Attachment 5: RRCA groundwater model analysis (revised)
Impact of Nebraska pumping and proposed remedy

Samuel P. Perkins[1] and Steven P. Larson[2]
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(see Appendix A for an explanation of revisions)

[1]Civil Engineer, Interstate Water Issues, Kansas Dept. Of Agriculture, Div. of Water Resources;
[2]S. S. Papadopulos & Associates, Inc., Bethesda, MD.

Introduction

The analysis described in Attachment 4 has shown that annual groundwater consumptive use in Nebraska must be reduced to 175,000 acre-feet in order to achieve sustained compliance with the compact. The approved RRCA groundwater model was used to determine the reduction in pumping necessary for Nebraska to meet this requirement and thereby achieve sustained compliance with the Republican River Compact. This memo describes the basis for the projected depletions computed by the groundwater model under both status quo and reduced pumping scenarios.

In order to reach and then sustain a groundwater consumptive use of 175,000 acre-feet (AF) needed to comply with the Compact over the next 50 years, the proposed remedy case imposes the following conditions on future groundwater pumping for irrigation within the Republican River basin in Nebraska: first, a no-pumping zone for irrigation is imposed within 2.5 miles of RRCA groundwater model stream cells; second, groundwater irrigation area is held at 2000 levels at distances greater than 2.5 miles from stream cells; third, commingled irrigation area is held at 2006 levels at all distances from stream cells within the Republican River basin in Nebraska. Under this scenario, future groundwater irrigation area in Nebraska is reduced by 514,610 acres, including 350,970 acres within the no-pumping zone and 163,640 acres outside the no-pumping zone. For comparison, Nebraska's reported groundwater irrigated acreage within the Republican River basin has increased by 211,000 acres since 2000 and by 309,900 acres since 1990.

The proposed remedy is intended to allow recovery of streamflow as quickly as groundwater response will allow by focusing on groundwater pumping near the Republican River and its tributaries. The groundwater model was used to represent impacts of Nebraska groundwater pumping on Republican river streamflow and of imported water supply from the Platte River. Model scenarios were run to represent both status quo conditions and the proposed remedy. Projected Nebraska impacts for a 51-year future time period, as well as computed Republican River streamflow, are presented here under both scenarios.

Projected average annual impacts over 51 years (2007-2057) on Republican River streamflow under status quo conditions are 268,000 acre-feet per year (afy) for Nebraska groundwater pumping, reduced by 11,700 afy for imported water supply credit from Platte River imports, for a net impact of 256,300 afy. The corresponding impacts under the reduced pumping scenario are 164,700 afy for Nebraska pumping, reduced by 27,600 afy for imported water supply credits, for a net impact of 137,100 afy. Compared with the base case scenario, the proposed remedy scenario shows an average decrease in pumping impact of 103,300 afy and increase in imported water supply credit of 16,000 afy, for a reduction in Nebraska's net impact of 119,300 afy. However, the net impact under the proposed remedy shows an initial decline followed by an upward trend for years 2015-2057, indicating a possibly larger net impact beyond the simulated time period.

Using a sequence of historical years to represent futures

Model datasets for historical years 1990-2006 were used to construct future scenarios. These years were chosen initially because of the higher quality of Kansas water use reporting data beginning in 1990. The sequence of historical years 1990-2006, beginning with year 1990, was repeated three times to represent future scenarios for years 2007-2057. Median annual precipitation for years 1990-

2006, spatially averaged over the groundwater model domain, is 19.58 inches/year. Compared against the model's years of record 1918-2006, this corresponds to a probability of 54.5 percentile, which is slightly above median rainfall of 19.28 in/yr for years 1918-2006. This indicates that the sequence is a reasonable projection, at least with respect to the historical record. Additionally, the sequence consists of a relatively wet period (1990-1999) followed by a relatively dry period (2000-2006).

Hydrologic conditions for future years were represented by the conditions of the historical sequence of years. These conditions include mean monthly streamflow and reservoir elevations at the end of each month, both of which are specified for the stream (STR) package, and evapotranspiration (for the EVT package) as input to Modflow (mf2k). Groundwater recharge, pumping and irrigated area are also based on conditions of the historical sequence of years, but with adjustments to specify conditions for the specific cases as input files to the pumping (WEL) and recharge (RCH) packages. Irrigated area is a consideration due to the dependence of precipitation recharge on whether or not the land is irrigated. Input files to Modflow were assembled by the preprocessor programs mketff (EVT package), mkstrff (STR package) and rrppf (RCH and WEL packages) [version: rrppf_v519].

Status quo scenario

Recharge and pumping for the status quo scenario were represented by historical conditions with adjustments as follows.

Kansas data for irrigated area, groundwater pumping and return flow in future years were based on corresponding historical years' data, but with adjustments to reflect 2006 conditions with respect to return flow (based on improvements in irrigation systems), metering and development.

Data for irrigated area served by groundwater and commingled pumping as reported in 2006 by Colorado and Nebraska were used to represent all future years under base case conditions. Irrigated area served by surface water in future years was represented by data for the corresponding historical years. For Colorado, 2006 groundwater irrigated area was substituted for the corresponding historical years' area as a correction to the Colorado dataset from authorized area, as specified in years 1990-2000, to reported area used for irrigation, as specified in years 2001-2006. No corresponding adjustment was made to groundwater pumping for Colorado.

In the case of Nebraska, 2006 groundwater and commingled irrigated area were substituted for corresponding historical years' data in order to represent continued development through 2006. Groundwater pumping by Nebraska in future years was represented by reported pumping in the corresponding historical years to reflect hydrological conditions. To reflect the change in development associated with irrigation from a given historical year to the year 2006, historical pumping corresponding to each grid cell was multiplied by the ratio of total groundwater and commingled irrigated area in 2006 to the total area for the corresponding historical year. In order to reflect differences in development across Natural Resource Districts in Nebraska, this ratio was calculated for each NRD within the groundwater model domain, and applied to total reported pumping and groundwater return flow for each model grid cell within the corresponding District. NRD boundaries are shown in Figure 1.

The assumptions of historical conditions for the Nebraska dataset that are projected into the future include return flow from groundwater pumping for irrigation, which is assumed to be 20 percent. This is considered to be a generous assumption, even for recent historical years, and may warrant revision for scenario refinements, especially if allocations imposed by Natural Resource Districts are to be incorporated.

Proposed remedy case: reduced Nebraska pumping scenario

Conditions for the reduced Nebraska pumping scenario are summarized above in the Introduction. The conditions are explained in greater detail as follows.

No-pumping zone

The no-pumping zone was specified in terms of model grid cells as an approximation of an actual zone, which would likely be independent of the model grid; for example, it might reference a boundary based on the Public Land Survey System. The grid-based approximation has the advantage of allowing the affected pumping in Nebraska to be selected from datasets previously prepared by Nebraska for the model, including groundwater pumping, recharge and irrigated area. Additionally, defining the no-pumping zone with reference to model stream cell centers is intended to be consistent with prior decisions made during model development to represent the stream network.

Figure 1 shows the extent of the proposed no-pumping zone on Nebraska groundwater pumping for irrigation within the Republican River basin as gray-shaded grid cells. Model cells representing streams and federal reservoirs (turquoise) are included in the no-pumping zone. By selecting model grid cells whose centers lie within two miles of stream cell centers, the resulting no-pumping zone applies to groundwater diversions within 2.5 miles of the stream. The model grid cells corresponding to the no-pumping zone were selected in GIS and converted into a "mask", i.e., an array of 1's and 0's that was written to a text file for input to a preprocessor to identify grid cells for which pumping is to be excluded.

2000 irrigated area

Outside the no-pumping zone, groundwater irrigation area for the year 2000 was substituted for corresponding historical years' data to hold development at 2000 levels. Groundwater pumping by Nebraska in future years was represented by reported pumping in the corresponding historical years to reflect hydrological conditions, multiplied by a factor to reflect the change in irrigated area, given by the ratio of groundwater irrigated area in 2000 to groundwater irrigated area in the corresponding historical year. Ratios were calculated for each Natural Resource District (NRD) and applied to corresponding pumping within the NRD.

