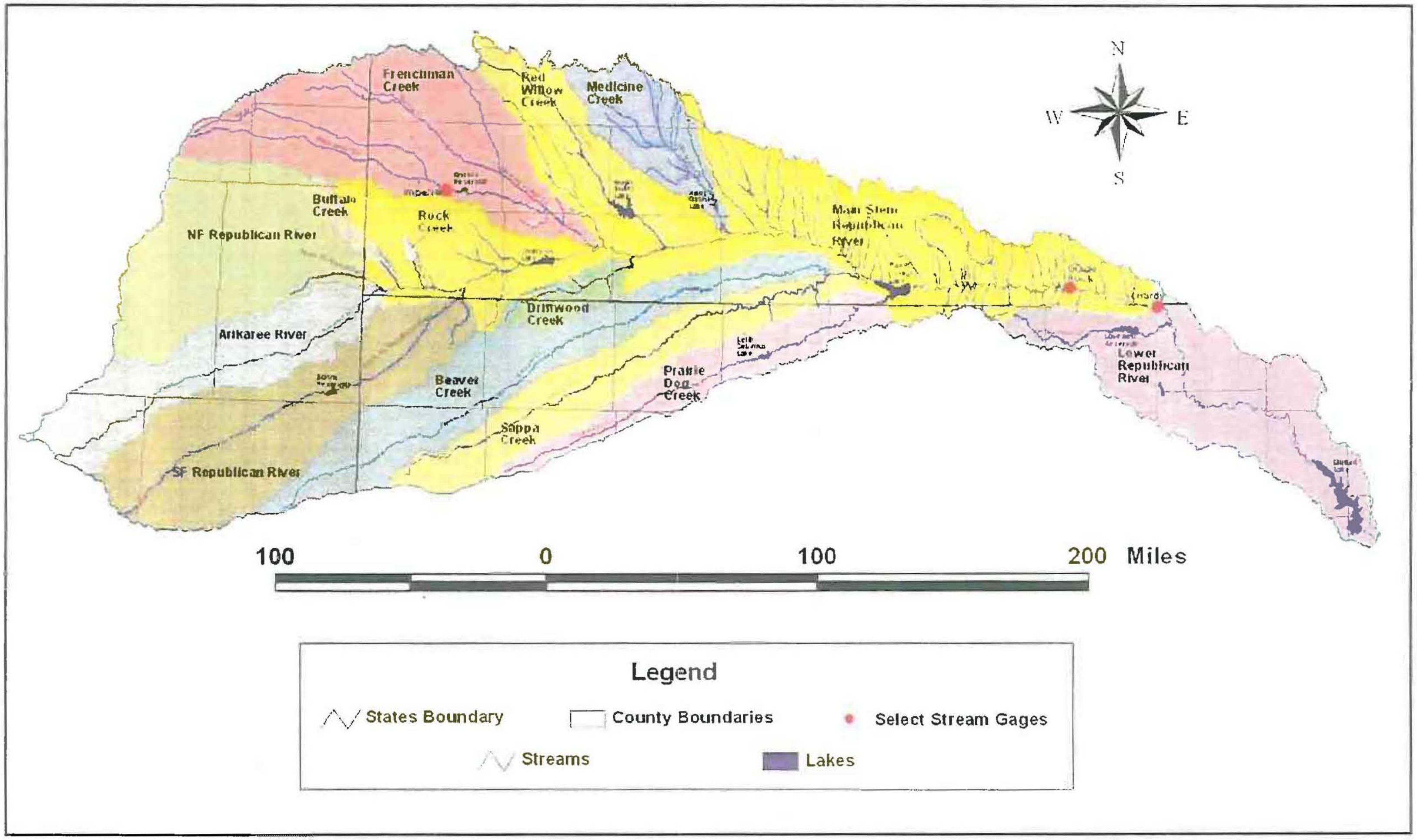

Figure 1. The Republican River Basin, showing the 12 sub-basins and the remaining drainage to the Main Stem

2.2 Groundwater Hydrology and the High Plains Aquifer

The following general discussion of groundwater hydrology is a summary of numerous standard references on the subject, including Fetter (2001) and Schwartz and Zhang (2003). A geologic unit is a volume of the subsurface that contains material with similar properties. A geologic unit (or group of units) that readily transmits water is known as an aquifer. A geologic unit that retards the movement of water through the subsurface is known as an aquitard. An aquifer is generally underlain by an aquitard; this boundary defines the base of the aquifer. Some aquifers are also overlain by an aquitard; these aquifers are known as confined aquifers. Where no aquitard overlies an aquifer it is known as an unconfined aquifer. Within the aquifer, the void space between the geologic material (e.g., the pore space between sand grains) is filled with water and is said to be saturated. The top of an unconfined aquifer is the point at which the pore spaces are no longer saturated. This top boundary is known as the water table.

When an aquifer is unconfined, some of the water that falls on the ground as precipitation (rain or snow) will percolate into the subsurface (figure 2). Some or all of that water will eventually flow downward and reach the water table. Recharge is the process of water reaching the water table and entering the aquifer, and this represents the primary source of water to the aquifer in many cases. A primary pathway for water to be discharged from an aquifer is to a stream; this discharge creates the stream baseflow that contributes to total streamflow. Water levels in an aquifer tend to follow a gradient from recharge areas, where water levels are higher, to discharge areas, where water levels are lower. This difference in water level produces a flow of water away from the recharge areas and toward the discharge areas.

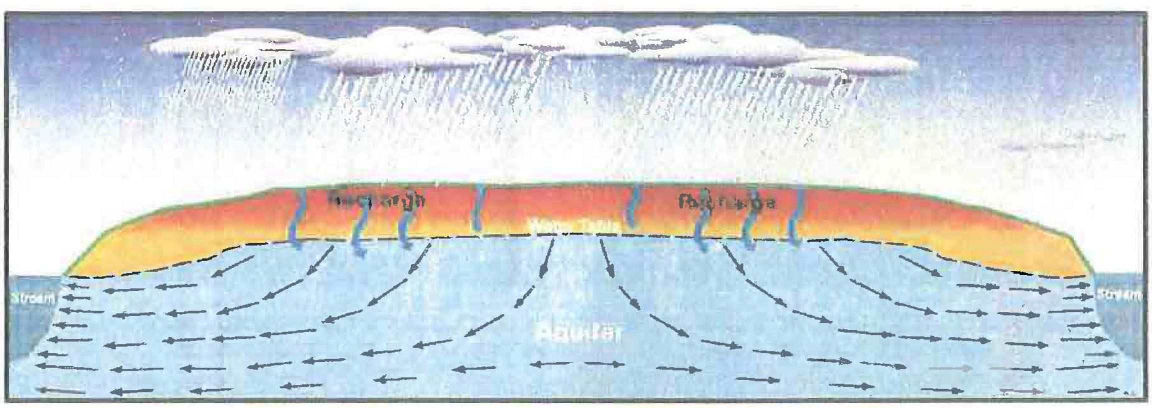

Figure 2. Idealized cross-section showing the movement of water from the atmosphere to the aquifer (recharge), and the subsequent movement of water through the aquifer until it discharges to a stream.

The rate at which groundwater flow occurs depends on the difference in hydraulic head[2] as well as the specific properties of the aquifer. The properties of importance to groundwater flow in the Basin are the thickness of the aquifer and the relative ability of the material to transmit water, known as hydraulic conductivity. A thicker aquifer and/or one with higher hydraulic conductivity (e.g. coarse sand) will transmit water more readily than an aquifer that is thinner and/or has a lower hydraulic conductivity (e.g. silt). Note that the horizontal distance may be quite substantial (many miles) so that the travel time of groundwater through an aquifer can be on the order of many years to decades.

Just as a divide can be delineated for a surface basin (or sub-basins), a groundwater divide defines the boundary between groundwater that flows in one direction and groundwater that flows in other directions. Whereas a surface drainage divide is defined by topography, groundwater divides do not necessarily follow surface water divides. Instead, groundwater divides are influenced by recharge and discharge patterns throughout the aquifer. The implication of this is that groundwater can move across surficial sub-basin divides, and changes in hydrology in one surficial sub-basin (e.g., increasing recharge or discharge in one area relative to another) can cause changes to the aquifer condition (e.g., rate or direction of groundwater flow) in another surficial sub-basin.

The Republican River Basin is underlain by the High Plains Aquifer (Weeks et al., 1988), a vast aquifer underlying the High Plains region of United States from Texas to South Dakota (figure 3). In the Basin, the High Plains Aquifer is made up of a combination of shallow alluvial deposits, which include sands, silts and gravels, and bedrock units. The High Plains Aquifer is an unconfined aquifer, which ranges from being relatively thin at its margins and in the vicinity of streams to being many hundreds of feet thick, and has a generally moderate hydraulic conductivity. The aquifer's characteristics result in a range of groundwater travel times through the aquifer of less than one year from the point of recharge to the point of discharge to times in excess of one hundred years; travel time is also heavily dependent on distance. The aquifer is naturally recharged by precipitation, and water from the aquifer discharges to streams. In some cases water that is discharged to or runs off into a stream may, after flowing downstream, soak from the stream into the aquifer providing recharge in that area. Another mechanism for discharge from the aquifer is directly through plants whose roots have access to the aquifer. These plants, known as phreatophytes, are generally located along stream channels (the riparian zone); this discharge process is known as transpiration. Transpiration and evaporation are sometimes lumped together as an undifferentiated term in hydrologic analyses and referred to as evapotranspiration (ET).

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[2] Hydraulic head is a measure of the energy available in a body of water to drive flow and depends on both the elevation of the water and its pressure.

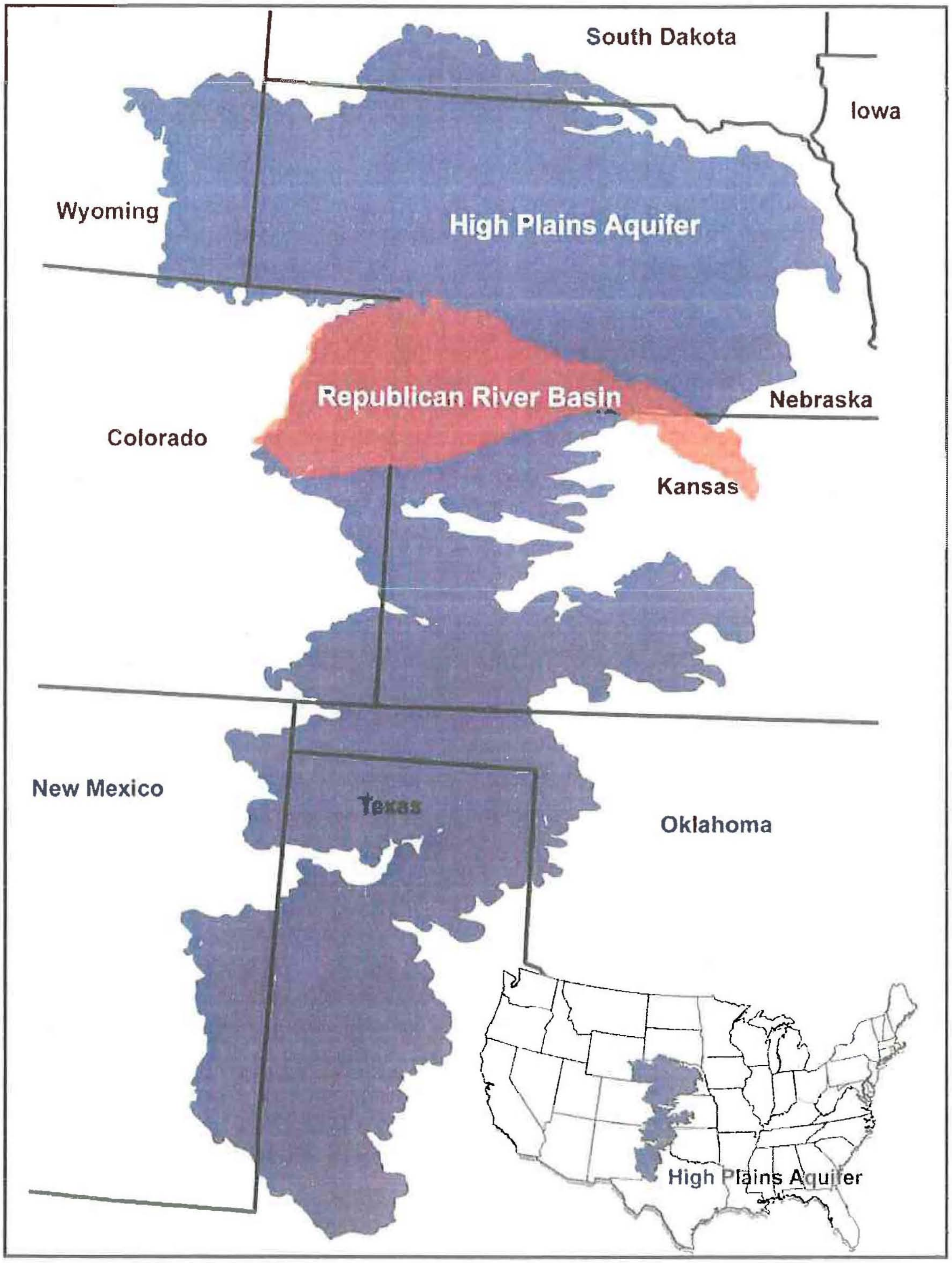

Figure 3. The High Plains Aquifer (Weeks et al., 1988).

2.3 Human Interactions

The natural hydrologic conditions of a surface water basin and/or an associated aquifer can be altered by human activities. In some cases these alterations are dramatic. An obvious example of an activity that significantly affects a stream is the building of a dam to produce a reservoir on the stream. Reservoirs are built for many purposes, including flood control and municipal or irrigation water supply. Seven large reservoirs have been constructed by the United States Bureau of Reclamation in the Republican River Basin. Two primary purposes of these reservoirs are flood control and irrigation. Many other small reservoirs have also been constructed in the Basin for various other purposes. Evaporation from these reservoirs removes water from the Basin.

In general, the advent of irrigated agriculture has caused the most change to the hydrologic system in the Republican River Basin. Beginning well before the large reservoirs were built, water was diverted from the Republican River and its tributaries for distribution on crops. The diversions reduced flow in the streams, increased ET to the atmosphere and increased percolation into the ground from canal seepage and excess irrigation (referred to as return flow). Percolation into the ground increased recharge to the aquifer which, in turn, increased both ET in the riparian zone and baseflow discharge to rivers. The depletion in streamflow caused by the surface water diversion occurs immediately in time. The accretion (or increase) to streamflow caused by return flow, however, is delayed for years, as that additional recharge slowly moves through the aquifer to the stream.

The use of groundwater for irrigation, which first became significant in the Basin in the 1950s, further complicated the hydrologic system. Water pumped from the ground for irrigation intercepted flow that would otherwise have discharged to streams, reduced water available for ET in the riparian zone, and removed water stored in the aquifer causing a drop in the water table. Although much of the water pumped from the ground for irrigation was consumed by the crops being irrigated (i.e., removed from the Basin through ET), some of it percolated back into the ground as excess irrigation water.

Near a well, the water table is depressed as water is removed from the subsurface (figure 4). This depression in the water table causes water in the vicinity of a well to change its pre-pumping flow direction and instead move toward the well. The interception of water that would have otherwise discharged to streams reduces flow in streams. The removal of water stored in the aquifer near a stream can induce flow from the stream to the aquifer. Water removed from aquifer storage far from streams can ultimately reduce flow in the streams but this effect is comparatively less immediate. In addition, because groundwater may flow across surficial basin divides, pumping that occurs in one stream sub-basin may also affect stream baseflow in a different sub-basin.

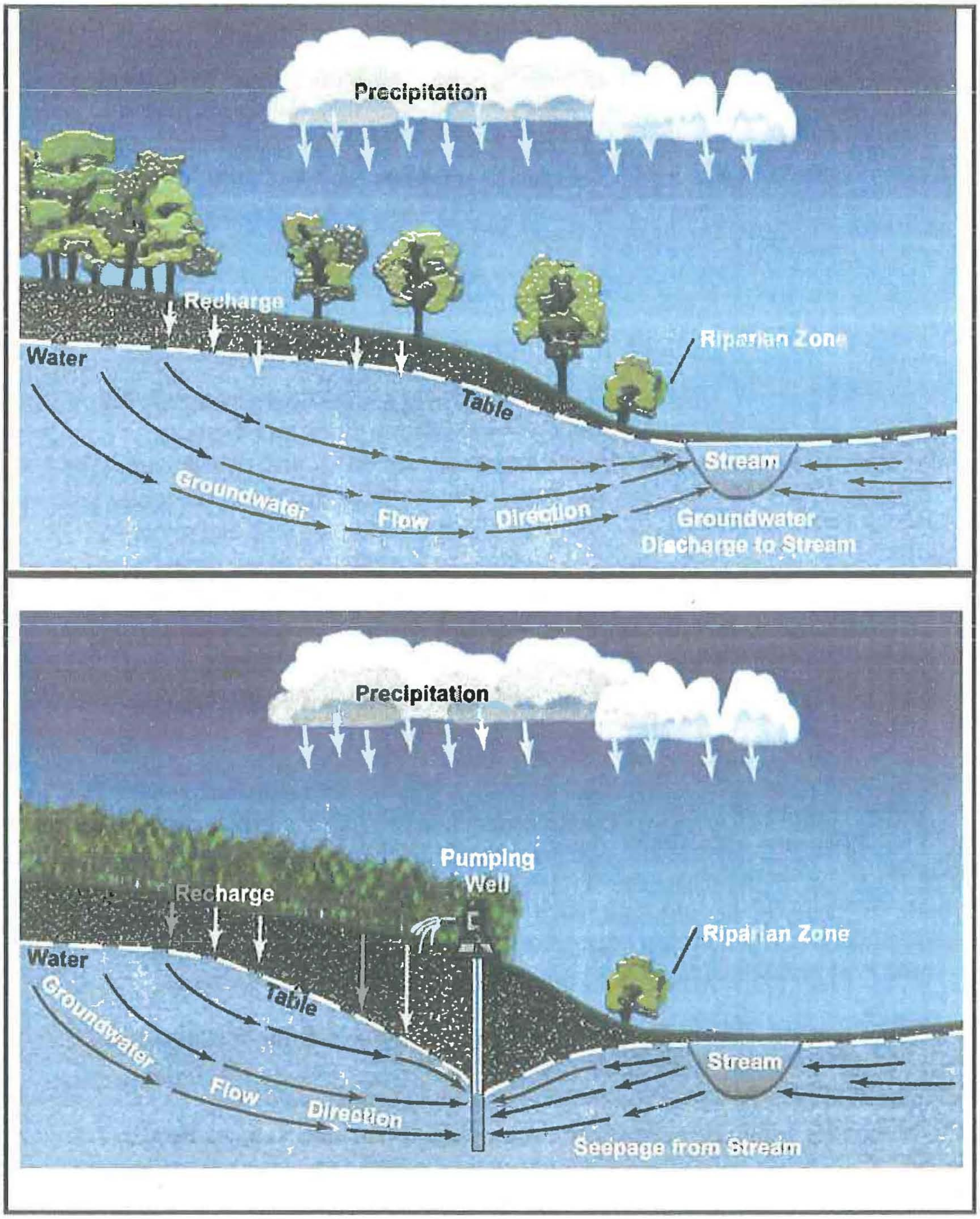

Figure 4. Idealized cross-section showing the effect of a groundwater well on the flow of groundwater through an aquifer, which impacts the discharge to or induces recharge from a nearby stream.

2.4 Water Budget of Basin

These processes involving the stream, the aquifer and the changing recharge and discharge over time in a basin can be analyzed using a water budget approach. Central to this approach is the principle that, over a given period, the difference between total inflows to the basin and total outflows from the basin will equal the change in the amount of water stored in the basin, either in reservoirs or underground.

The water budget for pre-development conditions (i.e., conditions before the addition of human actions on the hydrologic system) in the Basin is relatively simple. Precipitation brought water into the Basin, and streamflow and ET removed water from the Basin. Most of the precipitation that percolated into the ground ultimately discharged to the Republican River or its tributaries as stream baseflow; the remainder was discharged to the atmosphere as ET in the riparian zone. Surface runoff combined with the stream baseflow to produce the total streamflow. The water stored in the aquifer remained relatively constant; increasing somewhat in wet (high precipitation) years and decreasing somewhat in dry (low precipitation) years.

The water budget for post-development conditions is more complicated. In addition to the ongoing processes of recharge from precipitation and discharge through stream baseflow, surface water is diverted from streams, water is withdrawn through groundwater wells and irrigation water not consumed by crops returns to the subsurface. During the post-development period, aquifer storage and streamflow in some portions of the Basin have declined steadily. An additional complication is accounting for surface water diverted from the Platte River, located to the north of the Republican River basin, which is used to produce power and irrigate crops south of the Platte River. A significant portion of this water seeps from canals or percolates from irrigated fields and recharges the groundwater system. The imported Platte River water has caused a groundwater mound to develop, creating a groundwater divide between the Platte and the Republican Rivers (figure 5). Water that percolates south of that divide increases the flow in tributaries to the Republican River, especially Medicine Creek and small tributaries to the east of Medicine Creek. That water will be referred to as "mound recharge" in this report.

Tracking and quantifying the numerous sources of water to the aquifer, the numerous mechanisms for discharge, the change in aquifer storage over time and the streamflow that results from all of these factors is accomplished by the Model. Known sources and discharges of water (e.g., recharge and groundwater pumping, respectively) are input into the Model. The Model then calculates the change in aquifer storage and streamflow as they evolve over time in response to changes in source and discharge magnitudes.

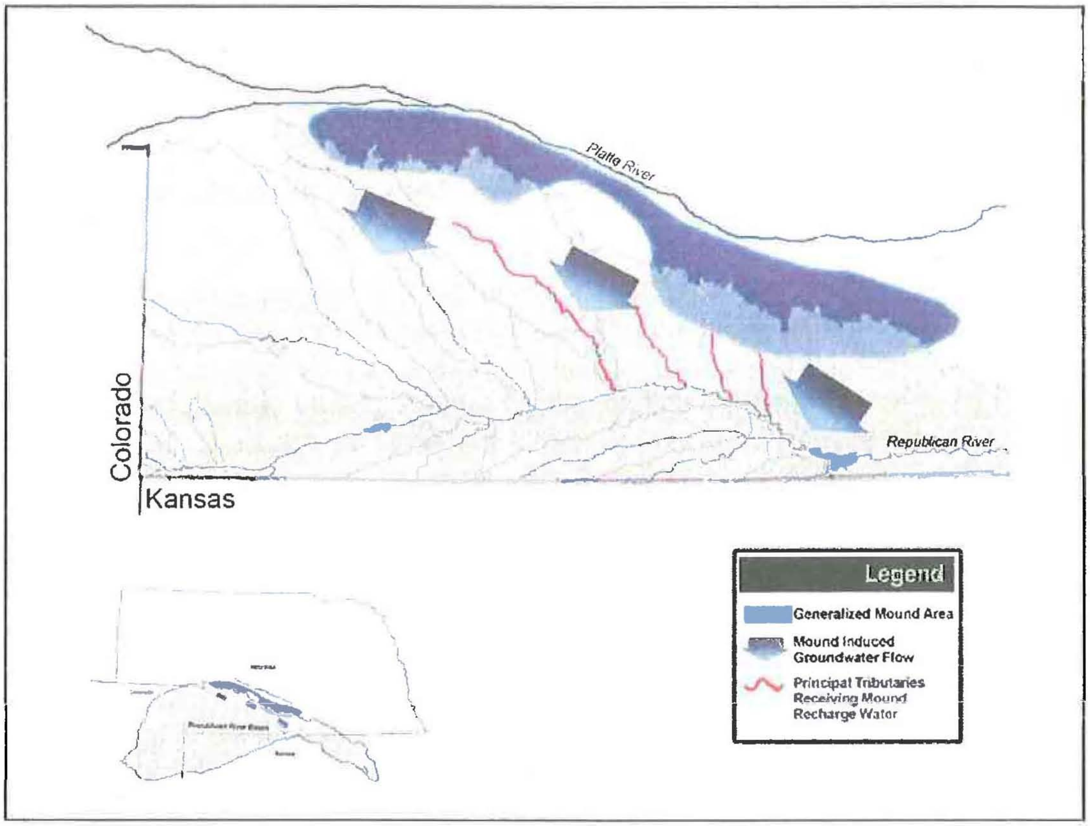

Figure 5. Diversions from the Platte River serve as the source of the mound recharge. This creates groundwater movement as shown, which has contributed to stream baseflow in tributaries of the Republican River.

3.0 RRCA GROUNDWATER MODEL AND CURRENT ACCOUNTING PROCEDURES

This section begins with a discussion of groundwater models in general and the RRCA Groundwater Model specifically. This discussion of groundwater modeling is based on numerous standard references on the subject, including Anderson and Woessner (1992) and Harbaugh et al. (2000). Following the overview of modeling, the Current Accounting Procedures are discussed, both in general terms and in relation to the Model.

The Model and the Current Accounting Procedures were developed to represent the portions of the physical system previously discussed in Section 2. The Compact divides (or allocates) the Virgin Water Supply (VWS) of the Basin, defined as the water supply unaffected by the activities of man. To do so, the impacts of the activities of man on streamflow must be understood. These impact estimates are combined with measured streamflow volumes to determine the VWS[3].

The Model was developed in accordance with the FSS, to be utilized in conjunction with the Current Accounting Procedures. An important objective of the FSS was to account fully for the impact of all groundwater pumping and all mound recharge that has an effect on streamflow in the Basin. The Model is required for this purpose because direct measurement of these impacts is not possible. The Model is the most technically appropriate method for estimating these impacts. The following discussion generally describes the function of a groundwater model, the development of the Model, the function of the Current Accounting Procedures, and the application of the Model within the Current Accounting Procedures.

3.1 Use of Groundwater Models

Many types of hydrologic models are used to simulate and understand different parts of the hydrologic system under differing sets of conditions. The Model is a numerical groundwater model, which is a numerical representation of a groundwater aquifer or aquifers. This type of model is well suited to simulating the conditions within an aquifer and the interactions between an aquifer and stream such as the High Plains Aquifer and the Republican River and its tributaries. Generally speaking, a numerical groundwater model contains specifications for the geometry and properties of the aquifer and any boundary conditions required to represent adequately flow into, through, and out of the model. A boundary condition is a numerical representation of a physical boundary between the aquifer and adjacent underground materials, surface water features, or the atmosphere.

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[3] VWS = Measured streamflow + Impacts to streamflow resulting from activities of man

A common boundary condition is a no-flow boundary, so named because water is not allowed to flow across that boundary in the model. This type of boundary condition can define the boundary between an aquifer and an aquitard (e.g., the base of the aquifer). A specified flow boundary condition defines a flow into or out of the model. Recharge to the aquifer or pumping by a well are examples of this. A head-dependent boundary condition allows water to flow into or out of the model in a manner dependent on the difference in the water level (i.e., "head") between the aquifer and the boundary. A stream or river is an example of this.

When represented by numerical models, water is treated as if flow rates are constant over a small time interval and over a small area. A specified flow of water entering or exiting the groundwater system by a given mechanism over a small time interval and a small area is known as a "stress." The time interval is referred to as a "stress period;" the small area is referred to as a "cell". Aquifer parameters (e.g., hydraulic conductivity, top and bottom of aquifer) are specified for each cell in the model, and boundary conditions are specified on a cell-by-cell basis where needed.

There is no one size fits all approach to groundwater modeling. In order to develop a useful modeling tool, the specific questions that the model will be used to answer need to be considered. A common question that a model is used to answer is to determine the impact of an activity or activities on some component of the hydrologic system. In this case hydrologists are typically interested in an impact that cannot be directly measured. In order for such a model to be useful, it needs to be able to simulate the hydrologic system during periods when a given activity is both present and not present. By sufficiently overlapping these periods, the model can be a useful tool in providing estimates of the impact of the activity or activities of interest.

When using a numerical model to represent an actual physical system, such as the Basin, it must undergo some level of calibration—a process of ensuring the model can reasonably replicate the physical system being modeled. The two most common calibration targets are measurements of groundwater levels (i.e. water table elevations) and estimates of stream baseflows. The calibration process involves these steps:

1) A model is constructed and run.

2) The output from the model is then compared to measured and estimated actual conditions.

3) Changes are made to the calibration parameters, most commonly the aquifer properties and the aquifer recharge, in an iterative fashion, until the model results closely match the measured and estimated actual conditions.

It is important also to constrain, as much as possible, the range of the calibration parameters, because there is generally an infinite combination of parameters that can yield a similar calibration to the measured and estimated actual conditions. For example, the range of aquifer properties allowed in the model should be constrained to some pre-defined range that is based on knowledge of the geology. Similarly, the range of recharge values for a given location in the model can be constrained based on knowledge of precipitation, soil types, and land cover. The point at which a model can be considered calibrated is subjective, as the model can never perfectly replicate the complexity of the actual hydrologic system. Professional judgment among the model developers is relied upon to make this decision. Subsequently, new data or understandings may lead to additional calibration efforts.

3.2 Development and Updating of RRCA Groundwater Model

When the FSS was ratified by the three states on December 15, 2002, the Model was not complete. The States had agreed on the calibration targets, the methods to estimate groundwater pumping and recharge, and the process to calibrate the Model. In spite of the incomplete state of the Model, the Current Accounting Procedures that were included in the FSS specified how the Model was to be used to calculate the depletions to streamflow caused by groundwater pumping in each state and the accretions to streamflow caused by mound recharge. The model was completed within the timeframe required by the FSS (RRCA, 2003).

The Model was developed by representing all major sources and discharges for water in the ground and properties of the subsurface material relating to the transmission and storage of water (figure 6). Cells in the Model are one square mile (640 acres) in area, with a vertical extent equal to the saturated thickness of the aquifer (ranging from ten feet to hundreds of feet). The base of the aquifer and lateral boundaries where the aquifer is reduced to zero thickness (i.e., "pinches out") are no-flow boundaries. Much of the northern boundary of the Model is coincident with the Platte River; here water flows into or out of the Model in quantities required by the specified head that represents the water level in the Platte River. The Republican River, its perennial tributaries (as well as several small tributaries to the Platte River) and surface reservoirs are represented in the Model and associated with specific Model cells.

The stress periods for the Model are one month long. Values for recharge and groundwater pumping are specified on a cell-by-cell basis and may change with each stress period. The groundwater pumping values are determined separately by each state for the wells in that state. Initially reviewed by the other states during calibration of the Model and they continue to be reviewed when the Model is updated with new data for ongoing accounting. Recharge from four sources is included: 1) precipitation; 2) canal leakage; 3) recharge of water applied through surface water irrigation; and 4) recharge of water applied through groundwater irrigation.

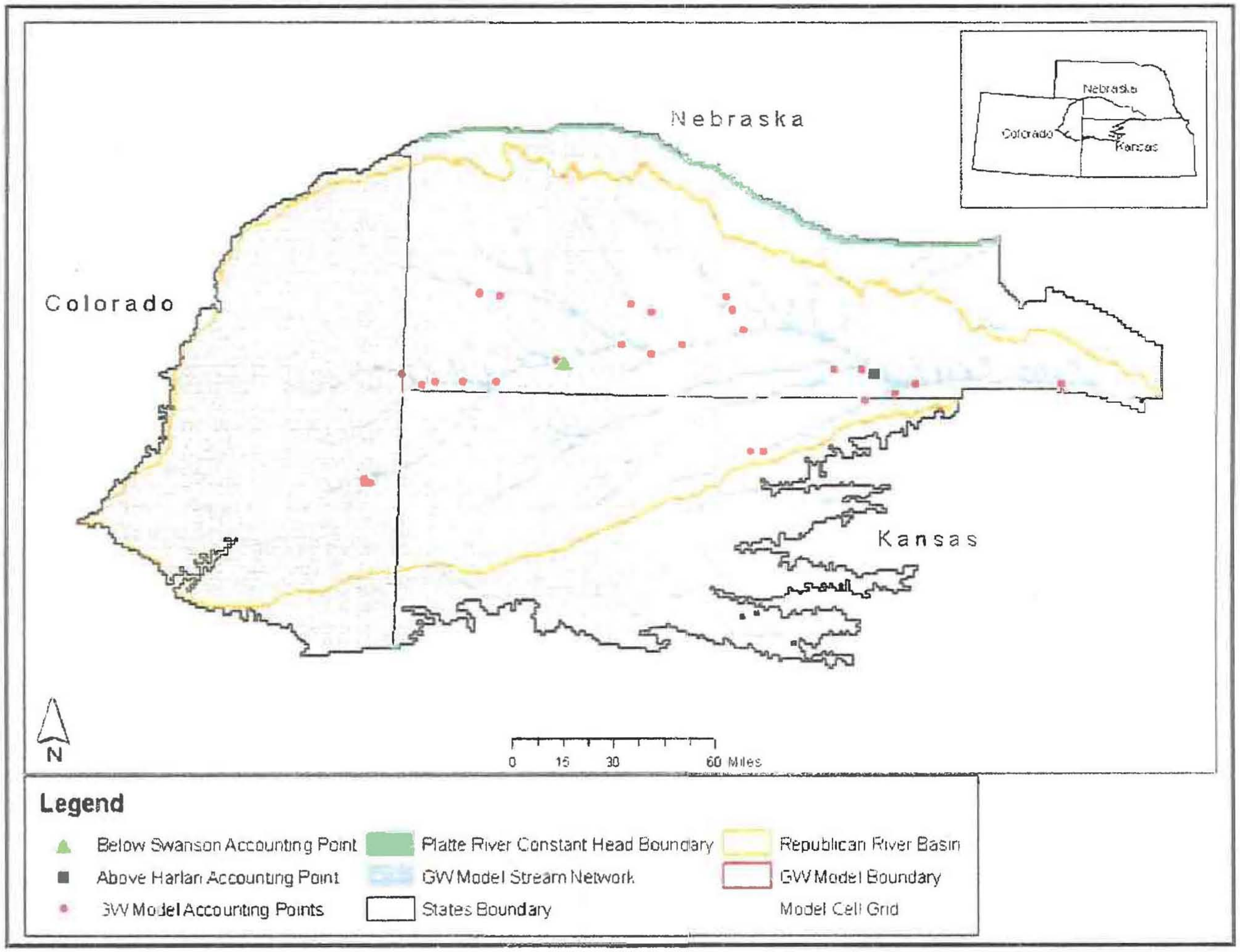

Figure 6. The RRCA Groundwater Model. Note the location of the "Below Swanson" and the "Above Harlan" accounting points, indicating the extent of the Swanson-Harlan Reach, which will be discussed in Section 4.4.

The Model was calibrated by comparing water levels calculated by the Model with those observed in the aquifer and comparing net stream baseflow, as calculated by the Model at gaging stations, with estimates of stream baseflow at the same gaging stations. Calibration parameters included the aquifer properties, the precipitation recharge, and properties associated with ET. The period of record over which such comparisons were made was 1918-2000. This period was chosen in part because it sufficiently overlapped time periods when groundwater pumping and mound recharge had not yet occurred (i.e., pre-development) and a time period when aquifer pumping and mound recharge began to occur (i.e., development period). The pre-development period ended sometime around 1950-60, though the change was not abrupt, but rather a gradual one.[4]

Figure 7 shows an example of the comparison between Model-calculated stream baseflow[5] and estimated stream baseflow for the gaging station on the Frenchman Creek near Imperial (figure 1). The horizontal axis indicates the time at which the stream baseflow (calculated or estimated) occurred. The vertical axis indicates the magnitude of the stream baseflow, given here as a volume of water (acre-feet) that passed the gaging station over the course of the indicated year. While the two lines do not track identically, the fit between them is generally good, particularly the overarching trend in the data. Note that the baseflows are fairly steady at around 45,000 to 50,000 acre-feet per year until around 1965, when they begin to decline, representing the beginning of the development period.

[4] There was some groundwater use and surface water use in the Model area much earlier than 1950, though this was generally minimal. Large scale man-made stresses to the system generally began around/after 1950.

[5] Note that the data from model runs presented in this report produce slightly different values from those officially adopted by the RRCA. The RRCA employs Principia Mathematica, Inc. to produce the official model runs, whereas the runs reported here have been completed on the computers of Nebraska staff. Model runs, using the same input but completed on different computers, can produce slightly different results because of differences in computer hardware. These differences are typically on the order of 0.1%. A slight versioning issue with Model files was discovered prior to submitting this report but subsequent to the stipulation by Nebraska on her overuse in 2006. This issue resulted in a difference of 215 acre-feet in that overuse value.

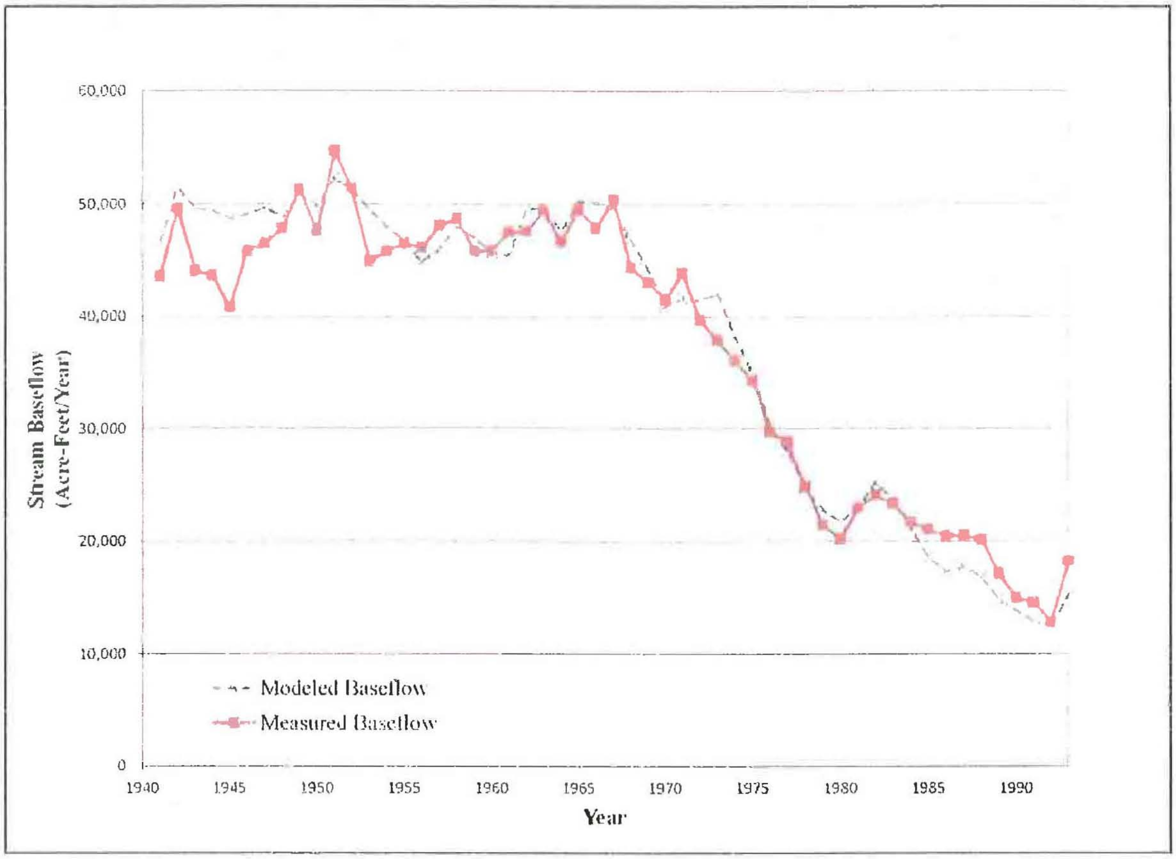

Figure 7. Comparison between estimated stream baseflows from gage data and Model-generated stream baseflows for the Frenchman Creek near Imperial.

It is important to emphasize that Nebraska is not seeking to alter the Model in any way through these proceedings. Rather, it is only the manner in which the outputs of the Model, namely the stream baseflows, are used in the Current Accounting Procedures that are at issue. Although additional runs of the Model are required under Nebraska's Proposed Procedures, none of the Model specifications or input data from a given year would be changed in these runs. Instead, Model input would be applied in some additional combinations in order to estimate better the impact of pumping and mound recharge.

3.3 RRCA Accounting Procedures

The Republican River Compact specifies the VWS for each sub-basin and the Main Stem, as well as the specific Allocations from that VWS provided to each of the states. It also states that if future water supplies vary by more than 10% from the values included in the Compact, then the volume of water each state receives could be adjusted in proportion to the original Allocations (Compact, 1943). The RRCA first developed a system for accounting for the water supplies and uses in 1961. These procedures have been updated and modified through the years to reflect advancing technologies and changing conditions in the Basin. The Current Accounting Procedures were adopted as part of the FSS in 2003, and the FSS included provisions to allow for future updates to these as necessary. For a more detailed discussion of the Current Accounting Procedures, particularly as they relate to the computation of the impact of groundwater pumping and mound recharge, see Ahlfeld et al. (2009).

3.3.1 Compact Allocations

The FSS allocates water in each sub-basin to the states based on fixed percentages of the estimated water supply in a given year (table 1). These fixed percentages are based on the original Compact VWS and Allocations. These fixed percentages are included in the Current Accounting Procedures.

Table 1. Fixed percentages that represent the Compact Allocations.

Basin	CO % of Basin Supply	KS % of Basin Supply	NE % of Basin Supply	% Unallocated
Arikaree	78.5%	5.1%	16.8%	-0.4%
Beaver	20.0%	38.8%	40.6%	0.6%
Buffalo			33.0%	67.0%
Driftwood		6.9%	16.4%	76.7%
Frenchman			53.6%	46.4%
North Fork	22.4%		24.6%	53.0%
Medicine			9.1%	90.9%
Prairie Dog		45.7%	7.6%	46.7%
Red Willow			19.2%	80.8%
Rock			40.0%	60.0%
Sappa		41.1%	41.1%	17.8%
South Fork	44.4%	40.2%	1.4%	14.0%
Main Stem + Unallocated		51.1%	48.9%	

To compute the volume of water that each state receives from these fixed percentages, an estimate of the VWS is needed, which involves combining the measured streamflow with estimates of the impact to streamflow for each sub-basin and the Main Stem. ***Thus accurate estimation of these impacts is critical to properly determining the VWS.***

Under the FSS, a new term was introduced, the Computed Water Supply (CWS), which is an adjustment to the VWS.[6] The CWS is now used in conjunction with the fixed percentages described above to determine the volume of water that each state receives from each sub-basin. Many sub-basins do not provide Allocations for all three states. Generally, some percentage of the water supply in each sub-basin is not allocated to a specific state. This unallocated water is combined with the CWS in the Main Stem and split between Kansas and Nebraska in the same manner as the CWS from the Main Stem. This means that:

1) Each state does not receive the same volume of water each year unless the CWS is the same;
2) Even if the total CWS is the same, a state may not receive the same volume of water from year to year, if water originates in different sub-basins; and
3) If the CWS is not determined correctly, then one or more states will not receive the correct volume of water.

Using Sappa Creek as an example, if the impact to stream baseflow from groundwater pumping is misestimated for Kansas ***or*** Nebraska, then ***the estimate of the CWS will be flawed***. Applying the fixed percentages from table 1 to this flawed CWS would result in flawed values for the volumes of water that Kansas ***and*** Nebraska receive. Similarly, a state would also receive the wrong volume of water if the estimates of CWS were correct, but the fixed percentages derived from the Compact were altered such that they no longer reflect Compact entitlements. Therefore, applying a flawed estimate of CWS in the accounting is akin to altering the fixed percentages (Allocations) that are derived from the Compact (i.e., altering Compact entitlements).

3.3.2 Use of Current Accounting Procedures

The Current Accounting Procedures are described in Appendix C (revised August 8, 2010) of the FSS. Definitions and formulas within the FSS and Appendix C make it clear that the working definition of VWS is to be understood as the water supply or streamflow of the Basin unaffected by human activities. To estimate VWS, the Current Accounting Procedures call for the estimation of Computed Beneficial Consumptive Use

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[6] The CWS is an adjustment to the VWS to account for changes in storage in federal reservoirs and flood flows. This difference essentially means that water that is stored in federal reservoirs is not counted until it is released and used, and that flows over certain thresholds are not counted.

(CBCU) and the impact of the mound recharge, also referred to as the Imported Water Supply Credit (IWS Credit). The CBCU is the streamflow depletion resulting from a specific list of human activities. The IWS Credit is defined as "the accretions to streamflow due to water imports from outside of the Basin as computed by the RRCA Groundwater Model" (FSS, 2002).

The Compact divides the Republican River Basin into twelve (12) sub-basins and the Main Stem. The VWS is computed independently for each sub-basin on an annual basis. In the case of a sub-basin that does not have any federal reservoirs or imported water supply effects, the VWS is computed as the sum of gaged streamflow, measured in the stream at the sub-basin or Main Stem outlet, and all CBCU in the sub-basin. The CBCU is generally caused by two activities, the stream baseflow depletion caused by groundwater pumping and the streamflow depletion caused by surface water diversions and other non-groundwater activities identified in the Current Accounting Procedures (e.g., evaporation).

In the Current Accounting Procedures, the annual gaged flows for a given sub-basin are determined by direct measurement at stream gages and surface water depletion is estimated based on direct measurements, such as tabulating the volumes of water actually diverted from streams during the year. Direct measurement of the impact of groundwater pumping and mound recharge is impossible. Estimation of these impacts is complicated by the fact that the impacts in one sub-basin may result from pumping or recharge that occurred in earlier years and/or in neighboring sub-basins. Because of these complicating factors, these impacts are estimated using the results of multiple runs of the Model.

In this way, the Current Accounting Procedures are used to estimate the VWS and the CWS. The annual volume of water each state receives is determined as a percentage of the CWS. This volume of water is then compared with an estimate of actual water use (less any IWS Credit) by that state to determine over or under-utilization by that state. The problem with the Current Accounting Procedures is a failure in the estimation of the impacts of groundwater pumping and mound recharge, which in turn affects the VWS, CWS, and the volume of water each state receives, which is derived from the CWS estimates using the fixed percentages. ***Solving this problem does not involve changing the fixed percentages; rather, the problem is solved by ensuring the impacts of groundwater pumping and mound recharge are determined properly.***

3.3.3 Current Accounting Procedures and the Model

The Current Accounting Procedures define a number of "accounting points" (figure 6) at the outlets of each sub-basin or Main Stem reach for the purpose of estimating the impact of groundwater pumping or mound recharge. The Main Stem is subdivided into multiple reaches. Multiple accounting points for a given sub-basin or Main Stem reach are needed in some cases. Each accounting point is located in a numerical cell in the Groundwater Model. Using the calibrated Model, a stream baseflow value is computed at the accounting point at each stress period[7] through the year 2000 (the end of the calibration period).

The Model-computed stream baseflow is not necessarily exactly equivalent to actual streamflow at an accounting point, but is instead only an estimate of that portion of streamflow attributable to groundwater discharge to the stream. Stream baseflow estimates for years following 2000 are obtained on an annual basis by updating the Model with new input data (e.g., pumping, recharge) and other required parameters that can change from year to year (e.g, maximum ET rate, reservoir elevation). Additional Model simulations are also needed for each year to determine the proportion of the total change in stream baseflow that is attributed to groundwater pumping in each state and to mound recharge. The Current Accounting Procedures contain specifications for accomplishing this. These procedures work well in many cases, but, as shown in Section 4, they fail in some cases and therefore require additional refinement.

The Current Accounting Procedures require an estimate of the impact of 1) groundwater pumping in Colorado, 2) groundwater pumping in Kansas, 3) groundwater pumping in Nebraska, and 4) mound recharge. For convenience, this report uses the term "Target Set" to indicate one of these four groups of stresses. For example, the Target Set for Kansas groundwater pumping is all stresses applied, during the entire Model run, at groundwater wells located in Kansas. The Total Impacts of these four Target Sets can be determined by comparing a Model run with all groundwater pumping in Colorado, Kansas, and Nebraska, and mound recharge On, to a run with all groundwater pumping in Colorado, Kansas, and Nebraska, and mound recharge Off. The difference between these two Model runs provides the ***only direct estimate*** of the Total Impacts.

A conventional way to estimate the impact of a Target Set is to run a numerical groundwater flow model, with the Target Set of stresses "On" and then with the Target Set of stresses "Off". The difference in the output is assumed to be a reasonable estimate of the impact of the Target Set of stresses. The Current Accounting Procedures use the model to provide estimates of stream baseflow at accounting points for a Model run with all Targets Sets On and four other Model runs with one of the Target Sets Off. The Current Accounting Procedures then use differences in these stream baseflow estimates to calculate the impacts on stream baseflow caused by each Target Set. The problem with the Current Accounting Procedures identified by Nebraska occurs because these differences do not account for the Total Impacts.

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[7] Terminology in the Current Accounting Procedures (e.g., section III.D.1) is not entirely consistent on the use of streamflow and baseflow. In this report, the net groundwater discharge to the stream is referred to as "stream baseflow."

The Total Impact of groundwater pumping on stream baseflows for the Frenchman Creek near Imperial can be seen in figure 8. This figure shows Model-calculated stream baseflows with all Target Sets On (same as in figure 7 above) and Model-calculated stream baseflows with all Target Sets Off. A comparison of these two lines shows that stream baseflows were essentially identical until around 1955, indicating that groundwater pumping had no effect in this part of the Basin up to that time. The impact of groundwater pumping causes only marginal differences between the two curves until around 1965, after which significant differences become apparent.

The upper line in figure 8 (i.e., all Target Sets Off) is a representation of what the stream baseflows would have been if groundwater pumping had never occurred (mound recharge has little to no impact at this accounting point). The slight increase in stream baseflows over time would be attributable to increases in recharge that occurred over this time period. Notice that the effect of this increased recharge is not evident from the stream baseflows produced with groundwater pumping On.

This is why it would be improper simply to take the stream gage data, pick a point in time, and estimate the impact of groundwater pumping based on the change in gaged flows over time. Using the estimates of stream baseflow from gage data (figure 7), one might choose 1965, thereby missing the impacts that occurred from 1955 to 1965. This single-point choice would also miss the fact that stream baseflows would have otherwise increased somewhat over time. The Model can produce estimates of stream baseflow with and without groundwater development, and the difference between these represents the Total Impact of groundwater pumping on stream baseflow in Frenchman Creek.

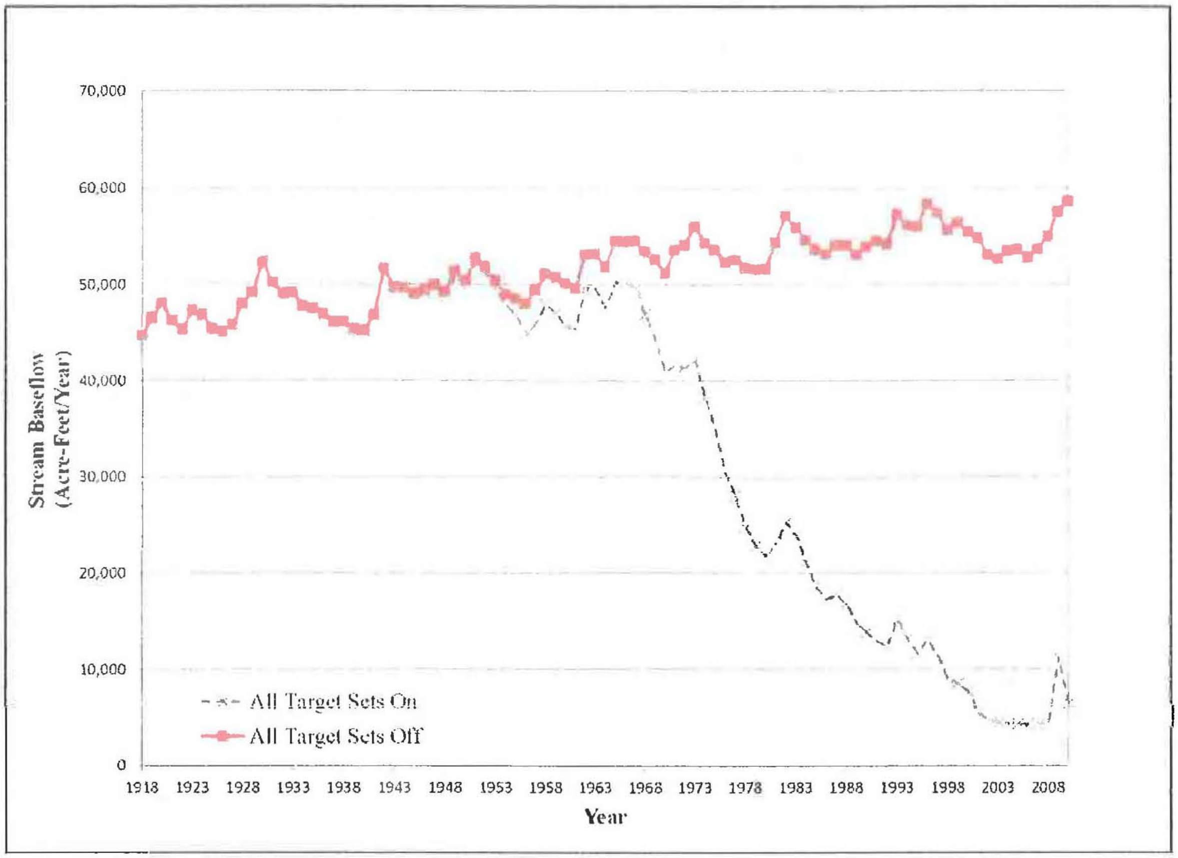

Figure 8. Comparison of Model-generated stream baseflows for the Frenchman Creek near Imperial for 1) all Targets Sets On, and 2) all Target Sets Off.

4.0 PROBLEM WITH CURRENT ACCOUNTING PROCEDURES

Nebraska has identified significant inadequacies in the Current Accounting Procedures' ability to account fully for the VWS of the Basin. This problem arises from the way in which the Model output is applied by the Current Accounting Procedures. No changes to the Model are required or sought by Nebraska to address this problem.

The problem manifests itself in multiple ways, a glaring example of which is presented in Section 4.4.2. This example shows that mound recharge supplied by Nebraska provides no accounting benefit over the long term. Moreover, by continuing to provide mound recharge, Nebraska's Compact accounting balances are ***adversely impacted*** over the long term as compared to discontinuing the mound recharge. This result demonstrates the nature of the problem.

Nebraska's first report (NDNR et al., 2008), along with previous interactions with the RRCA, continually refined Nebraska's Proposed Procedures to the form presented in arbitration (Ahlfeld et al., 2009). These reports contain detailed analyses of the behavior of the Model and provide technical explanations for the results the Model produces when it is used to determine impacts under the Current Accounting Procedures and Nebraska's Proposed Procedures. In this section, the problem with the Current Accounting Procedures will be demonstrated by using a simple analogy, which highlights the unrealistic nature of the results that can be obtained by the Current Accounting Procedures.

The analogy will first demonstrate a non-linear response of a single Target Set. Then, the analogy will demonstrate the complications that arise when a similar non-linear response is caused by two Target Sets. The analogies are useful for understanding these complications and demonstrates the failure in otherwise reasonable approaches to estimating impacts.

4.1 Weighing a Single Person on a Scale (One Target Set Analogy)

Any accounting procedure is fundamentally defined by operational rules. For example, when a person is weighed on a scale, the weight shown is the result of the difference between two readings: the reading of the weight from the scale when the person is on the scale minus the reading of the weight registered by the scale when the person is not on the scale. This procedure is greatly simplified by ensuring the scale reads zero pounds when the person is not on the scale, which eliminates the need for subtraction.

People are typically weighed individually on a scale, and in most cases a person weighs less than the scale capacity, which typical may have a limit of 300 pounds. One person can always be accurately weighed, regardless of the procedure used, as long as that person weighs less than the scale capacity. The person's weight can be derived in one of two ways. First, one can start with the person not on the scale and then have the person step on the scale. The weight will be calculated by comparing the scale reading with and without the person on the scale. Alternatively, one can start with the person on the scale and then have the person step off the scale. Again, the weight will be calculated by comparing the two scale readings. Both approaches yield the same result.

Note that if a 350-pound person is weighed on a scale with a capacity of 300 pounds, the impact the person has on the scale will always be 300 pounds regardless of whether the person starts the weighing procedure on or off the scale. ***The distinction between the actual weight of the person and the impact the person registers on the scale is important because it is the impact that is required for use in the RRCA Accounting Procedures.*** Determining the response of a scale to the weight of a person captures the case in which the person weighs more than the scale capacity.

For example, given a scale capacity of 300 pounds, the maximum impact a person weighing 150 pounds can have on the scale is 150 pounds (figure 9). Given the same person and a scale capacity of 100 pounds, however, the maximum impact the person can have on the scale is only 100 pounds, and the remaining 50 pounds of the person's actual weight has no additional impact on the scale. In this case, we can say that weighing the 150 pound person on a scale with a capacity of 100 pounds generates a non-linear scale response. As the person steps on the scale, the scale reading increases linearly (the scale reading increases by one pound for each additional pound of weight applied) until 100 pounds of the person's weight have been applied to the scale. At this 100-pound point, the scale's response becomes non-linear. After this point, the application of additional weight no longer results in any change in the scale reading.

This type of non-linear response is at the root of the issue regarding the Current Accounting Procedures. As set forth in Section 4.3, further potential complication arises when ***more than one person is on the scale***, and one wishes to determine ***the individual impact of each person.***

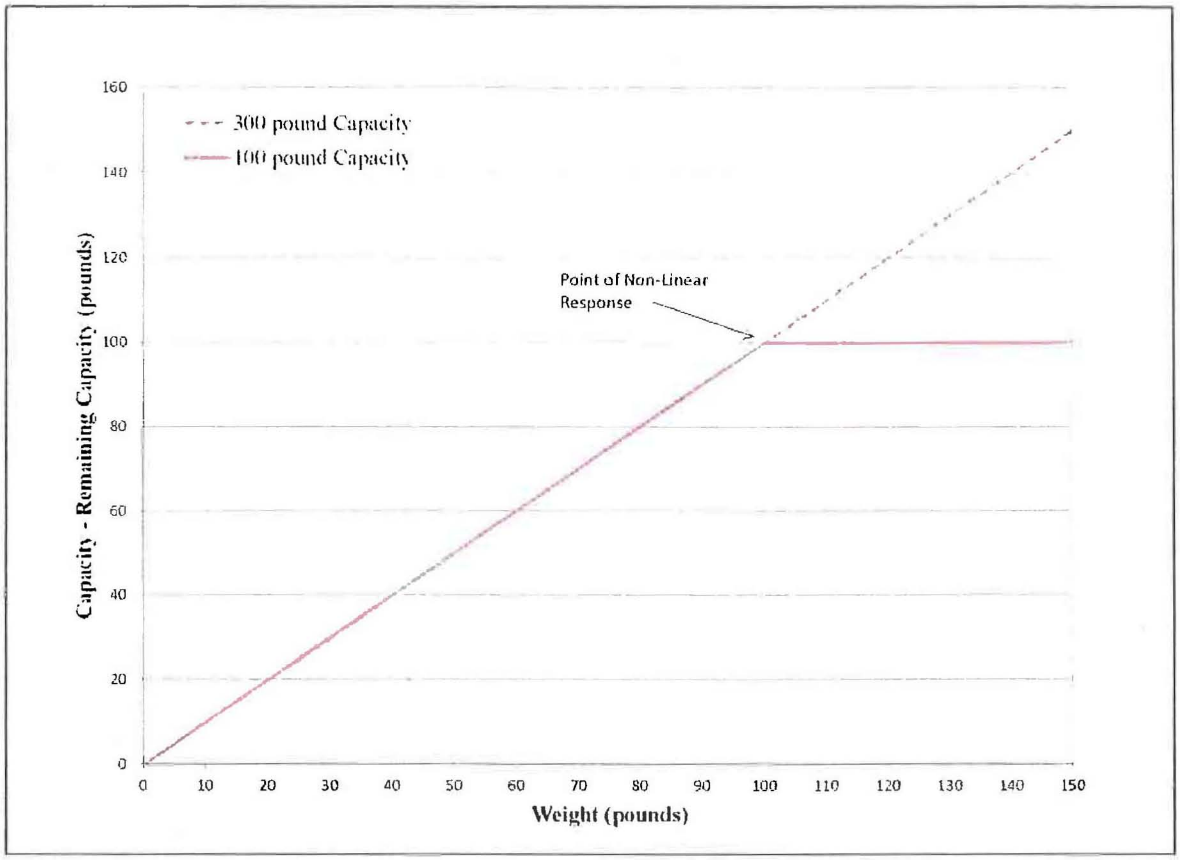

Figure 9. Comparison of the scale response with the application of 150 pounds of weight for scale capacity of 100 pounds and scale capacity of 300 pounds.

