Historical Crop Consumptive Use Analysis
North Platte River Basin

Final Report

October 2012

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1.0 Executive Summary

The North Platte River Basin historical crop consumptive use analysis was performed on a monthly basis for the period from 1956 through 2009 as part of the South Platte Decision Support System (SPDSS). The SPDSS project was developed jointly by the State of Colorado Water Conservation Board and the Division of Water Resources. The objective of the historical crop consumptive use portion was to quantify 100 percent of the basin's historical crop consumptive use. This report documents the input and results of this historical crop consumptive use analysis.

1.1 Background

The North Park basin lies in Jackson County in north-central Colorado and is comprised of the headwaters of the North Platte River and several major tributaries, including the Michigan River, Illinois River, and Canadian River. The basin opens northward into Wyoming, following the flow of the North Platte River. It is confined on the east by the Medicine Bow Range, on the west by the Park Range, on the south by the Rabbit Ears Range, and on the north by the Wyoming state line. The North Park Basin encompasses approximately 2,050 square miles, and most of the runoff is attributable to snowmelt from the higher elevation areas.

1.2 Approach

The North Platte River historical crop consumptive use analysis was performed using StateCU, a generic, data driven consumptive use model and graphical user interface. The objective of the model is to develop monthly consumptive use estimates for the assessment of historical and future water management policies. Key information used by the model to assess historical consumptive use includes irrigated acreage, crop types, monthly climate data, and diversion records.

The historical crop consumptive use analysis provides information to the basin surface water model (StateMod) analysis of the North Platte River Basin.

1.3 Results

Table 1 presents the average annual acreage and historical crop consumptive use analyses results for the 1956 to 2009 study period. As shown, the irrigation water requirement averages 195,264 acre-feet per year while water supply-limited consumptive use averages 125,187 acre-feet per year. The average annual shortage in the basin is 36 percent.

Table 1
Average Annual Acreage and Consumptive Use Results (1956 – 2009)

Water District	2001 Acres	Irrigation Water Requirement (acre-feet)	Supply-Limited CU (acre-feet)	Percent Short
47	117,032	195,264	125,187	36%

Likely due to the high elevation of the basin, only pasture grass is grown in the basin. Note that although there are five irrigated land coverages available in the North Platte basin that quantify the amount of pasture grass, the year 2005 coverage was under review at the time of this analysis and therefore not considered. The basin average irrigated acreage was 114,610 acres over the 1956 to 2009 period, and 117,032 acres in 2001.

Figure 1 presents the annual historical acreage, irrigation water requirement and supply limited consumptive use for the study period. Because crop type does not vary from year to year and total irrigated acreage varies only slightly, the pronounced yearly variations in irrigation water requirement are attributable to climate data in the analysis (temperature and precipitation). The percent of irrigation water requirement not satisfied averaged 36 percent over the study period. Many of the shortages are in late summer and early fall. Due to the limited growing season after the initial summer hay cutting, water users indicate they often limit further irrigation. Drought conditions also impacted shortages; from 2001 to 2003 shortages increased to an average of 55 percent, due to below average stream flows.

Figure 1
Historical Acreage, Irrigation Water Requirement and Supply Limited CU (1956-2009)

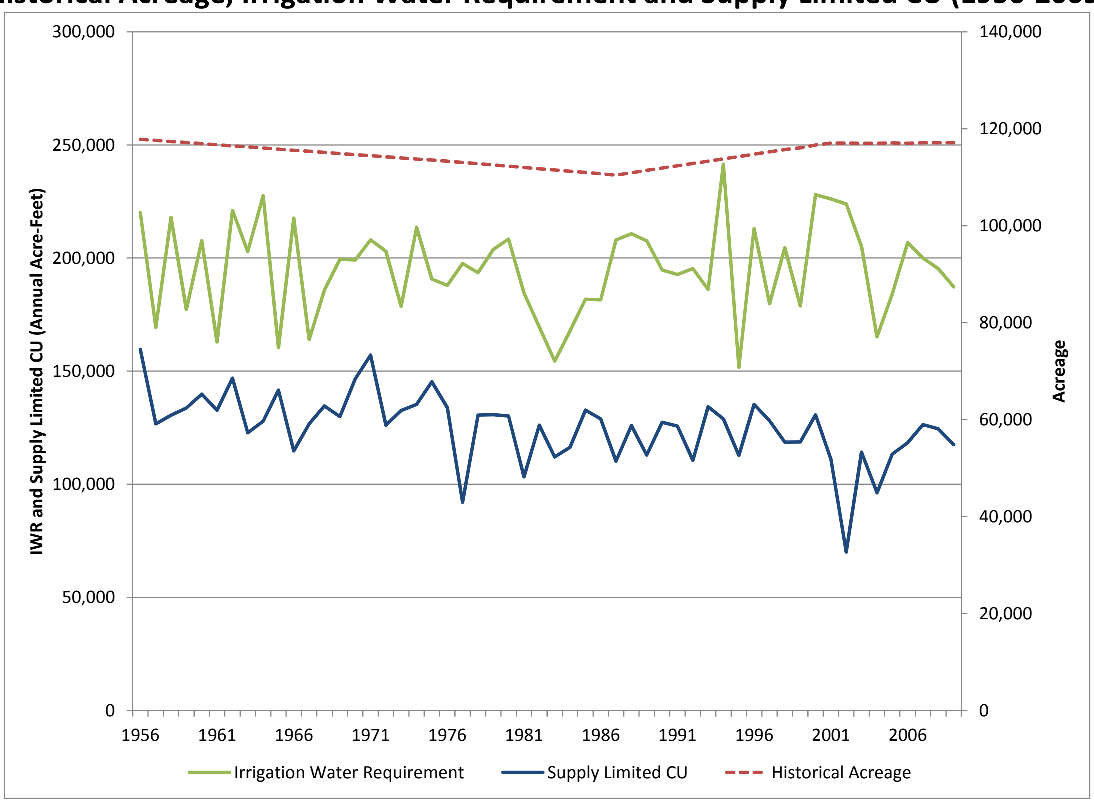
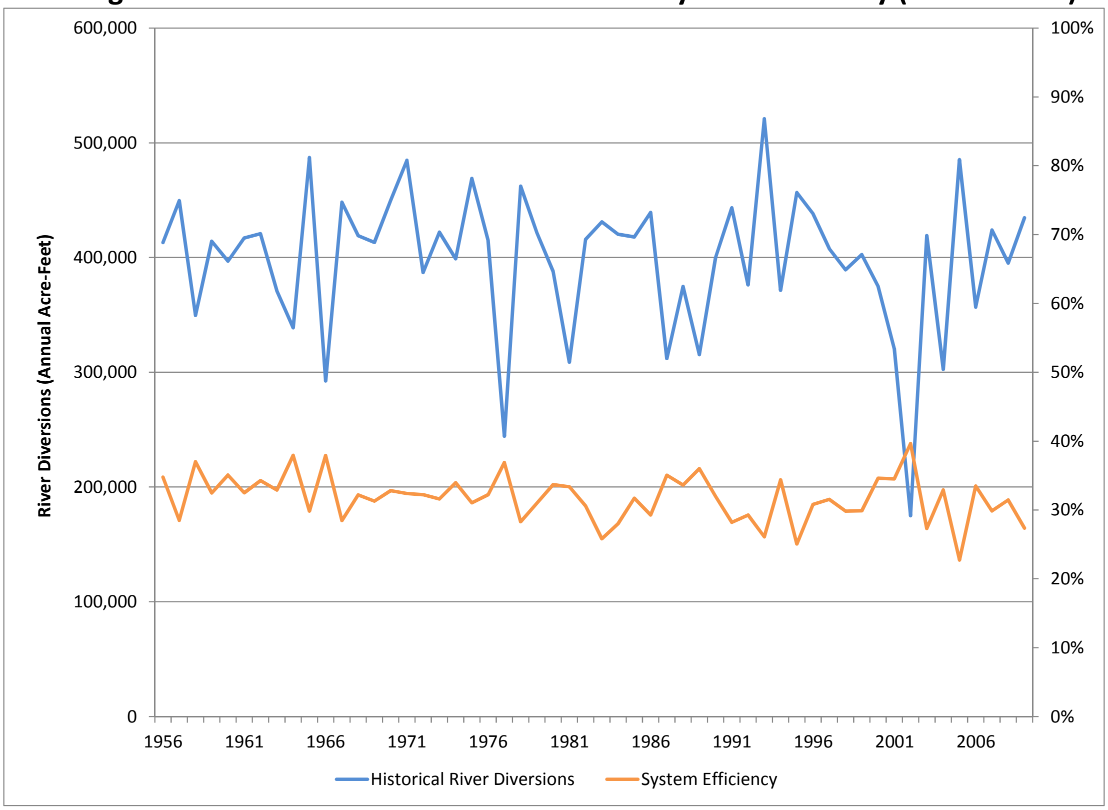


Figure 2 shows the annual estimated diversions from surface water to meet crop irrigation requirement and the average annual calculated system efficiency. The average annual surface water diversions from 1956 through 2009 were 398,196 acre-feet. The average annual surface water system efficiency from 1956 through 2009 was approximately 31 percent. System efficiency is calculated as total consumptive use met by diversions and soil moisture divided by total diversions, and reflects conveyance efficiency and irrigation application efficiency. Note that efficiency generally increases during periods of reduced water availability.

