Appendix 6-L

North Platte Focus Area Study

Appendix 6-L contains a technical memorandum summarizing the focus study of the North Platte River.

STUDY OF NORTH PLATTE FOCUS AREA PRELIMINARY RESULTS – AUGUST 2012
(DOCUMENTED EFFORTS THROUGH JUNE 2012)

Introduction

Attempts to calibrate the COHYST 2010 surface water and integrated model in the North Platte River area have been marginally successful to date. Comparisons of modeled and historic irrigation canal diversions along the North Platte River illustrate a large variance in many instances, and more importantly a systemic variance in many cases. In addition, the total flow comparisons between modeled and historic flows at the Sutherland and North Platte River gage locations contain significant variations in reach gains/losses and subsequent total flows in some years.

The primary purposes of the focused study of the North Platte reach are to: (1) diagnose the model and data to determine what is not being represented appropriately in the model and simulated in a realistic, technically sound manner, and (2) formulate revisions to the model that will achieve a suitable calibration. This effort is concentrated on the North Platte River below Lake McConaughy, but it is anticipated and intended that results from this focus study effort will inform calibration efforts in the remaining model domain.

Workplan Concept

The concept of this focus study effort is as follows:

1. Prepare gross water budget of the North Platte River focus study area using gaged/measured data to the extent possible.
2. Refine water budget to isolate surface water canal operation terms, again using gage/measured data to the extent possible.
3. Once the surface water canal term is isolated within the overall water budget, assess the components of the surface water canal operation term that are represented in the current COHYST 2010 modeling effort.
4. Evaluate model predictions for the components of the surface water canal operation term compared to gage/measured/estimated terms
5. Suggest refinements to the model parameters, focused primarily on the STELLA surface water operation model and watershed model.

Gross Water Budget

To better represent the operations of the surface water canals along the North Platte River below Lake McConaughy, the gross water budget for the reach during the irrigation season (April 1 – September 30) was evaluated.

The upstream reach boundary is the North Platte River gage below Keystone Diversion. The downstream boundary is the North Platte River at North Platte gage location. Elements of the water budget in this reach include:

- Platte river inflows and outflows at the reach boundaries
- Net evaporation on the river reach
- Runoff from three ungaged watersheds
- Runoff from one gaged watershed (Birdwood Creek)
- Operation of six irrigation canals (Keith-Lincoln, Paxton-Hershey, North Platte, Suburban, Cody-Dillon, and Birdwood Canals)
- Baseflow to the North Platte River reach

The first step was an evaluation of just the North Platte River inflows and outflows for the study reach based on historic gage data. Table 1 illustrates the annual irrigation season volumes, and the difference between inflows and outflows, or the total reach gain/loss (RGL).

Table 1. Irrigation Season (April 1 through September 30) Inflows and Outflows (AF), and RGL

Year	NP below Keystone	NP at NP	Reach Gain or (Loss)
1985	202,998	239,855	36,857
1986	622,467	672,264	49,797
1987	200,339	245,837	45,498
1988	224,164	289,488	65,324
1989	232,320	248,539	16,219
1990	293,833	291,667	(2,166)
1991	287,211	293,220	6,010
1992	131,060	182,273	51,213
1993	73,438	144,908	71,470
1994	196,656	217,208	20,552
1995	314,773	343,053	28,280
1996	198,541	254,368	55,827
1997	306,524	317,752	11,228
Total	3,284,325	3,740,434	456,109

It is noted that there is substantial variability in annual surface water volumes lost/gained in the study reach during this period (2,000 AF loss to over 71,000 AF gain). Water budget elements that contribute to the RGL term include:

- Watershed runoff

- Baseflows from groundwater
- Net river evaporation – (Evaporation – Precipitation)
- Surface water losses in the canal system (consumptive use by crops, canal evaporation, and canal seepage)

Isolate Surface Water Canal Operation Term

The second step is focused on isolating the surface water canal operations in the overall water budget based on the computed RGL (Table 1) and estimates for watershed runoff, baseflow from groundwater, and net river evaporation.