4.2 Estimating Impacts of Groundwater Pumping and Mound Recharge

The estimation of the impact of groundwater pumping and mound recharge for accounting purposes has similarities to the scale problem. The scale capacity can be related to the available baseflow in the stream. The impact of each person on the scale is analogous to the impact of groundwater pumping in each state.

The typical scale has an unimpacted reading (reading with nothing being weighed) of zero. The typical unimpacted stream has some non-zero amount of annual flow, termed the "Virgin Stream Baseflow" in this document. Placing people on the scale produces an impacted reading. Similarly, groundwater pumping reduces the stream baseflow to some amount less than the Virgin Stream Baseflow, termed the "Remaining Stream Baseflow" in this document. If sufficient weight is applied, the scale reaches its capacity, at which point the further addition of weight produces no additional response from the scale. Similarly, with enough pumping, the Remaining Stream Baseflow is reduced to zero, at which point additional pumping can have no further impact on the stream.

In order for the Current Accounting Procedures to be valid, they must be able to resolve the Total Impact to Virgin Stream Baseflow from four Target Sets[8] of stresses: 1) Nebraska groundwater pumping, 2) Kansas groundwater pumping, 3) Colorado groundwater pumping, and 4) mound recharge. The Total Impact of these four Target Sets can be directly estimated only by computing the difference between two Model runs: a Model run with all Target Sets On and a Model run with all Target Sets Off. This comparison is the "VWS Metric", conceptualized by Kansas in a memo dated September 18, 2007[9].

The Model-calculated stream baseflows vary nonlinearly with the level of Target Set activity in some cases. Because the approach of the Current Accounting Procedures requires a linear response, the approach utilized by the Current Accounting Procedures (i.e., estimating each individual impact of the four Target Sets, and then summing them together to estimate the Total Impacts), fails to account fully for the Total Impacts in those non-linear cases. ***The arbitrator's ruling recognized the fundamental properties of a non-linear system, by stating that Nebraska's calculation of Virgin Water Supply, which utilized these Total Impacts, was superior to the process outlined in the Current Accounting Procedures.***

In many sub-basins only one or two of the four Target Sets has any impact on Virgin Stream Baseflow. For the cases in which only one Target Set has an impact on Virgin Stream Baseflow, the Current Accounting Procedures are adequate. An example of this is the Driftwood Creek sub-basin, which covers areas of both Kansas and Nebraska (figure 1). In this sub-basin, groundwater pumping in Nebraska is the only Target Set that has an impact on Virgin Stream Baseflow at the accounting point for Driftwood Creek. Reasons for this may include a relative lack of groundwater pumping in the Kansas portion of the Driftwood Creek sub-basin or that Driftwood Creek is only an intermittent stream (i.e., without stream baseflow) in and near Kansas.

Figure 10 shows the Virgin Stream Baseflow in Driftwood Creek and the Remaining Stream Baseflow with groundwater pumping in Nebraska. The Virgin Stream Baseflow values can be obtained from any Model run with Nebraska groundwater pumping Off. From figure 10 it can be observed that the Virgin Stream Baseflows varied between about 1,500 acre-feet and about 3,500 acre-feet per year from 1950 to 2006. This variability is due to the amount of recharge experienced in the Driftwood Creek sub-basin. In a given year, the maximum impact that groundwater pumping in Nebraska can have on Driftwood Creek will depend on the Virgin Stream Baseflow in that same year. This annual change in Virgin Stream Baseflow has an effect on impact accounting analogous to changing the scale capacity.

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[8] See Section 2.3.3 for discussion of the use of this term throughout this report.
[9] See Appendix B for discussion of the VWS Memo.

Figure 10. Virgin Stream Baseflow and Remaining Stream Baseflow for Driftwood Creek.

The Remaining Stream Baseflow is also the same for Driftwood Creek whether the other Target Sets (Kansas and Colorado groundwater pumping and the mound recharge) are On or Off. Note that, even with Nebraska groundwater pumping active, the Remaining Stream Baseflows are always significantly greater than zero (i.e., less than the scale capacity). The difference between the two lines in figure 10 is the magnitude of the impact of groundwater pumping in Nebraska to Virgin Stream Baseflow in Driftwood Creek. This result would be obtained with both the Current Accounting Procedures and with the Nebraska's Proposed Procedures.

To summarize this example, groundwater pumping in Nebraska is the only Target Set that has an impact on Virgin Stream Baseflows in Driftwood Creek and the impact of that groundwater pumping has never been greater than the Virgin Stream Baseflow in Driftwood Creek (i.e., the Remaining Stream Baseflow is always greater than zero). In terms of the scale analogy, we are only weighing one person and the impacted reading on our scale is always less than the scale capacity. Therefore, given the range of historic conditions experienced (i.e., recharge due to precipitation, canal leakage, and excess surface water irrigation, groundwater pumping), the relationship between groundwater pumping in Nebraska and Virgin Stream Baseflow in Driftwood Creek has been essentially linear.

Complications can complication can arise when more than one Target Set has an impact on stream baseflow and when Remaining Stream Baseflow reaches zero (i.e. scale capacity is reached). These complications and significant difficulties they can cause, when the Current Accounting Procedures are utilized, are explained by returning to the scale analogy.

4.3 Weighing Two People on a Scale (Two Target Set Analogy)

Consider further the question of a scale with a 300 pound scale capacity, but now with two people (Person A and Person B) each weighing 250 pounds. The weight of each person will also be referred to as their Potential Impact in this discussion. Because of the limitation of the scale capacity, the maximum impact these two people can have on this scale is 300 pounds. If they both step on the scale the reading will be 300 pounds; this will be referred to as the Total Impact caused by the two people being on the scale. Now consider, how much of that 300-pound Total Impact to the scale is caused by each person? There are several ways to test this. If both people are placed on the scale, then Person A could first step off the scale, and the scale readings with and without Person A on the scale could be compared. The reading with Person A and Person B on the scale is 300 pounds, and the reading with only Person B on the scale is 250 pounds, so the impact on the scale of Person A would be calculated as 50 pounds. Repeating the same process for Person B, with Person A back on the scale, would yield the same result, 50 pounds of impact generated by Person B.

Under this system, each person would be charged with causing 50 pounds of impact to the scale. These values will be referred to as the Apparent Impact of these two people. The sum of the Apparent Impact values is 100 pounds, in this case. Thus, of the Total Impact to the scale, 300 pounds, 200 pounds is unaccounted for. ***This set of calculations does not produce a realistic result in this example. This process is analogous to the Current Accounting Procedures.*** The portion of the Total Impact that is not accounted for as part of the Apparent Impact of the two people will be called the Unaccounted Impact (see table 2 for definitions of these and other terms to be used for the remainder of this discussion). This is represented by the following relationship:

Unaccounted Impacts = Total Impacts – Sum of Apparent Impacts

Based on this relationship, the assignment of impact ("Assigned Impact") to each person should be calculated as follows:

Assigned Impact = Apparent Impact + Appropriate Assignment of Unaccounted Impact

The Appropriate Assignment of Unaccounted Impact associated with each person is based on each person's physical ability to have caused those Unaccounted Impacts. This is the basis for Nebraska's Proposed Procedures.

Table 2. Definitions of impact terminology.

Term	Definition
Total Impact	The combined impact of all Target Sets evaluated simultaneously. This is also the Kansas VWS Metric.
Potential Impact	The maximum impact that a single Target Set can have. This is equal to the weight of a person up to the scale capacity in a one or two Target-Set situation.[10]
Apparent Impact	The impact estimate that is obtained when evaluating the impact of a Target Set in the presence of all other Target Sets. For example, the relative impact of a person on the scale when all other people are also on the scale. This is the result obtained from the Current Accounting Procedures.
Unaccounted Impacts	The difference between the Apparent Impacts of all Target Sets and the Total Impacts.
Appropriate Assignment of Unaccounted Impacts	The portion of the Unaccounted Impacts assigned to each Target Set based on that Target Sets ability to have caused the Unaccounted Impacts.
Assigned Impacts	The Apparent Impact plus the Appropriate Assignment of Unaccounted Impacts

In the application of the accounting rules in the preceding example, one or both person's impact on the scale has been significantly underestimated. The Total Impact is 300 pounds, and the methods employed through the Current Accounting Procedures have

[10] The Potential Impacts become somewhat more complex when more than two Target Sets contribute to the Total Impacts. This will be explored further in Section 4.2.

only apportioned 100 of those pounds (i.e., sum of Apparent Impacts above). A second approach to estimating each person's impact on the scale would be to start with neither of them on the scale, and then to have each individual step on the scale in its unimpacted (empty) state. Starting with a reading of zero pounds, and comparing this to a reading of 250 pounds with either person on the scale, we would determine that each person has an impact of 250 pounds on the scale. Although this may accurately represent each individual weight, or Potential Impact, the combination of these two values exceeds the scale capacity (i.e., Virgin Stream Baseflow). Consequently, this accounting process fails to produce a reasonable result. ***Remember, we are not interested in each person's weight; we are interested in each person's individual impact to the scale when both people are on the scale.*** In contrast to the Current Accounting Procedures, summing the Potential Impacts to the scale in this example would significantly overestimate the impact of one or both people toward the Total Impact to the scale of 300 pounds, because our individual estimates total 500 pounds, but the scale capacity (i.e., Virgin Stream Baseflow) is only 300 pounds.

Two additional ways could be used to estimate the contribution of each person's weight towards the Total Impact of 300 pounds, but they are both arbitrary[11]. For example, one could estimate the impact of Person A by placing him on the scale first, and then calculating the difference between the scale reading with no one on the scale (zero pounds) and the scale reading with Person A on the scale (250 pounds); one would conclude, as a result, that Person A caused 250 pounds of the Total Impact. The impact of Person B could then be estimated by calculating the difference in the scale reading with only Person A on the scale (250 pounds) and the scale reading with Person A and B on the scale (300 pounds); this would yield an additional impact by Person B of 50 pounds. Conversely, we could use the same process in the opposite order to estimate that Person B caused 250 pounds of the impact and Person A caused 50 pounds of impact. The preference for which of these two approaches is used would depend on perspective; each person may prefer the order that charges them with the least amount of the impact. Both of these approaches have the advantage of apportioning 300 pounds in total such that the Total Impacts is equaled but not exceeded, but they are both arbitrary and, for that reason, not desirable.[12]

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[11] The term arbitrary in this report is used to describe any situation in which an order for testing the impact of two or more Target Sets is needed, but there is no particular reason for the choice of the order for testing the two sets.

[12] An accounting method for the streamflow impacts that has an order might be acceptable if those impacts actually occurred in a certain order in time. For example, if Nebraska groundwater development occurred, and the effects of this development were fully realized at the stream before groundwater development occurred in Kansas and Colorado then an order of evaluating the impacts of Nebraska first may not be arbitrary. Kansas and Colorado could only cause impacts to any remaining streamflow after Nebraska had impacted it., the development of groundwater pumping and mound recharge happened more or less simultaneously throughout the Republican River Basin, however, making any ordering of the evaluation of impacts arbitrary.

So the question remains: how should the impact be apportioned between both people? To consider this question, suppose the scale capacity were to increase by ten pounds. With both Person A and Person B on the scale the Total Impact would increase to 310 pounds. Now, which person contributed the extra ten pounds of impact to the scale? With the methods already described, there is no way to distinguish which pounds of body weight from each person contributed to the extra ten pounds of impact on the scale. In fact, the Apparent Impact estimates for both people would increase by 10 pounds each. That is, the addition of 10 pounds to the scale capacity increases the Apparent Impact of each person from an estimate of 50 pounds, when the scale capacity is 300 pounds, to an estimate of 60 pounds, when the scale capacity became 310 pounds. From this, it would appear that both people fully caused the increased impact. This comparison is summarized in table 3. One can only conclude, based on the above procedure, that each person contributed equally (five pounds) to the additional impact (i.e., their Potential Impact exceeds their Apparent Impact). See Appendix C for additional discussion on this two Target Set analogy.

Table 3. Comparison of results for scale capacity of 300 and 310 pounds respectively with two people who each weigh 250 pounds.

Scale Capacity	Total Impact	Sum Potential Impacts	Sum Apparent Impacts	Unaccounted Impacts
300	300	500	100	200
310	310	500	120	190

Of course, this simple scale analogy cannot, and is not intended to, capture all the complexity of the Model and the Compact Accounting. Nevertheless, some of the concepts introduced by the scale example apply regardless of model complexity. These are summarized as follows:

1) If scale capacity is not exceeded then individual impacts can be easily determined by adding weight to the empty scale or subtracting weight from a loaded scale.

2) If the combined weights (sum of Potential Impacts) exceed the scale capacity, then different methods (i.e. adding vs. subtracting) produce different calculated impacts for each individual contributing weight.

3) In cases in which the sum of the Apparent Impacts does not equal the Total Impacts, an Appropriate Assignment of the Unaccounted Impact is required to ensure that the impacts assigned to each individual add up to the same amount as the Total Impact registered on the scale.

4.4 Impact of Two Target Sets in the Republican River Main Stem

The Current Accounting Procedures do not properly account for the Total Impacts to Virgin Stream Baseflow. This problem is most evident in the Republican River Main Stem reach between Swanson Lake and Harlan County Lake (Swanson-Harlan Reach). This reach lies between the accounting point below Swanson Lake and the accounting point above Harlan County Lake (see figure 6). The three key concepts developed in Section 4.3 will assist in understanding this problem and developing a solution.

Groundwater pumping in Nebraska and the mound recharge are the two Target Sets that cause most of the impacts to Virgin Stream Baseflow in this reach[13]. Contrary to the scale analogy presented in Section 4.3, these Target Sets have an opposing impact on Virgin Stream Baseflow. In spite of this difference, the key concepts developed from the scale analogy are still valid. The Current Accounting Procedures significantly misestimate the combined impact of groundwater pumping in Nebraska and the mound recharge in this reach. The effect on Compact Accounting results is substantial and particularly detrimental to Nebraska.

4.4.1 Demonstration of Problem with Current Accounting Procedures

The discussion begins by considering the Total Impact of groundwater pumping and mound recharge computed as the difference between the Virgin Stream Baseflow (all Target Sets Off) and the Remaining Stream Baseflow with all Target Sets On. These are then compared with the sum of the Apparent Impacts of these two Target Sets using the Current Accounting Procedures. These values are plotted in figure 11. The sum of the Apparent Impacts generally matches the Total Impacts for the period up to around 1980, and then this value is generally greater than the Total Impacts. This discrepancy increases substantially after the year 2000. The difference between these Total Impacts and the sum of the Apparent Impacts derived using the Current Accounting Procedures is shown in figure 12. This difference represents the Unaccounted Impacts, which, in this case, is a negative value.

[13] Groundwater pumping in Kansas and Colorado do have very small impacts to this reach in some years; these are neglected to simplify this discussion.

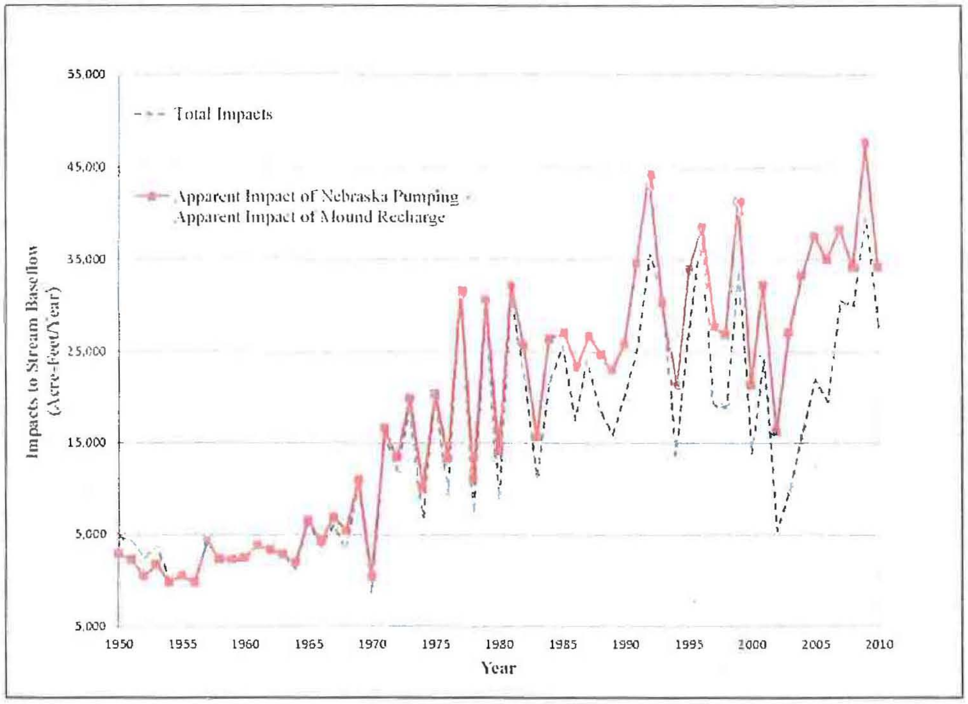

Figure 11. Comparison of the Total Impacts and the sum of Apparent Impact of Nebraska pumping and mound recharge for the Swanson-Harlan Reach.

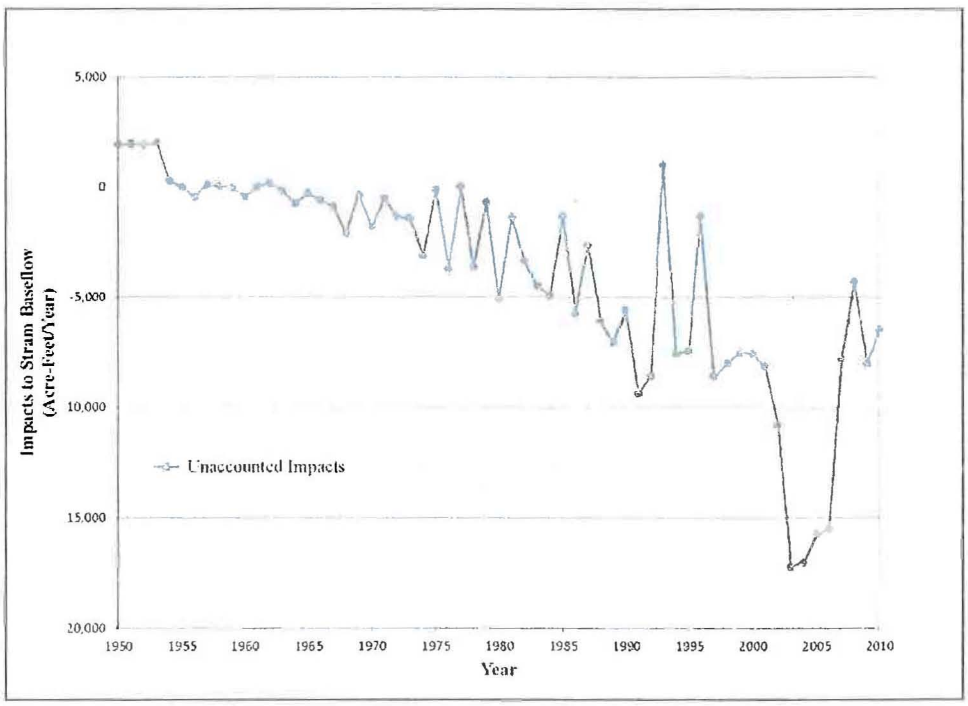

Figure 12. The Unaccounted Impacts for the Swanson-Harlan Reach.

This result is similar to the issue encountered when the Current Accounting Procedures are applied to the problem of weighing two people whose combined weight exceeds the scale capacity. Specifically, the Current Accounting Procedures assign a combined impact to the two Target Sets that differs from the Total Impacts to Virgin Stream Baseflow. In this case, the Current Accounting Procedures produces Apparent Impact values that, when summed, are greater than the Total Impacts, resulting in a negative value for the Unaccounted Impacts. This occurs because the Target Sets of stresses in the Swanson-Harlan Reach impact stream baseflow in opposite directions (groundwater pumping decreases Virgin Stream Baseflow, mound recharge increases Virgin Stream Baseflow). This situation was not specifically discussed in terms of the scale analogy, but it is nonetheless compatible with it. The useful concepts from the scale analogy, summarized at the end of Section 4.3, still hold.

The reasons for the Unaccounted Impacts displayed in figure 12 are technically complex; they are discussed in detail in prior reports (NDNR et al., 2008; Ahlfeld et al., 2009). Some insight into the underlying reasons can be gained from figure 13 which shows the Apparent Impact of the mound recharge and groundwater pumping in Nebraska. Note that the Apparent Impact of groundwater pumping increases overall until around 1980 and are generally between 30,000 and 50,000 acre-feet per year after 1980. The Apparent Impact of the mound recharge (i.e., IWS Credit) increases steadily throughout this entire time period up to about 2000. This trend is expected because the mound recharge generally occurs at some distance from the Main Stem and its tributaries and the impact of mound recharge should grow slowly and steadily over time, in spite of any short-term variability in actual mound recharge rates.

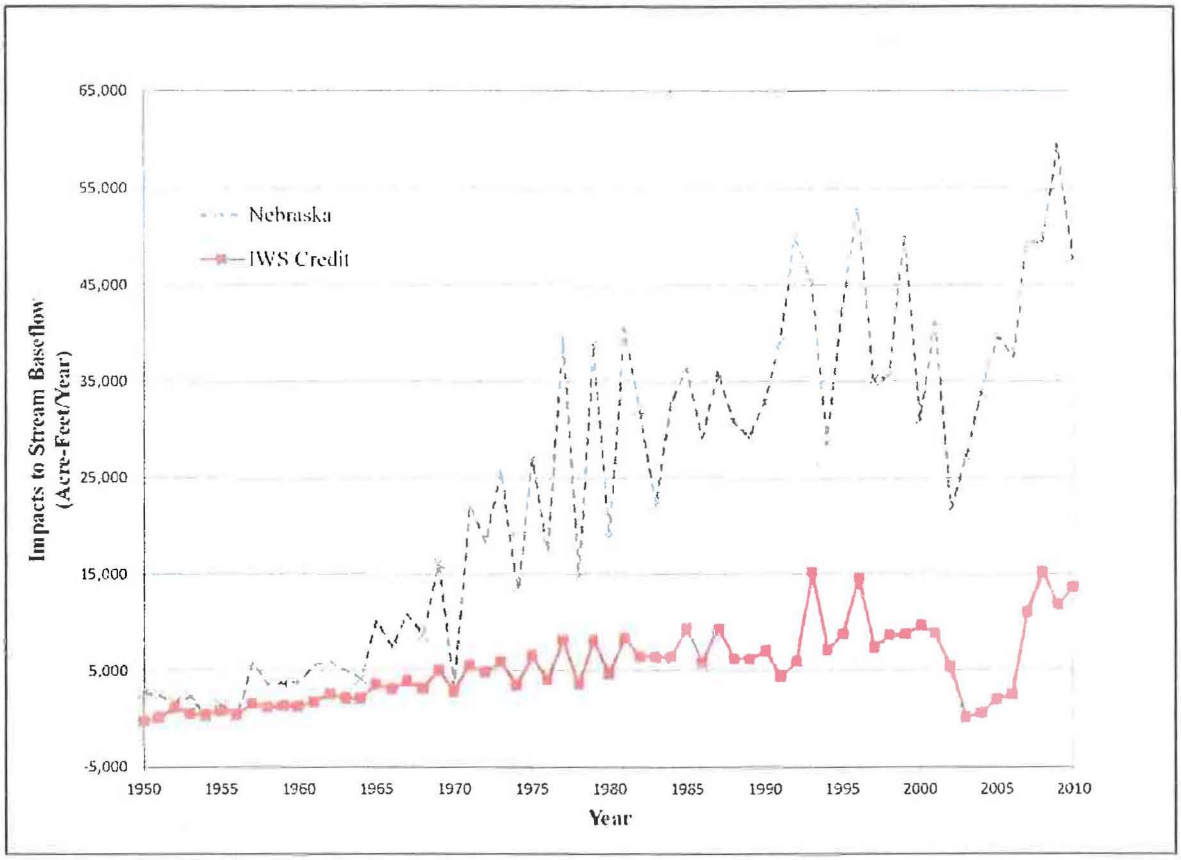

Figure 13. Apparent Impact of Nebraska pumping and mound recharge for the Swanson-Harlan Reach. The IWS Credit is computed as a positive value and subtracted from the impact of groundwater pumping to account for its opposite effect from groundwater pumping.

What is surprising in figure 13 is the sudden change in this increasing trend at about 2000, when the Apparent Impact of mound recharge is reduced to zero or near zero. This anomalous decrease in IWS Credit results from a significant failure in Compact accounting that is detrimental to Nebraska. The harm to Nebraska is essentially 51% of the value shown in figure 12 (see Appendix D), and the magnitude of this harm on Nebraska's annual Compact accounting balance[14] in this reach is shown in figure 14. As long as the Total Impacts are represented properly in the accounting, so that there are no Unaccounted Impacts, a reasonable result is obtained. The effect on Nebraska's annual Compact accounting balance has been approximately 8,000 acre-feet per year in recent years[15]. So, approximately eighty percent of the Basin-wide effect (10,000 acre-

[14] Nebraska's annual Compact balance is calculated as Allocation – (CBCU – IWS Credit).

[15] A positive value in terms of the effect on Nebraska's annual accounting results reflects a value that is detrimental to Nebraska.

feet; see Section 6) in recent years on Nebraska's annual Compact accounting balance, resulting from the failure of the Current Accounting Procedures, originates in the Swanson-Harlan Reach.

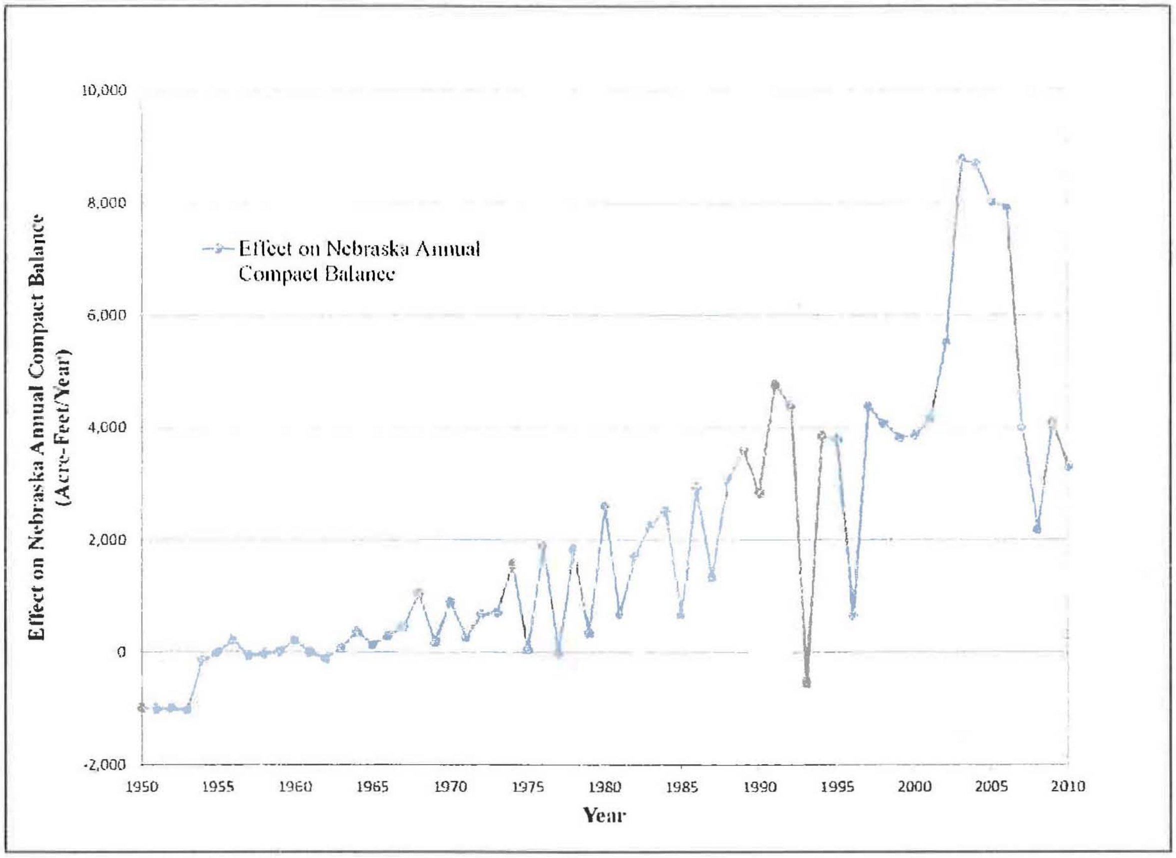

Figure 14. The effect of the Unaccounted Impacts in the Swanson-Harlan Reach on Nebraska's annual Compact balances. A positive value indicates a ***detriment*** to Nebraska's Compact balance.

4.4.2 Future Benefit of the Mound Recharge

The harm to Nebraska in the Swanson-Harlan reach from the Current Accounting Procedures results because the impacts of Nebraska groundwater use and mound recharge are regarded as separate Target Sets in this reach, although no essential reason exists for separating these two Target Sets for the purposes of Compact accounting. If these two Target Sets had been combined together as one Target Set, this problem would not arise in the Swanson-Harlan Reach, and the Unaccounted Impacts in that reach would be zero or near zero.

The recognition of the IWS Credit was critical to Nebraska's agreeing to the terms of the FSS. The mound recharge, approximately 500,000 acre-feet per year, transfers water from the Platte River Basin to the Republican River Basin, thereby increasing water supplies in the Republican River Basin. The intent of including the IWS Credit in the FSS was to recognize this benefit, which provides Nebraska with the incentive to continue this practice.

The misestimations of the impacts of Nebraska pumping and mound recharge derived from the Current Accounting Procedures may create an unrealistic result. This is clearly illustrated by analyzing the scenario offered by Kansas in its filing to the Supreme Court (Kansas petition C20)[16]. Generally speaking, this future scenario described in Kansas' filing simulates average climatic and water-use conditions for a future period of 50 years, beginning in 2009. The Kansas filing shows the impact of Nebraska groundwater pumping over this period under these conditions. For the sake of simplicity, it is more appropriate to combine the impact of Nebraska groundwater pumping and mound recharge to represent the combined impact of activities of man in Nebraska on the VWS. To understand better the failures of the Current Accounting Procedures, Nebraska utilized this same scenario, running it for two conditions: 1) the mound recharge is continued, and 2) the mound recharge is not continued[17]. Conceptually speaking, the combined impact of Nebraska groundwater pumping and mound recharge should be less, with the continuation of the mound recharge, than it would be if the mound recharge were not continued. Otherwise, no credit for Nebraska from the mound recharge could be possible.

Figure 15 shows the combination of the Apparent Impacts of groundwater pumping in Nebraska and mound recharge for the entire Basin (CBCU - IWS Credit), under Kansas' average conditions scenario and using the Current Accounting Procedures. This figure illustrates the value of the (CBCU – IWS Credit) computation that would result with the continuation of mound recharge. It then shows the value of the (CBCU – IWS Credit) computation that would result if the mound recharge were not continued.

Nebraska is more likely to have a negative annual Compact accounting balance when the value for (CBCU – IWS Credit) increases. As can be seen from figure 15, all other things being equal, Nebraska's annual Compact accounting balances in the future would receive no benefit from the mound recharge. Further, Nebraska's annual Compact accounting balances in the future would actually be improved [i.e., (CBCU-IWS Credit) is decreased] if the mound recharge was not continued.

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[16] The files were obtained in July 2011 from http://dwr.kda.ks.gov/20110725Production/KS000010 rrca_model_data.zip

[17] Under this scenario, all recharge associated with the mound is discontinued. It would be as if the diversion of water from the Platte River into the canals south of the Platte River were permanently discontinued.

In short, the Current Accounting Procedures produce the absurd result that the continuation, of groundwater recharge by Nebraska, in amounts in excess of approximately 500,000 acre-feet per year, will cause greater harm toward Nebraska's future compliance efforts than recharging no water at all. This is directly contrary to a reasonably-anticipated conclusion that recharging water should, logically, increase stream baseflows. This accounting outcome fails to reflect the actual benefits of the mound recharge.

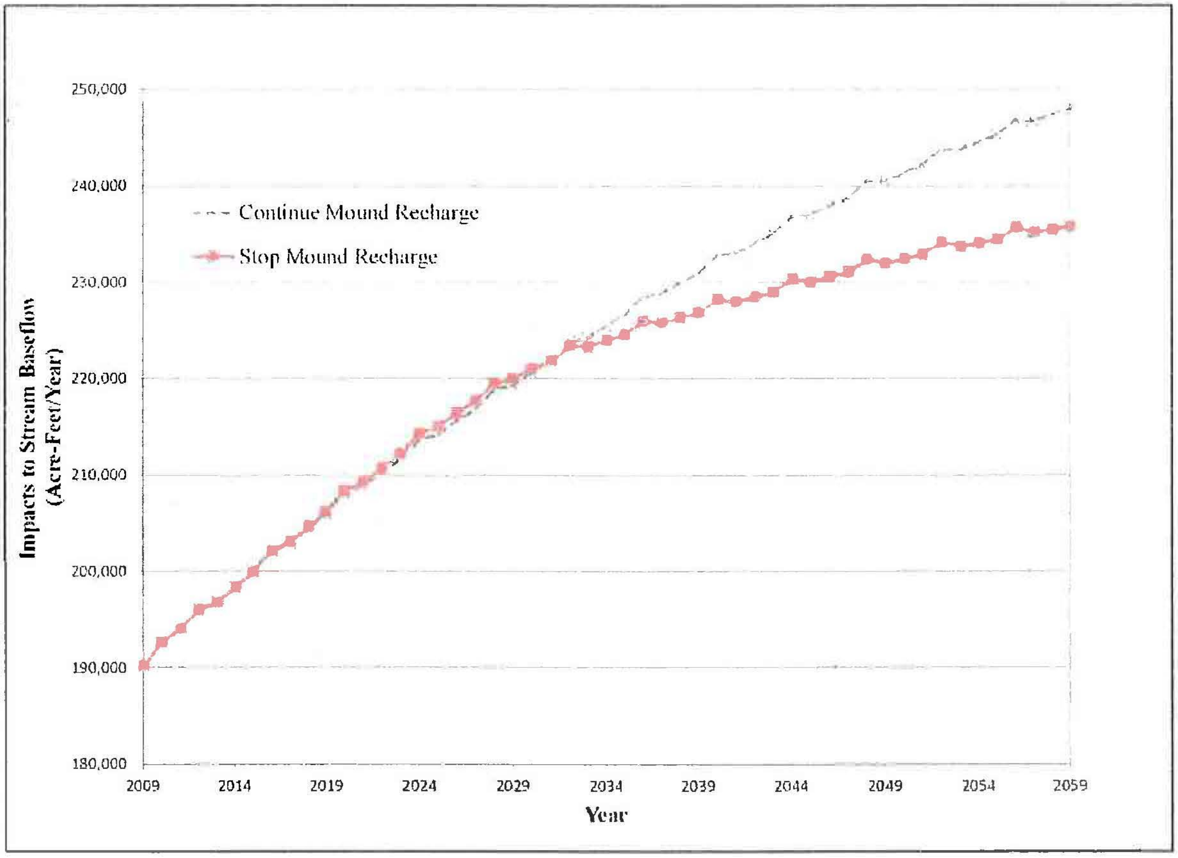

Figure 15. Basin-wide Apparent Impacts of Nebraska pumping and mound recharge (CBCU-IWS Credit) under the Kansas future scenario with mound recharge continuing and mound recharge not continuing. The difference between these two lines was previously illustrated in figure ES-2.

4.5 Impacts in other Sub-basins and Basin-wide

The Current Accounting Procedures also fail to account for the Total Impact due to groundwater pumping and mound recharge in numerous other sub-basins and Main Stem reaches. Figure 16 shows the Unaccounted Impacts for other sub-basins for which the Apparent Impacts of the two or more Target Sets do not equal the Total Impacts.

Detailed technical analysis for some of these sub-basins can be found in NDNR et al. (2008) and Ahlfeld et al. (2009). In some cases, the sum of Apparent Impacts is less than the Total Impact (shown as positive Unaccounted Impacts in figure 16), and, in other cases, the sum of Apparent Impacts is greater than the Total Impacts (shown as negative Unaccounted Impacts in figure 16). Using procedures that yield more scientifically reasonable and realistic results, the values in figure 16 would always be zero. Nebraska's Proposed Procedures accomplish just this anticipated result.

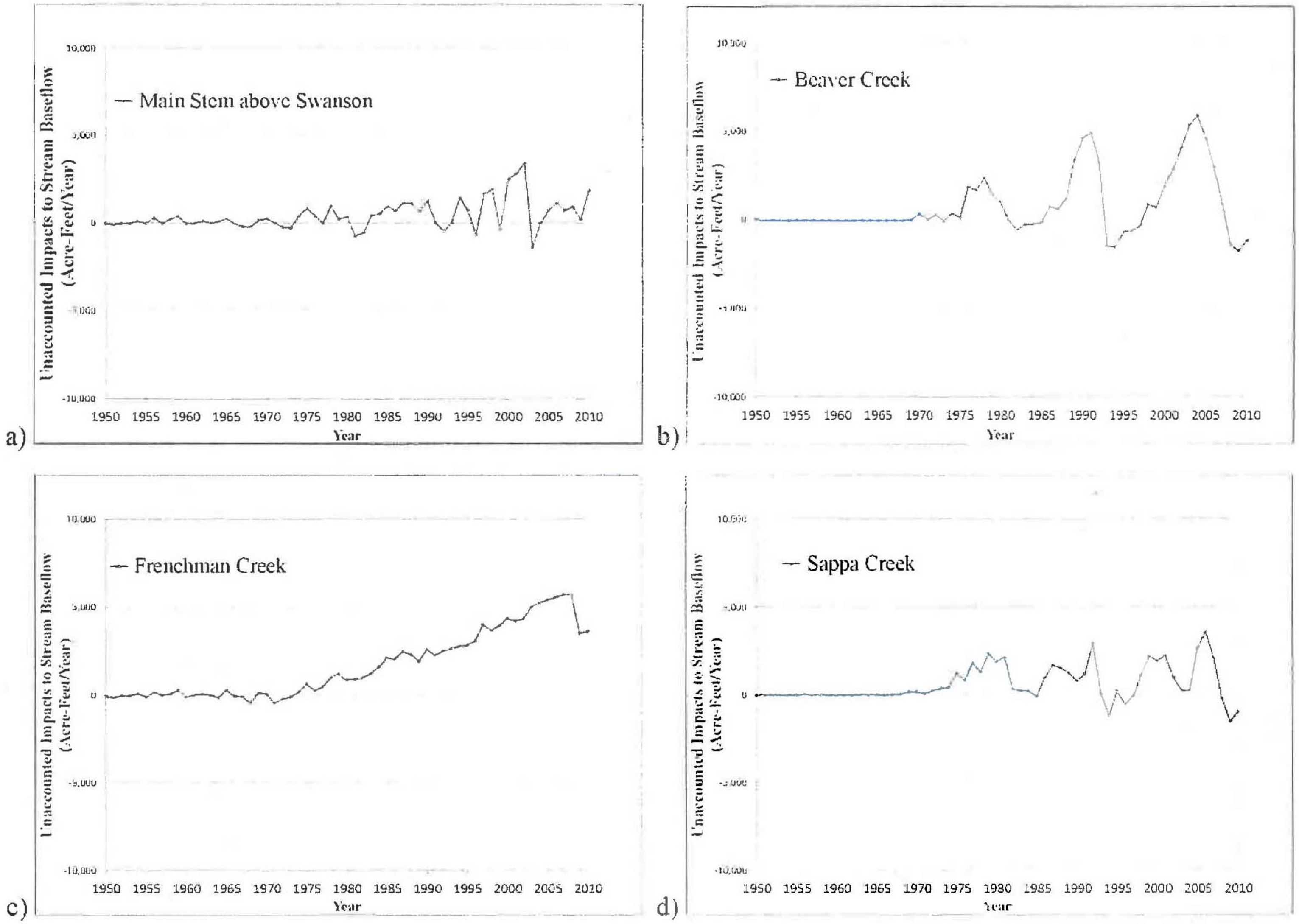

Figure 16. The Unaccounted Impacts for a) the Main Stem above Swanson, b) Beaver Creek, c) Frenchman Creek, and d) Sappa Creek.

Recall from Section 4.4.1 that the Unaccounted Impacts in the Swanson-Harlan Reach were negative (figure 12). Notice that for many of the sub-basins and years in figure 16, the Unaccounted Impacts are positive. If the Unaccounted Impacts are summed for the entire Basin, these problems are masked because, in many years, negative and positive values roughly balance each other (figure 17). This is a false assessment of this problem, however, for several reasons. First, the various sub-basins and the Main Stem all have different Allocations assigned to each of the three states out of the sub-basins. Second, regarding the impacts of groundwater pumping, the presence and magnitude of each state's impact on the sub-basins and the Main Stem vary across the Basin. Finally, and most importantly, the accounting problems that arise in the sub-basins and Main Stem reaches impacted primarily by mound recharge and Nebraska groundwater pumping (e.g., Swanson-Harlan Reach) dramatically impact Nebraska, as discussed in Section 4.4.1 and shown in figure 14. ***The Unaccounted Impacts in the Swanson-Harlan Reach cannot be balanced under current Compact accounting by additional Unaccounted Impacts in other sub-basins.*** In other words, these two wrongs do not make it right. The Unaccounted Impacts in the other sub-basins simply add to the total problem of adverse effects on Nebraska's annual Compact accounting balance.

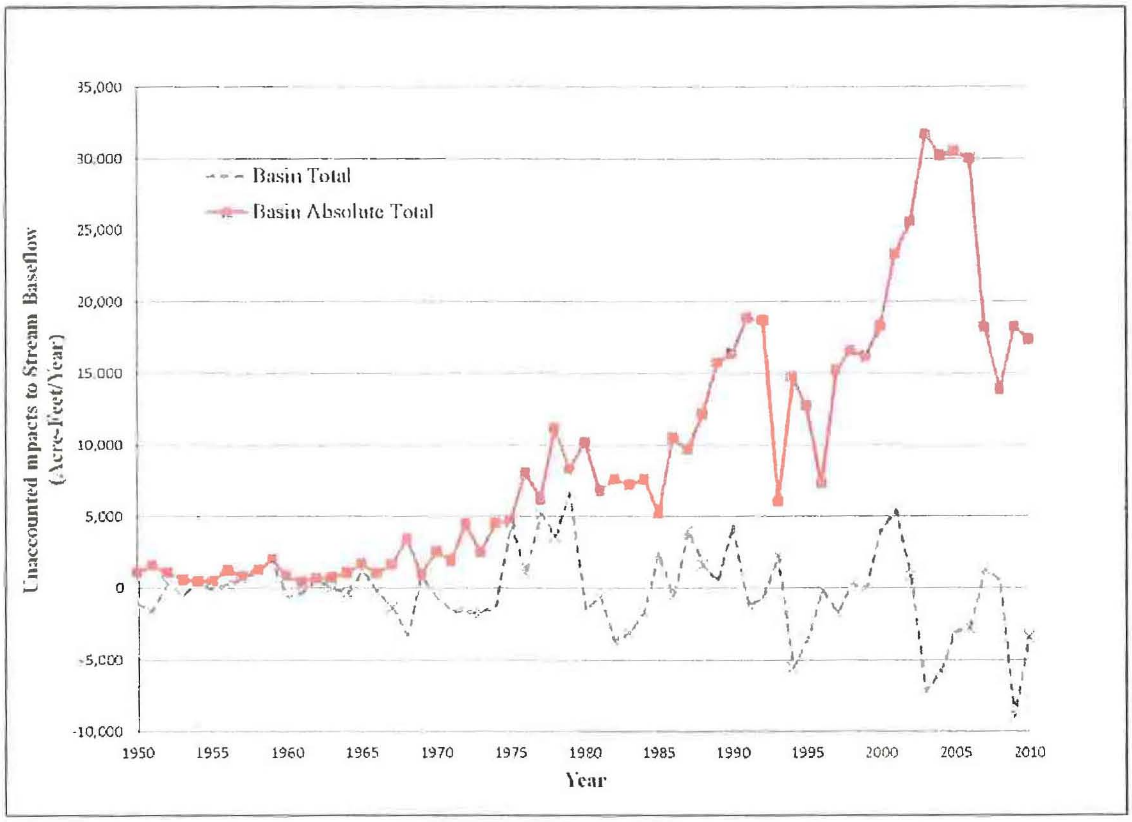

Figure 17. The sum of Unaccounted Impacts for the entire Basin (Basin Total), and the sum of the absolute value of the Unaccounted Impacts for the entire Basin (Basin Absolute Total).

Computing the absolute values[18] of the Unaccounted Impacts shows the full magnitude of the failure of the Current Accounting Procedures across the Basin. All values are assigned a positive sign, and then summed together as shown by the Basin Absolute Total in figure 17. In recent years the total magnitude of the Unaccounted Impacts has been approximately 30,000 acre-feet per year. The failure of the Current Accounting Procedures has deprived Nebraska of Compact entitlements of up to 10,000 acre-feet per year in recent years, as shown in Section 6.1.

[18] The absolute value of a number is the numerical value of that number regardless of its sign. The absolute value of a number can be thought of as its distance from zero.

5.0 THE SOLUTION

As demonstrated in Section 4, the problem with the Current Accounting Procedures occurs in many sub-basins and Main Stem reaches. Four total Target Sets are present in Republican River Compact Accounting, and the number of individual Target Sets involved in determining impacts from these Target Sets varies by sub-basin/Main Stem reach and over time. Therefore, a solution that can deal with any combination of these four Target Sets is developed below. The changes to the RRCA Accounting Procedures and Reporting Requirements (revised August 8, 2010) required to implement Nebraska's Proposed Procedures are explained in Appendix E.

5.1 Criteria for Appropriate Solution

Several important general qualities are desirable in any procedure that is used to estimate the quantity of something (e.g., the individual impact of two people on a scale or of two Target Sets on Virgin Stream Baseflow). First, the procedure needs to produce reasonable and realistic results. Second, the procedure should not be arbitrary. When no reason to apply any ordering exists, the assignment of impacts should not depend on an arbitrary ordering.

In order to develop, Nebraska's Proposed Procedures, two criteria were defined to be consistent with these qualities. The first criterion is that Nebraska's Proposed Procedures should produce individual values for impacts of Target Sets that when summed together are equal to the Total Impact of the combination of the Target Sets. This concept is identical to the VWS Metric proposed by Kansas (Appendix B). This criterion meets the requirement for apparently realistic results, but, more precisely, the results should not just seem realistic but should be verifiable and reproducible by a separate test. This process of verification involves running the Model with all Target Sets On, running the Model with all Target Sets Off, and comparing the resulting stream baseflows.

The second criterion is that impacts should be determined using the same modeling approach used in the Current Accounting Procedures, and when the Current Accounting Procedures already meet the first criterion, the result of Nebraska's Proposed Procedures should be identical. Thus, in addition to the general qualities that the accounting process produce realistic results and not be arbitrary, the following specific criteria are also met in development of Nebraska's Proposed Procedures:

1) The sum of the individually derived impacts should equal the Total Impacts.

2) The result obtained from Nebraska's Proposed Procedures should be identical to that of the Current Accounting Procedures in all cases in which the Current Accounting Procedures' results already satisfy criterion (1) above. This also

means that any given Target Set would only be simulated as fully On or fully Off[19].

Nebraska Proposed Procedures, outlined below, are consistent with these criteria.

5.2 Nebraska's Proposed Procedures

As previously mentioned, four Target Sets are applied in the Model in the Republican River Compact Accounting: 1) groundwater pumping in Nebraska, 2) groundwater pumping in Kansas, 3) groundwater pumping in Colorado, and 4) the mound recharge. The number of combinations that are possible for a given number of Target Sets, assuming each Target Set is either fully On or fully Off, is equal to 2^n (two to the power of n), where n is equal to the number of Target Sets of interest. For the case in which four Target Sets are of interest, the total number of combinations is equal to 16 ($2^n = 2^4$ = two to the power of four = 2 * 2 * 2 * 2 = 16). These are shown in table 4.

Nebraska's Proposed Procedures utilize the Model to complete simulations that represent these 16 combinations. The letters in the Run Name column represent which Target Set is On during the run. For instance, C indicates that groundwater pumping in Colorado is On, K indicates that groundwater pumping in Kansas is On, N indicates that groundwater pumping in Nebraska is On, and M indicates that the mound recharge is On. The symbol θ (the Greek letter "Theta") is used to indicate the model run with all four Target Sets Off.

The output of Model run θ includes the Virgin Stream Baseflows in the sub-basins and Main Stem reaches. The other runs represent the Remaining Stream Baseflow in the presence of one or more of the Target Sets of stresses. Table 5 shows the combinations of Model runs that represent the Apparent Impact calculation obtained from the Current Accounting Procedures.

Recall that the Unaccounted Impacts are the difference between the Total Impacts and the sum of Apparent Impacts:

Unaccounted Impacts = Total Impacts – Sum of Apparent Impacts.

[19] This criterion was separated into two criteria in earlier reports (NDNR et al., 2008; Ahlfeld et al., 2009).

Table 4. The 16 potential combinations of Target Sets with each Target Set either fully On or fully Off.

Run Name	Colorado Pumping	Kansas Pumping	Mound Recharge	Nebraska Pumping
Θ	OFF	OFF	OFF	OFF
CKMN	ON	ON	ON	ON
CKM	ON	ON	ON	OFF
CMN	ON	OFF	ON	ON
CKN	ON	ON	OFF	ON
KMN	OFF	ON	ON	ON
CK	ON	ON	OFF	OFF
CM	ON	OFF	ON	OFF
CN	ON	OFF	OFF	ON
KM	OFF	ON	ON	OFF
KN	OFF	ON	OFF	ON
MN	OFF	OFF	ON	ON
C	ON	OFF	OFF	OFF
K	OFF	ON	OFF	OFF
M	OFF	OFF	ON	OFF
N	OFF	OFF	OFF	ON

When the sum of the Apparent Impact values is equal to the Total Impacts, there are no Unaccounted Impacts and the result of the calculations in table 5 is adequate. When there are Unaccounted Impacts, these must be assigned to each Target Set in some manner by combining some portion of the Unaccounted Impact with the Target Set's Apparent Impact. This assignment must be based on the Targets Set's ability to have caused the Unaccounted Impact. In Nebraska's Proposed Procedures, this is accomplished by using the difference of the Potential Impact and the Apparent Impact. In contrast to the situation with only two Target Sets, the evaluation of Potential Impact with four Target Sets is complex. For each Target Set of interest, eight differences can be evaluated, in which the Target Set is On in one Model run and Off in another Model run, while all other Target Sets remain unchanged. These are all considered in developing the methodology for determination of the Potential Impact for each Target Set, as described in Appendix F.

Table 5. The Apparent Impact calculations used in the Current Accounting Procedures.

Calculation	Result
CKMN-KMN	Apparent Impact of Colorado pumping
CKMN-CMN	Apparent Impact of Kansas pumping
CKN-CKMN[20]	Apparent Impact of mound recharge
CKMN-CKM	Apparent Impact of Nebraska pumping

The basic equation for calculating the Assigned Impact with four Target Sets is:

Assigned Impact = Apparent Impact + [(Potential Impact – Apparent Impact)/4]

Combining the Potential Impact with the Apparent Impact according to this equation, and rearranging terms yields the following equations for determining the Assigned Impact for these four Target Sets:

Assigned Impact of groundwater pumping in Colorado = [(θ-C) + ((K-CK) + (M-CM) + (N-CN))/3 + ((KM-CKM) + (KN-CKN) + (MN-CMN))/3 + (KMN-CKMN)]/4

Assigned Impact of groundwater pumping in Kansas = [(θ-K) + ((C-CK) + (M-KM) + (N-KN))/3 + ((CM-CKM) + (CN-CKN) + (MN-KMN))/3 + (CMN-CKMN)]/4

Assigned Impact of groundwater pumping in Nebraska = [(θ-N) + ((C-CN) + (M-MN) + (K-KN))/3 + ((CM-CMN) + (CK-CKN) + (KM-KMN))/3 + (CKM-CKMN)]/4

Assigned Impact of mound recharge = [(M-θ) + ((CM-C) + (KM-K) + (MN-N))/3 + ((CKM-CK) + (CMN-CN) + (KMN-KN))/3 + (CKMN-CKN)]/4

These are Nebraska's Proposed Procedures. Application of these equations, utilizing the appropriate Model output for each Model run, produces results that:

[20] The differences in this equation, and all other equations for calculation of the impact of mound recharge (IWS Credit) are reversed to produce a positive result. The convention in Compact Accounting is to represent the IWS Credit as a positive value, then to subtract it in the accounting to generate a "credit." The effect is the same as producing a negative value and then adding it into the Accounting balances.

o

- Always fully distribute any Unaccounted Impacts, such that the sum of these impact estimates always equals the Total Impacts;
- Always produce the same results as the Current Accounting Procedures when there are no Unaccounted Impacts; and
- Always produce the same results as the simpler equations for two Target Sets (see Appendix C) when there are only two Target Sets that impact a given sub-basin or Main Stem reach.

Examples of these cases using the scale analogy are presented in Appendix G.

5.3 Application to the Swanson - Harlan Reach

For the purpose of demonstrating the effect of the Nebraska's Proposed Procedures relative to the Current Accounting Procedures, results are presented for the Swanson-Harlan Reach for groundwater pumping in Nebraska and for mound recharge. Kansas and Colorado both have minor impacts to this reach in some years. Nebraska's Proposed Procedures produce individual values for the impact of groundwater pumping and mound recharge that sum to the Total Impact of these Target Sets on the Swanson to Harlan Reach. Recall that Nebraska's Proposed Procedures start with the Apparent Impact (result of Current Accounting Procedure) and add an Appropriate Assignment of the Unaccounted Impacts (if any) to each Target Set based on their ability to have caused the Unaccounted Impacts.

Figures 18 and 19 show the Apparent Impacts and Assigned Impacts from Nebraska's Proposed Procedures for groundwater pumping in Nebraska and mound recharge, respectively. Notice that Nebraska's Proposed Procedures only produce a different result when Unaccounted Impacts exist. The same is true for the impact due to groundwater pumping in Kansas and the mound recharge. The difference between the Apparent Impact and the Assigned Impact is roughly proportional to the difference between the Potential Impact and the Assigned Impact. This is because only two Target Sets (Nebraska groundwater pumping and mound recharge) have a significant effect on Virgin Stream Baseflow in this reach.

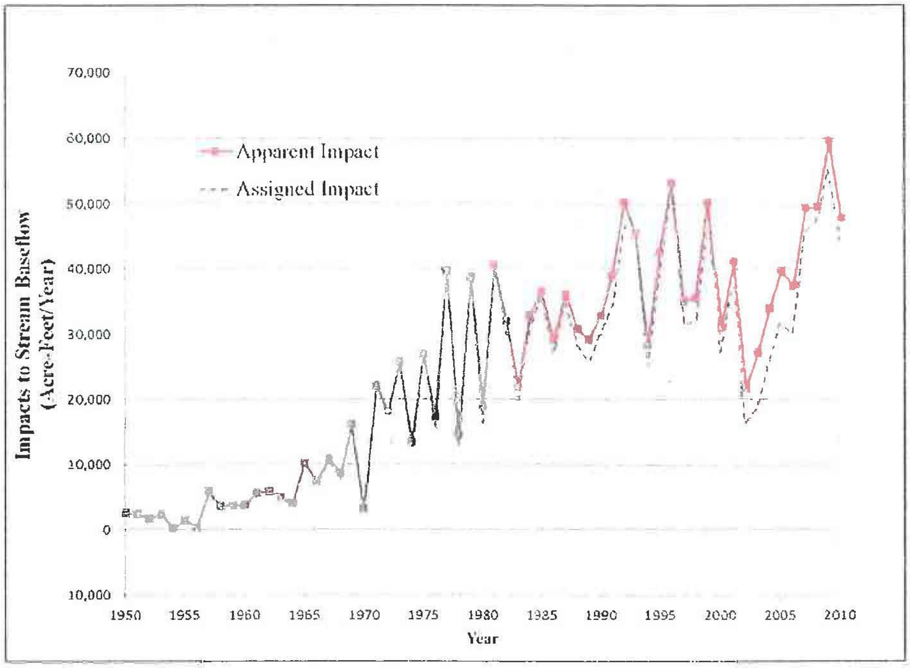

Figure 18. The Assigned Impact and the Apparent Impact for groundwater pumping in Nebraska in the Swanson-Harlan Reach.

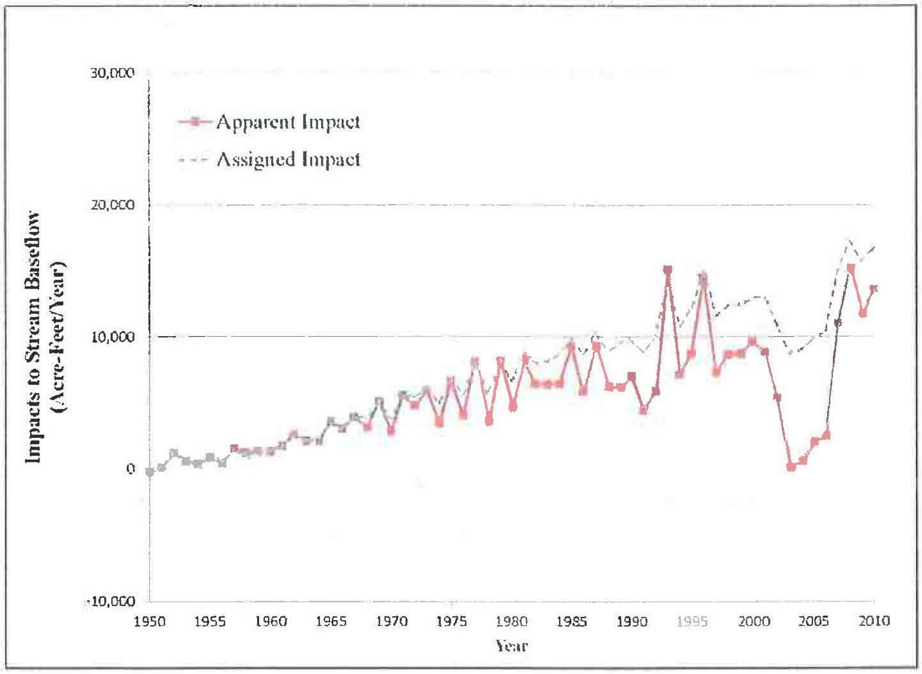

Figure 19. The Assigned Impact and the Apparent Impact for mound recharge in the Swanson-Harlan Reach.

