The Lower Arkansas Valley Water Conservancy District – Super Ditch Delivery Engineering

The modeling effort anticipated in the original Super Ditch Delivery Engineering Scope of Work [see January 10, 2011 Water Supply Reserve Statewide Account Grant Application] was based on the use of the State of Colorado's StateMod program to represent historical and current water uses and operations on the Arkansas River main stem between Pueblo Reservoir and John Martin Reservoir. The model was to be calibrated to historical conditions over a recent period that is indicative of Winter Water Storage operations. Future operations anticipated as part of the Super Ditch rotational fallowing project would then be incorporated into the calibrated model in order to estimate the exchange potential through various sub-reaches of the Arkansas River.

During 2013 and 2014, a significant amount of information and data was reviewed, analyzed and manipulated as part of the modeling effort. This included review of available information and program algorithms developed for various Arkansas River basin modeling efforts (e.g., H-I Model, ISAM and the SDS and AVC models) and communication and meetings with representatives of various governmental and private entities, including the Colorado Division of Water Resources, the Bureau of Reclamation, Ditch and Reservoir Companies, municipal and industrial interests and water resources engineers.

A StateMod model data set was developed for the Arkansas River main stem from the Portland gage, located above Pueblo Reservoir, down to the Colorado-Kansas state line. Tributary inflows are represented as inflows recorded at the stream gages located near the mouths of the tributaries. Well use is not explicitly represented in the model. The model network and input data were developed according to the standard CDSS protocol.

Data inconsistencies and/or lack of detail identified between the uses of water and colors of water in various ditch and reservoir systems were identified, as discussed in the Task 1 memoranda on the Colorado Canal, Holbrook Canal, and Fort Lyon Canal systems. Complexities involved with Pueblo Reservoir and Winter Water Storage operations and the availability and quality of records associated with reservoir operations are discussed in the memoranda developed for Task 2 and Task 3, respectively.

Model simulations and review of output highlighted some of the more difficult aspects of basin operations to be represented. In particular, solutions were not identified in the existing StateMod operational rules for settling the annual Winter Water Storage Program (WWSP) amounts among the 11 water users in 5 on- and off-channel reservoirs. The overlap of the WWSP and simulation of Article II and Article III water in John Martin Reservoir also caused problems with model simulations. As a consequence of these difficulties, the model data set was not calibrated to historical conditions and not simulated to represent future operations.

Although the Lower Arkansas Valley Water Conservancy District (LAVWCD) model has not been simulated with the latest version of the StateMod executable (v15.00.01), it is believed the StateMod code will still need to be enhanced to facilitate the operations that were not able to be represented with the version of StateMod (v13.00.00) used during development of the LAVWCD model. These enhancements are planned in the future development of ArkDSS.

LAVWCD Memorandum
Final

To: Jay Winner

From: Rick Parsons

Subject: Lower Arkansas Valley Water Conservancy District, Super Ditch Engineering
Task 1 – Colorado Canal Operations

Date: July 10, 2014

INTRODUCTION

Some of the Task 1 objectives are to:

> *Review and document an understanding of the operations of key water use facilities in the basin in order to facilitate surface water modeling and to support analysis of reservoir operations as part of an alternative to agricultural transfer program. Gathering and review of available data, including comparison to input data and variables from other modeling efforts will be used to develop complete input data sets for the StateMod model representation of the Lower Arkansas River basin. This understanding will be developed through interviews with Division 2 personnel, operators of large canal and reservoir systems, and representatives of federal facilities.*

The key reservoir systems identified in Task 1 of the Lower Arkansas Valley Water Conservancy District (LAVWCD) Super Ditch Engineering include:

- Colorado Canal System – Lake Meredith and Lake Henry
- Holbrook Canal System – Holbrook Reservoir and Dye Reservoir
- Fort Lyon Canal System – Adobe Creek Reservoir, Horse Creek Reservoir and Great Plains Reservoirs
- John Martin Reservoir
- Pueblo Reservoir (addressed in Task 2)

Lake Meredith and Lake Henry, under the Colorado Canal system, have been identified as key structures for the potential lease-fallowing operations in the Lower Arkansas Valley. The purpose of this Task 1 memorandum is to document physical, legal, and operational aspects of these structures and to develop complete input data sets for use in the StateMod modeling effort.

The information provided in this memorandum was developed from publicly accessible sources, discussions with Division 2 personnel, DWR Modeling Group personnel and a meeting with Scott Campbell, General Manager of the Twin Lakes Reservoir & Canal Company and Colorado Canal Company and meeting with Kevin Lusk, President of the Lake Henry Reservoir Company. A draft of this memorandum was provided to Messrs.

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Campbell and Lusk for review. No comments were provided on the draft memorandum.

Information in this memorandum is believed to be accurate. However, information should not be relied upon in any legal proceeding.

SYSTEM OVERVIEW

The Colorado Canal, Lake Meredith and Lake Henry are respectively owned by the Colorado Canal Company, Lake Meredith Reservoir Company and Lake Henry Reservoir Company. These companies operate together to provide irrigation supplies to lands located in Pueblo and Crowley Counties.

The Colorado Canal headgate is located on the Arkansas River near Boone, Colorado about 3 miles upstream of the confluence of the Huerfano River. In addition to providing water for direct irrigation, the Colorado Canal is used to deliver storage diversions to Lake Henry and Lake Meredith. The canal runs around to the north and east of Lake Henry and then empties into either Lake Henry or Lake Meredith Reservoir.

All lands under the system have shares in the Colorado Canal Company. Lands down gradient from Lake Henry also have shares the in the Lake Henry Reservoir Company whereas other lands have shares in the Lake Meredith Reservoir Company. Lands under Lake Henry are irrigated by gravity flow. Lake Meredith was originally a natural lake with no tributary connection to the Arkansas River. The lake is topographically too low to irrigate lands by gravity flow. Therefore, water used from Lake Meredith must be released to the Arkansas River and exchanged up to the Colorado Canal. Water in storage in Lake Meredith may be owned by other water users since it is a pivotal aspect of Winter Water Storage Program operations. Therefore, releases from Lake Meredith may also be used to deliver water into the Fort Lyon Storage Canal and the Holbrook Canal and released to the river for diversion by the Fort Lyon Canal. Releases from Lake Meredith may also be exchanged up to Pueblo Reservoir for subsequent use by municipal shareholders.

Approximately 50,000 acres were originally irrigated under the canal and reservoir systems. The Colorado Canal once had exclusive control over the Twin Lakes Reservoir and transmountain diversion system. Irrigators under the canal have sold most of their rights under the Colorado Canal, Lake Meredith, Lake Henry and Twin Lakes Reservoir and Canal Company. Colorado Springs Utilities (CSU) and the City of Aurora are the major shareholders and have changed their irrigation and storage rights in Division 2 water court over the last 30 or so years. When those entities use these water supplies for municipal uses, approximately 10,000 to 15,000 acres under the canal are irrigated. During wet years when municipal interests have more local water supplies in their systems, up to 30,000 acres may be irrigated under the canal.

A breakdown of the ownership within the companies, as of 2004, is shown in Table 1.

Table 1
Ownership of Colorado Canal Companies

Entity	Company Shares			Percent Ownership		
	Colorado Canal[1]	Lake Meredith	Lake Henry	Colorado Canal	Lake Meredith	Lake Henry
Colorado Springs	28,012.760	21,084.750	6,923.150	56.4%	51.9%	77.2%
City of Aurora	14,225.380	13,061.800	1,163.580	28.7%	32.2%	13.0%
City of Fountain	512.500	512.500	0.000	1.0%	1.3%	0.0%
Pueblo West	360.330	360.330	0.000	0.7%	0.9%	0.0%
Woodland Park	583.250	336.000	247.250	1.2%	0.8%	2.8%
Other Uses[2]	1,108.584	946.184	123.000	2.2%	2.3%	1.4%
Agricultural	4,836.171	4,319.821	510.600	9.7%	10.6%	5.7%
Total	49,638.975	40,621.385	8,967.580	100.0%	100.0%	100.0%

Source: MWH Americas, Inc. Table 55.
Notes:
(1) Total Colorado Canal shares are typically sold as "paired shares" and are the sum of Lake Meredith and Lake Henry shares. However, this is not always true, and thus an entity's shares in the Colorado Canal system may not equal the sum of shares in the Lake Henry and Lake Meredith system.
(2) Includes municipal and industrial uses and uses for augmentation.

Key facilities identified in the Colorado Canal, Lake Meredith and Lake Henry Reservoir Systems are as follows. Also listed below are ditches and reservoirs which are outside of the Colorado Canal and Reservoir System, but are essential to system operation.

1) Colorado Canal
2) Lake Meredith
3) Lake Henry
4) Pueblo Reservoir
5) Holbrook Canal
6) Holbrook Reservoir
7) Fort Lyon Storage Canal
8) Fort Lyon Canal

The contact information for the Colorado Canal Company is:

Scott Campbell, General Manager
331 Main Street
Ordway, Colorado
719.267.4411

The general locations of the Colorado Canal, Lake Meredith and Lake Henry Reservoir system and associated structures are shown on **Figure 1**. Irrigated parcels outlined in the figure are from the State of Colorado's Decision Support System (CDSS) 2003 GIS coverage.

