Addendum to Expert Report of January 4, 2008 (Revised Attachment 5 to Dec. 19, 2007 Kansas Letter)
Projected Reduction of Nebraska Impact under the NRD IMPs

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Introduction

In David Barfield's letter of December 19, 2007 to RRCA, Attachment 4 showed that Nebraska's groundwater consumptive use in the Republican River basin must be reduced to an average of 175,000 acre-feet/year for Nebraska to achieve sustained compliance with the Compact. In Attachment 5 of the same letter (revised January 4, 2008), consumptive use by Nebraska under baseline conditions was projected to average 268,000 acre-feet/year for future years 2007-2057, and presented a remedy that is projected to achieve compliance in less than a decade. The proposed remedy does this by, first, shutting down irrigation within an average of 2.5 miles from the Republican River and tributaries and second, cutting back irrigated area within the Republican River basin to Nebraska's reported area in the year 2000 (see map in Fig. 1 of Attachment 5). The first component of Kansas' proposed remedy, i.e. the focused shutdown along streams, was preceded by similar concepts that have been explored by Nebraska (DNR designation of Quick Response Areas, December 2, 2004: Quick Response Area Wells map, attached).

In response to Kansas' proposed remedy for Nebraska compliance presented in a letter from David Barfield, Nebraska proposed the Integrated Management Plans (Nebraska, Feb 2008, Tab 3a) for Nebraska's Upper, Middle and Lower Republican River Natural Resource Districts (collectively, the NRD IMPs) as a means of achieving compliance with the Compact.

Subsequent to Nebraska's proposal of the NRD IMPs, Kansas developed a future scenario using the RRCA groundwater model of Nebraska's proposed remedy under the NRD IMPs. This Attachment presents the methods and assumptions for this scenario, the reduction of Nebraska's impacts that might be expected under the IMPs, and an assessment of their potential effectiveness.

Method and assumptions

Based on suggestions by Nebraska (February 2008, Tab 2a), Kansas developed a variation on its future scenarios under baseline conditions and its proposed remedy in which the spatial distribution of Nebraska pumping in future years is consistent with the current spatial distribution of irrigated area as developed by Nebraska. To utilize this distribution for future years, pumping in each grid cell is specified as the product of current irrigated area and irrigation depth (acre-ft/acre, or ft) in the NRD associated with the cell for the historical year corresponding to the future year. This variation on our future scenarios was found to have only a small and insignificant effect on projected impacts of Nebraska pumping and imported water

supply credits. However, the baseline scenario resulting from this exercise was found to be useful as a basis for evaluating NRD IMP scenarios.

To isolate the effect of the NRD IMPs, conditions differ from the above version of the baseline scenario only in the groundwater irrigation depths that are applied in the three Republican River NRDs. Baseline conditions are applied to the remaining NRDs. The primary assumption for the NRD IMP scenarios is that groundwater irrigation depths are to be, on the average, 80 percent of historical irrigation depths for the years 1998-2002, as prescribed by the IMPs. A secondary assumption for the scenarios is that a temporal variation is superimposed on the irrigation depths for the three Republican River NRDs that mimics the temporal variation of historical irrigation depths under baseline conditions for the years 1990-2006.

The effect of the Republican River NRD IMPs on groundwater irrigation depths for the model scenarios is summarized in Table 1a, Lines 1-5 as follows.
1. Historical irrigation depths for each of the three Republican River NRDs averaged over the years 1990-2006 as the basis for our future scenarios (ft of water pumped per unit area irrigated).
2. Historical irrigation depths averaged over the years 1998-2002 (ft).
3. IMP irrigation depths as 80 percent of the 1998-2002 average depths (ft).
4. Differences between the IMP irrigation depths [3] and the 1990-2006 average depths [1] (ft).
5. Change in irrigation under IMPs as a fraction of baseline conditions, [4] / [1].