The Appropriate Assignment of Unaccounted Impacts is approximately equally split between Nebraska groundwater pumping and mound recharge (figure 20). The Unaccounted Impacts assigned to groundwater pumping in Kansas and Colorado are essentially zero. Therefore, the Assigned Impact from Nebraska's Proposed Procedures is essentially equal to the results of the Current Accounting Procedures for these two Target Sets. This is because Kansas groundwater pumping and Colorado groundwater pumping have little or no ability to cause the Unaccounted Impacts in this reach.

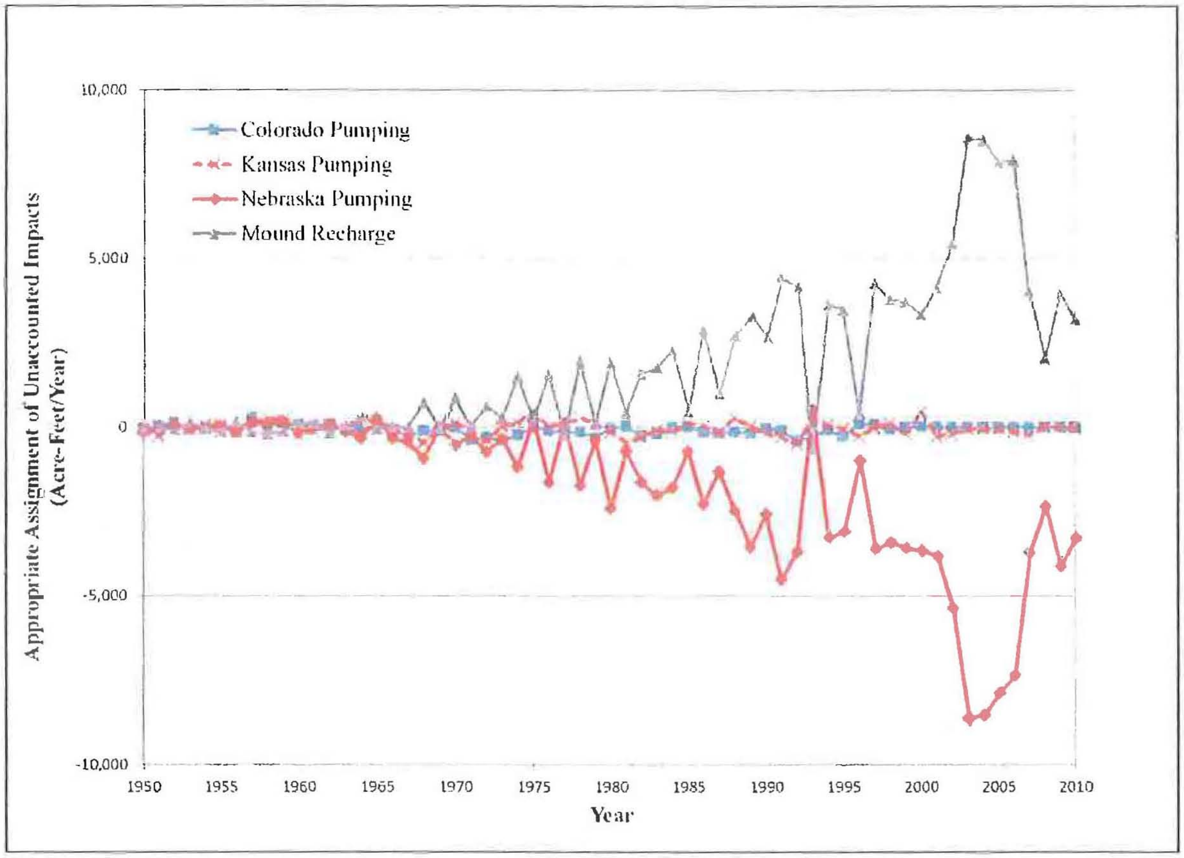

Figure 20. The Appropriate Assignment of Unaccounted Impacts for Colorado groundwater pumping, Kansas groundwater pumping, Nebraska groundwater pumping and mound recharge in the Swanson-Harlan Reach.

5.4 Future Benefit of Mound Recharge under Proposal

Recall from Section 4.4.2 (see figure 15) that the Current Accounting Procedures produce an absurd result with respect to the benefit of continued mound recharge. Using the future scenario developed by Kansas, the Current Accounting Procedures would make it appear that continuing the mound recharge would actually be harmful to the Basin and to Nebraska's compliance ability in the future. Mound recharge is an activity of man that actually increases the water supply of the Basin; the FSS recognized that Nebraska should receive full credit for that beneficial activity. Under the Current Accounting Procedures, for the simulations presented here, the continuation of the mound recharge is detrimental to Nebraska.

Figure 21 shows the same information for the same scenario shown in figure 15 above, except that the depletions due to groundwater pumping in Nebraska and the mound recharge are determined using Nebraska's Proposed Procedures. Under these latter procedures, the continuation of the IWS recharge actually does create a credit for Nebraska and if the mound recharge were to be permanently discontinued (all other things being equal) Nebraska's annual Compact balance would be diminished. This is a reasonable result. This is a perfect example of how Nebraska's Proposed Procedures address the issues arising from the application of the Current Accounting Procedures in certain instances.

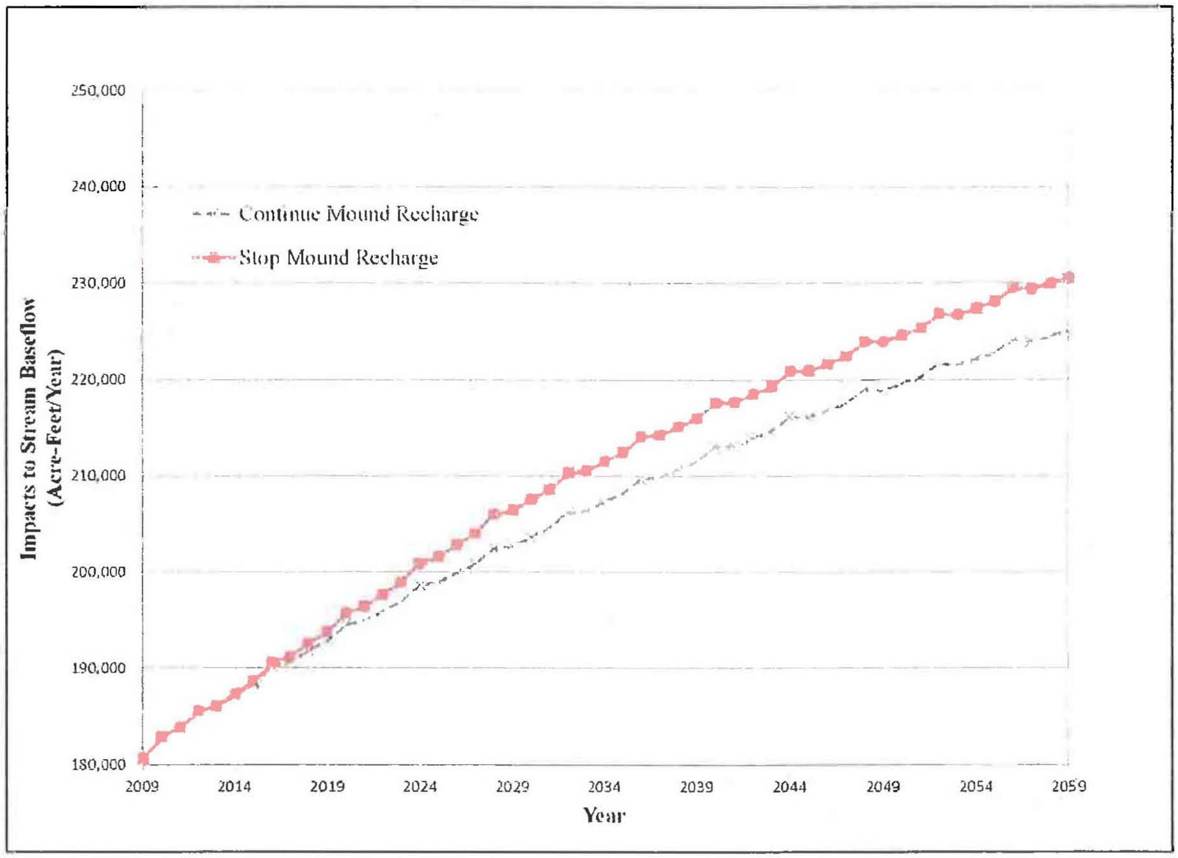

Figure 21. Basin-wide Assigned Impact of Nebraska pumping and mound recharge (CBCU-IWS Credit) under the Kansas future scenario with mound recharge continuing and mound recharge not continuing. The difference between these two lines was previously illustrated in figure ES-3.

6.0 SIGNIFICANCE

In Section 4, the problem with the Current Accounting Procedures in the Swanson-Harlan Reach was analyzed. The results of the Current Accounting Procedures cause harm to Nebraska's annual Compact accounting balances, in amounts exceeding 8,000 acre-feet per year in recent years. Using Nebraska's Proposed Procedures developed in Section 5, the annual Compact accounting balances from previous years can be computed in a manner that accounts for the Total Impacts. In this section, the Basin-wide effect of this problem, if left unresolved, will be illustrated for past and future years. In the recent past, the basin-wide harm to Nebraska was approximately 10,000 acre-feet per year. The potential effect of this problem in future years may exceed 20,000 acre-feet per year.

6.1 Results of Previous Accounting

Figure 22 shows the net change (Nebraska's Proposed Procedures minus Current Accounting Procedures) in Nebraska's annual Compact accounting balance[21] calculated back to 1981. Note several things from this graph. First of all, the Current Accounting Procedures are always detrimental to Nebraska. In one year (1993), the difference was very nearly zero. Otherwise, the difference has generally been at least 1,000 acre-feet per year. Second, for the period 1981-2000, the difference was generally between 1,000 and 5,000 acre-feet per year; the five-year moving average was generally between 2,000 and 4,000 acre-feet per year; and the average difference was about 3,300 acre-feet per year. The difference slowly increases by about 150 acre-feet per year during this period. Also note that, during the drought of 1988-1991, no significant change in this discrepancy can be seen. Next, notice that for the period after 2000, the difference increases dramatically. The average difference during this time period is about 8,000 acre-feet per year. In four of these years, including the period 2005-2006, the difference is approximately 10,000 acre-feet per year. Based on the trend from 1981-2000, even if this issue had been fully understood at the time of the settlement, this level of discrepancy should not have been expected until the year 2035. Although any discrepancy is unacceptable, this alarming increase in recent years, coming during a critical dry period with regard to Compact compliance, underscores the importance of resolving this issue.

[21] These Compact balances were derived from Table 3C of accounting procedures.

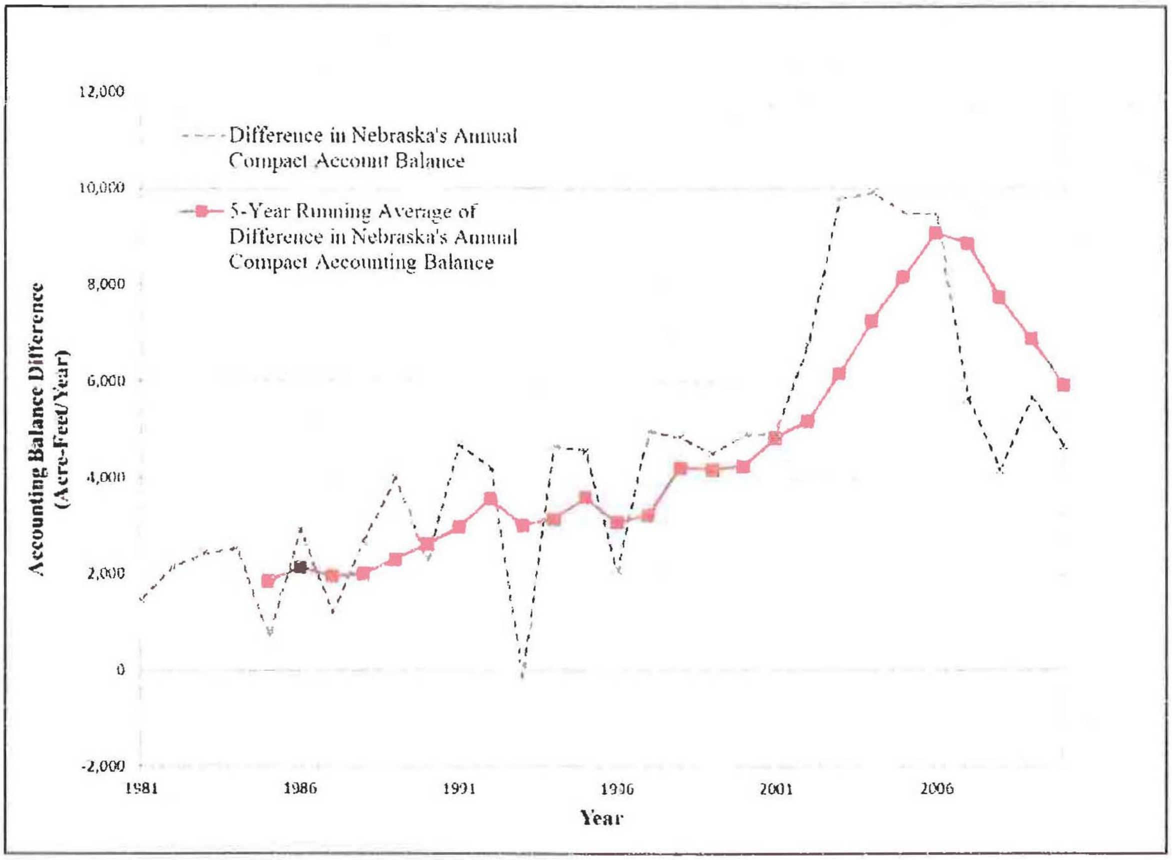

Figure 22. The historic difference in Nebraska's annual Compact accounting balances between the Apparent Impact and the Assigned Impact. A positive value indicates a ***detriment*** to Nebraska's Compact balance.

6.2 Future Results if Left Unresolved

It is not possible to know with certainty if this discrepancy, left unresolved, will continue to increase at such an alarming rate. The analysis presented by Kansas in their Petition to the Supreme Court (Kansas Petition C20) can be used to examine how this discrepancy affects the future compliance picture for Nebraska. This analysis utilized average conditions that were repeated for a period of 50 years. The difference (Nebraska's Proposed Procedures minus Current Accounting Procedures) in Nebraska's annual compliance balance under this future scenario is shown in figure 23.

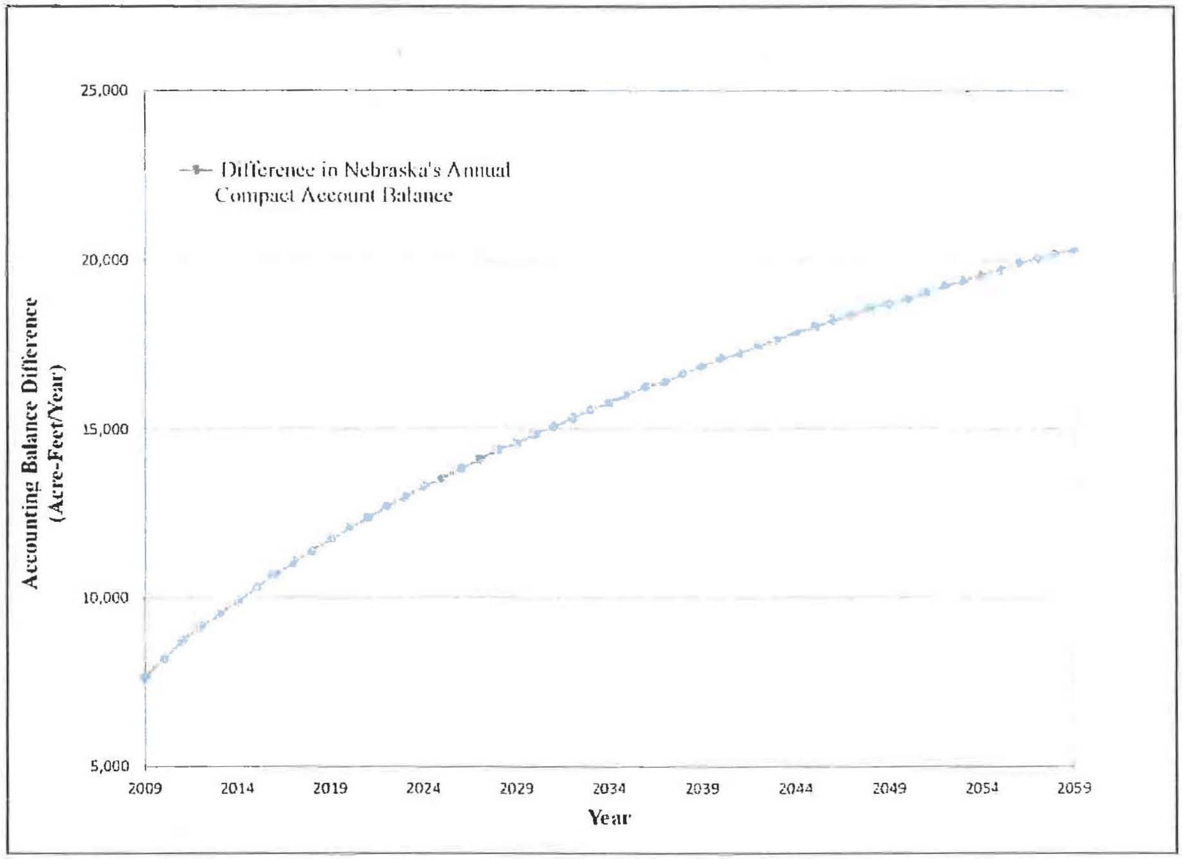

Figure 23. The future difference in Nebraska's annual Compact accounting balances between the Apparent Impact and the Assigned Impact, using the Kansas future scenario. A positive value indicates a ***detriment*** to Nebraska's Compact balance.

As this figure shows, the discrepancy grows significantly over time under this scenario, increasing to greater than 20,000 acre-feet per year after 50 years. Remember that this scenario utilizes average conditions; recent experience has shown that this discrepancy is worst in dry years. Without question, the Current Accounting Procedures cause a result that is significantly injurious to the State of Nebraska and her water users. The economic impact that would be created by a future need to compensate for this accounting problem would be immense. Over this fifty-year period, Nebraska would need to under-utilize its Compact entitlement by nearly 800,000 acre-feet of water. This amounts to approximately one-quarter of a ***trillion*** gallons of water. Put another way, this would provide an average annual public water supply for a city of 80,000 people (Hutson et al., 2004), larger than the city of Portland, Maine. In agricultural terms, tens of thousands to hundreds of thousands of acres[22] of irrigation would need to cease. In addition, this is only a fifty-year projection; the Compact has already been in place for longer than 60 years, and water use for irrigation has existed in the basin for more than 100 years. Therefore, the insistence by Kansas and Colorado on continuing the use of the Current Accounting Procedures produces a gross harm to the State of Nebraska and its water users. These accounting procedures must be changed, and Nebraska's Proposed Procedures should be implemented.

[22] Generally, irrigators in the Republican Basin are allowed between 9 to 12 inches of water per year. However, pumping one acre-foot of groundwater can have a much lower effect to streamflow, depending on the proximity to the stream. Therefore, an acre-foot of stream depletions can irrigate much more than an acre of ground in some cases.

7.0 SUMMARY

Republican River Compact Accounting began approximately 50 years ago and has been refined numerous times, as engineering knowledge has advanced and as physical changes have occurred in the basin. The Current Accounting Procedures fail to determine the impacts of groundwater pumping in each state and of mound recharge. Nebraska's Proposed Procedures must be adopted because

- They eliminate Unaccounted Impacts, effecting a better accounting of the VWS, the volume of water each state receives, the IWS Credit, and the State's annual Compact accounting balances.
- The Current Accounting Procedures yield an absurd result for the Total Impact of groundwater pumping and the mound recharge.
- The result of the Current Accounting Procedures is detrimental to Nebraska, and provides unwarranted benefits to Kansas and Colorado.
- Nebraska's Proposed Procedures are not a wholesale alteration, but rather a necessary refinement, that yields essentially the same result as the Current Accounting Procedures in cases in which there are no Unaccounted Impacts.
- If the problem remains uncorrected, Nebraska will be required to consume less water than the quantity to which it is entitled under the Compact. This is tantamount to a redistribution of the Virgin Water Supply Allocations specified in the Compact.

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APPENDIX A. Curriculum Vitae for James C. Schneider, Ph.D.

Areas of Specialization

- Water resources management and planning
- Ground-water flow modeling
- Administration of interstate water Compacts, Decrees, and Agreements
- Hydrogeology
- Statistical analysis of hydrologic data
- Surface-water hydrology
- Environmental geophysics

Education

- Ph.D. in Geology (May 2003) - University of South Florida, Tampa, FL
- M.S. in Geology (May 1998) - Northern Illinois University, DeKalb, IL
- B.S. in Geology (May 1996) - Northern Illinois University, DeKalb, IL

Professional History

- **Deputy Director (2010-)** ***Nebraska Department of Natural Resources (DNR)***

  Responsibilities: Advising and assisting the Director in formulating and administering department policies, budget, organization, and work assignments; assisting in formulation of state water policies, particularly as they pertain to water quantity issues, including serving as liaison with the legislature, other state and local agencies, and public interest groups; overseeing the general administration of the department and assuming responsibility for the department's operation in the Director's absence; assisting the Director in administration of interstate compacts and decrees; serving as the State's Representative on technical committees for compacts and decrees; overseeing the work of consultants and preparing special reports related to surface water or surface and ground water interactions; assisting the Director in reviewing permit applications and groundwater management plans; and assisting the Director in water rights hearings and analysis of permit applications; supervising the Integrated Water Management Division.

- **Head, Integrated Water Management Division (2008-2009)** ***Nebraska DNR***

  Responsibilities: Manage the integrated water management planning process at the Department, including oversight of surface- and groundwater related studies, development and implementation of integrated management plans, supervision of the Integrated Water Management Division and coordination with other Department Divisions, Natural Resources Districts, and other State and Federal agencies.

- **Senior Groundwater Modeler (2007)** ***Nebraska DNR***

  Responsibilities: Serve as NDNR groundwater flow modeling expert.

- **Senior Hydrogeologist/Geophysicist (2006)** ***SDII Global Corporation***

  Responsibilities: Manage hydrogeology and geophysics projects and prepare contract reports and publications. Serve as company groundwater flow modeling expert. Serve as company geophysics expert.

- **Staff Geologist (2003 – 2005)** ***SDII Global Corporation***

  Responsibilities: Conduct hydrogeology projects and prepare hydrogeology contract reports and publications. Assist senior staff as technical resource for litigation and peer reviews of technical reports. Serve as company groundwater flow modeling expert. Serve as resource to subsidence investigation group.

- **Research Assistant (1998 – 2002)** ***University of South Florida, Geology Dept.***

  Responsibilities: Conducting field research, data interpretation, geophysical surveys and groundwater model development for a variety of projects throughout Florida as well as in other states and in Jamaica. Teaching undergraduate and graduate level lab and lecture courses.

Publications

Schneider, J.C., S.B. Upchurch, J. Chen, C. Cain, J. Good, 2008. Simulation of groundwater flow in North Florida and South-central Georgia. Peer reviewed technical report issued to the Suwannee River Water Management District.

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Interstate Organizations

- **Republican River Compact Administration (2007-)**

  Responsibilities: Participate in Engineering Committee and Compact Administration Meetings representing State of Nebraska. Serve as official representative on the Engineering Committee beginning in 2010.

- **Platte River Recovery Implementation Program (2007-)**

  Responsibilities: Participate in Water Advisory Committee and in implementation of Nebraska New Depletions Plan. Represent Nebraska on the Governance Committee (Chair 2011) and the Finance Committee beginning in 2010.

- **North Platte Decree Committee (2010-)**

  Responsibilities: Nebraska alternate to the North Platte Decree Committee.

- **Interstate Council on Water Policy (2010 -)**

  Responsibilities: Represent Nebraska on Committees and at annual meetings. Elected to the Board of Directors in 2011.

Expert Witness Testimony

- **Non-binding arbitration in *Kansas v. Nebraska & Colorado*, No. 126 Orig. (2008)**

  Responsibilities: Provide deposition and trial testimony in non-binding arbitration initiated in October 2008 relating to Kansas' claims for damages and future compliance and Nebraska's proposal to fix accounting errors.

- **Non-binding arbitration in *Kansas v. Nebraska & Colorado*, No. 126 Orig. (2010)**

  Responsibilities: Provide deposition and trial testimony in non-binding arbitration initiated in May 2010 relating to Nebraska's crediting issue and Colorado's augmentation pipeline.

APPENDIX B. The Kansas Virgin Water Supply Metric

On September 18, 2007, Kansas provided Nebraska with a memo[23] summarizing their views of the Current Accounting Procedures and the issues Nebraska had brought up relative to those procedures (herein referred to as the VWS Metric Memo). This memo is attached to the end of this Appendix as Exhibit A.

Kansas began the VWS Metric Memo by summarizing their understanding of Nebraska's concerns at that time. Then Kansas went on to describe what the model is intended to accomplish, some of the consideration given to this in developing the Current Accounting Procedures leading up to the signing of the FSS, and a test they applied to Nebraska's proposal and the results of the Current Accounting Procedures.

Kansas points out that '[t]he only question with respect to the Model's result s (sic) that affect compact compliance is the extent to which activities in a state, either pumping or importation of water, affect base flow in the Republican River. To the extent these activities affect base flows in the river, ***they must be counted***." (Emphasis added) Kansas further noted that "[i]t is clear that (sic) only quantification that is relevant to the compact accounting is the depletion or accretion to Republican River stream flow."

After a brief discussion about impacts to the Republican River from pumping and recharge that occurs outside the basin, Kansas continued:

> In order to provide this quantification using the groundwater model, it was agreed in the settlement that the impact of each state's pumping or water importation would be determined by comparing the model-computed historical base flow condition to the model-computed base flow condition without that activity. The states recognized that the sum of the impacts of these individual activities would not necessarily exactly equal the model-computed impact of all of the activities considered simultaneously. If the groundwater model were mathematically linear, it would, in fact, be the case that the sum of the individual affects (sic) would equal the affect (sic) determined by considering all of the activities simultaneously. However, because the groundwater model is mildly non-linear, this mathematical equality does not occur.
>
> It should be noted that if the impact of all activities considered simultaneously were used, it would be necessary to have a method for apportioning the impact among the various activities. Such a process was considered unnecessary and it was agreed that the impacts from each state's activity would be computed separately in spite of the fact that the sum of those impacts may not exactly equal the impact of all activities considered simultaneously.

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[23] Kansas' Review of Nebraska's Request for Change in Accounting Procedure, September 18, 2007

Nebraska understands that the Current Accounting Procedures, as included in the FSS, determine the impact of each activity (pumping in a state or recharge of the IWS) by comparing the historic model run with all activities included to a run with the specific activity not included. Kansas is apparently arguing here that the States accepted this process, in spite of clear understanding that the sum of the impacts of these activities would not ***exactly*** equal the model computed impacts of all of these activities considered simultaneously (i.e. total impacts, VWS Metric). Nebraska agrees that a very small departure between the sum of these impacts and the total impact might be acceptable, considering that, as Kansas further notes, a method for apportioning the total impacts would otherwise need to be developed. In fact, the definition of Computed Beneficial Consumptive Use included in the RRCA Accounting Procedures specifically excludes small uses of water (e.g., irrigation of less than two acres of land, non-irrigation diversions of less than 50 acre-feet). However, as demonstrated in this report, in several of the sub-basins, particularly in recent years (post-FSS), it is not a matter of whether the two methods match exactly, but rather a situation where the Current Accounting Procedures deviate from the total impact by ***thousands*** of acre-feet per year. Therefore, Nebraska has determined that a process for apportioning the total impact among the various activities is now necessary, because it is now clearly not simply a matter of the sum of the currently determined impacts matching somewhat less than exactly.

Kansas next goes on to define a VWS Metric and describe what it represents:

> The ultimate goal of the RRCA Groundwater Model is to provide a measure of what base flows would have been if the States had not pumped groundwater or recharged imported water. That overall measure could be determined by comparing the model-computed historical stream flows to the model-computed stream flows with all pumping and recharge of imported water removed from the analysis (herein referred to as the "virgin water supply metric"). This measure gives us the total impact on stream flows caused by the States' pumping and the recharge of imported water. As described above, however, this result does not apportion the impact among the States. Conceptually, the condition with no pumping and no imported water represents what the stream flows would have been if none of this activity had occurred. In that sense, it represents a "virgin water supply" condition with respect to the modeled elements of the groundwater model and their impact on Republican River stream flows.
>
> This measure does provide a metric for comparing the accounting method agreed to in the settlement with Nebraska's alternative accounting proposal. It is a relatively straightforward process to add up the impacts using the accounting method agreed to in the settlement or to add up the impacts from Nebraska's alternative accounting proposal and compare those totals to the virgin water supply metric described above. If the Nebraska alternative accounting proposal provides a better approximation of this metric, it is worthy of further consideration.

The second paragraph in this quote from the VWS Metric Memo might seem to indicate that the VWS Metric is only a test of potential alternative methodologies for determining the impact of the three States pumping and the IWS. However, subsequent to receiving this Memo, in order to fully understand the VWS Metric, Nebraska requested clarification from Kansas as to the exact Model runs that were performed to compute the VWS Metric. The reply stated:

> The "virgin water supply metric" is the difference [between] two runs: 1) a new run which simultaneously turns off CO pumping, KS pumping, NE pumping, and the mound imports minus 2) the Base run done as per the RRCA accounting procedures. ***It thus determines the net impact of all these effects of man in one impact run*** (emphasis added).[24]

This makes the Kansas position regarding the VWS Metric very clear; it represents the "net impact" of these four activities of man, namely pumping in the three States and the mound recharge. Nebraska agrees that this VWS Metric is the best estimate that we can generate (given the current Model) of the net impact of these four activities of man. This is identical to the Total Impact values used throughout this report.

[24] Email transmission from David Barfield sent September 18, 2007, attached to this Appendix as Exhibit B.

Exhibit A

Kansas' Review of Nebraska's Request for Change in Accounting Procedure
September 18, 2007

This memo is intended to summarize Kansas' understanding of the Nebraska's proposal for changing the agreed upon method of computing pumping impacts using results from the Republican River Compact Administration Groundwater Model (Model) and to summarize our initial response to the proposal.

Nebraska believes that the calculation of pumping impacts using results from the groundwater model improperly includes the consumption of imported water. Nebraska argues that because some of the water pumped by wells is or could be water that originated from imported water, the consumption of that water should not be counted in determining the virgin water supply in the accounting process. This argument is difficult to understand since no one has ever determined the specific origin of groundwater that is pumped and consumed. In other words, whether the origin of the pumped water is from natural recharge within the Republican River basin, natural recharge outside the Republican River basin, stored groundwater, or imported water has never been determined and probably cannot be determined with any degree of reliability.

In terms of the use of the Model to determine compliance with the Compact, however, the specific origin of the water that is pumped and consumed is not the determining factor. The only question with respect to the Model's result s that affect compact compliance is the extent to which activities in a state, either pumping or importation of water, affect base flow in the Republican River. To the extent these activities affect base flows in the river, they must be counted. In other words, it is not the source of water that counts, but the depletion or accretion to base flow that is associated with the activity that determines the amount of impact that must be considered in the compact accounting process. This concept is precisely what is included in the Accounting Procedures adopted by the Settlement and what the special master based his rulings on in determining that those effects to stream flows in the Republican River are regulated by the compact. As it is stated in the Final Report of the Special Master's With Certification of Adoption of Republican River Compact Administration Groundwater Model, September 2003: "*... the RRCA Groundwater Model which would, for use in the accounting formulas for administering the Republican River Compact, determine both stream flow depletions caused by groundwater pumping and streamflow accretions resulting from recharge by imported water*" (Page 1). It is clear that only quantification that is relevant to the compact accounting is the depletion or accretion to Republican River stream flow.

The quantification of depletion or accretion to Republican River base flow is not limited to activities that are solely within the boundaries of the Republican River Basin. Recharge from imported water can cause accretion to Republican River base flow even if the recharge occurs outside the boundary of the basin. To the extent that such recharge provides accretions to Republican River base flow, it is counted in the accounting process. Similarly, pumping from locations outside the basin can cause depletions to Republican River base flow. To the extent that such pumping causes depletions to base flow, it is counted in the accounting process. Thus both positive effects (accretions) and negative effects (depletions) on Republican River base flows caused by activities outside the physical boundaries of the basin are treated equally.

In order to provide this quantification using the groundwater model, it was agreed in the settlement that the impact of each state's pumping or water importation would be determined by comparing the model-computed historical base flow condition to the model-computed base flow condition without that activity. The states recognized that the sum of the impacts of these individual activities would not necessarily exactly equal the model-computed impact of all of the activities considered simultaneously. If the groundwater model were mathematically linear, it would, in fact, be the case that the sum of the individual affects would equal the affect determined by considering all of the activities simultaneously. However, because the groundwater model is mildly non-linear, this mathematical equality does not occur.

It should be noted that if the impact of all activities considered simultaneously were used, it would be necessary to have a method for apportioning the impact among the various activities. Such a process was considered unnecessary and it was agreed that the impacts from each state's activity would be computed separately in spite of the fact that the sum of those impacts may not exactly equal the impact of all activities considered simultaneously.

Nebraska has proposed an alternative method of computing the impacts associated with each state's activity. This alternative has been proposed to correct what they see as an inappropriate accounting of consumed water. While the connection between Nebraska's proposed alternative accounting method and their concept of what water is actually consumed is far from apparent, we have evaluated the merits of this alternative method regardless of its basis.

The ultimate goal of the RRCA Groundwater Model is to provide a measure of what base flows would have been if the States had not pumped groundwater or recharged imported water. That overall measure could be determined by comparing the model-computed historical stream flows to the model-computed stream flows with all pumping and recharge of imported water removed from the analysis (herein referred to as the "virgin water supply metric"). This measure gives us the total impact on stream flows caused by the States' pumping and the recharge of imported water. As described above, however, this result does not apportion the impact among the States. Conceptually, the condition with no pumping and no imported water represents what the stream flows would have been if none of this activity had occurred. In that sense, it represents a "virgin water supply" condition with respect to the modeled elements of the groundwater model and their impact on Republican River stream flows.

This measure does provide a metric for comparing the accounting method agreed to in the settlement with Nebraska's alternative accounting proposal. It is a relatively straightforward process to add up the impacts using the accounting method agreed to in the settlement or to add up the impacts from Nebraska's alternative accounting proposal and compare those totals to the virgin water supply metric described above. If the Nebraska alternative accounting proposal provides a better approximation of this metric, it is worthy of further consideration.

Our calculations, as summarized in the table below, show that the accounting agreed to in the settlement provides a better approximation of the virgin water supply metric than the Nebraska proposed accounting method. The table shows that the accounting agreed to in the settlement results in both positive and negative annual differences from the virgin water supply metric. The resultant average for the years 1990 – 2000, the last ten years of the calibration of the model is -150 acre-feet. For the last six years, 2001-2006, the average difference is 2,053 acre-feet. The Nebraska alternative accounting proposal departs significantly further from the virgin water supply metric than the accounting method agreed to in the settlement, has a negative bias, and for the period studied is increasing.

It remains our view, based on our understanding of the agreement of the States at the time of the settlement and these results, that the current accounting methods are appropriate.

Table: Comparison of total impacts under adopted procedures and as proposed by Nebraska versus the virgin water supply metric.

Year	Virgin Water Supply Metric	Compact Method Total	Nebraska Proposed Alternative	Difference [Compact Method – Metric]	Difference [Nebraska Proposal – Metric]
1990	180542	176749	170646	-3793	-9896
1991	200582	200424	191432	-158	-9150
1992	206037	204478	195938	-1559	-10099
1993	213153	210926	212593	-2227	-560
1994	188954	194203	186345	5249	-2609
1995	219075	220673	213807	1598	-5268
1996	229586	228517	228167	-1069	-1419
1997	208878	212730	202992	3852	-5886
1998	210089	208778	200587	-1311	-9502
1999	230055	231109	222053	1054	-8002

2000	203222	199934	192856	-3288	-10366
2001	236771	230905	221333	-5866	-15438
2002	196546	195685	183123	-861	-13423
2003	221307	228528	210485	7221	-10822
2004	231704	237594	219651	5890	-12053
2005	237802	240969	224287	3167	-13515
2006	219356	222122	204589	2766	-14767
Averages:					
1990-2000	208198	208047	201583	-150	-6614
1990-2006	213745	214372	204758	627	-8987
2001-2006	223914	225967	210578	2053	-13336

Exhibit B

Schneider, Jim

From: Schneider, Jim
Sent: Tuesday, November 15, 2011 1:08 PM
To: Schneider, Jim
Subject: FW: Nebraska proposal--Privileged and Confidential Attorney-Client Communication Regarding the Republican River

James C. Schneider, Ph.D.
Deputy Director
Nebraska Department of Natural Resources

301 Centennial Mall South
Fourth Floor, State Office Building
P.O. Box 94676
Lincoln, NE 68509-4676

Office: 402-471-3141
Fax: 402-471-2900
Cell: 402-450-2744
E-Mail: jim.schneider@nebraska.gov
Web: www.dnr.ne.gov

-----Original Message-----
From: Barfield, Dave [mailto:DBARFIELD@KDA.STATE.KS.US]
Sent: Tuesday, September 18, 2007 8:14 PM
To: Schneider, Jim; Sullivan, Megan; Williams, Jim; Koester, Paul; gndwater@aol.com; mmacps@aol.com; Willem.Schreuder@prinmath.com
Cc: Justin Lavene; Theis, Ron; Steve Larson; Perkins, Sam; Dale Book; Willem.Schreuder@prinmath.com; Knox, Ken; Ann Bleed
Subject: RE: Nebraska proposal--Privileged and Confidential Attorney-Client Communication Regarding the Republican River

Jim,

The "virgin water supply metric" is the difference two runs: 1) a new run which simultaneously turns off CO pumping, KS pumping, NE pumping, and the mound imports minus 2) the Base run done as per the RRCA accounting procedures. It thus determines the net impact of all these effects of man in one impact run.

The "Compact method total" sums the CO pumping impacts, KS pumping impacts, NE pumping impacts and Mound credits as done according to the current accounting procedures.

The "NE proposed alternative" sums these same 4 impacts according to NE's proposed method.

Let me know if this is still unclear.

Thanks.

David

-----Original Message-----
From: Schneider, Jim [mailto:jschneider@dnr.ne.gov]
Sent: Tuesday, September 18, 2007 4:08 PM
To: Barfield, Dave; Sullivan, Megan; Williams, Jim; Paul Koester; gndwater@aol.com; mmacps@aol.com; Willem.Schreuder@prinmath.com
Cc: Justin Lavene; Theis, Ron
Subject: RE: Nebraska proposal--Privileged and Confidential Attorney-Client Communication Regarding the Republican River

Dave,

Thank you for providing us with your comments. One thing that would really help would be some information on exactly what model runs where performed to get those numbers for the "Virgin Water Supply Metric". We understand the rest but it is not clear exactly what runs you are using for that. Thanks.

Jim

-----Original Message-----
From: Williams, Jim
Sent: Tuesday, September 18, 2007 11:31 AM
To: Jim Schneider; Paul Koester; Mike McDonald (gndwater@aol.com); Chuck Spaulding (mmacps@aol.com)
Cc: Justin Lavene; Theis, Ron
Subject: Nebraska proposal--Privileged and Confidential Attorney-Client Communication Regarding the Republican River

Privileged and Confidential Attorney-Client Communication Regarding the Republican River

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Jim, Paul: Please review and let's discuss between now and Thursday.

--Jim

James R. Williams, P.E., CFM
Republican River Coordinator

Direct: (402) 471-1026
Main: (402) 471-2363, Fax: (402) 471-2900
E-Mail: jwilliams@dnr.ne.gov
301 Centennial Mall South
P.O. Box 94676, Lincoln, Nebraska 68509-4676 www.dnr.ne.gov
-----Original Message-----

From: Barfield, Dave [mailto:DBARFIELD@KDA.STATE.KS.US]
Sent: Tuesday, September 18, 2007 10:02 AM
To: Williams, Jim; Sullivan, Megan; Willem Schreuder
Cc: Ann Bleed; Knox, Ken; Steve Larson; Austin, George; Dale Book; Perkins, Sam; Billinger, Mark; Ross, Scott
Subject: RE: Nebraska proposal

Jim and others,

Attached is a document that provides Kansas comments from its initial review of Nebraska proposal for our discussion on Thursday.

See you then.

David Barfield

APPENDIX C – Further discussion of two Target Set scale analogy

This Appendix continues the discussion of the two Target Set analogy. The specific equations for a two Target Set situation are developed and applied. The analogy is developed by considering a scale capacity of 300 pounds and two people with a Potential Impact (weight) of 250 pounds. Using the Current Accounting Procedures, the Apparent Impact is 50 pounds for each person. The Apparent Impacts add up to 100 pounds, leaving 200 pounds as the Unaccounted Impacts. With only 50 pounds assigned as a portion of the Total Impact, each person has enough remaining Potential Impact (200 pounds) to cause all of the Unaccounted Impacts. This is a general quality of a two Target Set situation; if there are any Unaccounted Impacts, the difference between each person's Apparent Impact and Potential Impact will always be equal to the Unaccounted Impacts. This leads to the conclusion that any Unaccounted Impact in a two Target Set situation should be equally divided between the two people in proportion to the remaining ability of each person to cause additional impact. In other words the appropriate assignment of Unaccounted Impacts is equal to the Potential Impact minus the Apparent Impact, divided by two. The 200 pounds of Unaccounted Impact is equally divided between the two people so that each is assigned 150 pounds out of the total of 300 pounds. This relationship can be summarized in this equation:

Assigned Impact = Apparent Impact + (Potential Impact – Apparent Impact)/2

For a situation with impact from two Target Sets this general relationship corresponds to the following mathematical equations:

Assigned Impact of Person A = $(AB-B) + [(A-\theta) - (AB-B)]/2$

Assigned Impact of Person B = $(AB-A) + [(B-\theta) - (AB-A)]/2$

Where:

AB = the reading with both persons on the scale

A = the reading with only Person A on the scale

B = the reading with only Person B on the scale

θ = the reading with no one on the scale (the unimpacted reading)

$(AB-B)$ and $(AB-A)$ = the Apparent Impact for Person A and B, respectively

$(A-\theta)$ and $(B-\theta)$ = the Potential Impact for Person A and B, respectively

The computations using these equations would then look like:

AB = 300 pounds

A = 250 pounds

B = 250 pounds

θ = zero pounds

Assigned Impact of Person A = (300-250) + [(250-0)-(300-250)]/2

= 50 + [250-50]/2

= 50 + 100 = 150 pounds

Assigned Impact of Person B = (300-250) + [(250-0)-(300-250)]/2

= 50 + [250-50]/2

= 50 + 100 = 150 pounds

These equations reduce to the following forms:

Assigned Impact of Person A = [(AB-B) + (A-θ)]/2

Assigned Impact of Person B = [(AB-A) + (B-θ)]/2

In this example, the Appropriate Assignment of the Unaccounted Impacts can probably be deduced without these equations. However, the equations are very useful in situations where the answer is less obvious. For example, what if the two persons weigh 170 pounds and 220 pounds? Using these equations we can determine that they should be assigned 125 pounds and 175 pounds of the impact to the scale, respectively. ***Note that if the combined weight of the two persons is less than 300 pounds, the equations simply yield the persons Potential Impact (weight).*** In other words, this procedure, which is Nebraska's Proposed Procedure for two Target Sets, yields the same result as the Current Accounting Procedures when there are no Unaccounted Impacts. Table 6 shows combinations of the two persons' Potential Impact, Apparent Impacts, the Unaccounted Impacts, and the appropriate assignment of the impact for each of those weights using the equations presented above.

Table 6. Apparent Impact, Unaccounted Impact, and Assigned Impact for two people with different combinations of Potential Impact (weight).

Person A Potential Impact	Person B Potential Impact	Person A Apparent Impact	Person B Apparent Impact	Unaccounted Impact	Person A impact	Person B impact
130	160	130	160	0	130	160
170	220	80	130	90	125	175
100	400	0	200	100	50	250
300	500	0	0	300	150	150
150	200	100	150	50	125	175
150	400	0	150	150	75	225
10	500	0	290	10	5	295
50	280	20	250	30	35	265

One question that could arise from these relationships is, why a person weighing very little (e.g., 20 pounds) is assigned any impact, even when the other person weighs much more (e.g., 480 pounds) than the scale capacity (e.g., 300 pounds)?[25] In this example Person A, weighing 20 pounds, would have an Apparent Impact of 0 pounds, and Person B, weighing 480 pounds, would have an Apparent Impact of 280 pounds, leaving Unaccounted Impacts of 10 pounds (table 7). Is it reasonable to assign Person 1 with any of the Unaccounted Impacts, given that Person B could cause all of the impact on their own (i.e., Potential Impact of Person B is equal to or greater than the Total Impact)? The problem with this argument is that it relies on an arbitrary ordering of the causes of the impacts. Person A is assumed to be in place on the scale before Person B steps on. ***One of the fundamental considerations for any method of assigning the impacts is that it should not be arbitrary.*** Given the Apparent Impact values for each person, they are both equally capable of causing all of the Unaccounted Impacts (i.e., Person A has an Apparent Impact of zero pounds and a Potential Impact of 20 pounds; this difference is equal to the Unaccounted Impacts). Therefore, the appropriate impact

[25] While this issue may seem more significant by taking it to much further extremes (e.g., 1 pound versus 1 million pounds), this is extremely hypothetical and not relevant to the ultimate issue, the RRCA Accounting Procedures, where difference of two orders of magnitude (e.g., 10 versus 1,000) are generally the extreme. There do exist some situations where one or more Target Sets has an impact to the stream baseflow of thousands or tens of thousands of acre-feet, and one other Target Set appears to have an impact to stream baseflow of one or a couple of acre-feet. These occurrences of very small impacts are most likely due to minor rounding issues between model runs and should not be considered in this discussion. Official RRCA accounting generally rounds values to the nearest ten acre-feet.

assignment for each person should be 10 pounds greater than each Person's Apparent Impact.

Table 7. Comparison of results for a range of scale capacities with two people weighing 20 pounds and 480 pounds.

Scale Capacity	Person A Apparent Impact	Person B Apparent Impact	Unaccounted Impact	Person A Assigned Impact	Person B Assigned Impact
300	0	280	20	10	290
400	0	380	20	10	390
480	0	460	20	10	470
490	10	470	10	15	475
500	20	480	0	20	480

Consider again what would happen if the scale capacity was to increase to 400 pounds (table 7). The Total Impact would increase from 300 to 400 pounds, however, the only change under the Current Accounting Procedures would be an increase in the Apparent Impact of Person B. The Unaccounted Impact is the same, whether the scale capacity is 300 pounds or 400 pounds. Therefore, the appropriate assignment of impact to Person A would remain the same (10 pounds); for Person B it would change to 390 pounds. In other words, all of the increase in the appropriate assignment of impact would be assigned to Person B under the Current Accounting Procedures.

Now increase the scale capacity to 490 pounds. The Total Impact to the scale increases to 490 pounds, and the Unaccounted Impact is now only 10 pounds. Using the Assigned Impact equation, the appropriate assignment of impacts would change to 15 pounds for Person A and 475 pounds for Person B. Notice this is the first time the Unaccounted Impacts are less than either Persons Potential Impacts (i.e., neither person could cause the Total Impact alone). So it is clear that when the sum of the Potential Impacts exceed the scale capacity by an amount greater than or equal to the smaller of the two Potential Impacts, this smaller value will be the amount of Unaccounted Impacts (20 pounds in this example). This Unaccounted Impact is split, because we cannot know which of the two people caused it, and either person is equally capable of causing it (i.e., both people can cause an impact of 20 pounds by themselves).

APPENDIX D. Mound Recharge and Nebraska Groundwater Pumping

The behavior of the Current Accounting Procedures when Nebraska groundwater pumping and mound recharge are the only Target Sets that impact Virgin Stream Baseflow can only be detrimental to Nebraska (i.e., it can never benefit Nebraska). When the impact of groundwater pumping in Nebraska is overestimated, this results in a detriment to Nebraska. When the impact of mound recharge is underestimated, Nebraska is deprived of water that it is entitled to under the FSS. This is much different than the effect of the Current Accounting Procedures in their application to the scale. This situation in the Swanson-Harlan reach underscores the importance of this issue to Nebraska.

This problem could be fixed in two arbitrary manners, or through a system of averaging. For example, we could attribute the entire misestimation to the impact of groundwater pumping in Nebraska, reducing this value accordingly and not changing the impact of mound recharge. We could also take the opposite approach, changing the impact of mound recharge and not changing the impact of groundwater pumping. The system of averaging introduced above would essentially split the difference between these two extremes. It actually turns out that the manner in which we modify the Current Accounting Procedures to appropriately account for the Total Impact of these two Target Sets in the Swanson-Harlan reach is largely immaterial, because of the way in which these results percolate through Current Accounting Procedures[26]. In fact, there is no practical reason for differentiating these two terms as separate Target Sets.-

This is basically due to the fact that the impacts of groundwater pumping and mound recharge are both Nebraska terms in the accounting. The annual Compact accounting balances developed for Colorado and Kansas simply compare the annual volume of water that each state receives to the annual uses (termed Computed Beneficial Consumptive Use, or CBCU). For Nebraska the annual volume of water that it receives is compared to the CBCU adjusted for any impact of the mound recharge (term the Imported Water Supply Credit, or IWS Credit). Adjusting either the CBCU or the IWS Credit effects not only the balance of CBCU – IWS Credit, but also the VWS and ultimately the volume of water each state receives. This results from the way in which the VWS is computed, which is essentially the gaged stream flows plus all CBCU minus any IWS Credit. So a smaller value for CBCU results in a smaller VWS, and a larger value for IWS results in a smaller VWS. If the magnitude of either is the same, the effect is exactly the same. So the VWS is reduced by the same amount as the CBCU-IWS Credit is reduced, however the volume of water Nebraska receives, when computed is reduced

[26] This again ignores minor effects of pumping in Kansas and Colorado, and the minor changes this would make in this result.

by a lesser amount (because the Allocation is always less than the VWS in every sub-basin and the Main Stem. The following simple example illustrates these relationships.

<u>Current Accounting Procedures:</u>

Sum of Apparent Impacts of Nebraska groundwater pumping and mound recharge = 1,100 acre-feet

Gaged streamflow = 1,100 acre-feet

VWS = 2,200 acre-feet

Nebraska's water supply = VWS * Allocation = 2,200 * 48.9% = 1,076 acre-feet

Nebraska's water supply – (CBCU – IWS Credit) = 1,076 – 1,100 = -24 acre-feet

<u>Corrected Accounting:</u>

Total Impacts = 1,000 acre-feet

Gaged streamflow = 1,100 acre-feet

VWS = 2,100 acre-feet

Nebraska's water supply = 2,100 * 48.9% = 1,027 acre-feet

Nebraska's water supply – (CBCU – IWS Credit) = 1,027 – 1,000 = 27 acre-feet

The overestimate of Total Impacts by the Current Accounting Procedures is 100 acre-feet in this example. This results in harm to Nebraska of approximately 51 acre feet. Generally speaking, Nebraska is harmed by approximately 51% of the misestimate of the Total Impacts in this reach. This results from the fact that Nebraska receives an Allocation of approximately 49% in the Main Stem. The volume of water Nebraska receives is reduced by 49% of the difference between the results of the Current Accounting Procedures and the Total Impacts, and the CBCU – IWS Credit is reduced by 100% of this difference, for a net effect of 51%. This is evident in the example above. The difference in the impacts is 100 acre-feet, the volume of water Nebraska receives is changed by 49 acre-feet, thus the balance increases by 51 acre-feet.

The exact effect in any given year does depend on the magnitude of any impacts from Kansas or Colorado pumping. To resolve any effect of these impacts Nebraska's Proposed Procedures are required, however the difference between those results and the results demonstrated in this Appendix are very minor.

APPENDIX E. Changes to RRCA Accounting Procedures and Reporting Requirements to implement Nebraska's Proposed Procedures

In order to implement Nebraska's Proposed Procedures, Section III.A.3 and Section III.D.1 of the RRCA Accounting Procedures and Reporting Requirements would need to be revised. The specific revisions were included as Exhibit A to the Answer and Amended Counterclaims and Cross-claim of the State of Nebraska. This exhibit is reproduced as Exhibit A to this Appendix.

EXHIBIT A

III.A.3. Imported Water Supply Credit Calculation:

The amount of Imported Water Supply Credit shall be determined by the RRCA Groundwater Model. The Imported Water Supply Credit of a State shall not be included in the Virgin Water Supply and shall be counted as a credit/offset against the Computed Beneficial Consumptive Use of water allocated to that State. Currently, the Imported Water Supply Credits shall be determined using sixteen~~two~~ runs of the RRCA Groundwater Model. These runs are named using a combination of variables representing Colorado groundwater pumping and pumping recharge (C), Kansas groundwater pumping and pumping recharge (K), the surface water recharge associated with Nebraska's Imported Water Supply, or "mound" (M), and Nebraska groundwater pumping and pumping recharge (N), with the presence of the variable indicating that the stress is "on" and the absence of the variable indicating that the stress is "off". These will be the same runs used to determine groundwater Computed Beneficial Consumptive Uses, as described in Section III.D.1.

CKMN~~The "base" run~~ shall be the "base" run with all groundwater pumping, groundwater pumping recharge, and surface water recharge within the model study boundary for the current accounting year turned "on." ~~This will be the same "base" run used to determine groundwater Computed Beneficial Consumptive Uses.~~

CKN~~The "no NE import" run~~ shall be the run with the same model inputs as the base run with the exception that surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

KMN shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado shall be turned "off."

CMN shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Kansas shall be turned "off."

CKM shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Nebraska shall be turned "off."

CK shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Nebraska and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

CM shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Nebraska and Kansas shall be turned "off."

CN shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Kansas and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

KM shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Nebraska and Colorado shall be turned "off."

KN shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

MN shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado and Kansas shall be turned "off."

C shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Kansas and Nebraska and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

K shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado and Nebraska and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

M shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado, Kansas, and Nebraska shall be turned "off."

N shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado and Kansas and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

θ ("theta") shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado, Kansas and Nebraska and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

The Imported Water Supply Credit shall be based on the difference in stream flows between these eight pairstwo of model runs where the only difference between the two runs is that the surface water recharge associated with Nebraska's Imported Water is "on" in one run and "off" in the other (e.g., CKMN vs. CKN). The formula to be used is:

Imported Water Supply Credit = [(M-θ) + ((CM-C) + (KM-K) + (MN-N))/3 +
((CKM-CK) + (CMN-CN) + (KMN-KN))/3 + (CKMN-CKN)]/4

Differences in stream flows shall be determined at the same locations as identified in Subsection III.D.1for the "no pumping" runs. Should another State import water into the Basin in the future, the RRCA will develop a similar procedure to determine Imported Water Supply Credits.

III.D.1. Groundwater

Computed Beneficial Consumptive Use of groundwater shall be determined by use of the RRCA Groundwater Model. The Computed Beneficial Consumptive Use of groundwater for each State shall be determined as the difference in streamflows using sixteen~~two~~ runs of the model. These runs are named using a combination of variables representing Colorado groundwater pumping and pumping recharge (C), Kansas groundwater pumping and pumping recharge (K), the surface water recharge associated with Nebraska's Imported Water Supply, or "mound" (M), and Nebraska groundwater pumping and pumping recharge (N), with the presence of the variable indicating that the stress is "on" and the absence of the variable indicating that the stress is "off".

CKMN~~The "base" run~~ shall be the "base" run with all groundwater pumping, groundwater pumping recharge, and surface water recharge within the model study boundary for the current accounting year "on".

CKM~~The "no State pumping" run~~ shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Nebraska~~of that State~~ shall be turned "off."

CKN shall be the run with the same model inputs as the base run with the exception that surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

CMN shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Kansas shall be turned "off."

KMN shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado shall be turned "off."

CK shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Nebraska and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

CM shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Nebraska and Kansas shall be turned "off."

CN shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Kansas and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

KM shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Nebraska and Colorado shall be turned "off."

KN shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

MN shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado and Kansas shall be turned "off."

C shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Kansas and Nebraska and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

K shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado and Nebraska and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

M shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado, Kansas, and Nebraska shall be turned "off."

N shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado and Kansas and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

θ ("theta") shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado, Kansas and Nebraska and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

An output of the model is baseflows at selected stream cells. Changes in the baseflows predicted by the model between eight pairs of model runs where the only difference between the two runs is that the groundwater pumping and pumping recharge in a state is "on" in one run and "off" in the other run (e.g., CKMN vs. CKM) will" ~~base" run and the "no State pumping" model run is assumed to~~ be used to determine the depletions to streamflows. i.e., groundwater computed beneficial consumptive use, due to State groundwater pumping at that location. The formulas to be used are:

Colorado groundwater computed beneficial consumptive use = [(θ-C) + ((K-CK) + (M-CM) + (N-CN))/3 + ((KM-CKM) + (KN-CKN) + (MN-CMN))/3 + (KMN-CKMN)]/4

Kansas groundwater computed beneficial consumptive use = [(θ-K) + ((C-CK) + (M-KM) + (N-KN))/3 + ((CM-CKM) + (CN-CKN) + (MN-KMN))/3 + (CMN-CKMN)]/4

Nebraska groundwater computed beneficial consumptive use = [(θ-N) + ((C-CN) + (M-MN) + (K-KN))/3 + ((CM-CMN) + (CK-CKN) + (KM-KMN))/3 + (CKM-CKMN)]/4

The values for each Sub-basin will include all depletions and accretions upstream of the confluence with the Main Stem. The values for the Main Stem will include all depletions and accretions in stream reaches not otherwise accounted for in a Sub-basin. The values for the Main Stem will be computed separately for the reach above Guide Rock, and the reach below Guide Rock.

APPENDIX F. Development of Nebraska's Proposed Procedures

Nebraska's Proposed Procedures essentially begin with the Apparent Impact calculation from the Current Accounting Procedures and assign any Unaccounted Impacts to the Target Sets in a manner related to their ability to cause those Unaccounted Impacts. The Unaccounted Impacts are the difference between the Total Impacts and the sum of Apparent Impacts:

Unaccounted Impacts = Total Impacts – Sum of Apparent Impacts.

Under certain circumstances, the Apparent Impacts produced by the Current Accounting Procedures sum to a value different than the Total Impacts causing Unaccounted Impacts.

The Nebraska's Proposed Procedures eliminate Unaccounted Impacts. This is accomplished by defining an Assigned Impact which is calculated by adding an Appropriate Assignment of Unaccounted Impacts (AAUI) to the Apparent Impact of each Target Set so that:

Assigned Impact = Apparent Impact + AAUI.

The AAUI values are determined in such a way that the Total Impacts minus the sum of Assigned Impacts equal zero, that is,

Unaccounted Impacts = Total Impacts – Sum of Assigned Impacts = 0.

The AAUI values are only relevant in those cases where Unaccounted Impacts occur. If there are no Unaccounted Impacts then all AAUI values will be zero. Describing how the AAUI values are determined is the subject of this Appendix.

To avoid arbitrariness, the assignment of Unaccounted Impacts should be shared over all Target Sets. That is, when multiple Target Sets have impact, it should not be the case that the AAUI value for only one Target Set is set to a non-zero value with all others set to zero.