An implicit assumption of the above conditions for the proposed remedy scenario is that pumping within the no-pumping zone cannot be transferred outside the zone.

The combined effects of imposing the no-pumping zone and fixing irrigated area at 2000 elsewhere in the Republican River basin are to reduce groundwater irrigated area within the Republican River basin by 514,600 acres, or 43 percent, from 1,200,600 acres under the status quo scenario to 686,000 acres under the proposed remedy.

Commingled irrigated area

In applying the proposed remedy, the condition to hold groundwater irrigation area to 2000 levels is not applied to commingled irrigation area, which is instead held at 2006 levels for all of Nebraska within the RRCA groundwater model domain. Within the no-pumping zone, commingled irrigation area is retained, under the assumption that commingled area could be irrigated if surface water is available. Total 2006 commingled irrigated area in Nebraska was 119,000 acres. Within the no-pump zone, 2006 commingled irrigation area was 11,040 acres; Within the Republican River basin and outside the no-pump zone, 2006 commingled area was 2,230 acres.

Evaluation of impacts of Nebraska pumping under status quo and reduced pumping conditions

In order to compute Nebraska impacts of both groundwater pumping and imported water supply, three additional cases were run for comparison against the status quo and reduced pumping cases, above. Conditions for the third case specify no groundwater pumping in Nebraska for the entire simulation period, beginning in 1918, but are otherwise the same as conditions for the base case. Similarly, conditions for the fourth case specify no imported water supply from the Platte River in Nebraska for the entire simulation period, beginning in 1918, but are otherwise the same as conditions for the base case. The fifth case is identical to the reduced pumping cases (above), except for the assumption that future imported water supplies from the Platte River are excluded.

Based on these five future scenario runs, impacts of Nebraska pumping and imported water supply were evaluated with respect to both baseline and reduced pumping conditions. First, the impact of Nebraska pumping under status quo conditions was evaluated as the difference given by computed Republican River flows for the "no Nebraska pumping" case minus corresponding flows for the status quo case. Second, the impact of Nebraska pumping under the proposed remedy is evaluated as the difference given by computed Republican River flows for the "no Nebraska pumping" case minus corresponding flows for the proposed remedy case. Similarly, imported water supply credits were evaluated twice: first, with respect to status quo conditions, and then with respect to reduced pumping conditions under the proposed remedy case.

Results: impacts of Nebraska pumping and imported water supply from Platte River

The reduction in groundwater irrigated area of 514,600 acres within the Republican River basin under the proposed remedy results in a groundwater pumping reduction of 619,900 acre-feet/year. Impacts of this reduction on streamflow are presented here.

Table 1 lists computed annual impacts of Nebraska pumping on Republican River streamflow and of imported water supply under both the status quo and reduced pumping scenarios for years 2007-2057, and averages over the same period. The rightmost column of Table 1 lists the reduction of impacts achieved under the reduced pumping scenario.

Table 1 shows that projected average annual impacts over 51 years (2007-2057) on Republican River streamflow under baseline, conditions are 268,000 acre-feet/per year (afy) for Nebraska groundwater pumping, reduced by 11,700 afy for imports from the Platte River, for a net impact of 256,300 afy. The corresponding impacts under the reduced pumping scenario are 164,700 afy for Nebraska pumping, reduced by 27,600 afy for imported water supply for a net average impact of 137,100 afy. Compared with the base case scenario, the proposed remedy scenario shows an average decreased pumping impact of 103,300 afy, and an increase in imported water supply credit of 16,000 afy, for an average net Nebraska impact reduction of 119,300 afy. However, the net impact under the proposed remedy shows an initial decline followed by an upward trend for years 2015-2057 that indicates a possibly larger net impact beyond the modeled time period.

Nebraska impacts on Republican River streamflow are shown graphically in Figures 2 and 3. Figure 2 shows the separate impacts of Nebraska pumping and imported water supply credit under both scenarios. Figure 3 shows the net sum of pumping impact and imported water supply credit for each scenario.

Figure 2 shows historical impacts of Nebraska pumping on Republican River streamflow and imported water supply credit according to the RRCA groundwater model for years 1960-2006. The historical impact of Nebraska pumping reached peak levels of 212,900 acre-feet/year in 2001 and 213,100 acre-feet/year in 2004, and was 198,400 acre-feet/year in 2006. Figure 2 also shows projected impacts of Nebraska pumping on Republican River streamflow and imported water supply credit under both the status quo scenario and the reduced pumping scenarios for years 2007-2057.

The impact of Nebraska pumping on Republican River streamflow in future years under the status quo scenario shows greater variability than under the reduced pumping scenario because of the greater magnitudes of the pumping under the status quo scenario. Projected pumping impacts under both scenarios appear to have upward trends, although impacts under status quo conditions show a decreasing rate of change. Imported water supply credits under the proposed remedy are greater and show less variability than do those under status quo conditions.

Table 1. Projected impacts of Nebraska pumping and Platte River imports under both status quo conditions and the proposed remedy (acre-feet/year)

year	Status quo conditions			Proposed remedy			Impact reduction
	pumping	imports	Net impact	pumping	imports	Net impact	
2007	206,685	15,945	190,740	189,290	17,476	171,814	18,926
2008	228,723	10,519	218,204	185,972	18,160	167,812	50,392
2009	232,212	10,058	222,154	184,619	24,438	160,181	61,973
2010	268,248	28,216	240,032	188,316	28,869	159,447	80,585
2011	234,826	18,396	216,430	167,740	23,517	144,223	72,207
2012	257,288	16,004	241,284	169,116	25,785	143,331	97,953
2013	279,390	19,589	259,801	170,714	27,116	143,598	116,203
2014	253,960	20,178	233,782	161,514	25,630	135,884	97,898
2015	239,184	13,010	226,174	153,278	24,317	128,961	97,213
2016	259,639	12,697	246,942	162,518	27,757	134,761	112,181
2017	235,315	12,933	222,382	149,632	23,936	125,696	96,686
2018	249,836	11,921	237,915	151,570	26,762	124,808	113,107
2019	220,215	8,478	211,737	137,938	20,590	117,348	94,389
2020	239,380	9,005	230,375	151,122	25,655	125,467	104,908
2021	249,061	9,087	239,974	155,209	27,349	127,860	112,114
2022	248,073	9,400	238,673	152,490	25,855	126,635	112,038
2023	232,745	9,054	223,691	148,589	26,396	122,193	101,498
2024	241,650	9,967	231,683	150,586	25,203	125,383	106,300
2025	260,704	8,756	251,948	158,291	26,119	132,172	119,776
2026	261,893	9,493	252,400	159,352	27,569	131,783	120,617
2027	310,470	20,000	290,470	168,124	29,958	138,166	152,304
2028	266,199	17,524	248,675	157,838	27,737	130,101	118,574
2029	288,790	11,750	277,040	161,625	29,072	132,553	144,487
2030	315,741	13,507	302,234	167,204	30,214	136,990	165,244
2031	281,880	17,106	264,774	161,227	29,113	132,114	132,660
2032	268,225	9,908	258,317	155,858	27,867	127,991	130,326
2033	287,840	10,699	277,141	165,875	30,366	135,509	141,632
2034	260,095	9,511	250,584	155,124	27,216	127,908	122,676
2035	275,704	9,444	266,260	157,893	29,493	128,400	137,860
2036	240,324	7,342	232,982	146,034	23,234	122,800	110,182
2037	253,962	8,401	245,561	159,222	28,213	131,009	114,552
2038	268,318	8,603	259,715	163,913	29,615	134,298	125,417
2039	272,377	9,011	263,366	161,569	28,314	133,255	130,111
2040	254,226	8,699	245,527	158,492	28,645	129,847	115,680
2041	262,968	8,440	254,528	160,150	27,552	132,598	121,930
2042	281,574	8,280	273,294	169,229	28,218	141,011	132,283
2043	282,715	9,153	273,562	170,738	29,665	141,073	132,489
2044	340,444	14,502	325,942	180,788	32,343	148,445	177,497
2045	285,259	15,373	269,886	168,711	29,938	138,773	131,113
2046	310,820	9,985	300,835	173,741	31,303	142,438	158,397
2047	339,785	11,229	328,556	180,301	32,442	147,859	180,697
2048	302,494	15,013	287,481	174,016	31,491	142,525	144,956
2049	286,563	8,973	277,590	167,400	29,872	137,528	140,062
2050	305,555	10,562	294,993	179,129	32,415	146,714	148,279
2051	278,614	8,926	269,688	167,245	29,129	138,116	131,572
2052	293,521	9,281	284,240	170,714	31,589	139,125	145,115
2053	250,743	6,952	243,791	156,746	24,702	132,044	111,747
2054	265,943	8,337	257,606	171,879	29,872	142,007	115,599
2055	280,141	8,709	271,432	176,507	31,446	145,061	126,371