Table 1a. IMP average irrigation depths for the Republican River NRDs, ft (acre-ft/acre)

Line	item	Upper Repub	Middle Repub	Lower Repub	Sum over Repub NRDs
1	1990-2006 average baseline, ft/yr	1.16721	1.28654	0.99052	1.14928
2	1998-2002 average baseline, ft/yr	1.34554	1.46353	1.10480	1.30908
3	IMP=0.8*(1998-2002 avg), ft/yr	1.07643	1.17083	0.88384	1.04727
4	IMP – (1990-2006 avg baseline), ft/yr	-0.09077	-0.11571	-0.10669	-0.10201
5	Irrigation change as fraction of 1990-2006 average baseline conditions = [4]/[1]	-0.0778	-0.0899	-0.1077	-0.08876

Table 1b shows the effect of the IMPs on pumping and net extraction (pumping – return flow = consumptive use). 2006 historical irrigated area (Line 6) is assumed for pumping under both baseline conditions (Line 7) and the NRD IMP conditions (Line 8). The change in pumping under the IMPs (Line 9) is with respect to baseline conditions [8] – [7]. The change in net extraction (pumping – return flow = consumptive use) is given by Line 10, assuming continued 20 percent return flow, or by Line 11, assuming 15 percent return flow for the Republican River NRDs.

Table 1b. Effect of IMPs on pumping and consumptive use,.

Line	item	Upper Repub	Middle Repub	Lower Repub	Sum over Repub NRDs
6	2006 gw irrigated area, acres	459849	277778	292087	1029713
7	projected baseline pumping, AF/yr	536738	357372	289319	1183429
8	projected IMP pumping, AF/yr	494996	325229	258158	1078383
9	Change in pumping under IMP, AF/yr	-41741	-32142	-31162	-105045
10	Change in CU under IMP at 20pct rf, AF/yr	-33393	-25714	-24929	-84036

11	Change in CU under IMP at 15pct rf, AF/yr	-8643	-9452	-12021	-30117

A secondary assumption under the NRD IMP scenario is that the temporal variation of annual irrigation depths for the Republican River NRDs would be similar to the temporal variation under baseline conditions. Pumping under baseline conditions for the future scenario is represented by the irrigation depths for each NRD in years 1990-2006 listed in Table 2. The temporal variation of the irrigation depths for the Republican NRDs was applied to the NRD IMP scenario as follows. For each of the three Republican River NRDs, the left half of Table 3 shows the ratios of annual irrigation depths to the average for years 1990-2006 under baseline conditions; the average taken over each set of ratios for years 1990-2006 equals 1. The products of these ratios and the IMP average depths for the NRDs (from Line 3 of Table 1a), shown in the right half of Table 3, are used to represent irrigation depths under the IMPs. As a check, the averages of the irrigation depths listed in Table 3 for years 1990-2006, shown at the bottom of Table 3, equal the averages listed on Line 3 of Table 1a.

Table 2. Applied groundwater irrigation depth, ft (acre-ft/acre) by NRD 1990-2006: baseline scenario (includes extent of proposed no-pump zone).

Year	Little Blue	South Platte	Twin Platte	Central Platte	Upper Repub	Middle Repub	Lower Repub	Tri-Basin
1990	0.7664	2.4690	1.7183	1.3757	1.4224	1.5982	1.1434	1.0617
1991	1.1633	2.5162	1.7247	1.4874	1.2537	1.5999	1.4713	1.3636
1992	0.4861	1.5654	1.0926	0.9873	0.9119	0.9065	0.7805	0.7426
1993	0.1738	1.0931	0.6921	0.2650	0.7149	0.3592	0.2327	0.2736
1994	0.6616	2.4035	1.5676	0.9823	1.3437	1.4630	0.9061	0.7943
1995	1.0591	2.2331	1.5790	1.3958	1.1743	1.6209	1.3224	1.2443
1996	0.6298	1.4251	0.9104	0.8874	0.8550	0.9142	0.6441	0.6925
1997	0.8904	2.0783	1.3868	1.4261	1.2994	1.4691	1.1101	1.1093
1998	0.6128	2.1737	1.3426	1.1554	1.3565	1.4969	0.9211	0.8514
1999	0.6550	1.7658	1.0672	0.7689	1.0319	0.6937	0.7351	0.7086
2000	1.0267	3.3118	2.0487	1.5421	1.7295	1.8577	1.1816	1.2248
2001	0.9242	2.2754	1.5682	1.1912	1.0987	1.3996	1.0766	0.9353
2002	1.2898	3.0184	2.2156	1.9472	1.5111	1.8698	1.6095	1.2772
2003	1.1704	2.9853	1.8799	1.7464	1.2501	1.4574	1.1801	1.1931
2004	0.9479	2.4981	1.4686	1.4657	1.0571	1.2496	0.9696	1.0464
2005	0.8716	2.2417	1.3131	1.2921	0.8991	1.0107	0.8860	0.9498
2006	0.8944	2.7437	1.8240	1.3838	0.9332	0.9048	0.6686	0.8982
'90-'06	0.8367	2.2822	1.4941	1.2529	1.1672	1.2865	0.9905	0.9628

Table 3. The ratios of annual irrigation depths to the average over years 1990-2006 under baseline conditions for the Republican River NRDs (left-hand columns) are multiplied by the NRD IMP depths (from Line 3 of Table 1) to give the assumed annual groundwater irrigation depths for the Republican River NRDs 1990-2006 under the NRD IMP scenario (right-hand columns).