To be realistic, the value of AAUI for each Target Set should be related to the ability of that Target Set to have caused the Unaccounted Impact. In the Nebraska's Proposed Procedures, the remaining ability of the Target Set to cause an impact is determined as the difference between the Potential Impact and Apparent Impact. This difference is computed for each Target Set. By subtracting the impact already assigned to the Target Set (the Apparent Impact) from the maximum impact that could be caused by the Target Set (the Potential Impact) we arrive at an estimate of the maximum

Unaccounted Impact that can be attributed to the Target Set. The AAUI is taken to be a fraction of this remaining ability. In the case of four Target Sets this fraction is ¼. The resulting definition of AAUI for four Target Sets is:

AAUI = ¼(Potential Impact – Apparent Impact).

Note that the AAUI is realistic because its value is proportional to the remaining ability of the Target Set to have an impact. The AAUI value is non-arbitrary because the same fraction (1/4) of the remaining ability is assigned to each Target Set.

We now turn to defining the Potential Impact. The case of two Target Sets was the subject of the scale analogy as discussed in Section 4.3. In this case, since only two Target Sets are relevant, the fraction applied to the difference between Potential Impact and Apparent Impact is ½ rather than ¼. The two Target Set case has two characteristics that are not present when three or four Target Sets are present. The first is that the difference between the Potential Impact and the Apparent Impact takes the same value for each Target Set. This, in turn, causes the AAUI for each Target Set to have the same value. The second characteristic is that the Potential Impact can be computed as the actual weight of the person up to the scale capacity. If the person's weight exceeds the scale capacity we say a nonlinearity has been encountered.

In the Model, nonlinearities occur for more complex reasons than in the scale analogy and can have more subtle effects on impact estimates. These nonlinearities have been analyzed in detail in prior reports (NDNR et al. 2008 and Ahlfeld et al.. 2009). They are generally caused by stream-drying, that is, the reduction, to zero, of modeled stream baseflow at a stream cell. The nonlinearities effects on the Virgin Stream Baseflow at an accounting point may be caused by stream drying at the accounting point, stream drying upstream of the accounting point and stream drying along the length of a stream at during prior stress periods.

If only two Target Sets are present, then these Model nonlinearities can still be addressed by also examining the impact of one Target Set alone in a manner analogous to the scale example (See Section 4.3 and Appendix C). However, when three or four Target Sets are present the complexity of these nonlinearities requires an expanded approach. Prior analysis by Nebraska has indicated that an effective way to address these nonlinearities is to consider the impact of the Target Set in every combination of all other Target Sets either On or Off. As defined in table 4 the four Target Sets are notated C, K, and N for Colorado, Kansas, and Nebraska pumping and M for mound recharge. There are 16 possible model runs with each stress either On or Off. Using the presence of the letter in the run name to indicate that the corresponding stress is On, these are:

θ, C, K, M, N, CK, CM, CN, KM, KN, MN, CKM, CKN, CMN, KMN, CKMN with θ representing the run with all stresses Off. Each run will produce computed baseflow at a given accounting point. For each Target Set of interest, there are eight differences that can be evaluated where the Target Set is On in one Model run and Off in another Model run, with all other Target Sets being unchanged. The Nebraska's Proposed Procedures consider all eight of these runs in arriving at a value for Potential Impact[27].

The Potential Impacts for each of the four Target Sets are given by combination of these eight differences as follows:

Potential Impact of groundwater pumping in Colorado =

$$x_1(\theta\text{-}C) + x_2(K\text{-}CK) + x_3(M\text{-}CM) + x_4(N\text{-}CN) + x_5(KM\text{-}CKM) +$$

$$x_6(KN\text{-}CKN) + x_7(MN\text{-}CMN) + x_8(KMN\text{-}CKMN)$$

Potential Impact of groundwater pumping in Kansas =

$$x_1(\theta\text{-}K) + x_2(C\text{-}CK) + x_3(M\text{-}KM) + x_4(N\text{-}KN) + x_5(CM\text{-}CKM) +$$

$$x_6(CN\text{-}CKN) + x_7(MN\text{-}KMN) + x_8(CMN\text{-}CKMN)$$

Potential Impact of groundwater pumping in Nebraska =

$$x_1(\theta\text{-}N) + x_2(C\text{-}CN) + x_3(M\text{-}MN) + x_4(K\text{-}KN) + x_5(CM\text{-}CMN) +$$

$$x_6(CK\text{-}CKN) + x_7(KM\text{-}KMN) + x_8(CKM\text{-}CKMN)$$

Potential Impact of mound recharge =

$$x_1(\theta\text{-}M) + x_2(C\text{-}CM) + x_3(K\text{-}KM) + x_4(N\text{-}MN) + x_5(CK\text{-}CKM) +$$

$$x_6(CN\text{-}CMN) + x_7(KN\text{-}KMN) + x_8(CKN\text{-}CKMN)$$

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[27] The mathematical basis for the Nebraska's Proposed Procedures has been discussed in both NDNR et al. (2008) and Ahlfeld et al. (2009). In brief, streamflow at an accounting point can be viewed as a continuous function of the level of activity at the four Target Sets. The 16 runs used in the proposed Accounting Procedures constitute the corner points of the four-dimensional domain space for this function. Taking the difference between two of these runs, one with the Target Set present and one without the Target Set gives an estimate of the gradient of the function surface. There are eight possible differences that can be taken, given the 16 available corner point runs. When the surface is nonlinear, an interpolation of these eight gradient estimates provides a better estimate of the gradient than the single difference used by the current Accounting Procedures. The interpolation is formed with eight coefficients that need to be determined. They are determined by enforcing the requirement that the Proposed Impact produce no Unaccounted Impact.

where x_n represents the coefficient on the n[th] difference pair. Note that the Current Accounting Procedures assign a value of one to x_8 and zero to all other coefficients.

Combining the Potential Impacts with the Apparent Impacts in the following equation:

Assigned Impact = Apparent Impact + (Potential Impact – Apparent Impact)/4

The Assigned Impact for each Target Set becomes:

Assigned Impact of groundwater pumping in Colorado = (KMN – CKMN) +

$\{[x_1(\theta\text{-C}) + x_2(\text{K-CK}) + x_3(\text{M-CM}) + x_4(\text{N-CN}) + x_5(\text{KM-CKM}) +$

$x_6(\text{KN-CKN}) + x_7(\text{MN-CMN}) + x_8(\text{KMN-CKMN})] - (\text{KMN-CKMN})\}/4$

Assigned Impact of groundwater pumping in Kansas = (KMN – CKMN) +

$\{[x_1(\theta\text{-K}) + x_2(\text{C-CK}) + x_3(\text{M-KM}) + x_4(\text{N-KN}) + x_5(\text{CM-CKM}) +$

$x_6(\text{CN-CKN}) + x_7(\text{MN-KMN}) + x_8(\text{CMN-CKMN})] - (\text{KMN-CKMN})\}/4$

Assigned Impact of groundwater pumping in Nebraska = (CKM – CKMN) +

$\{[x_1(\theta\text{-N}) + x_2(\text{C-CN}) + x_3(\text{M-MN}) + x_4(\text{K-KN}) + x_5(\text{CM-CMN}) +$

$x_6(\text{CK-CKN}) + x_7(\text{KM-KMN}) + x_8(\text{CKM-CKMN})] - (\text{CKM-CKMN})\}/4$

Assigned Impact of mound recharge[28] = (CKN – CKMN) +

$\{[x_1(\theta\text{-M}) + x_2(\text{C-CM}) + x_3(\text{K-KM}) + x_4(\text{N-MN}) + x_5(\text{CK-CKM}) +$

$x_6(\text{CN-CMN}) + x_7(\text{KN-KMN}) + x_8(\text{CKN-CKMN})] - (\text{CKN-CKMN})\}/4$

---

[28] For convenience of presentation in this Appendix, the differences in the equation for Mound recharge are arranged the same as the other Target Sets, which produces a negative result. For example, (θ-M) would be expected to produce a negative result because a run with Mound recharge present (M) will have more baseflow than a run without Mound recharge (θ). The convention in Compact Accounting is to compute the IWS Credit in a manner that produces a positive value, then subtract it in the accounting to generate a "credit." Insteadwe calculate a negative value and add it into the Accounting balances. The effect is the same.

Note that the same coefficients have been applied to similar terms in each equation. For example, (θ-C) and (θ-K) have the same coefficient. The intent of this assignment of coefficients is to avoid arbitrariness. As will be seen, all coefficients except x_1 and x_8 will take the same value so that the ordering of Target Sets is not important.

Determination of the eight unknown coefficients proceeds by imposing the requirement that the Unaccounted Impacts take the value of zero. That is,

Total Impacts = Sum of Assigned Impacts.

$$(\theta - CKMN) =$$

$$(KMN - CKMN) +$$

$$\{[x_1(\theta\text{-}C) + x_2(K\text{-}CK) + x_3(M\text{-}CM) + x_4(N\text{-}CN) + x_5(KM\text{-}CKM) +$$

$$x_6(KN\text{-}CKN) + x_7(MN\text{-}CMN) + x_8(KMN\text{-}CKMN)] - (KMN\text{-}CKMN)\}/4$$

$$+ (KMN - CKMN) +$$

$$\{[x_1(\theta\text{-}K) + x_2(C\text{-}CK) + x_3(M\text{-}KM) + x_4(N\text{-}KN) + x_5(CM\text{-}CKM) +$$

$$x_6(CN\text{-}CKN) + x_7(MN\text{-}KMN) + x_8(CMN\text{-}CKMN)] - (KMN\text{-}CKMN)\}/4$$

$$+ (CKM - CKMN) +$$

$$\{[x_1(\theta\text{-}N) + x_2(C\text{-}CN) + x_3(M\text{-}MN) + x_4(K\text{-}KN) + x_5(CM\text{-}CMN) +$$

$$x_6(CK\text{-}CKN) + x_7(KM\text{-}KMN) + x_8(CKM\text{-}CKMN)] - (CKM\text{-}CKMN)\}/4$$

$$+ (CKN - CKMN) +$$

$$\{[x_1(\theta\text{-}M) + x_2(C\text{-}CM) + x_3(K\text{-}KM) + x_4(N\text{-}MN) + x_5(CK\text{-}CKM) +$$

$$x_6(CN\text{-}CMN) + x_7(KN\text{-}KMN) + x_8(CKN\text{-}CKMN)] - (CKN\text{-}CKMN)\}/4$$

The correct value for each coefficient (x_n) can be determined by direct examination of this equation. The run θ occurs four times on the right side of the equation, each time divided by four, and only once on the left side of the equation. It follows that x_1 must equal 1 for the occurrences of θ to equate. The run CKMN occurs once on the left side of the equation, and eight times on the right side. To make these occurrences balance x_8 must equal -2. Given the values assigned to these two coefficients, the runs C, K, M, and N occur once with a negative sign and three times with a positive sign on the right side of the equation. They do not occur on the left side. The negative term already has a coefficient of 1, so each positive term must have a coefficient of $^1/_3$ so that they cancel. This results in x_2, x_3, and x_4 equaling $^1/_3$. Each run with two stresses on and two stresses off occur twice as a positive (after x_5, x_6, or x_7) and twice as a negative (after x_2, x_3, or x_4), requiring that these two sets of coefficients must be equal. In summary,

$$x_1 = 1\ ;\ x_8 = -2 \text{ and } x_2 = x_3 = x_4 = x_5 = x_6 = x_7 = {}^1/_3$$

These coefficients also ensure that the occurrences of CKM, CKN, KMN, and CMN cancel each other. Substituting these coefficients into the equations for the Assigned Impact of each Target Set yields:

Assigned Impact of groundwater pumping in Colorado = (KMN – CKMN) +

{[(θ-C) + 1/3(K-CK) + 1/3(M-CM) + 1/3(N-CN) + 1/3(KM-CKM) +

1/3(KN-CKN) + 1/3(MN-CMN) - 2(KMN-CKMN)]– (KMN-CKMN)}/4

Assigned Impact of groundwater pumping in Kansas = (CMN – CKMN) +

{[(θ-K) + 1/3(C-CK) + 1/3(M-KM) + 1/3(N-KN) + 1/3(CM-CKM) +

1/3(CN-CKN) + 1/3(MN-KMN) - 2(CMN-CKMN)]– (CMN-CKMN)}/4

Assigned Impact of groundwater pumping in Nebraska = (CKM – CKMN) +

{[(θ-N) + 1/3(C-CN) + 1/3(M-MN) + 1/3(K-KN) + 1/3(CM-CMN) +

1/3(CK-CKN) + 1/3(KM-KMN) - 2(CKM-CKMN)] – (CKM-CKMN)}/4

Assigned Impact of mound recharge = (CKN – CKMN) +

{[(θ-M) + 1/3(C-CM) + 1/3(K-KM) + 1/3(N-MN) + 1/3(CK-CKM) +

1/3(CN-CMN) + 1/3(KN-KMN) - 2(CKN-CKMN)] – (CKN-CKMN)}/4

The values for the Potential Impact of each Target Set are then:

Potential Impact of groundwater pumping in Colorado = {(θ-C) + [(K-CK) + (M-CM) + (N-CN)]/3 + [(KM – CKM) + (KN – CKN) + (MN – CMN)]/3 – 2(KMN-CKMN)}

Potential Impact of groundwater pumping in Kansas = {(θ-K) + [(C-CK) + (M-KM) + (N-KN)]/3 + [(CM – CKM) + (CN – CKN) + (MN – KMN)]/3 – 2(CMN-CKMN)}

Potential Impact of groundwater pumping in Nebraska = {(θ-N) + [(C-CN) + (K-KN) + (M-MN)]/3 + [(CK – CKN) + (KM – KMN) + (CM – CMN)]/3 – 2(CKM-CKMN)}

Potential Impact of mound recharge = {(θ-M) + [(C-CM) + (K-KM) + (N-MN)]/3 + [(CK – CKM) + (CN – CMN) + (KN – KMN)]/3 – 2(CKN-CKMN)}

Notice that the first term in each equation is the same as the definition of the Potential Impact for the situation with Two Target sets. The remaining seven terms are necessary for a better estimate of Potential Impacts when four Target Sets are present. Note that the first six of the seven terms have coefficients of 1/3 while the final term of the seven has a coefficient of minus 2. If all of these terms have the same value then they will tend to cancel with the first terms remaining dominant. Differences in the values of the terms reflect the nonlinear features of the four-dimensional surface that defines the impact of the four Target Sets.

Note that when nonlinearities are not present, each of the eight differences, for a given Target Set, will produce the same value. When the stream baseflow responds linearly, the Potential Impact will equal the Apparent Impact and the Assigned Impact will be identical to the impact calculated using the Current Accounting Procedures.

These equations can be conveniently rearranged to the following forms:

Assigned Impact of groundwater pumping in Colorado = [(θ-C) + ((K-CK) + (M-CM) + (N-CN))/3 + ((KM-CKM) + (KN-CKN) + (MN-CMN))/3 + (KMN-CKMN)]/4

Assigned Impact of groundwater pumping in Kansas = [(θ-K) + ((C-CK) + (M-KM) + (N-KN))/3 + ((CM-CKM) + (CN-CKN) + (MN-KMN))/3 + (CMN-CKMN)]/4

Assigned Impact of groundwater pumping in Nebraska = [(θ-N) + ((C-CN) + (M-MN) + (K-KN))/3 + ((CM-CMN) + (CK-CKN) + (KM-KMN))/3 + (CKM-CKMN)]/4

Assigned Impact of the IWS = [(θ-M) + ((C-CM) + (K-KM) + (N-MN))/3 + ((CK-CKM) + (CN-CMN) + (KN-KMN))/3 + (CKN-CKMN)]/4

The Assigned Impact equations are derived for the most general case of four Target Sets, however, they easily cover the cases when three, two or only one Target Set have significant impact on an accounting point. For example, consider a case in which Kansas and Nebraska pumping are the only Target Sets that cause significant change in baseflow at an accounting point. For this case, the following observations can be made:

1) C = M = CM = θ (turning on Colorado pumping and/or Mound recharge produces no change from the all-off condition)
2) CK =KM = CKM =K (adding Colorado pumping and/or Mound recharge does not change the impact of Kansas pumping)
3) CN =MN = CMN = N (adding Colorado pumping and/or Mound recharge does not change the impact of Nebraska pumping)
4) KMN = CKN = CKMN = KN (adding Colorado pumping and/or Mound recharge does not change the combined impact of Kansas pumping and Nebraska pumping)

Substituting these 4 statements into the Assigned Impact equations produces the following results:

Assigned Impact of groundwater pumping in Colorado = 0

Assigned Impact of groundwater pumping in Kansas = [(θ-K) + ((θ-K) + (θ-K) + (N-KN))/3 + ((θ-K) + (N-KN) + (N-KN))/3 + (N-KN)]/4

= [(θ-K) + (N-KN)]/2

Assigned Impact of groundwater pumping in Nebraska = [(θ-N) + ((θ-N) + (θ-N) + (K-KN))/3 + ((θ-N) + (K-KN) + (K-KN))/3 + (K-KN)]/4

= [(θ-N) + (K-KN)]/2

Assigned Impact of the IWS = 0

As can be seen, with the observations, the general four target equation reduces to the simpler two Target Set equation discussed in Section 4.3 when only two Target Sets are relevant. A similar analysis could be conducted for any combination of two stresses. In a similar fashion, if only three Target Sets are relevant to an accounting point, the impact of the irrelevant Target Set will be assigned a value of zero in Nebraska's Proposed Procedures.

APPENDIX G. Application of Nebraska's Proposed Procedures

The following examples demonstrate the behavior of Nebraska's Proposed Procedures under a range of conditions. The scale analogy is utilized for these examples. First, an example is presented in which there are no Unaccounted Impacts. In this case, the results of Nebraska's Proposed Procedures are identical to the Current Accounting Procedures. Next, the same example from Section 4.3 and Appendix C, with two people exceeding the scale capacity, is utilized. Here, Person C and Person D are simply represented with zero weight (impact). The results are identical to those obtained in Appendix C using the simplified equations for only two Target Sets. Finally, an example with four people whose combined Potential Impact is well in excess of the scale capacity. Here the Current Accouting Procedures account for zero pounds of impact. Nebraska's Proposed Procedures assign the Unaccounted Impact to each Person according to the ability of that person to cause those impacts. The result is that all impacts are accounted for.

Application of Nebraska's Proposed Procedures when there are no Unaccounted Impacts

When the sum of the Potential Impacts for the targets set(s) is equal to less than the scale capacity, Nebraska's Proposed Procedures produce the same values for the individual impacts Target Setas the Current Accounting Procedures. In this case, the Potential Impact will be the same as the Apparent Impact, and there are no Unaccounted Impacts. While Nebraska's Proposed Procedures are not necessary in this example, they do not change the result, instead simply making a few more computations than might be needed. Consider for example applying Nebraska's Proposed Procedures to the following situation:

Person A = 50 pounds

Person B = 75 pounds

Person C = 60 pounds

Person D = 80 pounds

Capacity = 300 pounds

The capacity of the scale in the following equations is represented by θ, and the remaining capacity with some combination of persons on the scale is represented by a variable with the number of those persons (e.g., 12 = remaining capacity with person 1 and 2 on the scale). So the values and computations would look like this:

θ = 0 pounds

A = 50 pounds

B = 75 pounds

C = 60 pounds

D = 80 pounds

AB = 125 pounds

AC = 110 pounds

AD = 130 pounds

BC = 135 pounds

BD = 155 pounds

CD = 140 pounds

ABC = 185 pounds

ABD = 205 pounds

ACD = 190 pounds

BCD = 215 pounds

ABCD = 265 pounds

The equations for the impact of each person would look similar to the equations presented in Section 5.2, with the substitution of the variable representing Persons A, B, C, and D for the variable representing Colorado pumping (C), Kansas pumping (K), Nebraska pumping (N), and mound recharge (M). The only other change is that each of the differences in reversed in order to produce a positive result (i.e., instead of θ-C, these equations would use C-θ). Therefore the appropriate equations representing the proposed accounting procedures are:

Impact of person A = [(A-θ) + ((AB-B) + (AC-C) + (AD-D))/3 + ((ABC-BC) + (ABD-BD) + (ACD-CD))/3 + (ABCD-BCD)]/4

Impact of person B = [(B-θ) + ((AB-A) + (BC-C) + (BD-D))/3 + ((ABC-AC) + (ABD-AD) + (BCD-CD))/3 + (ABCD-ACD)]/4

Impact of person C = [(C-θ) + ((AC-A) + (BC-B) + (CD-D))/3 + ((ABC-AB) + (ACD-AD) + (BCD-BD))/3 + (ABCD-ABD)]/4

Impact of person D = [(D-θ) + ((AD-A) + (BD-B) + (CD-C))/3 + ((ABD-AB) + (ACD-AC) + (BCD-BC))/3 + (ABCD-ABC)]/4

Inserting the appropriate values and making all the calculations results in:

Impact of person A = [(50-0) + ((125-75) + (110-60) + (130-80))/3 + ((185-135) + (205-155) + (190-140))/3 + (265-215)]/4

= [50 + (50 + 50 + 50)/3 + (50 + 50 + 50)/3 +50]/4 = 50 pounds

Impact of person B = [(75-0) + ((125-50) + (135-60) + (155-80))/3 + ((185-110) + (205-130) + (215-140))/3 + (265-190)]/4

= [75 + (75 + 75 + 75)/3 + (75 + 75 + 75)/3 +75]/4 = 75 pounds

Impact of person C = [(60-0) + ((110-50) + (135-75) + (140-80))/3 + ((185-125) + (190-130) + (215-155))/3 + (265-205)]/4

= [60 + (60 + 60 + 60)/3 + (60 + 60 + 60)/3 +60]/4 = 60 pounds

Impact of person D = [(80-0) + ((130-50) + (155-75) + (140-60))/3 + ((205-125) + (190-110) + (215-135))/3 + (265-185)]/4

= [80 + (80 + 80 + 80)/3 + (80 + 80 + 80)/3 +80]/4 = 80 pounds

As we can see, each of the 8 differences in any one of the impact equations has the same value. Multiplying each value by the appropriate weight and summing the results simply produces that value. Note that the last difference in each equation (e.g., 123-1234) represents the Current Accounting Procedures. Therefore, the Current Accounting Procedures would be sufficient in this case.

Application of Nebraska's Proposed Procedures with Two Target Sets exceeding Scale Capacity

It is not required to have four persons of interest in order to apply the equations for four Target Sets. In fact if there is only one person being weighed these equations are still appropriate, though certainly not necessary. As previously noted, most sub-basins and Main Stem reaches are not impacted significantly by all four Target Sets in the Model. We can apply the equations to the example from Section 4.3 and Appendix C, where only two people are being weighed, by simply accounting for Persons C and D with zero impact. The calculations would look like this:

θ = 0 pounds

A = 250 pounds

B = 250 pounds

C = 0 pounds

D = 0 pounds

AB = 300 pounds

AC = 250 pounds

AD = 250 pounds

BC = 250 pounds

BD = 250 pounds

CD = 0 pounds

ABC = 300 pounds

ABD = 300 pounds

ACD = 250 pounds

BCD = 250 pounds

ABCD = 300 pounds

Impact of person A = [(A-θ) + ((AB-B) + (AC-C) + (AD-D))/3 + ((ABC-BC) + (ABD-BD) + (ACD-CD))/3 + (ABCD-BCD)]/4

Impact of person B = [(B-θ) + ((AB-A) + (BC-C) + (BD-D))/3 + ((ABC-AC) + (ABD-AD) + (BCD-CD))/3 + (ABCD-ACD)]/4

Inserting the appropriate values and making all the calculations results in:

Impact of person A = [(250-0) + ((300-250) + (250-0) + (250-0))/3 + ((300-250) + (300-250) + (250-0))/3 + (300-250)]/4

= [250 + (50 + 250 + 250)/3 + (50 + 50 + 250)/3 +50]/4

= [250 + 550/3 + 350/3 + 50]/4 = [250 + 900/3 + 50]/4 = [250 + 300 + 50]/4

= 600/4 = 150 pounds

Impact of person B = [(250-0) + ((300-250) + (250-0) + (250-0))/3 + ((300-250) + (300-250) + (250-0))/3 + (300-250)]/4

= [250 + (50 + 250 + 250)/3 + (50 + 50 + 250)/3 +50]/4

= [250 + 550/3 + 350/3 + 50]/4 = [250 + 900/3 + 50]/4 = [250 + 300 + 50]/4

= 600/4 = 150 pounds

The result that is obtained from these more general equations (i.e., can accommodate four Target Sets as opposed to only two Target Sets) is exactly the same. More computations are involved, but these computations are readily automated through programing or other computing means. If there may be as many as four Target Sets to consider at some times, it would be much more efficient to implement the use of these equations in all cases (even when there are not four Target Sets), rather than to switch between sets of equations depending on the number of Target Sets. Note that inserting the appropriate values into the Impact equations for persons C and D produce values of zero impact for each.

Application of Nebraska's Proposed Procedures with Four Target Sets exceeding Scale Capacity

Now consider a similar example, except these people were each 100 pounds heavier (i.e., person 1 = 150 pounds, person 2 = 175 pounds, person 3 = 160 pounds, person 4 = 180 pounds). In this case the Current Accounting Procedures would produce an impact estimate for each person of zero pounds. The computations using Nebraska's Proposed Procedures would look like this:

θ = 0 pounds

A = 150 pounds

B = 175 pounds

C = 160 pounds

D = 180 pounds

AB = 300 pounds

AC = 300 pounds

AD = 300 pounds

BC = 300 pounds

BD = 300 pounds

CD = 300 pounds

ABC = 300 pounds

ABD = 300 pounds

ACD = 300 pounds

BCD = 300 pounds

ABCD = 300 pounds

Impact of person A = [(A-θ) + ((AB-B) + (AC-C) + (AD-D))/3 + ((ABC-BC) + (ABD-BD) + (ACD-CD))/3 + (ABCD-BCD)]/4

Impact of person B = [(B-θ) + ((AB-A) + (BC-C) + (BD-D))/3 + ((ABC-AC) + (ABD-AD) + (BCD-CD))/3 + (ABCD-ACD)]/4

Impact of person C = [(C-θ) + ((AC-A) + (BC-B) + (CD-D))/3 + ((ABC-AB) + (ACD-AD) + (BCD-BD))/3 + (ABCD-ABD)]/4

Impact of person D = [(D-θ) + ((AD-A) + (BD-B) + (CD-C))/3 + ((ABD-AB) + (ACD-AC) + (BCD-BC))/3 + (ABCD-ABC)]/4

Inserting the appropriate values and making all the calculations results in:

Impact of person A = [(150-0) + ((300-175) + (300-160) + (300-180))/3 + ((300-300) + (300-300) + (300-300))/3 + (300-300)]/4

= [150 + (125 + 140 + 120)/3 + (0 + 0 + 0)/3 +0]/4

= [150 + (385/3)]/4 = [150 + 128.3]/4 = 69.6 pounds

Impact of person B = [(175-0) + ((300-150) + (300-160) + (300-180))/3 + ((300-300) + (300-300) + (300-300))/3 + (300-300)]/4

= [175 + (150 + 140 + 120)/3 + (0 + 0 + 0)/3 +0]/4

= [175 + (410/3]/4 = [175 + 136.7]/4 = 77.9 pounds

Impact of person C = [(160-0) + ((300-150) + (300-175) + (300-180))/3 + ((300-300) + (300-300) + (300-300))/3 + (300-300)]/4

= [160 + (150 + 125 + 120)/3 + (0 + 0 + 0)/3 +0]/4

= [160 + (395/3)]/4 = [160 + 131.7]/4 = 72.9 pounds

Impact of person D = [(180-0) + ((300-150) + (300-175) + (300-160))/3 + ((300-300) + (300-300) + (300-300))/3 + (300-300)]/4

= [180 + (150 + 125 + 140)/3 + (0 + 0 + 0)/3 +0]/4

= [180 + (415/3)]/4 = [180 + 138.3]/4 = 79.6 pounds

Table 8 summarizes the weight of these four people and their impact as determined by the Current Accounting Procedures and the proposed accounting procedures.

Table 8. Comparison of Apparent Impact and Assigned Impact for case with four Target Sets that exceed the scale capacity.

Person	Weight	Impact – Current Accounting Procedures	Impact – Proposed Accounting Procedures
1	150	0	69.6
2	175	0	77.9
3	160	0	72.9
4	180	0	79.6
Sum	665	0	300

Notice that the proposed accounting procedures do account for the full 300 pounds of impacts. The heaviest person is assigned the greatest impact and the lightest person is assigned the smallest impacts. This is clearly preferred to the results of the Current Accounting Procedures, which allocate none of the impacts in this case.

EXHIBIT B

Colorado's Report in Response to Nebraska Expert Report in Support of Counterclaim and Crossclaim: Nebraska's Proposed Changes to the RRCA Accounting Procedures

Willem A. Schreüder, Ph.D

March 15, 2012

1. Introduction

This report provides a response to *Nebraska Expert Report in Support of Counterclaim and Crossclaim: Nebraska's Proposed Changes to the RRCA Accounting Procedures* by Dr. James C. Schneider dated November 18, 2011 (the "Report"). The Report builds upon a previous report titled *Estimating Computed Beneficial Consumptive Use for Groundwater and Imported Water Supply under the Republican River Compact* by Dr. David P. Ahlfeld, Michael G. McDonald and James C. Schneider dated January 20, 2009 (the "2009 Report").

The Report presents "The Problem" and "The Solution" as if there is a single problem and a single solution. This is incorrect. There are in fact a number of different mechanisms at work leading to the observations cited in the Report. Furthermore, not all these observations are necessarily errors in the RRCA Groundwater Model or the application of the Model. Instead, these observations are manifestations of the nonlinear behavior of the complex hydrology of the Republican River Basin itself.

To explain "The Problem", Nebraska introduces an analogy based on a simple weight scale with a limited capacity to weigh multiple objects. This analogy is misleading and inaccurate because it compares the RRCA Groundwater Model and Accounting Procedures to a flawed, nonlinear measurement device attempting to quantify a process that is inherently linear. The RRCA Groundwater Model is nonlinear because the underlying groundwater flow system in the Republican River Basin is nonlinear, and not as a result of any sort of flaw in the Model itself. Nebraska's analogy is therefore totally inappropriate and not helpful as an illustration.

As for "The Solution", it is but one of many different applications of the Model that will provide a result. However, Nebraska's proposed solution does not solve the underlying problem, is cumbersome in execution, and introduces new problems. Even if one were to accept what the Report characterizes as an error, the solution proposed by Nebraska is not appropriate.

Furthermore, the proposed solution burdens the States for the consumption of imported water in direct contradiction of the Final Settlement Stipulation (FSS) dated December 15, 2002. In fact, the proposed solution exacerbates the problem by increasing the amount of consumption of imported water added to the Computed Beneficial Consumptive Use (CBCU) of groundwater ($CBCU_G$)[1] for all three States.

The core of the Nebraska proposal is not to determine the Virgin Water Supply. Even under the proposed Nebraska procedures, the Virgin Water Supply could be very simply calculated using the difference between the historical simulation and a simulation with all pumping and imported water turned off. Instead, its complex procedure is required to attribute this difference to the States. Nebraska's proposed procedure would burden the States not only for the actual depletions to stream

1 Generally, the Compact accounting and equations uses the abbreviation CBCU to generically refer to Computed Beneficial Consumptive Use. A subscript is used to refer to some specific type of CBCU. Thus the total CBCU for all groundwater consumption is $CBCU_G$, while Nebraska's total groundwater consumption is $CBCU_N$, etc.

flows, but also for the potential depletions to stream flows that would have been caused had the other States not been pumping – a purely hypothetical exercise. Such a procedure benefits the State with the largest impacts, because it considers the potential impacts that would have occurred in the absence of the major stress that historically occurred in the basin. Since, historically, Nebraska's pumping impacts comprise more than 80% of all the pumping impacts to streams in the basin, this obviously favors Nebraska.

By burdening States with potential depletions rather than actual depletions, the Nebraska proposal essentially shifts the burden of some of Nebraska's pumping depletions to Colorado and Kansas, and thus reduces the ability of Colorado and Kansas to use their full allocations guaranteed under the Compact.

Colorado therefore objects to Nebraska's proposal to change the approved procedure to calculate the CBCU of groundwater for each State on the following technical grounds:

1. Nebraska's proposed solution burdens Colorado and Kansas, but mostly Nebraska itself, with consumption of imported water supply. This is counter to the conditions agreed to in the Accounting Procedures and Reporting Requirements attached as Appendix C to the FSS.

2. Nebraska's proposed method subtracts imported water from the gaged flow that would only have occurred in the absence of well pumping in Nebraska. This overestimates the amount of imported water that was actually measured under historical conditions.

3. Nebraska's proposed method does not match the net pumping minus imported water supply calculations within Nebraska, but rather overestimates the net impact within Nebraska.

4. Nebraska bases the necessity for changing the currently approved procedures on highlighting selected locations and periods where the current model application does not favor Nebraska. The magnitude of this deficiency is overstated. In agreeing to the current approved procedures, the States recognized that the RRCA Groundwater Model is an imperfect analog of reality that cannot be perfectly accurate in every location for every year. To mitigate the Model's limitations, the States agreed to assess Compact Compliance using a five year running average.

5. Nebraska's proposed method burdens Colorado and Kansas with impacts that would only have occurred if Nebraska had not been pumping, a situation outside of Colorado or Kansas' control. For example, Nebraska's pumping has dried up parts of Frenchman Creek. The proposed method includes impacts caused by wells in Colorado as if wells in Nebraska had never pumped and never dried up parts of Frenchman Creek.

6. Nebraska's proposed method assumes that the accuracy of the RRCA Groundwater Model is the same under all conditions. In reality, model results becomes increasingly uncertain the further away they get from the conditions the model was calibrated to. The currently approved method was adopted to deviate from the calibrated conditions only to the extent absolutely necessary to determine depletions to baseflow caused by groundwater withdrawals and to determine the effect of the imported water supply on surface streams. In Nebraska's proposed method, the impact calculation is dominated by conditions to which the RRCA Groundwater

Model was not calibrated.

7. The procedure proposed by Nebraska is but one of many alternatives to the procedure approved by the States and the RRCA as part of the FSS. If there is indeed a problem with the calculation of Imported Water Supply Credit in the approved procedure, the procedure proposed by Nebraska is not the appropriate solution. A method will be demonstrated that corrects a deficiency in computing the Imported Water Supply Credit without introducing additional complexity or introducing new problems.

This report will address the observations cited by Nebraska as well as the specific solution proposed by Nebraska, and demonstrate that the proposed modifications to the Accounting Procedures are inappropriate. In addition, this report will address consumption of imported water. This is mentioned in the Nebraska report, but Nebraska's proposal does not correct this problem. As an example of alternative procedures, this report will present a procedure designed to address this issue, although the procedure proposed in the report may not be the sole solution to the problem.

The graphs and results shown in this report are based on model simulations supplied by Nebraska to support its current Report and the report Nebraska submitted in support of its proposals in the 2009 nonbinding arbitration (2009 Report).

2. The perceived problem

Nebraska contends that the approved RRCA Accounting Procedures are flawed because the impacts computed for individual States do not equal the impacts for the three States combined, for each sub-basin, and for each year.

This result is not indicative of any error. Instead, this result is simply the consequence of the nonlinear behavior inherent in the Republican River groundwater system which is correctly represented in the RRCA Groundwater Model. The approved RRCA Accounting Procedures recognize that the nonlinearities in the model could cause the pumping impacts of wells in Colorado or Kansas to be greater in the absence of any pumping in Nebraska than the pumping impacts of wells in Colorado or Kansas when wells in Nebraska were actually pumping, as they did historically.

The approved RRCA Accounting Procedures satisfy an important requirement that Nebraska's proposed method does not: ***The pumping impacts assigned to a State cannot exceed the amount of additional baseflow that would be generated by curtailment of all the wells in only that State.*** Therefore, if all the wells in Colorado were curtailed, Colorado's Computed Beneficial Consumptive Use of Groundwater under the Compact cannot be greater than the amount of additional baseflow generated by only that action. This is not by accident. The committees that constructed the RRCA Groundwater Model and formulated the accounting procedures were well aware of the nonlinearities in the groundwater system and that were represented in the Model. The procedure in the RRCA Accounting Procedures to calculate the Computed Beneficial Consumptive Use of Groundwater for each State was agree to after careful consideration of such nonlinearities. Under Nebraska's proposed method, Colorado would be burdened with not only the additional baseflow that would be generated by curtailment of wells in Colorado, but also with the additional amount of baseflow that would have been generated had Nebraska never developed any wells, even though Nebraska had the right to develop and administer wells in Nebraska.

The primary purpose of the RRCA Groundwater Model is to determine the amount, location, and timing of stream flow depletions to the Republican River caused by well pumping and to determine stream flow accretions from recharge of water imported from the Platte River Basin in to the Republican River Basin[2]. This is accomplished by determining the effects of groundwater pumping and the imported water supply on baseflow[3] and the gaged surface flows. These calculations are complicated by factors that contribute to the nonlinear behavior of the model. Specifically, evapotranspiration by native vegetation, which constitutes a large fraction of the overall water budget, changes in response to changes in water levels. In addition, significant portions of some streams dry up, especially during dry periods, resulting in additional nonlinearities. This leads to a complex interaction between imported water and pumping impacts.

At times, some of the stream reaches dry out due to natural conditions, a condition that occurred historically and prior to development of the RGDSS Groundwater Model. However, imported water can increase the stream flows to the point where streams remain wet, and hence increase the potential for well pumping to cause additional depletions. It is therefore important to consider the interaction between the imported water and depletions caused by well pumping.

2.1 Nebraska's Demonstration of the Problem

To demonstrate the existence of a problem, Nebraska cites examples where Nebraska would benefit from a change in the approved accounting procedures. Specifically, in the 2009 Report, Nebraska demonstrates that in 2003 Nebraska would receive a larger allocation under the proposed method on Beaver Creek because the combined impacts for Kansas and Nebraska are greater than the individual impacts of Kansas and Nebraska added together. Further, Nebraska demonstrates that it will receive a larger allocation in 2003 under the proposed method on Frenchman Creek because the combined impacts for Colorado and Nebraska are greater than the individual impacts of Colorado and Nebraska added together. In addition, Nebraska demonstrates that in 2003, the imported water supply on the Main Stem under the proposed method would be greater than under the approved method. In the current Report, Nebraska concentrates on the Swanson-Harlan mainstem reach to illustrate how under the proposed method, Nebraska would benefit from a change in the procedures under projected future conditions.

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2 This imported water or "imported water supply" is a water supply imported to the Republican River Basin by a state resulting from the activities of man. Here we are concerned with water diverted from the Platte River in Nebraska, a portion of which recharges the groundwater system within the Republican River Basin, also referred to as "the mound." This water can result in additional baseflow and even CBCU that would not exist but for the imported water supply.

3 In simplified terms, "baseflow" may be thought of as the water that accretes to surface streams from an aquifer. It is a portion of, but not necessarily the entire amount, of water recorded at a stream gage. Gaged flows may also contain water that reached the stream directly from surface runoff, usually due to precipitation events.

Nebraska's conclusion that these demonstrations are indicative of errors in the current RRCA Accounting Procedures is not correct. Specifically, Nebraska's demonstrations rely on the necessary nonlinear behavior of the Model to show that if there had been no well development in Nebraska, then Kansas would have had bigger impacts on Beaver Creek and Colorado would have had bigger impacts on Frenchman Creek. Nebraska presents their proposed change to the accounting procedure as a correction needed because the approved method underestimates the virgin water supply.

However, Nebraska's proposed procedure incorrectly increases the calculation of Kansas and Colorado's well impacts on baseflow by basing that determination on a scenario where no other state developed its groundwater resources. Thus, the proposed method increases the calculated impacts of Kansas and Colorado wells on baseflow beyond their actual physical impact on the hydrologic system. For example, Nebraska's proposed method calculates that in 2003 Colorado pumping impacted Frenchman Creek by 2,565 acre-feet. However, the current application of the model shows that if Colorado had never developed a single well, there would be only 19 acre-feet of additional baseflow in Frenchman Creek. Similarly, Nebraska's proposed method calculates that in 2003 Kansas pumping impacted Beaver Creek by 2,021 acre-feet. However, the current application of the model shows that if Kansas had never developed a single well, there would be only 323 acre-feet of additional baseflow in Beaver Creek.

The reasons why the RRCA Groundwater Model predicts greater impacts from pumping in Colorado and Kansas in the absence of well development in Nebraska are detailed below.

2.2 Nonlinearity in the RRCA Groundwater Model

The RRCA Groundwater Model is, by necessity, a non-linear model. That means that the model outputs are not directly proportional to the model inputs. For example, if x acre-feet of pumping results in y acre-feet of stream depletions, then $2x$ acre-feet of pumping will not necessarily result in $2y$ acre-feet of stream depletions.

There are a number of mechanisms contributing to nonlinearity in the physical system, and therefore in the Model, including evapotranspiration, springs and streams. In particular, the MODFLOW stream package is used to track surface water along a stream course and will let streams go dry when losses exceed the inflow to a stream reach. When a stream reach goes dry, well impacts to streams will not increase as well pumping increases, because there is no baseflow to impact, leading to significantly nonlinear behavior.

The RRCA Groundwater Model is applied in a transient[4] mode, but the results are summarized on an annual basis for Compact Accounting purposes. Some of the nonlinear behavior may occur during only part of the year, but still result in nonlinear behavior on an annual basis. The nonlinear behavior may be exacerbated when, for example, the period of time during which the stream is dry changes between the simulations being compared.

4 Generally, groundwater models are run in either steady state or transient modes. Transient simulations are needed to analyze time-dependent problems. Transient simulations produce a set of groundwater heads or elevation for each time step, i.e. twice monthly, whereas steady-state simulations generate only one set of groundwater heads representing an average over time.

Although the nonlinear behavior of the RRCA Groundwater Model is recognized and accepted, it is also recognized that the Model will need to be operated on an ongoing basis. Therefore, a number of appropriate simplifications were incorporated into the Model. For example, instead of allowing the Model to calculate the saturated thickness as a function of change in water levels, the Model is operated with a saturated thickness that does not vary over time. This makes the Model behavior less nonlinear, but also results in a Model that is considerably more robust and easier to operate. All three States and the United States agreed to these modeling procedures and protocols.

The Accounting Procedures section III.D.1 establishes the procedure for running the Model in order to determine to what extent each State's consumption of groundwater depletes baseflow in the Republican River Basin. This procedure evaluates state by state pumping impacts by making paired Model runs which evaluate the difference in baseflow both with and without pumping within the State in question. Note that for this evaluation, whether the Model is linear or nonlinear does not affect the evaluation procedure. The Model can be used to directly compute the outputs for a given set of inputs. Whether a model is linear or nonlinear only matters when there is an expectation that the differences derived from these paired model simulations can be combined to derive a result without actually re-running the model.

The difference in the baseflow caused by turning off the wells is by definition the impact. Whether the baseflow is linearly or nonlinearly related to the pumping is immaterial when evaluating the impacts for one state using the RRCA approved method since the Model directly calculates the change in flow while considering all the nonlinear relationships. The Model explicitly evaluates the two conditions and by definition the change in baseflow between the conditions are the baseflow impacts used in the Compact Accounting. Nonlinearity only plays a role when it is expected that the individual State impacts should sum to the total impact computed as the difference between a simulation representing historical conditions and a simulation representing predevelopment conditions [5].

2.3 Computing Impacts

The procedure for estimating pumping impacts approved by the RRCA is defined in the Accounting Procedures III.D.1

> ***D. Calculation of Annual Computed Beneficial Consumptive Use***
>
> ***1. Groundwater***
>
> *Computed Beneficial Consumptive Use of groundwater shall be determined by use of the RRCA Groundwater Model. The Computed Beneficial Consumptive Use of groundwater for each State shall be determined as the difference in stream flows using two runs of the model:*
>
> *The "base" run shall be the run with all groundwater pumping, groundwater pumping*

5 A predevelopment condition means that no well development or imported water supply occurred anywhere in the basin.

recharge, and surface water recharge within the model study boundary for the period 1940 to the current accounting year "on".

The "no State pumping" run shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge of that State shall be turned "off."

An output of the model is baseflows at selected stream cells. Changes in the baseflows predicted by the model between the "base" run and the "no-State pumping" model run is assumed to be the depletions to stream flows. i.e., groundwater computed beneficial consumptive use, due to State groundwater pumping at that location. The values for each Sub-basin will include all depletions and accretions upstream of the confluence with the Main Stem. The values for the Main Stem will include all depletions and accretions in stream reaches not otherwise accounted for in a Sub-basin. The values for the Main Stem will be computed separately for the reach above Guide Rock, and the reach below Guide Rock

Therefore the approved procedure for estimating pumping impacts approved by the RRCA compares baseflow in a historical simulation with baseflow in a simulation where pumping for a State is removed. Similarly the imported water supply credits are calculated by subtracting stream flows in a simulation where the imported water supply is removed from the historical simulation. Following the nomenclature introduced by Nebraska in Table 10 of the 2009 Report, the approved methods for estimating impacts are

$$CBCU_C = KMN - CKMN \quad \textbf{(1a)}$$
$$CBCU_K = CMN - CKMN \quad \textbf{(1b)}$$
$$CBCU_N = CKM - CKMN \quad \textbf{(1c)}$$
$$IWS = CKMN - CKN \quad \textbf{(1d)}$$

so that

$$CBCU_C + CBCU_K + CBCU_N - IWS = KMN + CMN + CKM + CKN - 4CKMN \quad \textbf{(1e)}$$
$$CBCU_N - IWS = (CKM\text{-}CKMN) - (CKN\text{-}CKMN) = CKM + CKN - 2\ CKMN \quad \textbf{(1f)}$$

The physical interpretation of Eq. 1e and 1f is that the total basin wide impact and total Nebraska impact are simply the sum of the individual components that make up the sum. In general these sums will not match the values computed as Θ-CKMN and CK-CKMN if the model behaves nonlinearly, as it should in this circumstance.

The procedure first proposed by Nebraska in the January 2009 Report modifies the approved procedure to be

$$CBCU_C = (KMN\text{-}CKMN)/4 + (\Theta\text{-}C)/4 + (K\text{-}CK)/12+(M\text{-}CM)/12+(N\text{-}CN)/12+(KM\text{-}CKM)/12+(KN\text{-}CKN)/12+(MN\text{-}CMN)/12 \quad \textbf{(2a)}$$

$$CBCU_K = (CMN\text{-}CKMN)/4 + (\Theta\text{-}K)/4 + (C\text{-}CK)/12+(M\text{-}KM)/12+(N\text{-}KN)/12+(CM\text{-}CKM)/12+(CN\text{-}CKN)/12+(MN\text{-}KMN)/12 \quad \textbf{(2b)}$$

$$CBCU_N = (CKM\text{-}CKMN)/4 + (\Theta\text{-}N)/4 + (C\text{-}CN)/12+(M\text{-}MN)/12+(K\text{-}KN)/12+(CM\text{-}CMN)/12+(CK\text{-}CKN)/12+(KM\text{-}KMN)/12 \quad \textbf{(2c)}$$

$$IWS = (CKMN\text{-}CKN)/4 + (M\text{-}\Theta)/4 + (CM\text{-}C)/12+(KM\text{-}K)/12+(MN\text{-}N)/12+(CKM\text{-}CK)/12+(CMN\text{-}CN)/12+(KMN\text{-}KN)/12 \quad \textbf{(2d)}$$

so that

$$CBCU_C + CBUC_K + CBCU_N - IWS = \Theta\text{-}CKMN \quad \textbf{(2e)}$$

$$CBCU_N - IWS = (CKM\text{-}CKMN)/4 + (\Theta\text{-}N)/4+(C\text{-}CN)/12+(M\text{-}MN)/12+(K\text{-}KN)/12+(CM\text{-}CMN)/12+(CK\text{-}CKN)/12+(KM\text{-}KMN)/12 + (CKN\text{-}CKMN)/4 + (\Theta\text{-}M)/4+(C\text{-}CM)/12+(K\text{-}KM)/12+(N\text{-}MN)/12+(CK\text{-}CKM)/12+(CN\text{-}CMN)/12+(KN\text{-}KMN)/12$$
$$=(\Theta\text{-}CKMN)/2 + (K\text{-}M)/6+(C\text{-}N)/6+(CK\text{-}MN)/6+(CKM\text{-}CMN)/6+(CKN\text{-}KMN)/6 \quad \textbf{(2f)}$$

Note that the Nebraska proposal shown in Eqs. 2a-d assigns ¼ the weight to the original equation shown in Eqs. 1a-d, respectively. It then adds with the same ¼ weight the difference between a simulation where there is no development in the basin and a simulation where pumping in only one state is developed, or only surface water imports occur. The remaining six terms each have a 1/12 weight and adds to half the total weight. These six terms evaluate different combinations of development in well pumping or surface water imports.

The rationale provided in the Nebraska Report for this procedure is that the States should not only be charged for the **actual** depletions they caused, but also for the **potential** depletions they would have caused in the absence of pumping from other States. Furthermore, it should be noted that in half the simulations shown in Eqs. 2a-d imported water supply is included, which burdens all three states with the depletion of imported water in direct contradiction to the FSS.

The sixteen runs can be combined as weighted pairs in numerous different ways. Mathematical manipulation of the averages can lead to different results, but just because mathematical manipulation of the results provides a desirable outcome, it does not mean that it produces a "better", much less correct result for the three States, or enhances administration of the Republican River. It is important that the mathematical manipulation of these equations be interpreted in terms of the physical meaning of the terms. For example, in Section 3.1 below it will be shown how Eq. 2a physically means that the impact assigned to Colorado is the average of the impact that actually occurred historically and impacts that would have occurred had Nebraska never developed any wells. This is untenable. The mathematical manipulations must be tempered by sound engineering judgment as to whether such a procedure is "better" and correct under the Compact.

Nebraska's proposal has at its core the goal of matching the sum of state impacts to the total directly computed impacts Θ-CKMN. In order to achieve this goal, correctly computing the total Nebraska impact is sacrificed as shown in Eq. 2e. If instead, the goal is to correctly compute the impacts for each state, the model may, for example, be utilized in the following manner:

$CBCU_C = KN - CKN$ **(3a)**
$CBUC_K = CN - CKN$ **(3b)**
$CBCU_N = CK - CKN$ **(3c)**
$IWS = CKMN\text{-}CKN$ **(3d)**
so that
$CBCU_C + CBUC_K + CBCU_N - IWS = KN + CN - 2CKN + CK - CKMN$ **(3e)**
$CBCU_N - IWS = (CK\text{-}CKN) - (CKN\text{-}CKMN) = CK - CKMN$ **(3f)**

Note that Eqs. 3a-c are the same as Eqs. 1a-c except that pumping impacts are evaluated in the absence of the imported water supply, hence dropping the M factor from each term. Eq. 3d is identical to Eq. 1d. The physical interpretation of Eq. 3e is again that the total impact is simply the sum of the individual impacts. However, Eq. 3f shows that the Nebraska total impact matches the directly computed Nebraska impact. In practice, Eqs. 3a and 3b yield essentially the same result as Eqs. 1a and 1b since the Colorado and Kansas pumping impacts are not affected by imported surface water in more than a *de minimis* amount. However, under proper modeling protocols the pumping impacts should be evaluated in a consist manner.

This is not to suggest that the current approved protocol is necessarily in error, only that models and model results may be manipulated in any number of ways to reach a different result depending upon the goal of those who operate the model.

2.4 Quantitative Results

Tables 1 and 2 show the quantitative impact of the different methods shown above. Tables 1a-z show the results for each year from 1981-2006. Tables 2a, 2b and 2c show the average values for 1981-2000, 2001-2006 and 1981-2006, respectively.

Each table shows the amount calculated for $CBCU_C$, $CBUC_K$, $CBCU_N$ and IWS. In addition, the NE Residual column shows the residual calculated as for just Nebraska as

Nebraska Residual = $(CBCU_N - IWS) - (CK - CKNM))$, **(4)**

while the Basin Residual column shows the basin wide residual computed as

Basin Residual = $(CBCU_C + CBUC_K + CBCU_N - IWS) - (\Theta - CKNM))$. **(5)**

For each term in Tables 1 and 2, three methods are shown. The column labeled RRCA is the approved method currently in use.[6] The Jan09 column refers to the results computed using the Nebraska proposal of January 2009 as shown in Eqs. 2a-d. The NEnet column refers to results computed using the example computation shown in Eqs. 3a-d.

6 As noted in the introduction, the results shown are based on model runs provided by Nebraska. The values shown here as RRCA are calculated using the approved RRCA procedure, but using the Nebraska runs in order to provide a consistent comparison of the different methods. However, these impacts do not match the impacts calculated by the official version of the RRCA Groundwater Model and approved by the RRCA. The differences derive from the fact that the Nebraska simulations used incorrect stresses for the initial stress period and used a different stream package for period until 2000, which has lagged effects for several years beyond 2000. Correcting these errors does not materially alter the results or conclusions.

As can be seen in Tables 1 and 2, the Basin Residual using the method proposed by Nebraska (Jan09 column) is always zero. This is a matter of mathematical necessity as shown in Eq. 2e, but does not necessarily mean the Nebraska's method is appropriate. Similarly, the Nebraska Residual is always zero when using the NEnet method, as it must be from Eq. 3f.

It is also interesting to note that Table 2c shows that using the RRCA approved method from 1981 to 2006, the average Basin Residual is 361 acre-feet/year. That means that over this period, the individual computed impacts using the existing approved method matches the directly computed impacts to within 361 acre-feet/year out of a total of about 197,000 acre-feet/year, a residual of 0.18%. This residual is well within the accuracy of the RRCA Groundwater Model and two orders of magnitude smaller than the accuracy of surface water stream gages.

While the Basin Residual using the method proposed by Nebraska is identified as zero, Table 2c shows that the method has an average residual inside Nebraska of 3,470 acre-feet for 1981-2006. That means that the total impact inside Nebraska is overestimated by 3,470 acre-feet on average from 1981-2006. This is primarily the result of including consumption of imported water, as will be demonstrated below.

As shown in Tables 1 and 2, the different methods result in computed impacts that are quite different. In particular, Table 2c shows that on average for each year from 1981-2006, the method proposed by Nebraska increases the pumping impacts of Colorado by 2,096 acre feet, increases the pumping impacts of Kansas by 1,494 acre-feet, and decreases the pumping impacts of Nebraska by 206 acre-feet, while the Imported Water Supply is increased by 3,746 acre-feet.

By comparison, the method shown in Eqs. 3a-d results in Colorado's pumping impacts decreasing by 7 acre-feet, impacts of Kansas pumping decreasing by 233 acre-feet, impacts of Nebraska pumping by 7,422 acre-feet and Imported Water Supply remaining unchanged.

The different methods therefore do lead to quantitatively different outcomes. It appears that the method proposed by Nebraska may have been chosen based on the fact that it produces a result that is beneficial to Nebraska, rather than scientific merit.

2.5 Model Calibration and Uncertainty

The RRCA Groundwater Model was calibrated to historical conditions based on a steady state simulation to provided initial conditions for January 1, 1918, followed by a transient simulation from 1918 to 2000. The study period was selected to cover the period over which the Republican River Basin was developed which spanned approximately 1940 to 2000. However, since the Dust Bowl years immediately preceded this period, the lingering effects of the Dust Bowl would be difficult to estimate. The study period was therefore extended to before the Dust Bowl era. For these early years, precipitation recharge is the primary aquifer stress and the starting date for the transient simulation was therefore determined by the availability of precipitation data. For the pre-1918 initial steady state, the average precipitation recharge for 1918 to 1940 was calculated and then reduced to 75% of that amount based on observed water levels during later years.

The Model was not calibrated to pre-1918 conditions. Instead, the Model was calibrated in transient mode based on observed water levels and baseflow in the streams. Gaged stream flow records extend from approximately 1940 to 2000, although individual gage records may be for much shorter or intermittent periods. Groundwater levels for calibration extend to 1909, but most groundwater levels are from 1950 onwards.

The Model is calibrated to historical conditions which included well development over time and surface water imports, and the effects of these mechanisms on water levels. In the current RRCA approved procedures, the Model runs start from this historical condition which is based upon actual measured data and deviates only as necessary to evaluate the impacts of the various activities of man. In part, this approach was selected to minimize the uncertainty in the results produced by the model.

The uncertainty in a model's results is least under conditions to which the a model was calibrated. Under these conditions, the RRCA Groundwater Model has been shown to reproduce reasonably accurate representations of historical baseflow and water levels. One therefore has confidence that the RRCA Groundwater Model will be able to accurately predict changes from that condition. However, the further removed model predictions are from the conditions to which that model was calibrated, the more uncertain the model predictions. The more nonlinear a model is, the faster that uncertainty grows.

The Nebraska proposal gives equal weight to differences from the historical and the simulation without any development, despite the differences in their relative reliability. This is not a correct modeling protocol.

2.6 Selecting the best method

While the different methods differ quantitatively, determining which is the "best" method is not simply a matter of selecting a desirable outcome.

Nebraska argues that their proposal is appropriate as it results in no Basin Residual. However, it requires (1) that States be burdened with impacts that did not actually occur; (2) including consumption of imported water; (3) overestimating the net impacts inside Nebraska; and (4) computational awkwardness.

One could argue that the alternate method shown in Eq. 3a–f above is "better" because (1) it does not burden the States for impacts that did not historically occur; (2) it explicitly excludes consumption of imported water; (3) it has no net residual inside Nebraska; and (4) it requires no more complex computations than the approved method currently approved by the RRCA.

The States agreed to the current method after careful deliberation and considering numerous facts such as those enumerated above. Nebraska presents their proposal as an improvement based on a single criterion. Colorado disagrees with this position. As demonstrated by Table 2c, the average residual for the RRCA currently approved method is indeed small. Furthermore, there are many possible solutions, as demonstrated by the one alternative example cited. Nor is the Basin Residual criteria the only measure that can be used to evaluate the perceived "accuracy" of the procedure.

Nebraska is therefore wrong in arguing that there is one solution. Colorado therefore disagrees with the imperative to change the RRCA approved procedure and specifically finds Nebraska's proposal unacceptable, both in terms of proper modeling protocol and in terms of attempting to predict the depletions caused to the streams by each State's actual groundwater withdrawals.

3.0 Deficiencies in Nebraska's Proposed Solution

Even if one were to agree that the demonstration provided by Nebraska does indeed indicate that there is a problem with the current RRCA approved Accounting Procedures, it would not automatically follow that the Nebraska's proposed solution is appropriate. In fact, as will be demonstrated below, Nebraska's proposed procedure suffers from several deficiencies that preclude the results from being acceptable.

In the following sections, the specific demonstrations provided by Nebraska will be examined. It will be shown that what Nebraska identifies as a problem is not necessarily actually a problem, and that Nebraska's proposed procedure does not adequately address the deficiencies identified, but will instead introduce new problems.

3.1 Frenchman Creek Impacts

Frenchman Creek starts in Colorado. It appears on maps extending west of the town of Holyoke, Colorado, but has generally been farmed over and flows only for relatively short periods after exceptional rain events. The Republican River Compact allocates to Colorado the entire water supply of the Frenchman Creek drainage basin in Colorado. In the RRCA Groundwater Model, Frenchman Creek is modeled using the extent of perennial streams as described by the USGS. Figure 1 shows the model cells used to represent Frenchman Creek in the RRCA Groundwater Model from near the Colorado State Line until the Frenchman Creek near Imperial gage above Enders Reservoir.