2056	287,984	8,969	279,015	174,543	30,068	144,475	134,540
2057	270,883	8,707	262,176	169,789	30,174	139,615	122,561
2007-2057	268,023	11,678	256,345	164,696	27,643	137,053	119,292

Figure 2 shows that the impact of Nebraska pumping under the proposed remedy is projected to fall below 175,000 acre-feet/year for the first time in 2011, or in the fifth year of the future scenario, and then occasionally exceeds 175,000 acre-feet/year beginning in 2044. Based on linear trends for years 2011-2057, the impact of Nebraska pumping increases by 394 acre-feet/year under the proposed remedy, and by 1,055 afy under status quo conditions.

Figure 3 shows that the net impact of Nebraska pumping and imported water supply under the proposed remedy is projected to fall below 150,000 acre-feet/year for the first time in 2011, and then stay below 150,000 acre-feet/year for the remaining years of the simulation. Based on linear trends for years 2011-2057, the net impact of Nebraska pumping and imported water supply increases by 261 acre-feet/year under the proposed remedy, and by 1,179 afy under status quo conditions.

Figure 4 shows computed Republican River flows contributed by groundwater for the historical period 1960-2006 and for the two scenarios 2007-2057. Under status quo conditions, computed annual flows for years 1960-2057 diminish at an average rate of 2.5 percent per year, based on an exponential trend for years 2011-2057, as shown in Figure 4. Under the proposed remedy scenario, computed flows after 2006 show relatively rapid recovery during the first few years, followed by an average rate of decline of 0.23 percent per year, based on an exponential trend for years 2011-2057.

Future hydrologic conditions

It is important to keep in mind that the projections, particularly on an annual basis or in the short term, are dependent on the hydrological conditions of the assumed sequence of years. Because of this, the time required to reduce the impact of Nebraska pumping to less than 175,000 acre-feet/year, and the net impact of Nebraska pumping and imported water supply to less than 150,000 acre-feet/year, will be influenced by future and unknown hydrological conditions.

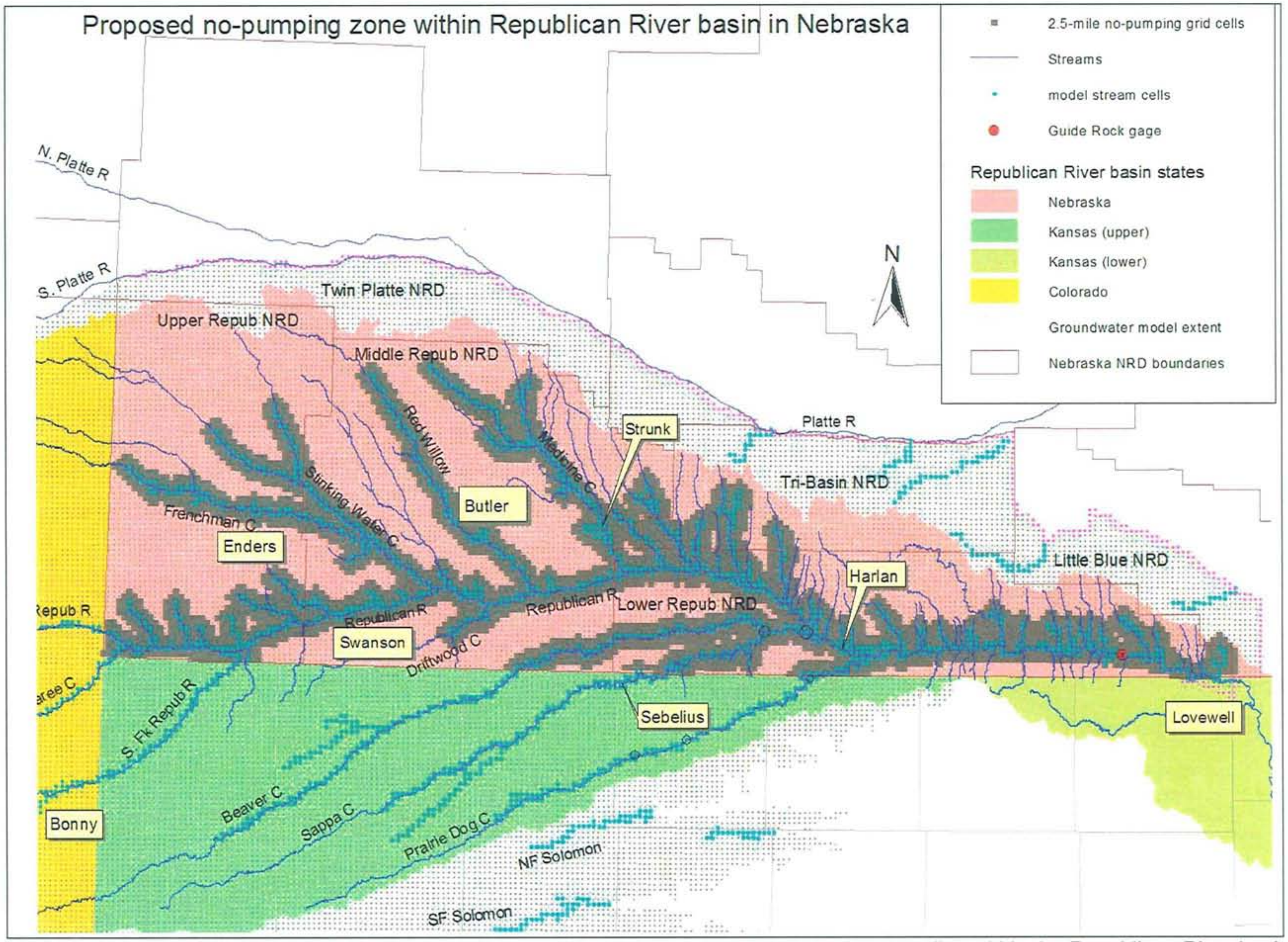

Fig. 1. Map showing part of RRCA groundwater model grid domain. Proposed no-pumping zone lies within the Republican River basin in Nebraska. Grid cells shaded dark gray are those whose centers lie within two miles of centers of stream cells (turquoise).