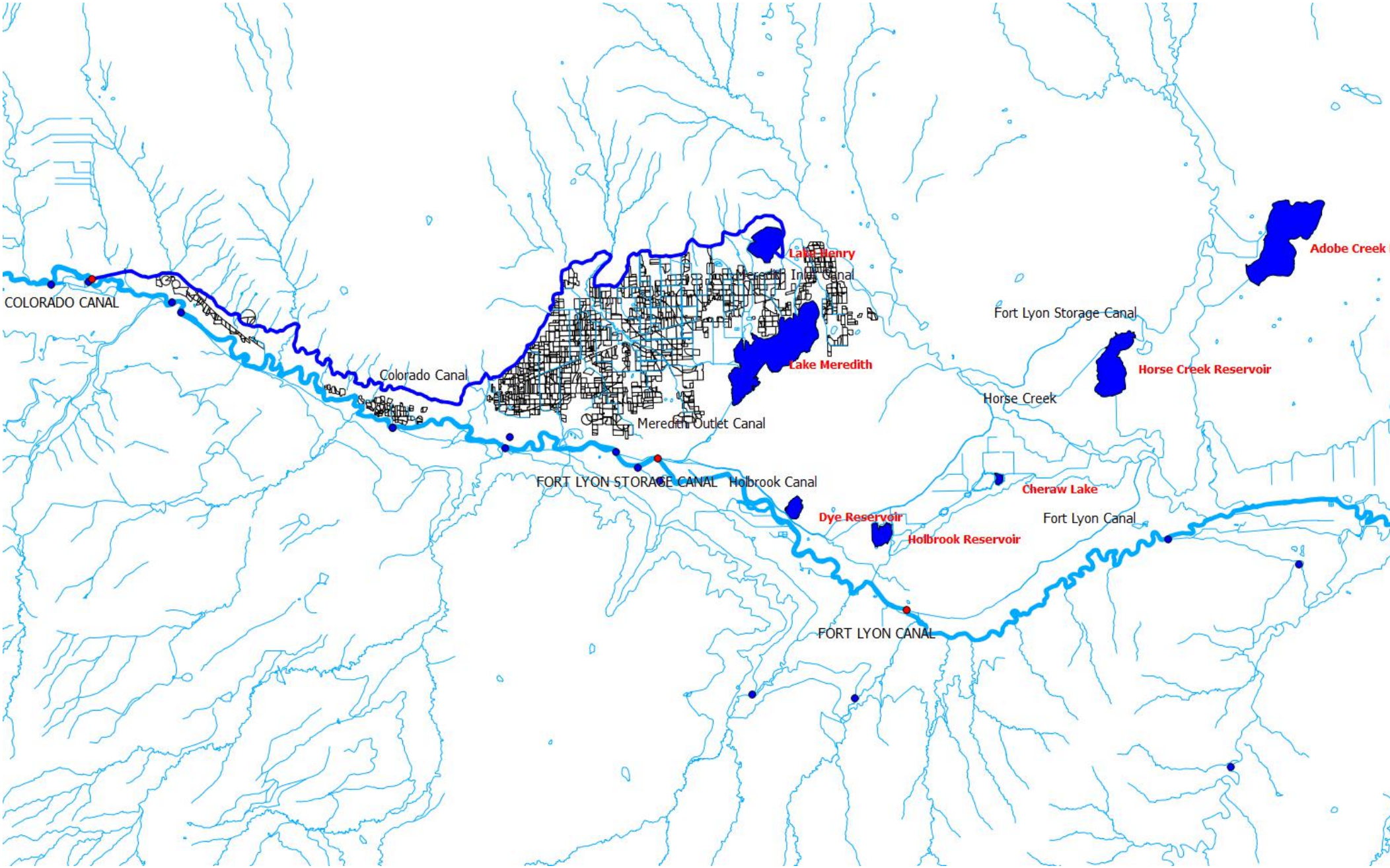

Figure 1: Colorado Canal, Lake Meredith and Lake Henry Reservoir System

PHYSICAL INFORMATION

Infrastructure information related to the ditch headgate, ditch layout, reservoirs, and associated elements of the system are summarized below. The primary source for this information is the water resources data and GIS coverages available on the State of Colorado Decision Support System website (http://cdss.state.co.us/Pages/CDSSHome.aspx).

Sources of data and inputs from other basin models are also included. These data come predominantly from the Hydrological-Institutional (H-I) Model and a 1985 W.W. Wheeler report. A basin model was previously developed to support the Colorado Springs Utilities Southern Delivery System Environmental Impact Statement (EIS) analysis. This model is also being used for the Arkansas Valley Conduit EIS. Documentation summarizing the EIS models indicates the operations of the Colorado Canal off-channel system is explicitly represented in detail in the models. The data from these models were not made available for this effort.

1) Colorado Canal (Structure ID 1700540)

The Colorado Canal runs along the north side of the Arkansas River generally parallel to the river. The canal turns away from the river near Olney Springs. Most of the irrigated land and ditch laterals are located between Olney Springs and Sugar City both north and south of Colorado Highway 96.

Data in HydroBase for the Colorado Canal is recorded under Structure ID 1700540 starting in 2000. Structure ID 1400540 is used for Colorado Canal data prior to that time.

Length: The length of the Colorado Canal to the Lake Henry inlet is approximately 50 miles. Approximately 40 percent (23 miles) of the canal is located above Olney Springs and the majority of irrigated lands under the system. The H-I Model lists a ditch length of 25 miles.

Capacity: The capacity of the Colorado Canal is approximately 850 cfs based on a review of daily records of total diversions over the 1911 to present period. Nonetheless, there are few daily records of diversions in excess of 850 cfs in June 1995.

Conveyance Efficiency: Total conveyance loss is estimated at 23.5 percent in the 1985 Wheeler report, based on a 15 percent loss in the main canal and a subsequent lateral canal loss of 10 percent [(1 – 0.15) times (1 – 0.1) = 0.765]. The H-I Model uses a loss of 19.1 percent over the 25-mile ditch length.

Colorado Canal Company personnel indicate ditch losses average approximately 30 percent.

Irrigated Acreage and Crop Types: GIS coverages from the State of Colorado's Decision Support System (CDSS) list approximately 36,000 acres under the Colorado Canal in 2003 and 2010, as summarized below in **Table 2**. Approximately 80 percent of the acreage is fallowed. The two primary crops that are irrigated under the Colorado Canal are Alfalfa and Grass Pasture.

Table 2
Colorado Canal Acreage

	Total Acreage	Irrigated	Not Irrigated
1998	31,197	8,287 (27%)	22,910 (73%)
2003	35,462	8,083 (23%)	27,379 (77%)
2010	35,717	8,041 (23%)	27,676 (77%)

Source: http://cdss.state.co.us/GIS/Pages/Division2Arkansas.aspx.

The Division 2 office maintains more detailed coverages of total acreage, field verifications of dry up acreage, well associations, augmentation plan assignments, etc. This information may be helpful in analysis of system operations and subsequent studies.

Ground Water Use: A small amount of ground water is used in this area. GIS estimates for the 2003 and 2010 irrigated lands coverages indicate approximately 1,000 acres total supplied by sole source and supplemental wells.

Return Flow Locations: Return flows from the ditch system accrue to the Arkansas River above the Fort Lyon Storage Canal and a small amount of land is tributary to Horse Creek. Return flows from up to two-thirds of the irrigated lands historically returned to Lake Meredith, which was originally a natural depression located within the Bob Creek tributary basin. The amount of return flows that accrue to Lake Meredith has changed over recent years due to the dry up of irrigated lands.

Return flows in the StateMod model are differentiated for the ditch losses and farm losses, as shown in **Table 3**. The spatial distribution of canal losses is based on approximately ditch lengths in relation to locations of gages, reservoirs and ditch headgates included in the model network. The spatial distribution of irrigation return flows is based on the layout of the 2003 GIS acreage, with slight modifications to improve model simulation output (see Task 4 – Model Operations memorandum).

Table 3
Colorado Canal
StateMod Model Return Flow Locations

Model Node	Structure ID	Canal Loss Return Percentage	Irrigated Lands Return Percentage
Arkansas River near Nepesta gage	07117000	---	3%
Rocky Ford Highline Canal	1400542	8%	---
Oxford Farmers Ditch	1400541	14%	---
Otero Canal	1700557	14%	2%
Catlin Canal	1700552	14%	1%
Holbrook Canal	1700554	21%	23%
Fort Lyon Storage Canal	1700648	---	13%
Arkansas R nr Rocky Ford gage	ARKROCCO	14%	18%
Lake Meredith	1703525	---	33%

Ft Lyon Canal	1700553	15%	---
Horse Ck near Hwy 194 gage	HRC194CO	---	7%
TOTAL		100%	100%

HydroBase Data: Diversion data are available in HydroBase from the early-1910s to present. Total diversions (see **Figure 2**) and diversions to irrigation (Use 1) are complete over the 1980 to 2010 StateMod model study period. Monthly diversions to storage (Use 0) are complete starting in 1986.

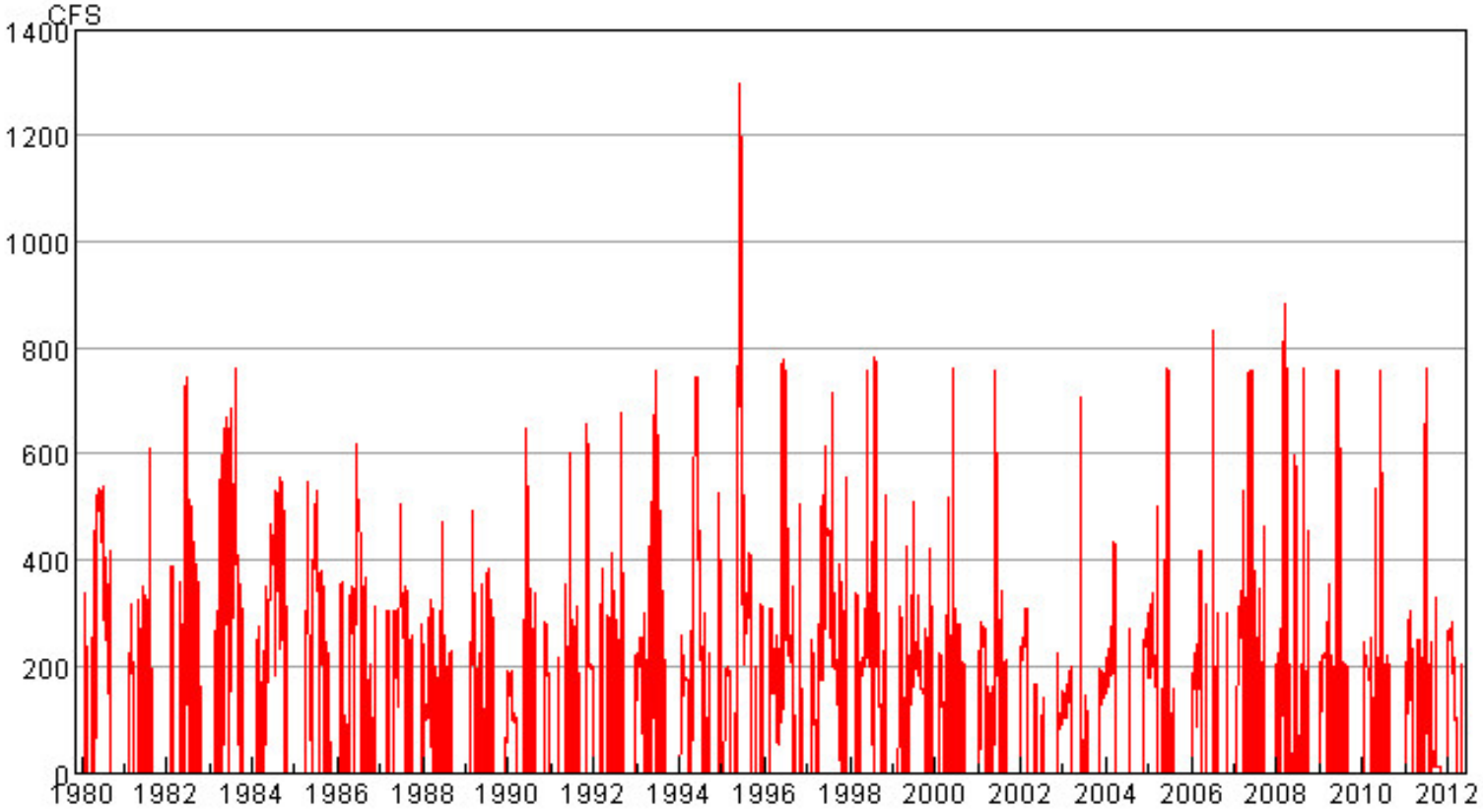

Figure 2: Colorado Canal River Headgate Diversions

2) Lake Meredith (Structure ID 1703525)