- Watershed Runoff – Runoff for the four contributing watersheds to the reach was estimated using the predicted monthly runoff volumes estimated from the watershed model, which was developed by M. Groff of The Flatwater Group using SWAT as part of the COHYST 2010 modeling effort (Run 008). Because the baseflow estimates described below include the Birdwood Creek contribution, the estimate of watershed runoff was used for the Birdwood Creek basin rather than the historic Birdwood Creek gage for this analysis.
- Baseflow from Groundwater – baseflow was estimated from anecdotal estimates from CNPPID and DNR staff. The average baseflow values used were 500 AF/day, with 220 AF/day coming from Birdwood Creek.
- Net river evaporation – Net river evaporation was treated as a constant value of 2000 AF per year for the reach during the irrigation season based on estimated surface water area and average evaporation rate for the reach.

These terms were then incorporated into the reach water budget to determine the surface water losses (or gains) due to canal operations. Table 2 summarizes these elements. Observed irrigation season precipitation was also included as an indication of the annual variations in climate.

Table 2. Study Reach Irrigation Season Water Budget Components

Year	NP below Keystone (AF)	Baseflow (AF)	Runoff (AF)	Net River Evap (AF)	NP at North Platte (AF)	SW Canal Loss (AF)	Irrigation Season Precip (in)
1985	202,998	91,500	39,024	(2,000)	239,855	(91,666)	15.54
1986	622,467	91,500	42,637	(2,000)	672,264	(82,340)	14.28
1987	200,339	91,500	58,912	(2,000)	245,837	(102,914)	17.17
1988	224,164	91,500	47,023	(2,000)	289,488	(71,199)	17.78
1989	232,320	91,500	30,928	(2,000)	248,539	(104,209)	10.21
1990	293,833	91,500	37,748	(2,000)	291,667	(129,414)	11.03
1991	287,211	91,500	42,023	(2,000)	293,220	(125,514)	11.84
1992	131,060	91,500	45,287	(2,000)	182,273	(83,574)	12.67
1993	73,438	91,500	80,654	(2,000)	144,908	(98,684)	17.4
1994	196,656	91,500	41,864	(2,000)	217,208	(110,811)	8.87
1995	314,773	91,500	52,321	(2,000)	343,053	(113,541)	16.08
1996	198,541	91,500	63,687	(2,000)	254,368	(97,360)	20.73
1997	306,524	91,500	38,702	(2,000)	317,752	(116,974)	12.53
Total	3,284,325	1,189,500	620,809	(26,000)	3,740,434	(1,328,200)	

The 'SW Canal Loss' column in Table 2 represents the losses associated with surface water irrigation and was computed based on a simple water balance equation for the reach:

$$NP_{Keystone} + Baseflow + Runoff + NEvap_{river} + SW\ Canal\ Loss = NP_{North\ Platte}$$

Table 3 compares the computed SW Canal Loss term from Table 2 with historic diversion volumes for the six surface water canals and irrigation season precipitation, as measured at the Kingsley meteorological measurement station.

Table 3. Computed Surface Water Canal Loss, Historic Diversion Volume, and Irrigation Season Precipitation

Year	SW Canal Loss (AF)	Historic Diversion Volume (AF)	Irrigation Season Precip (in)
1985	(91,666)	126,707	15.54
1986	(82,340)	123,770	14.28
1987	(102,914)	111,773	17.17
1988	(71,199)	112,286	17.78
1989	(104,209)	112,806	10.21
1990	(129,414)	115,736	11.03
1991	(125,514)	103,502	11.84
1992	(83,574)	86,851	12.67
1993	(98,684)	70,250	17.4
1994	(110,811)	105,939	8.87
1995	(113,541)	98,074	16.08
1996	(97,360)	83,133	20.73
1997	(116,974)	96,242	12.53
Total	(1,328,200)	1,189,500	

*Historic diversion volume is the sum of Keith-Lincoln, Paxton-Hershey, North Platte, Suburban, Cody-Dillon, and Birdwood canals

Two observations can made based on the information in Table 3:

1) In some years the computed SW Canal Loss exceeds the total historic diversion volume. It is further noted that a portion of the total historic diversion may be returned flows from upstream diversions, i.e. recycled water that is actually diverted twice. In addition, the variability in the SW Canal Loss term is also greater than the expected annual variability in crop demands, assuming the same irrigated acreage.