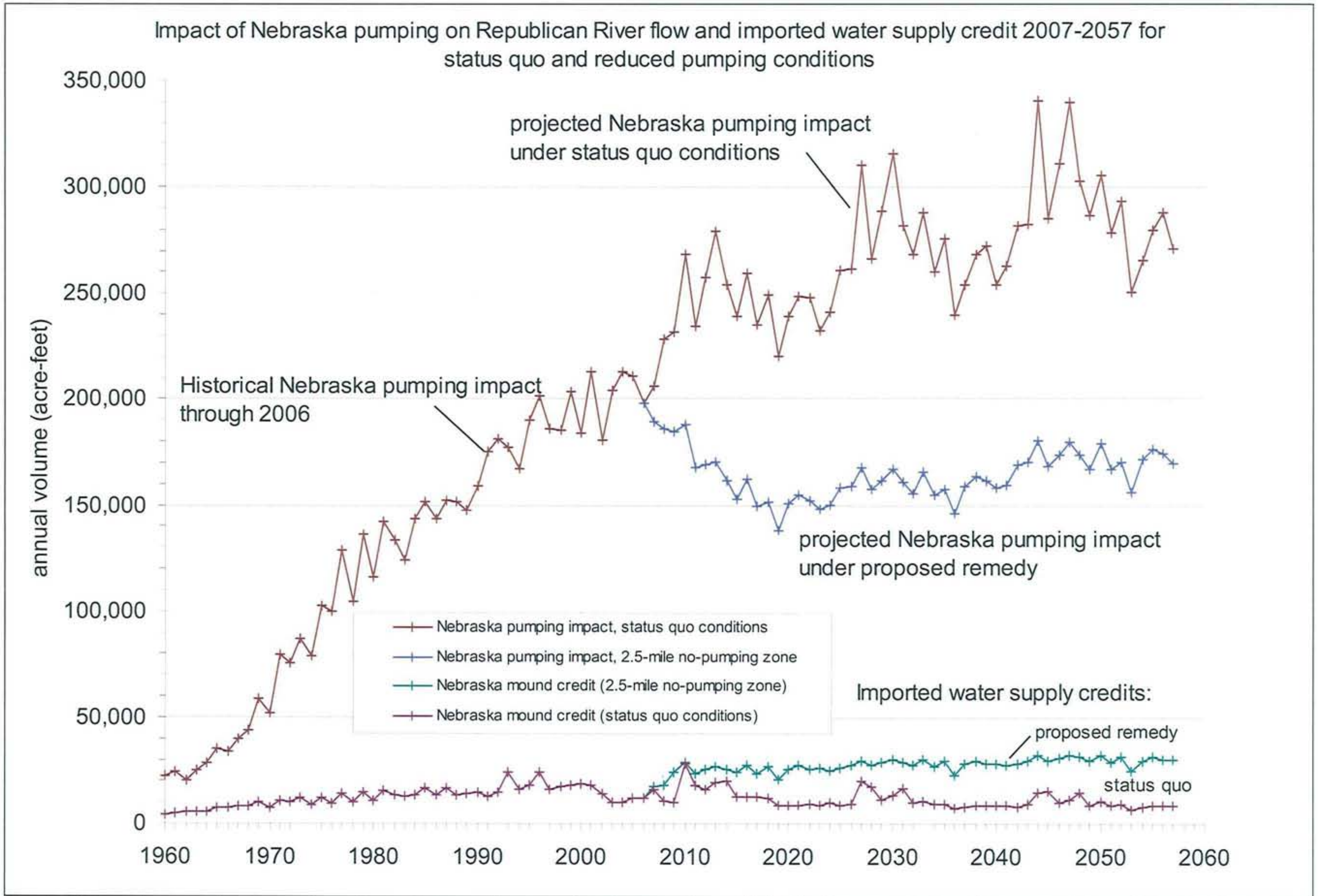

Fig. 2. Nebraska pumping impact on streamflow and imported water supply credit for both status quo and proposed remedy scenarios.

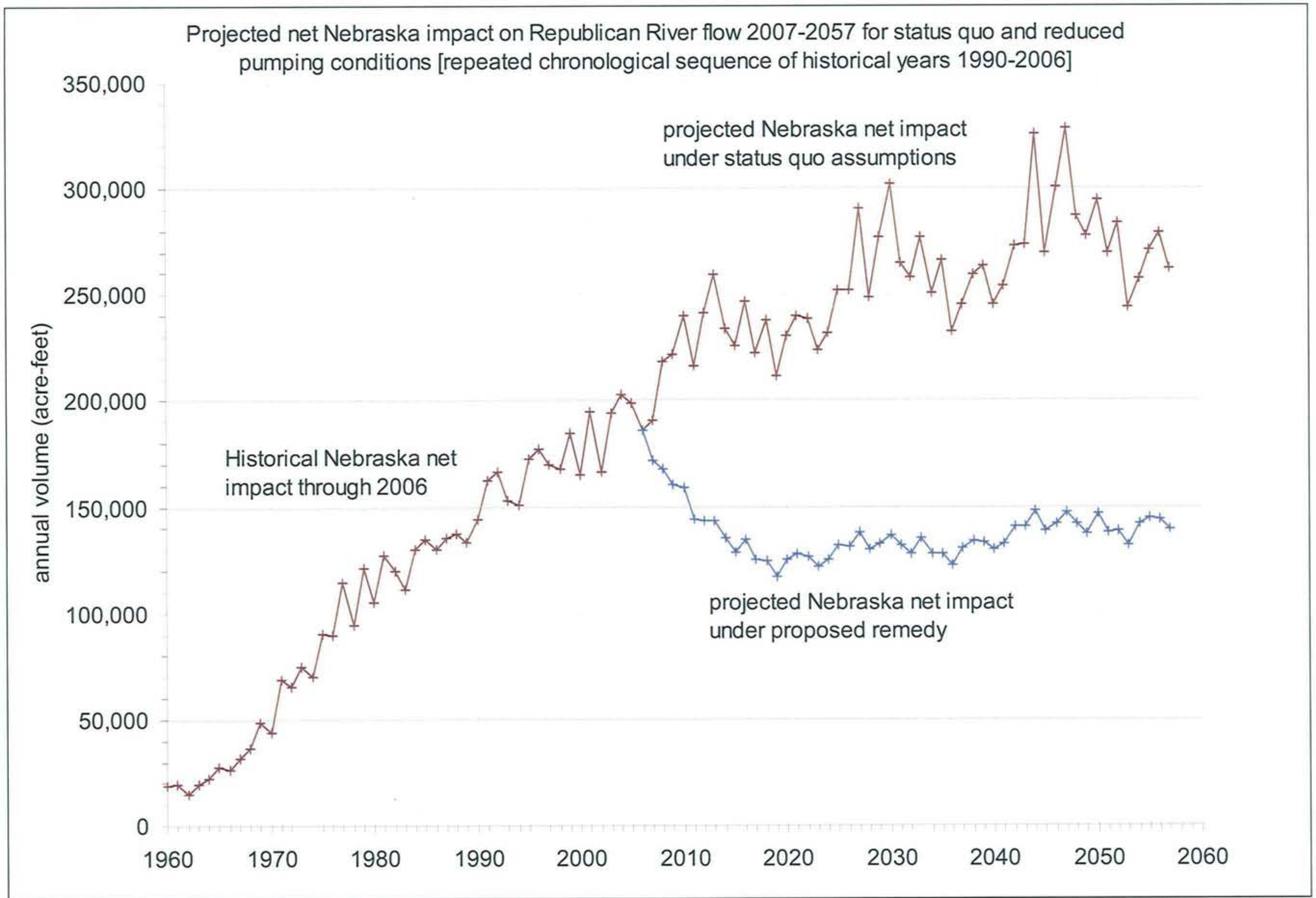

Fig. 3. Net sum of Nebraska pumping impact on streamflow and imported water supply credit for status quo and proposed remedy scenarios.