Figure 2
Average Annual Historical River Diversions and System Efficiency (1956 – 2009)



2.0 Introduction

The estimation of historical crop consumptive use in the North Platte River Basin and the tool used to perform the analysis are documented in three major reports as follows:

1. The Historical Crop Consumptive Use Analysis Report describes the climate and crop data from HydroBase used in the historical consumptive use analysis, and the parameters used in analysis, including Blaney-Criddle crop coefficients and characteristics. The document summarizes the results of the analysis, total irrigation water requirement, and the supply-limited total consumptive use for the North Platte River basin.

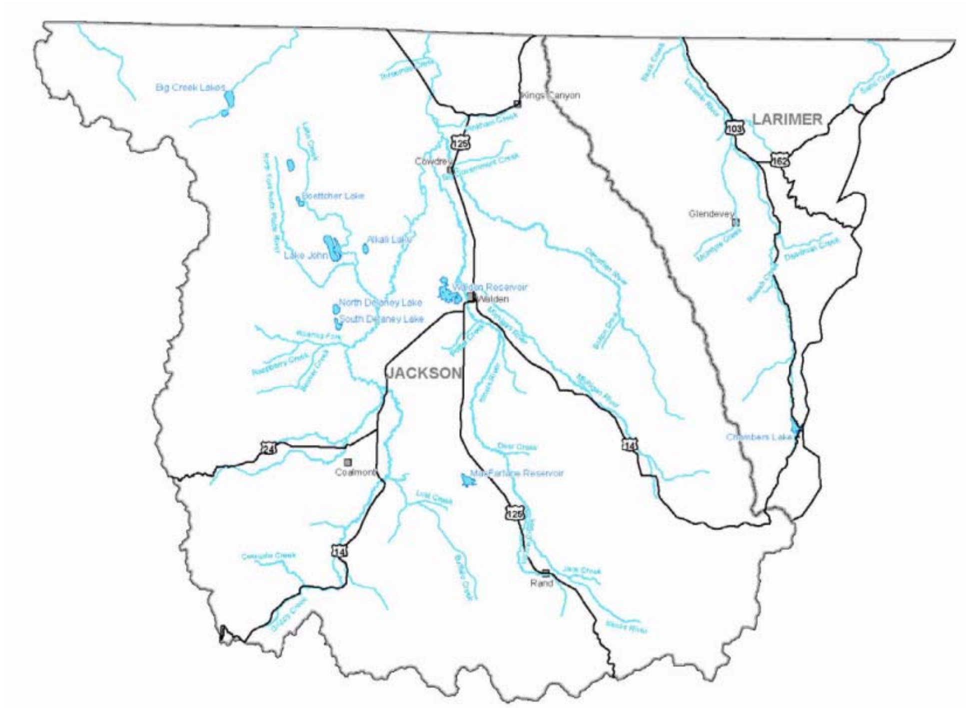
2. North Platte River Basin Water Resources Planning Model User's Manual describes the development of the North Platte River Basin StateMod surface water model. This document summarizes the process and results of developing the structure list of historical diversions for the historical consumptive use analysis.

3. The StateCU Documentation describes the consumptive use model and graphical user interface used to perform all consumptive use analyses conducted as part of the South Platte River Decision Support System.

2.1 Basin Description

The North Park basin, as shown in **Figure 3**, encompasses all of Jackson County in north-central Colorado and is comprised of the headwaters of the North Platte River and several major tributaries, including the Michigan River, Illinois River, and Canadian River. The basin opens northward into Wyoming, following the flow of the North Platte River. It is confined on the east by the Medicine Bow Range, on the west by the Park Range, on the south by the Rabbit Ears Range, and on the north by the Wyoming state line. The North Park basin covers approximately 2,050 square miles and the basin floor ranges in elevation between 8,000 and 9,000 feet. The North Park region includes the Routt National Forest which covers 1.1 million acres of federal lands from north-central Colorado up to central Wyoming. The region is covered with 46 percent of forested area including the Routt National Forest. Average annual rainfall on the basin floor ranges from approximately 10 to 15 inches between the Walden and Rand stations.

Figure 3
North Platte River Basin



2.2 Definitions

Several terms used in this report have been broadly used in other studies. The following definitions are consistent with the American Society of Civil Engineers Manuals and Reports on Engineering Practice No. 70 - Evapotranspiration and Irrigation Water Requirement.

Potential Evapotranspiration (ET) The total amount of water that would be used for crop growth if provided with an ample water supply, also called potential consumptive use.

Effective Precipitation The portion of precipitation falling during the crop-growing season that is available to meet the evapotranspiration requirement of the crop.

Winter Effective Precipitation The portion of precipitation falling during the non-growing season that is available for storage in the soil reservoir, and subsequently available to crops during the next growing season.

Irrigation Water Requirement The amount of water required from surface or ground water diversions to meet crop consumptive needs. Calculated as potential evapotranspiration less effective precipitation and stored winter precipitation.

Water Supply-Limited Consumptive Use The amount of water actually used by the crop, limited by water availability; also called actual consumptive use.

The following terms are commonly used in the CDSS efforts:

Irrigated Parcel An irrigated "field" having the same crop type, irrigation method (sprinkler or flood), and water source - not divided by a large feature, such as river or highway.

Ditch Service Area The area of land that a ditch system has either the physical ability or the legal right to irrigate. Note that a ditch service area often includes farmhouses, roads, ditches, fallow fields and undeveloped lands. Therefore a ditch service area is typically greater than the land irrigated under that ditch.

Key Diversion Structure A ditch system that is modeled explicitly in both the StateCU historic consumptive use model efforts and the StateMod water resources planning model. Ditch systems are generally defined as key if they have relatively large diversions, have senior water rights, or are important for administration.

Diversion System Structure A group of diversion structures on the same tributary that operate in a similar fashion to satisfy a common demand.

Multi-System Structure A group of diversion structures on different tributaries that operate in a similar fashion to satisfy a common demand.

Aggregated Diversion Structure A group of non-key structures. Aggregated diversions are typically aggregated based on location; e.g. diverting from the same river reach or tributary.

Demand Structure A defined agricultural demand that can be met from several surface water sources not diverted from the same point on the river. For instance, irrigation demand under Clayton Ditch (Clayton “Demand Structure”) can be met from a direct flow right through the ditch and, if necessary, from water released from Clayton Reservoir.

HydroBase The State of Colorado's relational database used in the CDSS efforts. HydroBase contains historic, real-time, and administrative water resources data.

Data Management Interface (DMI) A CDSS program that allows data to flow from HydroBase to the CDSS models using an automated data-centered approach.

StateMod The CDSS water allocation model used to analyze historic and future water management policies.

3.0 Model Development

The North Platte River historical crop consumptive use analysis was performed using StateCU, a generic data driven consumptive use model and graphical user interface. The objective of the model is to develop monthly consumptive use estimates for the assessment of historic and future water management policies.