The Lake Meredith is filled by the Colorado Canal. Lake Meredith is the most upstream off-channel reservoir in the Lower Arkansas Valley. Water stored under the Lake Meredith storage rights is available to Lake Meredith Company shareholders. Approximately 41,000 acres of the approximately 50,000 acres under the Colorado Canal are not served by Lake Henry and may be considered as being served by Lake Meredith. Based on the location of these lands, they cannot benefit directly from Lake Meredith. Storage water is therefore released to the river for re-diversion through the Colorado Canal via exchange.

In addition to storing changed water rights owned by municipalities, Lake Meredith plays a significant role in the Winter Water storage program (see Task 3 – Winter Water Storage Program memorandum).

Capacity:

- Total Storage: 42,355 ac-ft (Scott Campbell)
- Active Storage: 27,355 ac-ft (Total – Dead)
- Dead Storage: 15,000 ac-ft (Wheeler Report)
- Area/Capacity Data: The area/capacity data in **Table 4** were obtained from the Map of Lake Meredith Enlarged and Amended (accepted by State Engineer 3/12/1930). Low storage levels in recent years showed Company representatives the existing area-capacity table is not correct. A new survey is scheduled to be conducted in the near future. Nonetheless, the Table 4 values are appropriate for use in the model since these values correspond with the historical storage contents measurements.

Table 4
Lake Meredith Elevation – Area – Capacity

Gage Height (ft)	Surface Area (acres)	Cumulative Capacity (ac-ft)
0 - 4	-	-
5	2,017	-
6	2,234	2,264
7	2,511	4,775
8	2,759	7,534
9	3,006	10,539
10	3,253	13,806
11	3,744	17,305
12	4,235	21,295
13	4,727	25,775
14	5,218	26,032
15	5,709	36,211
16	6,314	42,222
17	6,929	48,843
18	7,479	56,047
19	7,896	63,735

Reservoir Storage Management: Storage levels in Lake Meredith are measured using a staff gauge.

Reservoir Seepage Information: Seepage from Lake Meredith is not routinely monitored. Seepage from the reservoir accrues mainly to the Lake Meredith Outlet Canal (see **Figure 1**).

The Lake Meredith Outlet Canal is used to deliver water to the Holbrook Canal or to the Arkansas River for delivery to downstream water users or for exchange to the Colorado Canal river headgate and other upstream locations. The capacity of the outlet canal is unknown.

HydroBase Data: Historical storage contents data are mostly complete in HydroBase starting in water year 1988 (see red line in **Figure 3**). The Colorado Canal Company provided a complete record of end-of-month storage contents for the January 1980 to present period (blue line). The Canal Company are generally consistent with the HydroBase data, with differences likely due to different days upon which staff gage readings were taken, minor differences in capacity estimates based on staff gage elevations, etc.

The Canal Company data were chosen as the primary source of model input data since these data are complete. The Canal Company also provided a complete record of Lake Meredith releases for the January 1985 to present period. The change in storage contents for Lake Meredith and Lake Henry were used with the Lake Meredith release data to estimate Lake Henry direct releases to irrigation. Some of the river headgate diversion data (total diversions and diversions to storage) and the storage contents and release data for Lake Meredith and Lake Henry are not consistent. Therefore, some of the colors of water at the river headgate (i.e., to irrigation and to storage) were revised to develop a "best fit" to make the various model input data consistent.

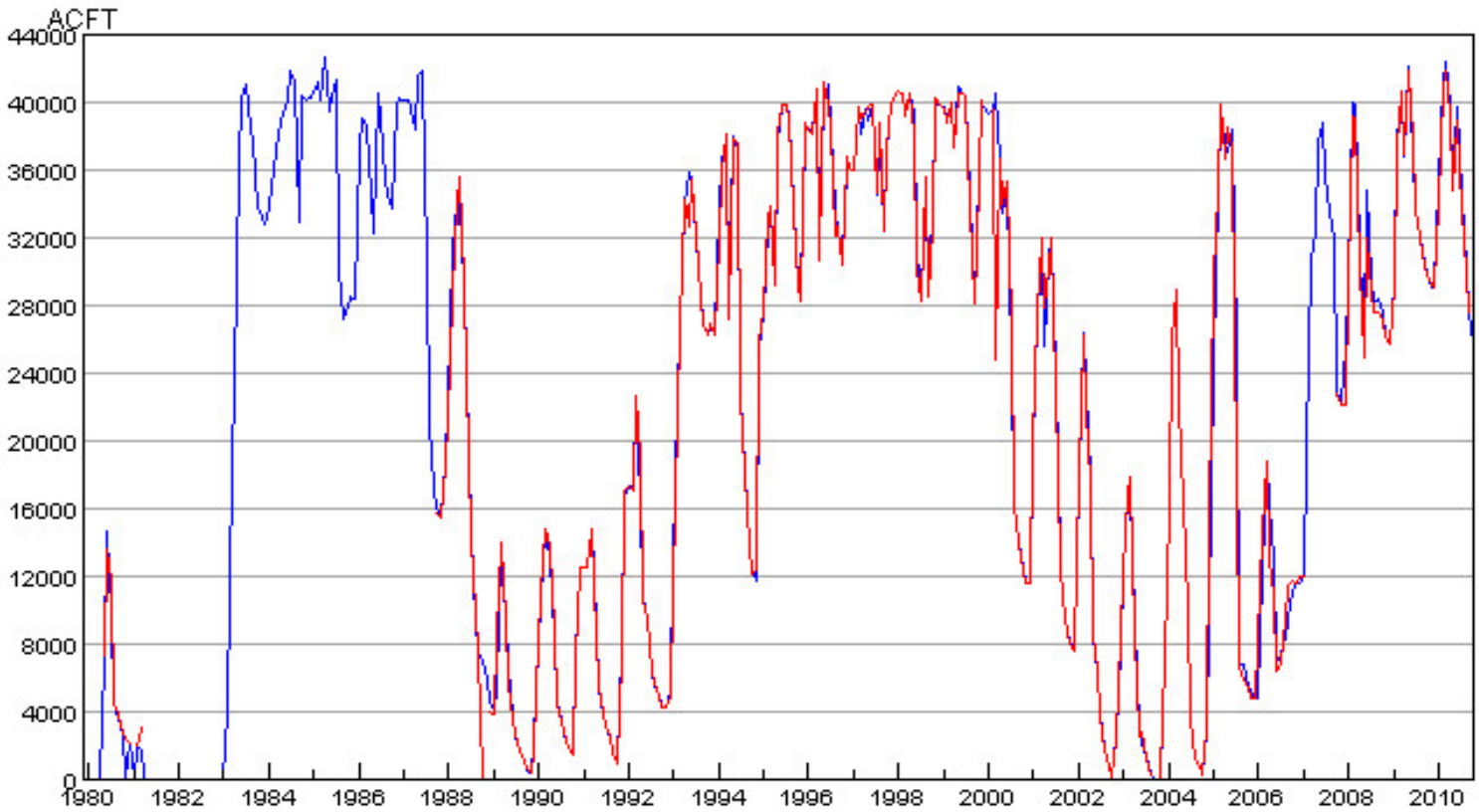

Figure 3: Lake Meredith Storage Contents

3) Lake Henry (Structure ID 1403524)

The Lake Henry is filled by the Colorado Canal. Water stored under the Lake Meredith storage rights is available to Lake Meredith Company shareholders. Approximately 9,000 acres of the

approximately 50,000 acres under the Colorado Canal are served by Lake Henry. Lands with shares in the reservoir company benefit directly from Lake Henry releases.

Lake Henry is operated in concert with Lake Meredith in relation to Winter Water operations and for the storage of changed reservoir company shares. In addition to making releases direct to irrigators, water from Lake Henry can be released to the Arkansas River through Lake Meredith and the Lake Meredith Outlet Canal.

Capacity:

- Total Storage: 8,906 ac-ft (Scott Campbell)
- Active Storage: 7,406 ac-ft (Total – Dead)
- Dead Storage: 1,500 ac-ft (Wheeler Report)
- Area/Capacity Data: The area/capacity data in **Table 5** were obtained from the Plat of the National Sugar Manufacturing Company's Enlargement of its Reservoir No. 1 Map (accepted by State Engineer 3/21/1910). Low storage levels in recent years showed Company representatives the existing area-capacity table is not correct. A new survey is scheduled to be conducted in the near future. Nonetheless, the Table 5 values are appropriate for use in the model since these values correspond with the historical storage contents measurements.

Table 5
Lake Henry Elevation – Area – Capacity

Gage Height (ft)	Surface Area (acres)	Cumulative Capacity (ac-ft)
0	13	-
1	16	156
2	212	327
3	268	567
4	329	868
5	402	547
6	460	1,667
7	574	2,184
8	644	2,793
9	690	3,460
10	771	4,191
11	836	5,006
12	882	5,864
13	946	6,778
14	1,030	7,766
15	1,079	8,820
15.3	1,114	9,916

Reservoir Storage Management: Storage levels in Lake Henry are measured using a staff gauge.