	Ratios of annual baseline irrigation depths to average for 1990-2006, $f_i=d_i/d_{avg}$				Annual IMP irrigation depths: product of ratio with NRD IMP depth, ft		
Year i	Upper Repub	Middle Repub	Lower Repub		Upper Repub	Middle Repub	Lower Repub
1990	1.2186	1.2422	1.1544		1.3117	1.4545	1.0203
1991	1.0741	1.2436	1.4854		1.1562	1.4560	1.3129
1992	0.7813	0.7046	0.7880		0.8410	0.8249	0.6965
1993	0.6125	0.2792	0.2349		0.6593	0.3269	0.2077
1994	1.1512	1.1371	0.9148		1.2392	1.3314	0.8085
1995	1.0061	1.2599	1.3350		1.0830	1.4751	1.1799
1996	0.7325	0.7106	0.6503		0.7885	0.8319	0.5748
1997	1.1132	1.1419	1.1207		1.1983	1.3370	0.9905
1998	1.1622	1.1635	0.9299		1.2510	1.3623	0.8219
1999	0.8841	0.5392	0.7422		0.9517	0.6313	0.6560
2000	1.4817	1.4440	1.1929		1.5950	1.6906	1.0543
2001	0.9413	1.0879	1.0869		1.0133	1.2737	0.9607
2002	1.2946	1.4534	1.6249		1.3936	1.7016	1.4361
2003	1.0711	1.1328	1.1914		1.1529	1.3263	1.0530
2004	0.9057	0.9713	0.9789		0.9749	1.1372	0.8652
2005	0.7703	0.7856	0.8944		0.8292	0.9198	0.7905
2006	0.7995	0.7033	0.6750		0.8606	0.8234	0.5966
'90-'06	1.0000	1.0000	1.0000		1.0764	1.1708	0.8838
Change:					-0.091	-0.116	-0.107

Results: Nebraska impact reduction under NRD IMPs

Compared to Kansas' baseline scenario, the NRD IMP scenario corresponds to average (2007-2057) reductions of 105,044 ac-ft/yr (afy) in pumping and 20,258 afy in return flow, or a net reduction in consumptive use of 84,786 afy. Under this scenario, the net sum of Nebraska pumping impact and imported water supply credit is reduced by 9,605 acre-feet/year.

Sensitivity analysis: NRD IMPs with 15 percent return flow

It would be more realistic, however, to assume that irrigation return flows will be reduced by irrigators' efforts to use water more efficiently when pumping amounts are restricted. Increased irrigation efficiency has already occurred in the basin during the recent decades. Without attempting to predict what might result, an alternative scenario was run as a sensitivity test in which a return flow fraction of 15 percent was assumed for the Republican River NRDs, but with no change to return flows elsewhere in the Nebraska portion of the model domain. For example, in other parts of the model domain the following return flow percentages were assumed: South Platte, 25.1 percent; Twin Platte, 21.2 percent; Central Platte, 22.9 percent; Tri-Basin, 20.96

percent. Under this sensitivity test of the NRD IMP scenario, average (2007-2057) pumping reduction remains at 105,044 afy, but return flow is reduced by 74,183 afy, and net pumping by only 30,861 afy. Under this sensitivity test scenario, the net sum of Nebraska pumping impact and imported water supply credit is reduced by only 3,823 acre-feet/year.

Figure 1 shows the projected annual net sum of Nebraska pumping impacts and imported water supply under baseline conditions (dark blue solid line, top), Kansas' proposed remedy (dark blue line, bottom), NRD IMPs with return flow continuing to be 20 percent (dashed line) and NRD IMPs with return flow reduced to 15 percent within the Republican River NRDs. Figure 2 shows computed Republican River baseflow under for the baseline scenarios and for the NRD IMP scenarios assuming 20 percent and 15 percent return flow.