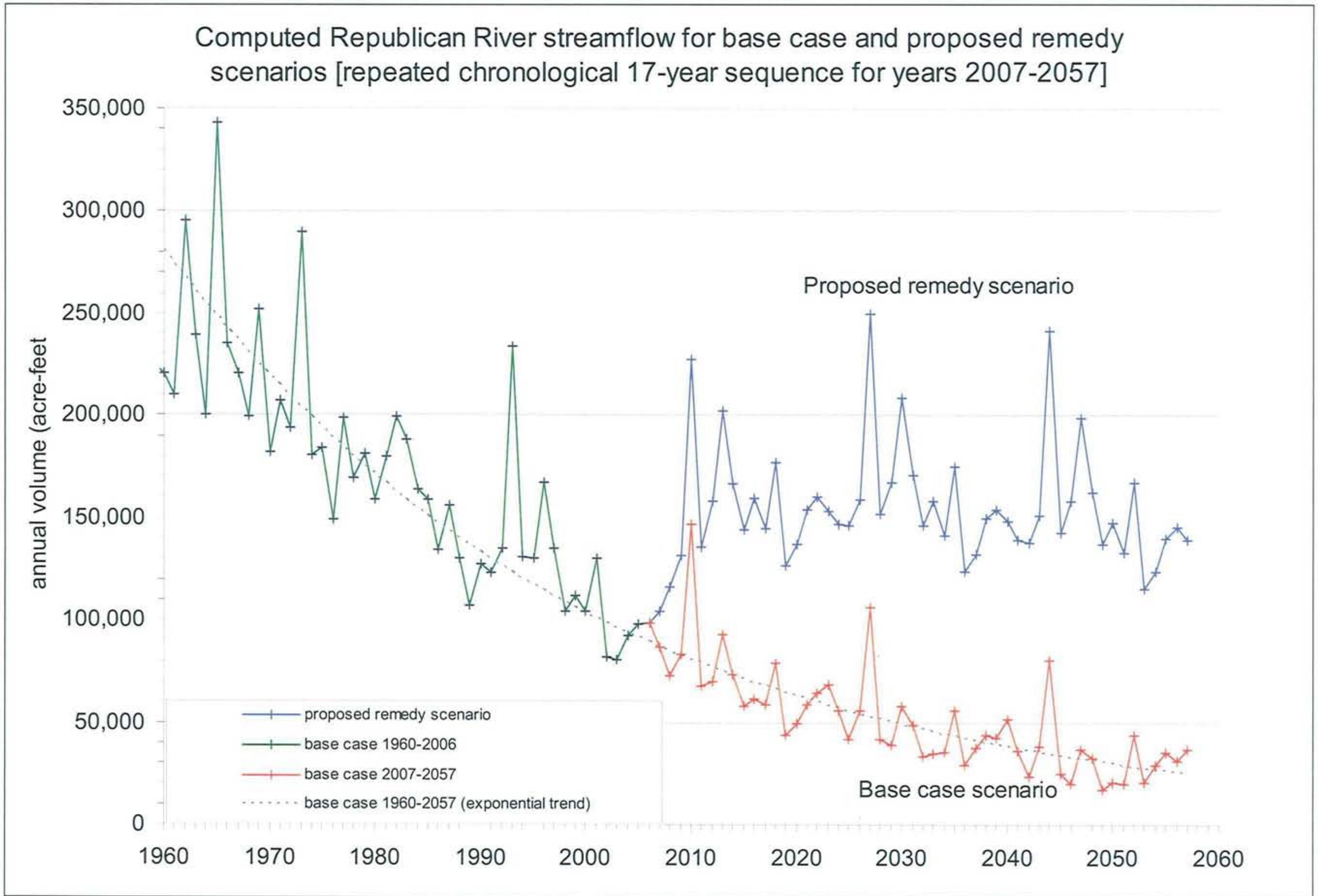

Fig. 4. Computed Republican River streamflow for status quo and proposed remedy scenarios.

Appendix A. Revisions to Attachment 5: RRCA groundwater model analysis
Impact of Nebraska pumping and proposed remedy

Samuel P. Perkins[1] and Steven P. Larson[2]

[1]Civil Engineer, Interstate Water Issues, Kansas Dept. Of Agriculture, Div. of Water Resources;
[2]S. S. Papadopulos & Associates, Inc., Bethesda, MD.

Four revisions were made to the future scenario model runs and their effects are described here. The first three of these are related to groundwater or commingled irrigation area, which mostly affect results for the status quo scenario and have a much smaller effect on the proposed remedy scenario. Annual changes in impacts of the first three revisions are shown in Table A1. Annual impacts and computed streamflow under the status quo and proposed remedy scenarios as originally reported and with revisions 1-3 are compared in Figures A2-A4. The fourth revision has to do with output control and has negligible effects on results, as shown in Table A3. The first three revisions are as follows.

1. Hold commingled irrigated area at 2006 levels under both future scenarios.
In applying the proposed remedy, the condition to hold groundwater irrigation area to 2000 levels was also applied to commingled irrigation area. This was revised so that commingled irrigation area is held instead at 2006 levels for all of Nebraska within the RRCA groundwater model domain. This change had a slight effect on Nebraska impacts under the reduced pumping scenario.

2. Scale groundwater pumping according to changes in groundwater irrigation area within each NRD.
Groundwater pumping scaling factors for the status quo scenario were based on statewide irrigation area ratios instead of NRD-specific irrigation area ratios, which were used for the reduced pumping scenario. Status quo cases were re-run using NRD-specific irrigation area ratios. This change affected impacts under only the status quo scenario.

3. Exclude commingled irrigation area from sums for the purpose of scaling groundwater pumping.
Sums of irrigation area that were used to compute scaling factors for groundwater pumping included both groundwater and commingled irrigated area. In order to represent increased development of groundwater irrigation correctly, these sums should have included only groundwater irrigation area. This change affected impacts under both scenarios, but more significantly under the status quo scenario. The sums of groundwater irrigated area within NRDs for years 1990-2006 that were used to calculate groundwater pumping scaling factors under the status quo and reduced pumping scenarios are listed below in Tables A4 and A5, respectively.

<u>Effects of revisions 1-3: calculated impacts on computed streamflow</u>

Under "Results," the original version of Attachment 5 stated: "The reduction in groundwater irrigated area of 514,600 acres within the Republican River basin under the proposed remedy results in a groundwater pumping reduction of 564,400 acre-feet/year." With the above revisions, average annual groundwater pumping under the proposed remedy is reduced by 619,900 acre-feet/year.

Table A1 summarizes calculated impacts on computed streamflow as originally reported in Attachment 5 ("Original impacts"), impacts after incorporating the first two revisions, impacts after incorporating the all three revisions, and the net effects of the three revisions on calculated Nebraska impacts. Under the status quo scenario, the revisions have the effect of increasing the net Nebraska impact on Republican River streamflow by 9,700 afy, whereas, under the proposed remedy scenario, the revisions increase the net Nebraska impact by 1,300 afy. Table A1 also shows the reduction in Nebraska's net impact under the proposed remedy was 110,800 afy as originally reported and 119,200 afy with revisions, for an increase of 8,400 afy in the proposed remedy's reduction in Nebraska's net impact. Table A2 lists the annual differences between the revised and original versions of Table 1 in Attachment 5. Figures A2 through A4 superimpose the original and revised graphs of computed impacts and flows shown in Figures 2-4 of the respective versions of Attachment 5.

Table A1. Summary of how revisions 1-3 affect Nebraska impacts on Republican River streamflow.

	Status quo scenario			Proposed remedy scenario			Reduction in net NE impact
	Pumping impact	Import credit	Net NE impact	Pumping impact	Import credit	Net NE impact	
Original impacts	259,900	13,300	246,600	163,500	27,700	135,800	110,800
Impacts with revisions 1 and 2	263,300	12,500	250,800	165,000	27,600	137,500	113,400
Impacts with revisions 1-3	268,000	11,700	256,300	164,700	27,600	137,100	119,200
Effect of revisions (1-3)	8,100	-1,600	9,700	1,200	-100	1,300	8,400

As noted above, the revisions have a much greater effect on impacts under the base case scenario. This can be seen by comparing computed Republican River flows under the base case scenario in Figure 4 with the same figure in the original version of Attachment 5. With the revisions, note that the exponential trend line for these flows appears to fall below 50,000 afy in 2030, which is about eight years earlier than that shown in Figure 4 of the original Attachment 5. On the other hand, computed flows under the proposed remedy scenario show a relatively small decrease, corresponding to the increase in net Nebraska impact of 1,300 afy with the revisions.

4. Output control file for revised runs specify that cell-by-cell flows for all budget terms be written for the second time step of each stress period instead of the first.

For final versions of future scenario cases, output control was specified by file TS2_88yrs.oc, which specifies that cell-by-cell flows are to be written only at the end of each stress period. This is consistent with the original historical simulations for years for years 1918-2000, and is considered sufficiently accurate for the future scenarios. TS2_88yrs.oc is a version of file 11_thru_2005.oc, which was constructed for a 1918-2005 run, and which begins with a steady-state stress period, whereas the future runs are continuations of transient runs. The second and third lines of file 11_thru_2005.oc were deleted to create file TS2_88yrs.oc. Output control files for the historical RRCA model runs beginning with year 2001 specify that cell-by-cell flows are written at the end of each time step, or twice per stress period. This distinction is recognized in specifying input to versions of the postprocessor readccf to read and summarize cell-by-cell flows.

