SSP-1414

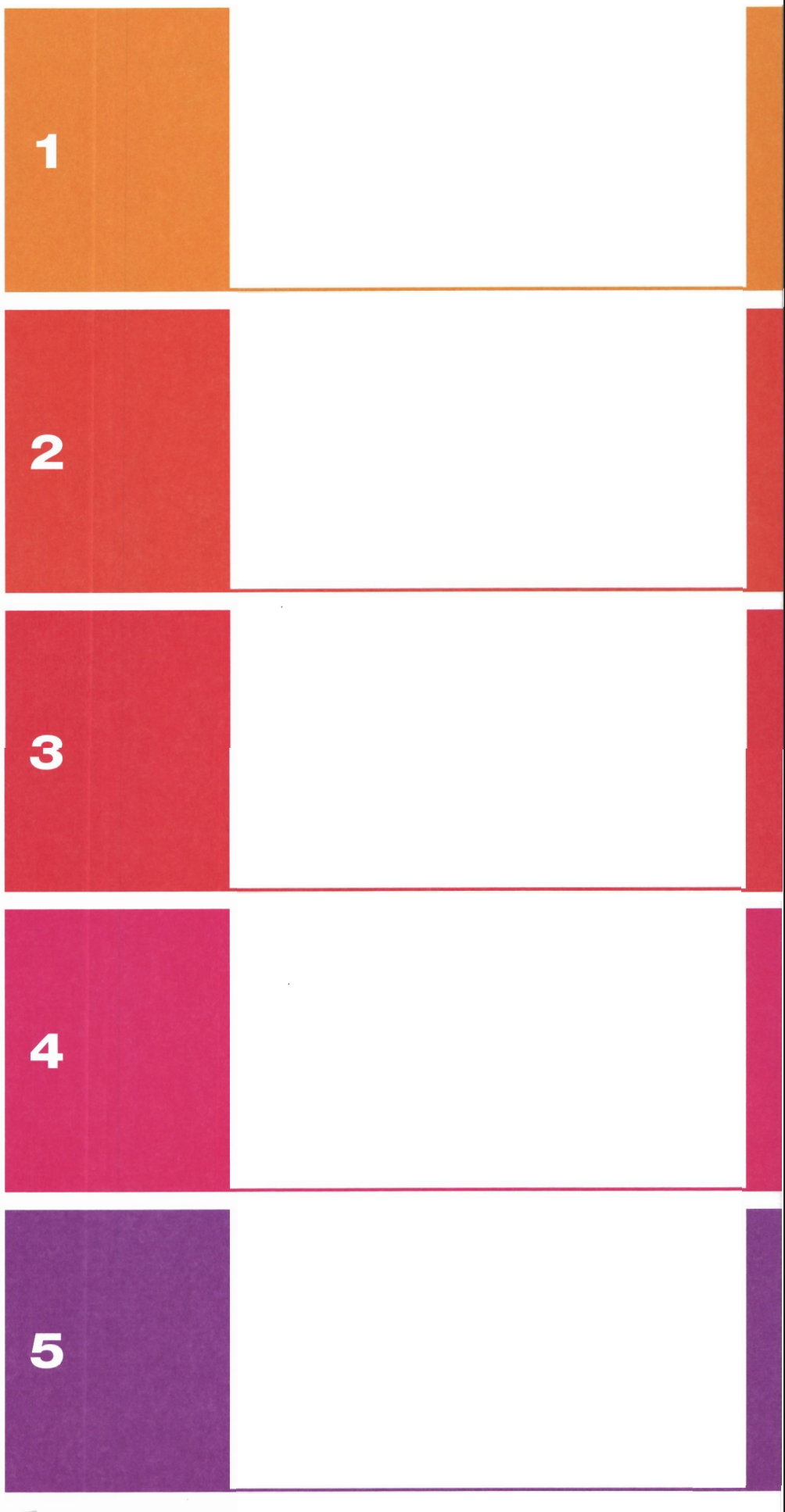
Republican River

Rock Creek

Augmentation

June 2013

SPL Miscellaneous



STATE OF NEBRASKA

Dave Heineman
Governor

DEPARTMENT OF NATURAL RESOURCES
Brian P. Dunnigan, P.E.
Director

February 8, 2013

IN REPLY TO:

David Barfield
Kansas Commissioner, RRCA
Kansas State Engineer
Division of Water Resources
109 SW 9th Street, 2nd Floor
Topeka, KS 66612-1283

Dick Wolfe
Colorado Commissioner, RRCA
Colorado State Engineer
Colorado Division of Water Resources
1313 Sherman Street, Room 818
Denver, CO 80203

RE: Rock Creek Augmentation Project; Submittal to RRCA

Dear Commissioners Barfield and Wolfe:

The State of Nebraska hereby submits its Rock Creek Augmentation Proposal (Proposal) to the RRCA pursuant to Subsection VII.A of the Final Settlement Stipulation. A complete description of the Proposal is set forth in the attached Exhibit A.

Pursuant to Subsection VII.A.3, Nebraska hereby designates this as a "Fast Track" issue and seeks its resolution within the next 30 days. A timeframe for resolution, including non-binding arbitration (if necessary), is included as Exhibit B. Accordingly, Nebraska requests that the Chairman please schedule a Special Meeting of the Republican River Compact Administration on or before March 10, 2013.

Sincerely,

Brian P. Dunnigan, P.E.
Director

Enclosures

cc: John Chaffin, U.S. Department of the Interior
James J. DuBois, U.S. Department of Justice
Col. Anthony J. Hofmann, U.S. Army Corps of Engineers
Aaron M. Thompson, U.S. Bureau of Reclamation

Exhibit A

Rock Creek Augmentation Project

Rock Creek Augmentation Project

Submitted to the Republican River Compact Administration

February 8, 2013

Nebraska
Department of Natural Resources

I. Project Background and FSS Requirements for Augmentation Projects

The Upper Republican Natural Resources District (URNRD) is developing the Rock Creek Augmentation Project (Project) located in southwest Nebraska (Figure 1). The purpose of this project is to assist Nebraska in maintaining compliance with the Republican River Compact (Compact). The Project involves the retirement of the 23 existing irrigation wells and the 3,262 certified irrigated acres those wells irrigated. Ten augmentation wells were drilled for the project, replacing the irrigation wells and providing an optimized capacity and spatial distribution to match the design capacity of the Project. The lands that were previously cropped are being seeded back to natural grasses. Groundwater pumped from the new augmentation wells will be delivered by means of a pipeline that spans the approximately six miles from the wells to the discharge location directly into Rock Creek.

The Final Settlement Stipulation (FSS) specifically recognizes augmentation as a management tool to facilitate Compact compliance. Augmentation is referenced in three locations throughout the FSS. The first occurs in Section III in the list of exceptions to the moratorium on new wells. Subsection III.B.1.k., states that the moratorium on new wells shall not apply to the following:

> *Wells acquired or constructed by a State for the sole purpose of offsetting stream depletions in order to comply with its Compact Allocations. Provided that, such Wells shall not cause any new net depletion to stream flow either annually or long-term. The determination of net depletions from these Wells will be computed by the RRCA Groundwater Model and included in the State's Computed Beneficial Consumptive Use.* ***Augmentation plans*** *and related accounting procedures submitted under this Subsection III.B.1.k. shall be approved by the RRCA prior to implementation.*

The second and third references to augmentation occur in Section IV, which lays out the provisions for Compact accounting under the FSS. Subsection IV.A. states:

> *The States will determine Virgin Water Supply, Computed Water Supply, Allocations, Imported Water Supply Credit,* ***augmentation credit*** *and Computed Beneficial Consumptive Use based on a methodology set forth in the RRCA Accounting Procedures, attached hereto as Appendix C.*

There presently are no "methodologies" set forth in the Republican River Compact Administration (RRCA) Accounting Procedures and Reporting Requirements (Accounting Procedures) to determine the augmentation credit referenced in Subsection IV.A. The only additional guidance in the FSS is found in Subsection IV.H., which states:

> ***Augmentation credit****, as further described in Subsection III.B.1.k., shall be calculated in accordance with the RRCA Accounting Procedures and by using the RRCA Groundwater Model.*

Finally, Subsection I.F. of the FSS provides:

> *The RRCA may modify the RRCA Accounting Procedures, or any portion thereof, in any manner consistent with the Compact and this Stipulation.*

Taken together, these references suggest the following:

1. If the project involves the acquisition or construction of augmentation wells in the moratorium area, those wells may not cause a "new" net depletion either annually or over the "long-term."

2. The RRCA Groundwater Model (Model) will be used to determine the extent of any net depletion and whether such net depletion is "new."

3. The Accounting Procedures will be revised to reflect the appropriate methodology for calculating the augmentation credit.

4. The Model will be used to calculate the credit, assuming, of course, that the project involves an activity that implicates groundwater Computed Beneficial Consumptive Use (CBCU).

5. The RRCA must approve any augmentation plan and related accounting procedures before a state may receive "augmentation credit" for the project, beyond the effect of simply increasing water supply, which will manifest itself in the current Accounting Procedures.

The States elaborated on these concepts before Special Master Vincent McKusick in 2003. (Transcript at 81-3; id. at 16-17.) Using the example there provided, a State would be entitled to claim as an "augmentation credit" all water pumped to the stream.

II. Baseline Conditions of the Project Area

This section describes the conditions of the project area prior to the acquisition of lands to implement the Project (Figure 2). Tables 1 and 2 provide information on the historical pumping and certified irrigated acreage of the 23 wells which were retired and decommissioned when the land acquisition was made. The cropped lands (irrigated acres and dryland acres) that were acquired as part of this project will be seeded back to natural grasses and irrigation that previously occurred will be retired permanently.

III. Operational Aspects of the Project

This section describes the operational conditions of the Project (see Figure 3). The new augmentation wells developed as part of the Project will be used to offset stream depletions to assist the State of Nebraska with Compact compliance efforts. The actual amount delivered in any one year will be subject to current conditions affecting Nebraska's Compact compliance outlook and on ensuring that no new net depletion is

associated with the project. Thus, Project operations will fall into two categories: 1) Annual operations to support Compact compliance efforts (Compact Operations Years) and 2) Annual operations specially designed to ensure that no new net depletions occur (Maintenance Operations Years) during those years when the Project is not needed to support Compact compliance efforts.

The groundwater pumping associated with the new augmentation wells will be incorporated into the Model on an annual basis and charged as groundwater CBCU by the State of Nebraska. The detailed analysis of potential net depletions associated with project operations relative to historical conditions, and an operational pattern that would have prevented the occurrence of any new net depletions, is described in Section IV.

The augmentation water delivered to Rock Creek via the Project pipeline will be measured and incorporated into the Accounting Procedures. Details of the Accounting Procedure modifications necessary to properly account for the Augmentation Water Supply (AWS) Credit are described in Section V and Appendix A.

IV. Groundwater Modeling Analysis of the Project

This section describes the evaluation of any change in the groundwater CBCU with respect to potential augmentation deliveries. Any increase in groundwater CBCU, or new depletion, is compared to the augmentation deliveries to assess the net impact of the project operations on streamflows of the Republican River Basin. The new depletion is determined by comparing the groundwater CBCU under the baseline (i.e., groundwater pumping for irrigation in the Project area) simulation of the Model to the groundwater CBCU that results from a Model simulation with the Project operating under this augmentation plan. Finally, any new depletion is compared to the AWS Credit in that same year to determine the net depletion to streamflow. The analysis in this section evaluates operations under a historical period, operations under a hypothetical future scenario, and a tracking system that will ensure no new net depletions as the project is operated going forward.

A. Net Depletions of Project Operations When Assessed Against Historical Baseline Conditions

This analysis evaluates hypothetical Project operations under historical circumstances that may have warranted operation- of the Project. The 1985-2010 period was chosen for this analysis to represent a reasonably long historic period as well as capture multiple cycles of Compact Operation Years. The historic groundwater CBCU under baseline Project conditions is represented by the Model simulations for the period 1985 through 2010 (26 years). The Model files used in this baseline simulation were intended to be consistent with the historical files developed for assisting with the RRCA annual accounting. These same Model simulations were then updated to reflect how Project operations may have functioned through this period. The key difference for the Model simulation of Project operations is that the historical recharge and groundwater pumping were modified for those Model cells which

correspond to the Project area. The recharge in the modified historical simulation differed from the recharge in the historical simulation in that the baseline recharge was modified to remove the additional recharge associated with Project irrigated lands for the entire simulation period.

The Project has the capacity to provide an augmentation delivery of up to 20,000 acre-feet in a given year. In this example, the baseline pumping conditions were modified in a manner that reduced groundwater pumping to 300 acre-feet during Maintenance Operations Years (17 of 26 years) and modified groundwater pumping to reflect a volume of 15,000 acre-feet during Compact Operations Years (Table 3). The 15,000 acre-feet value is intended to serve as a representative average value of typical Compact Operations Years. The minimum pumping value of 300 acre-feet was adopted as the Maintenance Operations Year pumping volume in this scenario because it was determined to be more than sufficient to offset any new depletion related to Compact Operations Years. Documentation and model files for this simulation are contained in Appendix B.

The Compact Operations Years include: 1988-1991 and 2002-2006. The Maintenance Operations Years for the simulation include: 1985-1987, 1992-2001, and 2007-2010. The Compact Operations Years were chosen from the historical record as they represent periods of lower water supplies when it is more likely that the project would be operated to offset a projected shortfall in Nebraska's Compact balance. The results of the historical simulation under Project operations, as compared to historical operations, are summarized in Table 4 and Figure 4. Under the Project operations described in Table 3, the Project would not cause a new net depletion in any of the historic years as shown in Table 4.

B. Net Depletions of Project Operations When Assessed Against Future Baseline Conditions

The second analysis of Project operations was to evaluate a hypothetical future scenario. While the process Nebraska intends to use to annually track net depletions of the Project will ensure the standard of no new net depletions is met each and every year now and into the future, a future scenario was developed to address questions or concerns that may be raised by the other States. This scenario was developed from a hypothetical future scenario first created by the State of Kansas. This scenario was utilized by Kansas for expert reports generated in 2011 for Kansas v. Nebraska and Colorado, Original No. 126. It is recognized that this scenario represents one of an infinite number of potential future scenarios and in no way serves as a barometer of what future conditions may be. Moreover, this analysis is simply presented to illustrate how net depletions may be manifest over the long term.

This portion of the analysis was completed by comparing the results of a simulation of hypothetical future conditions for the period 2010-2069 for the following conditions: 1) the certified irrigated acres continue to be irrigated in a manner consistent with the historical hydrology with some consideration for current regulations; and 2) with the irrigation removed and the project operated to provide augmentation deliveries. This hypothetical future scenario was developed by

repeating the years 1995-2009 four times into the future. The key difference for the simulation of project operations is that the recharge due to irrigation and groundwater pumping were modified for those model cells which correspond to the project area. The modified simulation differed from the "baseline" (unchanged) simulation in that the baseline recharge was modified to remove the additional recharge associated with project irrigated lands for the entire simulation period.

The baseline pumping conditions were modified in a manner that reduced groundwater pumping to 300 acre-feet during Maintenance Operations Years (40 of 60 years) and modified groundwater pumping to reflect a volume of 15,000 acre-feet during Compact Operations Years (Table 5). The results of the future simulation of new depletions and the net depletion given the AWS credit for each year are summarized in Table 6 and Figure 5. Documentation and model files for this simulation are contained in Appendix B.

As demonstrated by the results in Table 6, the net depletions are always negative for this scenario, indicating the AWS Credit is always greater than the new depletion and streamflow is increased by that value. Therefore, the pumping volume of 300 acre-feet per year for the Maintenance Operations Years is sufficient to ensure no new net depletions in this hypothetical future scenario. As stated above, this value would be adjusted as necessary to ensure no new net depletions in every year.

C. *Process for Tracking Net Depletions and Determining Future Pumping During Maintenance Operations Years to Ensure No New Net Depletions*

In the previous examples, the net depletions could be analyzed for the entire time period and a pumping volume chosen for the Maintenance Operations Years such that the project would not cause any new net depletion. For project operations going forward under this plan, a process is needed to be able to track any new depletions caused by the project operations to determine a sufficient pumping volume for the Maintenance Operations Years to ensure no new net depletions in those years. The following process will achieve that result.

The historic groundwater pumping for irrigation at the project site is well documented (Table 1). Therefore, while the official Model runs will incorporate the actual pumping that occurs in any given year, Nebraska will perform additional Model simulations to determine any new depletions that may occur each year due to the Project operations above those that would have existed had the Project remained under its historical operations (irrigated agriculture). These model simulations will essentially involve constructing an additional model scenario for each year that reflects the average historical irrigation pumping and irrigation recharge. The difference in the groundwater CBCU in this hypothetical simulation relative to the official Model runs will represent the increase (or decrease) in depletions as a result of the Project.

These simulations will only provide an indication of the new depletions that occurred under project operations after a given year has ended. However, the pumping volume

during a Maintenance Operations Year would need to be determined at the beginning of that year. Therefore, the pumping volume that will occur in a Maintenance Operations Year will be based on the maximum new depletion observed from project operations over time. This maximum value will be adjusted accordingly to account for potential increases in new depletions in that year over and above the historical observed maximum. In no event will the Maintenance Operation Year pumping be less than 300 acre-feet.

Nebraska will notify the states prior to the initiation of Project operations in the upcoming year to inform them of the volume of water that is intended to be pumped by the Project. Additionally, the Model runs conducted by Nebraska to determine the Maintenance Operations Year pumping will be exchanged with the other states during the annual data exchange. This additional element of the annual data exchange is set forth in Appendix A and reflects the fact that the State of Nebraska would annually report on the operations of the Project.

V. RRCA Accounting Procedure Modifications for Augmentation Credit Calculations

The examples above demonstrate how the Model would be used to determine any new depletion from the operation of the Project. This section describes the modifications to the Accounting Procedures needed to determine the augmentation credit to be provided in conjunction with the Project. The August 12, 2010, version of the Accounting Procedures are included as Appendix A, with the modifications required to implement this proposal indicated in red-line format. Below is an example of the current RRCA sub-basin calculations for determining the Virgin Water Supply (VWS) as well as the necessary modifications to account for the AWS and any new depletion caused by the Project.

Current Accounting Procedures Formula for Calculating Rock Creek Subbasin Virgin Water Supply:

VWS = Gage + All CBCU – IWS

VWS = 1,000 + 1,000 + 0 – 0 = 2,000

Nebraska Allocation = 0.6934[1] * 2,000 = 1,386.8

Kansas Allocation = 0.3066 * 2,000 = 613.2

Nebraska Balance in Rock Creek Subbasin = Nebraska Allocation – Nebraska CBCU = 1,386.8 – 1,000[2] = 386.8

[1] The allocation percentages for both Nebraska and Kansas include the each states share of the unallocated water supply and that the VWS is equivalent to the CWS (i.e., no flood flows included).
[2] Assumes all CBCU is assigned to Nebraska.

Proposed RRCA Accounting Procedures to include Augmentation Water Supply Credit (with Project operations of 300 acre-feet and an additional groundwater depletion of 5 acre-feet):

Gage + All CBCU – IWS – AWS

VWS = 1,295 + [1,005 - 300] + 0 – 0 = 2,000

Nebraska Allocation = 0.6934 * 2,000 = 1,386.8

Kansas Allocation = 0.3066 * 2,000 = 613.2

Nebraska Balance in Rock Creek Subbasin = Nebraska Allocation – Nebraska CBCU + AWS Credit = 1,386.8 – 1,005 + 300 = 681.8

The Main Stem accounting procedures would remain unchanged as the necessary modifications are reflected in the Designated Drainage Basin[3] where the Augmentation Plan is being implemented. Examples of the impact of the AWS Credit on the final Compact Accounting Balance for Tables 3C and 5C are illustrated below (Tables 7 and 8)[4]. Similar modifications to those made to Tables 3C and 5C of the Accounting Procedures would also be made to Tables 5D and 5E.