Reservoir Seepage Information: Seepage from Lake Henry is not routinely monitored. Seepage from the reservoir accrues mainly to Lake Meredith (see **Figure 1**).

HydroBase Data: Similar to Lake Meredith, the historical storage contents data are mostly complete in HydroBase starting in water year 1988 (see red line in **Figure 4**). The Colorado Canal Company provided a complete record of end-of-month storage contents for the January 1980 to present period (blue line). The Canal Company are generally consistent with the HydroBase data, with differences likely due to different days upon which staff gage readings were taken, minor differences in capacity estimates based on staff gage elevations, etc.

The change in storage contents for Lake Meredith and Lake Henry were used with the Lake Meredith release data to estimate Lake Henry direct releases to irrigation. Some of the river headgate diversion data (total diversions and diversions to storage) and the storage contents and release data for Lake Meredith and Lake Henry are not consistent. Therefore, some of the colors of water at the river headgate (i.e., to irrigation and to storage) were revised to develop a "best fit" to make the various model input data consistent.

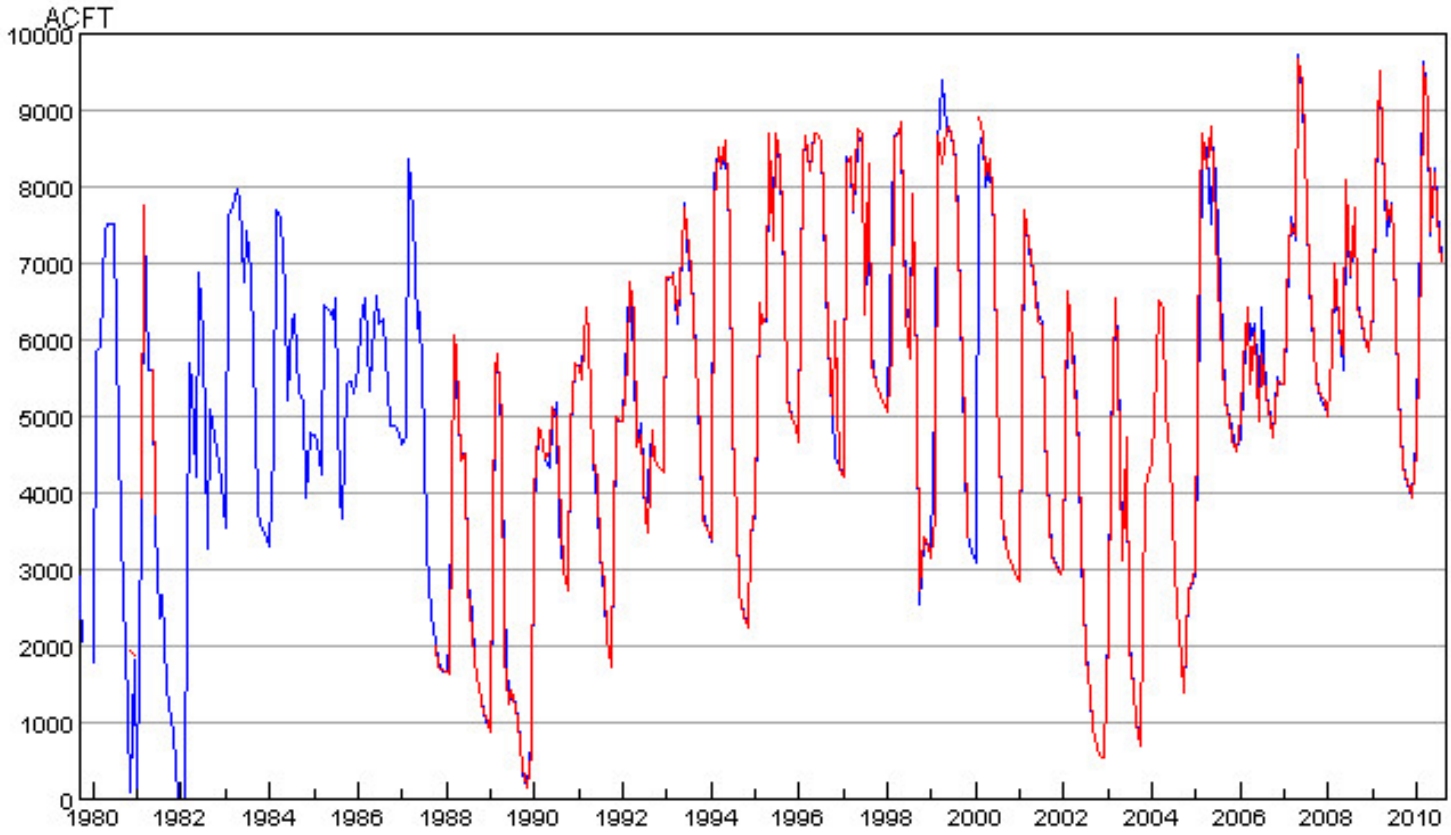

Figure 4: Lake Henry Storage Contents

WATER RIGHTS

Direct Flow Rights

The Colorado Canal Diversion System has a total decreed flow rate of 756.28 cfs from the Arkansas River for multiple uses, as summarized in **Table 6**. The water right was originally decreed solely for irrigation uses. The same rate was also included as a maximum filling rate in the storage decrees for Lake Meredith and Lake Henry. The original irrigation water right was changed in Case No. 86CW64 to include the other uses listed in Table 6. The 86CW64 decree also provided for the exchange of storage releases from Lake Meredith at a point on the Arkansas River at the confluence of the Lake Meredith Outlet Canal up to the Colorado Canal river headgate. This exchange provides Lake Meredith shareholders with the mechanism to receive supplemental storage releases from Lake Meredith.

Table 6
Direct Flow Rights – Colorado Canal Company

Structure	Appropriation Date	Adjudication Date	Admin. No.	Decreed Amount (cfs)	Case No.	Notes
Colorado Canal	6/9/1890	2/23/1896	14770.0	756.28	CA2535	Irrigation Use
					84CW64	Storage in Meredith Lake and Lake Henry
						Muni, Comm, Dom, Ind Uses
	3/9/1898	11/25/1916	17600.0	756.28	CA13693	Lake Meredith Exchange to Colorado Canal

Source: Colorado Water Rights Tabulation.

Storage Rights

The storage rights associated with Lake Meredith and Lake Henry are summarized in **Table 7**.

Lake Meredith has undergone one enlargement from its initial decreed capacity of 20,599.6 ac-ft: It increased the decreed storage capacity by 5,068.8 ac-ft to its current decreed capacity of 26028.4 acre-feet.

Table 7
Storage Rights – Lake Meredith and Lake Henry

Storage Unit	Appropriation Date	Adjudication Date	Admin. No.	Decreed Amount (ac-ft)	Case No.	Notes
Lake Meredith	12/31/1891	11/25/1916	19465.15340	6,355	84CW64	Lake Henry Alt Pt
	3/9/1898		19465.17600	20,959.6	CA13693	Absolute (Irrig)
				5068.8		Enl Absolute (Irrig)
				26,028.4	84CW64	Muni, Comm, Dom, Ind Uses
	6/15/1909		21715.0	3,561		Lake Henry Alt Pt
	9/10/1900	10/13/1932	24435.18515	2,000		
		Totals	26,028.4 (Storage)		11,916 (Alternate Point)	
Lake Henry	12/31/1981	11/25/1916	19465.15340	6,355	CA13693	Absolute (Irrig)
	6/15/1909		21715.0	3,561		Enl Absolute (Irrig)
	9/10/1900	10/13/1932	24435.18515	2,000	CA19693	Non-Irrig Uses

		Total	11,916	84CW64	Irrig, Muni, Comm, Dom, Ind Uses for all three Lake Henry storage rights

Source: Colorado Water Rights Tabulation and Pueblo County Court Decrees

Administration

Administration of the water rights associated with the Colorado Canal Company and Lake Henry Company involves interaction with the Water District 17 Water Commissioner and the Division 2 Engineer. The Superintendent of the canal company is more often in contact with these individuals during periods of storage and during periods when direct flow calls have been placed downstream on the Arkansas River.

OPERATIONAL INFORMATION

The general operating strategy for the Colorado Canal and Reservoir System in a typical year is as follows:

Non-Irrigation Season

The Colorado Canal typically shuts off by November 15, once the Winter Water season begins. The pro-rata share amount for the canal company and reservoir companies totals 10.69 percent of the first 100,000 ac-ft of Winter Water and a 12.8025 percent of amounts stored beyond 103,106 ac-ft. As discussed in the Task 3 memorandum, storage in Lake Henry and Lake Meredith is a pivotal part of the Winter Water Storage Program. The Winter Water storage amounts in the Colorado Canal system reservoirs are based on gage height rather than river diversions. Therefore, the Winter Water storage amounts are accounted after conveyance losses down the Colorado Canal. The companies try to finish the Winter Water season (March 15) with the reservoirs full. Although operations vary depending on the hydrologic year and other factors, a general approach to meeting this objective is to fill the reservoirs at the end of the Winter Water season, i.e., by estimating the expected rate of diversion available and the number of days it will take to fill unfilled capacity, going backward from May 15 and starting conveyance of water at that time.

Shareholders in the Colorado Canal and Lake Henry and Lake Meredith Reservoir Companies have first priority to water stored in the reservoirs during the Winter Water storage season. Additional water in storage is allocated to other Winter Water participants. These entities generally take delivery of their Winter Water early in the irrigation season since their water will be booked out if the Lake Henry or Lake Meredith storage rights come into priority during the spring runoff.

Irrigation Season

The Colorado Canal has a relatively junior direct flow right that is typically only in priority to divert during spring runoff and later in the summer in above average and wet years.

In wet years, CSU and Aurora lease their share water back to irrigators under the canal. During dry and average years, the cities try to exchange their supplies up-basin and divert their share water into storage under the Colorado Canal system when there is no river exchange potential.

The stored water is then exchanged up the river system later in the season or the following water year when exchange potential may become available.

Historically, irrigators under the ditch benefitted from Winter Water stored in Lake Meredith and Lake Henry, releases of Fry Ark Project water from Pueblo Reservoir and supplemental deliveries attributable to shares in the Twin Lakes Reservoir & Canal Company (TLCCo).