Conclusions

The IMP scenarios presented above show that the impact reduction that might be achieved under the IMPs is far less than what is required to bring Nebraska into compliance even under the unrealistic assumption that return flows of 20 percent can be maintained. We conclude that the IMPs would be ineffective, not only because the pumping cutbacks would be too small, they would also be too diffuse, rather than focused along streams; and, finally, because the IMPs do not specifically address the consumptive use associated with reduced return flows.

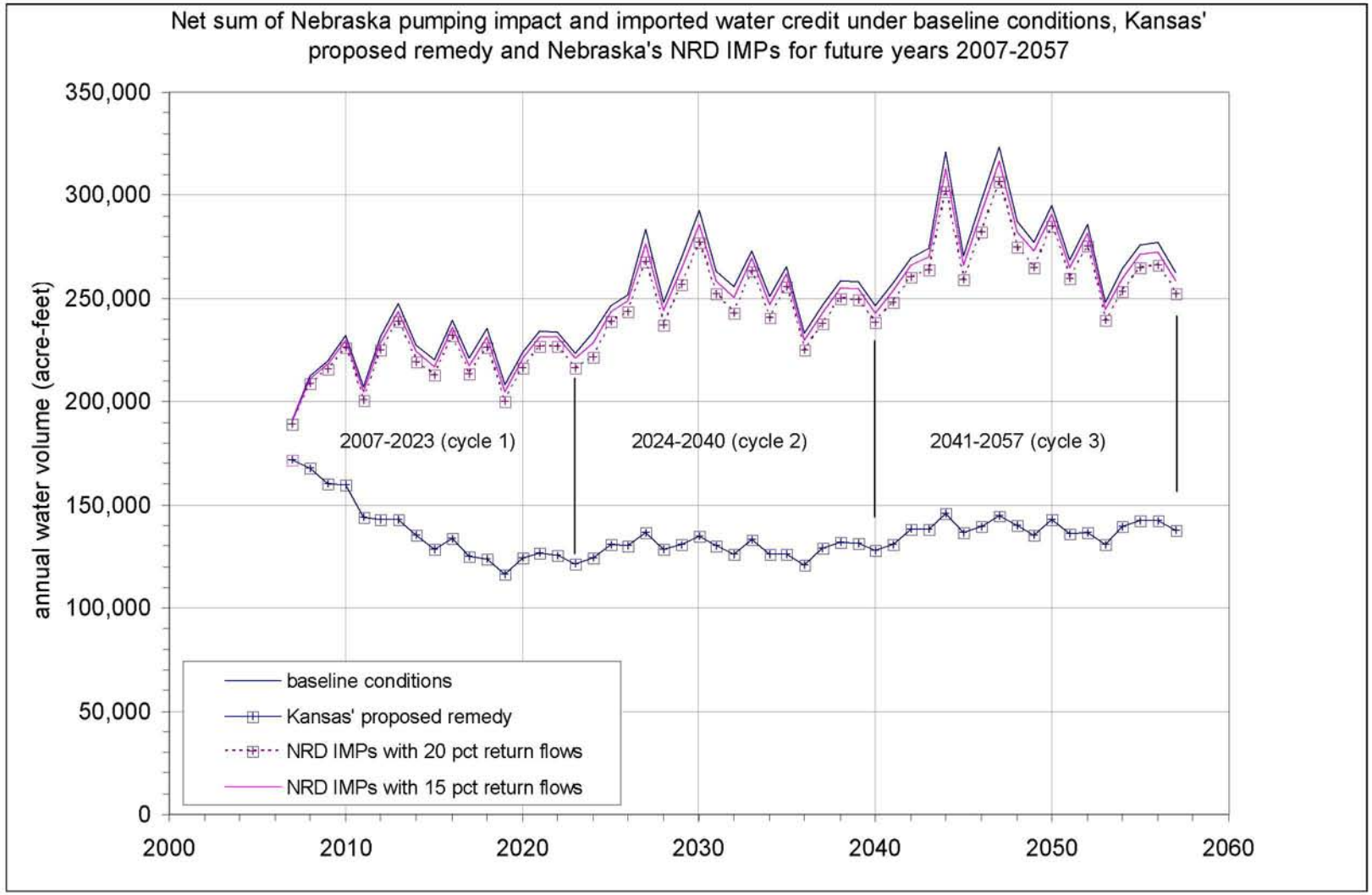


Fig. 1. Net sum of Nebraska pumping impact and imported water supply credit under baseline conditions, Kansas' proposed remedy and Nebraska's NRD IMPs assuming either 20 percent return flow (dashed line) or 15 percent return flow (pink line).