VI. Summary

This report has described the required elements of an augmentation plan pursuant to the requirements set forth in the FSS. Nebraska has included additional elements within this plan, beyond those strictly required by the FSS, to accommodate previous comments provided by the other states as wells as any concerns the states may have related to data sharing and future tracking of project operations. Nebraska submits this plan with time being of the essence and seeks the good faith efforts of the states in working to implement this plan in a timely fashion.

[3] As defined in the Accounting Procedures pg. 6.
[4] The values contained in Tables 7 and 8 are for illustrative purposes only.

WellID	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
49222	231	155	208	268	194	278	129	119	116	223	139	174	167
49223	152	183	191	208	179	219	124	149	126	106	158	94	117
49224	236	225	169	294	213	209	177	120	99	73	129	113	119
49225	278	213	214	262	221	275	145	112	154	107	192	252	339
49226	274	242	233	277	239	275	172	82	138	160	83	179	225
49227	268	236	244	305	213	267	140	85	147	152	93	155	112
49228	236	214	174	293	211	241	163	74	113	167	87	128	238
49229	242	207	176	283	215	264	195	73	118	178	73	122	219
49244	322	260	289	412	309	338	161	117	143	135	183	165	255
49245	256	231	231	276	256	300	193	81	129	200	192	139	117
49246	191	200	163	170	209	263	195	139	107	224	202	184	147
49367	278	259	229	318	230	329	152	137	125	111	174	143	212
49368	242	209	209	290	191	273	193	160	111	217	183	168	138
49369	419	359	289	429	265	418	318	281	175	389	359	241	444
49370	215	187	188	202	211	276	152	102	152	224	145	149	217
49472	236	227	223	306	194	279	142	116	129	97	138	134	195
51544	215	200	199	242	213	188	172	101	80	186	181	165	155
51545	239	228	223	266	227	194	207	121	68	172	206	180	152
51546	237	206	0	52	334	279	33	0	120	198	189	140	242
51722	233	133	233	309	177	195	140	103	14	157	148	183	244
51723	157	74	27	150	195	264	156	129	114	178	99	51	148
51724	172	77	154	289	206	276	203	150	109	162	179	122	222
52006	233	137	122	292	173	217	149	107	16	219	107	168	250
Total	5,561	4,664	4,390	6,192	5,073	6,117	3,811	2,659	2,601	4,035	3,641	3,548	4,673

Table 1. Historical Pumping 1985-2010 (ac-ft)

WellID	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Avg
49222	263	113	263	242	267	213	156	215	204	129	210	167	199	194
49223	118	112	183	223	280	163	244	115	185	157	80	88	68	155
49224	119	178	259	231	280	152	248	110	56	14	63	47	223	160
49225	349	228	355	302	351	376	288	32	130	137	195	146	114	222
49226	213	154	194	90	271	202	211	156	83	104	100	55	58	172
49227	223	149	212	103	33	143	213	144	183	164	135	39	150	166
49228	239	156	201	88	253	203	224	175	85	123	104	80	65	167
49229	221	165	210	94	110	141	189	139	184	186	182	143	188	174
49244	200	199	295	283	312	183	301	257	261	224	238	199	223	241
49245	169	169	182	176	81	154	150	113	71	95	103	71	75	162
49246	228	104	225	224	179	210	223	193	163	57	222	191	235	186
49367	177	171	160	170	206	210	222	97	230	212	217	192	218	199
49368	219	97	218	202	163	42	75	183	124	49	186	158	188	173
49369	496	236	512	431	487	396	334	18	144	115	148	105	85	304
49370	239	114	267	227	267	210	160	189	181	190	201	157	186	193
49472	148	142	230	218	255	131	252	114	221	178	207	172	215	188
51544	222	89	215	210	169	39	8	109	96	44	66	149	172	149
51545	226	102	227	218	180	45	48	155	143	50	211	166	215	172
51546	225	145	223	160	125	43	76	184	177	73	75	172	213	151
51722	141	164	263	225	275	207	259	128	157	140	150	190	185	183
51723	207	144	226	159	122	29	38	8	92	35	32	51	22	112
51724	213	143	184	82	256	191	207	151	65	88	80	0	0	153
52006	215	134	211	201	248	143	236	184	197	173	188	161	192	180
Total	5,070	3,407	5,517	4,562	5,171	3,827	4,360	3,168	3,430	2,736	3,393	2,900	3,486	4,154

Table 1 (Continued). Historical Pumping 1985-2010 (ac-ft)

WellID	2010 Certified Acres
49222	130.7
49223	133.8
49224	130.1
49225	224.7
49226	128.4
49227	133.6
49228	133.8
49229	132.8
49244	155.0
49245	132.3
49246	134.6
49367	128.0
49368	133.7
49369	251.0
49370	129.8
49472	134.0
51544	127.2
51545	124.8
51546	129.3
51722	132.4
51723	133.5
51724	133.4
52006	134.7
Total	3,261.6

Table 2. Historical Certified Acres.

Year	Type of Operation Year	Groundwater Pumping under Project Operations
1985	Maintenance	300
1986	Maintenance	300
1987	Maintenance	300
1988	Compact	15,000
1989	Compact	15,000
1990	Compact	15,000
1991	Compact	15,000
1992	Maintenance	300
1993	Maintenance	300
1994	Maintenance	300
1995	Maintenance	300
1996	Maintenance	300
1997	Maintenance	300
1998	Maintenance	300
1999	Maintenance	300
2000	Maintenance	300
2001	Maintenance	300
2002	Compact	15,000
2003	Compact	15,000
2004	Compact	15,000
2005	Compact	15,000
2006	Compact	15,000
2007	Maintenance	300
2008	Maintenance	300
2009	Maintenance	300
2010	Maintenance	300

Table 3. Groundwater pumping incorporated into the historical project operations simulation.

Year	New Depletion	AWS Credit	Net Depletion
1985	-4	-300	-304
1986	-29	-300	-329
1987	-54	-300	-354
1988	-60	-15,000	-15,060
1989	-27	-15,000	-15,027
1990	-40	-15,000	-15,040
1991	-8	-15,000	-15,008
1992	66	-300	-234
1993	144	-300	-156
1994	278	-300	-22
1995	171	-300	-129
1996	187	-300	-113
1997	174	-300	-126
1998	199	-300	-101
1999	173	-300	-127
2000	138	-300	-162
2001	13	-300	-287
2002	25	-15,000	-14,975
2003	-11	-15,000	-15,011
2004	0	-15,000	-15,000
2005	64	-15,000	-14,936
2006	118	-15,000	-14,882
2007	183	-300	-117
2008	233	-300	-67
2009	288	-300	-12
2010	261	-300	-39

Table 4. Simulated new depletion under project operations groundwater pumping, AWS credit, and the net depletions of project operation on the stream (negative depletion values indicate an accretion to streamflow). Net Depletion = New AWS credit + New Depletion.

Year	Type of Operation Year	Groundwater Pumping under Project Operations
2010	Maintenance	300
2011	Maintenance	300
2012	Maintenance	300
2013	Maintenance	300
2014	Maintenance	300
2015	Maintenance	300
2016	Maintenance	300
2017	Compact	15,000
2018	Compact	15,000
2019	Compact	15,000
2020	Compact	15,000
2021	Compact	15,000
2022	Maintenance	300
2023	Maintenance	300
2024	Maintenance	300
2025	Maintenance	300
2026	Maintenance	300
2027	Maintenance	300
2028	Maintenance	300
2029	Maintenance	300
2030	Maintenance	300
2031	Maintenance	300
2032	Compact	15,000
2033	Compact	15,000
2034	Compact	15,000
2035	Compact	15,000
2036	Compact	15,000
2037	Maintenance	300
2038	Maintenance	300
2039	Maintenance	300
2040	Maintenance	300
2041	Maintenance	300
2042	Maintenance	300

Table 5. Groundwater pumping incorporated into the future project operations simulation.

Year	Type of Operation Year	Groundwater Pumping under Project Operations
2043	Maintenance	300
2044	Maintenance	300
2045	Maintenance	300
2046	Maintenance	300
2047	Compact	15,000
2048	Compact	15,000
2049	Compact	15,000
2050	Compact	15,000
2051	Compact	15,000
2052	Maintenance	300
2053	Maintenance	300
2054	Maintenance	300
2055	Maintenance	300
2056	Maintenance	300
2057	Maintenance	300
2058	Maintenance	300
2059	Maintenance	300
2060	Maintenance	300
2061	Maintenance	300
2062	Compact	15,000
2063	Compact	15,000
2064	Compact	15,000
2065	Compact	15,000
2066	Compact	15,000
2067	Maintenance	300
2068	Maintenance	300
2069	Maintenance	300

Table 5 (Continued). Groundwater pumping incorporated into the future project operations simulation.

Year	New Depletion	AWS Credit	Net Depletion
2010	-1	-300	-301
2011	-24	-300	-324
2012	-40	-300	-340
2013	-60	-300	-360
2014	-119	-300	-419
2015	-106	-300	-406
2016	-152	-300	-452
2017	-100	-15,000	-15,100
2018	-120	-15,000	-15,120
2019	-100	-15,000	-15,100
2020	-99	-15,000	-15,099
2021	-71	-15,000	-15,071
2022	-56	-300	-356
2023	-30	-300	-330
2024	-1	-300	-301
2025	15	-300	-285
2026	37	-300	-263
2027	35	-300	-265
2028	31	-300	-269
2029	48	-300	-252
2030	23	-300	-277
2031	26	-300	-274
2032	13	-15,000	-14,987
2033	7	-15,000	-14,993
2034	-2	-15,000	-15,002
2035	7	-15,000	-14,993
2036	19	-15,000	-14,981
2037	47	-300	-253
2038	72	-300	-228
2039	124	-300	-176
2040	100	-300	-200

Table 6. Simulated future new depletion under project operations groundwater pumping, AWS credit, and the net depletions of project operation on the stream (negative depletion values indicate an accretion to streamflow). Net Depletion = AWS credit + New Depletion.

Year	New Depletion	AWS Credit	Net Depletion
2041	160	-300	-140
2042	122	-300	-178
2043	94	-300	-206
2044	188	-300	-112
2045	73	-300	-227
2046	117	-300	-183
2047	97	-15,000	-14,903
2048	87	-15,000	-14,913
2049	101	-15,000	-14,899
2050	115	-15,000	-14,885
2051	94	-15,000	-14,906
2052	146	-300	-154
2053	161	-300	-139
2054	242	-300	-58
2055	134	-300	-166
2056	291	-300	-9
2057	170	-300	-130
2058	180	-300	-120
2059	284	-300	-16
2060	136	-300	-164
2061	187	-300	-113
2062	130	-15,000	-14,870
2063	109	-15,000	-14,891
2064	80	-15,000	-14,920
2065	174	-15,000	-14,826
2066	118	-15,000	-14,882
2067	163	-300	-137
2068	176	-300	-124
2069	284	-300	-16

Table 6 (Continued). Simulated future new depletion under project operations groundwater pumping, AWS credit, and the net depletions of project operation on the stream (negative depletion values indicate an accretion to streamflow). Net Depletion = AWS credit + New Depletion.

Nebraska				
	Col. 1	Col. 2	Col. 3	Col. 4
Year	Allocation	Computed Beneficial Consumptive Use	Imported Water Supply Credit **and/or Augmentation Water Supply Credit**	Difference between Allocation and the Computed Beneficial Consumptive Use offset by Imported Water Supply Credit and/or Augmentation Water Supply Credit Col 1 – (Col 2- Col 3)
Year 2002	236,550 236,550	265,910 265,910	13,996 13,996	-15,364 -15,364
Year 2003	227,580 227,580	262,780 262,780	9,782 9,782	-25,418 -25,418
Year 2004	205,630 205,630	252,650 252,650	10,386 10,386	-36,634 -36,634
Year 2005	199,450 199,450	**253 ,940** 253,740	**26,965** 11,965	**-27,525** -42,325
Current Year 2006	187,090 187,090	**228,620** 228,420	**27,214** 12,214	**-14,316** -29,116
Average	211,260 211,260	**252,780** 252,700	**17,670** 11,670	**-23,850** -29,770

Table 7. Example of RRCA Accounting Procedure Table 3C Results with the Augmentation Water Supply Credit (top values in each column) and without the Augmentation Water Supply Credit (bottom values in each column). The gray shaded years (2005-2006) represent Compact Operation Years in which hypothetical new depletions (200 acre-feet) and deliveries (15,000 acre-feet) of operating the project are superimposed on the historical accounting data. Bold values represent data values that differ from the historical values due to project operations.

Nebraska								
Year	Allocation			Computed Beneficial Consumptive Use			Imported Water Supply Credit **and/or Augmentation Water Supply Credit**	Difference Between Allocation and the Computed Beneficial Consumptive Use offset by Imported Water Supply Credit and/or Augmentation Water Supply Credit Above Guide Rock
Column	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8
	State Wide Allocation	Allocation below Guide Rock	State Wide Allocation above Guide Rock	State Wide CBCU	CBCU below Guide Rock	State Wide CBCU above Guide Rock	Credits above Guide Rock	Col 3 – (Col 6 – Col 7)
Previous Year	199,450 199,450	4,586 4,586	194,864 194,864	**253,940** 253,740	4,052 4,052	**249,889** 249,689	**26,965** 11,965	**-28,060** -44,234
Current Year	187,090 187,090	2,286 2,286	184,804 184,804	**228.62** 228,420	3,057 3,057	**225,563** 225,363	**27,214** 12,214	**-13,545** -28,345
Average	193,270 193,270	2,286 3,440	189,830 189,830	**241,280** 241,080	3,550 3,550	**237,730** 237,530	**27,090** 12,090	**-20,800** -36,290

Table 8. Example of RRCA Accounting Procedure Table 5C Results with the Augmentation Water Supply Credit (top values in each column) and without the Augmentation Water Supply Credit (bottom values in each column). The gray shaded years (2005-2006) represent Compact Operation Years in which hypothetical new depletions (200 acre-feet) and deliveries (15,000 acre-feet) of operating the project are superimposed on the historical accounting data. Bold values represent data values that differ from the historical values due to project operations.