Future scenario cases preceding the final versions of Dec 28, 2007 were run using file 11_thru_2005.oc, which had the unintended consequence of writing out the cell-by-cell flows at the end of the first time step of each stress period instead of the second time step, i.e., flows for the first half of each stress period instead of the second half. This is because the above file includes lines for the steady-state period, but there is no corresponding steady-state period for the future scenario runs. Consequently, model results for these cases will not appear exactly the same as they would be if based on flows at the end of each stress period. However, the resulting differences should be very small, and comparisons between cases should be only negligibly affected. Model results would be more accurately represented by writing out cell-by-cell flows for every time step, as they are for the annual historical runs 2001-2006, although this would be only a slight improvement in accuracy and would have a negligible effect on comparisons.

By referencing the output control file 11_thru_2005.oc (above), all previous comparisons of model budgets for reduced pumping scenarios against the base case scenario have been made on the basis of cell-by-cell flows for the first time step of each stress period. To verify that differences between model results based on one or the other time step are small, a previous version of the status quo scenario was run both ways, using either of the output control files named file 11_thru_2005.oc or TS2_88yrs.oc to specify that cell-by-cell flows are written for either the first or the second time step of each stress period, respectively. Model budget flows for the two versions of the base case, denoted TS1 and TS2, were also averaged to represent flows based on both time steps, TSavg = (TS1 + TS2)/2. Differences between budget flows based on the first time step and those based on the average of both time steps were calculated as [TS1 – TSavg], summed over the Republican River basin component of the model domain.

Table A2. Changes in Table 1, "Projected impacts of Nebraska pumping and Platte River imports under both status quo conditions and the proposed remedy (acre-feet/year)"

year	Status quo conditions			Proposed remedy			Impact reduction
	pumping	imports	Net impact	pumping	imports	Net impact	
2007	1,845	-127	1,972	106	3	103	1,869
2008	4,211	-731	4,942	115	6	109	4,833
2009	3,887	-349	4,236	548	-176	724	3,512
2010	5,877	-1,609	7,486	1,205	100	1,105	6,381
2011	7,051	379	6,672	651	-42	693	5,979
2012	7,929	-2,466	10,395	864	-22	886	9,509
2013	9,589	-3,953	13,542	1,207	26	1,181	12,361
2014	6,647	1,576	5,071	1,023	-17	1,040	4,031
2015	6,591	-1,658	8,249	847	-23	870	7,379
2016	6,740	-1,312	8,052	1,201	11	1,190	6,862
2017	6,695	-1,615	8,310	875	-50	925	7,385
2018	7,926	-1,602	9,528	1,038	40	998	8,530
2019	7,116	-1,711	8,827	826	-26	852	7,975
2020	6,182	-842	7,024	976	-88	1,064	5,960
2021	5,385	-757	6,142	1,316	8	1,308	4,834
2022	5,331	-739	6,070	1,201	-14	1,215	4,855
2023	4,773	-668	5,441	1,219	11	1,208	4,233
2024	7,021	-1,811	8,832	1,040	-15	1,055	7,777
2025	7,157	-918	8,075	1,167	-46	1,213	6,862
2026	7,357	-719	8,076	1,369	-44	1,413	6,663
2027	11,434	-5,412	16,846	1,729	19	1,710	15,136
2028	8,910	-1,155	10,065	1,183	-46	1,229	8,836
2029	10,670	-2,636	13,306	1,397	-39	1,436	11,870
2030	12,432	-4,688	17,120	1,680	-7	1,687	15,433
2031	10,015	-2,846	12,861	1,393	-46	1,439	11,422
2032	9,180	-2,183	11,363	1,159	-55	1,214	10,149
2033	8,311	-1,054	9,365	1,529	-14	1,543	7,822
2034	9,221	-2,327	11,548	1,145	-49	1,194	10,354
2035	9,784	-1,591	11,375	1,292	-6	1,298	10,077
2036	7,907	-1,140	9,047	1,000	-47	1,047	8,000
2037	7,924	-1,102	9,026	1,214	-127	1,341	7,685
2038	7,324	-1,062	8,386	1,552	15	1,537	6,849
2039	7,274	-964	8,238	1,374	-12	1,386	6,852
2040	6,475	-836	7,311	1,392	-3	1,395	5,916
2041	7,466	-910	8,376	1,191	-17	1,208	7,168
2042	8,150	-1,094	9,244	1,361	-58	1,419	7,825
2043	9,265	-978	10,243	1,546	-41	1,587	8,656
2044	13,059	-5,464	18,523	1,928	14	1,914	16,609
2045	10,210	-2,690	12,900	1,292	-56	1,348	11,552
2046	11,231	-2,218	13,449	1,539	-41	1,580	11,869
2047	12,581	-3,377	15,958	1,849	-16	1,865	14,093
2048	11,694	-3,390	15,084	1,513	-65	1,578	13,506
2049	9,500	-1,495	10,995	1,237	-65	1,302	9,693
2050	9,256	-1,038	10,294	1,689	-19	1,708	8,586
2051	9,082	-1,121	10,203	1,181	-66	1,247	8,956
2052	10,084	-1,226	11,310	1,351	-20	1,371	9,939
2053	8,543	-1,348	9,891	1,021	-53	1,074	8,817
2054	8,661	-1,104	9,765	1,210	-116	1,326	8,439
2055	8,251	-873	9,124	1,584	14	1,570	7,554
2056	7,897	-1,078	8,975	1,413	-18	1,431	7,544
2057	7,809	-840	8,649	1,354	12	1,342	7,307
2007-2057	8,135	-1,586	9,721	1,218	-27	1,245	8,476

Model budget flows, averaged over years 2007-2057, are listed in Table A3. The line labeled "TSavg" in Table A3 shows the average of the first two lines (TS1 and TS2) for each budget term. The fourth line ("TS1 – Tsavg") shows the difference in acre-feet/year between the first line and the third. The fourth line shows these differences as fractions of the average values in line 3. The small differences, expressed either in acre-feet (line 4) or as fractions (line 5) and confirm that differences in model budget flows based on one or the other time step (TS1 or TS2) are negligible.

Table A3. Average model budget flows (afy) based on first and second time steps of each stress period.

time step	STO	CHD	EVT	WEL	DRN	RCH	STR
TS1	870353	-3013	-378322	-2231932	-2178	1692805	-58308
TS2	865473	-3013	-372438	-2231932	-2178	1692805	-59342
TSavg	867913	-3013	-375380	-2231932	-2178	1692805	-58825
TS1 – TSavg	2440	0	-2942	0	0	0	517
TS1 – TSavg / TSavg	0.0028	-0.000025	0.0078	0	0.000016	0	-0.0088