Impacts to Frenchman Creek are comprised of three parts. The first is impacts to Frenchman Creek between the Colorado State Line and the Frenchman Creek at Imperial stream gage. The second is impacts to Enders Reservoir. The third is impacts to Frenchman Creek from Enders Reservoir to the creek's confluence with the main stem of the Republican River. The impacts are calculated as differences between simulations. The difference in baseflow at the Frenchman Creek near Imperial gage, the difference in leakage for Enders reservoir, and the difference in baseflow at the confluence with the Main Stem are summed to give the total predicted impact to Frenchman Creek. The stage in Enders Reservoir is based on historical measurements, and baseflow is set to zero at Enders dam, so the three terms are effectively independent of each other.

Figure 1 shows the cells where Frenchman Creek is a live stream in the RRCA Groundwater Model as light blue cells. Each Model cell represents one square mile. Cells where the Model indicates that the stream is dry are shown in yellow. Note that under historical conditions, the Model shows that in July 2003, there are some sections where Frenchman Creek is a live stream, but others where it dries out. Only for the last three model cells is there a continuous live stream above the Frenchman Creek near Imperial gage. In effect, Frenchman Creek does not become a continuous live stream until more than 20 miles east of the Colorado State line, about two miles from the Frenchman Creek near Imperial gage.

Figure 2 shows the RRCA Groundwater Model predicted baseflow along Frenchman Creek as a blue line. The horizontal axis in Figure 2 represents stream reaches in the Model which does not translate linearly to river miles but does show the progression from upstream to downstream. The vertical axis represents the baseflow. The model predicts that under historical conditions, there is some baseflow from reaches 14 to 30, but that the stream dries up and only becomes live for reaches 34 to 39 which represent approximately the last two miles above the Frenchman Creek near Imperial gage.

When the RRCA Groundwater Model is run under predevelopment conditions, that is a simulation where no pumping occurs in either Colorado, Kansas or Nebraska and there are is no imported water supply, the Model predicts stream flows shown by a purple line in Figure 2. Note that in this simulation, there is a continuous live stream from reach 3 until the Frenchman Creek near Imperial gage. Figure 1 shows that the continuous live stream extends from about four miles from the Colorado State Line all the way to the Frenchman Creek near Imperial gage.

The Model can also be run assuming that these same historical conditions occur, except that no wells were ever developed in Colorado. The result of that simulation is shown as a green line in Figure 2. The difference between the green line and the blue line measures the predicted impact that the wells in Colorado have on the stream flow, and is highlighted in orange. As can be seen in Figure 2, in the absence of wells in Colorado, there is a small increase in stream flow from reach 14 to 23, but then the stream dries out regardless of whether any wells in Colorado pump or not. When the stream does become live at reach 34 the increase in baseflow at the Frenchman Creek near Imperial gage in the absence of Colorado pumping is 0.044 cfs.

If instead the Model is run assuming that only wells in Colorado were developed, and that no wells were developed in Kansas or Nebraska and no imported water supply occurred, the Model predicts baseflow shown as a red line in Figure 2. The impact of Colorado well pumping on Frenchman Creek under these conditions is the difference between the purple and red lines, which is shaded in yellow. As a result of lowering the water table, the reduction in stream gains in the form of baseflow in stream reaches 3 to 8 propagate all the way to the Frenchman Creek near the Imperial gage. In Figure 1, these impacts occur in the westernmost blue cells shown in the predevelopment frame, approximately four to six miles from the Colorado state line.

The July 2003 situation illustrated in Figures 1 and 2 is not unique. Figure 3 shows the Model predicted baseflow at the Frenchman Creek near Imperial gage. The horizontal axis represents time and covers the period from 1950 through 2006. The vertical axis represents baseflow at the Frenchman Creek near Imperial gage. Model simulated baseflow for different simulations are shown as lines in colors consistent with Figure 2. The difference between the green and blue lines which is colored orange shows that if wells in Colorado would have never pumped under otherwise historical conditions, additional baseflow would have only rarely showed up at the Frenchman Creek near Imperial gage. During 2003, this additional flow averages about 0.026 cfs.

However, Figure 3 also shows that there is a dramatic decline in baseflow at the Frenchman Creek at Imperial gage from about 1970 to 2000. This decline in baseflow is caused almost exclusively by nearby pumping in Nebraska. The Model simulations show that in the absence of any well development, baseflow would remain around 70 cfs as indicated by the purple line. More importantly, in the absence of well pumping in Nebraska, there would be a live stream from near the Colorado State Line to the Frenchman Creek near Imperial gage. The proximity of this live stream to wells in Colorado would cause greater stream depletions, resulting in baseflow shown as the red line, and hence the impacts from these wells would be the difference between the red and purple lines which is shaded in yellow.

Figure 3 shows that, had there never been well development in Nebraska, wells in Colorado would have impacted the amount of baseflow that reached the Frenchman Creek near Imperial gage. However, given the historical reality that wells in Nebraska were in fact developed, the Model simulations show that even if there had never been any well development in Colorado, there would be little additional baseflow at the Frenchman Creek near Imperial gage.

It is instructive to construct the Nebraska method for the simplified two state case that occurs on Frenchman Creek. Ignoring the impacts of imported water supply (the mound or M) and Kansas pumping K because they are so small on Frenchman Creek, the total impact on Frenchman Creek using the Nebraska definition is approximately Θ-CN. From basic arithmetic, we know that we can split one into two halves. Also, if you add and subtract the same quantity, the net result does not change. Therefore, we can split Θ and CN and add and subtract ½C and ½N without altering the result as

$$\Theta\text{-CN} = (\tfrac{1}{2}\Theta + \tfrac{1}{2}\Theta) - (\tfrac{1}{2}\text{CN} + \tfrac{1}{2}\text{CN}) + (\tfrac{1}{2}\text{C} - \tfrac{1}{2}\text{C}) + (\tfrac{1}{2}\text{N} - \tfrac{1}{2}\text{N})$$

$$= \tfrac{1}{2}(\Theta\text{-C}) + \tfrac{1}{2}(\text{N-CN}) + \tfrac{1}{2}(\Theta\text{-N}) + \tfrac{1}{2}(\text{C-CN}) \quad \textbf{(6)}$$

after regrouping the terms on the right hand side. Assigning terms differing in N to Nebraska and terms differing in C to Colorado, Eq. 6 can be rewritten as

$$\Theta\text{-CN} = CBCU_C + CBCU_N \quad \textbf{(7)}$$

where

$$CBCU_C = \tfrac{1}{2}(\Theta\text{-C}) + \tfrac{1}{2}(\text{N-CN}) \quad \textbf{(8a)}$$

$$CBCU_N = \tfrac{1}{2}(\Theta\text{-N}) + \tfrac{1}{2}(\text{C-CN}) \quad \textbf{(8b)}$$

Note that Eqs. 8a and 8b demonstrate mathematically that the essence of the Nebraska proposal is to average the actual and the potential depletions. The Colorado CBCU is the average of the actual historical depletion caused by Colorado N-CN and the depletion that would have occurred in the absence of Nebraska pumping Θ-C. Since pumping in Nebraska is much more and closer to Frenchman Creek than pumping in Colorado, the potential impacts Θ-C are much larger than then actual impacts N-CN. In particular for 2003, Θ-C is 5,099 acre-feet, while N-CN is 19 acre-feet. On the other hand Θ-N and C-CN are very similar because Colorado's pumping impacts to Frenchman Creek are small compared to those of Nebraska.

The full Nebraska proposal for the calculation of Colorado's pumping impacts ($CBCU_C$) is summarized in Figure 4. The proposal uses sixteen simulations. These sixteen simulations are viewed as eight pairs, each where one simulation includes and one excludes Colorado pumping. Figure 4 shows these eight pairs in individual frames. The $CBCU_C$ is then calculated as the weighted average of the different simulations.

Figure 4 shows that the eight pairs fall into two categories, four where the wells in Nebraska are pumping and four where there is no well pumping in Nebraska. In fact, the four combinations in each group of four, with or without Kansas pumping and with or without the imported water supply, makes so little difference as to be indistinguishable. For all practical purposes, therefore, the $CBCU_C$ for Frenchman Creek is the average of the two impacts shown in Figure 3. (Due to their distance from pumping in Colorado, the contribution from pumping impacts to Enders Reservoir and Frenchman Creek below Enders are *de minimis*). The approximation in the simplified two state example shown in Eqs. 8a and 8b therefore captures the essence of the Nebraska proposal for Frenchman Creek.

The Colorado pumping impact calculated as baseflow that occurs under historical conditions had Colorado wells never pumped is 19 acre-feet in 2003. The Colorado pumping impact calculated as the reduction in baseflow from predevelopment conditions if only Colorado wells pumped is 5,099 acre-feet in 2003.

The Nebraska pumping impact calculated as baseflow that occurs under historical conditions had Nebraska wells never pump is 81,188 acre-feet in 2003. The Nebraska pumping impact calculated as the reduction in baseflow from predevelopment conditions if only Nebraska wells pumped is 86,231 acre feet in 2003.

The total impact for 2003 estimated as the increase in baseflow if wells in Colorado never pumped (19 acre-feet) plus if wells in Nebraska never pumped (81,188 acre-feet) is 81,207 acre-feet. However, the total impact for Frenchman Creek calculated as Θ-CKMN is 86,231 acre-feet, which is 5,024 acre-feet more.

If one were to insist that the sum of the impacts match the total, one could increase the values proportionately. Since the Nebraska impacts are 99.976% of the total under historical conditions, one could proportionately apportion the 5,024 acre-feet as 5,023 acre-feet to Nebraska and 1 acre-feet to Colorado.

However, the method proposed by Nebraska essentially averages the historical conditions and the predevelopment conditions. So for Colorado, the 19 acre-feet under historical conditions and 5,099 acre-feet under predevelopment conditions are averaged. A strict arithmetic average as in Eq. 8a would be 2,559 acre-feet, but the full procedure proposed to Nebraska combines other simulations so that the result is actually 2,562 acre-feet, a difference of 3 acre-feet. For Nebraska, the 81,207 under historical conditions and 86,213 acre-feet under predevelopment conditions are averaged. A strict arithmetic average as in Eq. 8b would yield 83,710 acre-feet, but the full Nebraska proposal results in 83,704 acre-feet, a difference of 6 acre-feet.

The procedure proposed by Nebraska allocates the 5,099 acre-feet difference by increasing the Colorado impact by 2,543 acre-feet and the Nebraska impact by 2,516. This increases the Colorado impact by 13,384%, and the Nebraska impact by 3.1%. The justification given for this procedure is that Colorado's impacts would have been greater if Nebraska had never developed wells, a situation that is contrary to historical reality and completely out of the State of Colorado's control.

Colorado has no specific Compact Allocation for groundwater CBCU on Frenchman Creek. Therefore, Nebraska's proposed change increases Colorado's obligation under the Compact by 2,543 acre-feet based purely on impacts that did not and could not actually occur, but would have occurred only if Nebraska had never developed any wells. Such a procedure is untenable.

Another way to view the effect of the Nebraska proposal is that when a stream dries up, additional pumping cannot have any other effect on the stream itself, but the pumping continues to withdraw groundwater from storage in the aquifer itself. Nebraska's proposal essentially takes that amount of groundwater withdrawn from storage and divides it equally among the two states and charges those withdrawals as CBCU, even though there is no stream impact at that time from the withdrawals from storage. In the previous non-binding arbitration, Arbitrator Karl J. Dreher viewed the Nebraska proposal in this manner and found Nebraska's proposal inappropriate. Arbitrator's Final [Corrected] Decision, In *re Non-Binding Arbitration in Accordance with: Final Settlement Stipulation* (July 13, 2009) at ¶¶ 29-33. The Compact does not restrict the depletion of the groundwater aquifer, only the impact the aquifer depletions have on the surface streams.

3.2 Beaver Creek

The Beaver Creek sub-basin is the longest sub-basin in the Republican River Basin. It extends approximately 175 miles starting about 30 miles inside Colorado and ending at the confluence with Sappa Creek about 15 miles upstream of Harlan County Reservoir. The Beaver Creek stream channel is generally dry within Colorado.

In the RRCA Groundwater Model, the representation of Beaver Creek starts about 25 miles downstream of the Colorado state line inside Kansas, due to the historically dry stream channel in Colorado. Figure 5 shows the Model cells used to represent Beaver Creek. Color is used to represent dry and wet stream cells in the model for June 2003. Blue cells represent a live stream, and yellow cells represent cells where the stream dried up.

Figure 6 shows the June 2003 information as a graph of flow versus distance. The horizontal axis represents model stream reaches numbered consecutively from upstream to downstream, while the vertical axis represents the stream flow. The jump in stream flow at reach 76 occurs as a result of inflow from the Little and North Fork of Beaver Creek which is shown in Figure 5. The stream crosses the Kansas/Nebraska state line at reach 149 and is indicated in Figure 6 as a vertical line.

The Model predicted flow under historical conditions is shown as a blue line in Figure 6. The stream flows and dries out for some distance from the upstream end as shown by yellow cells in Figure 5. Then, from reach 34 there is a continuous live stream until reach 170. In Figure 5 it can be seen that this represents the stream from about 20 miles upstream of the confluence of Little and North Beaver Creeks to approximately 10 miles into Nebraska. From that point on there are some live sections of the stream, but for the most part the stream is dry.

In the absence of any actions of man, Beaver Creek is a gaining stream along most of its course through Kansas. This is shown as a purple line in Figure 6. Then, as it crosses the Kansas/Nebraska state line, it becomes a losing stream for about ten miles, after which the flow remains approximately constant.

In the absence of well pumping in Kansas, the Model predicted baseflow in Beaver Creek is essentially the same as under predevelopment conditions as illustrated by the green line in Figure 6. However, as the stream crosses into Nebraska, this baseflow is rapidly depleted by the wells in

Nebraska, such that at the confluence with Sappa Creek, where there is less than one cfs of flow remains.

In the absence of well pumping in Nebraska, the Model predicted baseflow in Beaver Creek is essentially the same as under historical conditions as illustrated by the red line in Figure 6. However, as the stream Beaver Creek crosses into Nebraska, the baseflow mirrors the behavior seen under predevelopment conditions. So for approximately the first ten miles inside Nebraska, the stream loses water, and then remains approximately the same.

Figure 6 shows that as long as either wells in Nebraska or wells in Kansas are pumping, the baseflow reaching the confluence with Sappa Creek will be minimal. Therefore even if there had never been any well pumping in Kansas there would be little improvement in baseflow.

Figure 7 shows the same information as Figure 6, but for June 1965. It is interesting to note that the modeled baseflow in 1965 shows qualitatively the same behavior as in 2003 with one significant exception. As in 2003, the baseflow in Kansas is practically the same as the predevelopment baseflow when the wells in Kansas are not pumping and the baseflow in Kansas is practically the same as the historical when the wells are pumping. Then, as Beaver Creek crosses into Nebraska, the stream flows for scenarios where Nebraska wells are not pumping (predevelopment and No Nebraska Pumping) and scenarios where Nebraska wells are pumping (historical and No Kansas Pumping) parallel each other.

The cause for the behavior discussed in the Report is clear from Figures 6 and 7. As a result of stream depletions caused by Nebraska wells, from where Beaver Creek crosses into Nebraska until the confluence with Sappa Creek, there is little improvement in baseflow in this reach of Beaver Creek even when there is no pumping in Kansas.

Figure 8 further illustrates this behavior. The red and green lines represent the increase in baseflow at the confluence of Beaver Creek with Sappa Creek in the absence of well pumping in Nebraska and Kansas, respectively. By definition, these are the pumping impacts for wells in Nebraska and Kansas on Beaver Creek, respectively. Adding the Nebraska and Kansas impacts together yields the blue line. The purple line is the combined impact of both Kansas and Nebraska, which in Figures 6 and 7 would be the difference between the predevelopment and historical predicted baseflow.

It is interesting to note in Figure 8 that until 1969, the sum of the individual impacts matches the combined impact. However, from 1970 onwards, the blue and purple lines increasingly diverge. There are period such as 1976-1978, 1988-1992 and 2002-2005 when the sum of the individual Nebraska and Kansas impacts are significantly lower than the combined Nebraska and Kansas impact. As demonstrated in Figures 6 and 7, this is largely caused by well pumping in Nebraska. To further illustrate the point, the total amount of agricultural well pumping in Furnas and Red Willow counties is shown in Figure 8. Beaver Creek flows into Red Willow County and then on into Furnas County. As can be seen in Figure 8, there is good correlation between increased well pumping in Nebraska and differences between the sum of the pumping impacts and combined impacts.

As in the case of Frenchman Creek above, the procedure proposed by Nebraska imposes impacts on Kansas that would have occurred only if there had been no wells in Nebraska. Figure 6 shows that, had there been no wells in Kansas, Beaver Creek baseflow would only increase by about 0.9 cfs, the difference between the blue and green lines. However, the Nebraska method also adds the more than 8 cfs difference between the purple and red lines, that is the amount of increase in stream flow that would have occurred had there not been any well development in Nebraska.

Again as in the case of Frenchman Creek, Nebraska seeks to impose an impact that did not occur historically, but would only have occurred had Nebraska not developed wells. And again, as found by Arbitrator Dreher, Nebraska is essentially taking the reduction in groundwater storage caused by pumping that does not result in stream depletions and averaging that change in storage between the states. This is not appropriate.

Therefore the procedure proposed by Nebraska is not sufficiently rigorous and does not supply the answer that the Compact requires.

3.3 Main Stem Swanson-Harlan

The purpose of the RRCA Groundwater Model is to estimate the net result of actions of man within the state on stream baseflows. In Colorado and Kansas, there is only one action of man being evaluated, namely well pumping. However, in Nebraska, the Model is used to evaluate two actions of man, namely well pumping and the imported water supply, and these two actions counteract each other.

Figure 9a shows a hydrograph of the inflow into Harlan County Reservoir. The simulated inflow in the historical simulation is shown as a blue line, while the simulated inflow in the absence of pumping in Nebraska is shown as a red line. By definition the impact of Nebraska pumping on the inflow into Harlan County Reservoir is the difference between the historical and No Nebraska Pumping simulations, which is depicted using yellow shading.

Figure 9b also shows a hydrograph of the inflow into Harlan County Reservoir. The blue line is the same simulated inflow from the historical simulation, while the purple line represents the simulated inflow in the absence of imported water from the mound. The difference between these simulations is the result of imported water, also called the Imported Water Supply (IWS) or Mound Credit.

Figure 9a represents the approved method for evaluating Nebraska's pumping impacts on stream flow. Figure 9b represents the approved method for evaluating the effects of Nebraska's imported water supply from the Platte River Basin on stream flow. As shown in Figure 9b there is very little inflow into Harlan County reservoir under historical conditions that can attributed to imported water supply. As shown by the purple line, in the absence of imported water supply, the inflow is zero except for a short period in 2001.

From Figure 9a and 9b one could conclude that Pumping Impacts on the inflow to Harlan County Reservoir do not depend on the imported water supply. This can be verified by performing a simulation where both Nebraska pumping and imported water supply are simultaneously switched off as shown in Figure 9c. In Figure 9c the purple line represents the no imported water supply simulation as shown in Figure 9b, and the green line represents the flow in a simulation where both Nebraska pumping and imported water supply are removed. The difference between these simulations represent the Nebraska pumping impacts in the absence of the imported water supply.

Comparing Figures 9a and 9c, it is clear that the pumping impacts with imported water supply are often greater than pumping impacts in the absence of the imported water supply. This trend is especially noticeable in dry years such as 2003 and 2004 when the stream would be mostly dry except but for the imported water supply. This is the result from the inherent and necessary nonlinear behavior in the RRCA Groundwater Model. The inflow into Harlan County Reservoir is greater when water is imported then when it is not. This is true regardless of whether wells in Nebraska are pumping or not. Nebraska's fallacy lies in the expectation that the inflow would increase by the same amount when the wells are pumping than when they are not.

Figures 9 show the impacts on baseflow at the inflow to Harlan County Reservoir. These flows are, of course, in part the result of changes of upstream inflows. Therefore, the term that appears in the RRCA Compact Accounting is actually the difference between the flow at this location and the sum of five upstream inflows, namely those from Frenchman, Driftwood, Medicine, Red Willow and Sappa creeks, and is called the Swanson-Harlan Mainstem Impacts. This pumping impacts evaluated in this way is by definition the groundwater ($CBCU_G$) used in the Compact Accounting.

Figure 10a shows the $CBCU_N$ in yellow calculated for the Swanson-Harlan reach as the difference between the historic simulation shown as a blue line and a No Nebraska Pumping simulation shown as a red line. Figure 10b shows the IWS in yellow calculated for the Swanson-Harlan reach as the difference between the historic simulation shown as a blue line and the No Nebraska Mound simulation shown as a purple line. Figure 10c shows $CBCU_N$ calculated for the Swanson-Harlan reach in the absence of imported water as the difference between a No Nebraska Pumping or Mound simulation shown in green, and the No Nebraska Mound simulation shown in purple.

Figure 10a represents the $CBCU_N$ calculated using the RRCA approved method shown in Eq. 1c. Figure 10c represents the $CBCU_N$ calculated using the alternate method shown in Eq. 3c. As shown in Figures 10a and 10c, the Nebraska pumping impacts for the Swanson-Harlan reach are greater with the imported water supply than without the imported water supply. As shown in Figure 9, this is primarily caused by the fact that in the absence of well pumping in Nebraska, more of the imported water supply reaches Harlan County Reservoir, than when the wells are operating at historical levels.

Figure 10c demonstrates why Eqs. 3a-d are effective in evaluating the impacts of pumping in a manner that does not include consumption of imported water. The method proposed by Nebraska, on the other hand, ***does*** include the consumption of imported water. In particular, Eq. 2c can be rewritten as

$$CBCU_N = [3(CKM\text{-}CKMN) + (M\text{-}MN) + (CM\text{-}CMN) + (KM\text{-}KMN)]/12 + [3(\Theta\text{-}N) + (C\text{-}CN) + (K\text{-}KN) + (CK\text{-}CKN)]/12 \quad \textbf{(9)}$$

Eq. 9 is algebraically identical to Eq. 2c, but Eq. 9 is written in this way to group Model simulations with the imported water supply "on" together (the name contains an M) and simulations with imported water supply "off" together (the name does not contain an M). Note that in Eq. 9 the coefficients of the first group of terms sum to ½, as does the second group of terms. Therefore the Nebraska proposal to estimate Nebraska's pumping impacts essentially averages the impacts calculated with imported water supply "on" and impacts calculated with imported water supply "off".

As shown in Figure 10, any simulation where the imported water supply is "on" will include consumption of the imported water supply. The Nebraska simulations that project 50 years into the future starting in 2009 are shown in Figure 11. The three frames in Figure 11 show the same quantities as Figure 10, just for the different period. Figure 11b shows that in this projection, almost no imported water supply reaches this reach of the stream. However, Figure 11a indicates that Nebraska's $CBCU_G$, indicated in yellow, will steadily rise because in the absence of pumping in Nebraska (the red line), the baseflow would steadily rise. This rise can be attributed to the imported water supply that would have reached the stream in the absence of Nebraska pumping.

The method proposed by Nebraska would continue to include this imported water supply in the $CBCU_G$ calculations. In fact, because the Nebraska method uses potential depletions, the $CBCU_G$ for all the states would contain increasing amounts of imported water supply in violation of the FFS.

By contrast, the alternative method illustrated in Figure 11c shows that the alternative method effectively filters out the effect of the imported water supply, and that the $CBCU_G$ calculated in the absence of imported water supply remains essentially the same over time.

The Imported Water Supply calculation is intended to subtract the imported water from the actual flow measured at the surface water gages. The purpose of this calculation is to correct the observed gaged surface flows for the increases due to the imported water supply. As in the case of estimating pumping impacts, Nebraska's proposed method calculates the imported water supply as a weighted average. Half of these differences included in the weighted average will consider the situation where wells in Nebraska had never been pumping. As demonstrated in Figures 9 and 10, the amount of the imported water supply that reaches the gage is greater in the absence of Nebraska pumping than when Nebraska pumping is present. The average would therefore overestimate the amount of imported water supply at the gage.

The surface water gages measure the actual historical surface water flow, including baseflow, overland or surface flow and imported water that makes it to the stream. The purpose of the Imported Water Supply calculation must therefore be to subtract the actual amount of imported water supply that was included as surface water flow in the measured gage flow. Eqs. 1d and 3d are identical, and reflect exactly what is required. The Nebraska proposal reflected in Eq. 2d incorrectly incorporates imported water supply that did not show up in the gage flow historically, and only would have shown up had wells in Nebraska never pumped.

As a result Nebraska's proposed method is not acceptable modeling protocol and is not a reasonable representation of the physical system.

4. Nebraska's Scale Analogy

In the their Report, Nebraska uses the analogy of a scale which is used to measure weights but reads low beyond a certain weight as an analogy to describe what they consider "The Problem". This analogy is very misleading, and is incorrect in several respects.

4.1 The Analogy Applies a Nonlinear Tool to a Linear Process

Weights are linearly additive. When two or more weights are added to the scale, the scale reading should be the sum of the individual weights. If the scale does not show a weight equal to the sum of the individual weights, the scale is operating incorrectly. This is entirely a failure in the scale and does not correctly reflect the behavior of the underlying process.

By using the scale as an analogy for the RRCA Groundwater Model, the implication is that the Model is operating incorrectly. This implication is totally incorrect. It implies that there is an underlying linear process, and that it is the failure is in the measurement tool. These implications are incorrect and misleading.

The groundwater flow system of the Republican River Basin is not linearly additive, but is inherently nonlinear. That means that the impacts of well pumping and similar operations on streams flows are not directly proportional. This behavior is caused by natural processes like evapotranspiration, and the complex interaction of surface and groundwater.

The RRCA Groundwater Model reasonably reflects this nonlinear behavior. The nonlinearities in the Model results are not a flaw in the Model, but rather a true reflection of the underlying physical processes. A model of the Republican River Basin which yields linear results would in fact be a poor approximation of the underlying nonlinear system.

By using the scale analogy, Nebraska implies that the nonlinearities are an artifact of the RRCA Groundwater Model (the scale), whereas the underlying groundwater flow processes are linear (the weights). Nothing could be further from the truth. The nonlinearities in the Model results are a reasonable representation of the underlying nonlinear processes in the groundwater system. As such, the scale analogy is misleading and not useful.

4.2 Using the Scale to Measure Allocation and Use

The Nebraska scale analogy is also misleading because it suggests that an unfair bargain was struck. Nebraska insinuates that the failure to measure correctly is purely the result of a bad tool. As such, Nebraska implies that the States are not allotted their correct measure of the water in the Republican River Basin under the Compact.

An important consideration, however, is that the same measure is used to not only determine the allotment, but also the consumptive use. The $CBCU_G$ term calculated by the RRCA Groundwater Model is used to calculate both the consumptive use by each State, and the Virgin Water Supply.

Nebraska has framed the argument as a failure of the RRCA Accounting Procedures to allocate to Nebraska its full entitlement. However, the opposite is also true. Fully applying Nebraska's theory, the RRCA Accounting Procedures shows that, under Nebraska's Theory, the Accounting Procedures also have not attributed to Nebraska the full impact of Nebraska's actual historical consumption of water.

The Virgin Water Supply can be readily calculated as the difference between a Model simulation with pumping in all three states and the imported water supply turned off, and a historical Model simulation with all these effects on.[7] The purpose of the remaining fourteen simulations is merely to allocate this difference among the States.

In the scale analogy, the scale is incapable of measuring the combined weight because it is beyond the maximum amount that the scale can measure. In the case of the RRCA Groundwater Model, however, Nebraska has argued that the Model can accurately measure this full difference. In fact, the whole purpose of the Nebraska procedure is to make the parts add up to this difference.

The scale analogy is therefore inappropriate because it implies that Nebraska was not allotted its due measure, but was charged a fair measure of use. In fact, using the RRCA approved procedure, the same tool was used to estimate both the groundwater components of allotment and use. The difficulties that arise due to the inherent nonlinear relationship between stream depletions and actions such as well pumping are not the result of an untrustworthy measuring device or an upper limit on the amount that can be measured.

4.3 Positive and negative weights

The scale analogy also fails because the concept of a negative weight is difficult to comprehend. In the case of the imported water supply from the Platte River Basin, it is necessary to consider negative weights (imported water supply) that offset positive weights (consumption of native water).

One might invoke an analogy of a symmetric balance scale, where weights are placed on both the side being measured and the reference side, but this analogy also fails because it requires that the negative weight simply adds linearly to the reference weights. Such linearity does not exist in this groundwater system. Besides, in order for a symmetric balance scale to read incorrectly, the reference weights have to be crooked, which is an inappropriate insinuation.

5. Summary and Conclusions

The RRCA has approved a procedure for the calculation of impacts to baseflow caused by pumping in Colorado, Kansas and Nebraska. The procedure also specifies the method for estimating the amount of the Imported Water Supply.

Nebraska demonstrated their perceived problem using examples from 2003, a year of extreme drought. The problem was presented in the light that the approved method underestimates the Virgin Water Supply. It should be noted, however, that the CBCU amounts are not only used to estimate the Virgin Water Supply and hence the allocation, but also is used to set the depletions for which the states are responsible under the Compact.

Using the RRCA approved procedure, the depletions attributed to a State cannot exceed the amount of additional baseflow that can be generated by complete curtailment of all wells in the corresponding

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7 The condition with all the pumping and mound in the basin turned off is very different from the condition to which the Model was calibrated. The validity of such a run is therefore in question. However, for the sake of this argument, it is assumed that such a result would be reliable.

State. Under the procedure proposed by Nebraska, it has been demonstrated that the depletions attributed to a State can be more than two orders of magnitude greater than what can be achieved by complete well curtailment in that State.

Nebraska has proposed a different procedure as "The Solution" to "The Problem". Their proposal uses as its justification the fact that under their proposed procedure the sum of the individual impacts matches the basin wide impacts. This is an incorrect conclusion.

While the Nebraska procedure does result in no basin wide residual, it does so at the expense of physical realism. In essence, the method calculates a weighted average of eight differences. As demonstrated above, this has the effect of including impacts that did not occur and never could occur. Specifically, upstream states are burdened with impacts that would only have occurred had Nebraska never developed wells. These impacts are typically the result of streams that historically have been dry in large part due to pumping in Nebraska, but would have been live and therefore could have been depleted, had the Nebraska well pumping not occurred. Furthermore, the Nebraska procedure adjusts the measured gage flows for the Imported Water Supply that would have occurred had there not been well pumping in Nebraska. These mathematical devices may yield no basin wide residual, but have no basis in reality. They are simply mathematical manipulations to achieve a desired result.

Some of the issues raised by Nebraska are caused by the inclusion of the imported water supply in the $CBCU_G$ calculations, even though this is contrary to the FSS. Nebraska's proposed solution actually increases the amount of $CBCU_G$ attributable to imported water, but Nebraska favors this solution because Nebraska's burden is effectively shifted to Colorado and Kansas so that Nebraska benefits overall. The alternative procedure demonstrated in this report provides an effective means to exclude the imported water supply from the $CBCU_G$ calculations without increasing the complexity of the calculations or simulations. This alternate procedure provides relief to Nebraska in terms of reduced $CBCU_G$ due to excluding the imported water supply approximately equal in magnitude to the benefit that would be provided by using the Nebraska proposal.

The scale analogy used by Nebraska to illustrate the problem is totally inappropriate. It is misleading in that it uses the analogy of a flawed tool with limited range to measure a linear process. The RRCA Groundwater Model and Accounting Procedures on the other hand deal with the complexity of an inherently nonlinear process, and the deviations from linearity reflect the physical reality, not a flaw in the tool or the analysis.

In addition, the Nebraska proposal implicitly assumes that all model runs are equally accurate. In reality, any model's predictions are increasingly uncertain the further the modeled scenario deviates from the historical conditions to which the model was calibrated. This is true for the RRCA Groundwater Model as well. Nebraska's proposed procedure increases the reliance on simulations far removed from the historical, which increases the uncertainty in the Model's predictions.

Finally, the procedure proposed by Nebraska is unnecessarily complex. As an example, a method was demonstrated that corrects for the consumption of imported water without adding any complexity to the current RRCA approved procedure.

Nebraska has failed to demonstrate an imperative need for changing the procedure as approved by the

RRCA. To the extent that imperfections exist in the procedure approved by the RRCA, the procedure proposed by Nebraska's proposed procedure fails to cure these imperfections and introduces new, much greater flaws. As such Nebraska has failed to demonstrate that their proposed procedure is in any way an improvement over the procedure currently approved by the RRCA or is otherwise reasonable.

6. References

In the Supreme Court of the United States, Case Number 126 Original, State of Kansas v. State of Nebraska and State of Colorado, *Final Settlement Stipulation*, December 15, 2002.

Nebraska Department of Natural Resources. Nebraska-*Related Documents for Special Meeting of the Republican River Compact Administration*, March, March 11-12, 2008

Nebraska Department of Natural Resources and McDonald Morrissey Associates Inc. and Dr. David P Ahlfeld. *Analysis of Current Methods Used to Calculate Groundwater Impacts for the Republican River Compact, August* 6, 2008.

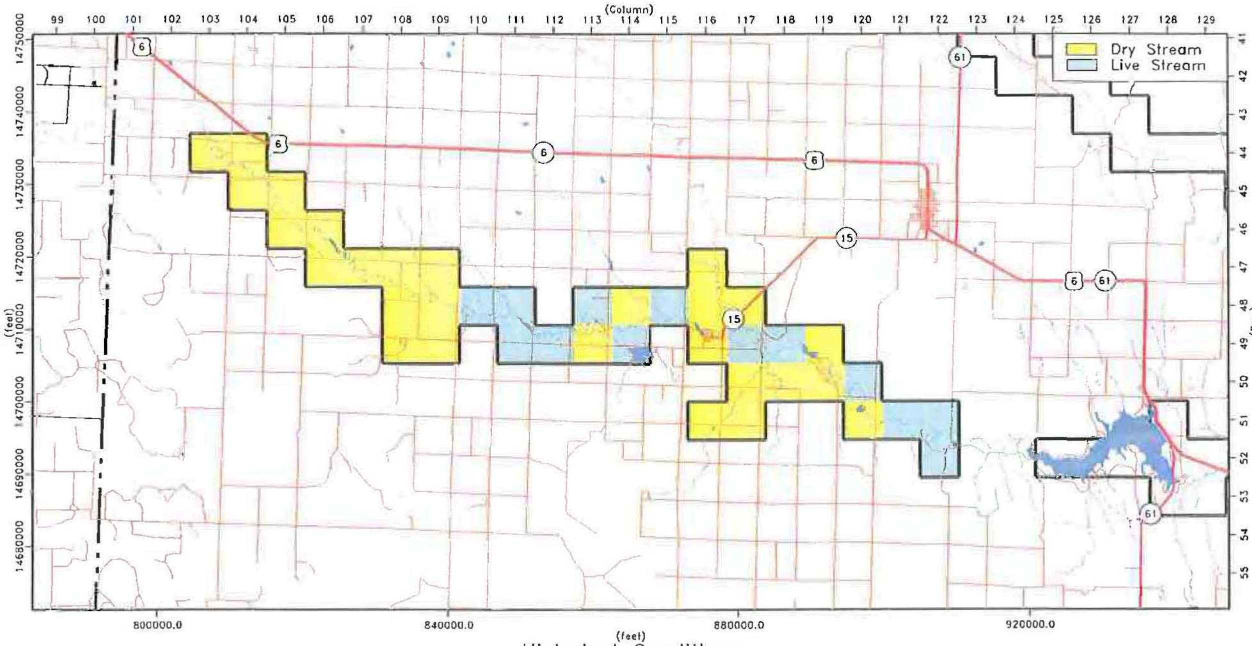
Dr. David P. Ahlfeld, Michael G. McDonald and James C. Schneider. *Estimating Computed Beneficial Consumptive Use for Groundwater and Imported Water Supply under the Republican River Compact, January* 20, 2009.

W.A. Schreüder. *Report in Response to Estimating Computed Beneficial Consumptive Use for Groundwater and Imported Water Supply under the Republican River Compact,* February 2009.

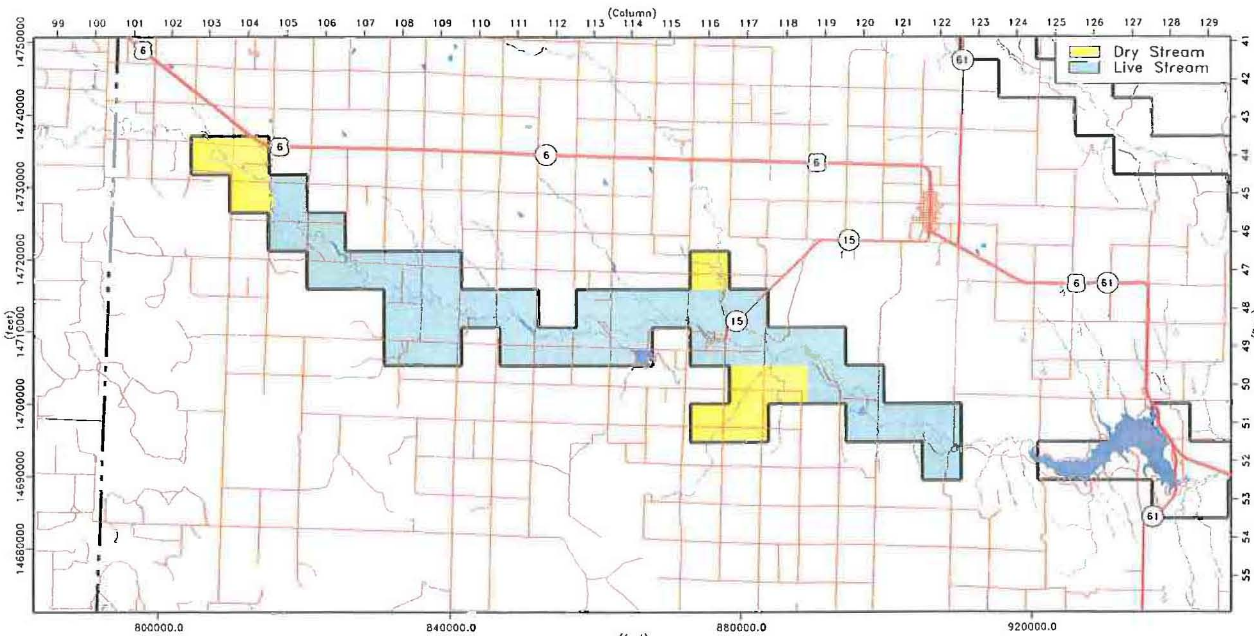
Arbitrator's Final [Corrected] Decision, In *re Non-Binding Arbitration in Accordance with: Final Settlement Stipulation* (July 13, 2009).

Frenchman Creek as Modeled for July 2003

Republican River Compact Administration Groundwater Model



Historical Conditions



Predevelopment Conditions

Figure 1.

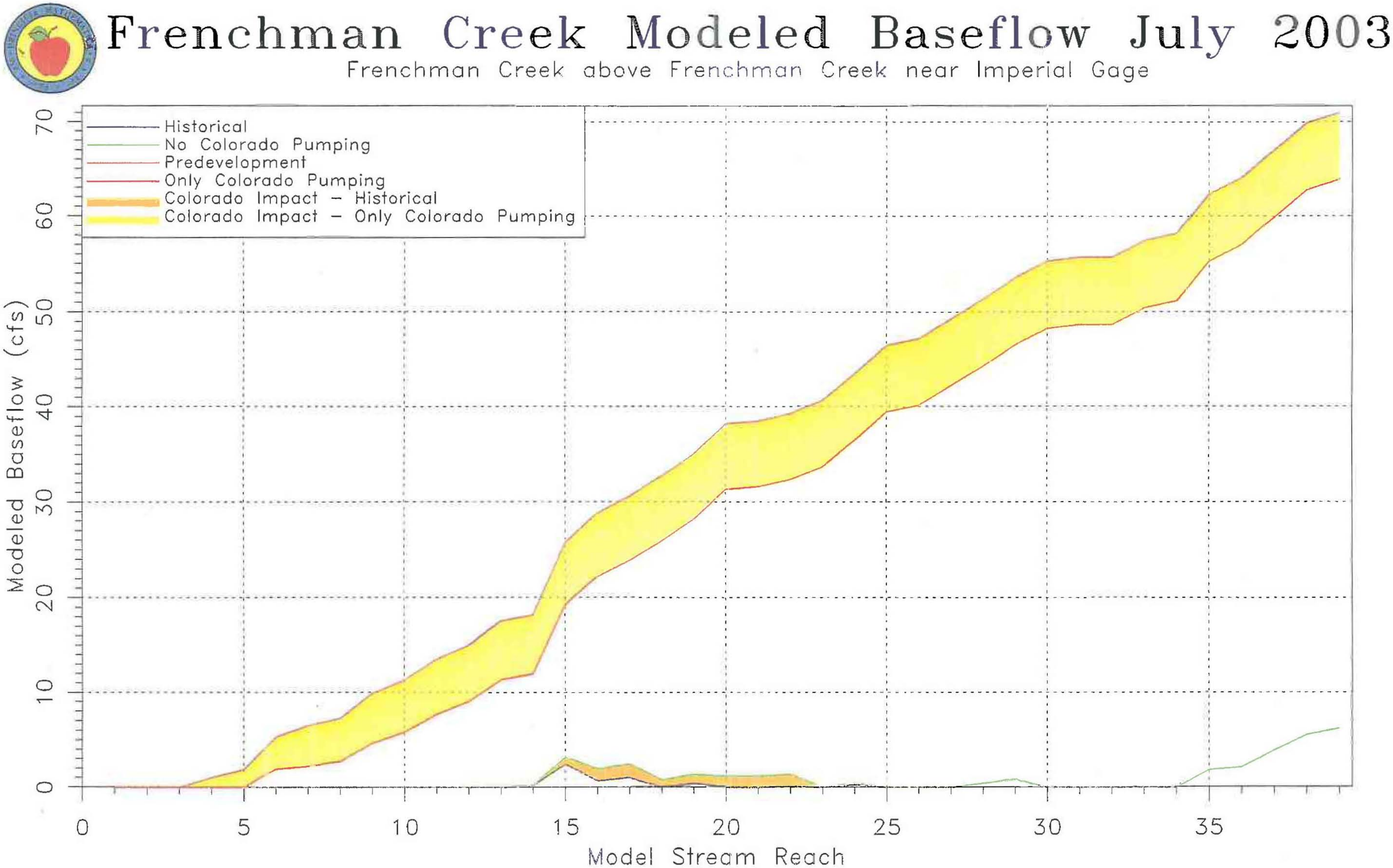

Frenchman Creek Modeled Baseflow July 2003
Frenchman Creek above Frenchman Creek near Imperial Gage
Historical
No Colorado Pumping
Predevelopment
Only Colorado Pumping
Colorado Impact – Historical
Colorado Impact – Only Colorado Pumping
Modeled Baseflow (cfs)
0
10
20
30
40
50
60
70
0
5
10
15
20
25
30
35
Model Stream Reach

Figure 2

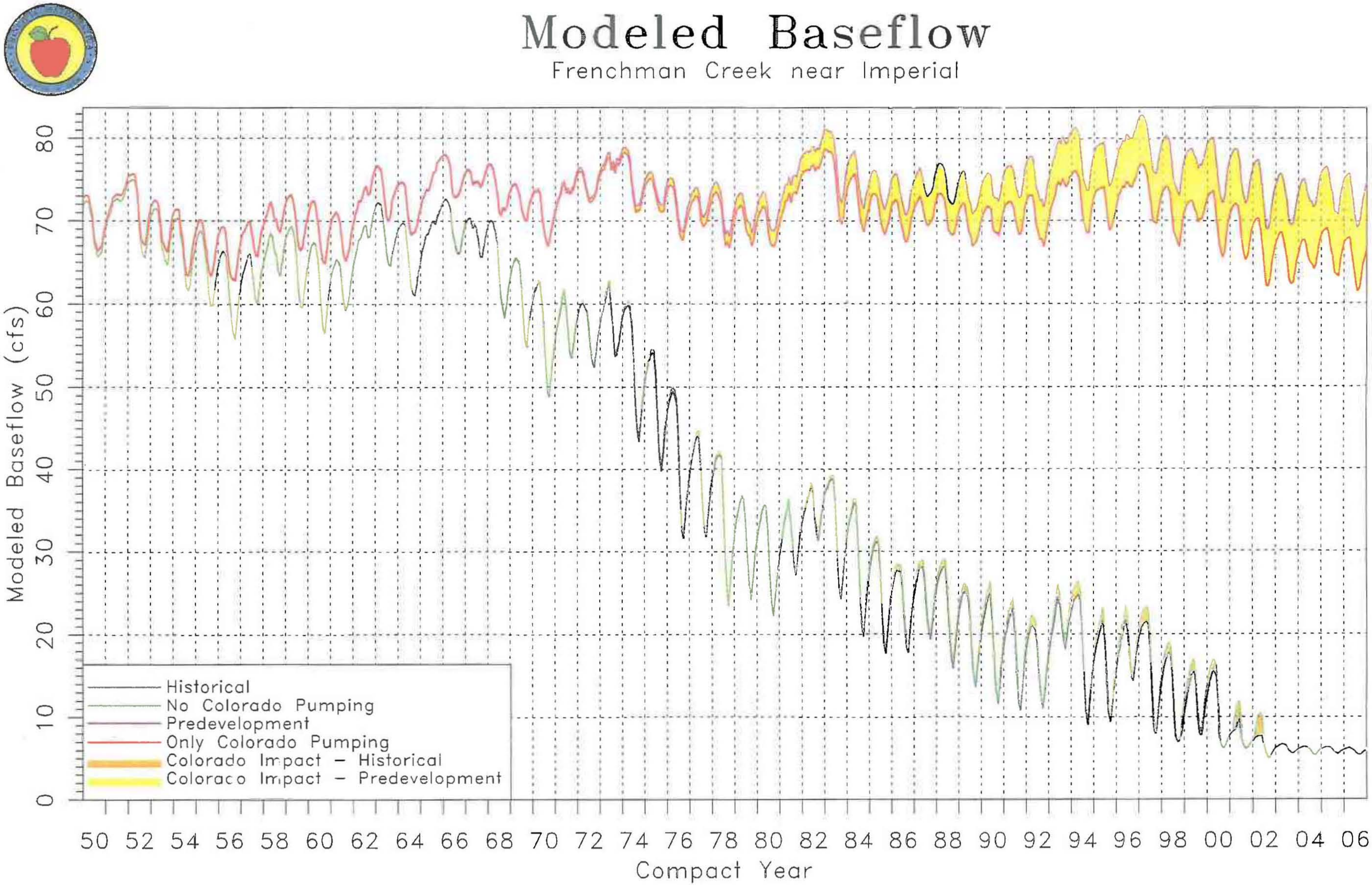

Modeled Baseflow
Frenchman Creek near Imperial
Modeled Baseflow (cfs)
0
10
20
30
40
50
60
70
80
50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90 92 94 96 98 00 02 04 06
Compact Year
Historical
No Colorado Pumping
Predevelopment
Only Colorado Pumping
Colorado Impact – Historical
Coloraco Impact – Predevelopment

Figure 3.

CBCU$_C$: Nebraska Proposal

Frenchman Creek near Imperial

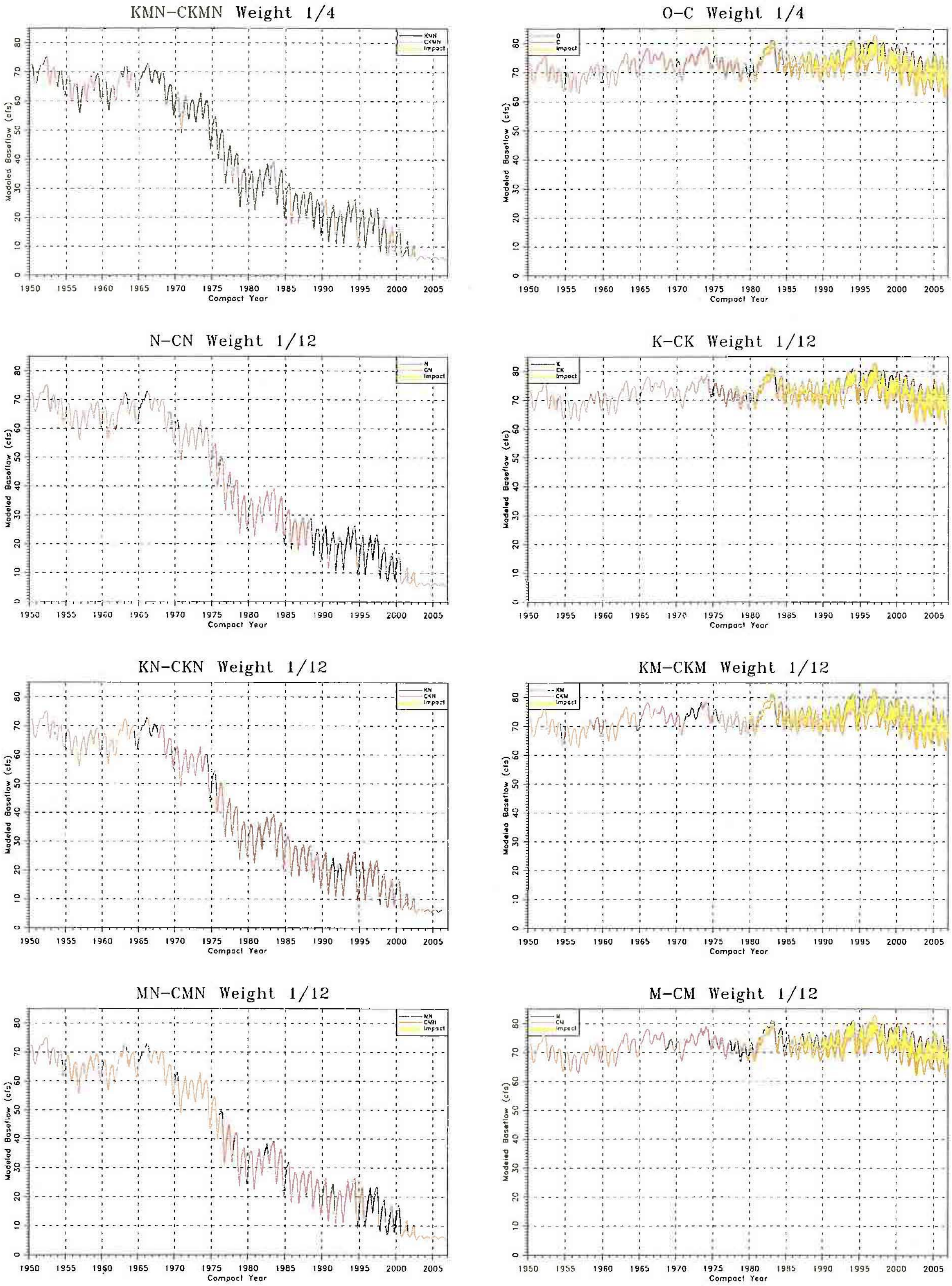


Figure 4.

Beaver Creek as Modeled for June 200 C-07

Republican River Compact Administration Groundwater Model

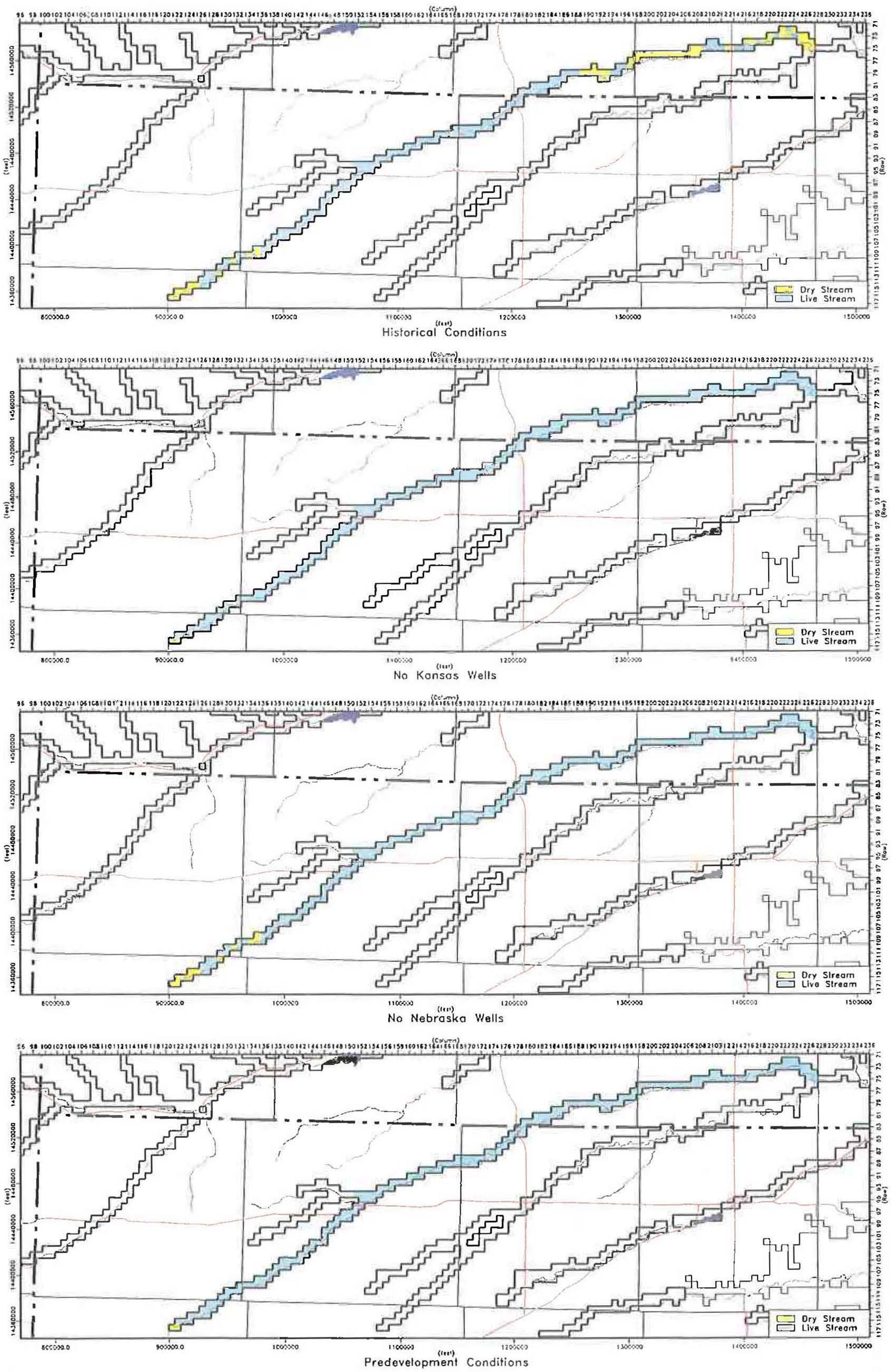


Figure 5.

Beaver Creek Modeled Baseflow June 2003

Beaver Creek above Confluence with Sappa Creek

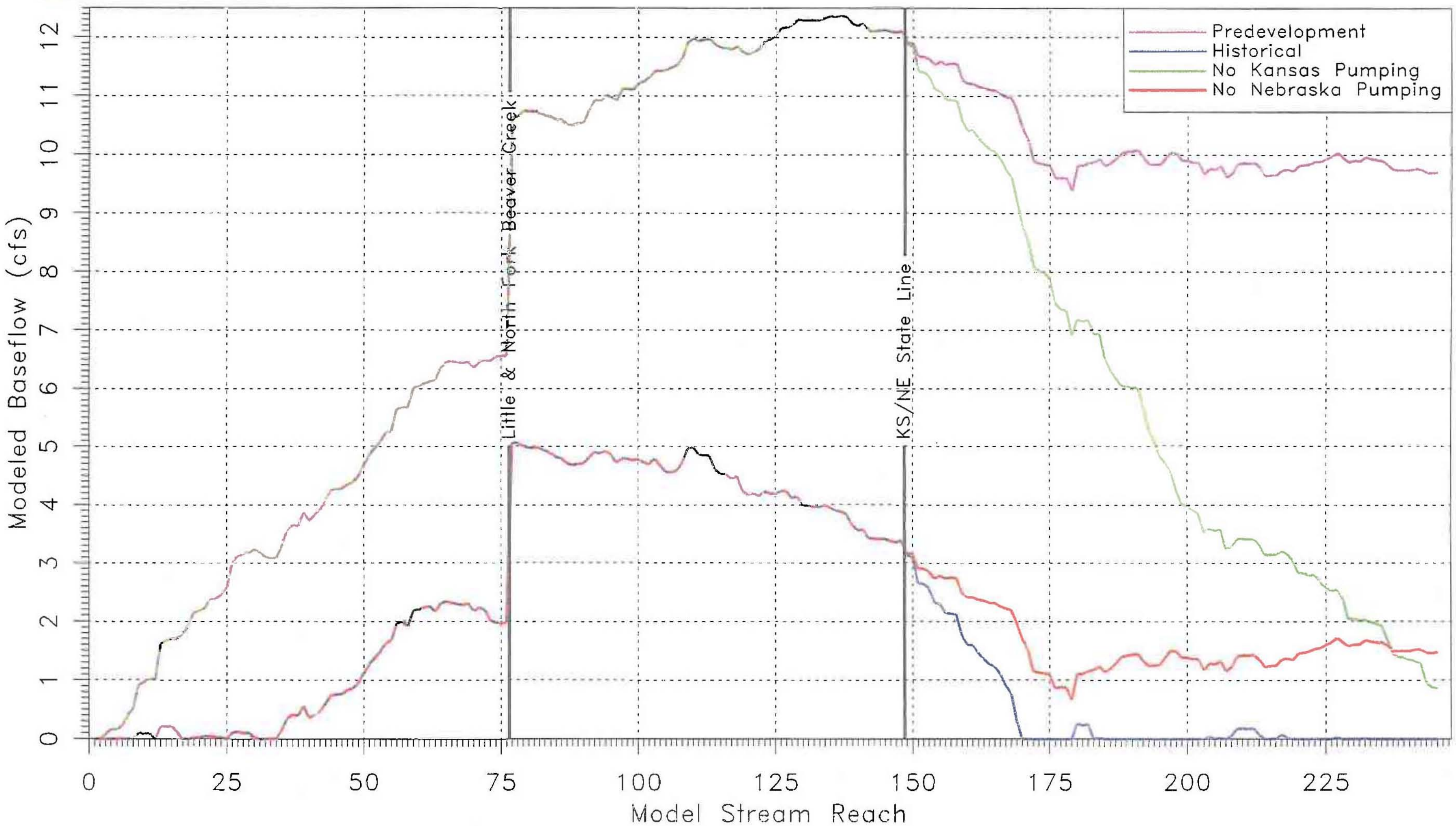


Figure 6.