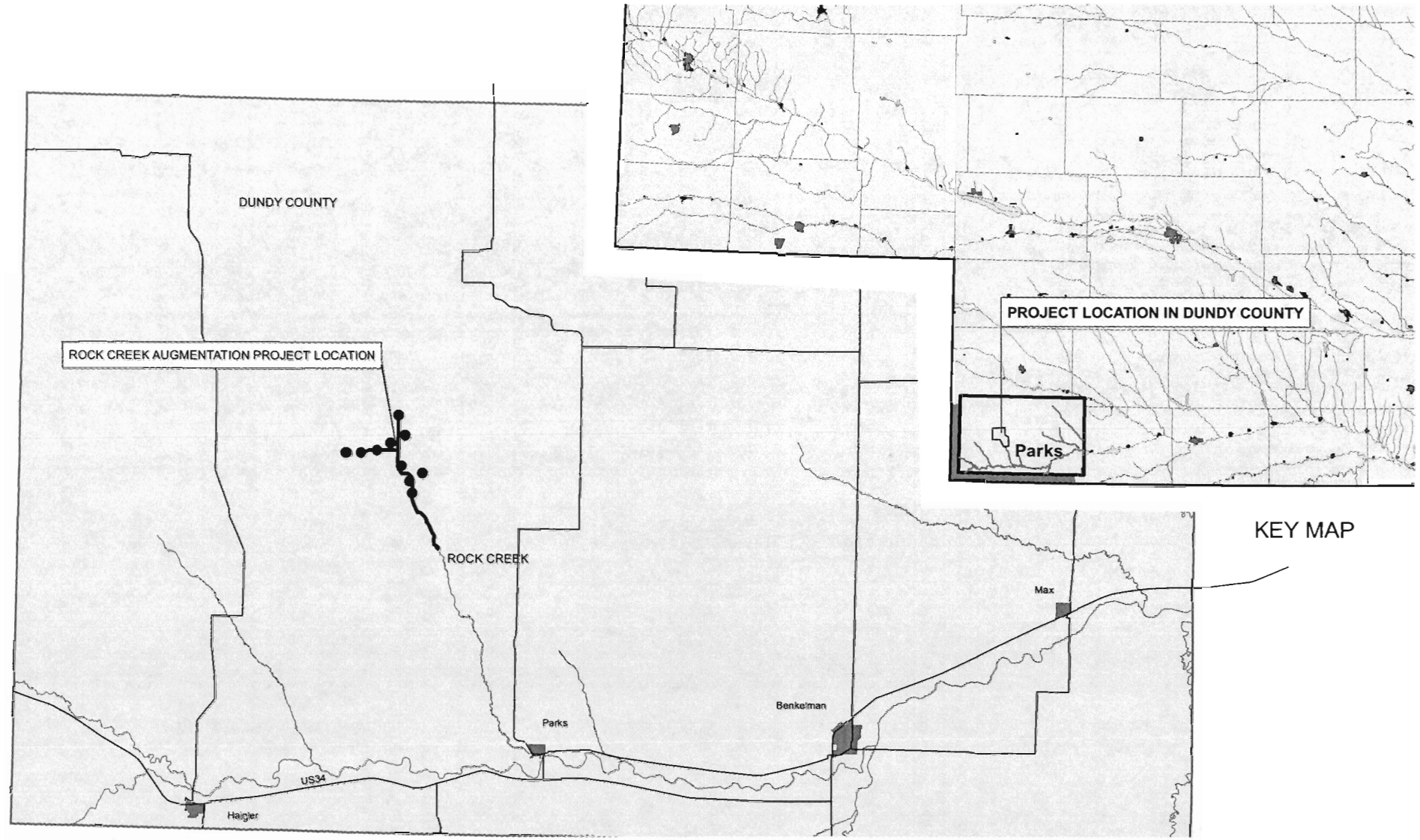


FIGURE 1: PROJECT LOCATION MAP

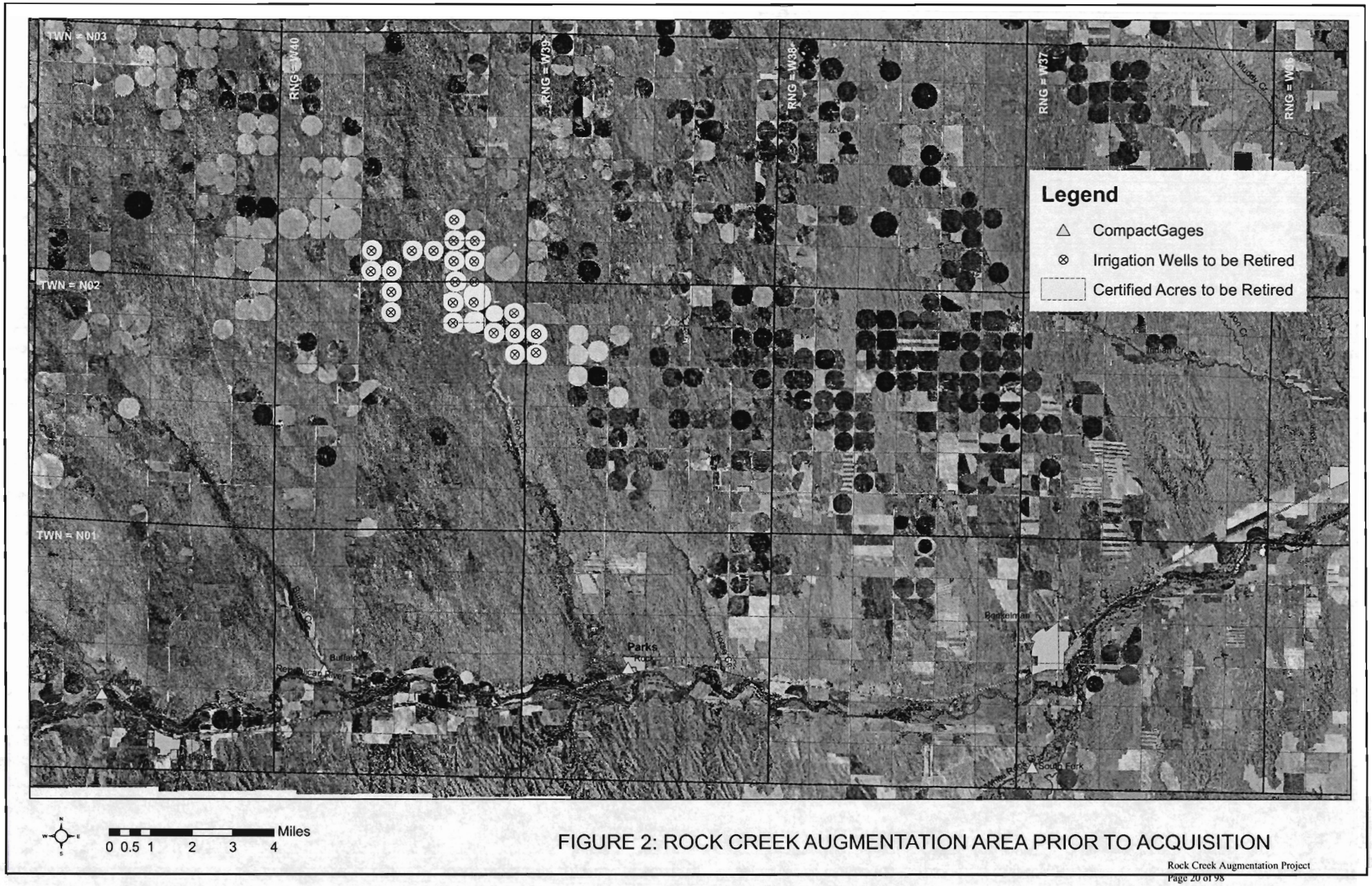


FIGURE 2: ROCK CREEK AUGMENTATION AREA PRIOR TO ACQUISITION

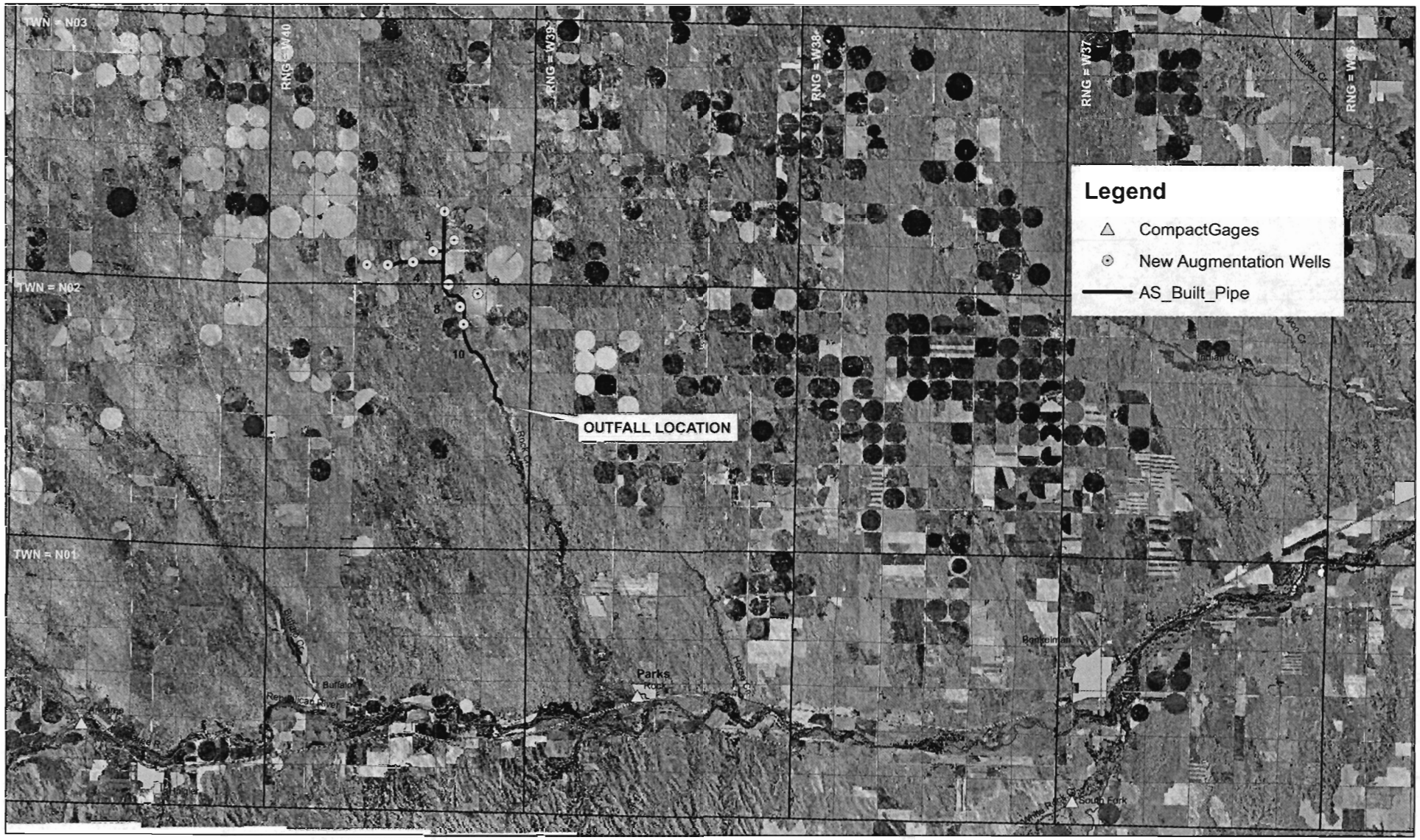


FIGURE 3: ROCK CREEK AUGMENTATION PROJECT PLAN

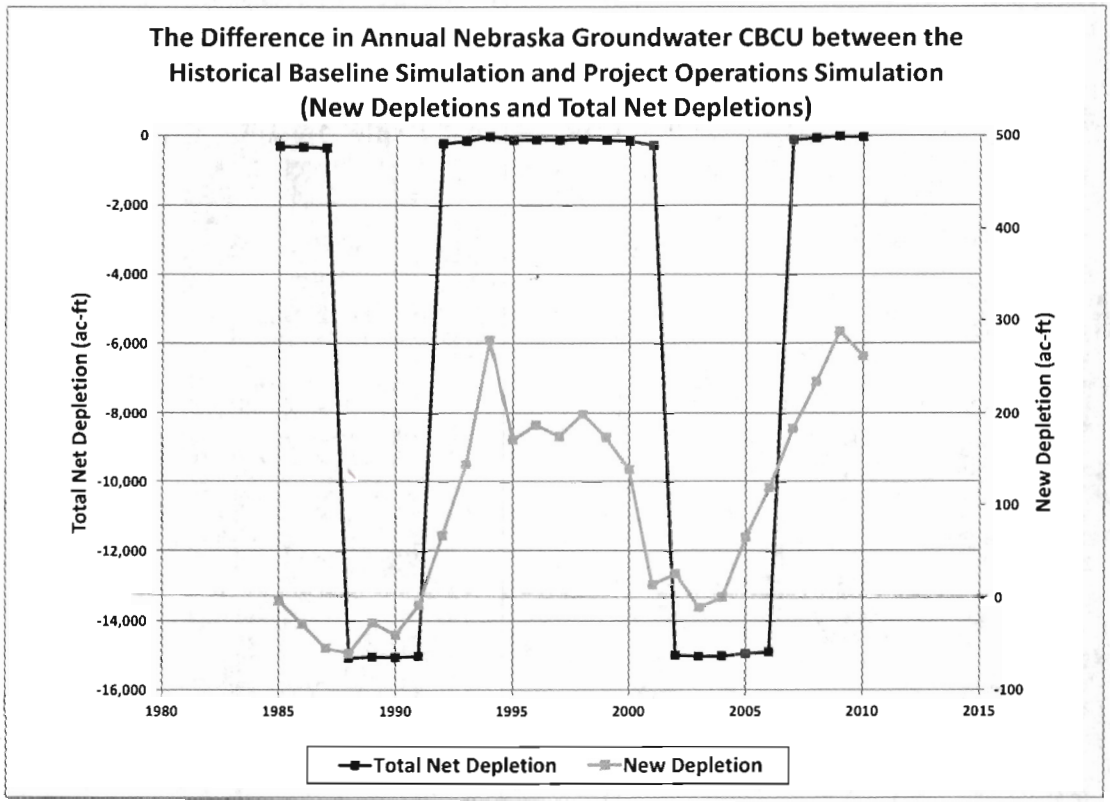


Figure 4. Simulated new depletion under projected future operations groundwater pumping, AWS credit, and the net depletions of project operation on the stream (negative net depletion values indicate no new net depletion).

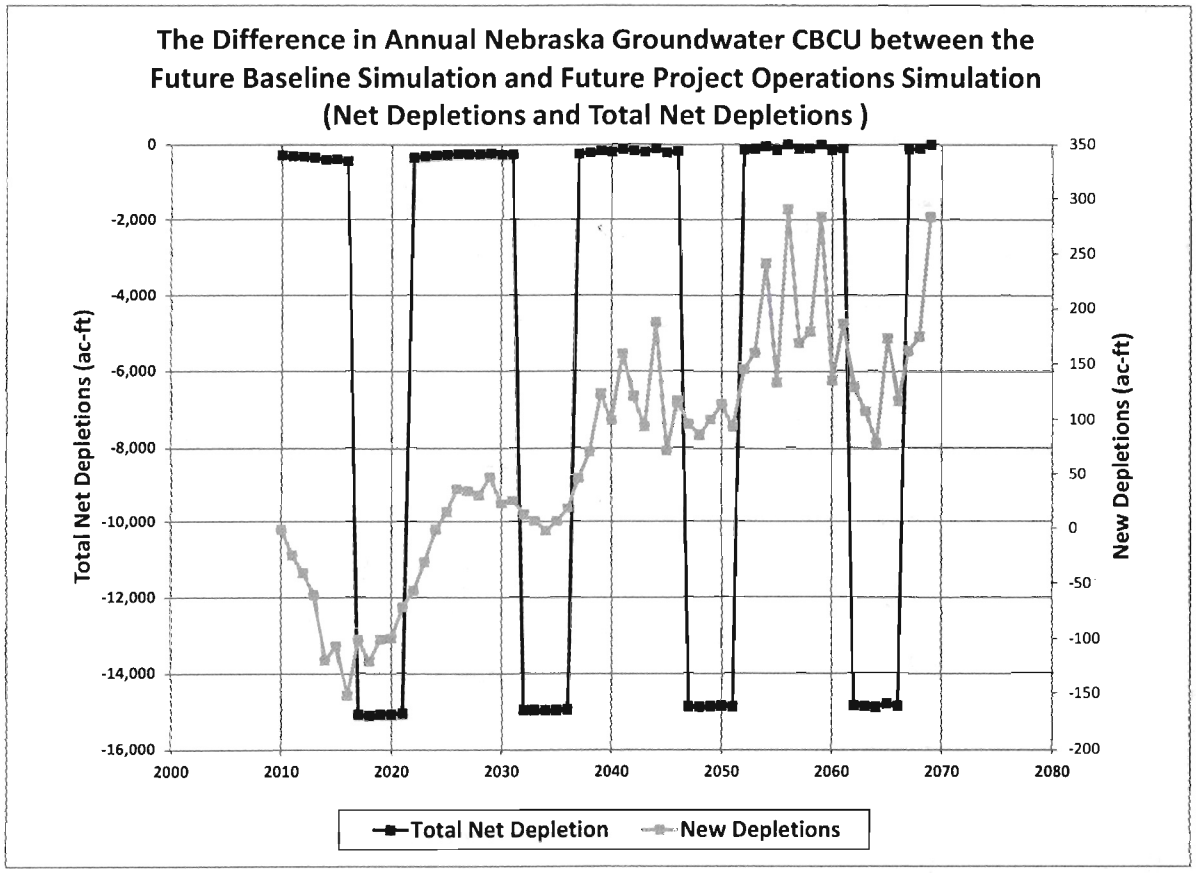


Figure 5. Simulated future net depletion of project operations groundwater pumping and augmentation vs. simulated baseline future groundwater pumping (negative values indicate no new net depletion).

2

Description of Methods Used to Develop Augmentation Simulation Data Sets

A.1 INTRODUCTION

This documentation summarizes the steps taken in developing data sets for the analysis of simulations of augmentation scenarios on behalf of the Nebraska Department of Natural Resources (NDNR) in support of discussions within the Republican River Compact Administration (RRCA).

Two analyses were completed. The first was an analysis of the impact of augmentation pumping near Rock Creek from groundwater sources in western Nebraska under conditions prevailing between 1985 and 2010. The augmentation pumping simulations were constructed to evaluate what the impact would have been if augmentation had historically occurred during the period 1985 to 2010. Irrigated land was assumed to have been purchased and set aside in 1985 and not-irrigated through 2010, i.e. retired. Augmentation pumping was simulated to have occurred during the two periods of droughts, 1988 to 1991 and 2002 to 2006. Augmentation pumping during these drought periods was simulated to be 15,000 acre-ft. Augmentation pumping during other periods from 1985 to 2010 was simulated to be 300 acre-ft.

The second analysis was an evaluation of the impact of augmentation pumping near Rock Creek under conditions assumed to occur from 2010 through 2069. Augmentation pumping simulations under these conditions were based on modifications of simulations completed by Kansas. Under this scenario, augmentation pumping was simulated to repeatedly occur during conditions equivalent to the drought period of 2002 to 2006. Augmentation pumping during these drought periods was simulated to be 15,000 acre-ft. Augmentation pumping during non-

drought periods, i.e. not during 2002 through 2006 equivalent years from 2010 through 2069 was simulated to be 300 acre-ft.

A.2 SELECTION OF MODEL INPUT DATA SETS FOR THE 1985 THROUGH 2010 AUGMENTATION SIMULATIONS

The RRCA model as completed July 1, 2003 simulates monthly groundwater flow for the period 1918 to 2000. For each year subsequent to 2000, Kansas, Colorado, and Nebraska provide data sets of pumping, canal losses, and irrigation return to the RRCA on an annual basis. These data are combined with basin-wide information on precipitation and evapotranspiration parameters and an annual simulation update is completed. Initial groundwater levels specified for each annual simulation were based on the previous year's final simulated groundwater levels.

For this investigation, groundwater flow model input data sets for the period January 1, 1918 to December 31, 2000 were run separately from runs completed for the period January 1, 2001 to December 31, 2010. All input data for analyses presented in this document were obtained from the website http:// www.republicanrivercompact. org, the official Republican River Compact website. Recently downloaded data are provided in original format in the external hard drive provided with this memorandum in the directory "3_Downloads_from_RRCA_Website." Model specification and preprocessor data sets were then modified as needed as described below.

The official data sets were downloaded on two occasions, May 28-29, 2008 and October 25, 2011. Those files downloaded May 28-29, 2008 are as follows:

1) From http://www.republicanrivercompact.org/v12p/html/ch00.html (MODFLOW input data files), MODFLOW-2000 model input data sets for 1918 to 2000→data0.zip.

2) From http://www.republicanrivercompact.org/v12p/html/ch00.html (MODFLOW input files generated from programs), MODFLOW-2000 model input data sets for 1918 to 2000→data1.zip.

Those files downloaded October 25, 2011 are as follows:

1) From http://www.republicanrivercompact.org/v12p/html/ch00.html (Colorado RRPP input data) Republican River Project Preprocessor (RRPP) input data sets for 1918 to 2000,→ co12b.zip.
2) From http://www.republicanrivercompact.org/v12p/html/ch00.html (Nebraska RRPP input data) Republican River Project Preprocessor (RRPP) input data sets for 1918 to 2000,→ ne12b.zip.
3) From http://www.republicanrivercompact.org/v12p/html/ch00.html (Kansas RRPP input data) Republican River Project Preprocessor (RRPP) input data sets for 1918 to 2000,→ ks12b.zip.
4) From http://www.republicanrivercompact.org/2001/html/index.html (2001 Simulation) Republican River Project Preprocessor (RRPP) parameter, flag file, and MODFLOW-2000 input data files for 2001→ 2001.zip.
5) From http://www.republicanrivercompact.org/2002/html/index.html (2002 Simulation) Republican River Project Preprocessor (RRPP) parameter, flag file, and MODFLOW-2000 input data files for 2002 → 2002.zip.
6) From http://www.republicanrivercompact.org/2003/html/index.html (2003 Simulation) Republican River Project Preprocessor (RRPP) parameter, flag file, and MODFLOW-2000 input data files for 2003 → 2003.zip.

7) From http://www.republicanrivercompact.org/2004/html/zip/index.html (2004 Simulation) Republican River Project Preprocessor (RRPP) parameter, flag file, and MODFLOW-2000 input data files for 2004 → 2004.zip.

8) From http://www.republicanrivercompact.org/2005/html/zip/index.html (2005 Simulation) Republican River Project Preprocessor (RRPP) parameter, flag file, and MODFLOW-2000 input data files for 2005 → 2005.zip.

9) From http://www.republicanrivercompact.org/2006/html/zip/index.html (2006 Simulation) Republican River Project Preprocessor (RRPP) parameter, flag file, and MODFLOW-2000 input data files for 2006 → 2006.zip.

10) From http://www.republicanrivercompact.org/2007/html/zip/index.html (2007 Simulation) Republican River Project Preprocessor (RRPP) parameter, flag file, and MODFLOW-2000 input data files for 2007 → 2007.zip.

11) From September 7, 2011 update http://www.republicanrivercompact.org/restricted/2008/html/zip/index.html (2008 Simulation) Republican River Project Preprocessor (RRPP) parameter, flag file, and MODFLOW-2000 input data files for 2008 → 2008.zip.

12) From September 7, 2011 update http://www.republicanrivercompact.org/restricted/2009/html/zip/index.html (2009 Simulation) Republican River Project Preprocessor (RRPP) parameter, flag file, and MODFLOW-2000 input data files for 2009 → 2009.zip.

13) From September 7, 2011 update http://www.republicanrivercompact.org/restricted/2010/html/zip/index.html

(2010 Simulation) Republican River Project Preprocessor (RRPP) parameter, flag file, and MODFLOW-2000 input data files for 2010 → 2010.zip.

14) From September 7, 2011 update

http://www.republicanrivercompact.org/restricted/2010/html/zip/index.html

(2010 Simulation) data and flag files → data0.zip.