As noted above, TLCCo deliveries for the last 20 to 30 years have been limited. CSU and Aurora typically take delivery of their ditch and reservoir company shares and TLCCo share water higher up in the Arkansas River basin. Therefore, since municipalities took over the majority of the share ownership in the canal and reservoir companies (post ~1980), typically less than 5 percent of TLCCo water owned by irrigators makes it past Pueblo Reservoir and down the Colorado Canal.

Fry Ark deliveries have generally been delivered from Pueblo Reservoir in the July / August period. Annual deliveries averaged about 1,700 acre-feet from the mid-1980s through mid-1990s. Deliveries during the 2000s have been more sporadic and have averaged closer to 500 acre-feet per year, which is consistent with reduced irrigation use under the Colorado Canal.

Although the sequence of delivery each year varies based on hydrologic conditions, ditch operational issues and other conditions, a general order of operations for water supplies into the Colorado Canal is as follows:

1. Direct Flow Water
2. Winter Water and water diverted under its storage from Lake Meredith (by exchange) and Lake Henry (direct)
3. Twin Lakes Canal Company and Fry-Ark Project Water from Pueblo Reservoir

REFERENCES

1) Bill Tyner, Division 2 Assistant Engineer. 719.542.3368 x2010.
2) Lonnie Spady, District 17 and 67 Commissioner. 719.250.1655.
3) Scott Campbell, General Manager. Twin Lakes Reservoir and Canal Company and Colorado Canal Company. 719.267.4411.
4) Kevin Lusk, President of Lake Henry Reservoir Company and Principal Engineer for Colorado Springs Utilities. 719.668.8719.
5) HydroBase Database. State of Colorado official water resources database developed under the Colorado Decision Support System.
6) State Engineer's Office. Straightline Diagrams and Maps and Filing Statements.
7) Abbott, P.O., Description of Water-Systems Operations in the Arkansas River Basin, Colorado. USGS Water Resources Investigations Report 85-4092. Lakewood, Colorado. 1985.
8) MWH Americas, Inc. Hydrologic Model Documentation Report Southern Delivery System Environmental Impact Statement, Prepared for Bureau of Reclamation Eastern Colorado Area Office. Loveland, Colorado. November 2007.

9) Pueblo County District Court decrees in Civil Actions 13693 and 19693.

10) W.W. Wheeler & Associates, Inc. Final Report Colorado Canal, Lake Henry and Lake Henry Change of Water Rights. Englewood, Colorado. October 1985 (Revised).

LAVWCD Memorandum
Final

To: Jay Winner

From: Rick Parsons

Subject: Lower Arkansas Valley Water Conservancy District, Super Ditch Engineering
Task 1 – Holbrook Canal Operations

Date: July 10, 2014

INTRODUCTION

Some of the Task 1 objectives are to:

> *Review and document an understanding of the operations of key water use facilities in the basin in order to facilitate surface water modeling and to support analysis of reservoir operations as part of an alternative to agricultural transfer program. Gathering and review of available data, including comparison to input data and variables from other modeling efforts will be used to develop complete input data sets for the StateMod model representation of the Lower Arkansas River basin. This understanding will be developed through interviews with Division 2 personnel, operators of large canal and reservoir systems, and representatives of federal facilities.*

The key reservoir systems identified in Task 1 of the Lower Arkansas Valley Water Conservancy District (LAVWCD) Super Ditch Engineering include:

- Colorado Canal System – Lake Meredith and Lake Henry
- Holbrook Canal System – Holbrook Reservoir and Dye Reservoir
- Fort Lyon Canal System – Adobe Creek Reservoir, Horse Creek Reservoir and Great Plains Reservoirs
- John Martin Reservoir
- Pueblo Reservoir (addressed in Task 2)

Holbrook Reservoir and Dye Reservoir under the Holbrook Canal System have been identified as key structures for the potential lease-fallowing operations in the Lower Arkansas Valley. The purpose of this Task 1 memorandum is to document physical, legal, and operational aspects of these structures and to develop complete input data sets for use in the StateMod modeling effort.

The information provided in this memorandum was developed from publicly accessible sources, discussions with Division 2 personnel, DWR Modeling Group personnel and a meeting with Canal Company Superintendent Bob Barnhart. Information in this memorandum is believed to be accurate. However, the information should not be relied upon in any legal proceeding.

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SYSTEM OVERVIEW

The Holbrook Canal, Holbrook Creek Reservoir and Dye Reservoir are owned by the Holbrook Mutual Irrigating Company. These canals and reservoirs are operated together to provide irrigation supplies to lands located north of the Arkansas River in Otero County.

The Holbrook Canal headgate is located on the Arkansas River approximately 1.5 miles northeast of Manzanola, Colorado. The canal runs along the north bank of the Arkansas River for approximately 25 miles until it terminates near Horse Creek, north of the Town of Cheraw.

Approximately 16,000 acres are irrigated under the canal and reservoir system. Direct flow and storage water is delivered to shareholders on a rotational basis to four sections.

Key facilities identified in the Holbrook Canal and Reservoir System are as follows.

1) Holbrook Canal
2) Holbrook Reservoir
3) Dye Reservoir
4) Pueblo Reservoir

The contact information for the Holbrook Canal Company is:

Bob Barnhart, Superintendent
26334 Hwy 266
Rocky Ford, Colorado 81067
719.469.1225

The general locations of the Holbrook Canal, Holbrook Reservoir and Dye Reservoir system and associated structures are shown on **Figure 1**. Irrigated parcels outlined in the figure are from the State of Colorado's Decision Support System (CDSS) 2003 GIS coverage.

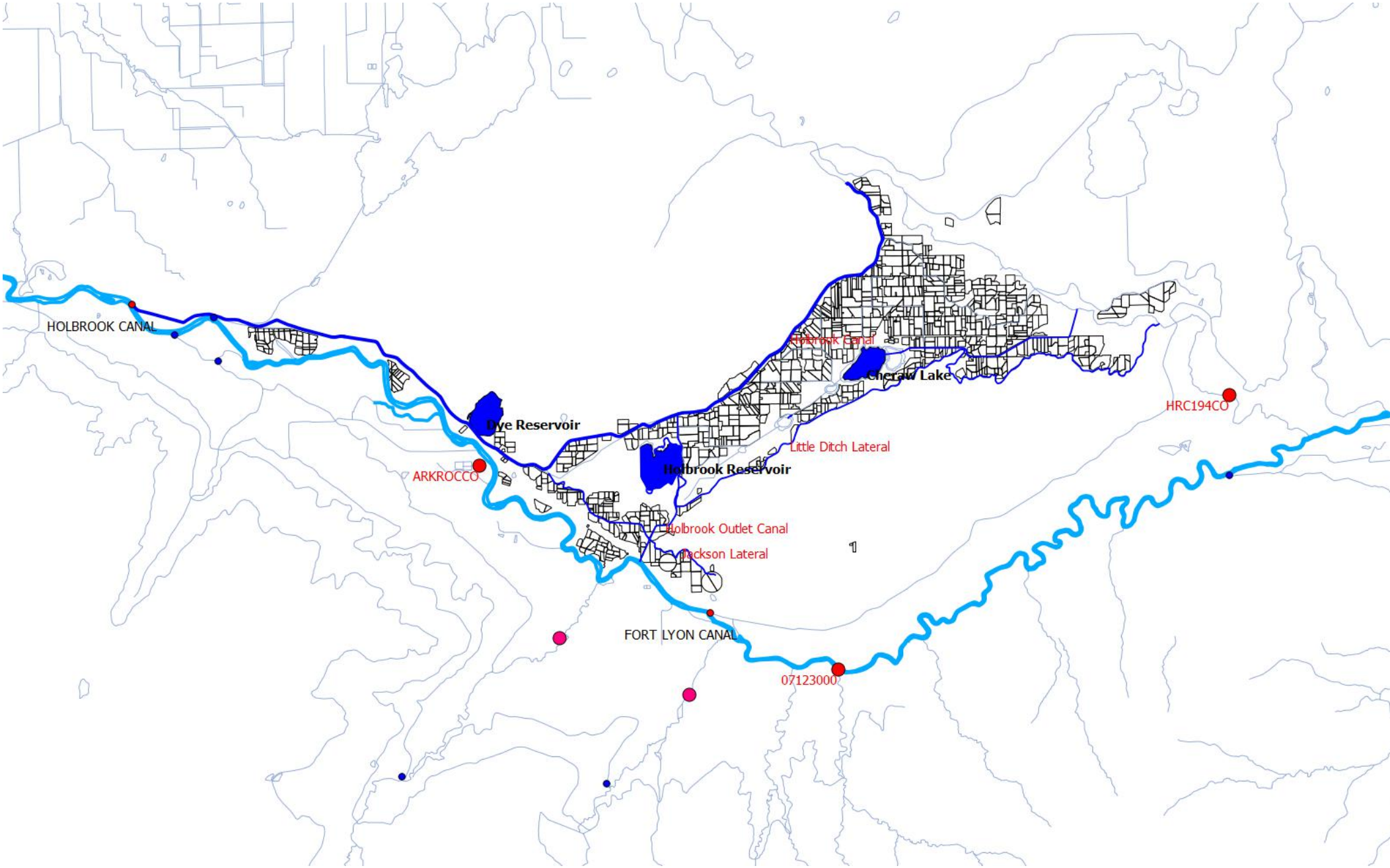

Figure 1: Holbrook Canal and Holbrook Storage Canal Systems

PHYSICAL INFORMATION

Infrastructure information related to the ditch headgate, ditch layout, reservoirs, and associated elements of the system are summarized below. The primary source for this information is the water resources data and GIS coverages available on the State of Colorado Decision Support System website (http://cdss.state.co.us/Pages/CDSSHome.aspx).

Sources of data and inputs from other basin models are also included. These data come predominantly from the Hydrological-Institutional (H-I) Model. A basin model was previously developed to support the Colorado Springs Utilities Southern Delivery System Environmental Impact Statement (EIS) analysis. This model is also being used for the Arkansas Valley Conduit EIS. Documentation summarizing the EIS models indicates the operations of the Holbrook Canal off-channel system is not explicitly represented in the models. The data from these models were not made available for this effort.

1) Holbrook Canal (Structure ID 1700553)

The Holbrook Canal runs along the north side of the Arkansas River generally parallel to the river. The Jackson Lateral, which serves approximately 20 percent of the land under the system, continues along the Arkansas River at a point near Rocky Ford where the canal turns north from the river.