The model originated at the USBR and has undergone substantial enhancements while being applied to the Colorado River Decision Support System, the Rio Grande Decision Support System, and the South Platte Decision Support System. The *StateCU Documentation* provides a complete description of the model and its capabilities.

3.1 Modeling Approach

To perform the historical crop consumptive use analysis, irrigated acreage and their associated crop types were either modeled explicitly (key structures) or in aggregate. A goal of this consumptive use analysis was to explicitly represent as many structures as possible; over 99% of the acreage is explicitly modeled. In 2001, only 428 acres of the 117,032 total irrigated acreage in the basin was modeled in an aggregate structure (i.e. a geographical grouping of non-key surface water structures).

The general methodology used to estimate historical consumptive use for the North Platte River Basin is as follows (See the *StateCU Documentation* for a more complete description of the calculation methods):

1) A North Platte River Basin structure scenario was developed that includes 100% of the 1956 through 2001 irrigated acreage in the North Platte River using key and aggregated structures and their associated acreage and crop patterns.
2) The Walden climate station was assigned to each structure. Climate data was adjusted using the standard Orographic Adjustment approach available in StateCU to more accurately represent climate conditions at the irrigated acreage location. Temperature was adjusted by the standard 3.6 degrees F per 1,000 feet rise in elevation between the Walden station and the irrigated land. Precipitation data was prorated up or down based on the average annual precipitation estimated by the Colorado Climate Center at location of the irrigated acreage compared to the location of the climate station.
3) Due to the elevation of the basin, potential ET was determined using the Original Blaney-Criddle consumptive use methodology with high-altitude crop coefficients adopted by SPDSS for acreage above 6500 feet. The SCS effective rainfall method outlined in the SCS publication Irrigation Water Requirement Technical Release No. 21 (TR-21) was used to determine the amount of water available from precipitation, resulting in irrigation water requirement.
4) Water supply-limited consumptive use was determined by including diversion records, conveyance efficiencies, application efficiencies, and soil moisture interactions. The model

determined water supply-limited consumptive use by first applying surface water to meet irrigation water requirement for land under the ditch system. If excess surface water still remained, it was stored in the soil moisture reservoir. Then if the irrigation water requirement was not satisfied, surface water stored in the soil moisture reservoir was used to meet remaining irrigation water requirement.

3.2 File Directory Convention

To assist in the file organization and maintenance of official State data, the files associated with a historic consumptive use analysis will install to the default subdirectory \cdss\data\ *Analysis_description* \StateCU. *Analysis_description* is **np2008** for the North Platte River crop consumptive use analysis, commenced in 2008. Other official State historical consumptive use data *Analysis_descriptions* include SP2008 for the South Platte River, rg2009 for the Rio Grande River, cm2009 for the Upper Colorado River Basin, etc. Note that these directory conventions are not a requirement of the model, simply a data management convention for official State data.

3.3 File Naming Convention

Specific file names or extensions are not a requirement of the model except for the StateCU response file (*.rcu). Standard extensions have been adopted by the State for data management purposes, and are outlined in **Section 4.0 Data Development**.

3.4 Data Centered Model Development

Nearly all the StateCU input files have been generated from HydroBase using the data management interfaces StateDMI (Version 3.11.01, 8/11/2010) and TSTool (Version 10.00.04beta, 7/3/2011). A description of these tools as applied to StateCU is included in **Section 4 Data Description,** where applicable.

3.5 Product Distribution

The StateCU model and CDSS input files can be downloaded from the State of Colorado's CDSS web page at http://cdss.state.co.us.

4.0 Data Description

The following sections provide a description of each input file, the source of the data contained in the input file, and the procedure for generating the input file. More detailed information regarding the file contents and formats can be found in the *StateCU Documentation*.

1. Simulation information files
   - StateCU Response File ***Section 4.1***
   - StateCU Control File ***Section 4.2***
2. Structure specific files
   - StateCU Structure File ***Section 4.3***
   - Crop Distribution File ***Section 4.4***
   - Annual Irrigation Parameter File ***Section 4.5***
   - Historical Diversion File ***Section 4.6***
3. Climate data related files
   - Climate Station Information File ***Section 4.7***
   - Climate Data Files ***Section 4.8***
4. Blaney-Criddle specific files
   - Blaney-Criddle Crop Coefficient File ***Section 4.9***
   - Crop Characteristics File ***Section 4.10***

4.1 StateCU Response File (np2008.rcu)

The StateCU response file contains the names of input files used for a StateCU analysis. The StateCU response file was created using a text editor for the North Platte River Basin. Input file names in the response file can be revised through the StateCU Interface.

4.2 StateCU Model Control File (np2008.ccu)

The StateCU Model control file contains the following information used in the historical consumptive use analysis:

- Beginning and ending year for simulation – The simulation period for the analysis was 1956 through 2009.
- Consumptive use analysis method – Monthly Original Blaney-Criddle analysis was used.
- Effective precipitation method – The SCS Effective Precipitation method, defined in TR-21 was used.
- Scenario type – The analysis was defined as a “structure” scenario.
- Water supply/rights consideration – The water supply/rights consideration switch was set to "1" which specifies that water supply-limited consumptive use was calculated considering surface water sources.

- Soil moisture consideration – The soil moisture switch was set to “1” indicating the analysis should include soil moisture accounting.
- Initial soil moisture information – The initial soil moisture was set to 50 percent of the capacity for each structure.
- Winter carry-over precipitation percent – The winter carry-over precipitation defines the amount of non-irrigation season precipitation that is available for storage in the soil moisture reservoir. Winter carry-over precipitation was not used for this scenario; set to zero.
- Output options – The output summary switch was set to "3" indicating a detailed water budget output should be generated.

The StateCU model control file was created using a text editor for the North Platte River Basin. Options in the model control file can be revised through the StateCU Interface.

4.3 StateCU Structure File (np2008.str)

A structure file defines the structures to be used in the analysis. The structure file contains physical information and structure-specific information that does not vary over time including location information; available soil capacity; and assignments of climate stations to use in the analysis and associated orographic adjustments. Location information includes the latitude, elevation, and county for each structure. The latitude is used in the Blaney-Criddle method to determine the hours of daylight during the growing season. The elevation is used to incorporate the orographic adjustment for temperature data.

Modeled Structures

The structure file used in the historical consumptive use analysis was created using **StateDMI** to extract diversion structure location information stored in HydroBase. Early in the CDSS process it was decided that, while all consumptive use should be represented in the models, it was not practical to model each and every water right or diversion structure individually. The goal of this analysis however, was to model as much of the irrigated acreage explicitly with very little aggregated acreage. With this objective in mind, a single aggregate structure was created for four structures located on small tributaries that were not explicitly modeled in the North Platte River StateMod model. Their historical diversions were developed by summing the historical diversions of the individual structures, and their irrigation water requirement is based on the total acreage associated with the aggregation.

The remaining key structures were evaluated to determine if they should be:

- combined into a diversion system or multi-structure system,
- modeled as a demand structure, or
- represented individually at their headgate location.

Structures that should be combined as diversion systems or represented as multi-structure systems were determined based on discussions with water users, water district 47 commissioners, and review of irrigated acreage assignments. In the consumptive use analysis, diversion system and multi-structure system historical diversions were developed by summing the historical diversions of the associated structures, and their irrigation water requirement is based on the total acreage associated with the system.

Evaluation of irrigation supplies and reservoir operations, as well as discussions with water users in the basin, assisted with the identification of structures that were modeled as demand structures. Demand structures were used to represent structures that receive water from several sources to meet a common irrigation demand. A demand structure was used if:

- Demand can be met through more than one river headgate,
- An off-channel reservoir delivers water directly to demand,
- Demand can be met through a single headgate, but water sources have different delivery losses,
- The source headgate delivers water to more than one demand, and at least one of those demands is irrigation.

The remaining structures were modeled with their demands assigned to their river headgate in both the consumptive use and surface water modeling efforts. The approach and results for identifying structures and aggregations are outlined in more detail in the *North Platte River Basin Water Resources Planning Model User's Manual.* **Table 2** shows the number of each structure type and their associated acreage in the North Platte River consumptive use analysis.