2) There is a 'break point' in the historic diversion record that occurs in approximately 1991, with historic diversion volumes subsequent to 1990 decreased by approximately 15% from those previous to 1991. It should be noted that this break point is also prevalent in the historic records of the Central Platte canals.

These findings of Step 1-3 were discussed with appropriate staff from DNR, CNPPID, and Twin Platte NRD to gain further insight. The results of this discussion include:

- **a.** Irrigated acreages for the six canals did not substantially change during the 1985 to 1997 period.
- **b.** Cropping patterns did substantially change during the 1985 to 1997 period.
- **c.** Irrigation practices did not substantially change during the 1985 to 1997 period (i.e. large change from flood to pivot systems).

d. Adjudication of the North Platte canals, which occurred in the late 1980's, did not change the diversion rights or patterns of the canals.
e. 1990-1991 were water short years. In looking at the historic record, Lake McConaughy storage dropped below 1,000,000 AF at the end WY 1990 for the first time since WY 1958.
f. In response to the water shortage, an operational change was made. All surface water canals that relied - at least in part - on Lake McConaughy storage started to delay the beginning of diversions by three to four weeks. This is generally confirmed by looking at the historic diversion records. Groundwater sources were used to supplement surface water sources in the early season (pre-July 1).
*(**Note:** Another operational change was made in response to the drought in the early 2000's, where the beginning of diversions was further delayed until June. The North Platte canals also reached an agreement with CNPPID to delay diversions and have storage water available during the irrigation season.)*
g. Baseflow in the Keystone to North Platte reach of the North Platte River can vary by 50-100 cfs based on the long-term release patterns to the river. Baseflow is particularly sensitive to Keystone Canal operations, with increased baseflow returns coinciding with extended diversion/usage of Keystone Canal in the previous year(s).

Based on these discussions, the baseflow and watershed runoff estimates in Table 2 were further evaluated. In March 2012 updated baseflow targets for this reach through 1993 were developed as part of the COHSYT 2010 modeling efforts and replaced the constant baseflow estimates used in Table 2.

As a check on the watershed runoff term, the Birdwood Creek gage data for 1985–1997 was partitioned into baseflow and runoff. Baseflow was estimated from the Birdwood Creek gage data based on historic October – March non-irrigation season gage data from 1985-1997, with an average baseflow value of 315 AF/day. This baseflow estimate was subtracted from the historic Birdwood Creek gage (including Birdwood Canal diversions) to estimate watershed runoff. This value is compared to the watershed runoff for the Birdwood Creek watershed from model Run 008 in Table 4.

Table 4. Comparison of Birdwood Creek Watershed Estimated and Predicted Runoff (Run 008)

Year	Estimated Birdwood Creek Annual Runoff Volume (AF)	Predicted Birdwood Creek Annual Runoff Volume - Run 008 (AF)	Difference - (Predicted - Estimated) (AF)
1985	1464	15970	14,506
1986	3991	19422	15,431
1987	3165	25119	21,954
1988	4007	21141	17,134
1989	2448	11403	8,955
1990	3238	16178	12,939
1991	2384	18414	16,030
1992	2993	19328	16,335
1993	2773	39315	36,542
Total	26,463	186,289	159,826

* Period limited to 1993 due to lack of historic Birdwood Creek gage records post-1993

Predicted runoff volumes from Run 008 are substantially greater than estimated runoff volumes. Combined with the findings of the Central Platte River focus study (L. Land, May 2012), revisions to the runoff parameters in the watershed model were made for the Birdwood Creek drainage area and watershed model Run 014 completed, with much better results as illustrated in Table 5.