Length: The length of the Holbrook Canal is approximately 24 miles. The H-I Model lists a ditch length of 15 miles for the Holbrook Canal.

Capacity: The capacity of the Holbrook Canal is approximately 1,000 cfs.

Conveyance Efficiency: Holbrook Canal Company personnel indicate ditch losses average approximately 24 percent in the Holbrook Canal system. The conveyance losses are split evenly above and below Holbrook Reservoir. Conveyance losses up-ditch of Holbrook Reservoir accrue to the Arkansas River system. Conveyance losses below Holbrook Reservoir and from the Little Ditch Lateral accrue to the natural depression in between the two ditches, which ultimately drains into Cheraw Lake. The H-I Model uses a loss of 11.9 percent for the Holbrook Canal.

Irrigated Acreage and Crop Types: GIS coverages from the CDSS list approximately 15,097 acres under the Holbrook Canal in 2003. Approximately 46 percent of the acreage is identified as fallow in the 2003 GIS coverage, as summarized below in **Table 1**. The primary crop that is irrigated under the Holbrook Canal is Alfalfa.

Table 1
Holbrook Canal 2003 Acreage

Crop	Acres
Alfalfa	7,195
Cereals	148
Grass Pasture	701
Fallow	6,955

Crop	Acres
Vegetables	86
Wheat	12
Total	15,097

Source: http://cdss.state.co.us/GIS/Pages/Division2Arkansas.aspx.

The Division 2 office maintains more detailed coverages of total acreage, field verifications of dry up acreage, well associations, augmentation plan assignments, etc. This information may be helpful in analysis of system operations and subsequent studies.

Ground Water Use: GIS estimates for the 2003 irrigated lands coverage indicate approximately 400 acres total (2.5%) are supplied by supplemental wells.

Return Flow Locations: Return flows from irrigated lands under the ditch system accrue as discussed above for conveyance losses. Approximately 20 percent of the irrigated land is tributary to the Arkansas River. The remaining lands are tributary to Cheraw Lake and ultimately to Horse Creek above Hwy 194 stream gage during average and wet years when water reaches a sufficient depth in Cheraw Lake and then overflows out of the pond toward the Horse Creek drainage.

Return flows in the StateMod model are differentiated for the ditch losses and farm losses, as shown in **Table 2**. The spatial distribution of canal losses is based on approximate ditch lengths in relation to locations of gages, reservoirs and ditch headgates included in the model network.

Note Cheraw Lake is excluded from the table since the lake is not explicitly represented in the model. Therefore, the evaporative losses from Cheraw Lake are essentially not tributary to the model network. This dynamic is addressed via modifications to the losses and associated efficiency of the Holbrook system (see Task 4 – Model Operations memorandum). The spatial distribution of irrigation return flows is based on the layout of the 2003 GIS acreage, with slight modifications to improve model simulation output

Table 2
Holbrook Canal
StateMod Model Return Flow Locations

Model Node	Structure ID	Canal Loss Return Percentage	Irrigated Lands Return Percentage
Arkansas River at Rocky Ford gage	ARKROCCO	25%	4%
Lake Meredith	1703525	---	2%
Fort Lyon Canal	1700553	25%	54%
Horse Ck nr Hwy 194 gage	HRC194CO	50%	40%
TOTAL		100%	100%

HydroBase Data: Diversion data are available in HydroBase from the early-1910s to present. Total diversions and diversions to irrigation (Use 1) are complete over the 1986 to 2010 StateMod model study period (see **Figure 2** for data since 1980). Monthly diversions from storage (Source 2) are available sporadically for John Martin Reservoir (1990-1994, 1996-1997, 2002, 2004-2006, 2008 and 2010) and Holbrook Reservoir (1996, 2006 and 2008). Winter Water deliveries are recorded from Pueblo Reservoir (1980-1981 and 2003-2006) and Holbrook Reservoir (1990, 1993, 2003-2005 and 2008-2009). Fry-Ark Project deliveries are recorded for 1980-1982, 1984, 1988-1994, 1996 and 1998-2010.

The Holbrook Augmentation Station is identified in HydroBase (Structure ID 1700806) but has no associated data other than water commissioner comment of "Gross releases of Holbrook shares to river for all augmentation plans dependent on Holbrook". The extent of plans dependent on augmentation station deliveries is understood to be fairly minor. Bob Barnhart indicated that this year two shareholders ran their share water through an augmentation station in 2013 on the northeast side of Holbrook Reservoir and pumped a like amount of water from their wells to approximately 900 acres of drip-irrigated crops.

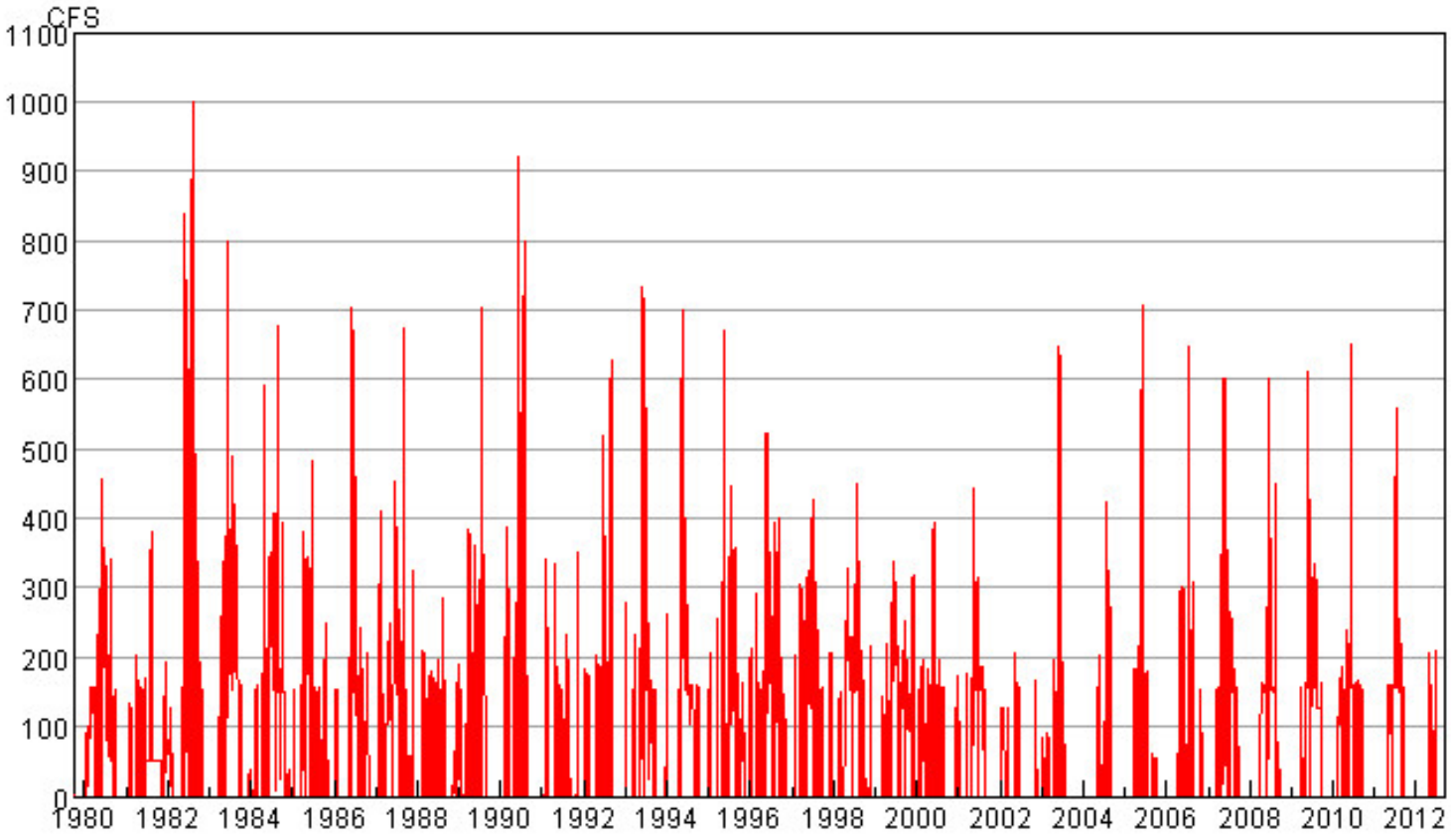

Figure 2: Holbrook Canal River Headgate Diversions

2) Holbrook Reservoir (Structure ID 1703546)

The Holbrook Reservoir is filled by the Holbrook Storage Canal. Water stored under the Holbrook Reservoir storage rights is available to Holbrook Canal Company shareholders.

In addition to storing the reservoir storage water right, Holbrook Reservoir is one of the off-channel reservoirs in the Winter Water storage program (see Task 3 – Winter Water Storage Program memorandum).

Capacity:

- Total Storage: Approximately 6,300 ac-ft
- Active Storage: 6,300 ac-ft
- Dead Storage: Unknown
- Area/Capacity Data: No area/capacity data were located for Holbrook Reservoir. A two-point area-capacity curve in **Table 3**, assuming an average depth of 30 feet is input to the StateMod model. Canal Company representatives indicated they had an area-capacity table but it was not provided for this effort.

Table 3
Holbrook Reservoir Elevation – Area – Capacity

Gage Height (ft)	Surface Area (acres)	Cumulative Capacity (ac-ft)
-	0	0
-	210	6,300

Reservoir Storage Management: It is believed that storage levels in Holbrook Reservoir are not typically measured.

Reservoir Seepage Information: Seepage from Holbrook Reservoir is not routinely monitored. Seepage from the reservoir accrues mostly to the Holbrook Reservoir Outlet Canal (see Figure 1).

The Holbrook Reservoir Outlet Canal is used to deliver water to Adobe Creek to be picked up by the Holbrook Canal for delivery to shareholders. The capacity of the outlet canal is unknown.

HydroBase Data: Historical end-of-month contents are mostly complete in HydroBase (red line) over the 1986 to 2010 StateMod model study period. Storage contents data since 1980 are missing for water years 1984 through 1987, 2004, portions of 1980 through 1983 and a few other months (see red line in **Figure 3**). The Holbrook Canal Company indicated they do not maintain storage contents data. These data were similarly not available from SEO.