Table 2
Key and Aggregate Structure Summary

Structure Type	**2001 Acres**	**Number of Structures [1)]**	**Percent of Total Acreage**
Headgate Diversion Structures	88,161	359	75%
Diversion Systems	17,607	37	15%
Multi-Structure Systems	8,046	13	7%
Demand Structures	2,790	6	2%
Aggregated Surface Water Structures	428	1	0%
Total Structures	**117,032**	**416**	**100%**

1) Number of total structure IDs included in the model. Aggregates, diversion system and multi-structure systems represent more than one physical structure.

Available Soil Moisture Capacities

Available soil moisture capacities were assigned to individual structures in the structure file. Available soil moisture capacities were determined using Colorado STATSGO mapping and irrigated acreage parcel locations, as described in the SPDSS Task 57- Assign Soil Moisture Water Holding Capacities to Structures memorandum, available on the CDSS website (cdss.state.co.us). Soil moisture capacities for each structure, in inches of holding capacity per inch of soil depth, were provided for key and aggregate structures from comma separated list files. Structure soil moisture capacity by structure ranges from 0.0608 to 0.1725 inches per inch.

Climate Station Assignment
Climate stations were selected for use in the consumptive use calculation based on their period of records and location with respect to irrigated land (see **Section 4.7** for more information on climate stations). Only one climate station, Walden, was selected in the North Platte River basin, therefore all structures were assigned 100 percent of the temperature and precipitation from this climate station in the structure file.

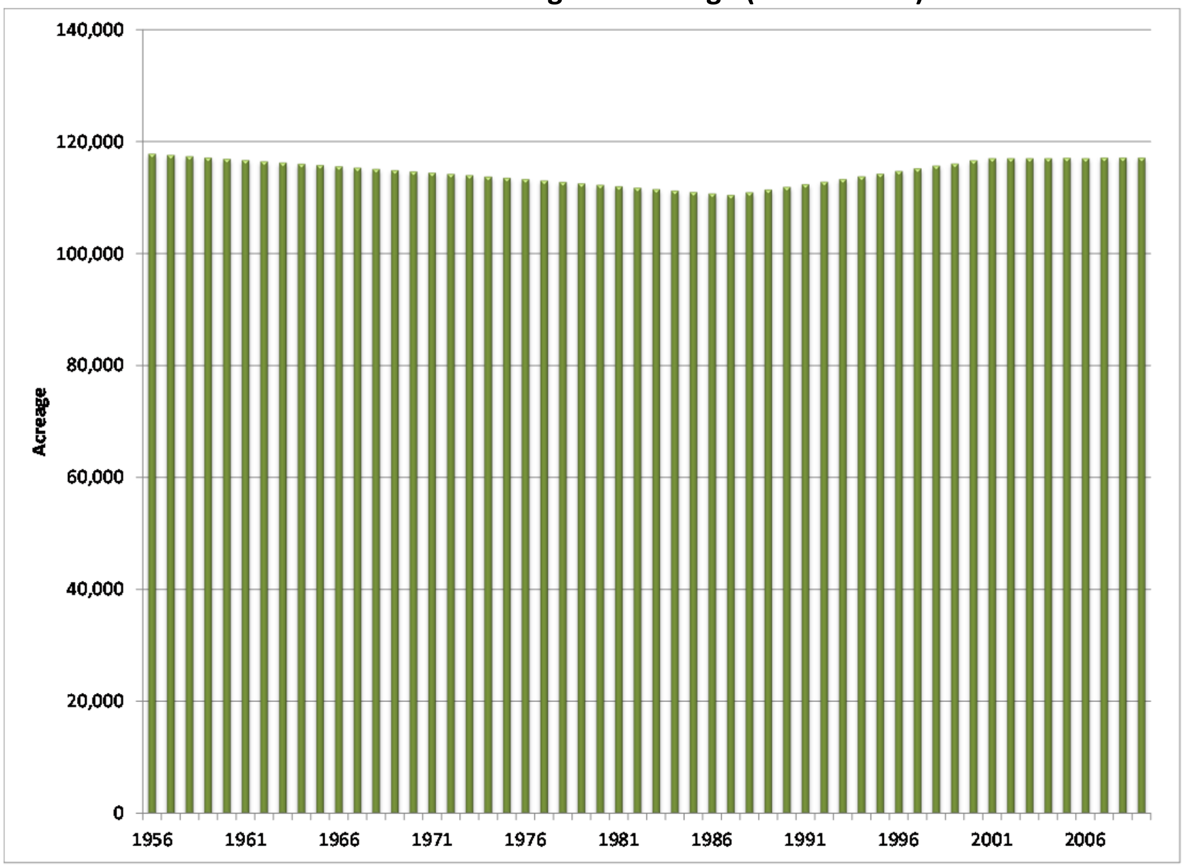
Climate Station Data Orographic Adjustment
Climate station orographic adjustment option was selected for structures in the North Platte basin to mitigate the use of a single climate station for estimating irrigation water requirements throughout the basin. Climate data was adjusted using the standard Orographic Adjustment approach available in StateCU to more accurately represent climate conditions at the irrigated acreage location. Temperature was adjusted by the standard 3.6 degrees F per 1,000 feet rise in elevation between the Walden station and the irrigated land. Precipitation data was prorated up or down based on the average annual precipitation estimated by the Colorado Climate Center at location of the irrigated acreage compared to the location of the climate station.

4.4 Crop Distribution File (np2008.cds)

The crop distribution file contains acreage and associated crop types for each represented surface water structures for every year in the analysis period (1956 through 2009). The irrigated acreage assessment in the North Platte River basin was originally developed by the Riverside Technology Inc., under SPDSS efforts. Further refinements were made, based on the 2001 acreage assessment, during the historical crop consumptive use analysis based on interviews with water users in the basin. The irrigated acreage, along with crop type identification, is available spatially through GIS shapefiles and is also available in HydroBase. Each irrigated parcel was assigned a crop type and provided a structure identifier (SWID) based on service area locations. Likely due to the high elevation in the basin, all acreage in the basin was identified as irrigation pasture grass.

The North Platte River historical crop consumptive use analysis is based on the 1956, 1976, 1987, and refined 2001 irrigated acreage coverage originally developed by Riverside Technology, inc (RTi) for SPDSS. The coverages include acreage and crop, as described in the SPDSS Task 93 Memorandum – Mapping Historic Land Use, RTi, available on the CDSS website. Each parcel receiving surface water was assigned to a ditch system structure identifier based on service area locations. Note that a 2005 coverage was also developed for the North Plate basin, but is undergoing review and was not used in the analysis. Interpolation was used to estimate acreage and crop types for the years between the available coverages, and then 2001 acreage information was carried forward through 2009. Note that some structures were not assigned acreage during the SPDSS efforts, however water users in the basin indicated that they have historically served acreage and user-supplied acreage information was used in the analysis. As discussed above, acreage for aggregates, diversion systems, multi-structure systems, and demand structures was based on the combined acreage of their associated structures associated. As shown in **Figure 4** irrigated acreage was estimated to change from approximately 117,825 in 1956 to 117,122 in 2006, with a low of 110,456 in 1987. Water users have indicated that acreage has not changed by the approximately 7,000 acres over the years, and further review of the 1976 and 1987 coverage is recommended.

Figure 4
North Platte Basin Irrigated Acreage (1956 – 2009)



The crop distribution file used in the historical consumptive use analysis was created using **StateDMI. StateDMI** was used to extract the acreage and crop type information from HydroBase and develop the crop distribution file.

4.5 Annual Irrigation Parameter File (np2008.ipy)

The annual irrigation parameter file contains yearly (time series) structure information required to run historical consumptive use simulation. The following information was required, by modeled structure, for the North Platte basin model:

- conveyance efficiencies
- maximum flood application efficiencies
- maximum sprinkler application efficiencies

- acreage flood irrigated with surface water only
- acreage sprinkler irrigated with surface water only
- acreage receiving supplemental ground water

The conveyance efficiency accounts for losses between the river headgate and the farm headgate, including losses through canals, ditches and laterals. The maximum flood irrigation and sprinkler efficiencies account for application losses between the farm headgate and the crops. Note that conveyance and maximum application efficiency data input data were not adjusted by year. However, a structure's overall, system efficiency may change by year due to changes in the percent of land served by sprinkler or flood application methods, or due to surface water supply in excess of crop requirement.