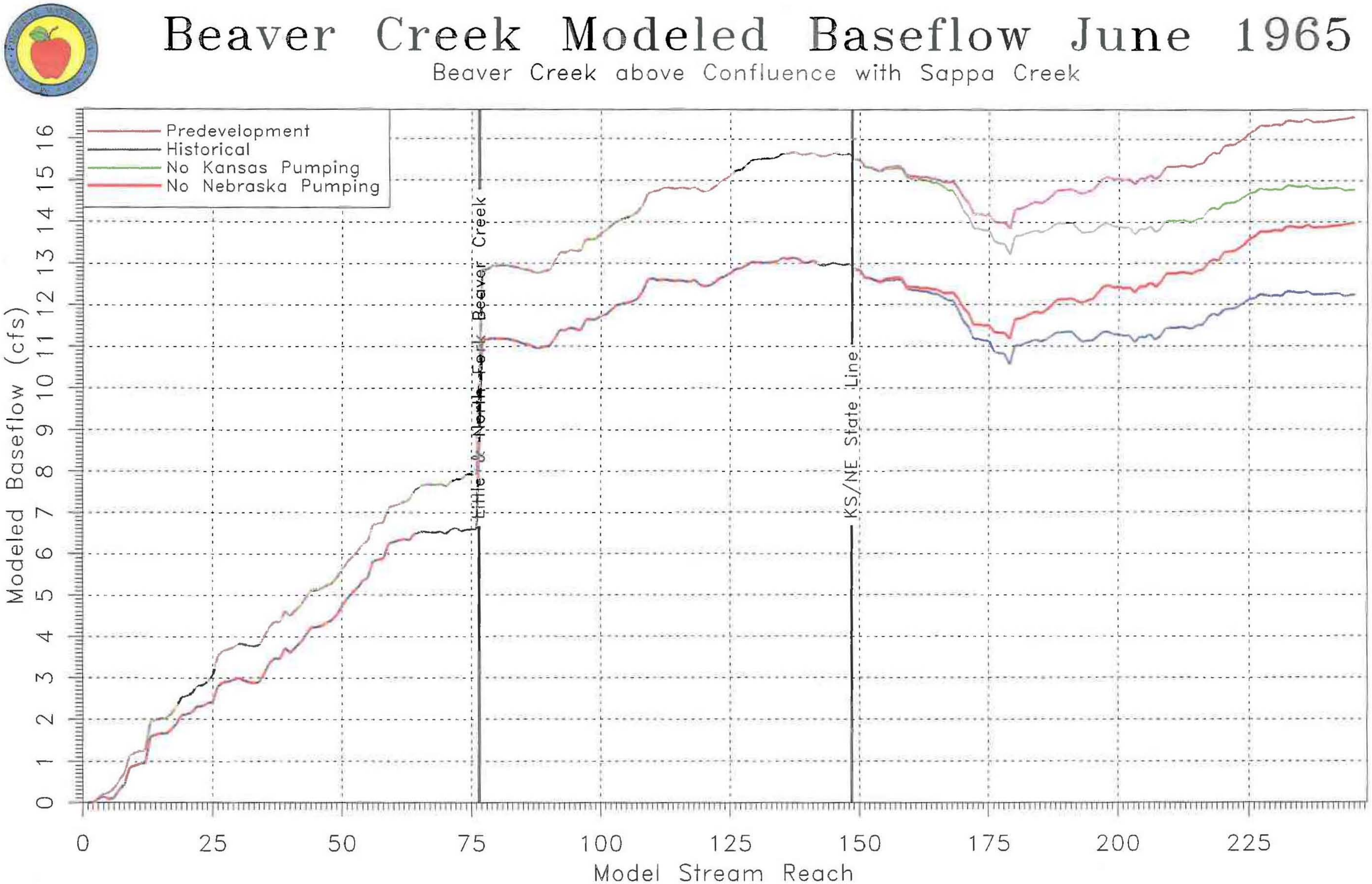
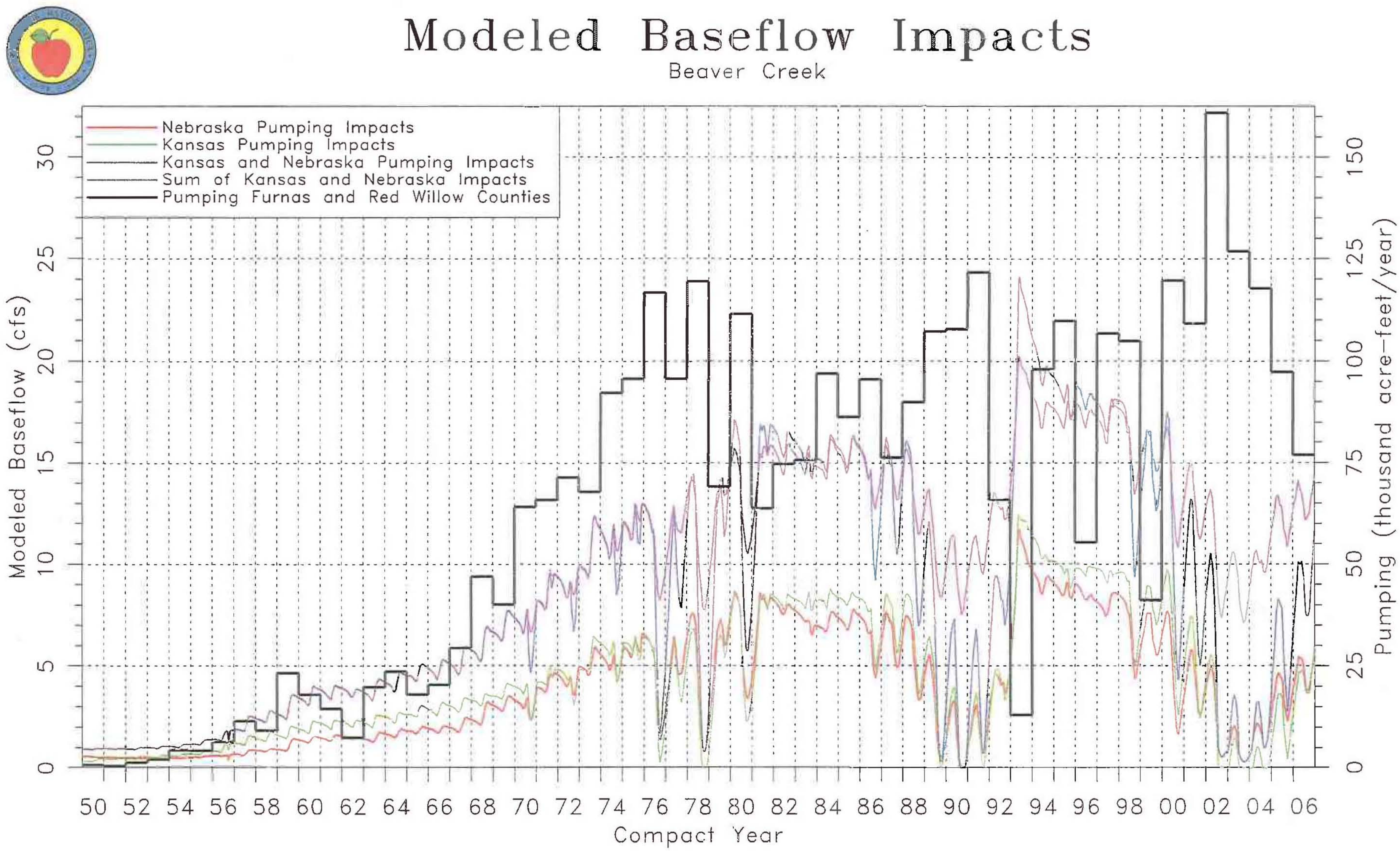

Beaver Creek Modeled Baseflow June 1965
Beaver Creek above Confluence with Sappa Creek
Predevelopment
Historical
No Kansas Pumping
No Nebraska Pumping
Little & North Fork Beaver Creek
KS/NE State Line
Modeled Baseflow (cfs)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
0
25
50
75
100
125
150
175
200
225
Model Stream Reach

Figure 7.



Modeled Baseflow Impacts
Beaver Creek
Nebraska Pumping Impacts
Kansas Pumping Impacts
Kansas and Nebraska Pumping Impacts
Sum of Kansas and Nebraska Impacts
Pumping Furnas and Red Willow Counties
Modeled Baseflow (cfs)
Pumping (thousand acre-feet/year)
Compact Year
0
5
10
15
20
25
30
0
25
50
75
100
125
150
50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90 92 94 96 98 00 02 04 06

Figure 8.

C-07

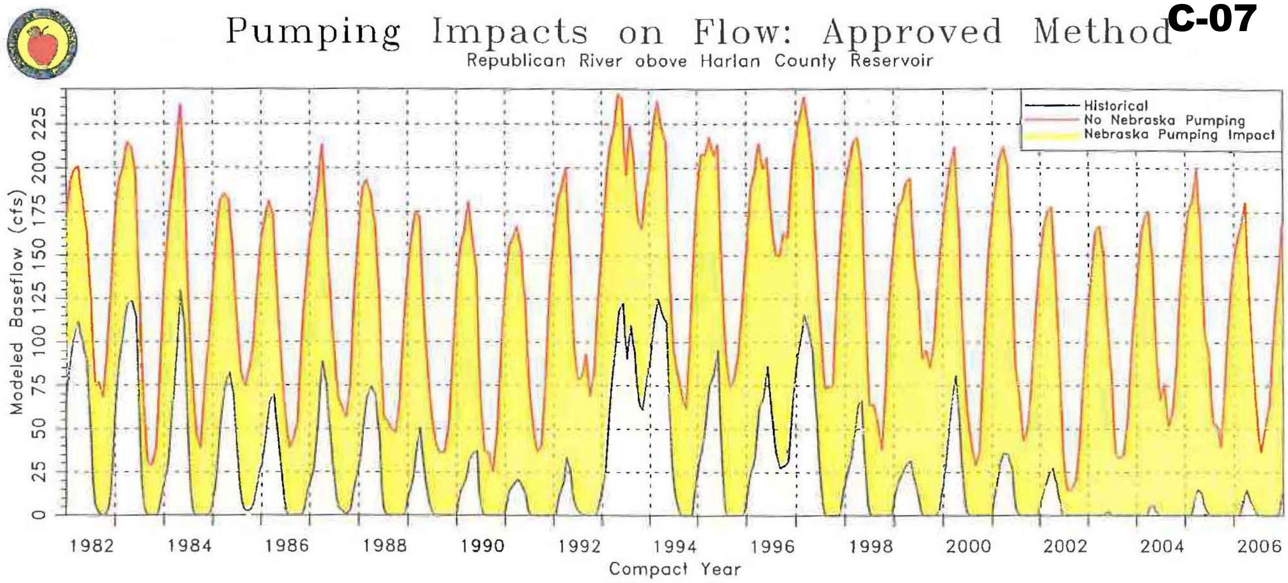


Figure 9a

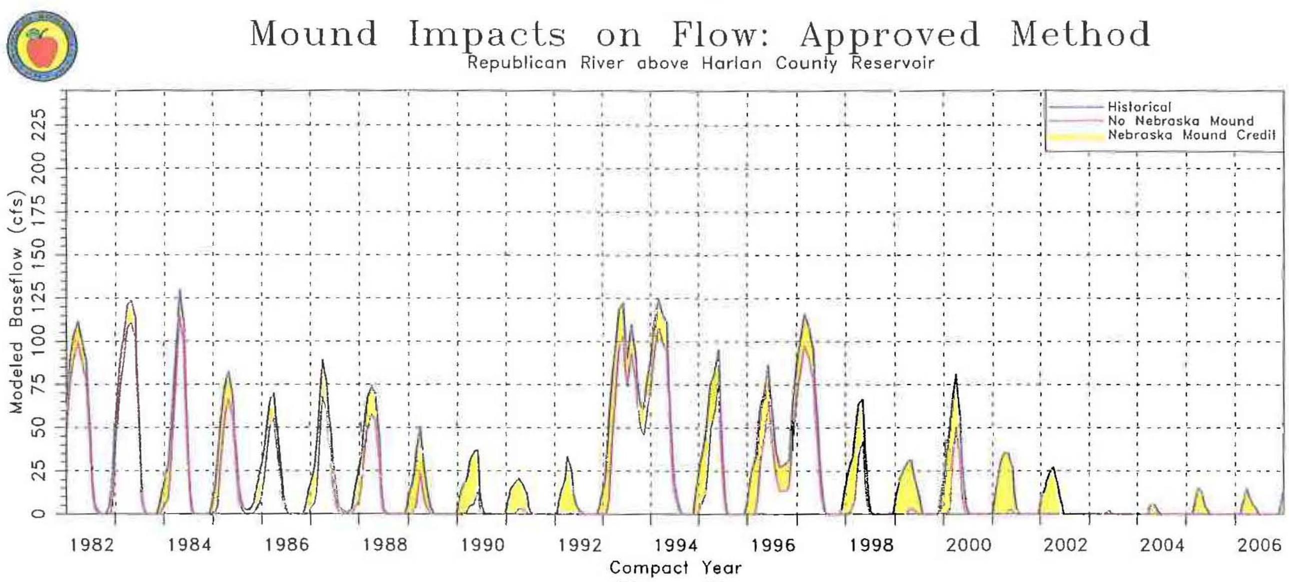


Figure 9b

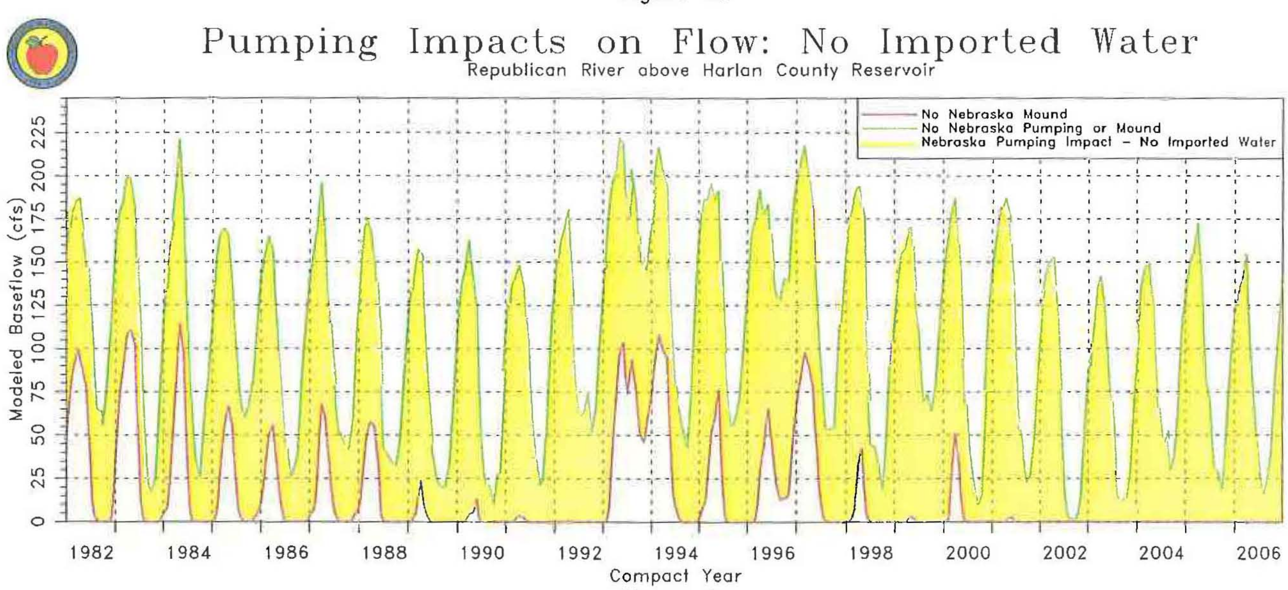


Figure 9c

Pumping Impacts: Approved Method
Mainstem Impacts Swanson – Harlan

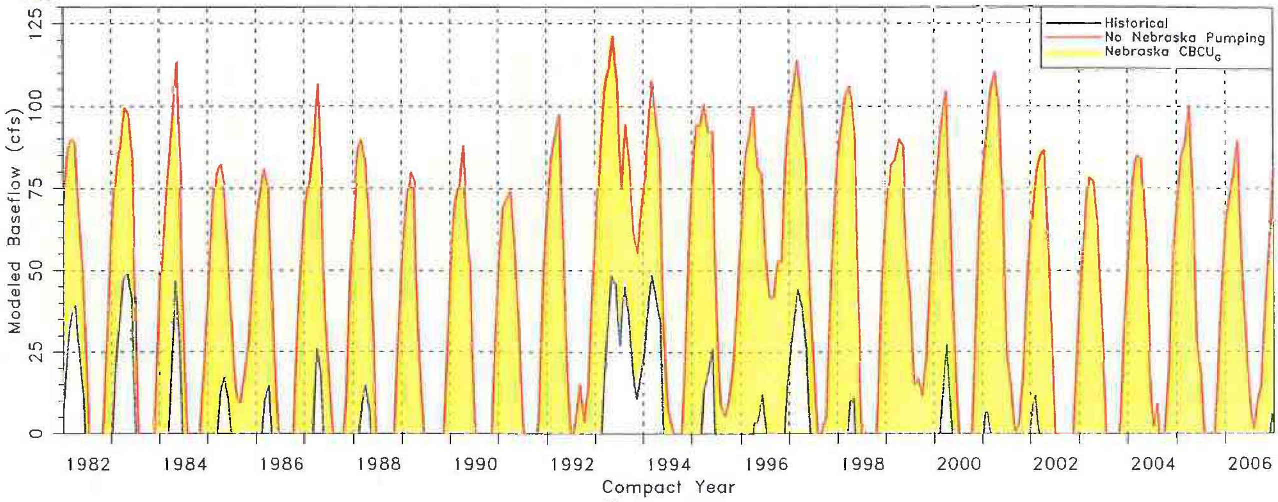


Figure 10a

Mound Credits: Approved Method
Mainstem Impacts Swanson – Harlan

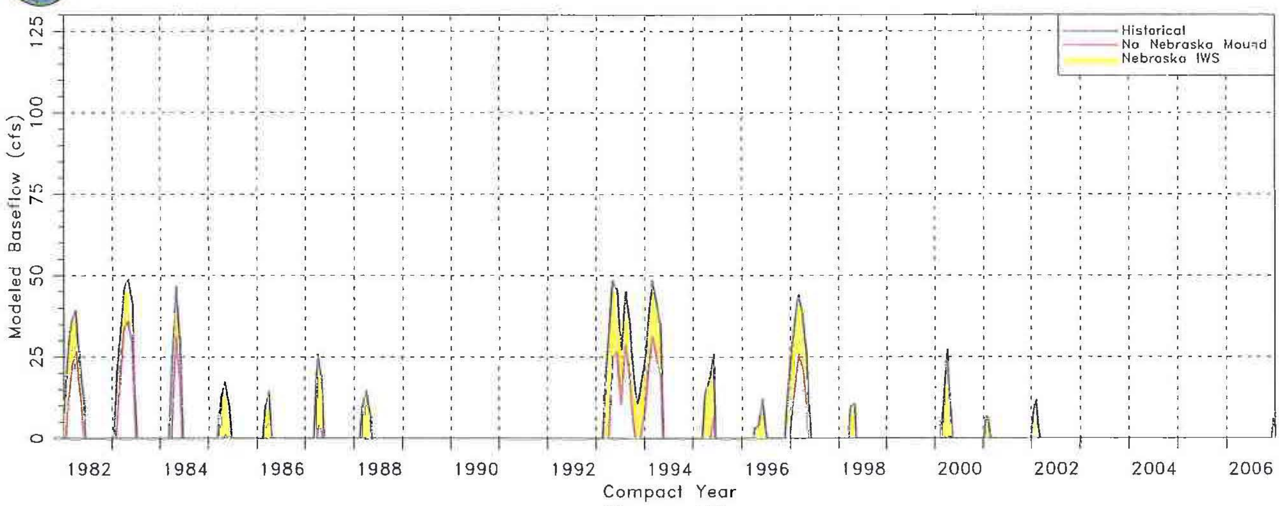


Figure 10b

Pumping Impacts without Imported Water
Mainstem Impacts Swanson – Harlan

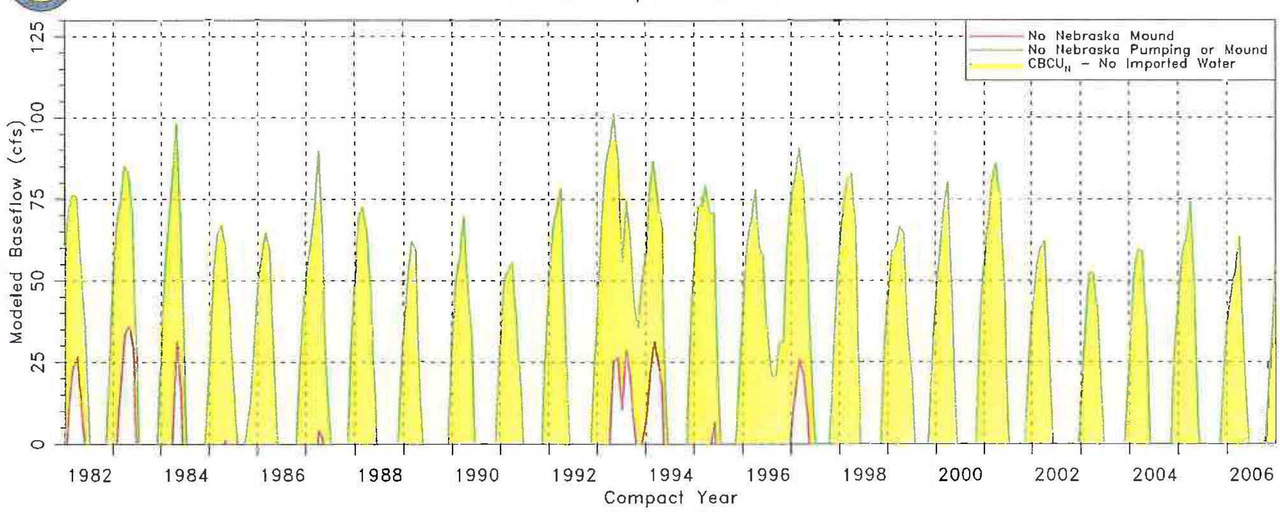


Figure 10c

C-07

Pumping Impacts: Approved Method

Mainstem Impacts Swanson – Harlan

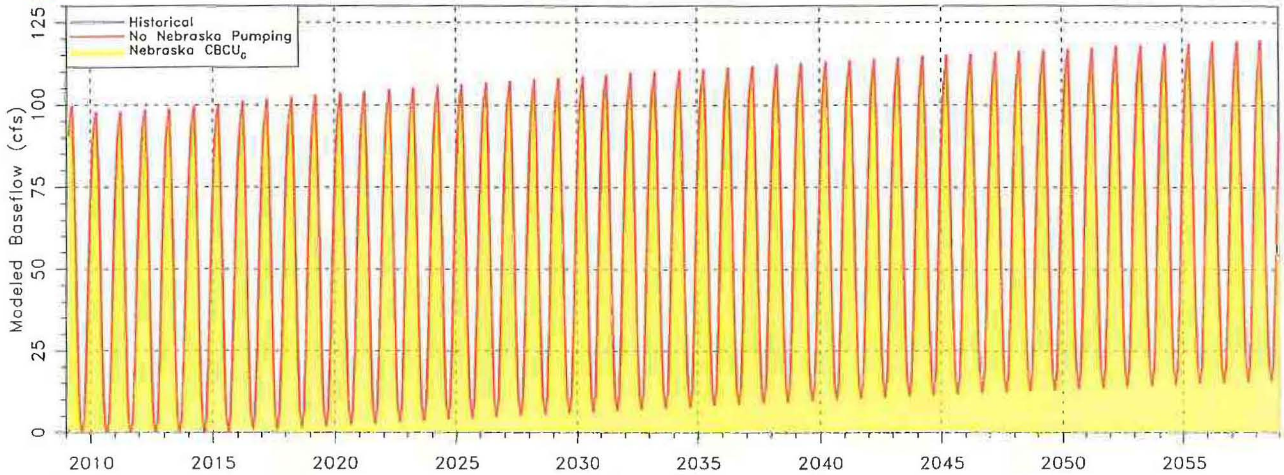


Figure 11a

Mound Credits: Approved Method

Mainstem Impacts Swanson – Harlan

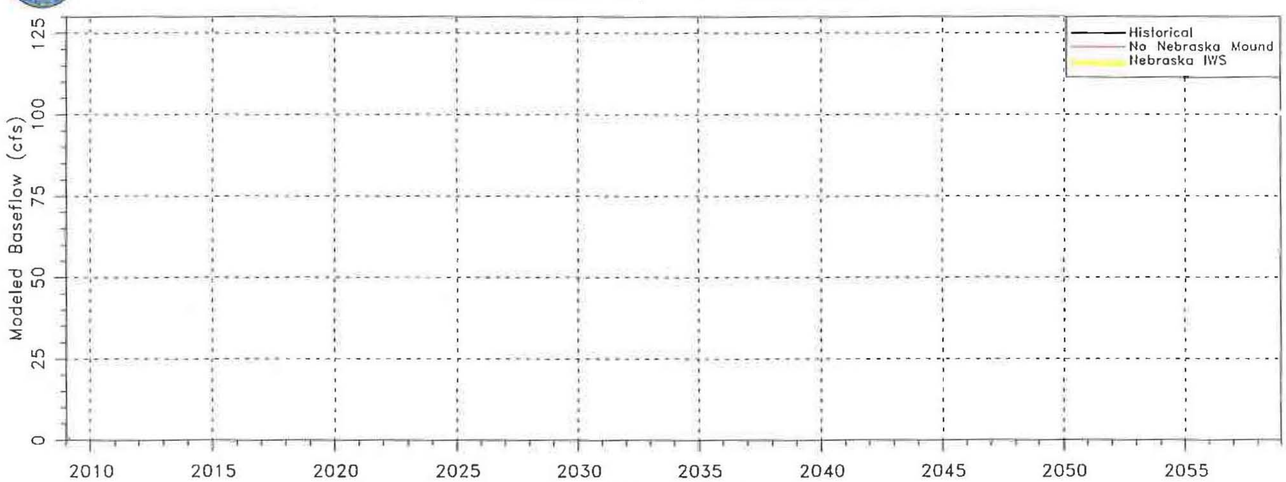


Figure 11b

Pumping Impacts without Imported Water

Mainstem Impacts Swanson – Harlan

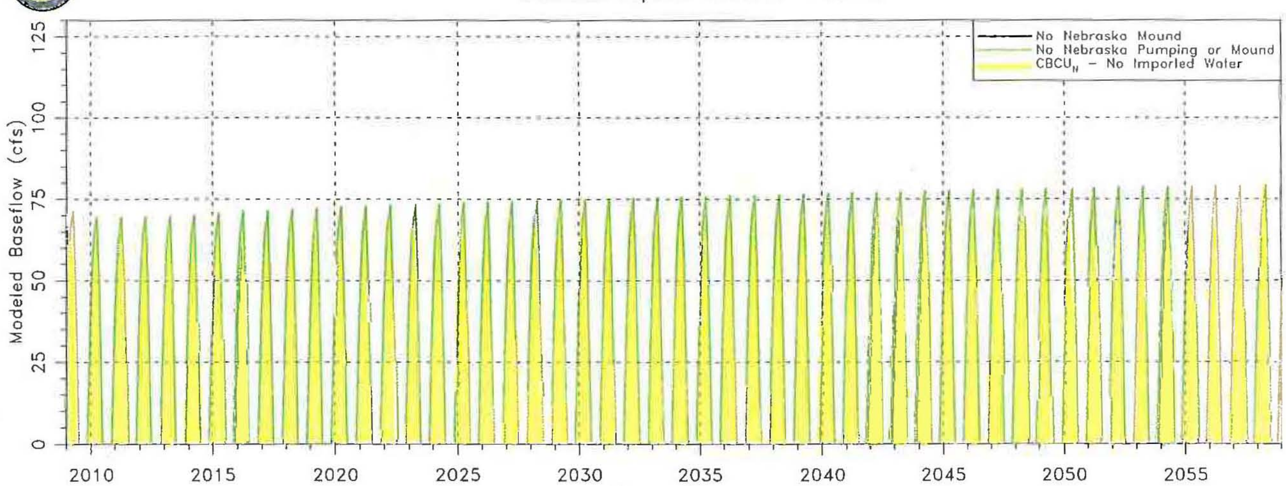


Figure 11c

Table 1a: 1981 (acre-feet/year)																		
Basin	$CBCU_C$			$CBCU_K$			$CBCU_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	799	821	798	430	446	430	260	255	260	0	0	0	0	0	0	-32	0	-33
Beaver	0	0	0	5300	5275	5301	5444	5418	5443	0	0	0	0	-25	0	52	0	52
Buffalo	33	42	33	0	0	0	1400	1410	1400	0	0	0	0	0	0	19	0	-19
Driftwood	0	0	0	0	0	0	835	835	835	0	0	0	0	0	0	0	0	0
Frenchman	243	858	240	0	0	0	50192	50798	50183	0	0	0	0	611	0	1216	0	-1230
North Fork	7530	7528	7529	12	11	13	214	213	216	0	0	0	0	0	0	0	0	0
Above Swanson	523	-641	-523	280	238	278	9721	9576	9736	14	0	14	15	-150	0	295	0	308
Swanson - Harlan	0	-18	0	230	69	127	40486	40047	39857	8509	8838	8509	628	-140	0	940	0	207
Harlan - Guide Rock	0	0	0	0	0	0	12567	12558	12565	62	63	62	0	0	0	16	0	16
Guide Rock - Hardy	0	0	0	236	235	237	1456	1456	1469	12	0	12	14	0	0	0	0	12
Medicine	0	0	0	0	0	0	9678	9612	9546	6624	6689	6624	132	0	0	130	0	0
Prairie Dog	0	0	0	4066	4067	4068	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	4046	4045	4044	11	12	11	0	0	0	0	0	0
Rock	0	0	0	0	0	0	1101	1101	1101	0	0	0	0	0	0	0	0	0
Sappa	0	0	0	-545	554	-551	1185	2287	1184	0	0	0	0	1101	0	2198	0	-2205
South Fork	960[illegible]	9599	9681	10985	10818	10980	977	911	985	0	0	0	0	-67	0	311	0	311
Hugh Butler	0	0	0	0	0	0	839	839	839	0	0	0	0	0	0	0	0	0
Bonny	758	758	758	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	359	359	359	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	1695	1695	1694		0	0	0	0	0	0	0	0
Harlan	0	0	0	25	25	25	621	620	621	0	0	0	0	0	0	0	0	0
Harry Strunk	0	0	0	0	0	0	119	119	119	0	0	0	0	0	0	0	0	0
Swanson	0	0	0	0	0	0	141	139	141	0	0	0	0	0	0	0	0	0
Mainstem	-531	-667	-532	743	536	640	64226	63637	63627	8596	8910	8596	601	-304	0	1247	0	542
Total	18524	18948	18514	21176	22087	21263	142975	143933	142239	15236	15611	15236	736	1319	0	-1718	0	-2577

Table 1b: 1982 (acre-feet/year)																		
Basin	$CBCU_C$			$CBCU_K$			$CBCU_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	2107	2141	2107	363	396	363	210	216	210	0	0	0	0	0	0	-72	0	-72
Beaver	0	0	0	5986	5692	5986	5707	5413	5706	0	0	0	0	-294	0	591	0	588
Buffalo	40	78	39	0	0	0	1475	1513	1475	0	0	0	0	38	0	76	0	-76
Driftwood	0	0	0	0	0	0	830	829	829	0	0	0	0	0	0	0	0	0
Frenchman	288	972	286	0	0	0	510[illegible]	51710	51025	0	0	0	0	679	0	135[illegible]	0	-1364
North Fork	7870	7867	7870	11	10	12	234	230	234	0	0	0	0	0	0	0	0	0
Above Swanson	875	-908	-873	21[illegible]	164	213	870[illegible]	8673	8690	12	0	-12	11	-24	0	117	0	108
Swanson - Harlan	0	-15	0	39	-61	-128	3111[illegible]	29826	28515	6961	8281	6961	2595	0	0	2631	0	-54
Harlan - Guide Rock	0	0	0	0	0	0	1245[illegible]	12436	12432	54	67	54	20	0	0	39	0	16
Guide Rock - Hardy	0	0	0	176	172	173	1424	1418	1421	0	0	0	0	0	0	16	0	11
Medicine	0	0	0	0	0	0	9461	9359	9258	669[illegible]	6794	6692	20[illegible]	0	0	20[illegible]	0	0
Prairie Dog	0	0	0	4544	4545	4543	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	3414	3413	3412	12	13	12	0	0	0	0	0	0
Rock	0	0	0	0	0	0	1281	1282	1281	0	0	0	0	0	0	0	0	0
Sappa	0	0	0	2128	2318	2128	2861	3052	2863	0	0	0	0	190	0	381	0	-378
South Fork	8582	8774	8582	[illegible]	6139	5889	596	673	589	0	0	0	0	83	0	521	0	-526
Hugh Butler	0	0	0	0	0	0	882	882	882	0	0	0	0	0	0	0	0	0
Bonny	760	760	760	0	0	0	0	0	0	0	0	0	0	0	0		0	0
Keith Sebelius	0	0	0	487	487	487	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	1802	1802	1802	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	23	22	23	670	669	671	0	0	0	0	0	0	0	0	0
Harry Strunk	0	0	0	0	0	0	127	127	127	0	0	0	0	0	0	0	0	0
Swanson	0	0	0	0	0	0	135	133	135	0	0	0	0	0	0	0	0	0
Mainstem	887	-931	-885	353	272	258	53687	52354	51058	6998	8343	6998	2629	-49	0	2803	0	80
Total	18765	19665	18764	19789	19877	19690	[illegible]	133657	131556	13695	15151	13695	2849	646	0	1213	0	-1734

Table 1c: 1983 (acre-feet/year)

Basin	CBCU$_C$			CBCU$_K$			CBCU$_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	1562	1554	1561	252	256	252	117	133	114	0	0	0	0	18	0	11	0	-15
Beaver	0	0	0	5901	5755	5901	5217	5071	5216	0	0	0	0	-146	0	293	0	291
Buffalo	46	93	46	0	0	0	1498	1545	1498	0	0	0	0	47	0	94	0	-94
Driftwood	0	0	0	0	0	0	922	922	922	0	0	0	0	0	0	0	0	0
Frenchman	353	1097	350	0	0	0	51342	52083	51338	0	0	0	0	744	0	-1480	0	-1487
North Fork	7959	7959	7958	13	17	13	299	302	300	0	0	0	0	0	0	0	0	0
Above Swanson	1779	-1440	-1779	260	278	261	7135	7471	7133	0	0	0	0	340	0	695	0	-696
Swanson - Harlan	0	-10	0	-136	-126	-283	21610	19945	18137	6364	8121	6364	3473	50	0	3421	0	-199
Harlan - Guide Rock	0	0	0	0	0	0	13864	13850	13844	65	76	65	21	0	0	28	0	0
Guide Rock - Hardy	0	0	0	198	197	198	1526	1523	1526	0	0	0	0	0	0	0	0	0
Medicine	0	0	0	0	0	0	9636	9477	9321	6676	6833	6676	115	0	0	317	0	0
Prairie Dog	0	0	0	4087	4088	4087	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	3131	3130	3130	13	13	13	0	0	0	0	0	0
Rock	0	0	0	0	0	0	1363	1364	1363	0	0	0	0	0	0	0	0	0
Sappa	0	0	0	2146	2277	2146	2820	2951	2820	0	0	0	0	131	0	262	0	-261
South Fork	8224	8130	8225	4268	4214	4268	610	626	604	0	0	0	0	24	0	130	0	125
Hugh Butler	0	0	0	0	0	0	925	925	925	0	0	0	0	0	0	0	0	0
Bonny	780	780	780	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	454	454	454	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	1895	1895	1895	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	20	20	20	680	679	680	0	0	3	0	0	0	0	0	0
Harry Strunk	0	0	0	0	0	0	134	134	134	0	0	0	0	0	0	0	0	0
Swanson	0	0	0	0	0	0	137	136	137	0	0	0	0	0	0	0	0	0
Mainstem	-1781	-1454	-1781	322	347	176	44136	42788	40640	6431	8195	6431	3496	384	0	2761	0	-882
Total	17153	18167	17148	17465	17423	17318	124860	124159	121035	13118	15040	13118	3825	1202	0	1651	0	-2326

Table 1d: 1984 (acre-feet/year)

Basin	CBCU$_C$			CBCU$_K$			CBCU$_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	951	964	951	308	333	308	180	196	180	0	0	0	0	16	0	55	0	-54
Beaver	0	0	0	6067	5949	6063	5197	5082	5196	0	0	0	0	-114	0	230	0	228
Buffalo	53	91	53	0	0	0	1550	1588	1550	0	0	0	0	38	0	-76	0	-76
Driftwood	0	0	0	0	0	0	1039	1039	1039	0	0	0	0	0	0	0	0	0
Frenchman	419	1221	418	0	-13	0	54330	55134	54326	0	0	0	12	801	0	-1582	0	-1593
North Fork	8191	8395	8393	18	27	18	330	337	330	0	0	0	0	0	0	17	0	-18
Above Swanson	1376	-1109	-1376	171	194	172	9567	9857	9565	0	0	0	0	292	0	579	0	-580
Swanson - Harlan	0	0	0	338	-257	-611	32922	31202	29072	6521	8489	6521	3850	161	0	3613	0	-509
Harlan - Guide Rock	0	0	0	0	0	0	14511	14494	14489	70	82	70	22	0	0	37	0	14
Guide Rock - Hardy	0	0	0	293	291	293	1362	1356	1360	0	0	0	0	0	0	14	0	13
Medicine	0	0	0	0	0	0	10608	10504	10404	7100	7202	7100	204	0	0	208	0	0
Prairie Dog	0	0	0	4056	4056	4057	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	3700	3699	3698	15	16	15	0	0	0	0	0	0
Rock	0	0	0	0	0	0	1426	1427	1426	0	0	0	0	0	0	0	0	0
Sappa	0	0	0	2375	2501	2373	2863	2990	2863	0	0	0	0	127	0	254	0	-255
South Fork	7856	7985	7856	[illegible]	7901	7710	665	755	665	0	0	0	0	90	0	410	0	-410
Hugh Butler	0	0	0	0	0	0	994	993	994	0	0	0	0	0	0	0	0	0
Bonny	835	835	835	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	754	754	754	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	2036	2036	2036	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	19	18	19	773	772	773	0	0	0	0	0	0	0	0	0
Harry Strunk	0	0	0	0	0	0	143	143	143	0	0	0	0	0	0	0	0	0
Swanson	0	0	0	0	0	0	149	147	149	0	0	0	0	0	0	0	0	0
Mainstem	-1363	-1111	-1362	125	224	-146	58362	56909	54487	6587	8569	6587	3876	440	0	3094	0	-1062
Total	17159	18391	17157	21425	21750	21157	144353	143750	140256	13701	15794	13701	4097	1401	0	1138	0	-3229

Table 1e: 1985 (acre-feet/year)

Basin	$CBCU_C$			$CBCU_K$			$CBCU_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	345	363	346	294	312	294	191	194	191	0	0	0	0	0	0	-37	0	-37
Beaver	0	0	0	6049	5978	6049	5284	5212	5282	0	0	0	0	-72	0	144	0	142
Buffalo	61	90	61	0	0	0	1646	1676	1646	0	0	0	0	30	0	59	0	-59
Driftwood	0	0	0	0	0	0	1052	1052	1052	0	0	0	0	0	0	0	0	0
Frenchman	455	1328	454	0	0	0	56305	57160	56286	0	0	0	17	869	0	1719	0	-1740
North Fork	8687	8686	8687	20	26	20	367	370	366	0	0	0	0	0	0	0	0	0
Above Swanson	-1445	-1145	-1443	151	183	146	10054	10349	10047	0	0	0	0	303	0	629	0	-639
Swanson - Harlan	0	0	0	186	99	416	36253	35313	34807	9442	10129	9442	1446	-181	0	1723	0	514
Harlan - Guide Rock	0	0	0	0	0	0	14564	14549	14545	78	89	78	18	0	0	27	0	0
Guide Rock - Hardy	0	0	0	220	219	219	1529	1526	1533	0	0	0	0	0	0	0	0	0
Medicine	0	0	0	0	0	0	11206	11106	11009	7197	7295	7197	198	0	0	201	0	0
Prairie Dog	0	0	0	3524	3524	3525	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	4168	4166	4165	16	17	16	0	0	0	0	0	0
Rock	0	0	0	0	0	0	1504	1504	1503	0	0	0	0	0	0	0	0	0
Sappa	0	0	0	2775	2748	2775	3200	3174	3203	0	0	0	0	-28	0	53	0	56
South Fork	9615	9710	9616	6635	6767	6634	719	787	712	0	0	0	0	75	0	-297	0	-303
Hugh Butler	0	0	0	0	0	0	1041	1041	1041	0	0	0	0	0	0	0	0	0
Bonny	841	841	841	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	655	655	655	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	2200	2200	2199	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	18	18	18	712	711	712	0	0	0	0	0	0	0	0	0
Harry Strunk	0	0	0	0	0	0	154	154	154	0	0	0	0	0	0	0	0	0
Swanson	0	0	0	0	0	0	156	154	156	0	0	0	0	0	0	0	0	0
Mainstem	-1441	-1153	-1434	556	499	780	62400	61737	60932	9510	10204	9510	1468	110	0	1124	0	-111
Total	18575	19876	18584	20527	20518	20748	152302	152397	150611	16715	17516	16715	1691	986	0	-587	0	-2048

Table 1f: 1986 (acre-feet/year)

Basin	$CBCU_C$			$CBCU_K$			$CBCU_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	311	336	311	246	279	246	177	192	177	0	0	0	0	14	0	-72	0	-72
Beaver	0	0	0	5081	5467	5081	4461	4847	4461	0	0	0	0	386	0	-770	0	-771
Buffalo	69	91	69	0	0	0	1728	1750	1728	0	0	0	0	22	0	-44	0	-44
Driftwood	0	0	0	0	0	0	1072	1072	1072	0	0	0	0	0	0	0	0	0
Frenchman	511	1445	511	0	-11	0	57359	58284	57351	0	0	0	0	930	0	1854	0	-1859
North Fork	8823	8822	8825	16	20	18	375	376	376	0	0	0	0	0	0	0	0	0
Above Swanson	1582	-1302	-1579	186	191	193	9132	9412	9134	0	0	0	0	280	0	567	0	-554
Swanson - Harlan	14	-20	-18	232	-201	-570	28896	26415	23578	5863	8576	5863	5318	125	0	5168	0	-492
Harlan - Guide Rock	0	0	0	0	0	0	14795	14779	14770	88	99	88	25	0	0	21	0	0
Guide Rock - Hardy	0	0	0	247	251	249	1339	1339	1340	0	0	0	0	0	0	0	0	0
Medicine	0	0	0	0	0	0	11709	11563	11421	7165	7309	7165	288	0	0	291	0	0
Prairie Dog	0	0	0	2195	2195	2195	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	4039	4037	4036	15	16	15	0	0	0	0	0	0
Rock	[illegible]	11	0	0	0	0	1590	1591	1590	0	0	0	0	0	0	[illegible]	0	0
Sappa	0	0	0	948	1442	944	2099	2595	2099	0	0	0	0	495	0	989	0	-993
South Fork	7576	7643	7578	6011	6091	6014	715	749	711	0	0	0	0	38	0	181	0	-180
Hugh Butler	0	0	0	0	0	0	1100	1108	1109	0	0	0	0	0	0	0	0	0
Bonny	860	860	860	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	616	617	616	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	2341	2341	2341	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	18	17	18	789	788	789	0	0	0	0	0	0	0	0	0
Harry Strunk	0	0	0	0	0	0	164	165	165	0	0	0	0	0	0	0	0	0
Swanson	0	0	0	0	0	0	154	153	154	0	0	0	0	0	0	0	0	0
Mainstem	-1602	-1329	-1597	197	244	-127	54162	51945	48822	5948	8668	5948	5340	403	0	4617	0	-1042
Total	16564	17882	16573	15323	16361	15003	144043	143557	138402	13132	16002	13132	5642	2285	0	1001	0	-4952

C-07

Table 1g: 1987 (acre-feet/year)

Basin	CBCUC			CBCUK			CBCUN			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	343	369	343	310	335	310	190	199	190	0	0	0	0	0	0	-60	0	-60
Beaver	0	0	0	5259	5574	5260	4648	4963	4648	0	0	0	0	315	0	629	0	-629
Buffalo	79	98	79	0	0	0	1798	1817	1798	0	0	0	0	20	0	39	0	-39
Driftwood	0	0	0	0	0	0	1103	1103	1103	0	0	0	0	0	0	0	0	0
Frenchman	584	1569	582	-10	-19	0	58479	59467	58454	17	0	-17	25	1000	0	1962	0	-1973
North Fork	9328	9326	9328	21	24	21	433	433	428	0	0	0	0	0	0	0	0	0
Above Swanson	1694	-1312	-1691	148	199	155	9257	9647	9233	20	-12	-20	24	405	0	816	0	-828
Swanson - Harlan	19	-12	-20	39	0	157	35066	33715	32596	9180	10401	9180	2469	-103	0	2600	0	246
Harlan - Guide Rock	0	0	0	0	0	0	15641	15624	15613	88	105	88	28	0	0	38	0	11
Guide Rock - Hardy	0	0	0	223	223	224	1378	1376	1377	12	-10	-12	0	0	0	0	0	0
Medicine	0	0	0	0	0	0	12154	12012	11873	7412	7552	7412	281	0	0	285	0	0
Prairie Dog	0	0	0	4495	4496	4496	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	4227	4224	4223	17	19	17	0	0	0	0	0	0
Rock	10	12	10	0	0	0	1705	1706	1705	0	0	0	0	0	0	0	0	0
Sappa	0	0	0	300	1159	293	1445	2305	1442	0	0	0	0	861	0	1716	0	-1726
South Fork	9818	9943	9822	8061	8199	8074	716	782	709	0	0	0	0	71	0	328	0	-318
Hugh Butler	0	0	0	0	0	0	1122	1122	1122	0	0	0	0	0	0	0	0	0
Bonny	900	900	900	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	551	551	551	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	2440	2440	2440	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	17	16	17	714	713	714	0	0	0	0	0	0	0	0	0
Harry Strunk	0	0	0	0	0	0	173	173	174	0	0	0	0	0	0	0	0	0
Swanson	0	0	0	0	0	0	154	151	153	0	0	0	0	0	0	0	0	0
Mainstem	-1717	-1333	-1715	408	424	534	61341	60361	58819	9236	10484	9236	2522	293	0	1828	0	-565
Total	19349	20886	19355	19413	20758	19552	152841	153974	149994	16637	18048	16637	2847	2569	0	-2604	0	-5306

Table 1h: 1988 (acre-feet/year)

Basin	CBCUC			CBCUK			CBCUN			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	782	811	782	289	323	289	169	176	169	0	0	0	0	0	0	68	0	-67
Beaver	0	0	0	4658	5272	4658	4009	4624	4010	0	0	0	0	613	0	1727	0	-1227
Buffalo	89	113	89	0	0	0	1873	1897	1873	0	0	0	0	24	0	48	0	-48
Driftwood	0	0	0	0	0	0	1098	1098	1098	0	0	0	0	0	0	0	0	0
Frenchman	651	1708	651	0	0	0	59737	60792	59730	0	0	0	0	1057	0	2102	0	-2113
North Fork	9762	9765	9764	18	26	19	483	489	483	0	0	0	0	0	0	17	0	-14
Above Swanson	1974	-1524	-1967	256	276	261	9342	9791	9343	0	0	0	0	450	0	921	0	-908
Swanson - Harlan	12	0	14	342	-283	-763	30381	27736	24494	6073	9086	6073	5886	229	0	5613	0	-692
Harlan - Guide Rock	6	0	11	0	0	0	18164	18147	18135	106	116	106	29	0	0	22	0	0
Guide Rock - Hardy	0	0	10	291	291	291	1538	1538	1540	0	0	0	0	0	0	0	0	0
Medicine	0	0	0	0	0	0	12460	12326	12195	7578	7711	7578	285	0	0	268	0	0
Prairie Dog	0	0	0	2499	2499	2498	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	4174	4172	4170	19	21	19	0	0	0	0	0	0
Rock	12	14	12	0	0	0	1833	1834	1833	0	0	0	0	0	0	0	0	0
Sappa	0	0	0	-83	691	-91	1247	2024	1245	0	0	0	0	777	0	-1548	0	-1558
South Fork	7813	7858	7817	7193	7274	7192	725	804	723	0	0	0	0	82	0	205	0	-204
Hugh Butler	0	0	0	0	0	0	1171	1171	1171	0	0	0	0	0	0	0	0	0
Bonny	950	950	950	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	613	613	612	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	2547	2547	2547	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	16	15	16	820	820	820	0	0	0	0	0	0	0	0	0
Harry Strunk	0	0	0	0	0	0	181	181	181	0	0	0	0	0	0	0	0	0
Swanson	0	0	0	0	0	0	160	156	160	0	0	0	0	0	0	0	0	0
Mainstem	-1963	-1520	-1932	205	285	-210	59424	57213	53512	6173	9190	6173	5912	684	0	4705	0	-1591
Total	18107	19700	18143	15406	16991	14981	152112	152324	145920	13773	16934	13773	6192	3242	0	-229	0	-6810

Table 1i: 1989 (acre-feet/year)

Basin	$CBCU_C$			$CBCU_K$			$CBCU_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	107	120	107	295	319	295	164	183	164	0	0	0	0	19	0	-55	0	-55
Beaver	0	0	0	2404	4103	2404	2072	3771	2072	0	0	0	0	1699	0	3398	0	-3398
Buffalo	99	117	98	0	0	0	1939	1957	1939	0	0	0	0	18	0	36	0	-36
Driftwood	0	0	0	0	0	0	1101	1101	1101	0	0	0	0	0	0	0	0	0
Frenchman	711	1806	709	0	0	0	60370	61459	60352	0	0	0	18	1099	0	2171	0	-2187
North Fork	9841	9839	9841	32	33	32	515	515	516	0	0	0	0	0	0	0	0	0
Above Swanson	1958	-1492	-1956	169	196	174	9017	9503	9016	0	0	0	0	489	0	-981	0	-976
Swanson - Harlan	0	0	0	180	97	418	28414	25237	22438	6177	9124	6177	5976	-149	0	6220	0	474
Harlan - Guide Rock	0	0	0	0	0	0	17744	17722	17708	113	130	113	36	0	0	44	0	10
Guide Rock - Hardy	0	0	0	234	234	236	1674	1671	1676	0	0	0	0	0	0	0	0	12
Medicine	0	0	0	0	0	0	13019	12839	12660	7506	7686	7506	358	0	0	362	0	0
Prairie Dog	0	0	0	752	752	751	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	4152	4150	4148	18	21	18	0	0	0	0	0	0
Rock	13	15	13	0	0	0	1915	1917	1915	0	0	0	0	0	0	0	0	0
Sappa	0	0	0	-823	-189	-829	688	1323	685	0	0	0	0	635	0	1266	0	-1275
South Fork	8588	8962	8589	6640	7030	6645	418	663	420	0	0	0	0	247	0	1012	0	-1004
Hugh Butler	0	0	0	0	0	0	1263	1263	1263	0	0	0	0	0	0	0	0	0
Bonny	968	968	968	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	682	682	682	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	2660	2661	2661	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	16	16	16	895	895	896	0	0	0	0	0	0	0	0	0
Harry Strunk	0	0	0	0	0	0	189	189	190	0	0	0	0	0	0	0	0	0
Swanson	0	0	0	0	0	0	159	158	160	0	0	0	0	0	0	0	0	0
Mainstem	-1946	-1502	-1950	585	529	831	56849	54132	50838	6287	9247	6287	6010	334	0	5289	0	-480
Total	18388	20328	18382	10588	13271	10836	148368	149177	141979	13813	16961	13813	6389	4051	0	-2284	0	-8431

Table 1j: 1990 (acre-feet/year)

Basin	$CBCU_C$			$CBCU_K$			$CBCU_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	400	437	401	359	403	359	203	232	203	0	0	0	0	29	0	-110	0	-110
Beaver	0	0	0	1217	3546	1217	1054	3383	1054	0	0	0	0	2329	0	4657	0	-4657
Buffalo	110	139	110		0	0	2055	2084	2055	0	0	0	0	29	0	58	0	-58
Driftwood	0	0	0	0	0	0	1121	1121	1121		0	0	0	0	0	0	0	0
Frenchman	691	1871	691	0	-12	0	63990	65162	63974	0	0	0	16	1180	0	2334	0	-2355
North Fork	10508	10503	10507	29	35	27	597	600	598	0	0	0	0	0	0	0	0	0
Above Swanson	2095	-1556	-2096	32	108	-41	10904	11513	10905	0	0	0	0	606	0	1285	0	-1293
Swanson - Harlan	0	-11	0	118	0	78	32829	29973	27295	7018	9793	7018	5535	-96	0	5756	0	183
Harlan - Guide Rock	0	0	0	0	0	0	18122	18092	18070	117	146	117	52	0	0	75	0	12
Guide Rock - Hardy	0	0	0	252	243	243	1571	1567	1574	0	0	0	0	0	0	20	0	14
Medicine	0	0	0	0	0	0	13983	13760	13540	7634	7855	7634	443	0	0	447	0	0
Prairie Dog	0	0	0	779	780	779	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	4549	4546	4543	19	22	19	0	0	0	0	0	0
Rock	15	17	14	[illegible]	0	0	2032	2039	2037	0	0	0	0	0	0	0	0	0
Sappa	0	0	0	780	-372	-789	616	1026	612	0	0	0	0	410	0	815	0	-827
South Fork	9851	10041	9854	9616	9942	9607	787	966	783		0	0	0	179	0	690	0	-702
Hugh Butler	0	0	0	0	0	0	1335	1335	1335	0	0	0	0	0	0	0	0	0
Bonny	985	985	985	0	0	0	0	0	0	0	0	0		0	0	0	0	0
Keith Sebelius	0	0	0	641	642	641	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	2795	2796	2795	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	15	17	15	906	908	907	0	0	0	0	0	0	0	0	0
Harry Strunk	0	0	0	0	0	0	199	201	200	0	0	0	0	0	0	0	0	0
Swanson	0	0	0	0	0	0	171	168	171	0	0	0	0	0	0	0	0	0
Mainstem	-2089	-1575	-2090	340	351	273	63427	61145	57844	7135	9944	7135	5583	492	0	4567	0	-1085
Total	20480	22420	20476	12216	15331	12123	159822	161471	153773	14788	17834	14788	6050	4652	0	3657	0	-9804

C-07

Table 1k: 1991 (acre-feet/year)

Basin	$CBCU_C$			$CBCU_K$			$CBCU_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	1216	1256	1216	447	489	446	298	308	298	0	0	0	0	0	0	93	0	-92
Beaver	0	0	0	1321	3787	1321	1354	3819	1354	0	0	0	0	2465	0	4931	0	-4930
Buffalo	122	189	121	0	0	0	2219	2286	2218	0	0	0	0	67	0	134	0	-135
Driftwood	0	0	0	0	0	0	1150	1150	1150	0	0	0	0	0	0	0	0	0
Frenchman	713	1980	711	0	0	-11	67072	68336	67059	0	15	0	13	1268	0	2511	0	-2539
North Fork	10923	10913	10923	46	29	46	595	576	594	0	0	0	0	-18	0	46	0	45
Above Swanson	1168	-1127	-1173	139	197	127	12258	12301	12265	0	0	0	0	37	0	142	0	-153
Swanson - Harlan	0	-18	0	0	-60	-136	38381	34176	29970	4504	8736	4504	8411	-26	0	8523	0	-26
Harlan - Guide Rock	0	0	0	0	0	0	20750	20726	20700	123	147	123	50	0	0	47	0	0
Guide Rock - Hardy	0	0	0	364	363	363	1865	1878	1886	0	0	0	-21	0	0	25	0	0
Medicine	0	0	0	0	0	0	15201	15034	14870	8018	8184	8018	332	0	0	337	0	0
Prairie Dog	0	0	0	2179	2179	2179	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	5184	5179	5175	20	25	20	0	0	0	11	0	0
Rock	16	20	16	0	0	0	2224	2228	2224	0	0	0	0	0	0	0	0	0
Sappa	0	0	0	1079	-483	-1088	578	1177	575	0	0	0	0	599	0	1191	0	-1203
South Fork	10667	10702	10668	[illegible]	10691	10615	965	1040	973	0	0	0	0	71	0	183	0	-180
Hugh Butler	0	0	0	0	0	0	1420	1420	1420	0	0	0	0	0	0	0	0	0
Bonny	975	975	975	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	658	658	658	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	2933	2933	2932	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	18	18	18	994	995	995	0	0	0	0	0	0	0	0	0
Harry Strunk	0	0	0	0	0	0	212	212	212	0	0	0	0	0	0	0	0	0
Swanson	0	0	0	0	0	0	165	160	165	0	0	0	0	0	0	10	0	0
Mainstem	-1167	-1146	-1171	506	499	352	73255	69082	64821	4637	8881	4637	8434	17	0	8403	0	-188
Total	23474	24891	23468	14722	17858	14539	175819	175935	167035	12690	17114	12690	8784	4477	0	-246	0	-9218

Table 1l: 1992 (acre-feet/year)

Basin	$CBCU_C$			$CBCU_K$			$CBCU_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	2048	2061	2046	388	410	388	207	226	206	0	0	0	0	19	0	-52	0	-55
Beaver	0	0	0	3008	4657	3009	3021	4669	3021	0	0	0	0	1648	0	3295	0	-3295
Buffalo	135	219	135	0	0	0	2294	2378	2294	0	0	0	9	84	0	168	0	-168
Driftwood	0	0	0	0	0	0	1153	1153	1153	0	0	0	0	0	0	0	0	0
Frenchman	733	2070	707	0	0	0	54283	65623	64266	0	15	0	14	1345	0	-2662	0	-2703
North Fork	11295	11287	11292	23	16	23	586	581	587	0	0	0	0	0	0	20	0	18
Above Swanson	1019	-1112	-1060	404	326	407	10265	10186	10275	10	0	10	16	-86	0	222	0	219
Swanson - Harlan	11	-20	17	52	-229	-1075	49746	46460	42537	6148	9925	6148	7209	147	0	7247	0	-956
Harlan - Guide Rock	0	0	0	0	0	0	18840	18786	18745	106	155	106	95	0	0	119	0	15
Guide Rock - Hardy		0	0	107	103	110	1658	1655	1666	0	0	0	0	0	0	13	0	16
Medicine		0	0	0	0	0	14920	14808	14698	8354	8466	8354	222	0	0	228	0	0
Prairie Dog	0	0	0	4454	4455	4454	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	5475	5470	5466	24	28	24	0	0	0	11	0	0
Rock	19	23	19	0	0	0	2373	2377	2373	0	0	0	0	0	0	0	0	0
Sappa	0	0	0	1714	-247	-1740	711	2189	707	0	0	0	0	1475	0	-2939	0	-2968
South Fork	10407	10467	10402	6550	6639	6551	925	913	930	0	0	0	0	-14	0	141	0	-140
Hugh Butler	0	0	0	0	0	0	1307	1307	1306	0	0	0	0	0	0	0	0	0
Bonny	991	994	994	0	0	0	0	0	0		0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	425	425	425	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	3040	3040	3040	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	16	18	16	842	845	843	0	0	0	0	0	0	0	0	0
Harry Strunk	0	0	0	0	0	0	219	219	220	0	0	0	0	0	0	0	0	0
Swanson	0	0	0	0	0	0	145	142	145	0	0	0	0	0	0	0	0	0
Mainstem	-1037	-1140	-1050	459	196	-555	80509	77087	73224	6270	10088	6270	7285	45	0	7607	0	-706
Total	24603	25982	24549	13613	16567	12577	162010	183026	174480	14665	18613	14665	7530	4598	0	-1401	0	-10021

Table 1m: 1993 (acre-feet/year)