15) From September 7, 2011 update

http://www.republicanrivercompact.org/restricted/2010/html/zip/index.html

(2010 Simulation) data and flag files → data.zip.

A.3 MODFLOW-2000 SOURCE CODE AND EXECUTABLE

Computer simulations were completed using MODFLOW-2000 version 1.10.01 as downloaded from the RRCA Website on May 28, 2008→ http://www.republicanrivercompact.org/2006/html/zip/index.html (Source Code). MODFLOW-2000 is a publicly available computer code that simulates groundwater flow. The 'Openspec.inc' file was set such that unformatted output data would be in data form "Unformatted" and data access format as "Transparent:"

```
C
C  Non-standard Fortran that causes code compiled by Lahey or Absoft
C  Fortran on personal computers to use unstructured non-formatted
C  files. This may make it possible for the non-formatted files used
C  by MODFLOW to be used with programs that are compiled by other
C  compilers.
   DATA ACCESS/'TRANSPARENT'/
C
```

```
C FORM specifier --
C
C  Standard Fortran, which results in vender dependent (non-portable)
C  files. Use unless there is a reason to do otherwise.
  DATA FORM/'UNFORMATTED'/
```

The source code was then compiled with Lahey-Fujitsu Fortran Professional Compiler v5.7 in double precision. The executable version of this code was named mf2k_1_10_RRCA_dbl.exe. The make file used to create this version is provided in the External Hard Drive provided with this memorandum.

A.4 RRPP SOURCE CODE AND EXECUTABLE

The Republican River Pre-Processor (RRPP) program is used to construct MODFLOW recharge and well pumping input files from cell-by-cell specification files. The specification files for each state are kept in a separate directory. The RRPP program reads the monthly and annual specification files for all three states, calculates recharge from precipitation and outputs the resulting recharge and well pumping data sets as input to the MODFLOW program.

To facilitate management simulation calculations, a modified version of RRPP (RRPP1_3CBCMI_CPS) was developed. This version has the capability to eliminate or reduce pumping and associated recharge within multiple model sub-regions defined by an array. Municipal and industrial wells within the sub-region are affected by the specified multiplier. In addition, to facilitate the simulation of the scenarios presented in this memorandum, the code was modified to accurately turn off mound recharge and pumping at the same time. To achieve this, the modified code reclassified the groundwater comingled (GWCO) acreage as "non-irrigated" acreage if both the mound and Nebraska pumping are off. In this way, precipitation

recharge for non-irrigated lands is specified for GWCO lands when pumping and mound recharge are turned off.

Source code for RRPP1_3CBCMI_CPS is provided the External Hard-Drive provided with this memorandum. The code was compiled with Compaq Visual FORTRAN Version 6.1. The executable version of this code was named RRPP1_3CBCMI_CPS.exe.

A.5 CREATION OF RRPP DATA SET INPUT

RRPP requires pumping and recharge specifications from each state as well as precipitation specifications for stations within the study area. Specification data files for each state were downloaded from the RRCA Compact Website (Website). The most recent available specifications for 1918 to 2010 from the Website were collated into state specific directories. Precipitation data specification files ppt.dat and loc.dat were extracted from the Website. The ppt.dat file contained all annual precipitation data available from 1918 to 2010. The file, loc.dat, contained precipitation station location data.

Additional files required by RRPP were obtained from the Website as follows:

File Name	Description
02.ibound	File containing boundary condition identifiers (IBOUND) in MODFLOW-2000 format.
soil.12o	File contain array of soil types. One value for each model cell.
terrain.flg	File contain array of terrain type. One value for each model cell. [Note the terrain flag file allows terrain multipliers to be calculated in uplands and overridden in areas assigned as alluvial soil types].
terrain.12p	File containing terrain multipliers at the centroid of counties.
states.flg	File containing array of RRCA designation of state by model cell. One value for each model cell.
moundarea.flg	File containing array that identifies which cells are included in the "mound" area. This is used in the current procedure for calculating the "mound credit."

Table A.1. Additional files required by RRPP.

To utilize the sub-region management abilities within RRPP1_3CBCMI_CPS, states.flg was modified and saved as Generic_States.flg. This file contained an array identifying cells by state with Nebraska equal to 100, Colorado equal to 200, and Kansas equal to 300. This array, along with Input.par and InputM.par was used in batch files to create recharge and well packages for 1918 to 2010 with differing fractions of reported pumping for each of the three states.

Input_Compact.par and InputM.par were modified from 12p.par, the original parameter input file for RRPP.

A.6 CREATION OF MODEL INPUT DATA SETS

MODFLOW-2000 input data sets for the 1918 to 2010 simulation period were required for each stress package; recharge, well, stream, drain, and evapotranspiration. In addition, updates of MODFLOW-2000 output control and time discretization input files were also required. Recharge and well package input files for 1918 to 2010 were generated using RRPP1_3CBCMI_CPS.

Prior to execution of RRRP1_3CBCMI_CPS, files containing specifications of monthly groundwater irrigation pumping (.pmp), monthly groundwater irrigation return flow (.rcg), annual irrigated acres (.agw), and annual municipal and industrial (.mi) were downloaded from the RRCA website were revised to account for augmentation. The revision was performed using the program, Prep_RRPP_Input_1_3. This program performs the following tasks:

1) Reads in a list of years and rates to augment.
2) Reads in a list of cells identifying retired irrigation cells.
3) Reads in a list of cells in which augmentation pumping (augmentation source cells) is to occur and the proportion of the total augmentation provided in (1) by cell.
4) Adds the amount of augmentation pumping to the .mi (municipal pumping file) for an augmentation year.
5) Turns off all pumping and return flow in the retired irrigation cells in the .pmp and .rcg files.
6) Turns off irrigated acres in the retired irrigation cells in the .agw files.
7) Overwrites the existing .pmp, .rcg, .agw, and .mi files with the revised information.

8) Creates a file called "already.ran" in the directory. Note that because the program overwrites existing files, it is important to make sure that program has not been "already run." If the file already.ran is present in the directory the user will be prompted to see if the program execution should proceed.

The FORTRAN coding for Prep_RRPP_Input_1_3 is provided in the External Hard Drive provided with this memorandum.

A stream package for the simulation period 1918 to 2000, the stream package 12p.str and the output control file 1918-2000.oc, were modified such that reach by reach information on stream discharge and gains was recorded in the MODFLOW-2000 listing file. The revised stream package and output control files were named, 12p_Printing_On.str, and 1918-2000_Print_Out.oc, respectively.

Note that groundwater flow model input data sets for the period 1918 to 2000 were run separately from runs completed for the period January 1, 2001 to December 31, 2010. For the simulation period 2000 to 2010 the stream packages 12s_2001-2010_Printing_On.str was used for the base simulation. The file 12s_2001-2010_Printing_On.str was created by appending input specifications from the following files:

File Name	Description
2001.str	MODFLOW-2000 stream package file with corrected stream cell locations for 2001.
2002.str	MODFLOW-2000 stream package file with corrected stream cell locations for 2002.
2003.str	MODFLOW-2000 stream package file with corrected stream cell locations for 2003.
2004.str	MODFLOW-2000 stream package file with corrected stream cell locations for 2004.
2005.str	MODFLOW-2000 stream package file with corrected stream cell locations for 2005.
2006.str	MODFLOW-2000 stream package file with corrected stream cell locations for 2006.
2007.str	MODFLOW-2000 stream package file with corrected stream cell locations for 2007.
2008.str	MODFLOW-2000 stream package file with corrected stream cell locations for 2008.
2009.str	MODFLOW-2000 stream package file with corrected stream cell locations for 2009.
2010.str	MODFLOW-2000 stream package file with corrected stream cell locations for 2010.

Table A.2. Stream package for the entire 2001 to 2010, 12s_2001-2010_Printing_On.str

The stream package, 12s_2001-2010_Printing_On .str was then modified such that, flows in individual stream reaches would be printed to the MODFLOW listing file.

The MODFLOW-2000 drain package annual.drn obtained from RRCA Website and used as the default drain package. This package repeats specifications sufficiently for 1918 to 2010 and beyond.

A MODFLOW-2000 Evapotranspiration package for the period 2001 to 2010, 12p_2001_2010.evt, was created by appending input specifications from the following files:

File Name	Description
2001.evt	MODFLOW-2000 evapotranspiration package file for 2001.
2002.evt	MODFLOW-2000 evapotranspiration package file for 2002.
2003.evt	MODFLOW-2000 evapotranspiration package file for 2003.
2004.evt	MODFLOW-2000 evapotranspiration package file for 2004.
2005.evt	MODFLOW-2000 evapotranspiration package file for 2005.
2006.evt	MODFLOW-2000 evapotranspiration package for 2006.
2007.evt	MODFLOW-2000 evapotranspiration package for 2007.
2008.evt	MODFLOW-2000 evapotranspiration package for 2008.
2009.evt	MODFLOW-2000 evapotranspiration package for 2009.
2010.evt	MODFLOW-2000 evapotranspiration package for 2010.

Table A.3. MODFLOW-2000 evapotranspiration package for the entire 2001 to 2010, 12p_2001_2010.evt

The MODFLOW-2000 discretization package, 12p.dis, was used for the simulation period 1918 to 2010 and was modified to include monthly stress period length specifications for the period 2001 to 2010. This file was renamed to 12p_2001-2010.dis. For the period 2001 to 2010, a new MODFLOW-2000 output control file, Save_2008_Heads.oc, was created to print budget terms for 2001 to 2010 and save heads at the end of 2008. The following files were obtained to complete the files necessary for MODFLOW simulations:

File Name	Description
12p.bas	MODFLOW-2000 basic package file. Contains calls to 02.ibound and 12p.shead
02.ibound	File containing boundary condition identifiers (IBOUND) in MODFLOW-2000 format.
12p.shead	File containing initial estimates of hydraulic head for the 1918 to 2000 simulation.
12p.lpf	MODFLOW-2000 layer property flow package file. Contains calls to 12p.k and 12.ss
12p.k	File containing hydraulic conductivity values.
12.ss	File containing array of storage values assigned in the RRCA model. [Note that these values must be multiplied by aquifer thickness to obtain specific yield values].
12.top	File containing array of aquifer top elevations [Called out by the discretization packages,12p_1918_2000.dis and 12p_2001-2010.dis]
12.bot	File containing array of aquifer bottom elevations [Called out by the discretization package,12p_1918_2000.dis and 12p_2001-2010.dis]
11.etsurf	File containing array of evapotranspiration surface [Called out by the evapotranspiration package, 12p_1918_2000.evt and 12p_2001_2010.evt].
12s.hyd	MODFLOW-2000 hydmod package file. Identifies stream segments and reaches for which model-calculated base-flow is to be stored in an unformatted file.

Table A.4. Files obtained to complete the files necessary for MODFLOW simulations

A MODFLOW-2000 name file Generic.nam was created to incorporate the new input specification files with imported water supply on. A MODFLOW-2000 name file GenericM_Compact.nam was created to incorporate the new input specification files with imported water supply off.

A.8 BATCH PROCESSING OF SIMULATIONS

To facilitate processing of model simulations, a series of DOS batch files and FORTRAN programs were created. These files include:

File Name	Function	Type
CompactDriver.bat	CompactDriver.bat passes information to other DOS Batch files, CompactWorker.bat, CompactWorkerM.bat. The information passed specifies the ratio of pumping to the base pumping rate for each state where 100 = 100% of the base pumping rate.	DOS Batch File
CompactWorker.bat	CompactWorker.bat specifies the exact tasks required for each simulation with the imported water supply (Mound) On. This includes changing file names based on information from CompactDriver.bat, executing ParMult, executing RRPP, executing MODFLOW-2000 and deleting temporary files. The name file used by MODFLOW-2000 is Generic.nam	DOS Batch File
CompactWorkerM.bat	CompactWorkerM.bat specifies the exact tasks required for each step for the imported water supply (Mound) Off. This includes changing file names based on information from CompactDriver.bat, executing ParMultM, executing RRPP, executing MODFLOW-2000 and deleting scratch files. The name file used by MODFLOW-2000 is GenericM.nam	DOS Batch File
ParMult.exe	Program that preprocesses specific terms	FORTRAN program

	in a RRPP par file for the imported water supply (Mound) On, Input_Compact.par. The specific terms are passed via command-line variables received from the DOS batch file CompactWorker.bat	[compiled using Compaq Visual Fortran Version 6.1, see External Hard-Drive provided with this memorandum for source code].
ParMultM.exe	Program that preprocess specific terms in a RRPP par file for the imported water supply (Mound) Off, InputM_Compact.par. The specific terms are passed via command-line variables received from the DOS batch file CompactWorker.bat	FORTRAN program [compiled using Compaq Visual Fortran Version 6.1, see External Hard-Drive provided with this memorandum for source code].

Table A.5. Series of DOS batch files and FORTRAN programs

A.9 SIMULATION NAMING CONVENTION

MODFLOW-2000 and related output files were assigned names based on the following convention: all files were assigned a prefix of "Compact" followed by 3 sets of numbers and no suffix or a suffix of "M." The first number referred to the percent of full pumping in Nebraska (0 to 100), the second number referred to the percent of full pumping in Colorado (0 to 100), the third number referred to the percent of full pumping in Kansas (0 to 100). The absence of the "M" suffix means that the imported water supply is on. The presence of the "M" suffix means that the imported water supply is off.

An alternative naming convention was also used where the presence of a letter (C for Colorado, K for Kansas, M for imported water supply, and N for Nebraska) indicates that the activity is on while its absence indicates that it is off. The Greek symbol Theta run has all activities off. This naming convention is outlined in Table 10 of the January 20, 2009 report

"Estimating Computed Beneficial Consumptive Use for Groundwater and Imported Water Supply under the Republican River Compact. "

A.10 POST-PROCESSING OF SIMULATIONS

Simulations results were post-processed in a number of formats. To facilitate post-processing of model simulations, a series of FORTRAN programs were created listed below. Certain data were also further processed using EXCEL spreadsheets. The results are contained in the spreadsheet→Comparison_of_Original_and_Augmented_Rock_Arb1_1985-2010_01_11_2013.xlsx. This spreadsheet compares the results of simulations run without well retirement and augmentation with those with well retirement and augmentation as described in the Introduction for 1985 to 2010. The accounting spreadsheet was implemented by copying appropriate .sfi files into the Accounting subdirectory and running the batch file Accounting.bat. Note that for the period 1918 to 2000 output from the accounting input file, 1800.ins, was used, from the period 2001 to 2008 the accounting input file, 0110s.ins, was used and from 2009 to 2010 the accounting input file, 0110s2.ins, was used.

The input data sets for results of simulations run without well retirement and augmentation were provided to the RRCA February 2012.

The FORTRAN programs include:

Program Name	Function	Input	Output
STATES16CD	STATES16CD is a FORTRAN program used to calculate impacts based on a number of MODFLOW runs.	16 unformatted hydmod output files (.sfi), and an instruction file which specifies the time period processed how streamflow data are to be processed.	ASCII files containing base-flows and base-flow impacts computed using the current, central difference, forward difference and metric accounting techniques.
Hyd_Extract_Compaq_dbl	Hyd_Extract_Compaq_dbl is a FORTRAN program used to extract stream flow from MODFLOW-2000 HYDMOD package output.	Unformatted hydmod output files (.sfi), and a definition file (.def) which specifies which stream segments and reaches to process.	Streamflow for each model time step in comma separated format for each stream segment and reach requested.

Table A-6. FORTRAN programs.

B.1 EVALUATION OF AUGMENTATION IMPACTS OVER LONG PERIODS

The long-term impact of augmentation on Medicine and Rock Creek was evaluated using simulation scenarios developed by Kansas. The Kansas scenarios involved four repeated cycles of conditions from 1995 to 2009 to represent conditions from 2010 to 2069. The scenarios were the basis for the expert report of Samuel Perkins and Steven Larson, "Future Impacts of Pumping on Ground Water Consumptive Use, November 18, 2011." According to this report, Nebraska pumping would be determined by Integrated Management Plans (IMP) in three NRD districts and future pumping would be eighty percent of the average pumping that occurred during the years 1998 to 2002. Average pumping amounts were assumed to apply to the irrigated acreage as of 2006. Climatic conditions such as precipitation and evapotranspiration for the years 1995 to 2009 were used to represent future hydrologic conditions. Results of augmentation pumping scenarios were compared against "baseline" conditions in which no augmentation pumping or well retirement occurred.

Data sets, executable files, and file structure for the Kansas four-cycle condition 2010 through 2069 scenario were provided to the Nebraska DNR in the fall of 2011 and form the basis for this analysis.

B.2 METHODOLOGY

The following describes the methodology used to simulate augmentation pumping in the Rock Creek basin for 2010 to 2069.

Input files into rrppf_v520NRD, Kansas' version of RRPP, the Republican River Preprocessing Code, identify specifications for groundwater irrigation pumping and return flow, surface water irrigation conveyance seepage, and return flow, municipal pumping, and irrigated

acreages on a model cell basis. Each state has provided the RRCA with these specifications. RRPP reads in this information for each state in a separate directory. RRPP the recompiles the information into MODFLOW input files based on the requirements outlined by the RRCA. The first step to completing the augmentation pumping simulations was copy the existing Nebraska specifications directory and appropriate files into a new directory. Then this directory was modified using the program, Prep_RRPP_Input_1_3 as described in Section A.6. This program revised the existing .irr and .rcg files to eliminate pumping and return flow from cells in which wells had been retired, added source augmentation pumping to the municipal pumping file (.mi), and eliminated irrigated acres from cells in which wells had been retired (.agw files). The revised Nebraska specifications directory was named, nef_Rock_Arb1.