The development of efficiency estimates were based on the approach described in the SPDSS Task 56 – Conveyance and Application Efficiencies memorandum, available on the CDSS website. Conveyance efficiencies in the North Platte basin are generally based on a relationship with soil type and the overall ditch and lateral length, as described in the memorandum. **Table 3** shows the results of this analysis and the number of ditches that are represented in each efficiency bracket. The maximum flood irrigation and sprinkler irrigation efficiencies were estimated to be 60 percent and 80 percent respectively.

Table 3
Conveyance Efficiency and Corresponding Number of Ditches

Conveyance Efficiency Range	Number of Ditches
70% to 79%	154
80% to 89%	203
> 90%	59
Total Structures	**416**

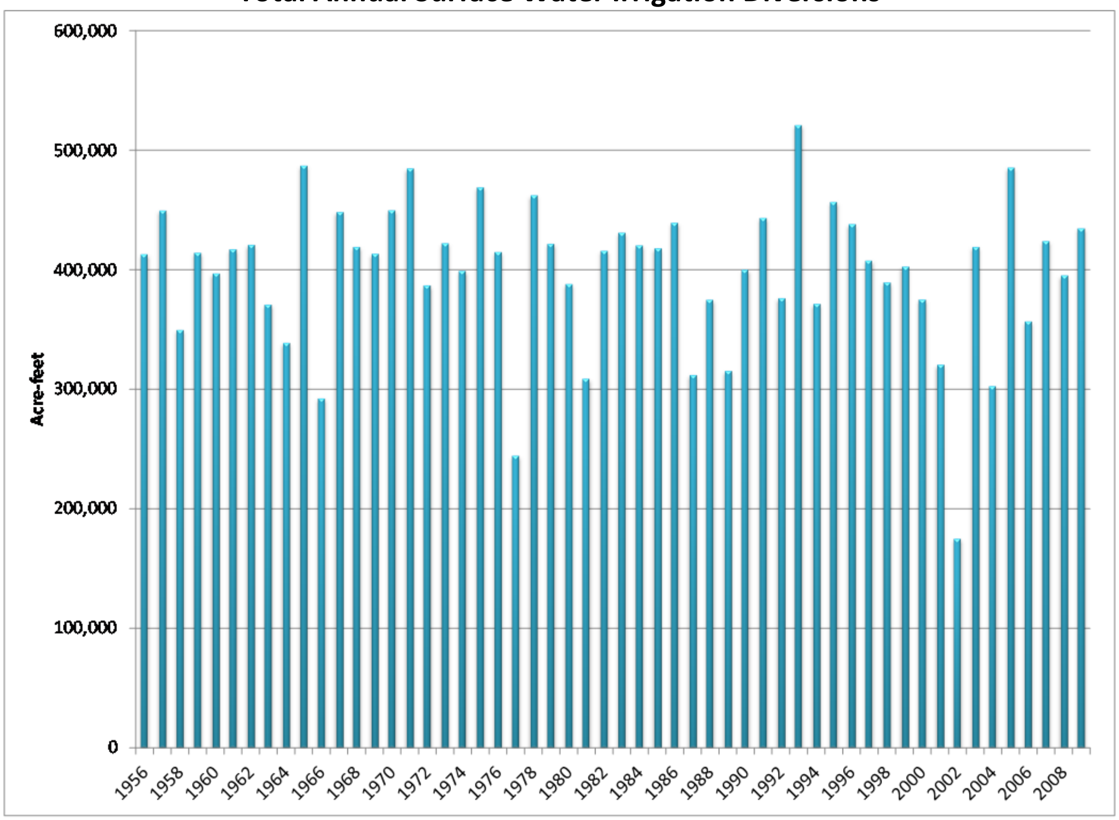
Irrigation methods (flood vs. sprinkler) and irrigation supply (surface water vs. ground water) information is stored in HydroBase. No sprinkler acreage was identified in any of the acreage coverages, therefore all the acreage is assigned an irrigation method of flood. A minimal amount of acreage in the analysis was identified as having a supplemental ground water supply. **StateDMI** was used to extract the time series information from HydroBase, set the derived efficiency values, and create the annual irrigation parameter file.

4.6 Historical Irrigation Diversion File (np2008_CU.ddh)

The historical diversion file provides surface water supply information required to estimate supply-limited consumptive use. Irrigation diversions are provided for each modeled structure. The development of surface water supply information was made more complex because of diversions and releases to off-channel reservoirs. It was necessary to isolate the diversions to irrigation from the diversions to storage, as well as include the releases from reservoirs as additional irrigation supply. Likewise, additional manipulation of diversion data was necessary to develop the total irrigation supply for diversion system and multi-structure systems. The approach used to generate these irrigation supplies was developed during SPDSS efforts, and was documented in the South Platte Historic Consumptive Use - Development of Historical Diversions memorandum, available on the CDSS website.

Figure 5 shows how surface water diversions for irrigation in the basin have changed over time. Surface water diversions for irrigation averaged approximately 265,000 acre-feet per year over the 1956 through 2009 study period. The variation seen in **Figure 5** is generally due to physical water supply limitations for the basin as a whole. For example, the two driest years during the study period, 1977 and 2002, show the lowest basin diversions.

Figure 5
Total Annual Surface Water Irrigation Diversions



StateDMI was used to extract diversion records from HydroBase and fill missing diversion data**.** During the initial review of diversion data, it was noted that monthly diversion data for structures in the North Platte River Basin appeared inflated during the 1970s and lower than expected during the 1950s compared to the more recent data. These data anomalies were reported to the Division Office for additional review. Only post-1977 diversion data was used from HydroBase; seeing data filling discussions below for techniques used to fill historical data.

Diversion data for structures included in an aggregate, diversion system, and multi-structure systems are first extracted and filled, then combined with each systems associated structures' diversion data. Note that diversion comments were considered when extracting data from HydroBase; for instance, if the diversion comment for a specific structure indicated the structure was not usable for a specific year, that year of data for that structure was set to zero.

Missing data was filled using a wet/dry/average pattern according to an "indicator" gage. Each month, streamflow at the indicator gage was categorized as a wet/dry/average month through a process referred to as "streamflow characterization". Months with gage flows at or below the 25^{th} percentile for that month are characterized as "dry", while months at or above the 75^{th} percentile are characterized as "wet", and remaining months are characterized as "average". Using this characterization, missing data points were filled based on the wet, dry, or average pattern. For example, a data point missing for a wet March was filled with the average of other wet Marches in the partial time series, rather than all Marches. The pattern streamflow gage used in the North Platte River basin is the North Platte River near Northgate, CO (06620000). If missing data still existed after filling with a pattern file, historical monthly averages were used to fill the remaining data.

TSTool was used to access diversion data and reservoir end-of-month content data from HydroBase and manipulate that data to separate diversions to storage from diversions to irrigation for demand structures. The reservoir supply to demand structures was estimated based on historical reservoir storage data, and added to the headgate supply. The resulting total irrigation supply estimates were read directly into **StateDMI** and incorporated into the final diversion file for use in the StateCU analysis. See the *North Platte River Basin Planning Model User's Manual* for more information on the development of diversion data.

4.7 Climate Station Information File (NPclim2008.cli)

The climate station information file provides climate station location information for climate stations used in the analysis, including latitude, elevation, county and HUC. The climate station information file was developed for the North Platte River basin and includes the single climate station used in the basin analysis, as recommended in the SPDSS Task 53.2 – Collect and Fill Missing Monthly Climate Data, available on the CDSS website. **Table 4** lists the period of record, and percent complete for temperature and precipitation data for the Walden station. The climate station information file was created using **StateDMI** to extract location information stored in HydroBase.

Table 4
Key Climate Station Information

Station ID	Station Name	WD	Period of Record	Elevation (feet)	Percent Complete (1956 – 2009)	
					Temperature	Precipitation
8756	Walden	47	1897 - 2010	8120	98%	98%

4.8 Climate Data Files (NPclim2008.tmp, NPclim2008.prc, NPclim2008.fd)

StateCU requires historical time series data, in calendar year, for temperature, frost dates, and precipitation. The North Platte River basin climate data files, developed using **TSTool**, contain monthly data for the Walden station. **Table 5** summarizes the average annual temperature, frost dates and precipitation based on filled data for the subset of stations used in the North Platte River analysis.