Basin	CBCU$_C$			CBCU$_K$			CBCU$_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	1802	1799	1801	448	441	449	190	189	189	0	0	0	0	0	0	12	0	0
Beaver	0	0	0	7720	6992	7719	7008	6280	7007	0	0	0	0	-728	0	1458	0	1455
Buffalo	147	244	147	0	0	0	2284	2381	2283	0	0	0	0	97	0	195	0	-195
Driftwood	0	0	0	0	0	0	1076	1076	1076	0	0	0	0	0	0	0	0	0
Frenchman	980	2324	974	0	0	0	63480	64827	63449	0	11	0	31	1360	0	2665	0	-2704
North Fork	11493	11488	11492	14	11	14	592	591	592	0	0	0	0	0	[illegible]	11	0	10
Above Swanson	1061	-1070	-1066	210	210	209	8532	8529	8527	0	0	0	0	0	0	19	0	0
Swanson - Harlan	0	-17	-46	127	165	818	45635	45928	46817	15495	14795	15495	-1182	-189	0	1012	0	813
Harlan - Guide Rock	0	0	0	14	0	-14	16855	16836	16816	189	206	189	39	0	0	26	0	-15
Guide Rock - Hardy	0	0	0	47	53	47	1360	1359	1356	0	0	0	0	0	0	0	0	-16
Medicine	0	0	0	0	0	0	13281	13229	13174	8878	8932	8878	107	0	0	108	0	0
Prairie Dog	0	0	0	14165	14167	14165	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	5082	5083	5083	39	39	39	0	0	0	0	0	0
Rock	21	25	21	0	0	0	2501	2505	2500	0	0	0	0	0	0	0	0	0
Sappa	0	0	0	2892	2936	2894	4252	4297	4262	13	0	13	0	39	0	88	0	-81
South Fork	9566	9480	9546	8322	8196	8322	805	784	803	0	0	0	0	-26	0	240	0	219
Hugh Butler	0	0	0	0	0	0	1112	1113	1113	0	0	[illegible]	0	0	0	0	0	0
Bonny	1005	1005	1005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	404	404	404	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	3080	3081	3080	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	57	62	57	637	642	635	0	0	0	0	0	0	10	0	-12
Harry Strunk	0	0	0	0	0	0	215	215	215	0	0	0	0	0	0	0	0	0
Swanson	0	0	0	0	0	0	129	128	129	0	0	0	0	0	0	0	0	0
Mainstem	-1063	-1082	-1120	371	421	1061	72381	72652	73516	15672	14997	15672	-1135	-189	0	-977	0	791
Total	23956	25285	23866	34403	33627	35089	178103	179065	179099	24596	24001	24596	-999	561	[illegible]	2112	0	-518

Table 1n: 1994 (acre-feet/year)

Basin	CBCU$_C$			CBCU$_K$			CBCU$_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	1029	1057	1030	206	250	207	116	144	116	0	0	0	0	28	0	99	0	-99
Beaver	0	0	0	7665	6914	7664	6636	5885	6634	0	0	0	0	-750	0	1502	0	1500
Buffalo	159	259	159	0	0	0	2293	2394	2293	0	0	0	0	101	0	201	0	-202
Driftwood	0	0	0	0	0	0	1043	1043	1043	0	0	0	0	0	0	0	0	0
Frenchman	890	2353	892	0	0	0	67828	69286	67809	0	12	0	19	1469	0	2909	0	-2923
North Fork	11698	11699	11698	12	17	12	694	695	694	0	0	0	0	0	0	0	0	0
Above Swanson	2725	-2038	-2721	224	196	225	9131	9843	9134	0	0	0	0	710	0	1372	0	-1363
Swanson - Harlan	0	0	17	229	-190	-495	28354	24926	21154	7277	10915	7277	7200	134	0	7040	0	-415
Harlan - Guide Rock	0	0	11	0	12	0	18748	18719	18703	189	209	189	4	0	0	47	0	11
Guide Rock - Hardy	0	0	10	268	271	271	1305	1301	1307	0	0	0	0	0	0	0	0	0
Medicine	0	0	0	0	0	0	13342	13197	13053	8434	8578	8434	288	0	0	291	0	0
Prairie Dog	0	0	0	6358	6363	6359	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	4382	4379	4377	30	33	30	0	0	0	0	0	0
Rock	23	28	23	0	0	0	2563	2568	2563	0	0	0	0	0	0	11	0	-11
Sappa	0	0	0	3873	3269	3880	4806	4205	4819	16	0	16	13	-606	0	1107	0	1216
South Fork	9034	9064	9041	3279	3399	3286	591	696	596	0	0	0	0	103	0	259	0	-239
Hugh Butler	0	0	0	0	0	0	1349	1348	1348	0	0	0	0	0	0	0	0	0
Bonny	1044	1044	1044	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	476	476	476	0	0	0	0	0	0	0	0	0	[illegible]	0	0
Enders	0	0	0	0	0	0	3164	3164	3164	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	112	101	112	869	858	869	0	0	0	0	-11	0	21	0	22
Harry Strunk	0	0	0	0	0	0	214	214	214	0	0	0	0	0	0	0	0	0
Swanson	0	0	0	0	0	0	156	154	155	0	0	0	0	0	0	1	0	0
Mainstem	-2710	-2041	-2683	271	289	11	57537	54790	50299	7458	11111	7458	7239	838	0	5733	0	-1758
Total	21174	23469	21210	[illegible]	21075	22012	167581	165022	160046	15951	19749	15951	7535	1179	0	[illegible]	0	-2500

Table 1o: 1995 (acre-feet/year)

Basin	$CBCU_C$			$CBCU_K$			$CBCU_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	1656	1682	1656	379	399	379	232	239	230	0	0	0	0	0	0	53	0	-54
Beaver	0	0	0	6973	6636	6973	6313	5976	6312	0	0	0	0	-337	0	676	0	674
Buffalo	172	276	172	0	0	0	2410	2514	2410	0	0	0	0	104	0	208	0	-208
Driftwood	0	0	0	0	0	0	1117	1117	1117	0	0	0	0	0	0	0	0	0
Frenchman	791	2377	789	0	0	0	70334	71903	70297	0	14	0	17	1590	0	3139	0	-3171
North Fork	12100	12098	12100	28	40	28	746	753	742	0	0	0	0	0	0	15	0	-19
Above Swanson	-2046	-1635	-2047	0	140	0	10636	11065	10626	0	0	0	10	436	0	-976	0	-985
Swanson - Harlan	-10	0	0	-396	-311	-883	41743	39097	35765	8943	12007	8943	5978	268	0	5621	0	-831
Harlan - Guide Rock	0	0	0	0	0	0	22103	22066	22028	189	224	189	75	0	0	70	0	0
Guide Rock - Hardy	0	0	0	362	363	363	1754	1751	1749	0	0	0	0	0	0	0	0	0
Medicine	0	0	0	0	0	0	14966	14833	14699	8750	8882	8750	267	0	0	268	0	0
Prairie Dog	0	0	0	3689	3689	3689	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	5470	5467	5464	35	38	35	0	0	0	0	0	0
Rock	25	31	25	0	0	0	2642	2648	2642	0	0	0	0	0	0	11	0	-12
Sappa	0	0	0	2256	2371	2253	3476	3595	3481	0	0	0	0	116	0	236	0	-234
South Fork	12098	12230	12099	8872	9082	8875	876	981	865	0	0	0	11	112	0	444	0	-450
Hugh Butler	0	0	0	0	0	0	1448	1448	1448	0	0	0	0	0	0	0	0	0
Bonny	1053	1053	1053	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	485	485	485	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	3299	3300	3299	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	82	69	82	956	944	957	0	0	0	0	-12	0	24	0	24
Harry Strunk	0	0	0	0	0	0	225	225	226	0	0	0	0	0	0	0	0	0
Swanson	0	0	0	0	0	0	154	150	154	0	0	0	0	0	0	0	0	0
Mainstem	-2058	-1642	-2044	-31	196	-514	76236	73978	70168	9127	12229	9127	8068	709	0	4717	0	-1820
Total	25943	28107	25855	22734	22965	22259	190899	190069	184508	17927	21186	17927	6391	2301	0	1594	0	-5259

Table 1p: 1996 (acre-feet/year)

Basin	$CBCU_C$			$CBCU_K$			$CBCU_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	1569	1593	1569	406	434	406	237	247	236	0	0	0	0	10	0	62	0	-63
Beaver	0	0	0	7098	6796	7098	6178	5875	6175	0	0	0	0	-301	0	607	0	603
Buffalo	186	307	186	0	0	0	2500	2621	2499	0	0	0	0	121	0	242	0	-243
Driftwood	0	0	0	0	0	0	1146	1146	1146	0	0	0	0	0	0	0	0	0
Frenchman	936	2600	937	0	0	0	70585	72235	70536	0	17	0	43	1677	0	[illegible]	0	-3331
North Fork	12354	12341	12354	31	20	31	755	743	753	0	0	0	0	-11	0	36	0	34
Above Swanson	829	-1010	-829	305	240	304	11071	10880	11072	0	0	0	0	-195	0	440	0	440
Swanson - Harlan	22	0	14	345	232	889	52755	51993	51996	14929	15218	14929	758	-293	0	1195	0	973
Harlan - Guide Rock	0	0	0	0	0	0	20692	20659	20629	216	248	216	63	0	0	67	0	0
Guide Rock - Hardy	0	0	0	318	318	318	1763	1760	1759	0	0	0	0	0	0	0	0	0
Medicine	0	0	0	0	0	0	15006	14943	14882	9141	9206	9144	124	0	0	130	0	0
Prairie Dog	0	0	0	5918	5918	5918	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	5933	5929	5926	38	42	38	0	0	0	0	0	0
Rock	28	35	28	0	0	0	2775	2782	2774	0	0	0	0	0	0	13	0	-14
Sappa	0	0	0	3084	2821	3086	4048	3787	4056	15	0	15	0	-264	0	519	0	530
South Fork	11061	11147	11060	7485	7609	7484	919	950	916	0	0	0	0	31	0	239	0	-244
Hugh Butler	0	0	0	0	0	0	1362	1362	1362	0	0	0	0	0	0	0	0	0
Bonny	1054	1054	1054	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	334	334	334	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	3385	3385	3384	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	63	51	64	771	758	771	0	0	0	0	-12	0	25	0	25
Harry Strunk	0	0	0	0	0	0	232	232	232	0	0	0	0	0	0	0	0	0
Swanson	0	0	0	0	0	0	142	139	142	0	0	0	0	0	0	0	0	0
Mainstem	-802	-1016	-811	969	789	1513	86280	85291	85457	15133	15457	15133	823	-490	0	1706	0	141[illegible]
Total	26392	28061	26382	25389	24766	25940	202252	202420	201241	24331	24746	24331	1010	764	0	-801	0	-1270

Table 1q: 1997 (acre-feet/year)

Basin	$CBCU_C$			$CBCU_K$			$CBCU_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	1549	1567	1549	282	312	282	165	194	163	0	0	0	0	31	0	77	0	-78
Beaver	0	0	0	6908	6723	6908	5873	5686	5869	0	0	0	0	-185	0	374	0	371
Buffalo	199	312	198	0	0	0	2564	2677	2563	0	0	0	0	114	0	227	0	-227
Driftwood	0	0	0	0	0	0	1150	1150	1150	0	0	0	0	0	0	0	0	0
Frenchman	959	2678	959	0	0	0	72866	74584	72842	0	19	0	44	1722	0	3389	0	-3428
North Fork	12406	12406	12406	22	26	22	865	867	861	0	0	0	0	0	0	0	0	0
Above Swanson	2575	-1944	-2572	222	218	226	10961	11604	10948	0	0	0	14	653	0	1267	0	-1273
Swanson - Harlan	-15	-14	-11	-415	-372	-1159	34424	30549	25796	7167	11601	7167	8626	319	0	8266	0	-1102
Harlan - Guide Rock	0	0	0	0	0	0	22493	22439	22389	199	250	199	104	0	0	107	0	0
Guide Rock - Hardy	0	0	0	308	307	309	1693	1690	1690	0	0	0	0	0	0	0	0	0
Medicine	0	0	0	0	0	0	15220	15084	14947	8994	9129	8994	273	0	0	273	0	0
Prairie Dog	0	0	0	4121	4122	4122	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	5312	5307	5302	39	43	39	0	0	0	0	0	0
Rock	31	39	31	0	0	0	2839	2846	2838	0	0	0	0	0	0	15	0	-15
Sappa	0	0	0	2542	2506	2538	3432	3399	3433	0	0	0	0	-34	0	69	0	66
South Fork	9177	9203	9181	5863	5924	5869	858	945	845	0	0	0	17	98	0	173	0	-175
Hugh Butler	0	0	0	0	0	0	1479	1479	1479	0	0	0	0	0	0	0	0	0
Bonny	1079	1078	1079	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	427	427	427	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	3464	3464	3463	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	53	41	53	963	952	964	0	0	0	0	-11	0	22	0	23
Harry Strunk	0	0	0	0	0	0	237	237	238	0	0	0	0	0	0	0	0	0
Swanson	0	0	0	0	0	0	161	158	161	0	0	0	0	0	0	0	0	0
Mainstem	2589	-1959	-2581	118	153	-622	69571	66282	60822	7358	11848	7358	8749	970	0	7114	0	-2367
Total	22810	25324	22830	20330	20229	19608	187039	185312	177942	16406	21061	16406	9097	2715	0	3985	0	-5831

Table 1r: 1998 (acre-feet/year)

Basin	$CBCU_C$			$CBCU_K$			$CBCU_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	1088	1116	1088	286	323	287	205	220	205	0	0	0	0	15	0	79	0	-79
Beaver	0	0	0	5710	6152	5711	4890	5330	4888	0	0	0	0	442	0	881	0	-882
Buffalo	210	302	209	0	0	0	2686	2779	2686	0	0	0	0	92	0	185	0	-185
Driftwood	0	0	0	0	0	0	1196	1196	1196	0	0	0	0	0	0	0	0	0
Frenchman	704	2577	703	0	-15	0	73757	75617	73733	11	23	11	24	1872	0	3707	0	-3728
North Fork	12621	12625	12621	20	29	21	936	941	936	0	0	0	0	0	0	16	0	-16
Above Swanson	3337	-2375	-3333	30	160	34	10164	11154	10167	0	0	0		987	0	2072	0	-2071
Swanson - Harlan	0	-29	0	-419	-332	-756	35089	31746	27875	8605	12272	8605	7214	204	0	6946	0	-606
Harlan - Guide Rock		0	0	0	0	0	21878	21800	21734	175	250	176	145	0	0	160	0	16
Guide Rock - Hardy	0	0	0	268	263	268	1598	1597	1606	0	0	0	0	0	0	0	0	13
Medicine	0	0	0	0	0	0	15926	15726	15531	8864	9060	8864	394	0	0	401	0	0
Prairie Dog	0	0	0	2543	2543	2544	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	5337	5330	5325	34	41	34	14	0	0	15	0	0
Rock	34	43	34	0	0	0	2894	2902	2894	0	0	0	0	0	0	17	0	-17
Sappa	0	0	0	892	1449	883	2383	2947	2388	0	0	0	0	560	0	1120	0	-1125
South Fork	11331	11539	11334	7707	7963	7711	799	941	803	0	0	0	0	140	0	609	0	-597
Hugh Butler	0	0	0	0	0	0	1548	1548	1548	0	0	0	0	0	0	0	0	0
Bonny	1121	1121	1121	0	0	0	0	0	0	0	0	0	0	0	0		0	0
Keith Sebelius	0	0	0	404	404	404	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	3606	3606	3605	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	47	37	47	949	940	949	0	0	0	0	0	0	19	0	20
Harry Strunk	0	0	0	0	0	0	248	248	248	0	0	0	0	0	0	0	0	0
Swanson	0	0	0	0	0	0	179	176	179	0	0	0	0	0	0	0	0	0
Mainstem	3337	-2410	-3339	-120	89	-452	61729	66298	61382	8788	12525	8788	7346	1178	0	5033	0	-2648
Total	23781	26913	23780	17496	18972	17166	186266	186744	178495	17724	21677	17724	7771	4297	0	1134	0	-9237

C-07

Table 1s: 1999 (acre-feet/year)																		
Basin	$CBCU_C$			$CBCU_K$			$CBCU_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	758	790	758	423	468	423	313	324	313	0	0	0	0	12	0	88	0	-88
Beaver	0	0	0	5781	6147	5781	4779	5144	4778	0	0	0	0	366	0	729	0	-730
Buffalo	222	321	222	0	0	0	2794	2893	2794	0	0	0	0	98	0	197	0	-197
Driftwood	0	0	0	0	0	0	1171	1171	1171	[illegible]	0	0	0	0	0	0	0	0
Frenchman	997	2824	994	0	0	0	75095	76899	75068	17	33	17	28	1815	0	3598	0	-3630
North Fork	13111	13104	13111	25	21	25	915	907	915	0	0	0	0	0	0	19	0	19
Above Swanson	-736	-983	-736	324	269	322	12820	12547	12831	0	0	0	12	-277	0	567	0	577
Swanson - Harlan	0	-22	0	34	-236	-1070	49587	46049	41900	8746	12772	8746	7687	122	0	7784	0	-939
Harlan - Guide Rock	0	0	0	0	0	0	21925	21837	21756	175	262	175	169	0	0	177	0	0
Guide Rock - Hardy	0	0	0	310	309	310	1679	1680	1687	0	0	0	0	0	0	0	0	0
Medicine	0	0	0	0	0	0	15287	15239	15197	9480	9525	9480	90	0	0	98	0	0
Prairie Dog	0	0	0	2481	2480	2480	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	6345	6335	6327	33	42	33	19	0	0	21	0	0
Rock	38	47	38	0	0	0	3023	3032	3023	0	0	0	0	0	0	18	0	-19
Sappa	0	0	0	135	978	-160	1123	2246	1118	0	0	0	0	1121	0	2228	0	-2257
South Fork	12488	12684	12488	8793	9067	8788	1040	1162	1044	0	0	0	0	123	0	597	0	-597
Hugh Butler	0	0	0	0	0	0	1344	1344	1344	0	0	0	0	0	0	0	0	0
Bonny	1117	1116	1117	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	356	356	356	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	3711	3711	3710	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	43	34	44	863	854	864	0	0	0	0	0	0	17	0	19
Harry Strunk	0	0	0	0	0	0	243	249	250	0	0	0	0	0	0	0	0	0
Swanson	14	0	14	0	0	0	178	172	179	0	0	0	0	0	0	15	0	15
Mainstem	-736	-1002	-736	601	340	-437	86011	82113	78175	8932	13035	8932	7836	-164	0	8527	0	-347
Total	28010	29889	28006	18384	19884	17317	204242	203794	196269	18482	22657	18482	7973	3350	0	1245	0	-7800

Table 1t: 2000 (acre-feet/year)																		
Basin	$CBCU_C$			$CBCU_K$			$CBCU_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	1794	1823	1794	245	294	246	195	234	194	0	0	0	0	40	0	116	0	-118
Beaver	0	0	0	4650	5600	4650	3481	4432	3481	0	0	0	0	949	0	[illegible]	0	-1898
Buffalo	[illegible]	330	237	0	0	0	2907	3000	2907	0	0	0	0	93	0	188	0	-187
Driftwood	0	0	0	0	0	0	1153	1153	1153	0	0	0	0	0	0	0	0	0
Frenchman	599	2689	588	0	0	0	74874	76944	74830	0	25	0	44	2090	0	4127	0	-4187
North Fork	13288	13285	13287	23	24	22	1039	1038	1038	0	0	0	0	0	0	0	0	0
Above Swanson	-4279	-3109	-4284	148	216	146	10282	11450	10275	0	0	0	0	1172	0	2403	0	-2416
Swanson - Harlan	13	0	0	245	-51	431	30875	27220	23853	9460	12864	9460	7022	-38	0	6873	0	506
Harlan - Guide Rock	0	0	0	0	0	0	25303	25195	25093	155	261	155	210	0	0	221	0	0
Guide Rock - Hardy	[illegible]	0	0	411	407	408	1764	1762	1765	0	0	0	0	0	0	0	0	0
Medicine	0	0	0	0	0	0	15926	15699	15476	9028	9252	9028	450	0	0	454	0	0
Prairie Dog	0	0	0	1392	1392	1391	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	5178	5169	5161	31	40	31	17	0	0	19	0	0
Rock	42	52	42	0	0	0	3125	3135	3125	0	0	0	0	10	0	20	0	-21
Sappa	0	0	0	641	354	-664	766	1770	762	0	0	0	0	1002	0	1991	0	-2019
South Fork	[illegible]	9283	9336	6277	6315	6273	975	1029	970	0	0	0	0	57	0	34	0	-46
Hugh Butler		0	0	0	0	0	1600	1600	1600	0	0	0	0	0	0	0	0	0
Bonny	1170	1170	1170	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	407	407	407	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	3847	3848	3847	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	41	32	41	987	981	989	0	0	0	0	0	0	16	0	16
Harry Strunk	0	0	0	0	0	0	251	253	252	0	0	0	0	0	0	0	0	0
Swanson	12	10	11	0	0	0	219	217	218	0	0	0	0	0	0	0	0	0
Mainstem	-4260	-3104	-4293	318	573	986	68274	65627	60986	9612	13126	9612	7238	1127	0	4701	0	-190
Total	22222	25536	22170	12724	14990	13360	184749	186129	176987	18689	22473	18689	7701	5358	0	-3176	0	-10354

Table 1u: 2001 (acre-feet/year)

Basin	$CBCU_C$			$CBCU_K$			$CBCU_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	1098	1148	1097	320	370	320	340	382	339	0	0	0	0	42	0	143	0	-143
Beaver	0	0	0	3645	5081	3645	2988	4423	2986	0	0	0	0	1436	0	2870	0	-2871
Buffalo	250	326	250	0	0	0	3094	3170	3094	0	0	0	0	76	0	151	0	-152
Driftwood	0	0	0	0	0	0	1221	1221	1221	0	0	0	0	0	0	0	0	0
Frenchman	559	2734	554	0	0	0	78272	80437	78229	0	23	0	43	2186	0	4316	0	-4368
North Fork	13656	13654	13655	23	29	23	1548	1552	1546	0	0	0	0	0	0	0	0	0
Above Swanson	4192	-2801	-4189	118	154	-119	11698	13124	11701	0	0	0	0	1427	0	-3094	0	-3089
Swanson - Harlan	0	11	0	143	-84	-672	41297	37473	33266	8833	12983	8839	[illegible]	63	0	[illegible]	0	-663
Harlan - Guide Rock	0	0	0	0	0	0	24310	24201	24089	170	281	170	221	0	0	220	0	0
Guide Rock - Hardy	0	0	0	217	216	218	1832	1836	1837	0	0	0	0	0	0	0	0	0
Medicine	0	0	0	0	0	0	17330	17137	16944	9303	9495	9303	386	0	0	385	0	0
Prairie Dog	0	0	0	3028	3027	3027	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	6173	6162	6150	29	41	29	23	0	0	24	0	0
Rock	46	57	46	0	0	0	3216	3227	3216	0	0	0	0	11	0	22	0	-23
Sappa	0	0	0	-939	182	-969	873	2007	869	0	0	0	0	1131	0	2246	0	-2281
South Fork	[illegible]	10385	9767	7398	8296	7397	637	1114	637	0	0	0	0	479	0	[illegible]	0	-1996
Hugh Butler	0	0	0	0	0	0	1593	1593	1593	0	0	0	0	0	0	0	0	0
Bonny	1217	1217	1217	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	378	378	378	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	3995	3996	3995	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	41	32	40	826	820	827	0	0	0	0	0	0	15	0	16
Harry Strunk	0	0	0	0	0	0	262	263	263	0	0	0	0	0	0	0	0	0
Swanson	11	11	11	0	0	0	244	244	244	0	0	0	0	0	0	0	0	0
Mainstem	-4201	-2794	-4192	245	289	-570	79137	76634	70894	9009	13257	9009	8243	1493	0	5300	0	-3750
Total	22407	26735	22406	14149	17689	13299	201749	204381	193046	18355	22837	18355	8702	6853	0	-6018	0	-15571

Table 1v: 2002 (acre-feet/year)

Basin	$CBCU_C$			$CBCU_K$			$CBCU_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	261	280	261	226	257	226	349	374	349	[illegible]	0	0	[illegible]	25	0	75	0	-75
Beaver	0	0	0	1739	3768	1739	1791	3820	1791	0	0	0	0	2029	0	4057	0	-4057
Buffalo	247	310	247	0	0	0	3221	3284	3220	0	0	0	0	63	0	126	0	-126
Driftwood	0	0	0	0	0	0	1272	1272	1272	0	0	0	0	0	0	0	0	0
Frenchman	[illegible]	2795	604	0	0	0	74126	76303	74084	0	24	0	42	2198	0	4344	0	-4381
North Fork	13691	13685	13691	25	22	25	1801	1796	1801	0	0	0	0	0	0	14	0	14
Above Swanson	6193	-4424	-6195	362	236	366	10148	11934	10148	0	0	0	0	1787	0	3431	0	-3428
Swanson - Harlan	0	0	0	104	0	-219	21705	16327	10950	5425	10874	5425	10755	-72	0	1102	0	-139
Harlan - Guide Rock	0	0	0	0	0	0	26230	26121	26003	172	288	172	233	0	0	230	0	0
Guide Rock - Hardy	0	0	0	276	275	277	1611	1615	1614	0	0	0	0	0	0	0	0	0
Medicine	0	0	0	0	0	0	18405	17857	17310	8373	8920	8373	1095	0	0	1096	0	0
Prairie Dog	0	0	0	2292	2294	2292	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	5192	5180	5169	24	35	24	23	0	0	24	0	0
Rock	53	63	53	0	0	0	3297	3307	3296	0	0	0	0	11	0	21	0	-21
Sappa	0	0	0	422	85	-435	695	1206	690	0	0	0	[illegible]	511	0	1014	0	-1032
South Fork	[illegible]	9554	9561	4854	4810	4855	1259	1463	1260	0	0	0	0	204	0	[illegible]	0	-153
Hugh Butler	0	0	0	0	0	0	1746	1746	1746	0	0	0	0	0	0	0	0	0
Bonny	1268	1267	1268	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	512	512	512	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	4128	4129	4128	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	39	32	40	892	887	894	11	10	11	0	0	0	[illegible]	0	13
Harry Strunk	0	0	0	0	0	0	271	273	273	0	0	0	0	0	0	0	0	0
Swanson	0	0	0	0	0	0	283	283	283	0	0	0	0	0	0	0	0	0
Mainstem	6197	-4428	-6196	836	512	429	59699	55998	48715	5590	11152	5590	10984	1721	0	7818	0	-3572
Total	19489	23531	19489	10107	12292	9692	178423	179175	166278	14007	20150	14007	12146	6754	0	-836	0	-13397

C-07

Table 1w: 2003 (acre-feet/year)

Basin	$CBCU_C$			$CBCU_K$			$CBCU_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	125	159	125	226	284	226	502	568	502	0	0	0	0	66	0	-159	0	-159
Beaver	0	0	0	323	3021	323	727	3425	727	0	0	0	0	2698	0	5394	0	-5395
Buffalo	268	309	268	0	0	0	3332	3374	3332	0	0	0	0	41	0	-82	0	-82
Driftwood	0	0	0	0	0	0	1391	1391	1391	0	0	0	0	0	0	0	0	0
Frenchman	19	2562	21	0	0	0	81188	83704	81143	0	26	0	46	2539	0	-5028	0	-5071
North Fork	14155	14149	14154	33	29	33	1257	1248	1257	0	0	0	0	0	0	19	0	18
Above Swanson	117	-642	117	-58	75	-58	18003	17250	18005	0	0	0	0	-755	0	1379	0	1381
Swanson - Harlan	11	0	10	53	-22	0	27253	18629	10077	140	8735	140	17176	-43	0	17301	0	71
Harlan - Guide Rock	0	0	0	0	0	0	27700	27576	27449	182	307	182	251	0	0	250	0	0
Guide Rock - Hardy	0	0	0	359	357	359	2251	2256	2257	0	0	0	0	0	0	0	0	0
Medicine	0	0	0	0	0	0	19809	19574	19339	9439	9674	9439	470	0	0	470	0	0
Prairie Dog	0	0	0	1136	1137	1136	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	6055	6035	6017	20	39	20	38	0	0	39	0	0
Rock	58	69	58	0	0	0	3419	3430	3419	0	0	0	0	11	0	22	0	-22
Sappa	0	0	0	323	-173	-323	500	648	495	0	0	0	0	150	0	295	0	-300
South Fork	10842	11209	10842	5284	5833	5285	1331	1672	1331	0	0	0	0	343	0	1259	0	-1258
Hugh Butler	0	0	0	0	0	0	1758	1758	1758	0	0	0	0	0	0	0	0	0
Bonny	1326	1326	1326	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebellus	0	0	0	542	542	542	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	4436	4438	4436	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	36	31	36	882	878	884	12	11	12	0	0	0	0	0	10
Harry Strunk	0	0	0	0	0	0	412	413	413	0	0	0	0	0	0	0	0	0
Swanson	20	15	20	0	0	0	483	477	483	0	0	0	0	0	0	14	0	14
Mainstem	**120**	**-642**	**119**	**357**	**411**	**304**	**75207**	**65711**	**57789**	**315**	**9033**	**315**	**17418**	**-795**	**0**	**18921**	**0**	**1449**
Total	**26930**	**29156**	**26930**	**7625**	**11113**	**7574**	**202689**	**198745**	**184714**	**9797**	**18791**	**9797**	**17975**	**5037**	**0**	**7224**	**0**	**-10802**

Table 1x: 2004 (acre-feet/year)

Basin	$CBCU_C$			$CBCU_K$			$CBCU_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	161	166	161	311	291	311	427	405	427	0	0	0	0	-22	0	37	0	37
Beaver	0	0	0	272	3233	272	1182	4143	1182	0	0	0	0	2961	0	-5921	0	-5921
Buffalo	294	341	293	0	0	0	3327	3375	3327	0	0	0	0	48	0	-96	0	-96
Driftwood	0	0	0	0	0	0	1479	1479	1479	0	0	0	0	0	0	0	0	0
Frenchman	39	2682	39	0	0	0	85170	87801	85123	0	28	0	56	2651	0	[illegible]	0	-5289
North Fork	14501	14499	14501	31	33	31	1307	1300	1302	0	0	0	0	0	0	0	0	0
Above Swanson	-1251	-1295	-1251	166	160	167	13837	13829	13834	0	0	0	0	0	0	57	0	55
Swanson - Harlan	0	0	0	96	0	0	33892	25370	16914	613	9117	613	16377	-48	0	17112	0	43
Harlan - Guide Rock	0	0	0	0	0	0	29142	29011	28873	198	331	198	269	0	0	268	0	0
Guide Rock - Hardy	0	0	0	177	174	178	2268	2273	2270	0	0	0	0	0	0	0	0	0
Medicine	0	0	0	0	0	0	20243	19986	19728	9533	9790	9533	514	0	0	514	0	0
Prairie Dog	0	0	0	1327	1327	1327	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	6446	6429	6412	25	42	25	34	0	0	34	0	0
Rock	57	72	57	0	0	0	3581	3597	3581	0	0	0	0	15	0	30	0	-30
Sappa	0	0	0	272	-133	-272	558	694	553	0	0	0	0	138	0	271	0	-276
South Fork	11586	11839	11586	5723	5973	5724	1188	1316	1190	0	0	0	0	128	0	632	0	-629
Hugh Butler	0	0	0	0	0	0	1772	1772	1772	0	0	0	0	0	0	0	0	0
Bonny	1343	1342	1343	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	496	496	496	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	4527	4529	4527	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	34	30	35	778	775	781	15	13	15	0	0	0	0	0	0
Harry Strunk	0	0	0	0	0	0	359	361	360	0	0	0	0	0	0	0	0	0
Swanson	18	12	18	0	0	0	486	480	486	0	0	0	0	0	0	15	0	15
Mainstem	-1261	-1307	-1259	441	343	350	79139	70482	61891	806	9440	806	17247	-43	0	17435	0	98
Total	26737	29645	26738	8372	11590	8283	211974	208924	194123	10386	19319	10386	17851	5868	0	5856	0	-12082

Table 1y: 2005 (acre-feet/year)

Basin	CBCU$_C$			CBCU$_K$			CBCU$_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	632	658	632	250	266	250	245	234	245	0	0	0	0	-11	0	31	0	-31
Beaver	0	0	0	1633	3950	1633	2588	4906	2588	0	0	0	0	2318	0	-4634	0	-4634
Buffalo	309	384	309	0	0	0	3351	3426	3351	0	0	0	0	75	0	149	0	-150
Driftwood	0	0	0	0	0	0	1481	1481	1481	0	0	0	0	0	0	0	0	0
Frenchman	52	2770	38	0	0	0	78056	80761	77999	0	28	0	58	2734	0	5385	0	-5456
North Fork	14485	14479	14484	30	33	30	1303	1302	1303	0	0	0	0	0	0	0	0	0
Above Swanson	-1966	-1644	-1974	100	156	99	11005	11345	11003	0	0	0	0	342	0	717	0	-729
Swanson - Harlan	20	-21	0	53	-27	-51	39778	31914	24107	2055	9905	2055	15672	-43	0	15795	0	34
Harlan - Guide Rock	0	0	0	0	0	0	29037	28900	28763	216	351	216	274	0	0	287	0	0
Guide Rock - Hardy	11	0	0	212	205	211	2800	2801	2801	0	-11	0	0	0	0	13	0	0
Medicine	0	0	0	0	0	0	19884	19625	19365	9644	9902	9644	518	0	0	519	0	0
Prairie Dog	0	0	0	5263	5265	5264	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	6595	6581	6568	34	48	34	27	0	0	28	0	0
Rock	60	77	60	0	0	0	3745	3762	3745	0	0	0	0	17	0	-34	0	-35
Sappa	0	0	0	1540	-193	-1583	703	2069	698	0	0	0	0	1361	0	2703	0	-2751
South Fork	13755	13712	13753	7162	7091	7164	1348	1289	1349	0	0	0	0	-56	0	170	0	170
Hugh Butler	0	0	0	0	0	0	1708	1708	1708	0	0	0	0	0	0	0	0	0
Bonny	1274	1273	1274	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	510	510	510	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	4649	4650	4649	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	32	30	33	858	857	863	17	14	17	0	0	0	0	0	0
Harry Strunk	0	0	0	0	0	0	316	316	317	0	0	0	0	0	0	0	0	0
Swanson	13	0	13	0	0	0	421	415	421	0	0	0	0	0	0	10	0	10
Mainstem	1966	-1662	-1979	371	333	266	82621	74960	66675	2261	10244	2261	15937	302	0	15379	0	-687
Total	28616	31700	28585	13722	17282	13577	209873	208344	193324	11962	20248	11962	16549	6734	0	3172	0	-13553

Table 1z: 2006 (acre-feet/year)

Basin	CBCU$_C$			CBCU$_K$			CBCU$_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	1019	1047	1019	141	164	141	122	120	122	0	0	0	0	0	0	51	0	-50
Beaver	0	0	0	3127	4629	3127	3431	4933	3430	0	0	0	0	1502	0	3004	0	-3004
Buffalo	323	399	322	0	0	0	3329	3405	3328	0	0	0	0	76	0	152	0	-153
Driftwood	0	0	0	0	0	0	1422	1422	1421	0	0	0	0	0	0	0	0	0
Frenchman	35	2839	38	0	0	0	73667	76441	73612	0	31	0	55	2803	0	5549	0	-5601
North Fork	14427	14424	14427	19	17	19	1233	1230	1233	0	0	0	0	0	0	0	0	0
Above Swanson	3042	-2454	-3043	212	202	211	8945	9533	8944	0	0	0	0	589	0	1167	0	-1169
Swanson - Harlan	0	-13	0	109	-256	-1149	37549	30174	22061	2523	10421	2523	15488	215	0	15429	0	-1098
Harlan - Guide Rock	0	0	-18	0	0	0	26639	26500	26350	224	370	224	284	0	0	287	0	-16
Guide Rock - Hardy	0	0	-14	116	115	116	2341	2345	2339	13	-11	-13	0	0	0	0	0	-12
Medicine	0	0	0	0	0	0	19116	18767	18418	9405	9754	9405	698	0	0	699	0	0
Prairie Dog	0	0	0	4970	4980	4979	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	6096	6080	6063	25	42	25	35	0	0	35	0	0
Rock	63	82	63	0	0	0	3845	3864	3845	0	0	0	0	19	0	38	0	-38
Sappa	0	0	0	1828	-59	-1979	1028	2871	1023	0	28	0	0	1820	0	3584	0	-3739
South Fork	10556	10585	10555	4340	4350	4340	1023	1028	1026	0	0	0	0	0	0	41	0	-43
Hugh Butler	0	0	0	0	0	0	1647	1647	1646	0	0	0	0	0	0	0	0	0
Bonny	1263	1262	1263	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	531	531	531	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	4624	4625	4624	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	31	30	31	813	814	818	18	16	18	0	0	0	0	0	0
Harry Strunk	0	0	0	0	0	0	293	294	294	0	0	0	0	0	0	0	0	0
Swanson	14	12	14	0	0	0	373	370	373	0	0	0	0	0	0	0	0	0
Mainstem	3059	-2477	-3080	225	65	-816	75474	68551	59694	2733	10779	2733	15780	812	0	14542	0	-2295
Total	24648	28172	24623	11572	14712	10383	197536	196462	180973	12193	20654	12193	16664	7028	0	7871	0	-14907

Table 2a: Average 1981- 2000 (acre-feet/year)

Basin	$CBCU_C$			$CBCU_K$			$CBCU_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	1111	1133	1111	333	361	333	201	215	200	0	0	0	0	14	0	64	0	-65
Beaver	0	0	0	5238	5651	5238	4631	5044	4630	0	0	0	0	413	0	-824	0	-826
Buffalo	123	186	123	0	0	0	2096	2158	2095	0	0	0	0	62	0	125	0	-125
Driftwood	0	0	0	0	0	0	1076	1076	1076	0	0	0	0	0	0	0	0	0
Frenchman	661	1917	657	0	0	0	63167	64415	63145	0	0	0	21	1259	0	2488	0	-2512
North Fork	10500	10497	10499	22	23	22	578	578	578	0	0	0	0	0	0	0	0	0
Above Swanson	1755	-1442	-1755	190	210	191	9948	10268	9946	0	0	0	0	321	0	652	0	-654
Swanson - Harlan	0	-12	0	-82	-102	-230	36228	33878	31423	8169	10597	8169	4805	27	0	4808	0	-145
Harlan - Guide Rock	0	0	0	0	0	0	18101	18066	18038	128	159	128	62	0	0	69	0	0
Guide Rock - Hardy	0	0	0	257	256	257	1562	1560	1564	0	0	0	0	0	0	0	0	0
Medicine	0	0	0	0	0	0	13150	13017	12888	7976	8107	7976	262	0	0	265	0	0
Prairie Dog	0	0	0	3915	3916	3915	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	4665	4661	4659	24	27	24	0	0	0	0	0	0
Rock	19	22	19	0	0	0	2136	2140	2135	0	0	0	0	0	0	0	0	0
Sappa	0	0	0	1021	1454	1014	2210	2667	2231	0	0	0	0	435	0	869	0	-875
South Fork	9639	9722	9639	7339	7463	7339	784	858	782	0	0	0	0	76	0	282	0	-283
Hugh Butler	0	0	0	0	0	0	1232	1232	1232	0	0	0	0	0	0	0	0	0
Bonny	962	962	962	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	509	509	509	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	2797	2797	2797	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	36	32	36	821	817	821	0	0	0	0	0	0	0	0	0
Harry Strunk	0	0	0	0	0	0	194	195	195	0	0	0	0	0	0	0	0	0
Swanson	0	0	0	0	0	0	157	155	157	0	0	0	0	0	0	0	0	0
Mainstem	-1754	-1456	-1755	365	363	217	65838	63771	60971	8294	10753	8294	4866	341	0	4228	0	-786
Total	21262	22986	21261	18775	19765	18627	165752	165796	160593	16303	18908	16303	5159	2598	0	-144	0	-5461

Table 2b: Average 2001- 2006 (acre-feet/year)

Basin	$CBCU_C$			$CBCU_K$			$CBCU_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	549	576	549	246	272	246	331	347	331	0	0	0	0	16	0	70	0	-70
Beaver	0	0	0	1790	3947	1790	2118	4275	2117	0	0	0	0	2157	0	4313	0	-4314
Buffalo	282	345	282	0	0	0	3276	3339	3275	0	0	0	0	63	0	126	0	-126
Driftwood	0	0	0	0	0	0	1377	1378	1377	0	0	0	0	0	0	0	0	0
Frenchman	216	2730	216	0	0	0	78415	80908	78365	0	27	0	50	2519	0	4976	0	-5028
North Fork	14152	14148	14152	27	27	27	1407	1405	1407	0	0	0	0	0	0	0	0	0
Above Swanson	2754	-2210	-2756	110	164	111	12273	12836	12273	0	0	0	0	564	0	1162	0	-1163
Swanson - Harlan	0	0	0	[illegible]	-64	-348	33579	26648	19563	3266	10339	3266	14016	12	0	14141	0	-292
Harlan - Guide Rock	0	0	0	0	0	0	27177	27051	26921	194	321	194	256	0	0	257	0	0
Guide Rock - Hardy	0	0	0	226	224	226	2184	2188	2187	0	0	0	0	0	0	0	0	0
Medicine	0	0	0	0	0	0	19132	18824	18517	9283	9589	9283	614	0	0	614	0	0
Prairie Dog	0	0	0	3004	3005	3004	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	6093	6078	6063	26	41	26	30	0	0	31	0	0
Rock	56	70	56	0	0	0	3517	3531	3517	0	0	0	0	14	0	28	0	-28
Sappa	0	0	0	-887	-48	-927	726	1582	722	0	0	0	0	852	0	1686	0	-1730
South Fork	11011	11214	11011	5794	6059	5794	1131	1314	1132	0	0	0	0	183	0	651	0	-651
Hugh Butler	0	0	0	0	0	0	1704	1704	1704	0	0	0	0	0	0	0	0	0
Bonny	1282	1281	1282	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	495	495	495	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	4393	4394	4393	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	36	31	36	842	839	845	14	12	14	0	0	0	0	0	0
Harry Strunk	0	0	0	[illegible]	0	0	319	320	320	0	0	0	0	0	0	0	0	0
Swanson	14	11	14	0	0	0	382	378	382	0	0	0	0	0	0	0	0	0
Mainstem	-2761	-2218	-2765	413	326	0	75213	68723	60943	3452	10651	3452	14220	581	0	13233	0	-1 59
Total	24805	28156	24795	10925	14113	10468	200374	199338	185409	12784	20333	12784	14964	6379	0	2045	0	-13385

Table 2c: Average 1981- 2006 (acre-feet/year)

Basin	$CBCU_C$			$CBCU_K$			$CBCU_N$			IWS			NE Residual			Basin Residual		
	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet	RRCA	Jan09	NEnet
Arikaree	981	1005	981	313	341	313	231	246	230	0	0	0	0	15	0	-65	0	-66
Beaver	0	0	0	4442	5258	4442	4051	4866	4050	0	0	0	0	816	0	1630	0	-1631
Buffalo	160	222	160	0	0	0	2368	2430	2368	0	0	0	0	63	0	125	0	-125
Driftwood	0	0	0	0	0	0	1146	1146	1146	0	0	0	0	0	0	0	0	0
Frenchman	558	2105	555	0	0	0	66685	68221	66658	0	14	0	28	1550	0	-3062	0	-3093
North Fork	11343	11340	11342	23	24	23	770	769	769	0	0	0	0	0	0	0	0	0
Above Swanson	-1985	-1619	-1986	172	199	172	10484	10860	10483	0	0	0	0	377	0	-770	0	-771
Swanson - Harlan	0	-11	0	-47	-93	-257	35617	32209	28686	7038	10538	7038	6931	23	0	6962	0	-179
Harlan - Guide Rock	0	0	0	0	0	0	20195	20139	20088	143	197	143	107	0	0	113	0	0
Guide Rock - Hardy	0	0	0	250	248	250	1705	1705	1708	0	0	0	0	0	0	0	0	0
Medicine	0	0	0	0	0	0	14530	14358	14187	8278	8449	8278	343	0	0	346	0	0
Prairie Dog	0	0	0	3705	3705	3705	0	0	0	0	0	0	0	0	0	0	0	0
Red Willow	0	0	0	0	0	0	4995	4988	4983	24	30	24	12	0	0	13	0	0
Rock	27	33	27	0	0	0	2454	2461	2454	0	0	0	0	0	0	-12	0	-13
Sappa	0	0	0	580	1107	566	1883	2417	1883	0	0	0	0	531	0	-1050	0	-1072
South Fork	9956	10067	9955	6982	7139	6983	864	963	863	0	0	0	0	101	0	-367	0	-368
Hugh Butler	0	0	0	0	0	0	1341	1341	1341	0	0	0	0	0	0	0	0	0
Bonny	1036	1036	1036	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keith Sebelius	0	0	0	506	506	506	0	0	0	0	0	0	0	0	0	0	0	0
Enders	0	0	0	0	0	0	3165	3166	3165	0	0	0	0	0	0	0	0	0
Harlan	0	0	0	36	32	36	825	822	826	0	0	0	0	0	0	0	0	0
Harry Strunk	0	0	0	0	0	0	223	223	224	0	0	0	0	0	0	0	0	0
Swanson	0	0	0	0	0	0	209	206	209	0	0	0	0	0	0	0	0	0
Mainstem	-1986	-1632	-1988	376	354	166	68001	64914	60965	7177	10729	7177	7036	397	0	6306	0	-942
Total	22083	24179	22076	16967	18461	16744	173742	173536	166320	15491	19237	15491	7421	3470	0	361	0	-7290

EXHIBIT C

Attachment 1

Calculation of Computed Beneficial Consumptive Use And Imported Water Supply Using the RRCA Ground Water Model

Nebraska Department of Natural Resources

The state of Nebraska has determined that methods used to calculate Computed Beneficial Consumptive Use (***CBCU***) of water in the Nebraska portion of the Republican Basin have overstated the consumptive use. Imported Water Supply has been incorrectly included as part of the Virgin Water Supply. Therefore, Imported Water Supply has been incorrectly included as part of the ***CBCU***. This incorrect calculation has overstated Nebraska's consumptive use of water in the Republican Basin by approximately 7,000 acre-feet per year.

INTRODUCTION

The Beneficial Consumptive Use of Imported Water Supply is discussed in Section IV.F. of the Republican River *Final Settlement Stipulation,* dated December 15, 2002:

> *Beneficial Consumptive Use of Imported Water Supply shall not count as Computed Beneficial Consumptive Use or Virgin Water Supply. Credit shall be given for any remaining Imported Water Supply that is reflected in increased stream flow, except as provided in Subsection V.B. Determinations of Beneficial Consumptive Use from Imported Water Supply (whether determined expressly or by implication), and any Imported Water Supply Credit shall be calculated in accordance with the RRCA Accounting Procedures and by using the RRCA Groundwater Model.*

The calculations, as they have been incorporated in the past, are written into the Final Settlement Stipulations, Appendix C, Section III, primarily in Subsections A, B, and D. Imported water that makes its way to a stream gage may be counted as a credit. During a Water Short Year this credit must meet the requirements of Section V.B.2.b:

> *Nebraska may offset any Computed Beneficial Consumptive Use in excess of its Allocation that is derived from sources above Guide Rock with Imported Water Supply Credit. If Nebraska chooses to exercise its option to offset with Imported Water Supply Credit, Nebraska will receive credit only for Imported Water Supply that: (1) produces water above Harlan County Lake; (2) produces water below Harlan County Lake and above Guide Rock that can be diverted during the Bostwick irrigation season; (3) produces water that can be stored and is needed to fill Lovewell Reservoir; or (4) Kansas and Nebraska will explore crediting water that is otherwise useable by Kansas.*

VARIABLE DESCRIPTIONS

The acronyms or variables are used in this paper are described in Table 2. For the purpose of this paper, flood flows and the change in storage in Federal reservoirs are ignored; therefore the Computed Water Supply is the same as the Virgin Water Supply.

Table 2. Variable Names.

Variable	Description
V	Virgin Water Supply: The Water Supply within the Basin undepleted by the activities of man. $V = VWS = V_{GAGE} + V_{CONSUMED}$
V_{GAGE}	Amount of base flow at the gaged accounting points that may be attributed to V.
$V_{CONSUMED}$	Amount of V that is depleted by Ground Water Pumping.
I	Imported Water Supply: The water supply imported by a State from outside the Basin resulting from the activities of man. $I = I_{GAGE} + I_{CONSUMED}$
I_{GAGE}	Amount of base flow at the gaged accounting points that may be attributed to I. $I_{GAGE} = IWS =$ Imported Water Supply Credit in Appendix C
$I_{CONSUMED}$	Amount of I that is consumed by ground water pumping.
T	Total Water Supply from ground water. $T = T_{GAGE} + T_{CONSUMED}$ And $T = V + I$
T_{GAGE}	Total base flow at the gaged accounting points.
$T_{CONSUMED}$	Total depletions to stream flow due to ground water pumping.

EXAMPLE CALCULATIONS

In order to demonstrate how the Mound Credit should be applied, the following example will use the values shown in Table 3. (These values are not related to actual values from any one year.) The values shown would be in units of thousands of acre-feet (kAF).

Table 3. Values Used In Example Calculations.

Variable	Value
$V = V_{GAGE} + V_{CONSUMED}$	280
V_{GAGE}	130
$V_{CONSUMED}$	150
$I = I_{GAGE} + I_{CONSUMED}$	70
$I_{GAGE} = IWS$	20
$I_{CONSUMED}$	50
$T = V + I = T_{GAGE} + T_{CONSUMED}$	350
$T_{CONSUMED}$	200
$T_{GAGE} = V_{GAGE} + I_{GAGE}$	150

The Republican River Compact Administration (RRCA) Groundwater Model is used to calculate the ground water base flows at key stream gages for each basin by comparing three model runs as shown in Table 4. The calculations are specified in Appendix C, Section III of the settlement.

Table 4. Current Model Calculations.

Run Name	Imported Water (Mound)	Ground Water Pumping	Measured or Calculated Stream Flow	Calculation and Result
Base Run	On	On	150	$T_{GAGE} = V_{GAGE} + I_{GAGE}$ $= 130 + 20 = 150$
No NE Import	Off	On	130	V_{GAGE}
No State Pumping	On	Off	350	$T = V_{GAGE} + I_{GAGE} + T_{CONSUMED}$ $= 130 + 20 + 200$

Correct Calculation of *IWS*. The first scenario, Mound On|Pumping On, is referred to as the *Base Run* in Appendix C. The ground water base flow from the second run is subtracted from the Base Run to calculate the Imported Water Supply Credit (Section C.III.A.3).

$$
\begin{aligned}
I_{GAGE} &= IWS \\
&= \text{[Mound On|Pumping On]} - \text{[Mound Off|Pumping On]} \\
&= T_{GAGE} - V_{GAGE} \\
&= 150 - 130 = 20
\end{aligned}
$$

This calculation is correct; it is consistent with the wording of the FSS.

Incorrect Calculation of *CBCU*. As currently defined in Appendix C, the Base Run is subtracted from the third run in order to calculate the ***CBCU*** of ground water (Section C.III.D.1):

$$
\begin{aligned}
CBCU &= \text{[Mound On|Pumping Off]} - \text{[Mound On|Pumping On]} \\
&= T - T_{GAGE} \\
&= T_{CONSUMED} \\
&= 350 - 150 = 200
\end{aligned}
$$

This formula is incorrect because it calculates the total impact of pumping on stream flow, which includes the consumptive use of the Imported Water Supply. Instead, according to the FSS, the ***CBCU*** should consist only of Virgin Water Supply depleted by pumping. Therefore the ***CBCU*** calculation should result in $V_{CONSUMED}$, the amount of Virgin Water Supply depleted by wells, which in this example = 150.

This incorrectly-defined ***CBCU*** is then used to calculate *V*, the Virgin Water Supply.

Correct Calculation of *CBCU*. Instead of starting with calculating CBCU as described above, and subsequently calculating V, we should instead start by calculating V directly from a single model run. This more direct way to calculate *V* is to run the ground water model with the fourth option not specified in Appendix C: remove the impact of activities of man by turning all the ground water pumping off and the mound recharge off, as shown in Table 5:

Table 5. Direct Calculation of Virgin Water Supply Using the Ground Water Model.

Imported Water (Mound)	Ground Water Pumping	Calculated Stream Flow	Calculation
Off	Off	280	$V = VWS$ $= V_{GAGE} + V_{CONSUMED}$ $= 130 + 150 = 280$

The result from the [Mound Off|Pumping Off] model run is the total amount of *V* in the basin. To arrive at the correct ***CBCU,*** which is defined in the Stipulations as derived entirely from ***VWS,*** we need to subtract the I_{CREDIT}, or that portion from the ground water mound that goes to the stream, from the (total) Imported Water Supply to arrive at the amount of ***I*** that is being consumed by wells in the basin. This number must then be subtracted from the total depletion from pumping to arrive at the ***CBCU,*** or $V_{CONSUMED}$, the depletion from the Virgin Water Supply.

Alternatively, we can calculate ***CBCU*** by subtracting the Virgin Water Supply at the gage from the modeled total Virgin Water Supply:

$$
\begin{aligned}
CBCU &= V_{CONSUMED} \\
&= V - V_{GAGE} \\
&= \text{[Mound Off|Pumping Off]} - \text{[Mound Off|Pumping On]} \\
&= 280 - 130 = 150
\end{aligned}
$$

Using the correct method to calculate CBCU, the basic formula for calculating the Virgin Water Supply (which uses gage measurements rather than modeled base flows at the gages) remains correct:

$$
\begin{aligned}
V &= VWS \\
&= \text{Gage} + \text{All } \boldsymbol{CBCU} - \boldsymbol{IWS} \\
&= T_{GAGE} + V_{CONSUMED} - I_{GAGE} \\
&= 150 + 150 - 20 = 280
\end{aligned}
$$

SUMMARY

The RRCA Accounting Procedures need to be revised as suggested in this document, so that they conform to the letter and spirit of the Final Settlement Stipulations. A State that imports water and uses it in the Republican Basin should not have that use charged as if it were Computed Beneficial Consumptive Use derived from the Virgin Water Supply of the basin.

EXHIBIT D

Q Okay. The so-called 16-run proposal that's in Dr. Schneider's report is not the first proposal Nebraska developed to address its concerns about the imported water supply, is it?

A No, I don't think so.

Q Do you happen to recall the original proposal that Nebraska presented?

A Not off the top of my head, no.

Q I have a few documents. Hopefully I can refresh your recollection here.

I believe this is a copy of an engineering committee report. Does this look familiar to you in any regard?

MR. DRAPER: Are you marking this as an exhibit, Tom?

MR. WILMOTH: If he --

MR. DRAPER: Not yet?

MR. WILMOTH: -- can identify it, yeah.

A So the question was, does this look familiar to me?

Q (BY MR. WILMOTH) Yes. Do you typically keep --

A Not exactly.

Q Do you participate on the engineering committee?

A No, I don't.
Q You don't? Okay.
I'd like to direct your attention here to the second page, bottom paragraph. Could you just read that paragraph for me? We don't need to read it out loud.
A This is the one, little "iii" there?
Q Yes, sir. "On June 20, 2007."
(A pause occurred in the proceedings.)
Q (BY MR. WILMOTH) Understanding that you haven't seen this document, does the event referenced in that paragraph ring any bells for you?
A I do recall some time ago that there was one, or maybe more than one, proposal that we had reviewed, and I suspect this may have been one of them.
MR. WILMOTH: Now we'll go ahead and mark that as Exhibit 3.
Q (BY MR. WILMOTH) There's a reference in that paragraph to a document, which I will give you now and ask if you have seen this document, by chance.
(Deposition Exhibit 3 was marked.)
A Yes, I think I have seen this document.
Q (BY MR. WILMOTH) Could you just generally describe your understanding of this document, what it is and when you first laid eyes on it?

MR. DRAPER: Did you mark this one as an exhibit, Tom?

MR. WILMOTH: Yes. Let's go ahead and mark that Exhibit 4, please.

(Deposition Exhibit 4 was marked.)

A My recollection -- this is from some time ago -- that this was a description of one of the proposals at that time. That's about all I remember about it.

Q (BY MR. WILMOTH) Do you recall evaluating that proposal for Kansas or working with the Kansas team to do so?

A I do recall working with the Kansas team evaluating different proposals.

Q Do you recall working on that particular proposal?

A I believe so, yes.

Q And do you recall developing a response to that proposal?

A Vaguely.

Q Do you recall what the Kansas response was?

A Not off the top of my head, no.

Q Mr. Larson, do you believe the current accounting procedures include imported water supply as part of the virgin water supply?

A My -- are you asking, do they include the imported water supply credit as part of --

Q Do they include imported water as part of the virgin water supply?

A My understanding is that imported water supply credit is deducted or subtracted somehow in the calculation process of estimating the computed water supply or whatever. That's my understanding. It's deducted from the gage flow, is my understanding.

Q So is your answer no, that the accounting procedures do not include imported water as part of the virgin water supply?

A My understanding is that imported water supply credit is deducted from the gage flows as part of the process of estimating the water supply.

Q And how do the gage flows relate to the virgin water supply?

A Gage flows are among the components that are used to calculate the water supply.

Q So do you know whether the imported water supply is included as part of the virgin water supply?

A Well, I'm not an expert on the accounting process. My understanding is that it's subtracted from the gage flows.

Q Do you know whether the current procedures include imported water as part of Nebraska's CBCU, computed beneficial consumptive use?

A Well, like I said, my understanding is that the imported water supply credit is deducted from the gage flows.

Q So you're not sure?

A Well, that's the extent of my understanding.

Q Okay. Let me turn you to the top of page 4 of Exhibit 4?

A Is 4 this Attachment 1?

Q Yes. There are some figures there, and then there's a paragraph that reads, "This formula is incorrect . . ."

Do you see that paragraph?

A Yes.

Q I'd like you to read that paragraph and set aside, for purposes of this question, characterizations of correctness or incorrectness. But as a factual matter, do you agree with the statements made in that paragraph; in particular, the first sentence?

A I don't know if I can agree or disagree just based on what I've read here.

Q Okay. Do you recall preparing any formal response to that proposal?

A I do recall participating in the preparation of a response. I'm not exactly sure if it was this proposal or not.

Q Was a meeting held perhaps in September of '07 of the RRCA engineering committee to address this issue?

A I don't know.

Q I'm going to hand you a couple of documents here. One is an email transmitting another document and just ask if this refreshes your recollection at all. This will be Exhibit 5, collectively Exhibit 5.

(Deposition Exhibit 5 was marked.)

A Refresh my recollection about what? About the --

Q (BY MR. WILMOTH) Does this refresh your recollection as to whether Kansas ever provided a written response to the proposal I gave you earlier?

A Well, it doesn't exactly refresh my recollection, but I do recall participating in the preparation of a response. I don't know exactly how it was transmitted, although this suggests it was transmitted by email.

Q Is the document there, entitled "Kansas' Review of Nebraska's Request for Change in Accounting Procedures" the response you recall?

Exhibit
3
Patterson Reporting & Video
Larson 4/9/12

Republican River Compact Administration
Engineering Committee Report
August 15, 2007

Assignments

At the 2006 annual meeting of the Republican River Compact Administration, the Commissioners assigned the Engineering Committee the following tasks:

1. Complete the user's manual for accounting procedures and provide a resolution for its adoption.
2. Complete the accounting for 2006 using the preliminary information provided by April 15, 2007 and the final exchange by July 15, 2007.
3. Continue to work to resolve different recharge and return flow methods.
4. By November 15, 2006, develop a resolution regarding the Harlan County Lake evaporation split when only one state takes a release.
5. Add documentation requirements of acreage retirement to the user's manual.
6. Retain Principia Mathematica to perform maintenance of the groundwater model.