The storage has been depleted to zero on a number of occasions. As noted above, no diversions were made through the Holbrook Storage Canal during 2003 through 2005. No storage contents data for Holbrook Reservoir are available during that period and are assumed to be zero.

Missing storage contents (blue line) were estimated based on review of available daily storage contents data, review of diversion data for the Holbrook Canal discussed above, water commissioner records and comments, monthly and daily storage contents and linear interpolation of short periods of missing data. Note the river headgate diversion data and storage contents data in Holbrook Reservoir and Dye Reservoir are not

consistent. Therefore, estimation of missing storage contents focused on development a "best fit" to make the various model input data consistent.

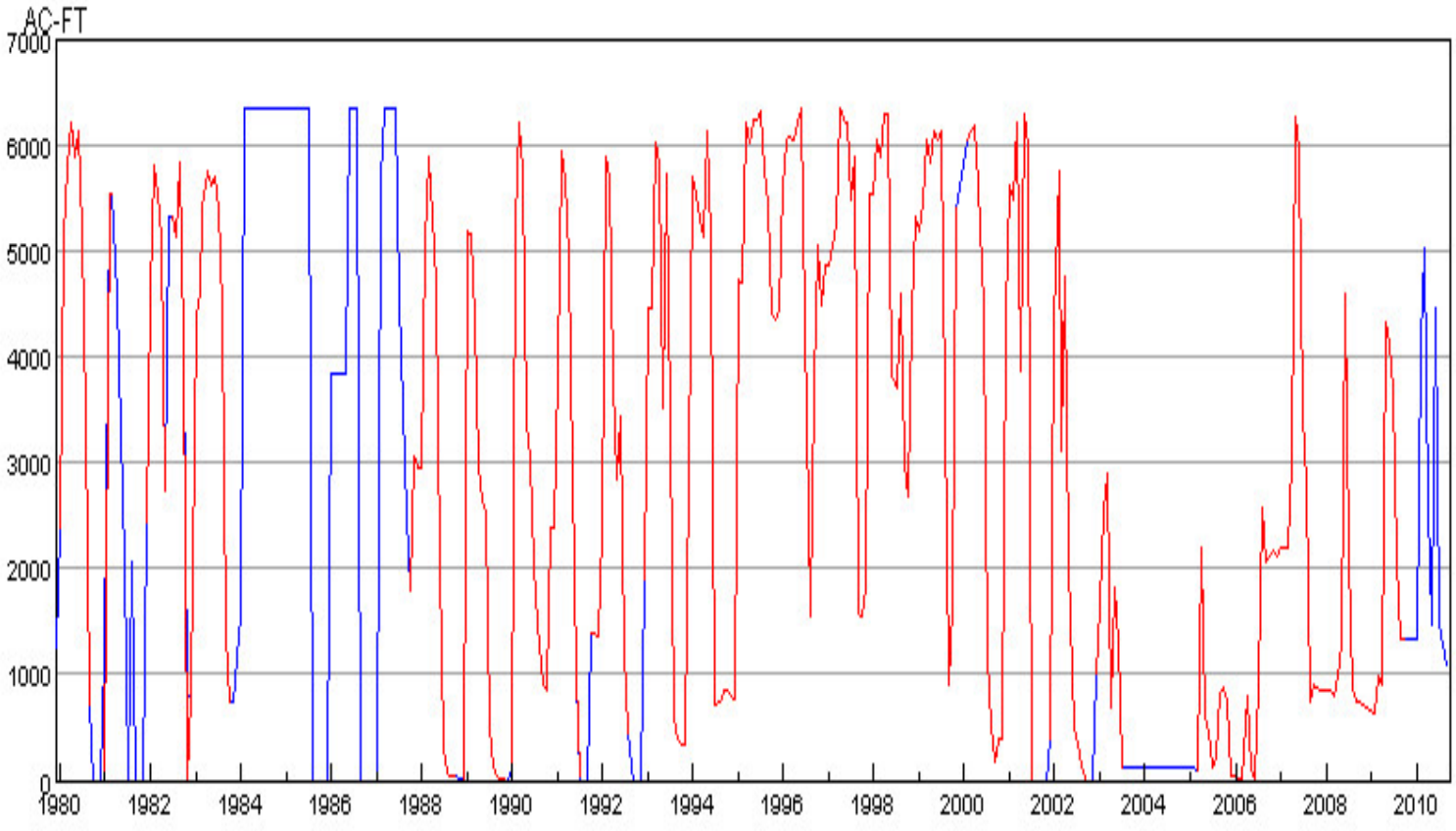

Figure 3: Holbrook Reservoir Storage Contents

3) Dye Reservoir (Structure ID 1703546)

The Dye Reservoir is filled by the Holbrook Storage Canal. Water stored under the Dye Reservoir storage rights is available to Holbrook Canal Company shareholders.

In addition to storing the reservoir storage water right, Dye Reservoir was historically one of the off-channel reservoirs in the Winter Water storage program (see Task 3 – Winter Water Storage Program memorandum).

Capacity:

- Total Storage: 2,500 ac-ft
- Active Storage: 2,500 ac-ft
- Dead Storage: Unknown
- Area/Capacity Data: The area/capacity data in **Table 4** were obtained from the Map of Dye Reservoir and Dye Reservoir Outlet Ditch (approved by State Engineer 11/1/1909). The Filing Map included in the Statement of Claim Canal Company representatives indicated they had an area-capacity table but it was not provided for this effort.

Table 4
Dye Reservoir Elevation – Area – Capacity

Gage Height (ft)	Surface Area (acres)	Cumulative Capacity (ac-ft)
0	29	-
4	43	143
8	86	413
12	148	899
16	211	1,616
20	271	2,566
24*	333	3,743
28*	404	5,233
32	481	7,044
36	695	9,464
40	997	12,736
44	1,153	16,956

* The Filing Map for the Statement of Claim for Dye Reservoir includes a figure on Sheet 1 that indicates a Capacity of 5,052 ac-ft and Surface Area of 371.2 acres

Reservoir Storage Management: It is believed that storage levels in Dye Reservoir are not typically measured.

Reservoir Seepage Information: Seepage from Dye Reservoir is not routinely monitored. Seepage from the reservoir accrues mostly to the Dye Reservoir Outlet Canal.

The Dye Reservoir Outlet Canal is used to deliver water to the Arkansas River to be diverted by exchange at the Holbrook Canal for delivery to shareholders. The capacity of the outlet canal is unknown although the Filing Map for the Statement of Claim for Dye Reservoir noted an outlet capacity of 100 cfs.

HydroBase Data: A significant amount of historical end-of-month contents are missing in HydroBase (red line) over the 1986 to 2010 StateMod model study period. Storage contents data since 1980 are available for 1988, the late-1990s and portions of the early-1980s (see **Figure 4**). Missing data were not available from the Holbrook Canal Company or the SEO. Water commissioner notes indicate “No Water Available”, “Water Available / Not Taken” or “Not Used” over the 2003 through 2010 period. No storage contents data for Dye Reservoir are available during that period and are assumed to be zero.

Missing storage contents (blue line) were estimated based on the review of data discussed above for estimating missing Holbrook Reservoir contents. The estimation of missing storage contents focused on development a “best fit” to make the various model input data consistent. Water year 1992 values in excess of the estimated storage capacity of 2,500 acre-feet correlate with Holbrook Canal diversions and are presumed to be related to unknown conditions, which may include water levels near the reservoir spillway and ditch losses greater than estimated.

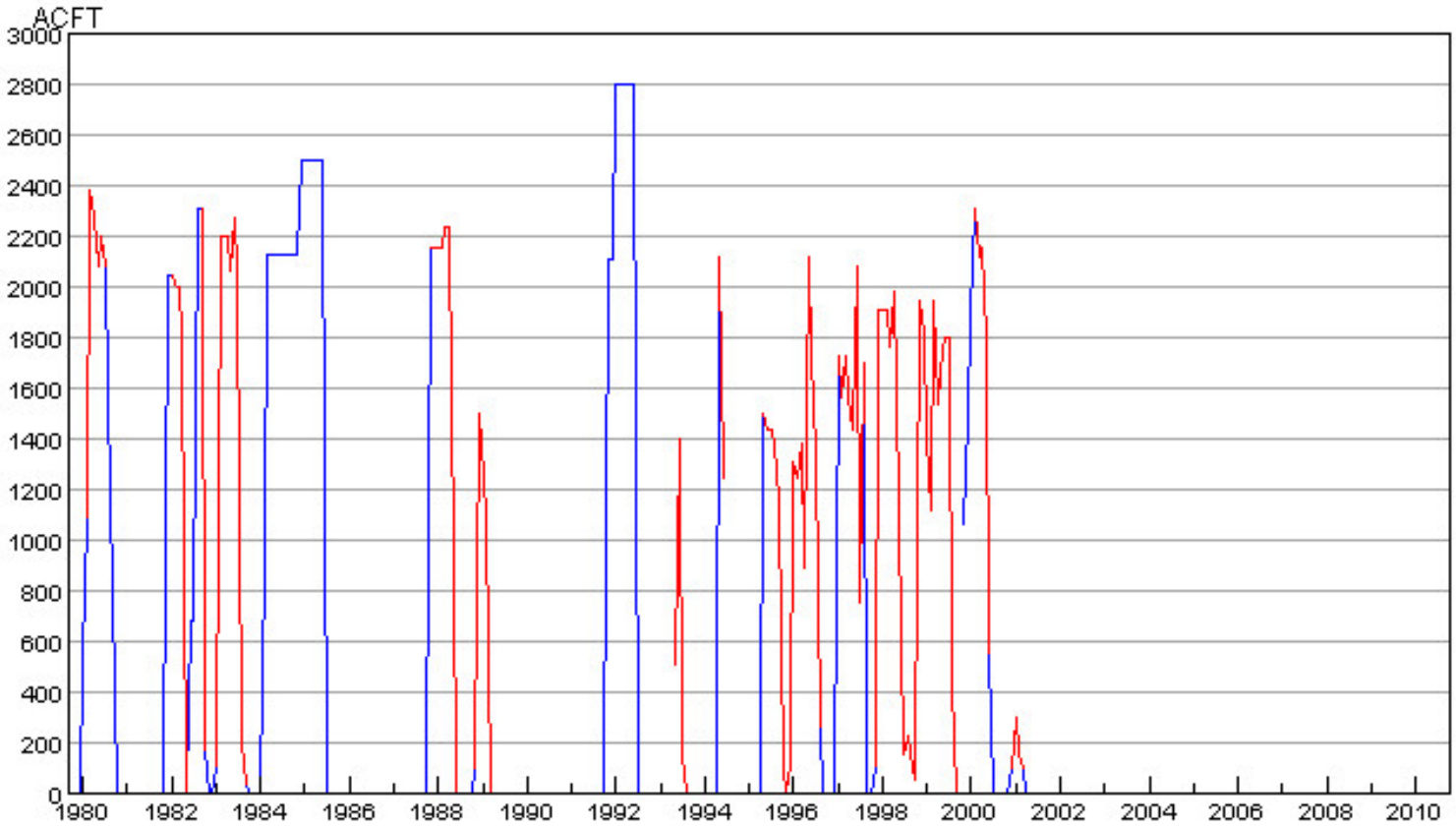

Figure 4: Dye Reservoir Storage Contents

WATER RIGHTS

Direct Flow Rights

The Holbrook Canal Diversion System has a total decreed flow rate of 600 cfs for irrigation uses, as summarized in **Table 5**. Also listed in Table 5 is the filling rates for the Holbrook Reservoir and Dye Reservoir storage decrees (see Table 6).