Table 5
Average Annual Filled Climate Values 1956 through 2009

Station Name	Station ID	Average Annual (1956 – 2009)		Frost Dates - Degrees F			
		Temperature (Degrees F)	Precipitation (Inches)	Spring 28 Deg	Spring 32 Deg	Fall 32 Deg	Fall 28 Deg
Walden	8756	37.03	11.15	7-Jun	21-Jun	25-Jul	19-Aug

Figures 6 and **7** show the 1956 through 2009 average monthly precipitation and temperature for the Walden (8756) climate station, located in the center of the North Platte River Basin. Historical missing data for the climate station was filled from 1956 through 2009 using **TSTool.** Climate station data was available for entire study period, with just a few missing months of temperature and precipitation data**.** Historical month averages were used to fill the missing precipitation data and linear regression with the Spicer climate station was used to fill missing temperature data**.**

Figure 6
Average Mean Monthly Temperature
Walden Climate Station (1956 – 2009)

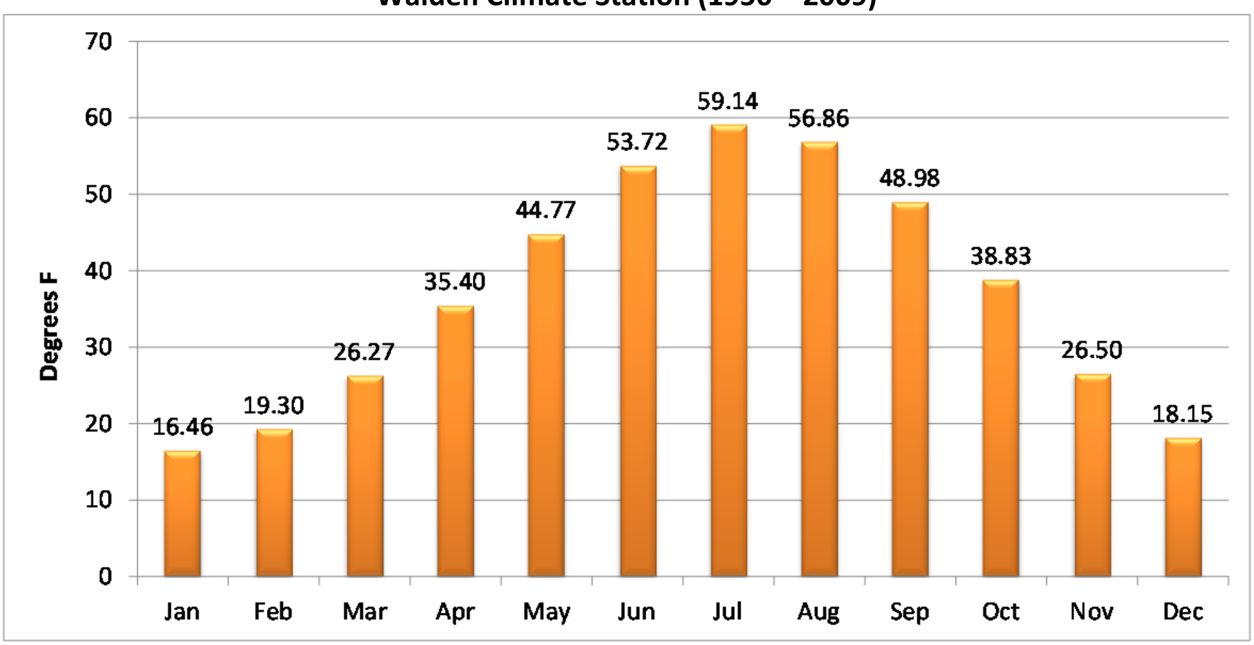
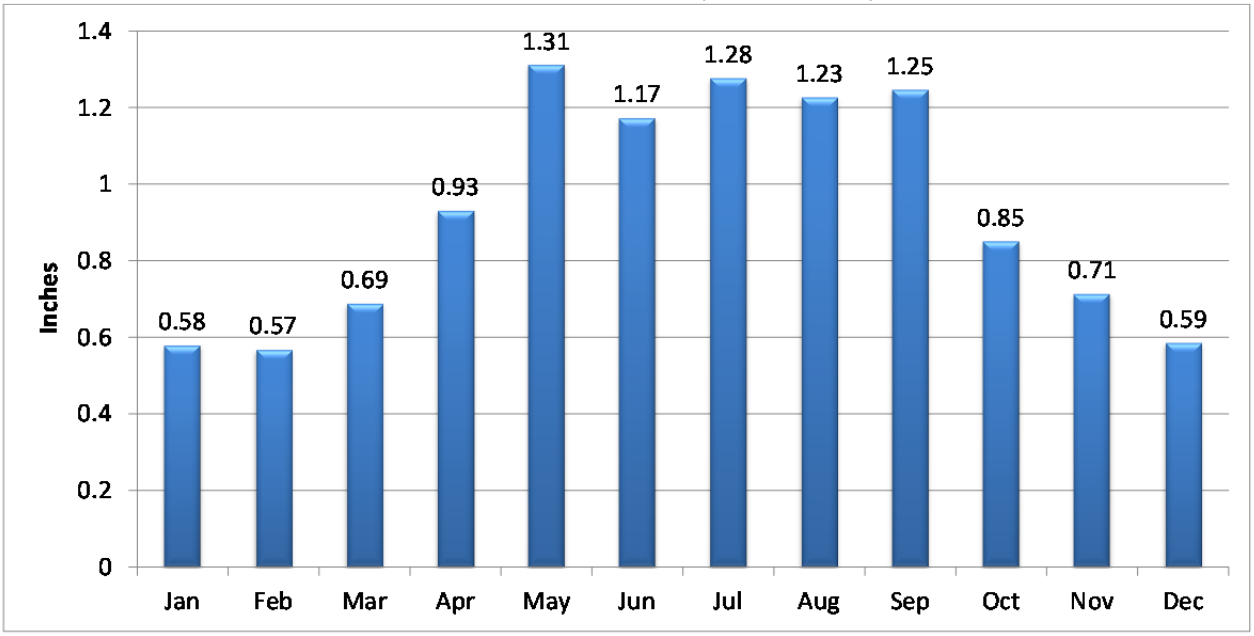


Figure 7
Average Mean Monthly Precipitation
Walden Climate Station (1956 – 2009)



4.9 Blaney-Criddle Crop Coefficient File (CDSS.kbc)

The Blaney-Criddle crop coefficient file contains crop coefficient data used in the historical consumptive use analysis. This file contains crop coefficient curve data for several crops, however only pasture grass is modeled in the North Platte River Basin. Several high-altitude crop studies were reviewed to determine appropriate coefficients to represent grass pasture grown in high elevation meadows in Colorado. The calibrated crop coefficients recommended in the comprehensive study sponsored by Denver Water were selected for use in the analysis. Additional information regarding Denver Water high altitude crop coefficients, including a review of previous lysimeter studies, provided in SPDSS Task 59-1 – Develop Locally Calibrated Blaney-Criddle Crop Coefficients, available on the CDSS website. The crop coefficient file used in the historical consumptive use analysis was created using **StateDMI** to extract the representative crop coefficients from HydroBase.

4.10 Crop Characteristic File (CDSS.cch)

The crop characteristic file contains information on planting, harvesting, and root depth. Standard TR-21 Blaney-Criddle crop characteristics were adapted in the analysis. Crop characteristics from the Denver Water study were used for grass pasture. The beginning temperature and ending calibrated temperature used to define the growing season of high altitude grass pasture is 42 degrees Fahrenheit. Because grass pasture is a perennial crop, the length of season is set to 365 days. **Table 6** illustrates the crop characteristics for the crops grown in the North Platte River basin, including high altitude grass pasture.

The crop characteristic file used in the historical consumptive use analysis was created using **StateDMI** by extracting the representative crop characteristics from HydroBase and develop the crop characteristics input file.