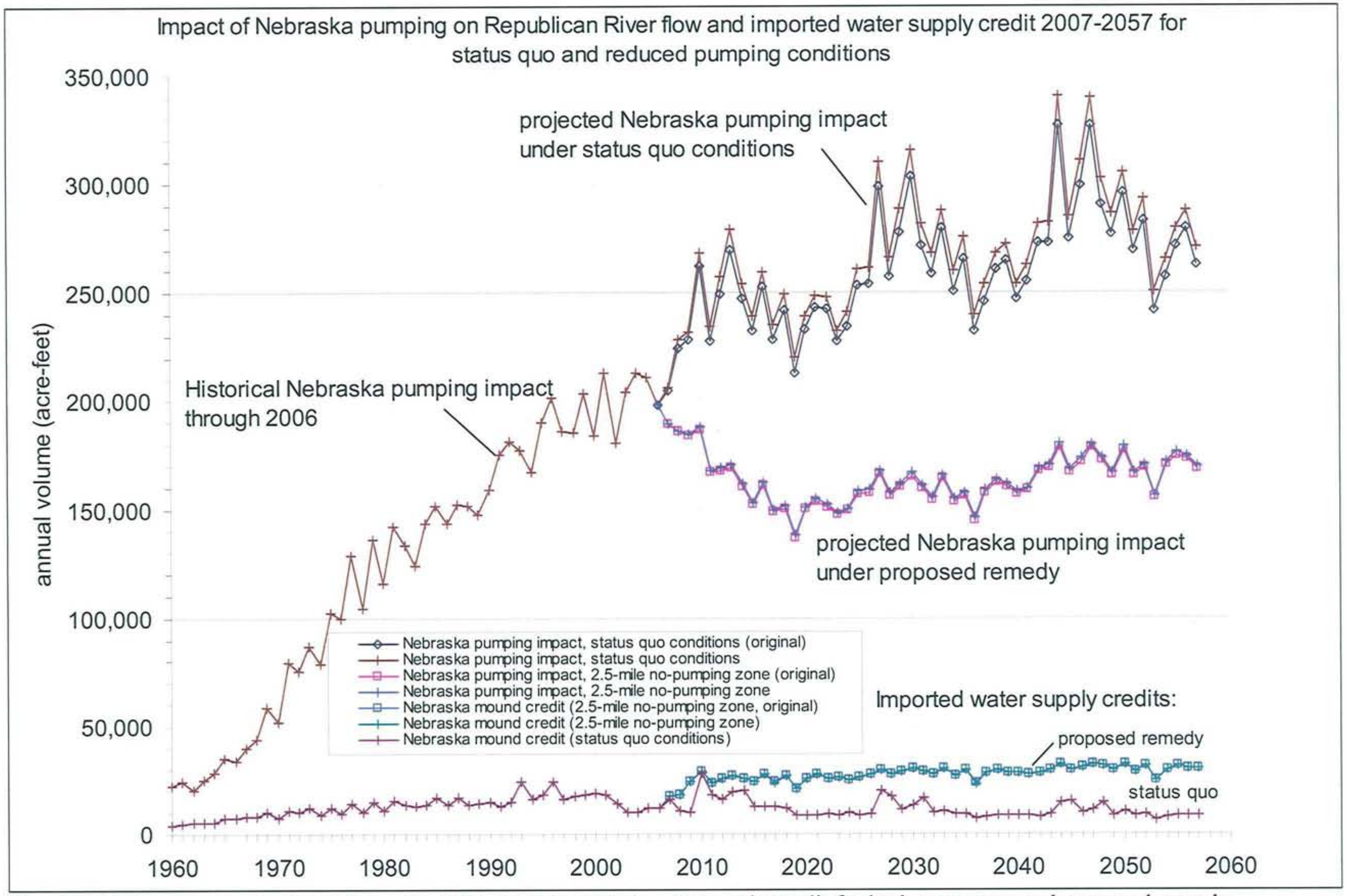

Fig. A2. Nebraska pumping impact on streamflow and imported water supply credit for both status quo and proposed remedy scenarios. Comparison of revised flows with originals shown in Fig. 2, Att. 5, Dec 18, 2007.

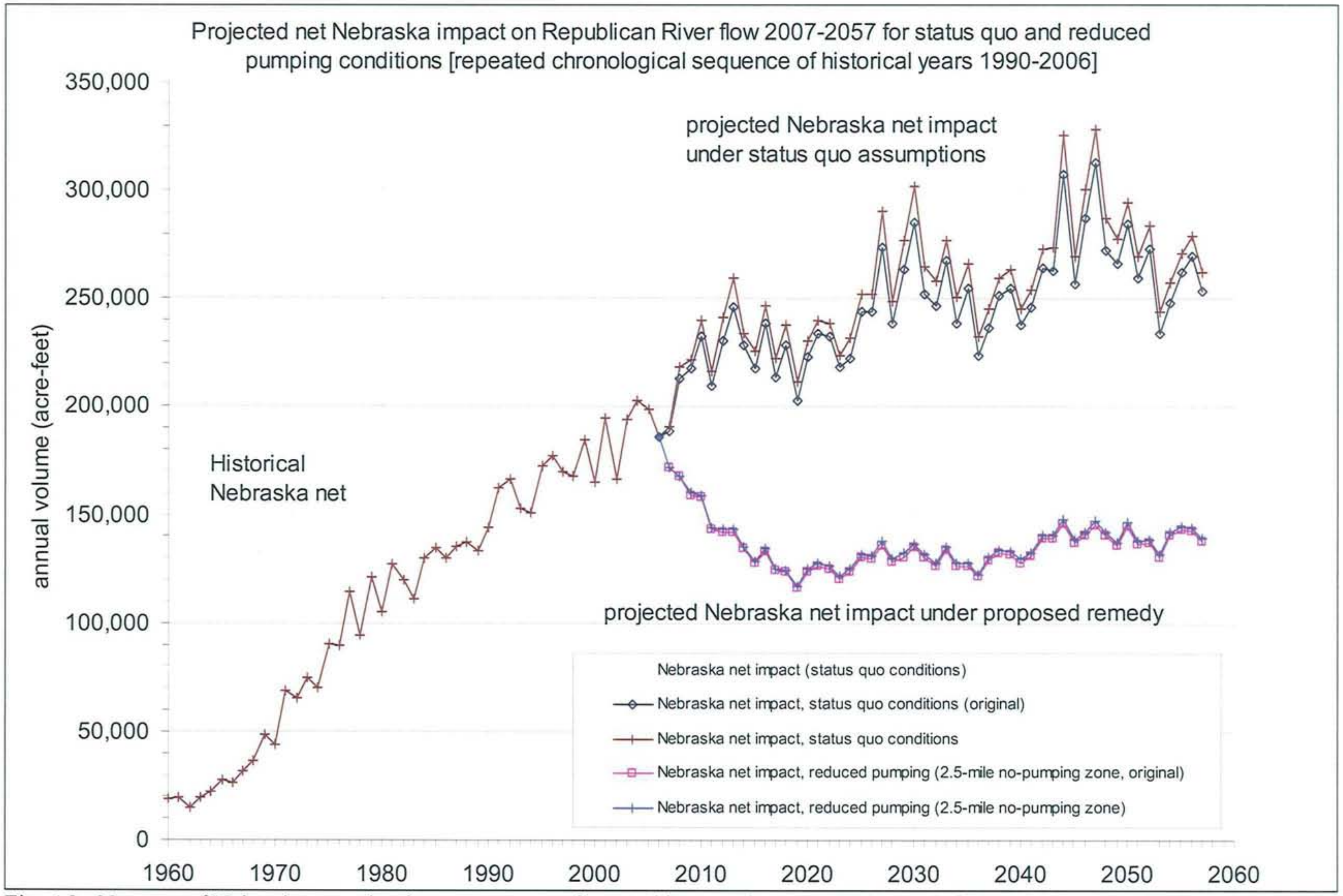

Fig. A3. Net sum of Nebraska pumping impact on streamflow and imported water supply credit for status quo and proposed remedy scenarios. Comparison of revised flows with originals shown in Fig. 3, Att. 5, Dec 18, 2007.