Once the revisions had been made to the appropriate RRPP input files, RRPP parameter files (.par) and MODFLOW name files (.nam) were developed to consider the following conditions:

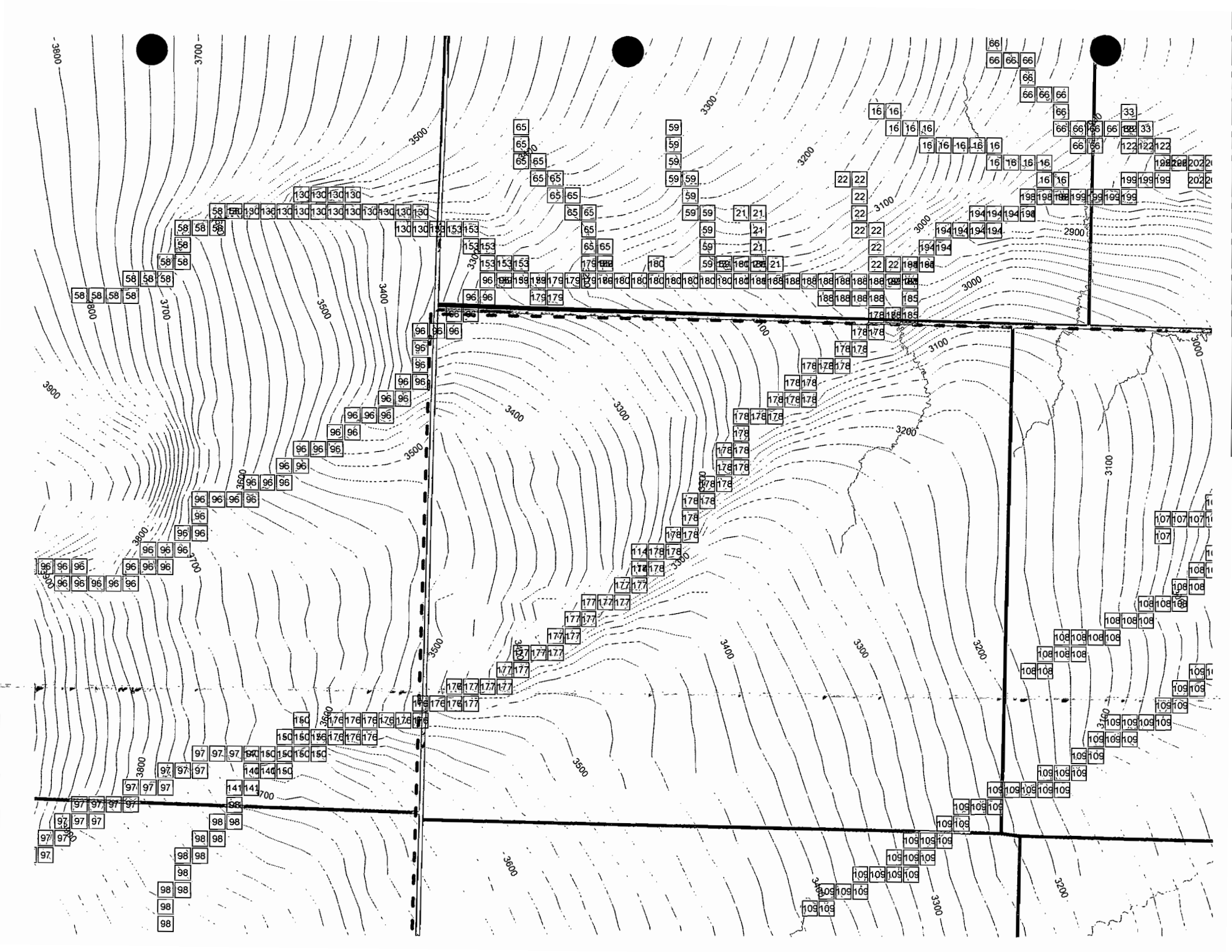
1) All states pumping on, mound source on.
2) Colorado pumping off only, mound source on.
3) Kansas pumping off only, mound source on.
4) Nebraska pumping off only, mound source on.
5) All states pumping on, mound source off.

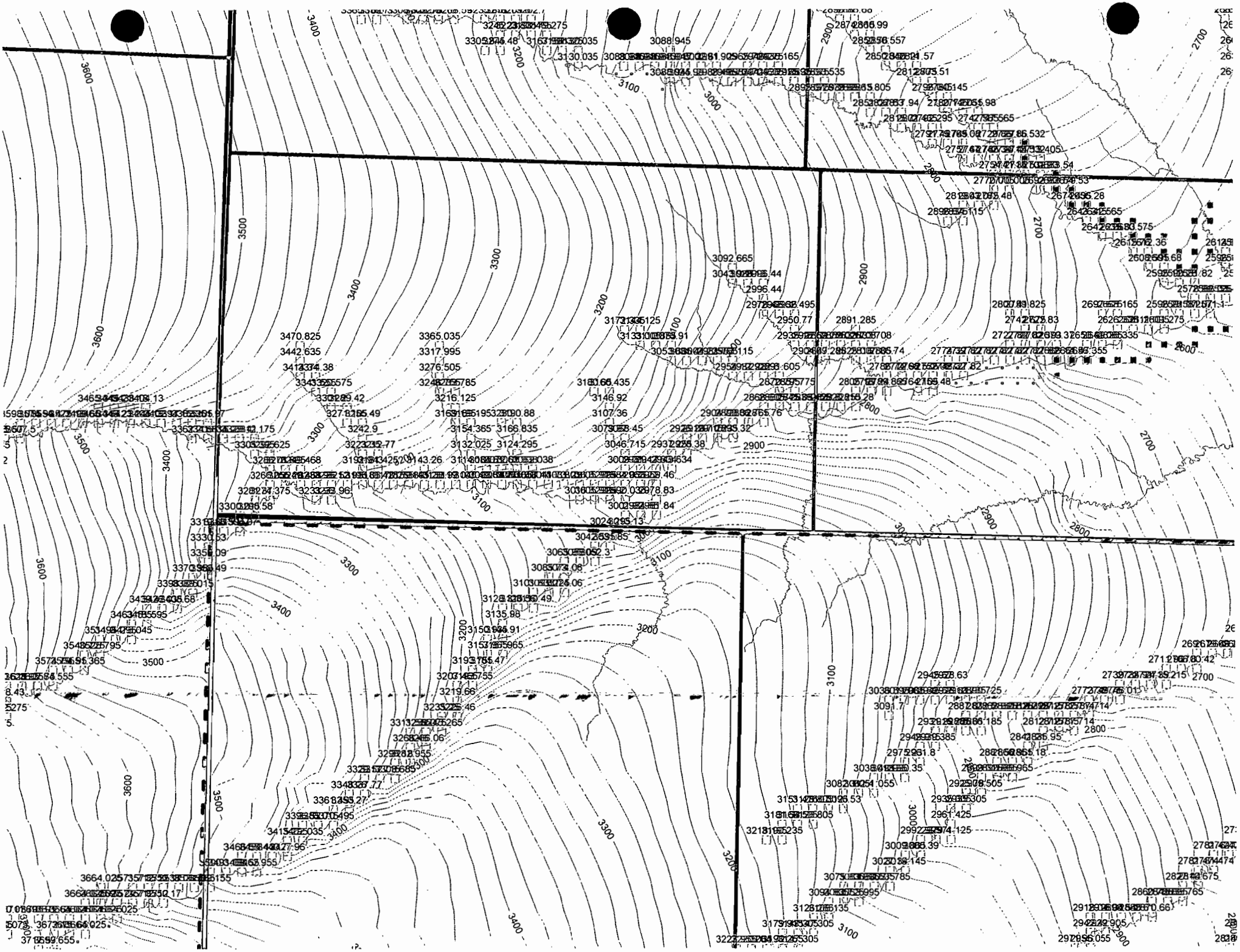
Both baseline conditions and the Rock Creek augmentation pumping scenario described in the introduction for 2010 through 2069 were simulated. Baseline conditions were simulated using the batch file, Run_Baseline_All.bat. The Rock Creek augmentation pumping scenario was completed using the batch file, Run_Rock_Arb1.bat.

B.3 ACCOUNTING

The results RRCA impacts and credits for the baseline scenario (non-augmentation) with RRCA impacts and credits were compared and are summarized in the spreadsheet→ Rock_Arb1_impacts_2010-2069_4x15yrs_IMP.xlsx. This spreadsheet was developed by processing MODFLOW HYDMOD package output (.sfi files) with the accounting program acct_basemon_ext.exe developed and provided by Kansas.

3





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Search Criteria

site_no list =
- 400519101281401

Minimum number of levels = 1

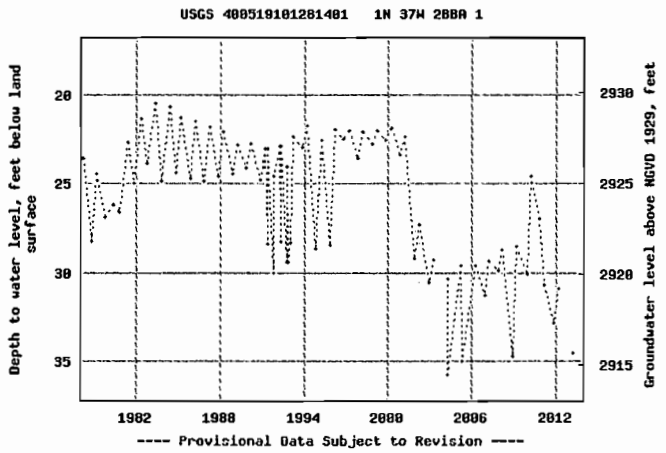
Save file of selected sites to local disk for future upload

USGS 400519101281401 1N 37W 2BBA 1

Available data for this site Groundwater: Field measurements GO

Dundy County, Nebraska
Hydrologic Unit Code 10250004
Latitude 40°05'19", Longitude 101°28'14" NAD27
Land-surface elevation 2,950.00 feet above NGVD29
This well is completed in the High Plains aquifer (N100HGHPLN) national aquifer.
This well is completed in the Ogallala Formation (121OGLL) local aquifer.

Output formats
- Table of data
- Tab-separated data
- Graph of data
- Reselect period



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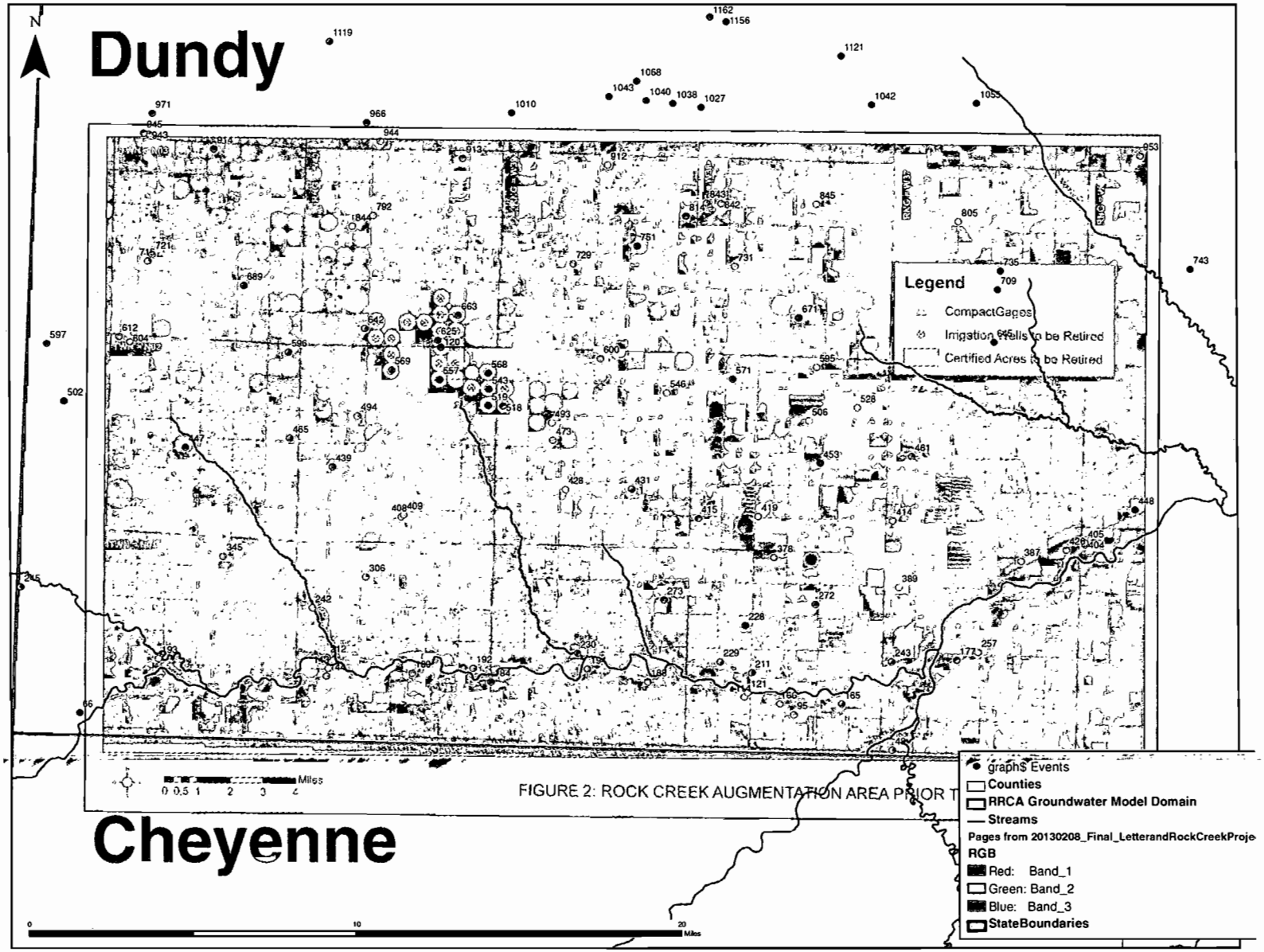
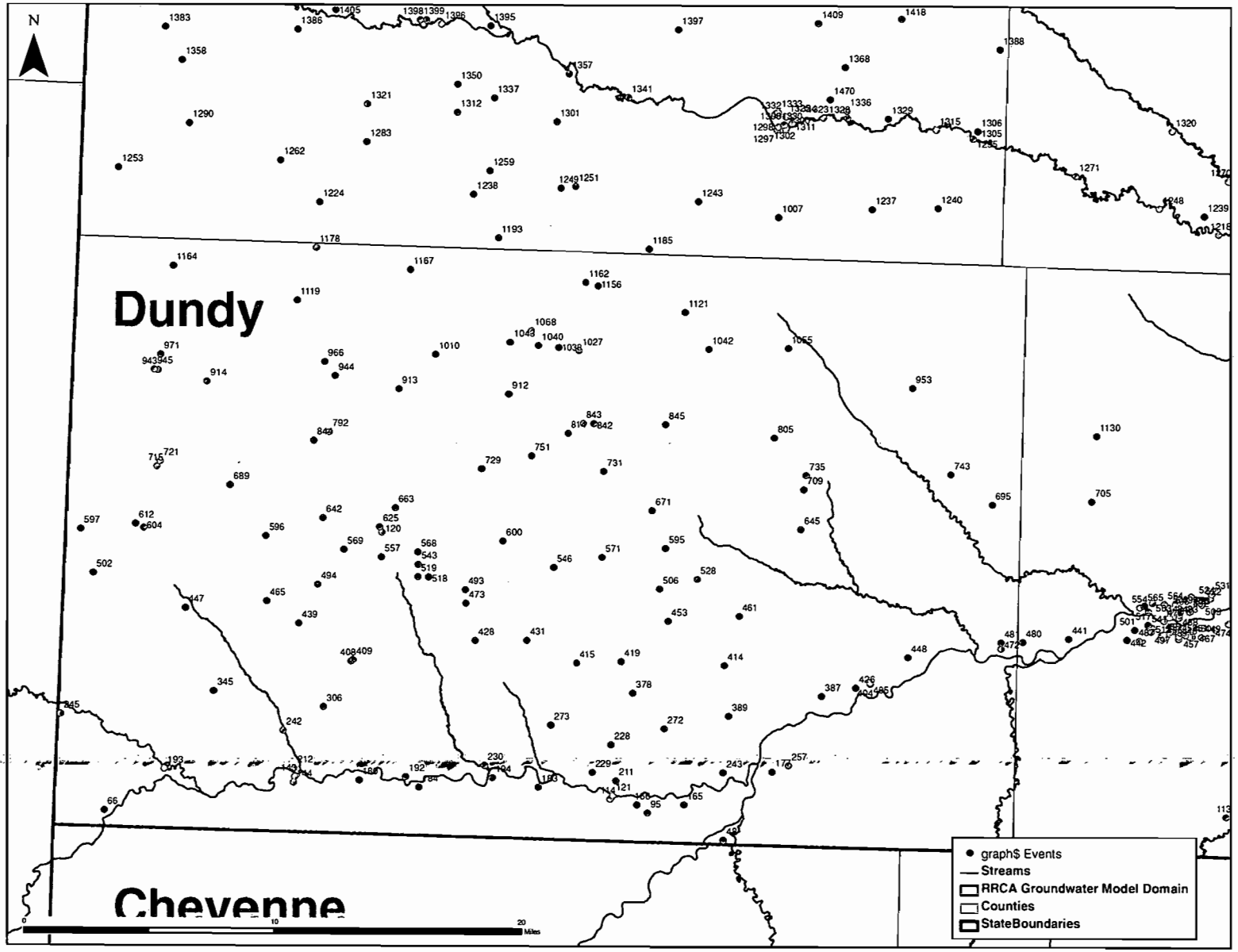