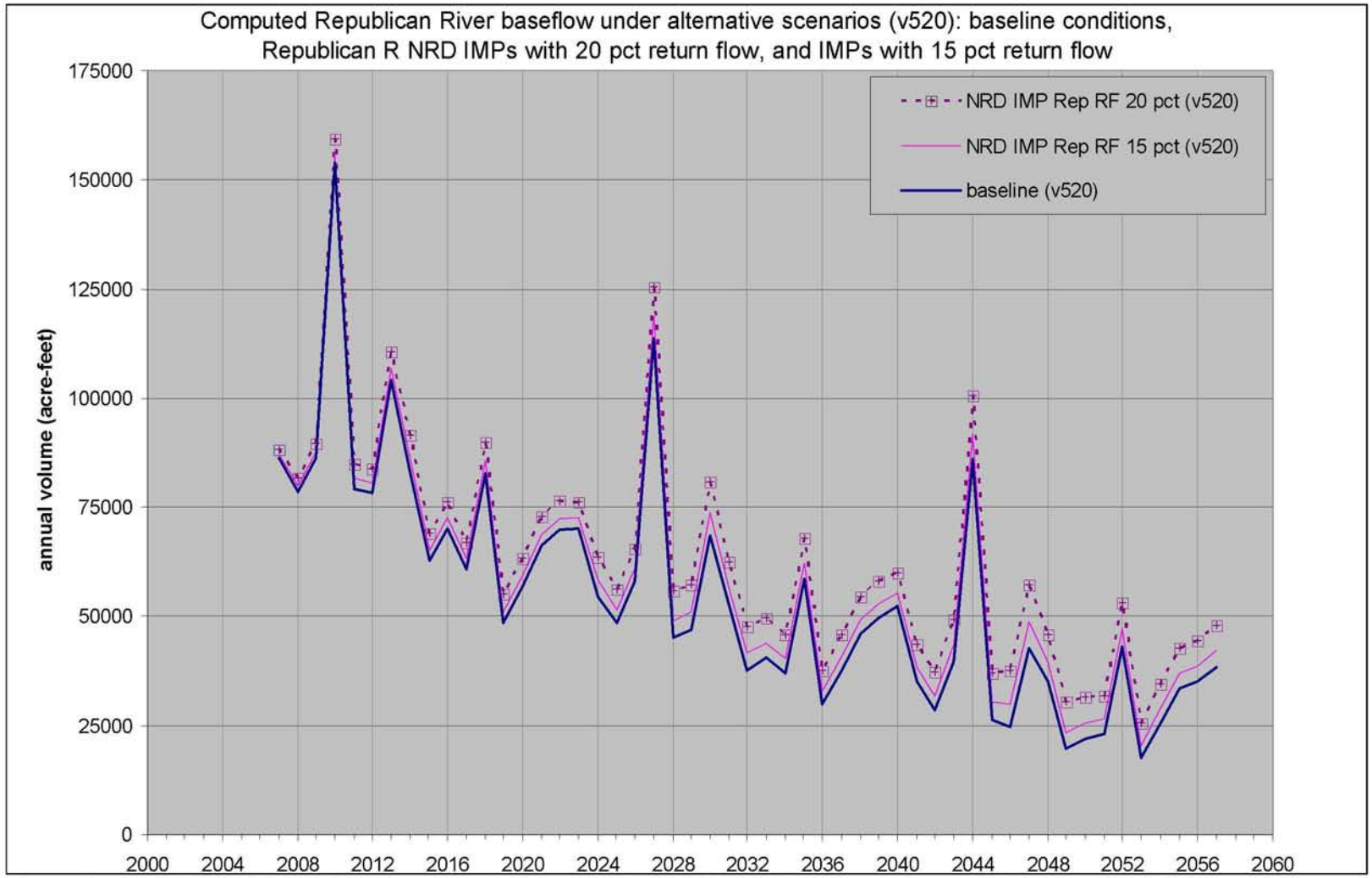
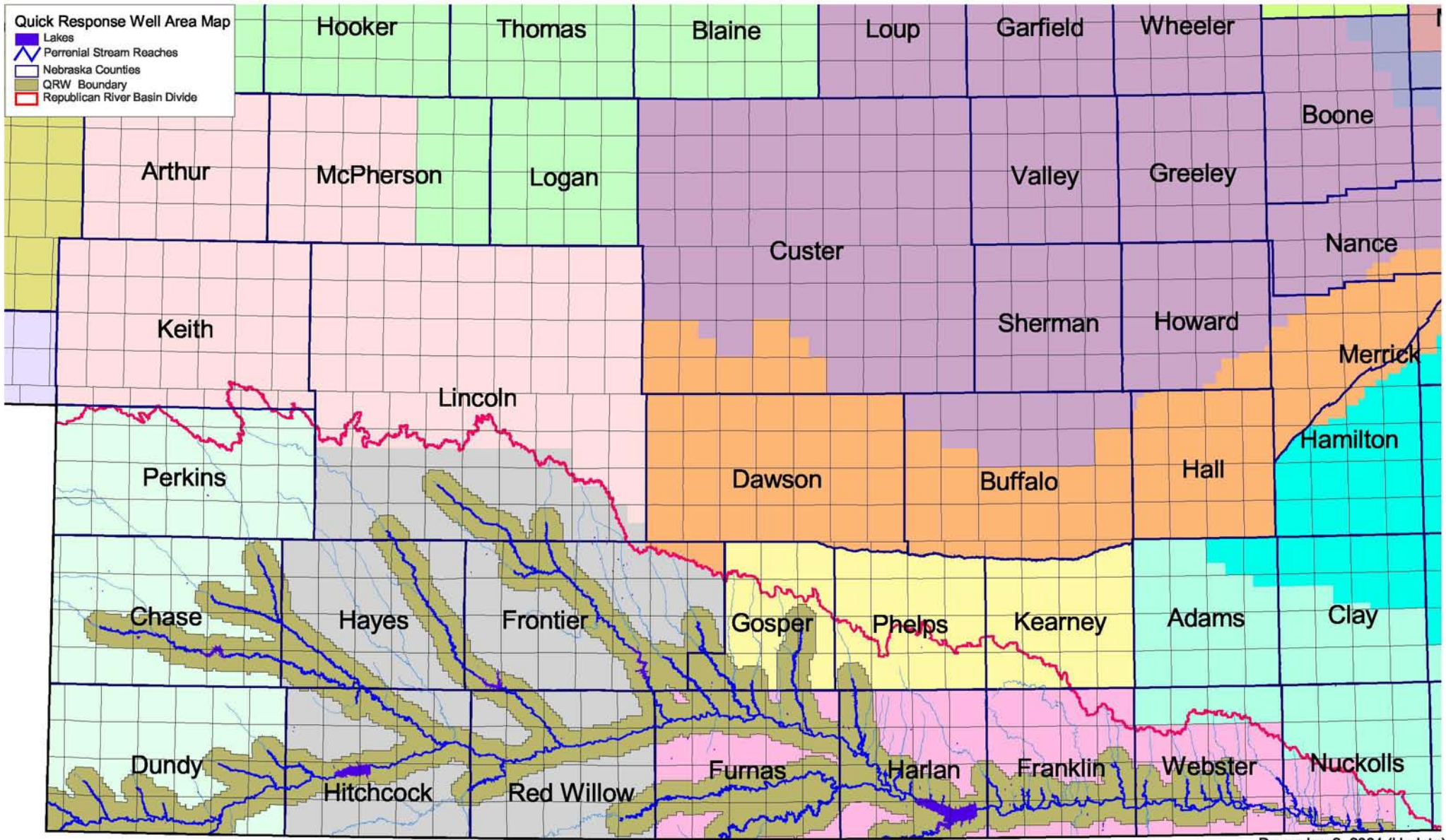


Fig. 2. Computed Republican River flow (total accounts) under baseline conditions and scenarios based on Nebraska's NRD IMPs assuming either 20 percent return flow (dashed line) or 15 percent return flow (pink line).



December 2, 2004 (Update)

Wells within the QRW Boundary were determined by the Republican River Compact Administration Ground Water Model to have a relatively short term affect on streamflow.

10 0 10 20 30 40 50 Miles

Stateplane Projection NAD 1983 - Feet

For administration purposes the QRW boundary has been delineated to the nearest quarter section of land. Below Guide Rock only lands irrigated with water supplies originating above Guide Rock are shown.