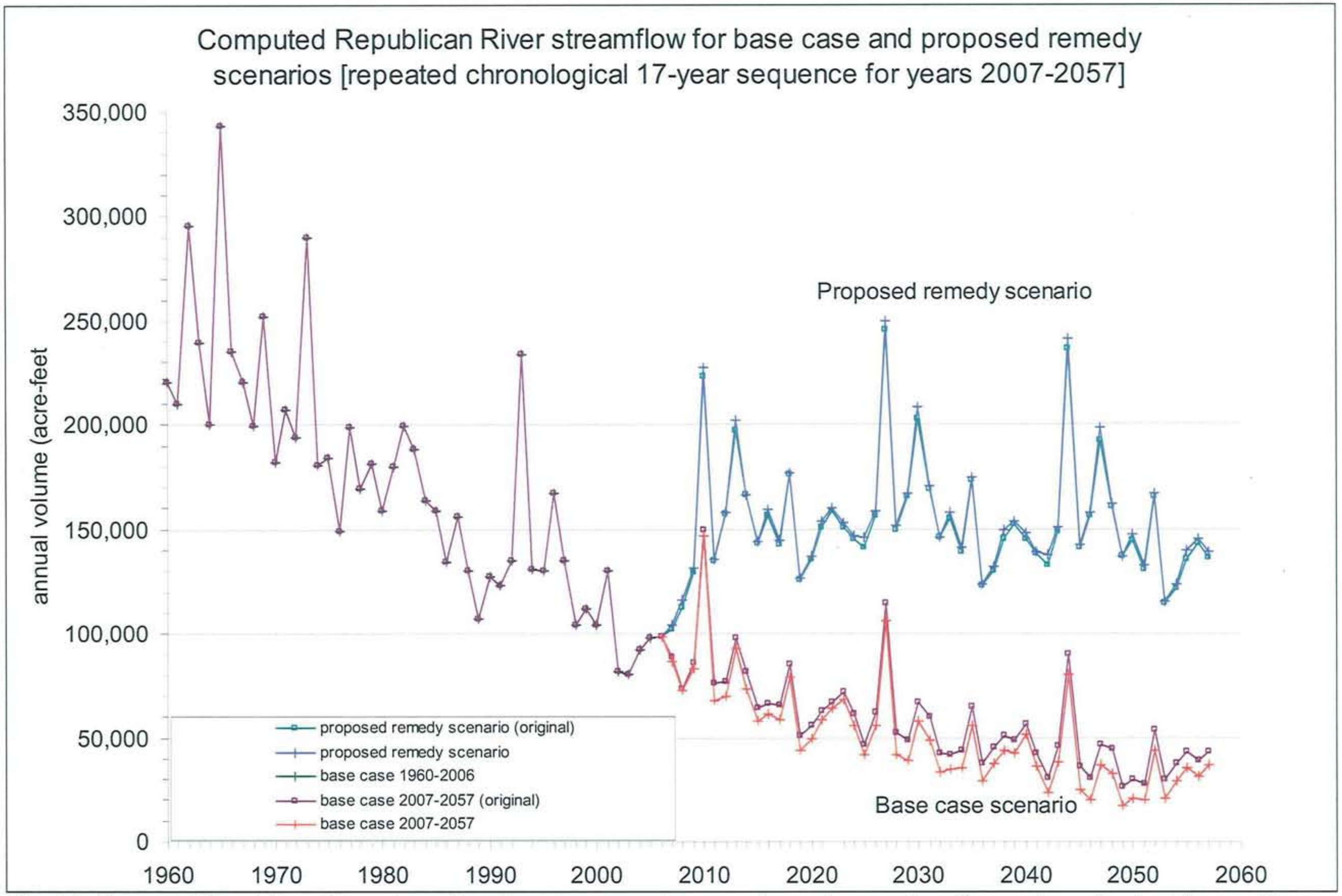

Fig. A4. Computed Republican River streamflow for status quo and proposed remedy scenarios. Comparison of revised flows with originals shown in Fig. 4, Att. 5, Dec 18, 2007.

Table A4. Sums of reported groundwater irrigation area within each state and each Natural Resource District in Nebraska 1990-2006; used to calculate groundwater pumping scaling factors under the status quo scenario.

year	CO gw Ac	KS gw Ac	NE gw Ac	Little Blue	South Platte	Twin Platte	Central Platte	Upper Repub	Middle Repub	Lower Repub	TriBasin
1990	673353	393706	1275917	42798	3282	90060	33273	355654	186740	188242	376017
1991	673632	395998	1304917	44722	3282	92992	33813	369960	187687	188066	384542
1992	673575	372655	1284484	44829	3277	90133	31189	368184	187152	186954	372903
1993	673587	374311	1218625	43464	3274	84523	31305	360123	169446	179631	346982
1994	673824	401827	1313617	45599	3276	92357	33070	369022	185585	193217	391628
1995	673797	391913	1287157	44630	3334	94187	32032	374808	172750	186606	378942
1996	673876	409561	1350855	46054	3278	105124	32890	384993	191323	193731	393597
1997	673885	418548	1370984	46281	3279	104292	32855	377365	196208	214664	396180
1998	673849	416564	1369353	49553	3280	108293	34310	371790	198687	211661	391912
1999	673840	413896	1371085	52792	3218	104779	35811	369231	195683	209422	400274
2000	673893	427428	1429348	52170	3216	108335	37174	384207	204587	223689	416119
2001	569357	412397	1510096	52083	3456	110615	36621	442733	219727	220605	424370
2002	569383	421964	1523417	52078	3452	109198	35774	443940	227604	223038	428462
2003	568630	424564	1565018	50562	3005	113183	34906	449725	240150	250007	423647
2004	568686	422715	1630667	53663	2855	124460	38821	441583	250351	280484	438583
2005	579368	417095	1639947	53188	2777	123911	38000	474615	239845	270383	437343
2006	573501	416729	1682593	52051	2853	113438	42218	459849	277778	292087	442442

Table A5. Sums of reported groundwater irrigation area within each state and each Natural Resource District in Nebraska 1990-2006, but excluding groundwater irrigation area within the proposed no-pump zone shown in Figure 1; used to calculate groundwater pumping scaling factors under the reduced pumping scenario.

year	CO gw Ac	KS gw Ac	NE gw Ac	Little Blue	South Platte	Twin Platte	Central Platte	Upper Repub	Middle Repub	Lower Repub	TriBasin
1990	673353	393706	1000929	42711	3282	90060	33273	269602	115627	91813	354562
1991	673632	395998	1025485	44628	3282	92992	33813	279076	117121	91832	362741
1992	673575	372655	1009142	44734	3277	90133	31189	279796	116258	91747	352009
1993	673587	374311	958557	43377	3274	84523	31305	274431	105511	89356	326781
1994	673824	401827	1036816	45507	3276	92357	33070	281974	116387	94148	370097
1995	673797	391913	1021193	44538	3334	94187	32032	287112	110830	91264	357897
1996	673876	409561	1068337	45952	3278	105124	32890	293536	122175	93869	371514
1997	673885	418548	1076867	46188	3279	104292	32855	286644	123839	106296	373475
1998	673849	416564	1079082	49443	3280	108293	34310	285366	126900	103703	367786
1999	673840	413896	1086754	52668	3218	104779	35811	283808	125743	104102	376624
2000	673893	427428	1125750	52074	3216	108335	37174	294682	132068	107259	390942
2001	569357	412397	1175475	51890	3456	110615	36621	323261	141222	110761	397650
2002	569383	421964	1181320	51882	3452	109198	35774	323841	144033	111551	401589
2003	568630	424564	1213099	50370	3005	113183	34906	347124	146019	122964	395527
2004	568686	422715	1256648	53470	2855	124460	38821	343812	152324	132343	408564
2005	579368	417095	1262877	53017	2777	123911	38000	370276	143745	126436	404715
2006	573501	416729	1331586	51867	2853	113438	42218	362774	182938	162804	412696

Attachment 6

Kansas v. Nebraska & Colorado,
No. 126, Orig., U.S. Supreme Court

Designated Schedule for Resolution

December 19, 2007	Kansas provides proposed remedy to Nebraska with copies to Colorado and United States.
February 4, 2008	If agreement is not reached, Kansas submits dispute to the Republican River Compact Administration (RRCA) as a "fast-track" issue.
March 5, 2008	By this date, the RRCA meets to resolve the dispute.
March 20, 2008	If the RRCA fails to resolve the dispute, Kansas invokes nonbinding arbitration.
April 3, 2008	Kansas or Nebraska may amend the scope of the dispute to address additional issues.
April 17, 2008	Kansas and Nebraska submit names of proposed arbitrators and qualifications to each other.
April 28, 2008	Kansas and Nebraska representatives meet in person or by telephone to confer and agree on arbitrators; if agreement cannot be reached, the selection is submitted to CDR Associates of Boulder, Colo.
May 1, 2008	Arbitrators engaged.
May 12, 2008	Initial meeting/scheduling conference of Kansas and Nebraska before the arbitrators.
November 12, 2008	Deadline to complete arbitration and render decision.
December 12, 2008	Kansas and Nebraska give written notice whether they will accept the arbitrators' decision.
Thereafter	If the dispute is not resolved, Kansas makes the appropriate filings in the U.S. Supreme Court.