Table 5. Birdwood Creek Watershed Estimated and Predicted Runoff (Runs 008 and 014)

Year	Estimated Birdwood Creek Annual Runoff Volume (AF)	Predicted Birdwood Creek Annual Runoff Volume - Run 008 (AF)	Predicted Birdwood Creek Annual Runoff Volume - Run 014 (AF)
1985	1,464	15,970	2,848
1986	3,991	19,422	3,378
1987	3,165	25,119	4,309
1988	4,007	21,141	3,677
1989	2,448	11,403	2,191
1990	3,238	16,178	2,905
1991	2,384	18,414	3,272
1992	2,993	19,328	3,435
1993	2,773	39,315	6,547
Total	26,463	186,289	32,561

The new estimates of baseflow and runoff volume were determined for the remaining three North Platte River basins using the information garnered through the analysis of Birdwood Creek. The revised water budget computations to estimate the surface water canal loss term is illustrated in Table 6.

Table 6. Study Reach Irrigation Season Water Budget Components – Revised

Year	NP below Keystone (AF)	Baseflow (AF)	Runoff (AF)	Net River Evap (AF)	NP at North Platte (AF)	SW Canal Loss (AF)	Irrigation Season Precip (in)
1985	202,998	87,966	15,727	(2,000)	239,855	(64,836)	15.54
1986	622,467	81,114	15,736	(2,000)	672,264	(45,053)	14.28
1987	200,339	94,411	19,466	(2,000)	245,837	(66,380)	17.17
1988	224,164	106,824	17,161	(2,000)	289,488	(56,662)	17.78
1989	232,320	74,385	14,923	(2,000)	248,539	(71,089)	10.21
1990	293,833	70,714	15,642	(2,000)	291,667	(86,522)	11.03
1991	287,211	70,000	16,372	(2,000)	293,220	(78,362)	11.84
1992	131,060	95,771	17,347	(2,000)	182,273	(59,905)	12.67
1993	73,438	106,885	26,124	(2,000)	144,908	(59,539)	17.40
1994	196,656	91,500	16,271	(2,000)	217,208	(85,219)	8.87
1995	314,773	91,500	18,214	(2,000)	343,053	(79,434)	16.08
1996	198,541	91,500	22,418	(2,000)	254,368	(56,091)	20.73
1997	306,524	91,500	15,822	(2,000)	317,752	(94,094)	12.53
Total	3,284,325	1,154,071	231,679	(26,000)	3,740,434	(903,185)	

* Baseflow target values were not available from 1994-1997, so the previous estimate of constant baseflow used

The revised watershed and baseflow estimates clarify some of the variance in both the SW Canal Loss term through the period and the discrepancy in the comparison of the SW Canal Loss term and historic diversion volumes – illustrated in Table 7.

Table 7. Computed Surface Water Canal Loss, Historic Diversion Volume, and Irrigation Season Precipitation for the North Platte River Reach – Revised based on Watershed Run 014

Year	SW Canal Loss (AF)	Historic Diversion Volume (AF)	Irrigation Season Precip (in)
1985	(64,836)	126,707	15.54
1986	(45,053)	123,770	14.28
1987	(66,380)	111,773	17.17
1988	(56,662)	112,286	17.78
1989	(71,089)	112,806	10.21
1990	(86,522)	115,736	11.03
1991	(78,362)	103,502	11.84
1992	(59,905)	86,851	12.67
1993	(59,539)	70,250	17.40
1994	(85,219)	105,939	8.87
1995	(79,434)	98,074	16.08
1996	(56,091)	83,133	20.73
1997	(94,094)	96,242	12.53
Total	(903,185)	1,347,067	

Table 7 totals indicate that that spills (total diversions – losses to the surface water system) are approximately 30%, which is reasonable based on conversations with the Sponsor technical workgroup and North Platte canal operators, and considering the historic operational patterns of these canals.

Components of the Surface Water Canal Operation Term

The components of the 'SW Canal Loss' term that are in the STELLA model include water delivered to crops, net evaporation from the canals, and seepage.

- Crop Delivery – The estimated crop delivery is based on predicted demands from CropSIM which considers precipitation, soil type, acreage, and cropping patterns of irrigated lands.
- Net Evaporation – Net evaporation from the canals is estimated from pan evaporation data, gaged precipitation depths, and estimates of canal surface area.
- Seepage – Constant seepage values are estimated for each canal based on evaluation of historic diversion records.