FIGURE 2: ROCK CREEK AUGMENTATION AREA PRIOR T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Streams
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Counties
StateBoundaries
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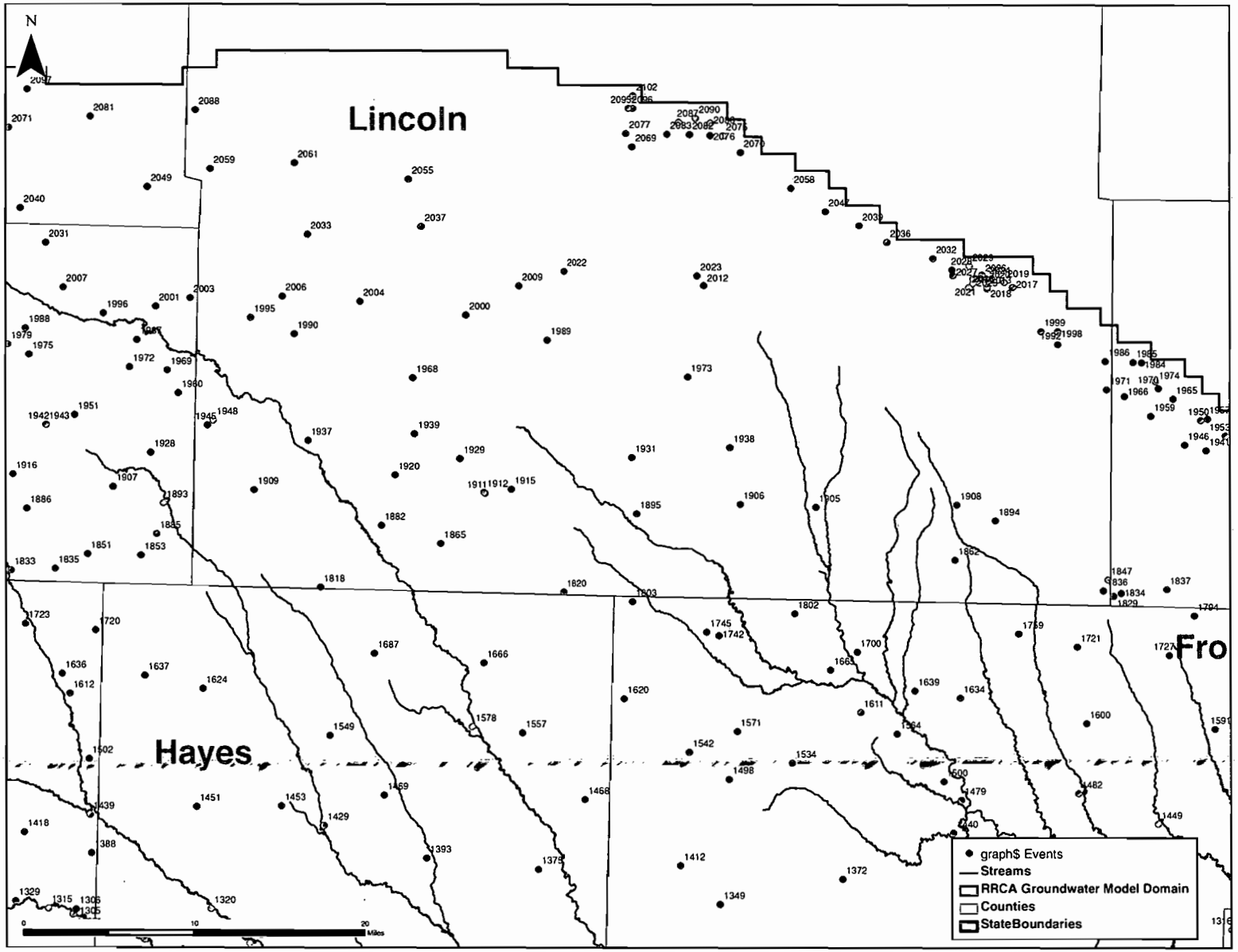
Miles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Streams
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Counties
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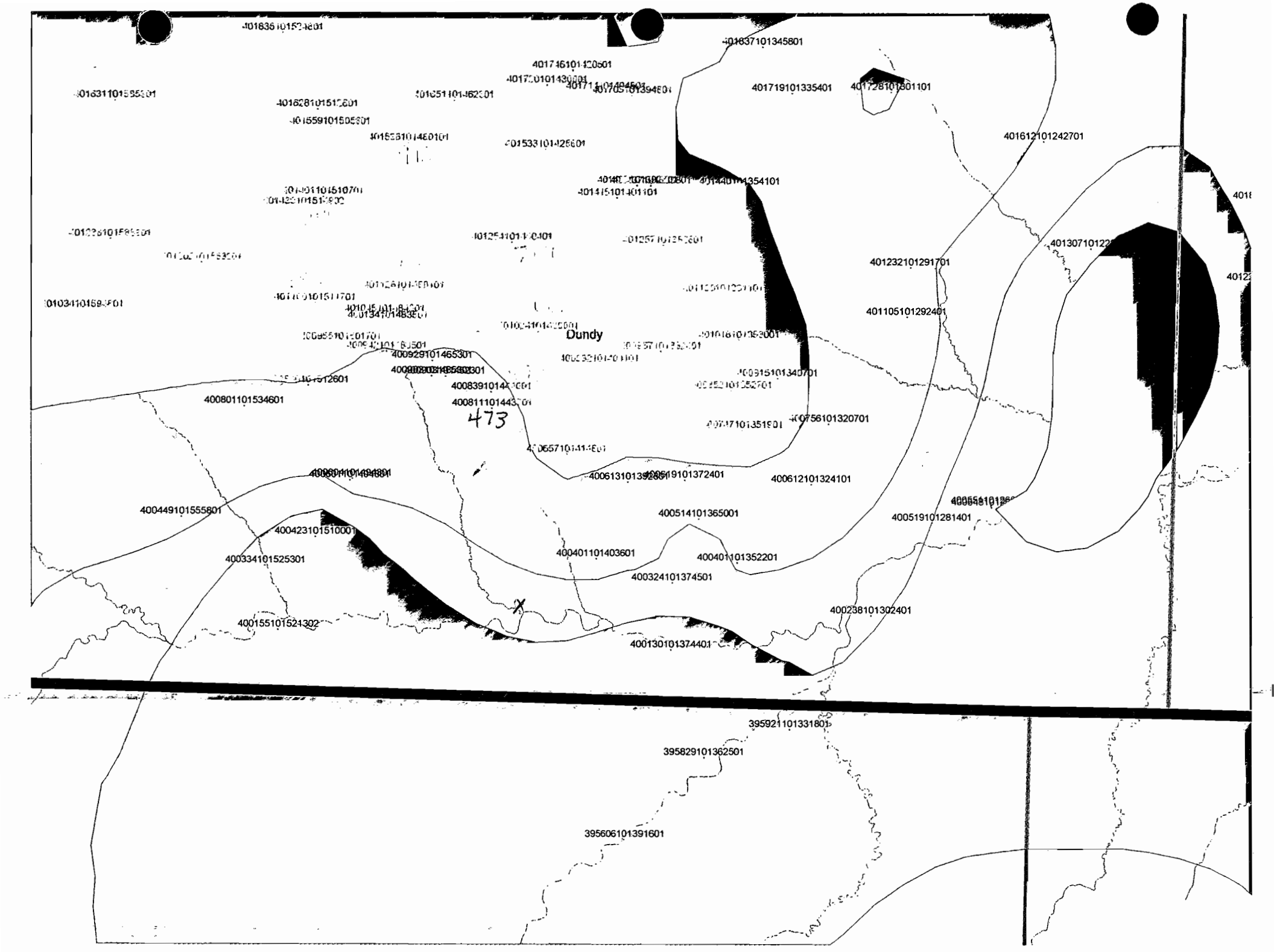
Miles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Minimum number of levels = 1

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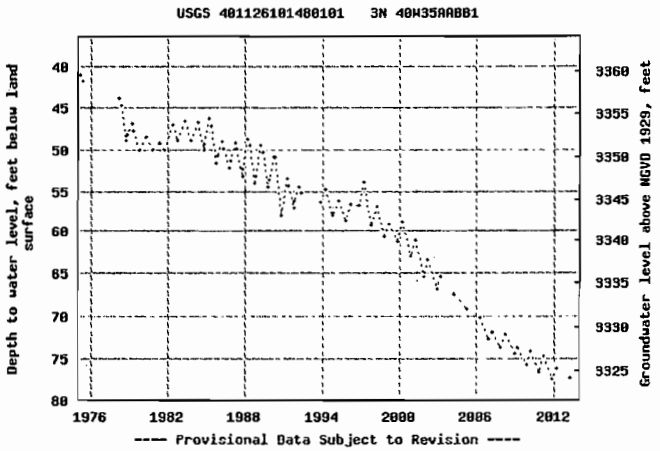
USGS 401126101480101 3N 40W35AABB1

Available data for this site: Groundwater: Field measurements | GO

Dundy County, Nebraska
Hydrologic Unit Code 10250002
Latitude 40°11'26", Longitude 101°48'01" NAD27
Land-surface elevation 3,401.00 feet above NGVD29
This well is completed in the High Plains aquifer (N100HGHPLN) national aquifer.
This well is completed in the Ogallala Formation (121OGLL) local aquifer.

Output formats
- Table of data
- Tab-separated data
- Graph of data
- Reselect period



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- 400903101462301

Minimum number of levels = 1

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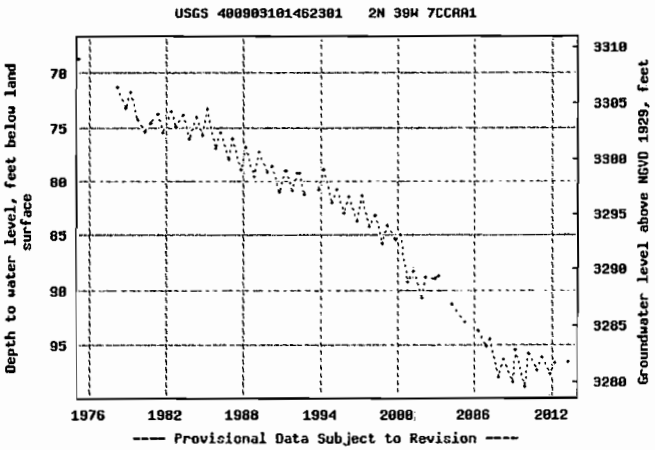
USGS 400903101462301 2N 39W 7CCAA1

Available data for this site Groundwater: Field measurements | GO

Dundy County, Nebraska
Hydrologic Unit Code 10250002
Latitude 40°09'03", Longitude 101°46'23" NAD27
Land-surface elevation 3,378.00 feet above NGVD29
This well is completed in the High Plains aquifer (N100HGHPLN) national aquifer.
This well is completed in the Ogallala Formation (121OGLL) local aquifer.

Output formats
- Table of data
- Tab-separated data
- Graph of data
- Reselect period



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Search Results -- 1 sites found

Search Criteria

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- 400839101444001

Minimum number of levels = 1

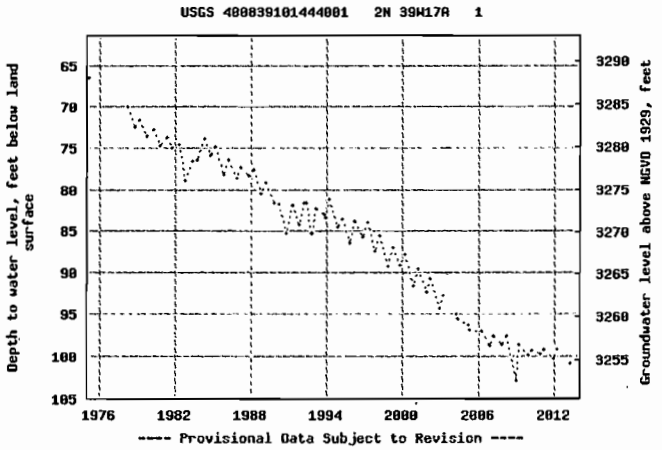
Save file of selected sites to local disk for future upload

USGS 400839101444001 2N 39W17A 1

Available data for this site Groundwater: Field measurements | GO

Dundy County, Nebraska
Hydrologic Unit Code 10250002
Latitude 40°08'39", Longitude 101°44'40" NAD27
Land-surface elevation 3,355.00 feet above NGVD29
This well is completed in the High Plains aquifer (N100HGHPLN) national aquifer.
This well is completed in the Ogallala Formation (121OGLL) local aquifer.

Output formats
- Table of data
- Tab-separated data
- Graph of data
- Reselect period



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USGS 400811101443701 2N 39W17DDBB1

Available data for this site Groundwater: Field measurements | GO

Dundy County, Nebraska
Hydrologic Unit Code 10250002
Latitude 40°08'11", Longitude 101°44'37" NAD27
Land-surface elevation 3,347.00 feet above NGVD29
This well is completed in the High Plains aquifer (N100HGHPLN) national aquifer.
This well is completed in the Ogallala Formation (121OGLL) local aquifer.

Output formats
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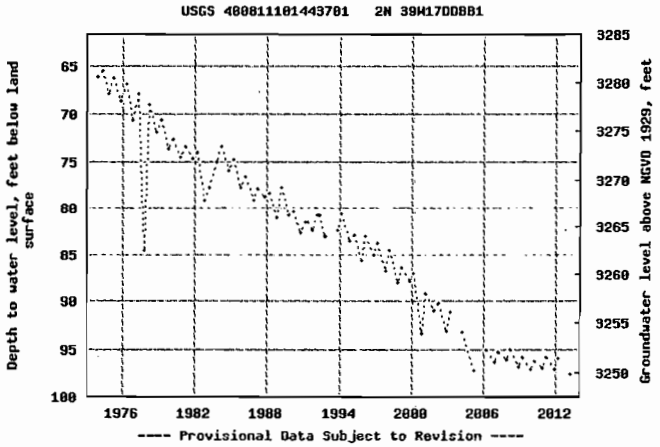
- Graph of data
- Reselect period



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site_no list =
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Minimum number of levels = 1

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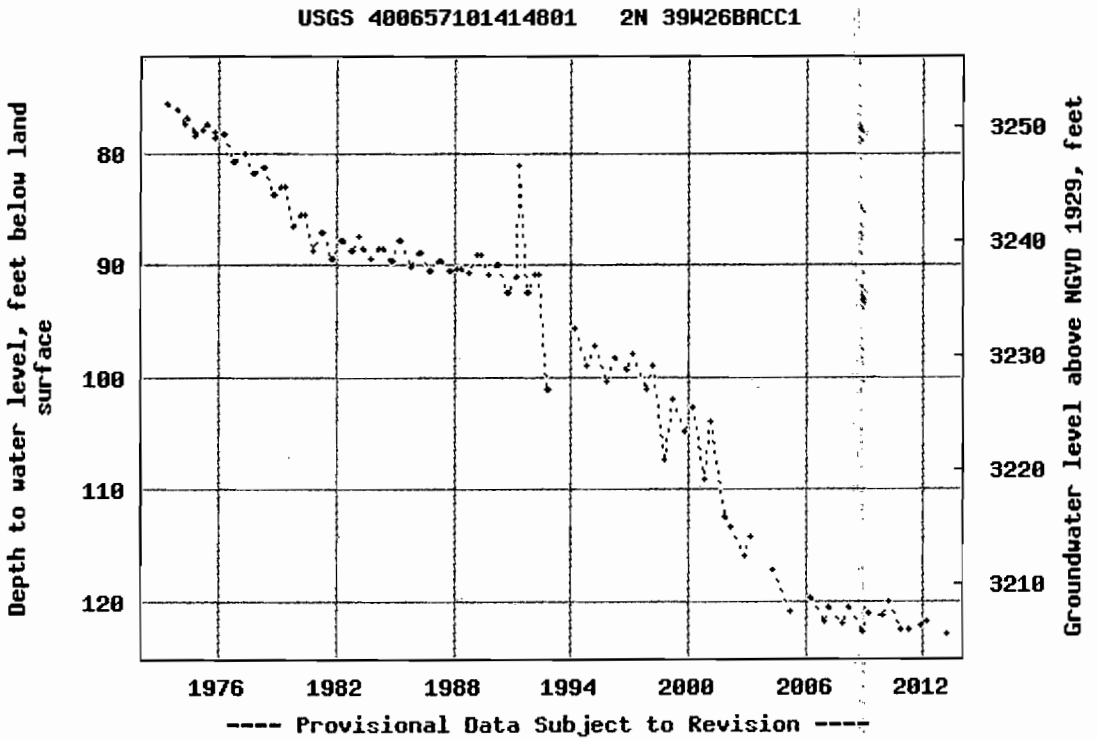
Available data for this site Groundwater: Field measurements | GO

Dundy County, Nebraska
Hydrologic Unit Code 10250002
Latitude 40°06'57", Longitude 101°41'48" NAD27
Land-surface elevation 3,328.00 feet above NGVD29
The depth of the well is 180.00 feet below land surface.
The depth of the hole is 180.00 feet below land surface.
This well is completed in the High Plains aquifer (N100HGHPLN) national aquifer.
This well is completed in the Ogallala Formation (121OGLL) local aquifer.

Output formats

- Table of data
- Tab-separated data
- Graph of data
- Reselect period



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USGS to Discontinue Streamgages Due to Sequestration

The U.S.Geological Survey (USGS) will discontinue operation of up to 375 streamgages nationwide due to budget cuts as a result of sequestration. Additional streamgages may be affected if partners reduce their funding to support USGS streamgages. The USGS is working to identify which streamgages will be impacted and will post this information as it becomes available. Streamgages are used nationwide to predict and address drought and flood conditions by monitoring water availability. The USGS and over 850 Federal, State, and local agencies cooperatively fund the USGS streamgaging network, which consists of over 8,000 streamgages. When budget fluctuates, the network is impacted. Impacts to Nebraska currently are not known, but are expected to be substantial.

USGS 06824000 Rock Creek at Parks, Nebr.

PROVISIONAL DATA SUBJECT TO REVISION

Available data for this site: Time-series: Daily data | GO

This station is operated by the USGS Nebraska Water Science Center and funded by the National Streamflow Information Program

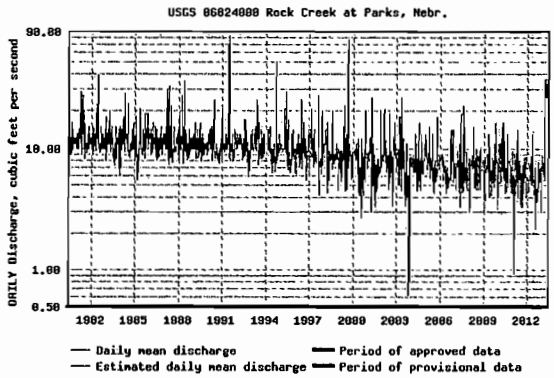
If precipitation, water temperature, and (or) air temperature are displayed for this station, then these values are temporary and will only be displayed for 120 days. The temporary classification means that the routine inspections and other quality assurance measures that would allow these data to be published are not routinely performed for this station.

This station managed by the North Platte Field Unit.

Available Parameters	Period of Record	Output format	Days (12053)	
☐ All 1 Available Parameters for this site		◉ Graph		
☑ 00060 Discharge(Mean)	1940-10-01 2013-06-11	○ Graph w/ stats	-- or --	GO
		○ Graph w/ meas	Begin date 1980-06-11	
		○ Graph w/ (up to 3) parms NEW	End date 2013-06-11	
		○ Table		
		○ Tab-separated		

Summary of all available data for this site
Instantaneous-data availability statement

Discharge, cubic feet per second



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USGS
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Data Category: Surface Water | Geographic Area: United States | GO

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USGS to Discontinue Streamgages Due to Sequestration

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USGS 06824000 Rock Creek at Parks, Nebr.

PROVISIONAL DATA SUBJECT TO REVISION

Available data for this site Time-series: Daily data GO

This station is operated by the USGS Nebraska Water Science Center and funded by the National Streamflow Information Program

If precipitation, water temperature, and (or) air temperature are displayed for this station, then these values are temporary and will only be displayed for 120 days. The temporary classification means that the routine inspections and other quality assurance measures that would allow these data to be published are not routinely performed for this station.

This station managed by the North Platte Field Unit.