Work activities related to these assignments

The Engineering Committee and technical representatives from the States of Colorado, Kansas, and Nebraska participated in numerous collaborative work activities and phone conferences as well as a face-to-face meeting on July 31, 2007. The following assignments and work activities were completed:

1. **Complete the user's manual for accounting procedures and provide a resolution for its adoption** - An initial draft of the users' manual was developed by Kansas' committee representatives in 2005. The draft consists of chapters on: 1) data sources, 2) data processing including the spreadsheets used by the committee, and 3) accounting results. As the committee envisions it, the user's manual will not repeat the accounting procedures nor the content of the groundwater model documentation which includes procedures used by each state to assemble its data for the groundwater model.

   The accounting spreadsheet includes an input page which is a listing of all the data used in the subsequent computations. Besides the model outputs, each input cell is the responsibility of one of the states, with the state of Nebraska compiling much of the federal data. The Engineering Committee representatives agreed that each state will develop documentation for the data it inputs into the spreadsheet noting where the data is obtained and how the data is processed prior to input into the spreadsheet.

   The assignment was not completed. Each state developed an outline of its data which was shared with the other states. The assignment should be continued next year.

2. **Complete the accounting for 2006 using the preliminary information provided by April 15, 2007 and the final exchange by July 15, 2007.**

a. As per the settlement's requirements, each state exchanged it model data sets and supporting data and other accounting data by April 15 or shortly thereafter. A preliminary run of the RRCA groundwater model was developed by Willem Schreuder and posted on the RRCA web site he maintains for the Administration.
b. The states exchanged final model data sets and supporting data by July 15 or shortly thereafter. On August 9, Colorado reported that it had discovered a minor error in its data and as a result, Willem did an updated run which is considered final by the Engineering Committee. Willem posted the updated run on the RRCA web site and has created CD's of this final run for each of the States.
c. Nebraska reported that in 2006 its computations relied on meter data collected by the Republican River basin Natural Resources Districts. Power data was used only outside of the Republican River boundary. New methods had to be employed to use the power records where part of the power service area was estimated using meter data and part using power data.
d. Final data sets were collected by the Committee for streamflow, climatological information, diversion records, and reservoir evaporation records of the three states and in cooperation with the U.S. Geological Survey, U.S. Bureau of Reclamation, and U.S. Army Corps of Engineers for 2006.
e. The 2006 model input and accounting data is considered final. The accounting of the virgin water supply, the computed water supply, and the beneficial consumptive uses in the Republican River Basin was not completed due to dispute regarding following matters:

    i. Non-federal reservoir evaporation below Harlan County Lake. Nebraska has noted that Section VI.A. of the Final Settlement Stipulation prescribes that only non-federal reservoir evaporation above Harlan County Lake should be included in the annual accounting. Kansas disagrees and believes non-federal reservoir evaporation should be included for the entire basin. At last year's annual meeting the matter was referred to a legal committee created to resolve the issue. The matter is still unresolved.
    ii. Division of Evaporative Loss from Harlan County Lake when only one state utilizes reservoir storage for irrigation. Kansas believes that the FSS and currently approved accounting procedures did not anticipate this condition and therefore do not provide clear and fair guidance on this split in this case. Nebraska believes that the current accounting methods clearly take into account the situation where only one state utilizes reservoir storage for irrigation. Last year the Administration asked the Engineering Committee to seek a resolution to the matter prior to November 15, 2006. Consensus had not been reached. See the discussion below for the States' positions.
    iii. On June 20, 2007, Nebraska provided the Engineering Committee with a proposed change in the accounting procedures and attached paper titled *Calculation of Computed Beneficial Consumptive Use and Imported Water Supply Using the RRCA Ground Water Model,* which provided the rationale for the proposed change. While Nebraska believes that the current method of model runs properly calculates the mound credit, it

believes it improperly includes, in its consumptive use computation, some consumption of the imported water.

The Committee was not able to reach consensus on these three matters.

3. **Continue to work to resolve different recharge and return flow methods** – Kansas continues to believe that with the limitations placed on irrigation diversions in Nebraska in recent years, continued use of an irrigation efficiency of 80% applied to all diversions in Nebraska results in an overestimation of irrigation recharge. While the Engineering Committee had discussion on this matter, little effort was given to the assignment. The Engineering Committee further recommends continuing this assignment.

4. **By November 15, 2006, develop a resolution regarding the Harlan County Lake evaporation split when only one state takes a release.** – Kansas offered a proposal by the November 15, 2006 deadline set by the Administration for resolution of the matter.

   The Committee has not yet reached agreement.

5. **Add documentation requirements of acreage retirement to the user's manual.** Both Colorado and Nebraska reported significant reduction in irrigation acreage estimate via either field work or retirement of acreage associated with incentive-based programs. Kansas has also had some limited retirements using such programs. Nebraska and Kansas have provided documentation to the other states as either GIS coverage (preferred) or a listing of legal tracts. The Kansas and Nebraska data is provided in sufficient detail to provide an opportunity for any state to determine compliance. Colorado is also working to collect and tabulate its data. This data could be exchanged annually and the requirement should be added to the accounting procedures.

6. **Retain Principia Mathematica to perform maintenance of the groundwater model.** Each state separately contracted with Principia Mathematica for the groundwater model services.

Other discussions

In the course of the Engineering Committee's work, it was discovered that Table 5B does not allow Kansas to use 51.1% of any unused portion of Colorado's allocations as per Settlement Stipulation in the water-short year test. The Engineering Committee recommends that this change be made in the accounting spreadsheet.

Recommended assignments for the coming year

The Engineering Committee recommends the Republican River Compact Administration assign the following tasks to be completed by the indicated dates:

1. Finalize work on a user's manual for the RRCA Accounting Procedures and provide a recommendation to the Administration for adoption at next year's annual meeting.

2. Exchange by April 15, 2008 the information listed in Section V of the Accounting Procedures and Reporting Requirements, all data required by the Republican River Compact accounting procedure, and use these data to complete the preliminary accounting of the virgin water supply, the computed water supply, and the beneficial consumptive uses in the Basin for the calendar year 2007. By July 15, 2008 exchange any updates to this data to complete the final accounting of the virgin water supply, the computed water supply, and the beneficial consumptive uses in the Basin for the calendar year 2007.

3. Continue efforts to resolve concerns related to varying methods of estimating ground and surface water irrigation recharge and return flows within the Republican River Basin and related issues.

4. Retain Principia Mathematica to perform on-going maintenance of the ground water and periodic updates requested by members of the Engineering Committee for calendar year 2007. The billable costs shall be limited to actual costs incurred, not to exceed $12,000.00 in total and will be apportioned in equal 1/3 amounts to the States of Colorado, Kansas, and Nebraska respectively.

The Engineering Committee requests the Administration determine steps to resolve accounting disputes noted above.

The Engineering Committee Report will be posted on the web at www.republicanrivercompact.org.

Attachment

Input page from the accounting spreadsheet

____
David W. Barfield
Engineer Committee Member for Kansas

____
Megan Sullivan
Engineer Committee Member for Colorado

____
James R. Williams
Engineer Committee Member for Nebraska

Exhibit 510
4
Patterson Reporting & Video
Larson 4/9/12

Attachment 1

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$V_{CONSUMED}$	Amount of V that is depleted by Ground Water Pumping.
I	Imported Water Supply: The water supply imported by a State from outside the Basin resulting from the activities of man. $I = I_{GAGE} + I_{CONSUMED}$
I_{GAGE}	Amount of base flow at the gaged accounting points that may be attributed to I. $I_{GAGE} = IWS =$ Imported Water Supply Credit in Appendix C
$I_{CONSUMED}$	Amount of I that is consumed by ground water pumping.
T	Total Water Supply from ground water. $T = T_{GAGE} + T_{CONSUMED}$ And $T = V + I$
T_{GAGE}	Total base flow at the gaged accounting points.
$T_{CONSUMED}$	Total depletions to stream flow due to ground water pumping.

EXAMPLE CALCULATIONS

In order to demonstrate how the Mound Credit should be applied, the following example will use the values shown in Table 3. (These values are not related to actual values from any one year.) The values shown would be in units of thousands of acre-feet (kAF).

Table 3. Values Used In Example Calculations.

Variable	Value
$V = V_{GAGE} + V_{CONSUMED}$	280
V_{GAGE}	130
$V_{CONSUMED}$	150
$I = I_{GAGE} + I_{CONSUMED}$	70
$I_{GAGE} = IWS$	20
$I_{CONSUMED}$	50
$T = V + I = T_{GAGE} + T_{CONSUMED}$	350
$T_{CONSUMED}$	200
$T_{GAGE} = V_{GAGE} + I_{GAGE}$	150

The Republican River Compact Administration (RRCA) Groundwater Model is used to calculate the ground water base flows at key stream gages for each basin by comparing three model runs as shown in Table 4. The calculations are specified in Appendix C, Section III of the settlement.

Table 4. Current Model Calculations.

Run Name	Imported Water (Mound)	Ground Water Pumping	Measured or Calculated Stream Flow	Calculation and Result
Base Run	On	On	150	$T_{GAGE} = V_{GAGE} + I_{GAGE}$ $= 130 + 20 = 150$
No NE Import	Off	On	130	V_{GAGE}
No State Pumping	On	Off	350	$T = V_{GAGE} + I_{GAGE} + T_{CONSUMED}$ $= 130 + 20 + 200$

Correct Calculation of *IWS*. The first scenario, Mound On|Pumping On, is referred to as the *Base Run* in Appendix C. The ground water base flow from the second run is subtracted from the Base Run to calculate the Imported Water Supply Credit (Section C.III.A.3).

$$\begin{aligned} I_{GAGE} &= IWS \\ &= [\text{Mound On}|\text{Pumping On}] - [\text{Mound Off}|\text{Pumping On}] \\ &= T_{GAGE} - V_{GAGE} \\ &= 150 - 130 = 20 \end{aligned}$$

This calculation is correct; it is consistent with the wording of the FSS.

Incorrect Calculation of *CBCU*. As currently defined in Appendix C, the Base Run is subtracted from the third run in order to calculate the ***CBCU*** of ground water (Section C.III.D.1):

$$
\begin{aligned}
\boldsymbol{CBCU} &= \text{[Mound On|Pumping Off]} - \text{[Mound On|Pumping On]} \\
&= T - T_{GAGE} \\
&= T_{CONSUMED} \\
&= 350 - 150 = 200
\end{aligned}
$$

This formula is incorrect because it calculates the total impact of pumping on stream flow, which includes the consumptive use of the Imported Water Supply. Instead, according to the FSS, the ***CBCU*** should consist only of Virgin Water Supply depleted by pumping. Therefore the ***CBCU*** calculation should result in $V_{CONSUMED}$, the amount of Virgin Water Supply depleted by wells, which in this example = 150.

This incorrectly-defined ***CBCU*** is then used to calculate ***V***, the Virgin Water Supply.

Correct Calculation of *CBCU*. Instead of starting with calculating CBCU as described above, and subsequently calculating V, we should instead start by calculating V directly from a single model run. This more direct way to calculate ***V*** is to run the ground water model with the fourth option not specified in Appendix C: remove the impact of activities of man by turning all the ground water pumping off and the mound recharge off, as shown in Table 5:

Table 5. Direct Calculation of Virgin Water Supply Using the Ground Water Model.

Imported Water (Mound)	Ground Water Pumping	Calculated Stream Flow	Calculation
Off	Off	280	$V = VWS$ $= V_{GAGE} + V_{CONSUMED}$ $= 130 + 150 = 280$

The result from the [Mound Off|Pumping Off] model run is the total amount of ***V*** in the basin. To arrive at the correct ***CBCU,*** which is defined in the Stipulations as derived entirely from ***VWS,*** we need to subtract the I_{CREDIT}, or that portion from the ground water mound that goes to the stream, from the (total) Imported Water Supply to arrive at the amount of ***I*** that is being consumed by wells in the basin. This number must then be subtracted from the total depletion from pumping to arrive at the ***CBCU,*** or $V_{CONSUMED}$, the depletion from the Virgin Water Supply.

Alternatively, we can calculate ***CBCU*** by subtracting the Virgin Water Supply at the gage from the modeled total Virgin Water Supply:

$$CBCU = V_{CONSUMED}$$
$$= V - V_{GAGE}$$
$$= \text{[Mound Off|Pumping Off]} - \text{[Mound Off|Pumping On]}$$
$$= 280 - 130 = 150$$

Using the correct method to calculate CBCU, the basic formula for calculating the Virgin Water Supply (which uses gage measurements rather than modeled base flows at the gages) remains correct:

$$V = VWS$$
$$= \text{Gage} + \text{All } \boldsymbol{CBCU} - \boldsymbol{IWS}$$
$$= T_{GAGE} + V_{CONSUMED} - I_{GAGE}$$
$$= 150 + 150 - 20 = 280$$

SUMMARY

The RRCA Accounting Procedures need to be revised as suggested in this document, so that they conform to the letter and spirit of the Final Settlement Stipulations. A State that imports water and uses it in the Republican Basin should not have that use charged as if it were Computed Beneficial Consumptive Use derived from the Virgin Water Supply of the basin.

From: Barfield, Dave <DBARFIELD@KDA.STATE.KS.US>
Sent: Tuesday, September 18, 2007 10:02 AM
To: Williams, Jim <james.williams@nebraska.gov>; Sullivan, Megan <Megan.Sullivan@state.co.us>; Willem Schreuder <willem@prinmath.com>
Cc: Ann Bleed <ableed@dnr.state.ne.us>; Knox, Ken <Ken.Knox@state.co.us>; Steve Larson <slarson@sspa.com>; Austin, George <GAUSTIN@KDA.STATE.KS.US>; Dale Book <debook@spronkwater.com>; Perkins, Sam <sperkins@KDA.STATE.KS.US>; Billinger, Mark <MBILLINGER@KDA.STATE.KS.US>; Ross, Scott <SROSS@KDA.STATE.KS.US>
Subject: ***OLD ADDRESS*** RE: Nebraska proposal
Attach: Kansas Review of Nebraska Request for Change in Accounting Procedure.doc

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Jim and others,

Attached is a document that provides Kansas comments from its initial review of Nebraska proposal for our discussion on Thursday.

See you then.

David Barfield

Exhibit 5
Patterson Reporting & Video
Larson 4/9/12

Kansas' Review of Nebraska's Request for Change in Accounting Procedure
September 18, 2007

This memo is intended to summarize Kansas' understanding of the Nebraska's proposal for changing the agreed upon method of computing pumping impacts using results from the Republican River Compact Administration Groundwater Model (Model) and to summarize our initial response to the proposal.

Nebraska believes that the calculation of pumping impacts using results from the groundwater model improperly includes the consumption of imported water. Nebraska argues that because some of the water pumped by wells is or could be water that originated from imported water, the consumption of that water should not be counted in determining the virgin water supply in the accounting process. This argument is difficult to understand since no one has ever determined the specific origin of groundwater that is pumped and consumed. In other words, whether the origin of the pumped water is from natural recharge within the Republican River basin, natural recharge outside the Republican River basin, stored groundwater, or imported water has never been determined and probably cannot be determined with any degree of reliability.

In terms of the use of the Model to determine compliance with the Compact, however, the specific origin of the water that is pumped and consumed is not the determining factor. The only question with respect to the Model's result s that affect compact compliance is the extent to which activities in a state, either pumping or importation of water, affect base flow in the Republican River. To the extent these activities affect base flows in the river, they must be counted. In other words, it is not the source of water that counts, but the depletion or accretion to base flow that is associated with the activity that determines the amount of impact that must be considered in the compact accounting process. This concept is precisely what is included in the Accounting Procedures adopted by the Settlement and what the special master based his rulings on in determining that those effects to stream flows in the Republican River are regulated by the compact. As it is stated in the Final Report of the Special Master's With Certification of Adoption of Republican River Compact Administration Groundwater Model, September 2003: "*... the RRCA Groundwater Model which would, for use in the accounting formulas for administering the Republican River Compact, determine both stream flow depletions caused by groundwater pumping and streamflow accretions resulting from recharge by imported water*" (Page 1). It is clear that only quantification that is relevant to the compact accounting is the depletion or accretion to Republican River stream flow.

The quantification of depletion or accretion to Republican River base flow is not limited to activities that are solely within the boundaries of the Republican River Basin. Recharge from imported water can cause accretion to Republican River base flow even if the recharge occurs outside the boundary of the basin. To the extent that such recharge provides accretions to Republican River base flow, it is counted in the accounting process. Similarly, pumping from locations outside the basin can cause depletions to Republican River base flow. To the extent that such pumping causes depletions to base flow, it is counted in the accounting process. Thus both positive effects (accretions) and negative effects (depletions) on Republican River base flows caused by activities outside the physical boundaries of the basin are treated equally.

In order to provide this quantification using the groundwater model, it was agreed in the settlement that the impact of each state's pumping or water importation would be determined by comparing the model-computed historical base flow condition to the model-computed base flow condition without that activity. The states recognized that the sum of the impacts of these individual activities would not necessarily exactly equal the model-computed impact of all of the activities considered simultaneously. If the groundwater model were mathematically linear, it would, in fact, be the case that the sum of the individual affects would equal the affect determined by considering all of the activities simultaneously. However, because the groundwater model is mildly non-linear, this mathematical equality does not occur.

It should be noted that if the impact of all activities considered simultaneously were used, it would be necessary to have a method for apportioning the impact among the various activities. Such a process was considered unnecessary and it was agreed that the impacts from each state's activity would be computed separately in spite of the fact that the sum of those impacts may not exactly equal the impact of all activities considered simultaneously.

Nebraska has proposed an alternative method of computing the impacts associated with each state's activity. This alternative has been proposed to correct what they see as an inappropriate accounting of consumed water. While the connection between Nebraska's proposed alternative accounting method and their concept of what water is actually consumed is far from apparent, we have evaluated the merits of this alternative method regardless of its basis.

The ultimate goal of the RRCA Groundwater Model is to provide a measure of what base flows would have been if the States had not pumped groundwater or recharged imported water. That overall measure could be determined by comparing the model-computed historical stream flows to the model-computed stream flows with all pumping and recharge of imported water removed from the analysis (herein referred to as the "virgin water supply metric"). This measure gives us the total impact on stream flows caused by the States' pumping and the recharge of imported water. As described above, however, this result does not apportion the impact among the States. Conceptually, the condition with no pumping and no imported water represents what the stream flows would have been if none of this activity had occurred. In that sense, it represents a "virgin water supply" condition with respect to the modeled elements of the groundwater model and their impact on Republican River stream flows.

This measure does provide a metric for comparing the accounting method agreed to in the settlement with Nebraska's alternative accounting proposal. It is a relatively straightforward process to add up the impacts using the accounting method agreed to in the settlement or to add up the impacts from Nebraska's alternative accounting proposal and compare those totals to the virgin water supply metric described above. If the Nebraska alternative accounting proposal provides a better approximation of this metric, it is worthy of further consideration.

Our calculations, as summarized in the table below, show that the accounting agreed to in the settlement provides a better approximation of the virgin water supply metric than the Nebraska proposed accounting method. The table shows that the accounting agreed to in the settlement results in both positive and negative annual differences from the virgin water supply metric. The resultant average for the years 1990 – 2000, the last ten years of the calibration of the model is -

150 acre-feet. For the last six years, 2001-2006, the average difference is 2,053 acre-feet. The Nebraska alternative accounting proposal departs significantly further from the virgin water supply metric than the accounting method agreed to in the settlement, has a negative bias, and for the period studied is increasing.

It remains our view, based on our understanding of the agreement of the States at the time of the settlement and these results, that the current accounting methods are appropriate.

Table: Comparison of total impacts under adopted procedures and as proposed by Nebraska versus the virgin water supply metric.

Year	Virgin Water Supply Metric	Compact Method Total	Nebraska Proposed Alternative	Difference [Compact Method – Metric]	Difference [Nebraska Proposal – Metric]
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1993	213153	210926	212593	-2227	-560
1994	188954	194203	186345	5249	-2609
1995	219075	220673	213807	1598	-5268
1996	229586	228517	228167	-1069	-1419
1997	208878	212730	202992	3852	-5886
1998	210089	208778	200587	-1311	-9502
1999	230055	231109	222053	1054	-8002
2000	203222	199934	192856	-3288	-10366
2001	236771	230905	221333	-5866	-15438
2002	196546	195685	183123	-861	-13423
2003	221307	228528	210485	7221	-10822
2004	231704	237594	219651	5890	-12053
2005	237802	240969	224287	3167	-13515
2006	219356	222122	204589	2766	-14767
Averages:					
1990-2000	208198	208047	201583	-150	-6614
1990-2006	213745	214372	204758	627	-8987
2001-2006	223914	225967	210578	2053	-13336

EXHIBIT E

From: Barfield, Dave <DBARFIELD@KDA.STATE.KS.US>
Sent: Tuesday, September 18, 2007 10:02 AM
To: Williams, Jim <james.williams@nebraska.gov>; Sullivan, Megan <Megan.Sullivan@state.co.us>; Willem Schreuder <willem@prinmath.com>
Cc: Ann Bleed <ableed@dnr.state.ne.us>; Knox, Ken <Ken.Knox@state.co.us>; Steve Larson <slarson@sspa.com>; Austin, George <GAUSTIN@KDA.STATE.KS.US>; Dale Book <debook@spronkwater.com>; Perkins, Sam <sperkins@KDA.STATE.KS.US>; Billinger, Mark <MBILLINGER@KDA.STATE.KS.US>; Ross, Scott <SROSS@KDA.STATE.KS.US>
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Jim and others,

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September 18, 2007

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EXHIBIT F

No. 126, Original

In The

Supreme Court of the United States

STATE OF KANSAS,

Plaintiff,

v.

STATE OF NEBRASKA

and

STATE OF COLORADO,

Defendants.

ANSWER AND AMENDED COUNTERCLAIMS AND CROSS-CLAIM OF THE STATE OF NEBRASKA

JON C. BRUNING
Attorney General of Nebraska
DAVID D. COOKSON
Deputy Attorney General

JUSTIN D. LAVENE
Counsel of Record
Assistant Attorney General
Post Office Box 98920
Lincoln, Nebraska 68509-8920
(402) 471-2682

DONALD G. BLANKENAU
THOMAS R. WILMOTH
Special Assistant Attorneys General
BLANKENAU WILMOTH LLP
206 South 13th Street, Suite 1425
Lincoln, Nebraska 68508-2002
(402) 475-7080
Attorneys for State of Nebraska

July 25, 2011

ANSWER

The State of Nebraska ("Nebraska"), Defendant, pursuant to Case Management Order No. 1, for its answer to the Petition filed by the State of Kansas ("Kansas"), Plaintiff, states:

1. Nebraska admits the averments set forth in Paragraph 1 of the Petition.

2. Nebraska admits the averments set forth in the first sentence of Paragraph 2 of the Petition. Nebraska denies the remaining averments of Paragraph 2 of the Petition.

3. Nebraska admits the averments set forth in Paragraph 3 of the Petition.

4. Nebraska admits the averments set forth in the first sentence of Paragraph 4 of the Petition. Nebraska denies the remaining averments contained in Paragraph 4 of the Petition.

5. Nebraska admits the averments set forth in Paragraph 5 of the Petition.

6. Nebraska admits the averments set forth in Paragraph 6 of the Petition to the extent the Republican River Compact Administration ("RRCA") is composed of three commissioners, one from each state. Nebraska denies the remaining averments contained in Paragraph 6.

7. Nebraska admits the averments set forth in Paragraph 7 of the Petition to the extent that beginning in the 1980s and continuing into the 1990s, Kansas complained to the RRCA that Nebraska's increasing groundwater development was causing violations of the Compact. Nebraska denies the remaining averments contained in Paragraph 7.

8. Nebraska denies the averments contained in Paragraph 8 of the Petition.

9. Nebraska denies the averments contained in Paragraph 9 of the Petition.

10. Nebraska admits the averments contained in Paragraph 10 of the Petition.

11. Nebraska admits the averments contained in Paragraph 11 of the Petition to the extent that Kansas filed a Motion for Leave to File Bill of Complaint with the United States

Supreme Court in 1998, that the motion was granted, and that Nebraska was allowed to file a motion to dismiss. Nebraska denies the remaining averments contained in Paragraph 11.

12. Nebraska admits the averments contained in Paragraph 12 of the Petition.

13. Nebraska admits the averments contained in Paragraph 13 of the Petition.

14. Nebraska admits the averments contained in Paragraph 14 of the Petition to the extent that Colorado is also bound by the Decree. The remaining averments contained in Paragraph 14 state a legal position to which Nebraska is not required to respond.

15. Nebraska denies the averments contained in Paragraph 15 of the Petition to the extent it asserts the Final Settlement Stipulation ("FSS") resolved "many details of Compact interpretation that otherwise would likely have been the subject of litigation among the States." Nebraska admits the remaining averments of Paragraph 15.

16. Nebraska denies the averments contained in Paragraph 16 of the Petition to the extent it asserts that each and every year, Nebraska is required to comply in the same year with more than one of the tests set forth in the FSS. Nebraska admits the remaining averments contained in Paragraph 16.

17. Nebraska denies the averments contained in Paragraph 17 of the Petition.

18. Nebraska denies the averments contained in Paragraph 18 of the Petition.

19. Nebraska denies the averments as they are stated in Paragraph 19 of the Petition.

20. Nebraska denies the averments contained in Paragraph 20 of the Petition.

21. Nebraska denies the averments contained in Paragraph 21 of the Petition.

22. Nebraska denies the averments contained in Paragraph 22 of the Petition.

23. Nebraska denies the averments contained in Paragraph 23 of the Petition.

24. Nebraska denies the averments contained in Paragraph 24 of the Petition.

25. Nebraska denies the averments contained in Paragraph 25 of the Petition.

26. Nebraska denies the averments contained in Paragraph 26 of the Petition.

27. Nebraska denies the averments contained in Paragraph 27 of the Petition.

28. Nebraska admits the averments contained in Paragraph 28 of the Petition.

29. Nebraska denies any and all averments in Paragraphs 1, 2, 3, 4, 5, 6, 7, and 8 of the "Prayer" contained in the Petition.

AFFIRMATIVE DEFENSES

30. Nebraska incorporates each and every admission, denial, and averment made by Nebraska in Paragraphs 1 through 29 as thoroughly set forth herein. Nebraska asserts separately and/or alternatively, even if inconsistent, the following affirmative defenses:

FIRST AFFIRMATIVE DEFENSE (Ripeness)

31. At the conclusion of the arbitration leading to these proceedings, the Arbitrator indicated that Nebraska's dry year provisions might be inadequate to avoid a future Compact violation during prolonged drought conditions.

32. Since the arbitration was completed, Nebraska has adopted new dry year provisions and forecasting procedures.

33. The present dry year provisions and forecasting procedures will avoid a future Compact violation.

34. No violation has occurred under the present dry year provisions.

35. No future violation is presently identifiable.

36. Any allegation that such violation is likely in the future is wholly speculative.

37. Kansas' claims are barred, in whole or in part, because they are not ripe.

SECOND AFFIRMATIVE DEFENSE (Failure to Exhaust Remedies)

38. Article VII of the FSS requires that all Issues be presented to the RRCA for attempted resolution.

39. If no resolution is available, the States are required to engage in non-binding arbitration before pursuing resolution of any outstanding issue before this Court.

40. At the conclusion of the arbitration leading to these proceedings, the Arbitrator indicated that Nebraska's dry year provisions might be inadequate to avoid a future Compact violation during prolonged drought conditions.

41. After the arbitration was completed, Nebraska adopted new dry year provisions and forecasting procedures.

42. Nebraska offered to discuss these new dry year provisions with Kansas to explain how such provisions will avoid a future Compact violation.

43. Kansas has never presented any concerns about the new dry year provisions to the RRCA for attempted resolution.

44. Kansas' claims are barred, in whole or in part, by Kansas' failure to exhaust all administrative remedies as required by the FSS.

THIRD AFFIRMATIVE DEFENSE (Unclean Hands)

45. The existing Accounting Procedures employed by the RRCA fail to reflect true impacts of consumption on the River.

46. Kansas has prevented changes to the RRCA Accounting Procedures that would better reflect the true impact of consumption and better estimate the extent of Nebraska's alleged violation of the Compact.

47. Kansas has unilaterally applied an interpretation of how to account for evaporation from Harlan County Lake that is not supported by the FSS.

48. The calculations of Nebraska's overuse alleged by Kansas are artificially inflated by Kansas' continued adherence to Accounting Procedures that do not reflect the true impact of consumption on the River and its interpretation of how to account for evaporation from Harlan County Lake.

49. Kansas claims are barred, in whole or in part, by the doctrine of unclean hands.

FOURTH AFFIRMATIVE DEFENSE (Mistake)

50. An accurate calculation of Virgin Water Supply and Computed Beneficial Consumptive Use is required to achieve a scientifically sound result, supportive of the purposes of the Compact.

51. Such result is necessary to ensure each State receives the water to which it is entitled under the Compact and no more.

52. The present Accounting Procedures adopted as part of the FSS fail to calculate the true impact of consumption on the River, undermining the integrity of the Compact.

53. This failure is contrary to the understanding of, and was unforeseen to the States at the time they adopted the FSS and Accounting Procedures.

54. Kansas claims are barred, in whole or in part, by mistake.

FIFTH AFFIRMATIVE DEFENSE (Waiver/Release)

55. The States agreed to the terms of the FSS to settle outstanding claims of issues known at the time of the settlement.

56. The FSS expressly states that 2006 will be the first year in which its terms may be enforced.

57. Kansas agreed to waive its claims for damages (and to release Nebraska from the same) that might arise from overuse of allocations that might occur during the three-year period postdating the FSS.

58. During this three-year period, in reliance on the FSS, Nebraska undertook substantial reorganization of its legal and regulatory regime expressly to implement the FSS.

59. Kansas made its waiver knowing Nebraska required time to reorganize its legal and regulatory regime expressly to implement the FSS.

60. Kansas' claims for damages arising from alleged non-compliance with the FSS in 2005 are barred, in whole or in part, by waiver and/or release.

SIXTH AFFIRMATIVE DEFENSE (Intervening Acts and Omissions)

61. The State of Colorado has, for a number of years, violated the Compact and the FSS by using more water than it was allocated.

62. Colorado's actions diminished the flow of the River as it enters Nebraska.

63. The reduction of flow into the State of Nebraska affected water operations in Nebraska and resulted in a reduction in the amount of water available to Kansas.

64. Kansas' claims are barred, in whole or in part, by the intervening actions of the State of Colorado.

SEVENTH AFFIRMATIVE DEFENSE (Non-Party)

65. The State of Colorado has, for a number of years, violated the Compact and the FSS by using more water than it was allocated.

66. Colorado's actions diminished the flow of the River as it enters Nebraska.

67. The reduction of flow into the State of Nebraska affected water operations in Nebraska and resulted in a reduction in the amount of water available to Kansas.

68. The injuries or damages of which Kansas complain were caused in whole or in part by non-parties whom plaintiffs have failed to claim against in this action.

EIGHTH AFFIRMATIVE DEFENSE (Contribution)

69. The State of Colorado has, for a number of years, violated the Compact and the FSS by using more water than it was allocated.

70. Colorado's actions diminished the flow of the River as it enters Nebraska.

71. The reduction of flow into the State of Nebraska affected water operations in Nebraska and resulted in a reduction in the amount of water available to Kansas.

72. Any harm alleged can be attributed to several causes and the damages for this harm, if any, should be apportioned among the various causes according to the contribution of each cause to the harm sustained.

NINTH AFFIRMATIVE DEFENSE (Moot)

73. At the conclusion of the arbitration leading to these proceedings, the Arbitrator indicated that Nebraska's dry year provisions might be inadequate to avoid a future Compact violation during prolonged drought conditions.

74. Since the arbitration was completed, Nebraska has adopted new dry year provisions and forecasting procedures.

75. The present dry year provisions and forecasting procedures will avoid a future Compact violation.

76. The alleged threat of future non-compliance with the Compact has been removed, and Kansas cannot be injured thereby.

77. Kansas' claims are barred, in whole or in part, because they are moot.

TENTH AFFIRMATIVE DEFENSE (Failure to State Claim)

78. Kansas has failed to state a claim upon which relief may be granted.

ELEVENTH AFFIRMATIVE DEFENSE (Failure to Mitigate)

79. Kansas has failed, in whole or in part, to mitigate its alleged damages.

TWELFTH AFFIRMATIVE DEFENSE (Setoff)

80. To the extent Kansas or its individual water users have been compensated for the harm or damages alleged by Kansas from other persons or entities, the amount of any such compensation should be set off against any recovery Kansas might receive in this action.

NOTICE OF ADDITIONAL AFFIRMATIVE DEFENSES

81. Nebraska hereby gives notice that it intends to rely upon such other affirmative defenses as may become available or apparent during the course of discovery and thus reserves the right to amend its Answer to assert such defenses.

AMENDED COUNTERCLAIMS

Pursuant to FED. R. CIV. P. 8 and 13, Nebraska asserts the following counterclaims against Kansas, even if found to be alternative to or inconsistent with Nebraska's other claims or defenses in this action, stating and alleging as follows:

♦

JURISDICTION AND VENUE

1. Jurisdiction and venue are proper before this court pursuant to art. III, § 2, cl. 2 of the Constitution of the United States in conjunction with 28 U.S.C. § 1251(a) for the reason that this is a controversy between two or more states.

♦

HISTORY OF EVENTS

2. The Republican River Compact ("Compact") annually apportions the "virgin water supply" ("VWS") of the Republican River Basin among the States of Colorado, Kansas, and Nebraska.

3. Article II of the Compact defines the VWS "to be the water supply within the Basin undepleted by the activities of man." The Compact does not provide a formula or accounting procedures by which the States can determine the VWS.

4. An accurate calculation of the VWS is essential in order to achieve the purposes of the Compact and for each of the States to receive the water to which it is entitled.

5. In the late 1950s, the Republican River Compact Administration ("RRCA") was created by the States, in part, to annually calculate the VWS for apportionment purposes.

6. The RRCA issued its First Report in 1961 containing the accounting for the prior year.

7. By the time the First Report was issued, the States had unanimously agreed to an accounting procedure to determine the VWS.

8. In the late 1980s and into the 1990s, Kansas expressed dissatisfaction with the accounting procedures and proposed changes to the procedures to include the impact to streamflow resulting from the use of non-alluvial groundwater. Kansas' proposed changes were rejected by the other States.

9. In 1999, Kansas was granted leave to file its Bill of Complaint with the Supreme Court to, among other things, force the adoption of accounting procedures to include the impact to streamflow caused by non-alluvial wells.

10. Nebraska shortly thereafter filed an Answer and Counterclaims, without leave from the Court. Kansas responded with a Motion to Strike Nebraska's Counterclaims.

11. After briefing, the Supreme Court denied the Kansas Motion to Strike and referred the case to Special Master Vincent McKusick.

12. In his First Report, Special Master McKusick concluded that the meaning of VWS within the Compact required the accounting of the impacts to streamflow caused by the use of non-alluvial groundwater.

13. Special Master McKusick followed with several other rulings prompting the States to engage in settlement discussions.

14. In 2003, the States entered into the Final Settlement Stipulation ("FSS") and resolved issues remaining at that time.

15. Pursuant to the FSS, a groundwater model and accounting procedures were collaboratively developed by the States. The Accounting Procedures are attached to the FSS as Appendix C.

16. The groundwater model is a mathematical model that provides a calculation of the baseflow in the Republican River and its tributaries under conditions including or excluding groundwater use in each state and the recharge of imported water from the Platte River Basin in Nebraska.

17. The Accounting Procedures use the output from the groundwater model along with surface water data to calculate the VWS, each State's allocation, and determine their respective Beneficial Consumptive Use.

18. Like the Compact itself, a goal of the accounting established by the FSS is to estimate the total water supply and identify the true impact of consumption on the Republican River and its sub-basins.

19. As explained by Special Master McKusick in his Second Report: "To make the required determinations, the RRCA will adopt and use the Groundwater Model, which matches as closely as possible the actual effects of both alluvial and table-land groundwater pumping on stream flow in the Basin." Second Report at 37.

PRESENT CONTROVERSY

Proposed Refinement of CBCU Calculations

20. In 2006-2007, Nebraska identified a significant discrepancy in the accounting steps used for determining the "Computed Beneficial Consumptive Use" ("CBCU") for groundwater and the Imported Water Supply Credit.

21. To address the discrepancy, Nebraska developed a change to the FSS Accounting Procedures without changing the groundwater model. Nebraska presented the CBCU issue and

its proposed solution to the RRCA's Engineering Committee in 2007. Kansas' representatives on the Engineering Committee acknowledged that the existing CBCU calculation method might not reflect the true impact of consumption on the River and offered specific criticisms to Nebraska's proposed solution. Specifically, the Kansas representatives stated that Nebraska's proposal failed to meet the Virgin Water Supply Metric ("VWS Metric").

22. In response to the Kansas criticism, Nebraska next refined its solution so that it would satisfy the VWS Metric. Nebraska thereafter presented its refined solution to the RRCA for adoption into the FSS Accounting Procedures. Kansas, however, rejected Nebraska's solution without elaboration.

23. The arbitrary sequence of the current FSS Accounting Procedures provides results that violate simple mathematical principles. Nebraska's proposed solution addresses the shortcomings of the current sequence of groundwater model simulations required by the current FSS Accounting Procedures. The current FSS Accounting Procedures produce estimates of the individual impacts of the three states pumping and the Imported Water Supply and assumes the sum of these individual values represents the combined impact of these stresses. However, the combined impact of the three States' groundwater pumping and Imported Water Supply can be independently determined by comparing two model runs: one that includes all stresses on and one with all stresses off. Comparison of the results of this run with the individually derived values from the current Accounting Procedures shows that they do not equal. This test, which the current Accounting Procedures fail, is identical to the VWS Metric that Kansas previously proposed.

24. The magnitude of this discrepancy varies from year-to-year depending on climatic changes. In recent drought years it has been approximately 10,000 acre-feet per year in terms of

Nebraska's final balance in the Compact accounting. It is reasonable to expect that the magnitude of this discrepancy will equal or exceed this value in future drought years, and could average close to this value over the long-term, including drought and non-drought years.

25. Correcting this discrepancy is not always advantageous to Nebraska. However, Nebraska's proposed solution addresses the arbitrary nature of the current FSS Accounting Procedures by considering all potential methods for determining each state's impact due to pumping and Imported Water Supply Credit. The proposed method is preferable to the existing method because it more accurately reflects the impact of each state's pumping and the Imported Water Supply, ensuring a more accurate calculation of the VWS.

26. This observed discrepancy is significantly greater during years subsequent to 2000 than it was in prior years. The observed magnitude of this discrepancy in recent years count not have been anticipated at the time the FSS was signed.

27. The discrepancy must be addressed to maintain scientific and mathematical integrity and to ensure Compact entitlements are fully protected.

Kansas' View of Harlan County Lake Evaporation

28. An additional, distinct accounting dispute arose when Kansas unilaterally applied a change to the provisions of the FSS relating to the calculation of evaporation from Harlan County Lake.

29. Section IV.A.2.e.1 of Appendix C in the FSS provides: "The total annual net evaporation (Acre-feet) will be charged to Kansas and Nebraska in proportion to the annual diversions made by Kansas Bostwick Irrigation District and the Nebraska Bostwick Irrigation District during the time period each year when irrigation releases are being made from Harlan County Lake."

30. In 2006, Nebraska compensated the Nebraska Bostwick Irrigation District ("District") in exchange for the District's commitment to forgo its diversion of natural flow and its use of water stored in Harlan County Lake.

31. This transaction was completed in an effort to reduce Nebraska's consumption and comply with the Compact.

32. The water not diverted by the District was available for use by Kansas and was not consumed by the District or any other user in Nebraska.

33. Subsequently, Kansas asserted Nebraska should be charged with evaporation losses proportionate to the amount of water the District agreed to forego.

34. Kansas maintains that Nebraska's CBCU for 2006 should be increased by approximately 8,000 acre-feet as a result of the evaporation loss.

IMPACT OF THE PRESENT CONTROVERSY

35. The States' inability to agree on these two accounting issues precludes the RRCA from conducting the tasks assigned it under the Compact and the FSS.

36. Because the accounting cannot be finalized, the RRCA cannot definitively determine annual allocations or CBCU.

37. Because the accounting cannot be finalized, the RRCA cannot definitively determine whether any state has in fact complied with, or violated, any provision of the Compact or the FSS.

38. Kansas' actions continue to render the Compact and FSS functionally invalid and pose a continuing challenge to Nebraska's water management efforts.

39. Without knowing what the actual accounting is, Nebraska must manage its portion of the Basin in an overly aggressive manner to ensure against a potential Compact violation that may, or may not, occur once the accounting is eventually finalized. This

constitutes a continuing harm to the State of Nebraska, its political subdivisions, and its water users.

40. In 2008, because it was unable to determine the VWS, allocations, and compliance, Nebraska brought these accounting issues to non-binding arbitration pursuant to the FSS dispute resolution provisions provided in Article VII of the FSS.

41. The accounting issues were arbitrated to conclusion in the same proceeding as the Kansas issues that initiated this action.

FIRST CLAIM FOR RELIEF

(Breach of Compact and FSS for Failing to Account Properly For Groundwater Use)

42. Nebraska incorporates by reference the allegations in Paragraphs 1 through 41 of the Counterclaim as though fully set forth herein.

43. The current FSS Accounting Procedures do not reflect the true impact of consumption on the River.

44. Under the Compact, the States have a duty to determine the VWS, allocations, and Beneficial Consumptive Use.

45. Kansas has breached the Compact and the FSS by attempting to perpetuate Accounting Procedures that fail to account for the true impact of consumption on the River and thus improperly determine the VWS, allocations, and Beneficial Consumptive Use.

46. By refusing to make an accounting as required by the Compact, Nebraska's annual allocation has been wrongly determined or cannot be determined at all.

47. This constitutes a continuing harm to Nebraska for the reasons set forth herein.

SECOND CLAIM FOR RELIEF

(Breach of Compact and FSS for Failing to Account Properly for Evaporation from Harlan County Lake)

48. Nebraska incorporates by reference the allegation in Paragraphs 1 through 41 of the Counterclaim as though fully set forth herein.

49. Kansas has a duty to account for evaporation from Harlan County Lake as specified at § IV.A.2.e.1 of Appendix C of the FSS.

50. Kansas has refused to account for evaporation as required by the FSS and is attempting to charge Nebraska wrongly for evaporation from Harlan County Lake for 2006.

51. Kansas has breached the Compact and the FSS by attempting to perpetuate its erroneous view of § IV.A.2.e.1 of Appendix C of the FSS.

52. By refusing to make an accounting as required by § IV.A.2.e.1 of Appendix C of the FSS, Nebraska's annual allocation has been wrongly determined or cannot be determined at all.

53. This constitutes a continuing harm to Nebraska for the reasons set forth herein.

PRAYER FOR RELIEF

WHEREFORE, Nebraska respectfully prays that the Court (Special Master):

(a.) Issue an Order incorporating Nebraska's proposed change to the FSS Accounting Procedures as set forth in Exhibit "A," attached hereto and fully incorporated herein.

(b.) Issue an Order charging Kansas with total net evaporation losses from Harlan County Lake for the year 2006 and all future years in which Nebraska Bostwick Irrigation District does not divert water from Harlan County Lake.

(c.) Order such other and further relief as the Court may deem just and equitable.

(d.) Order Kansas to pay Nebraska's costs and expenses, including attorney's fees.

♦

CROSS-CLAIM

Pursuant to SUP. CT. R. 17.2, FED. R. CIV. P. 13(g) and FED. R. CIV. P. 15, Nebraska asserts the following cross-claim against Colorado, even if found to be alternative to or inconsistent with Nebraska's other claims or defenses in this action, stating and alleging as follows:

♦

JURISDICTION AND VENUE

1. Jurisdiction and venue are proper before this Court pursuant to Article III, Section 2, Clause 2 of the Constitution of the United States in conjunction with 28 U.S.C. § 1251(a) for the reason that this is a controversy between more than two States.

♦

HISTORY OF EVENTS

2. The Republican River Compact ("Compact") annually apportions the "virgin water supply" ("VWS") of the Republican River Basin among the States of Colorado, Kansas, and Nebraska (collectively the "States").

3. Article II of the Compact defines the VWS "to be the water supply within the Basin undepleted by the activities of man." The Compact does not provide a formula or accounting procedures by which the States can determine the VWS.

4. An accurate calculation of the VWS is essential in order to achieve the purposes of the Compact and for each of the States to receive the water to which it is entitled.

5. In the late 1950s, the Republican River Compact Administration ("RRCA") was created by the States, in part, to annually calculate the VWS for apportionment purposes.

6. The RRCA issued its First Report in 1961 containing the accounting for the prior year.

7. By the time the First Report was issued, the States had unanimously agreed to an accounting procedure to determine the VWS.

8. In the late 1980s and into the 1990s, Kansas expressed dissatisfaction with the accounting procedures and proposed changes to the procedures to include the impact to streamflow resulting from the use of non-alluvial groundwater. Kansas' proposed changes were rejected by Nebraska and Colorado.

9. In 1999, Kansas was granted leave to file its Bill of Complaint with the Supreme Court to, among other things, force the adoption of accounting procedures to include the impact to streamflow caused by non-alluvial wells.

10. Nebraska responded shortly thereafter with its Answer and Counterclaims which was later amended to include a cross-claim against the State of Colorado for consuming water in excess of its annual allocations as a direct result of adding non-alluvial ground water to the RRCA Accounting procedures.

11. In 2003, the States entered into the Final Settlement Stipulation ("FSS") and resolved all issues remaining at that time. Resolution of those issues included changing the Compact accounting applicable to all States, including Colorado. The Accounting Procedures are attached to the FSS as Appendix C.

12. The groundwater model is a mathematical model that provides a calculation of the baseflow in the Republican River and its tributaries under conditions including or excluding groundwater use in each state and the recharge of imported water from the Platte River Basin in Nebraska.

13. The Accounting Procedures use the output from the groundwater model along with surface water data to calculate the VWS, each State's allocation, and determine their respective Beneficial Consumptive Use.

14. Like the Compact itself, a goal of the accounting established by the FSS is to estimate the total water supply and identify the true impact of consumption on the Republican River and its sub-basins.

15. As explained by Special Master McKusick in his Second Report: "To make the required determinations, the RRCA will adopt and use the Groundwater Model, which matches as closely as possible the actual effects of both alluvial and table-land groundwater pumping on stream flow in the Basin." Second Report at 37.

PRESENT CONTROVERSY

Proposed Refinement of CBCU Calculations

16. In 2006-2007, Nebraska identified a significant discrepancy in the accounting steps used for determining the "Computed Beneficial Consumptive Use" ("CBCU") for groundwater and the Imported Water Supply Credit.

17. To address the discrepancy, Nebraska developed a change to the FSS Accounting Procedures without changing the groundwater model. Nebraska presented the CBCU issue and its proposed solution to the RRCA's Engineering Committee in 2007. Colorado's representatives on the Engineering Committee acknowledged that the existing CBCU calculation

method might not reflect the true impact of groundwater pumping and the Imported Water Supply.

18. In response to specific criticism from Kansas, Nebraska refined its solution. Nebraska thereafter presented its refined solution to the RRCA for adoption into the FSS Accounting Procedures. Colorado, however, rejected Nebraska's solution.

19. The arbitrary sequence of the current FSS Accounting Procedures provides results that violate simple mathematical principles. Nebraska's proposed solution addresses certain shortcomings of the sequence of groundwater model simulation required by the current FSS Accounting Procedures. The current FSS Accounting Procedures produce estimates of the individual impacts of the three states pumping and the Imported Water Supply and assumes the sum of these individual values represents the combined impact of these stresses. However, the combined impact of the three States' groundwater pumping and the Imported Water Supply can be independently determined by comparing two model runs: one that includes all stresses on and one with all stresses off. Comparison of the results of this run with the individually derived values from the current Accounting Procedures shows that they do not equal. This test, which the current Accounting Procedures fail, is identical to the VWS Metric that Kansas previously proposed.

20. The magnitude of this discrepancy varies from year-to-year depending on climatic changes. In recent drought years it has been approximately 10,000 acre-feet per year in terms of Nebraska's final balance in the Compact accounting. It is reasonable to expect that the magnitude of this discrepancy will equal or exceed this value in future drought years, and could average close to this value over the long-term, including drought and non-drought years.

21. Correcting this discrepancy is not always advantageous to Nebraska. However, Nebraska's proposed solution addresses the arbitrary nature of the current FSS Accounting Procedures by considering all potential methods for determining each state's impact due to pumping and Imported Water Supply Credit. The proposed method is preferable to the existing method because it more accurately reflects the impact of each state's pumping and the Imported Water Supply, ensuring a more accurate calculation of the VWS.

22. This observed discrepancy is significantly greater during years subsequent to 2000 than it was in prior years. The observed magnitude of this discrepancy in recent years could not have been anticipated at the time the FSS was signed.

23. The discrepancy must be addressed to maintain scientific and mathematical integrity and to ensure Compact entitlements are fully protected.

IMPACT OF THE PRESENT CONTROVERSY

24. The States' inability to agree on this accounting issue precludes the RRCA from conducting the tasks assigned it under the Compact and the FSS.

25. Because the accounting cannot be finalized, the RRCA cannot definitively determine annual allocations or CBCU.

26. Because the accounting cannot be finalized, the RRCA cannot definitively determine whether any state has in fact complied with, or violated, any provision of the Compact or the FSS.

27. Colorado's actions continue to render the Compact and FSS functionally invalid and pose a continuing challenge to Nebraska's water management efforts.

28. Without knowing what the actual accounting is, Nebraska must manage its portion of the Basin in an overly aggressive manner to ensure against a potential Compact

violation that may, or may not, occur once the accounting is eventually finalized. This constitutes a continuing harm to the State of Nebraska, its political subdivisions, and its water users.

29. In 2008, because it was unable to determine the VWS, allocations, and compliance, Nebraska brought these accounting issues to non-binding arbitration pursuant to the FSS dispute resolution provisions provided in Article VII of the FSS.

30. The accounting issues were arbitrated to conclusion in the same proceeding as the Kansas issues that initiated this action.

CLAIM FOR RELIEF

(Breach of Compact and FSS for Failing to Account Properly For Groundwater Use)

31. Nebraska incorporates by reference the allegations in Paragraphs 1 through 30 of the Cross-claim as though fully set forth herein.

32. The current FSS Accounting Procedures do not reflect the true impact of consumption on the River.

33. Under the Compact, the States have a duty to determine the VWS, allocations, and Beneficial Consumptive Use.

34. Colorado has breached the Compact and the FSS by attempting to perpetuate Accounting Procedures that fail to account for the true impact of consumption on the River and thus improperly determine the VWS, allocations, and Beneficial Consumptive Use.

35. By refusing to make an accounting as required by the Compact, Nebraska's annual allocation has been wrongly determined or cannot be determined at all.

36. This constitutes a continuing harm to Nebraska for the reasons set forth herein.

PRAYER FOR RELIEF

WHEREFORE, Nebraska respectfully prays that the Court (Special Master):

(a.) Issue an Order incorporating Nebraska's accounting change to the FSS Accounting Procedures as set forth in Exhibit "A," attached hereto and fully incorporated herein.

(b.) Order such other and further relief as the Court may deem just and equitable.

(c.) Order Colorado to pay Nebraska's costs and expenses, including attorney's fees.

Respectfully submitted,

STATE OF NEBRASKA,

JON C. BRUNING
Attorney General of Nebraska
DAVID D. COOKSON
Deputy Attorney General

JUSTIN D. LAVENE
Counsel of Record
Assistant Attorney General
Post Office Box 98920
Lincoln, Nebraska 68509-8920
(402) 471-2682

DONALD G. BLANKENAU
THOMAS R. WILMOTH
Special Assistant Attorneys General
BLANKENAU WILMOTH LLP
206 South 13th Street, Suite 1425
Lincoln, Nebraska 68508-2002
(402) 475-7080

Attorneys for State of Nebraska

CERTIFICATE OF SERVICE

I, Justin D. Lavene, *Counsel of Record* for the State of Nebraska in the above-captioned matter, hereby certify that I made service by causing a PDF copy of the foregoing to be sent by electronic mail on this 25th day of July, 2011, and by causing duplicate copies of the same to be sent to the following addresses by first class mail on the same date:

Hon. William J. Kayatta, Jr.
Special Master
PIERCE ATWOOD LLP
One Monument Square
Portland, ME 04101
eumland@PierceAtwood.com

John B. Draper
Counsel of Record
MONTGOMERY & ANDREWS, PA
P.O. Box 2307
Santa Fe, NM 87504-2307
jdraper@montand.com

Derek Schmidt
Attorney General
State of Kansas
120 SW 1Oth Street
Topeka, KS 66612
John.Campbell@ksag.org
Jeff.Chanay@ksag.org
Chris.Grunewald@ksag.org
Burke.Griggs@kda.ks.gov

Peter J. Ampe
Counsel of Record
First Assistant Attorney General
Autumn L. Bernhardt
Assistant Attorney General
Federal & Interstate Water Unit
Natural Resources & Environment Section
1525 Sherman Street, 7th Floor
Denver, CO 80203
peter.ampe@state.co.us
autumn.bernhardt@state.co.us

Neal Kumar Katyal
Counsel of Record
Acting Solicitor General
Department of Justice
Washington, DC 20530-0001
supremectbriefs@usdoj.gov
james.dubois@usdoj.gov

Justin D. Lavene
Counsel of Record

EXHIBIT A

III.A.3. Imported Water Supply Credit Calculation:

The amount of Imported Water Supply Credit shall be determined by the RRCA Groundwater Model. The Imported Water Supply Credit of a State shall not be included in the Virgin Water Supply and shall be counted as a credit/offset against the Computed Beneficial Consumptive Use of water allocated to that State. Currently, the Imported Water Supply Credits shall be determined using sixteen~~two~~ runs of the RRCA Groundwater Model. These runs are named using a combination of variables representing Colorado groundwater pumping and pumping recharge (C), Kansas groundwater pumping and pumping recharge (K), the surface water recharge associated with Nebraska's Imported Water Supply, or "mound" (M), and Nebraska groundwater pumping and pumping recharge (N), with the presence of the variable indicating that the stress is "on" and the absence of the variable indicating that the stress is "off". These will be the same runs used to determine groundwater Computed Beneficial Consumptive Uses, as described in Section III.D.1.

CKMN~~The "base" run~~ shall be the "base" run with all groundwater pumping, groundwater pumping recharge, and surface water recharge within the model study boundary for the current accounting

Compare to Notice of Stipulation, Ex. A, IIIA3a year turned "on." ~~This will be the same "base" run used to determine groundwater Computed Beneficial Consumptive Uses.~~

CKN~~The "no NE import" run~~ shall be the run with the same model inputs as the base run with the exception that surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

Compare to Notice of Stipulation, Ex. A, IIIA3b

KMN shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado shall be turned "off."

CMN shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Kansas shall be turned "off."

CKM shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Nebraska shall be turned "off."

CK shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Nebraska and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

CM shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Nebraska and Kansas shall be turned "off."

CN shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Kansas and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

KM shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Nebraska and Colorado shall be turned "off."

KN shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

MN shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado and Kansas shall be turned "off."

C shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Kansas and Nebraska and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

K shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado and Nebraska and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

M shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado, Kansas, and Nebraska shall be turned "off."

N shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado and Kansas and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

θ ("theta") shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado, Kansas and Nebraska and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

The Imported Water Supply Credit shall be based on the difference in stream flows between ~~these~~ eight pairs~~two~~ of model runs where the only difference between the two runs is that the surface water recharge associated with Nebraska's Imported Water is "on" in one run and "off" in the other (e.g., CKMN vs. CKN). The formula to be used is:

Imported Water Supply Credit = [(M-θ) + ((CM-C) + (KM-K) + (MN-N))/3 + ((CKM-CK) + (CMN-CN) + (KMN-KN))/3 + (CKMN-CKN)]/4

Compare to C000000405 Equation 3d

Differences in stream flows shall be determined at the same locations as identified in Subsection III.D.1~~for the "no pumping" runs~~. Should another State import water into the Basin in the future, the RRCA will develop a similar procedure to determine Imported Water Supply Credits.

III.D.1. Groundwater

Computed Beneficial Consumptive Use of groundwater shall be determined by use of the RRCA Groundwater Model. The Computed Beneficial Consumptive Use of groundwater for each State shall be determined as the difference in streamflows using sixteen~~two~~ runs of the model. These runs are named using a combination of variables representing Colorado groundwater pumping and pumping recharge (C), Kansas groundwater pumping and pumping recharge (K), the surface water recharge associated with Nebraska's Imported Water Supply, or "mound" (M), and Nebraska groundwater pumping and pumping recharge (N), with the presence of the variable indicating that the stress is "on" and the absence of the variable indicating that the stress is "off".

CKMN~~The "base" run~~ shall be the "base" run with all groundwater pumping, groundwater pumping recharge, and surface water recharge within the model study boundary for the current accounting year "on".

CKM~~The "no State pumping" run~~ shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Nebraska~~of that State~~ shall be turned "off."

CKN shall be the run with the same model inputs as the base run with the exception that surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

Compare to Notice of Stipulation, Ex. A, III D1; *See also* III A3b

CMN shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Kansas shall be turned "off."

KMN shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado shall be turned "off."

CK shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Nebraska and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

Compare Notice of Stipulation Ex. A, III D1

CM shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Nebraska and Kansas shall be turned "off."

CN shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Kansas and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

Compare Notice of Stipulation Ex. A, III D1

KM shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Nebraska and Colorado shall be turned "off."

KN shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

Compare Notice of Stipulation Ex. A, III D1

MN shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado and Kansas shall be turned "off."

C shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Kansas and Nebraska and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

K shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado and Nebraska and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

M shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado, Kansas, and Nebraska shall be turned "off."

N shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado and Kansas and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

θ ("theta") shall be the run with the same model inputs as the base run with the exception that all groundwater pumping and pumping recharge in Colorado, Kansas and Nebraska and surface water recharge associated with Nebraska's Imported Water Supply shall be turned "off."

An output of the model is baseflows at selected stream cells. Changes in the baseflows predicted by the model between eight pairs of model runs where the only difference between the two runs is that the groundwater pumping and pumping recharge in a state is "on" in one run and "off" in the other run (e.g., CKMN vs. CKM) will"base" run and the "no State pumping" model run is assumed to be used to determine the depletions to streamflows. i.e., groundwater computed beneficial consumptive use, due to State groundwater pumping at that location. The formulas to be used are:

Colorado groundwater computed beneficial consumptive use =
[(θ-C) + ((K-CK) + (M-CM) + (N-CN))/3 + ((KM-CKM) + (KN-CKN) + (MN-CMN))/3 + (KMN-CKMN)]/4

Compare to C000000405 Equation 3a

Kansas groundwater computed beneficial consumptive use =
[(θ-K) + ((C-CK) + (M-KM) + (N-KN))/3 + ((CM-CKM) + (CN-CKN) + (MN-KMN))/3 + (CMN-CKMN)]/4

Compare to C000000405 Equation 3b

Nebraska groundwater computed beneficial consumptive use =
[(θ-N) + ((C-CN) + (M-MN) + (K-KN))/3 + ((CM-CMN) + (CK-CKN) + (KM-KMN))/3 + (CKM-CKMN)]/4

Compare to C000000405 Equation 3c

The values for each Sub-basin will include all depletions and accretions upstream of the confluence with the Main Stem. The values for the Main Stem will include all depletions and accretions in stream reaches not otherwise accounted for in a Sub-basin. The values for the Main Stem will be computed separately for the reach above Guide Rock, and the reach below Guide Rock.