Table 8 summarizes the predicted values for these three terms from the COHYST 2010 modeling effort and provides a comparison with the computed SW Canal Loss term from the gross water budget in Table 7.

Table 8. Model Predicted Canal Surface Water Losses to Computed Surface Water Canal Loss Term

Year	CROPSIM Demand - Run 014 (AF)	Canal Evap (AF)	Canal Seepage (AF)	Total SW Loss (AF)	Computed SW Canal Loss (AF) from Table 7	Difference (Col. 5 - Col. 4)	Irrigation Season Precip (in)	Historic Diversion Volume (AF)
	1	2	3	4 = 1+2+3	5	6	7	8
1985	45,700	1,417	49,841	96,958	64,836	-32,122	15.54	126,707
1986	43,100	1,392	50,223	94,715	45,053	-49,662	14.28	123,770
1987	39,600	1,361	49,751	90,713	66,380	-24,333	17.17	111,773
1988	40,800	1,377	49,825	92,001	56,662	-35,340	17.78	112,286
1989	56,500	1,536	49,295	107,331	71,089	-36,241	10.21	112,806
1990	48,300	1,467	49,873	99,639	86,522	-13,117	11.03	115,736
1991	41,000	1,369	49,592	91,962	78,362	-13,599	11.84	103,502
1992	38,900	1,262	48,420	88,581	59,905	-28,676	12.67	86,851
1993	31,800	1,100	46,522	79,422	59,539	-19,884	17.40	70,250
1994	42,400	1,379	49,709	93,487	85,219	-8,269	8.87	105,939
1995	41,800	1,374	49,227	92,401	79,434	-12,967	16.08	98,074
1996	33,300	1,200	48,136	82,635	56,091	-26,544	20.73	83,133
1997	43,300	1,384	49,201	93,884	94,094	209	12.53	96,242
Total	546,500	17,616	639,614	1,203,730	903,185	(300,545)		1,347,067
Minimum	31,800	1,100	46,522	79,422	45,053	(49,662)		70,250
Maximum	56,500	1,536	50,223	107,331	94,094	209		126,707
Mean	42,038	1,355	49,201	92,595	69,476	(23,119)		103,621

Summary of Focus Study Findings (to date through June 2012)

1. Volumes of watershed runoff volume from Run 008 generally overestimated watershed runoff, consistent with the Central Platte River focus area study. Runoff parameters were adjusted for the four North Platte River tributary basins and Run 014 results in a better match with gaged runoff values. Continued adjustment of watershed model runs will occur during the calibration effort and will be informed in part by this focus study effort. The Birdwood runoff volume estimated from gage data will be useful as an independent check in this area of the model domain.
2. Cropping patterns, irrigated acreages, and irrigation practices are largely unchanged through our modeling period. Variances in diversion volumes are therefore due to canal operational changes, supply changes, or climatic effects, not from changes to the land use or irrigated acres served by the canals.
3. Three distinct canal diversion patterns should be developed for the STELLA model to reflect the changes in operations due to water shortages. The periods are roughly 1985-1990, 1991-2000, and 2000-2005. Each period has a later start date to diversions. This adjustment will help match the historic cumulative diversions where distinct breaks were observed over time reflecting these changes. It is noted that these periods apply to the

central Platte River canals as well as the North Platte River canals included in this focus study.

4. The model predicted annual surface water losses do not reflect the wide variability found in historic observations.
5. Through the gross water budget analysis a target value for the loss to the surface water system has been developed to guide calibration. This value will be kept current by including new baseflow and watershed runoff estimates as they are developed.
6. The modeled components of the surface water canal term (crop demand, net evaporation, and seepage) generally over predict losses to the surface water system. Further investigation and adjustment of these parameters will be made throughout calibration. Adjustments will be informed by not only the total surface water canal term, but also the individual canal elements.
7. The analyses included herein will be extended through the 1998-2005 period to inform the model calibration through the extended period.