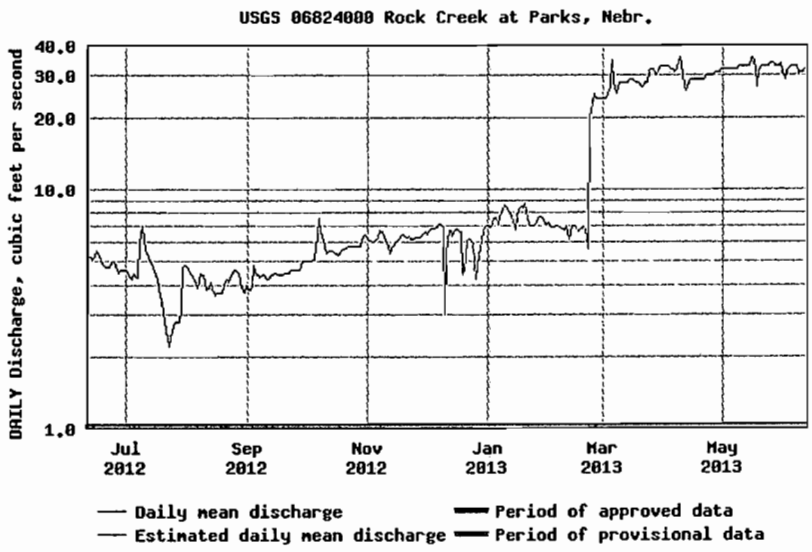
Available Parameters	Period of Record
☐ All 1 Available Parameters for this site	
☑ 00060 Discharge(Mean)	1940-10-01 2013-06-11

Output format
- ◉ Graph
- ○ Graph w/ stats
- ○ Graph w/ meas
- ○ Graph w/ (up to 3) parms NEW
- ○ Table
- ○ Tab-separated

Days (365)
-- or --
Begin date 2012-06-11
End date 2013-06-11
GO

Summary of all available data for this site
Instantaneous-data availability statement

Discharge, cubic feet per second



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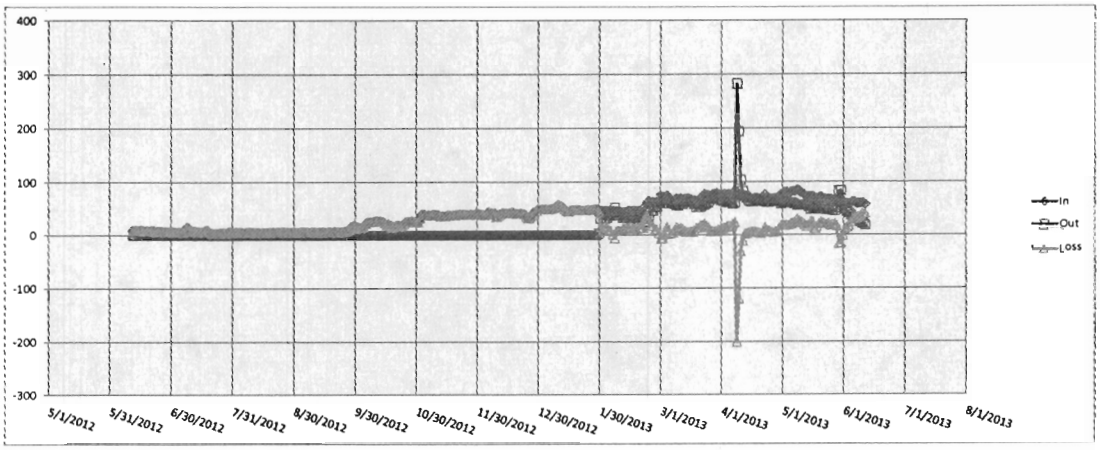
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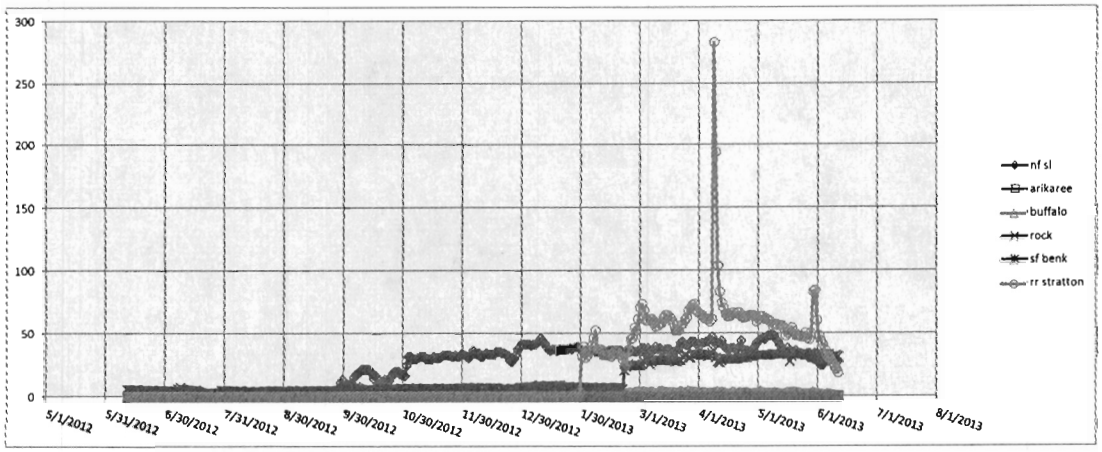
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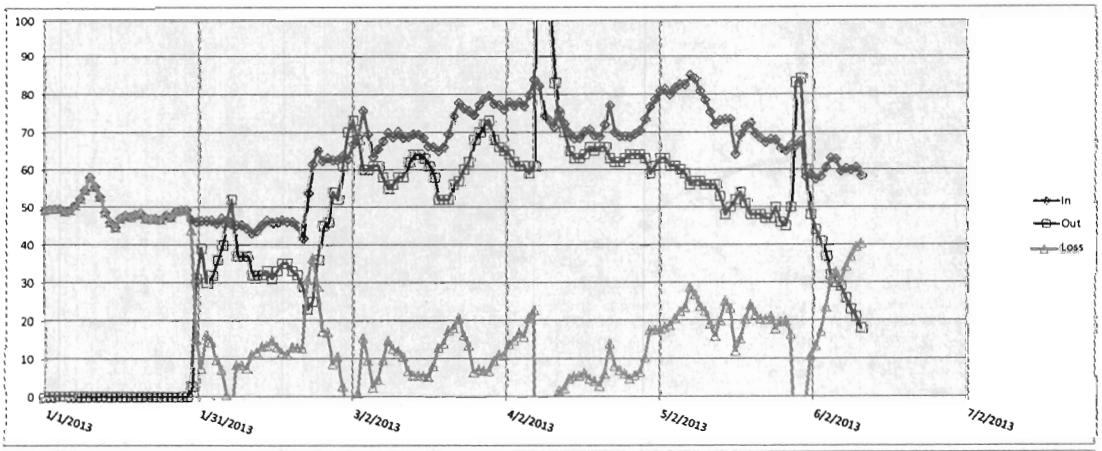
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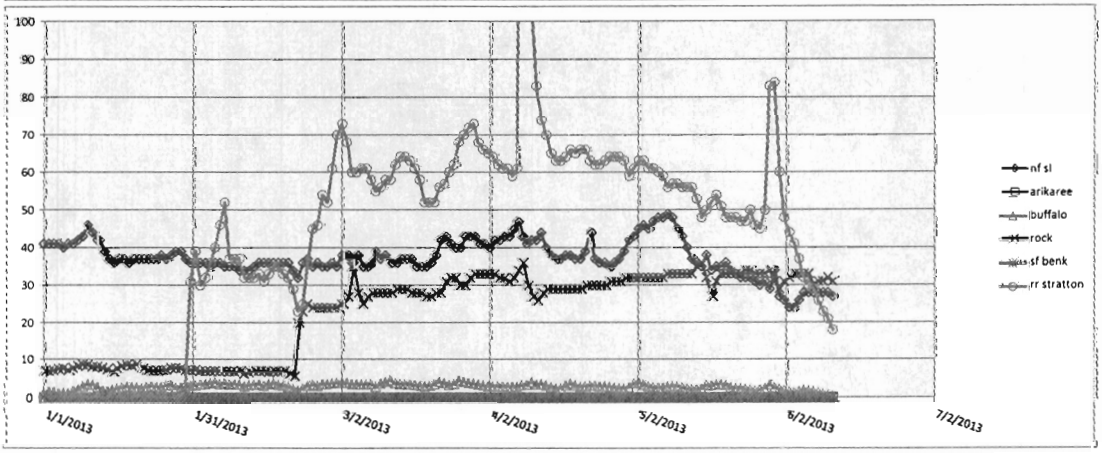
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rock
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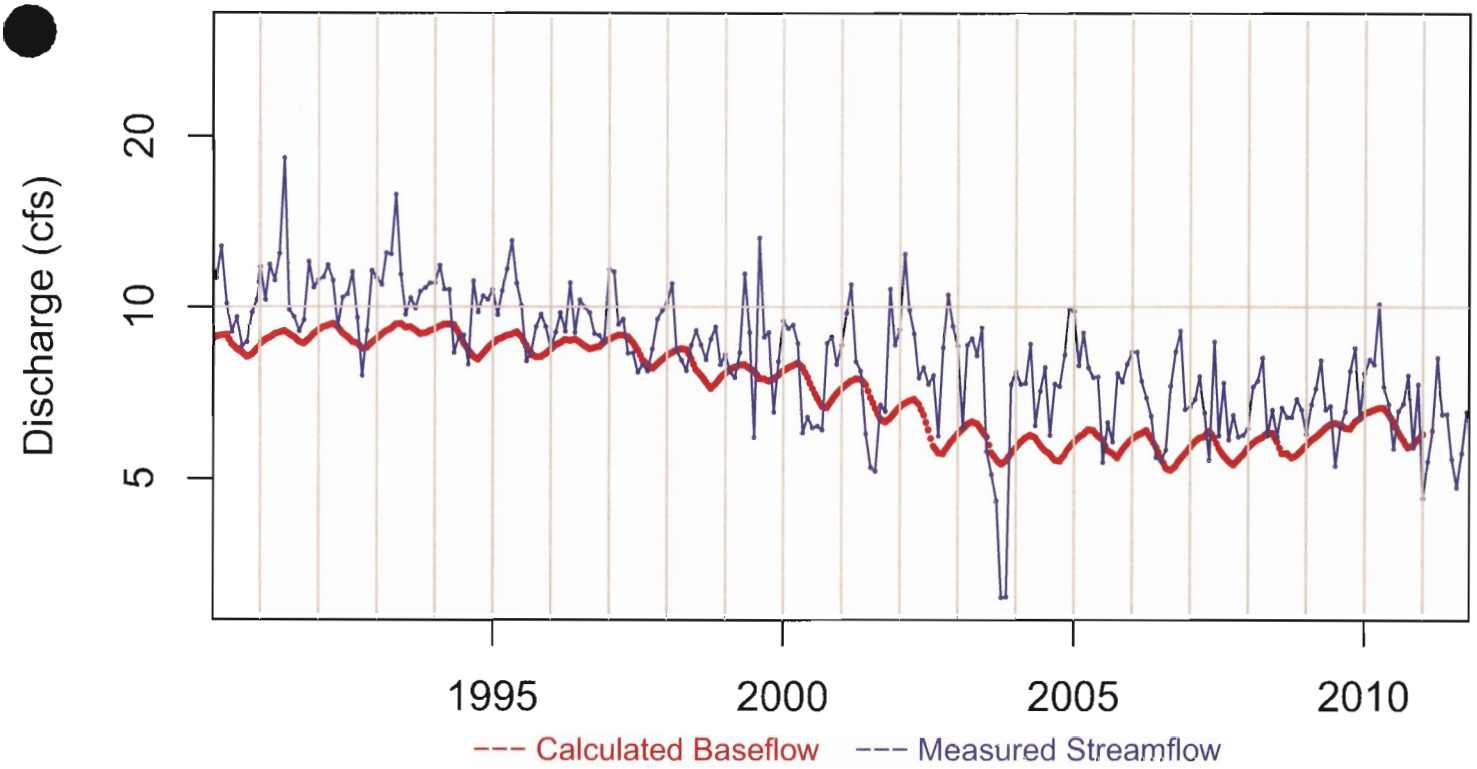
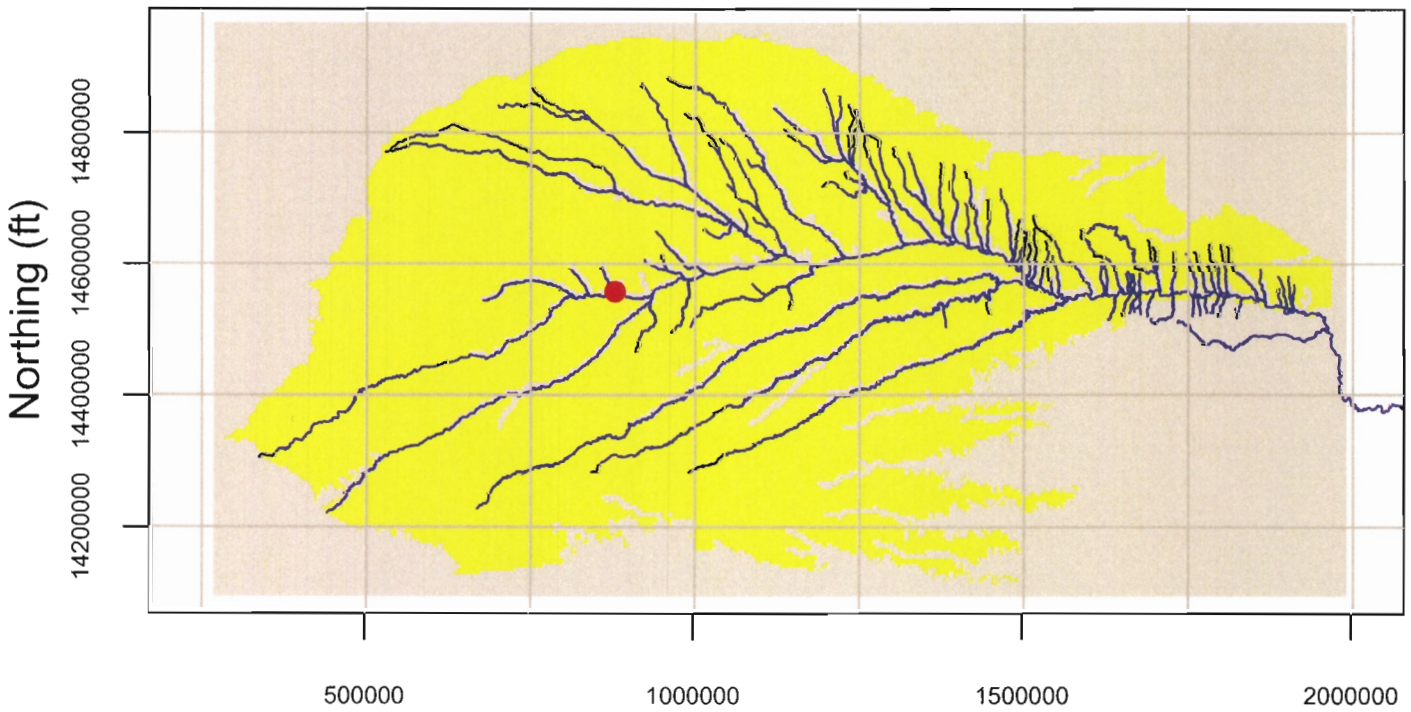
rr stratton

Rock Creek at Parks, Nebr.



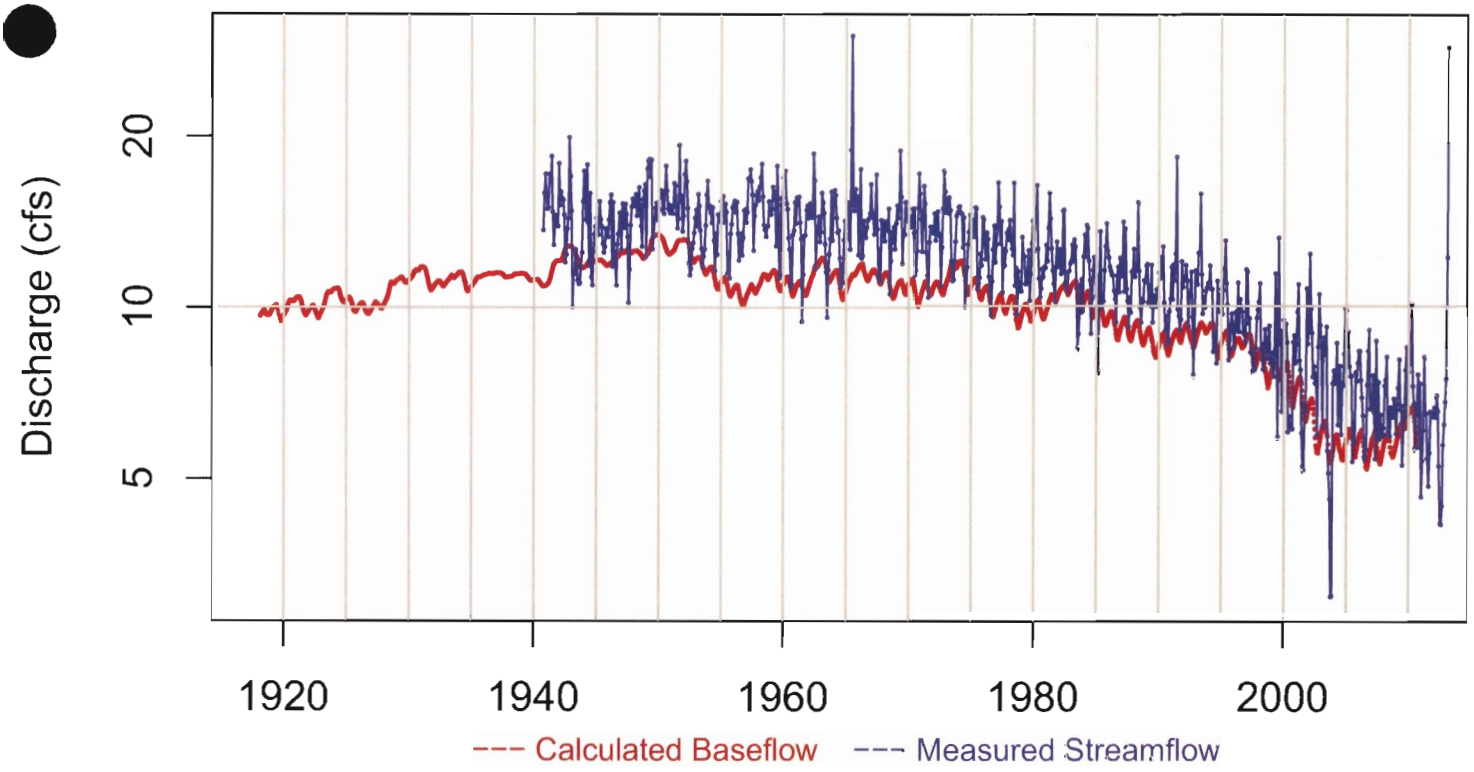
Historic and Calculated Gage Discharge

USGS Gage ID: 6824000 Seq No: 31



Gage Location with Respect to Model Extent (NAD27 UTM Z 14N)

Rock Creek at Parks, Nebr.