Table 6
Characteristics of North Platte River Basin Crops

Crop Type	Source	Length of Season	Beginning Temperature	End Temperature
High Altitude Grass Pasture	Denver Water Study	365	42	42

5.0 Results

The North Platte River Basin historical crop consumptive use results are a product of the input files described in **Section 4**. This section provides a summary of historical crop consumptive use and system efficiencies. Results for individual key and aggregated structures can be easily viewed and printed by obtaining the StateCU input files and StateCU model from the CDSS website (see **Section 3.5**).

5.1 StateCU Model Results

Tables 7 shows the average annual basin consumptive use water budget accounting for the period 1956 through 2009. The individual component results are discussed in detail in the following sections.

Table 7
Basin Average Annual Results
1956 through 2009 (acre-feet)

Irrigation Water Required	Surface Water Diversion Accounting					Estimated Crop CU		
	River Headgate Diversion	Surface Water Diversion To: CU	Surface Water Diversion To: Soil	Surface Water Diversion To: Non-Consumed	Calculated System Efficiency	From SW	From Soil	Total
195,264	398,196	100,497	24,438	273,260	31%	100,497	24,690	125,187

Irrigation Water Required is potential consumptive use less the amount of precipitation effective in meeting crop demands directly during the irrigation season. The *Non-Consumed* represents the total water not consumed by the crops, i.e. loss through canal conveyance and during application of the irrigation water. Calculated system efficiency includes both conveyance loss and application loss factors, as presented in **Section 4.5**.

5.2 Historical Crop Consumptive Use

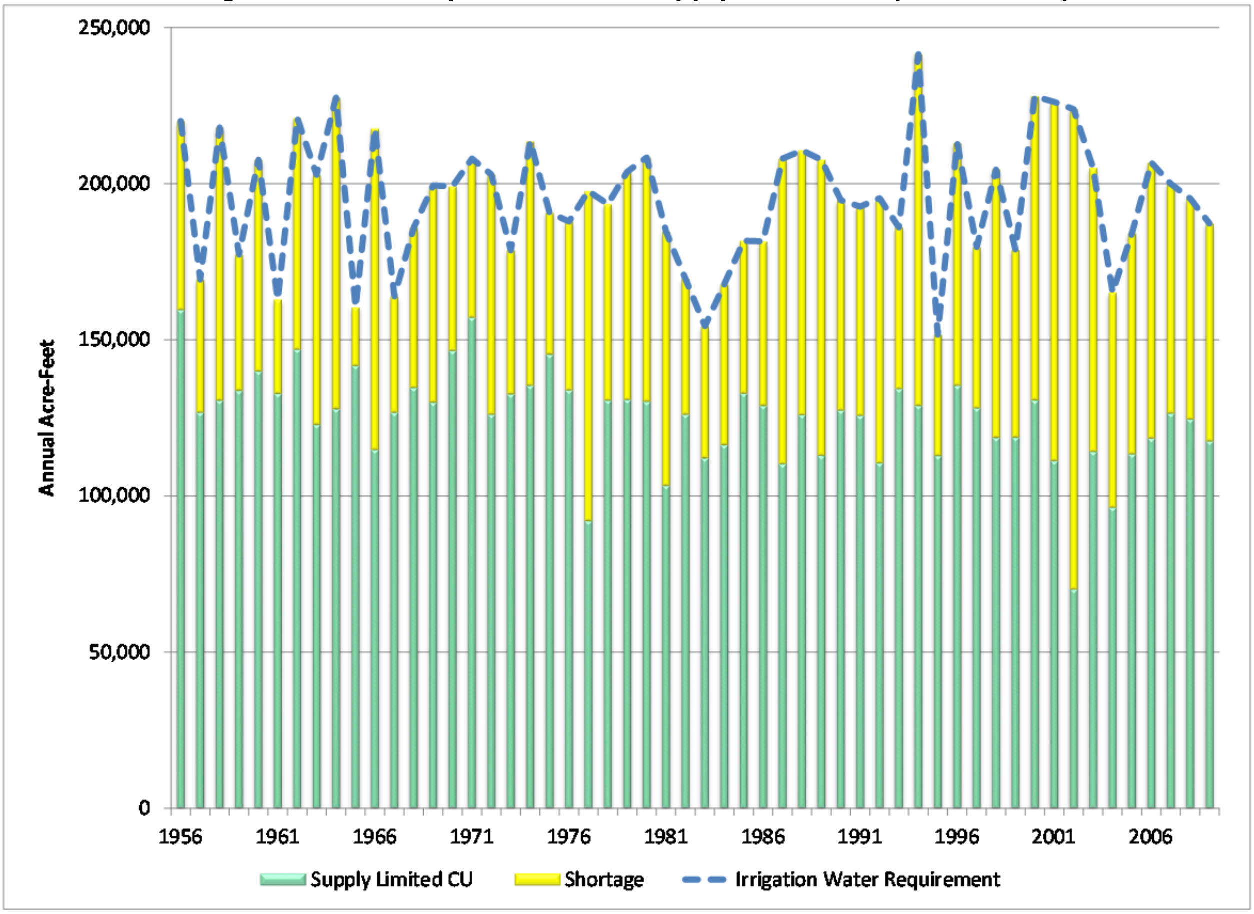
Table 8 presents the historical crop consumptive use analysis results for the 1956 to 2009 study period. Irrigation water requirement in the North Platte River basin is satisfied from surface water diversions, resulting in an estimate of water supply limited consumptive use. The North Platte River basin averages 125,187 acre-feet of water supply limited consumptive use annually. The average annual shortage in the basin is 36 percent. Note the consumptive use from surface water includes excess surface water stored in the soil moisture and then subsequently used by crops.

Table 8
Average Annual Consumptive Use Results
1956 through 2009

2001 Acres	Irrigation Water Requirement (acre-feet)	Supply-Limited CU (acre-feet)	Percent Short
117,032	195,264	125,187	36%

Figure 8 presents basin crop consumptive use results by year and shows that the percent of irrigation water requirement is directly related to water supply. As discussed above, because crop type does not vary from year to year and total irrigated acreage varies only slightly, the pronounced yearly variations in irrigation water requirement are attributable to climate data in the analysis (temperature and precipitation). The percent of irrigation water requirement not satisfied averaged 36 percent over the study period. Many of the shortages are in late summer and early fall. Due to the limited growing season after the initial summer hay cutting, water users indicate they often limit further irrigation. Through conversations with water users in the basin, it was understood that irrigation practices are largely responsible for the shortages in the basin. Drought conditions also impacted shortages; from 2001 to 2003 shortages increased to an average of 55 percent, due to below average stream flows.

Figure 8
Irrigation Water Requirement and Supply Limited CU (1956 – 2009)