Historic and Calculated Gage Discharge

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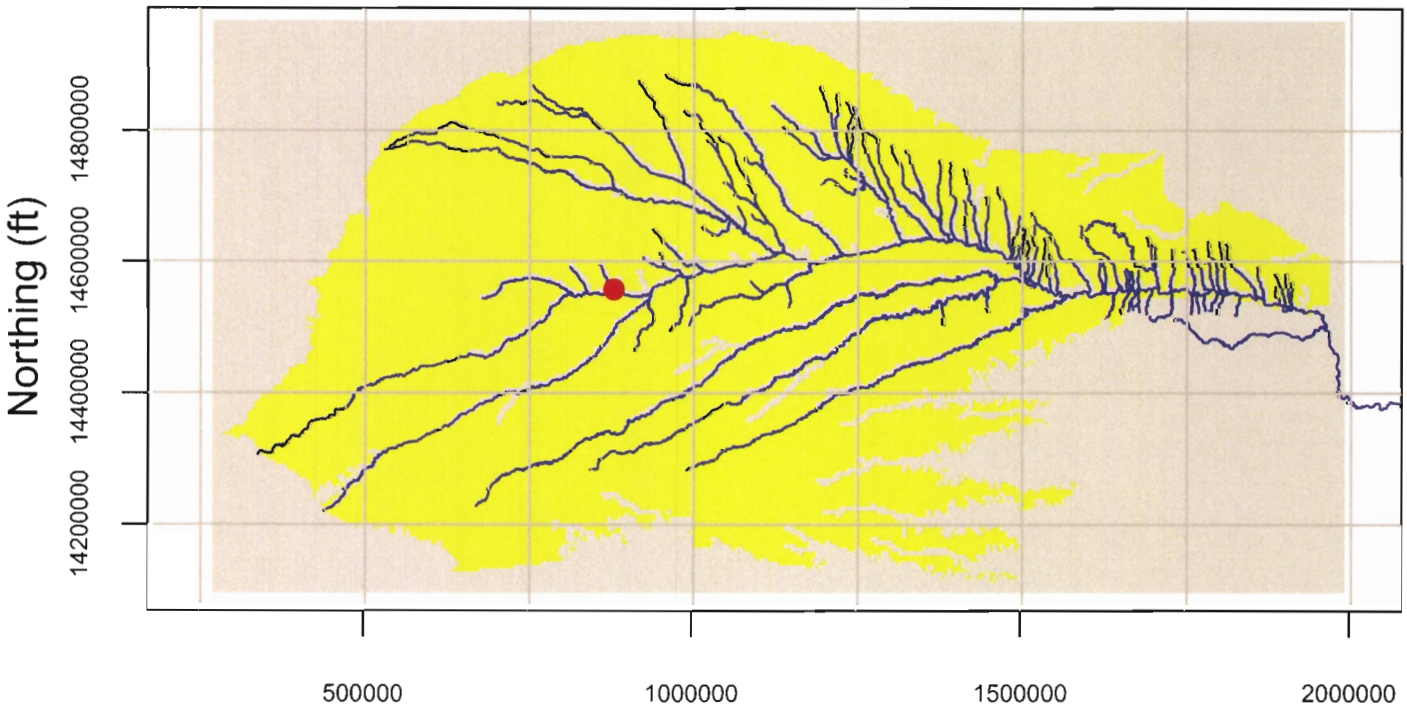
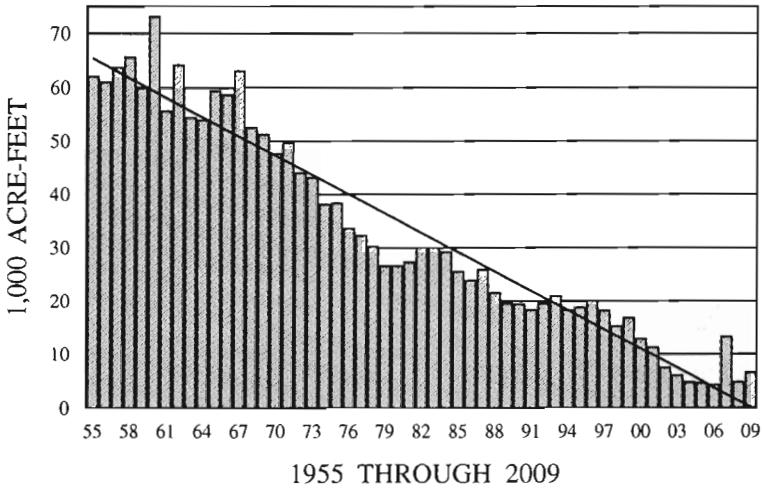
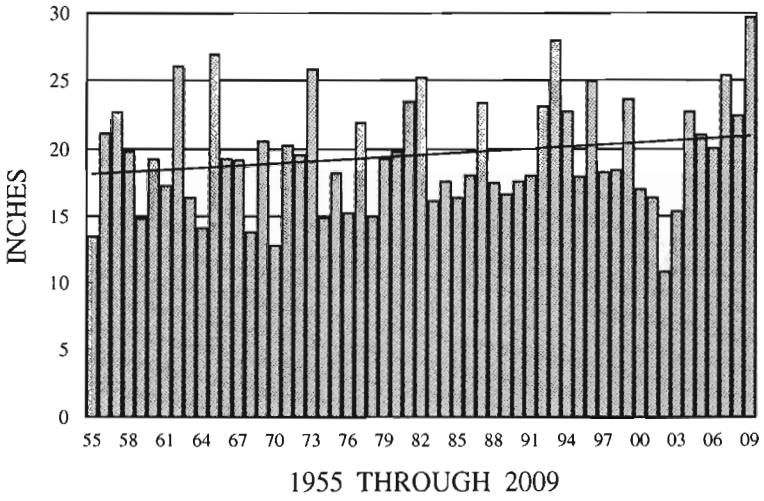


Gage Location with Respect to Model Extent (NAD27 UTM Z 14N)

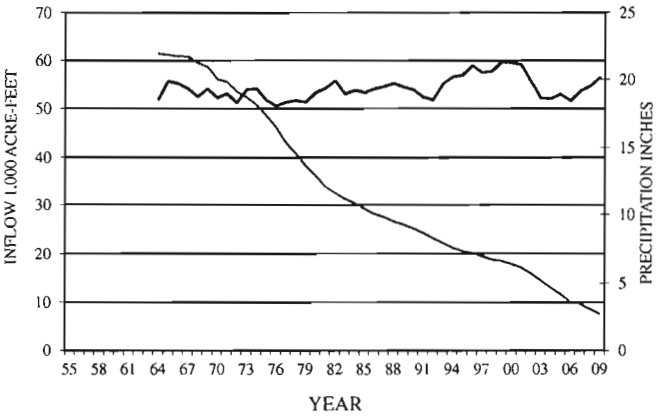
ENDERS DAM & RESERVOIR
YEARLY HISTORICAL INFLOW



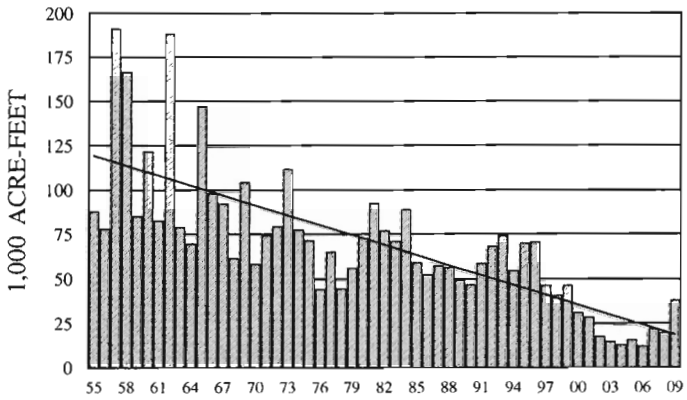
ENDERS DAM
YEARLY PRECIPITATION



ENDERS RESERVOIR
10-Year Moving Average - Inflow & Precipitation

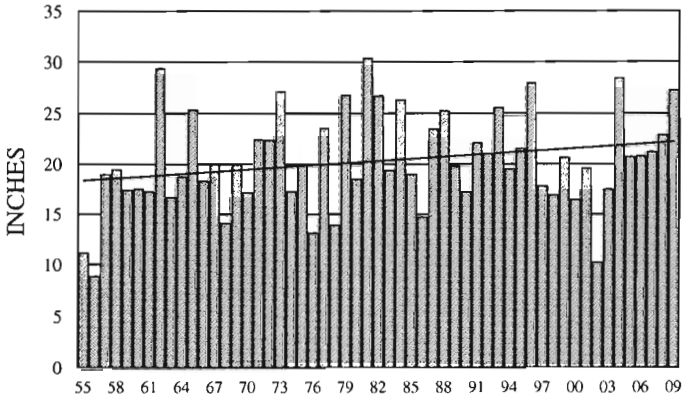


TRENTON DAM
YEARLY HISTORICAL INFLOW



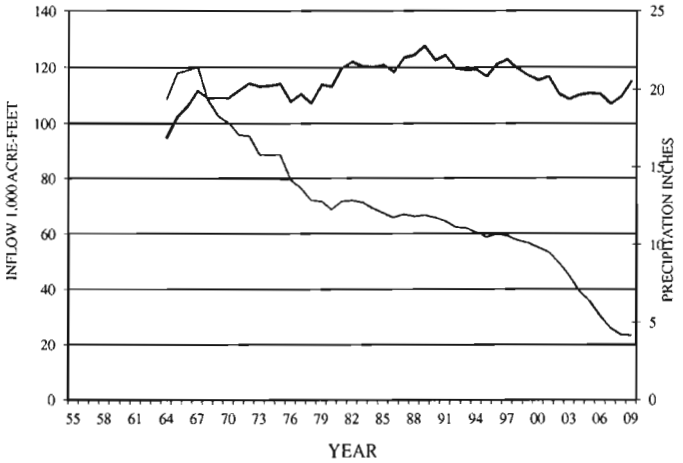
1955 THROUGH 2009

TRENTON DAM
YEARLY PRECIPITATION

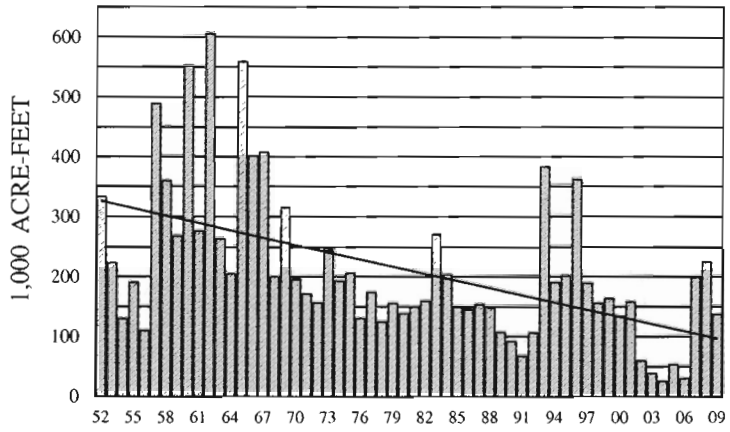


1955 THROUGH 2009

SWANSON LAKE
10-Year Moving Average - Inflow & Precipitation

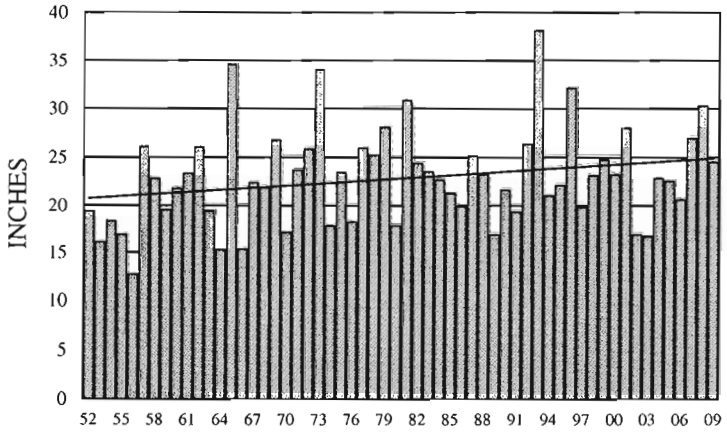


HARLAN COUNTY DAM
YEARLY HISTORICAL INFLOW



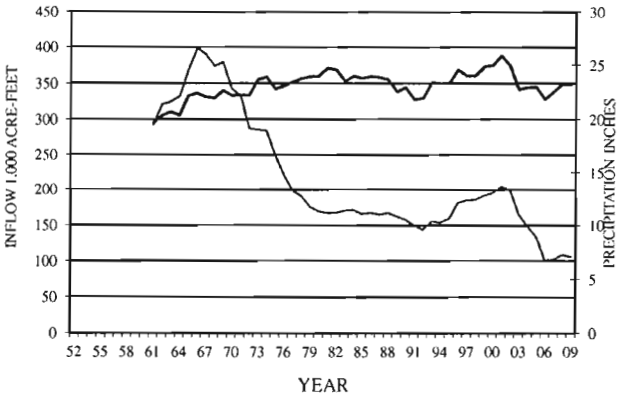
1952 THROUGH 2009

HARLAN COUNTY DAM
YEARLY PRECIPITATION



1952 THROUGH 2009

HARLAN COUNTY LAKE
10-Year Moving Average - Inflow & Precipitation



YEAR

5

HYDROGRAPHIC REPORT

2010

INTRODUCTION and EXPLANATION OF DATA

Most stream gaging data in Nebraska are published in the Nebraska Department of Natural Resource's Hydrographic Report and the Water Resources Data for Nebraska compiled by the U. S. Geological Survey.

The Water Resources Data for Nebraska, an online publication by the U. S. Geological Survey, includes stream and river data for gaging stations operated by the U. S. Geological Survey and its cooperators, including the Department of Natural Resources. Information can be obtained by contacting the Director, U. S. Geological Survey, Nebraska Water Science Center, 5231 South 19th Street, Lincoln, Nebraska 68512-1271. These data are not published in this report.

The Hydrographic Report for water year 2010 provides a record of stream flow, reservoir storage, and diversions for irrigation and power in Nebraska for gages operated by the Nebraska Department of Natural Resources according to statutory authority granted under Statutes 61-208, 61-209, 61-211, 46-227, 46-256, and 46-261. This report also includes some records for gages operated by agencies other than the Department of Natural Resources and U.S. Geological Survey. These sites and the operating agency are identified in the station headings. Stations are listed in order from upstream to downstream (downstream order) according to the river basin map on the next page. Multiple gages on a canal system are also in downstream order on the canal. The data presented include mean daily discharges for streams and canals and both daily and monthly reservoir storage values. Instantaneous and daily discharge values are expressed in cubic feet per second (cfs), monthly and annual totals are cubic foot per second-days (cfs-days) and acre-feet. Reservoir storage values are in acre-feet. Zero means there is no flow, a blank indicates no record was made. An "e" next to a daily record indicates an estimated value. Estimated values usually result from either a poor stage-discharge relationship due to a backwater condition or a missing or poor gage height record. Headings describe the period of record, type of gage and locations of gage sites by legal coordinates of Section, Township, and Range, East or West of the 6th Principal Meridian. The "Remarks" section for stations operated year round includes a statement on the accuracy of daily records. U.S. Geological Survey criteria are adopted for these accuracy ratings: If 95 percent of daily discharges are within 5 percent of true values the record is rated "excellent," if they are within 10 percent, the rating is "good," within 15 percent is "fair," and more than 15 percent is "poor."

Data may be converted to other common units of measurement using the table of equivalents listed below:

1 cubic foot	7.48 gallons or 62.4 lbs. of water
1 cubic foot	0.02832 cubic meters
1 acre-foot	43,560 cubic feet or 325,851 gallons
1 cubic foot per second (cfs)	448.8 gallons per minute
1 cfs for 24 hours	1.983 acre-feet
1,000 gallons per minute	2.23 cfs
1,000 gallons per minute	4.42 acre-feet per day

The Hydrographic Report is available on the internet at the department's web page address www.dnr.ne.gov. Copies of the Hydrographic Report can be obtained by contacting the Nebraska Department of Natural Resources, PO Box 94676, Lincoln, Nebraska 68509-4676. Questions or comments can be directed to this address or (402) 471-2363.

Gage records from this and previous years publications are also provided on the Nebraska Department of Natural Resources' computerized Data Bank. This information can be obtained on the internet at the Department of Natural Resources web page address www.dnr.ne.gov or by contacting the Data Bank , Nebraska Department of Natural Resources, PO Box 94676, Lincoln, Nebraska 68509-4676. For email requests, use gayle.follmer@nebraska.gov.

FRENCHMAN CREEK near Imperial, 06831500

LOCATION.--SW1/4NW1/4 Sec. 3-5-38 W., Chase County, Lat. 40°25'45", Long. 101°37'25", on right bank, 0.2 mile downstream from bridge on county road; 5.8 miles upstream from Enders Dam; 1 mile east and 6.1 miles south of Imperial.

DRAINAGE AREA.--880 square miles, approximately 720 square miles contributes directly to surface runoff.

GAGE.--Continuous stage recorder. Elevation of the gage is approximately 3130 feet from topographic map.

PERIOD OF RECORD.--1940 - present (published as Frenchman River near Imperial 1965-1972)

REMARKS.--Published by U. S. Geological Survey up to Oct. 1, 1994. Records are fair, excepted estimated records are poor.

EXTREMES FOR PERIOD OF RECORD.--Peak discharge 3,780 cubic feet per second June 12, 2007, gage height 10.01 feet; minimum daily discharge 1.7 cubic feet per second July 24 & 25, 2003 and July 31, August 1 and 6, 2006.

EXTREMES FOR CURRENT YEAR.--Peak discharge 132 cubic feet per second August 3, gage height 2.75 feet; minimum daily discharge 3.8 cubic feet per second October 1.

DISCHARGE (CFS), WATER YEAR 2010

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	3.8	7.0	4.9	5.3	5.7	8.1	8.4	7.9	5.9	7.0	4.8	4.3
2	3.9	6.3	4.9	5.2	5.7	8.2	8.3	7.5	5.8	7.3	4.7	4.2
3	4.2	5.9	4.8	5.3	5.7	8.1	8.2	7.2	5.8	7.6	14	4.2
4	4.5	5.7	4.8	5.3	6.2	8.0	8.0	6.8	5.6	6.9	7.3	4.2
5	4.6	5.6	4.9	5.5	5.9e	8.1	7.8	6.7	5.5	8.4	6.2	4.1
6	4.6	5.6	4.9	5.1	6.0e	8.1	8.1	6.8	5.4	7.5	6.6	4.0
7	4.5	5.5	4.8	5.2	6.0e	7.9	9.8	6.7	5.5	7.7	5.8	3.9
8	4.6	5.3	4.5e	5.0	6.1e	9.9	9.8	6.5	5.7	8.5	5.4	4.1
9	4.7	5.2	4.5e	5.0	6.1e	15	9.5	6.6	5.3	10	5.8	4.3
10	5.0	5.2	4.5e	5.2	6.2e	17	9.1	7.0	5.2	10	8.3	4.5
11	5.0	5.3	4.7	5.4	6.4	16	8.7	7.0	7.7	9.9	6.4	4.3
12	5.0	5.3	4.8	5.6	6.5	14	8.3	7.7	11	9.2	5.9	4.2
13	5.4	5.2	5.0	6.0	6.8	12	8.5	7.7	12	8.7	5.4	4.2
14	5.4	5.1	4.9	6.1	6.4	11	8.9	7.6	10	8.0	5.2	4.3
15	5.1	5.4	4.8	6.0	6.5	10	8.6	8.0	11	7.4	5.2	4.4
16	4.8	5.2	5.0	6.3	6.3	9.8	8.3	8.5	10	7.1	7.0	4.4
17	4.6	5.1	5.2	6.4	6.4	9.4	8.0	8.3	8.7	6.6	13	4.4
18	4.6	5.1	5.4	6.2	6.4	9.1	7.6	8.2	7.7	6.4	7.7	4.4
19	4.5	5.1	5.5	6.2	6.7	9.3	7.4	10	9.1	6.2	7.2	4.5
20	4.6	5.1	5.7	6.2	6.7	9.1	7.8	10	8.2	6.0	6.9	4.7
21	6.4	5.1	5.7	6.1	7.0	8.8	7.9	11	15	6.0	6.9	4.8
22	9.7	5.0	5.8	6.3	7.0	8.7	8.6	9.8	33	6.3	6.6	4.8
23	7.6	5.2	5.8	6.3	7.2	8.5	12	8.6	47	6.1	6.2	5.2
24	6.4	5.3	5.5	6.1	7.2	8.7	15	8.2	23	5.8	5.9	5.1
25	5.8	5.1	5.0	6.0	7.3	8.4	16	7.5	16	5.8	5.5	4.9
26	5.4	5.0	5.2	5.8	7.5	8.3	13	7.3	12	5.7	5.2	4.8
27	5.3	5.1	5.3	5.7	7.5	8.3	11	6.9	11	5.3	4.8	4.7
28	5.3	5.0	5.4	5.7	7.7	8.3	9.9	6.5	9.8	5.2	4.4	4.7
29	6.2	5.0	5.4	5.7	---	8.4	8.7	6.3	8.7	5.1	4.3	4.6
30	7.7	5.0	5.4	5.7	---	8.3	8.4	6.0	7.7	4.9	4.3	4.5
31	7.5	---	5.4	5.7	---	8.4	---	5.9	---	4.8	4.2	---
TOTAL	166.7	160	158.4	177.6	183.1	301.2	279.6	236.7	334.3	217.4	197.1	133.7
MEAN	5.4	5.3	5.1	5.7	6.5	9.8	9.3	7.6	11.1	7.0	6.4	4.5
MAX	9.7	7.0	5.8	6.4	7.7	17	16	11	47	10	14	5.2
MIN	3.8	5.0	4.5	5.0	5.7	7.9	7.4	5.9	5.2	4.8	4.2	3.9
AC-FT	331	317	314	352	363	597	555	469	663	431	391	265

CAL YEAR 2009	TOTAL	1786	MEAN	4.9	MAX	10.0	MIN	3.0	AC-FT	3542
WTR YEAR 2010	TOTAL	2546	MEAN	7.0	MAX	47.0	MIN	3.8	AC-FT	5050

e indicates estimated discharge.