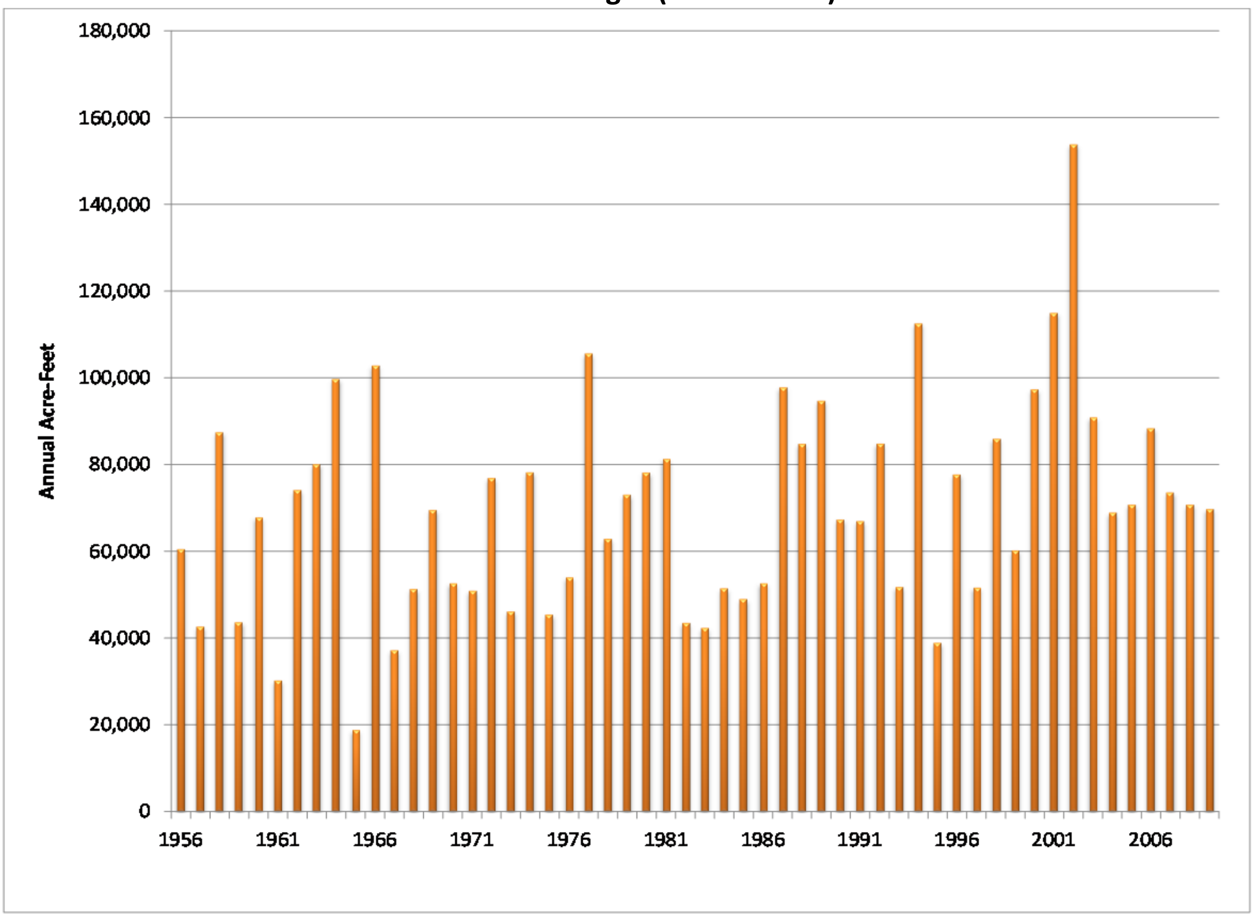
Average monthly shortages for the study period vary from a low of 11 percent in June to a high of 88 percent in September, as shown in **Table 9**. As discussed above, the shortages are high later in the season, primarily due to irrigation practices in the basin.

Table 9
Average Monthly Shortages (1956 – 2009)

Apr	May	Jun	Jul	Aug	Sep	Oct
53%	22%	11%	32%	66%	88%	85%

Figure 9 presents shortages by year. Shortages increased dramatically in the drought years in the early 2000s.

Figure 9
Annual Shortages (1956 – 2009)



5.3 Estimated Actual Efficiencies

As described in the StateCU Documentation, the amount of surface water available to meet the crop demand is the river headgate diversion less conveyance and maximum application losses. If the surface water supply exceeds the irrigation water requirement, water can be stored in the soil moisture up to its water holding capacity.

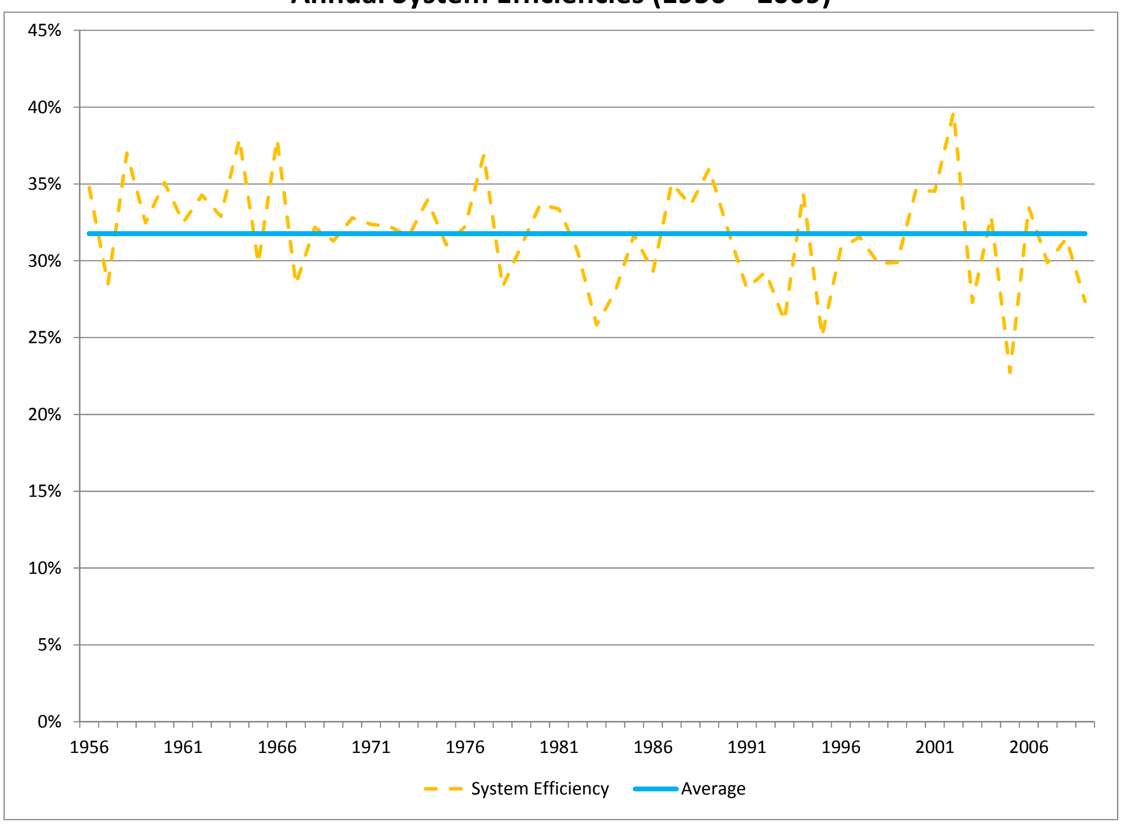
Maximum system efficiencies for surface water diversions are provided as input to StateCU, as described in **Section 4.5**. Actual system efficiencies are calculated based on the amount of water available to meet crop demands and the application method (e.g. flood or sprinkler). All of the acreage in the North Platte River basin, based on the four acreage coverages, is irrigated with flood irrigation practices and is modeled with a 60 percent maximum irrigation efficiency.

Table 10 provides the average monthly calculated system efficiencies for surface water supplies (i.e. diversions to consumptive use and soil moisture divided by total headgate diversions) and **Figure 10** presents this same data by year graphically. Surface water system efficiencies have remained relatively constant throughout the study period, with the slight variations due to water availability. For example, efficiency is higher in significantly dry years, such as 2002, compared to wetter years, such as 2005.

Table 10
Average Monthly Calculated System Efficiencies (1956 – 2009)

Apr	May	Jun	Jul	Aug	Sep	Oct
38%	35%	28%	36%	40%	41%	37%

Figure 10
Annual System Efficiencies (1956 – 2009)



6.0 Comments and Concerns

The historical crop consumptive use estimates are based on measured and recorded data; information from other studies; information provided by local water commissioners and users; and engineering judgement. The results developed for this project are considered appropriate to use for planning efforts in the North Platte River basin. Areas of potential improvement or concern include:

- Historical Acreage. The irrigated acreage assessed for year 1956, 1976, 1987 and 2001 serves as the basis for estimating historical acreage and is considered relatively accurate. Additional water user review resulted in enhancements to the 2001 coverage. It is recommended that those enhancements be included in previous coverages. Irrigated acreage estimates for year 2005 are currently under review, and were therefore not used in the analysis. In general, any additional reliable irrigated acreage assessment years would improve the historical analysis.
- Water Use. The results presented are based on an approach that attempts to represent how water is actually applied to crops in the basin. The approach used is based on engineering judgment and discussions with water users. The effort did not include determining surface water shares for each owner under a ditch or specific irrigation practices followed by individual irrigators. Instead water was shared equally based on acreage. Therefore, this basin-wide historical crop consumptive use analysis is appropriate for planning purposes. However, it should be used as a starting point only for a more detailed ditch level analysis.