Table 5
Direct Flow Rights – Holbrook Canal Company

Structure	Appropriation Date	Adjudication Date	Admin. No.	Decreed Amount (cfs)	Case No.	Notes
Holbrook Canal	9/25/1889	4/8/1905	14513.0	155	4/8/1905	Irrigation Use
	8/30/1893		15948.0	445		
			Total	600		
	10/10/1903	2/3/1927	19640.0	595	2/3/1927	Exchange from Dye Reservoir
	9/15/1909		21807.0	230		Exchange from Holbrook Reservoir
	3/2/1892	4/8/1905	15402.0	600	4/8/1905	Storage in Holbrook Reservoir
	10/10/1903	2/3/1927	20186.19640	600	2/3/1927	Storage in Dye Reservoir
	9/3/1909		21795.0	400		Storage in Dye Reservoir
	9/15/1909		21807.0	600		Storage in Holbrook Reservoir

Source: Colorado Water Rights Tabulation.

Storage Rights

The storage rights associated with Holbrook Reservoir and Dye Reservoir are summarized in **Table 6**.

Holbrook Reservoir has undergone one enlargement from its initial decreed capacity of 4,247.06 ac-ft; the enlargement increased the decreed storage capacity by 3,196 ac-ft, of which 2,000 ac-ft was transferred to Dye Reservoir. In addition, 2,000 ac-ft of the senior storage right in Dye Reservoir was transferred to Holbrook Reservoir, bringing Holbrook Reservoir to its current decreed capacity of 7,443.06 acre-feet.

Dye Reservoir had an initial decreed capacity of 4,500 ac-ft, of which 2,000 ac-ft was transferred to Holbrook Reservoir. Dye Reservoir has undergone one enlargement from its original decreed capacity; the enlargement increased the decreed storage capacity by 3,486 ac-ft. In addition, 2,000 ac-ft of the second storage right in Holbrook Reservoir was transferred to Dye Reservoir, bringing Dye Reservoir to its current decreed capacity of 7,986 acre-feet.

Table 6
Storage Rights – Holbrook Canal Company

Storage Unit	Appropriation Date	Adjudication Date	Admin. No.	Decreed Amount (ac-ft)	Case No.	Notes
Holbrook Reservoir	3/2/1892	4/8/1905	15402.0	4,247.06	4/8/1905	
	10/10/1903	2/3/1927	20186.19640	2,000	W-3905	Transferred from Dye Reservoir
	9/15/1909		21807.0	1,196	2/3/1927	Portion of original 3,396 ac-ft right transferred to Dye Reservoir
			Total	7,443.06		
Dye Reservoir	10/10/1903	2/3/1927	20186.19640	2,500	2/3/1927	Portion of original 4,500 ac-ft right transferred to Holbrook Reservoir
	9/3/1909		21795.0	3,486		
	9/15/1909		21807.0	2,000	W-3905	Transferred from Holbrook Reservoir
			Total	7,986		

Source: Colorado Water Rights Tabulation

Administration

Administration of the water rights associated with the Holbrook Canal Company involves interaction with the Commissioner for Water Districts 17 and 67 and the Division 2 Engineer. The Superintendent of the canal company is more often in contact with these individuals during periods of storage and during periods when direct flow calls have been placed downstream on the Arkansas River.

OPERATIONAL INFORMATION

The general operating strategy for the Holbrook Canal and Reservoir System in a typical year is as follows:

Non-Irrigation Season

Once the irrigation season has finished, Holbrook Canal Company flows are focused on its Winter Water. The canal company's pro-rata share amounts to 38.16 percent of the first 100,000 ac-ft of Winter Water and a similar percentage of amounts stored beyond 103,106 ac-ft. The Holbrook Canal Company is also entitled to 356 ac-ft of the first 3,106 ac-ft of Winter Water accounted for above 100,000 ac-ft. As noted above, these supplies were historically stored under the Holbrook Storage Canal but the canal company has stored its pro-rata share in Lake Meredith for the last 8 to 10 years.

The Holbrook Canal Company entered into an operating agreement with the City of Aurora in 2006 that has prompted storage of the Holbrook Winter Water in Pueblo Reservoir. Under the agreement, Aurora may request the City's transferable yield in the Rocky Ford Ditch be stored in Holbrook Reservoir. In the winters before the years that operation is anticipated to occur, the Holbrook Canal Company will store its Winter Water in Pueblo Reservoir and then book that water over to the City of Aurora for a like amount of Rocky Ford Ditch consumptive use credits

stored in Holbrook Reservoir. This has apparently occurred a few times in recent years and may occur into the future, depending on various circumstances.

Irrigation Season

The Holbrook Canal has a relatively junior direct flow right that is typically only in priority to divert during spring runoff and later in the summer in above average and wet years.

The Holbrook Canal Company generally takes delivery of its Winter Water in Lake Meredith early in the irrigation season since its water will be booked out if the Lake Henry or Lake Meredith storage rights come into priority during the spring runoff. Water stored in Lake Meredith can be released to the river via the Meredith Outlet Canal and re-diverted at the Holbrook Canal headgate. Alternately, water released from Lake Meredith can be picked up in the Holbrook Canal prior to Meredith Outlet Canal releases reaching the Arkansas River. These releases from Lake Meredith are then typically stored in Holbrook Reservoir and later released to the Holbrook Canal.

Historically, irrigators under the ditch benefitted from river diversions to storage or Winter Water stored in Holbrook Reservoir and Dye Reservoir and took late-season delivery of water from storage. Fry-Ark Project water released from Pueblo Reservoir is also diverted into the Holbrook Canal later in the season.

Although the sequence of delivery each year varies based on hydrologic conditions, ditch operational issues and locations of storage of its Winter Water and other supplies, a general order of operations for water supplies into the Holbrook Canal is as follows:

1. Direct Flow Water
2. Winter Water from Lake Meredith
3. Winter Water and Storage Rights from Holbrook Reservoir and Dye Reservoir
4. Fry-Ark Project Water from Pueblo Reservoir

REFERENCES

1) Bill Tyner, Division 2 Assistant Engineer. 719.542.3368 x2010.
2) Lonnie Spady, District 17 and 67 Commissioner. 719.250.1655.
3) Bob Barnhart, Superintendent Holbrook Canal Company. 719.469.1225.
4) Tom Simpson. Senior Water Resources Engineer. City of Aurora Lower Arkansas Valley team. 719.254.7984.
5) HydroBase Database. State of Colorado official water resources database developed under the Colorado Decision Support System.
6) State Engineer's Office. Straightline Diagrams and Maps and Filing Statements.
7) Abbott, P.O., Description of Water-Systems Operations in the Arkansas River Basin, Colorado, USGS Water Resources Investigations Report 85-4092, Lakewood, Colorado, 1985.
8) Aqua Engineering, Inc. Super Ditch Rotational Fallowing – Water Leasing Program Report. Prepared for the Lower Arkansas Valley Super Ditch Company as part of Task C of a

Colorado Water Conservation Board Water Supply Reserve Account Grant. December 30, 2010 (Revised).

LAVWCD Memorandum
Final

To: Jay Winner

From: Rick Parsons

Subject: Lower Arkansas Valley Water Conservancy District, Super Ditch Engineering
Task 1 – Fort Lyon Canal Operations

Date: July 10, 2014

INTRODUCTION

Some of the Task 1 objectives are to:

> *Review and document an understanding of the operations of key water use facilities in the basin in order to facilitate surface water modeling and to support analysis of reservoir operations as part of an alternative to agricultural transfer program. Gathering and review of available data, including comparison to input data and variables from other modeling efforts will be used to develop complete input data sets for the StateMod model representation of the Lower Arkansas River basin. This understanding will be developed through interviews with Division 2 personnel, operators of large canal and reservoir systems, and representatives of federal facilities.*

The key reservoir systems identified in Task 1 of the Lower Arkansas Valley Water Conservancy District (LAVWCD) Super Ditch Engineering include:

- Colorado Canal System – Lake Meredith and Lake Henry
- Holbrook Canal System – Holbrook Reservoir and Dye Reservoir
- Fort Lyon Canal System – Adobe Creek Reservoir, Horse Creek Reservoir and Great Plains Reservoirs
- John Martin Reservoir
- Pueblo Reservoir (addressed in Task 2)

Adobe Creek Reservoir (aka Blue Lake) and Horse Creek Reservoir (aka Timber Lake), under the Fort Lyon Storage Canal system along with the Great Plains Reservoirs under the Fort Lyon Canal System have been identified as key structures for the potential lease-fallowing operations in the Lower Arkansas Valley. The purpose of this Task 1 memorandum is to document physical, legal, and operational aspects of these structures and to develop complete input data sets for use in the StateMod modeling effort.

The information provided in this memorandum was developed from publicly accessible sources, discussions with Division 2 personnel, DWR Modeling Group personnel and meetings with past Canal Company Superintendent Manny Torrez, Canal Company engineer Tom Williamsen and the Fort Lyon Canal

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Company Board. A draft of this memorandum was provided to the Division 2 office, DWR Modeling Group and Mr. Williamsen for review. Mr. Williamsen provided comments on the draft memorandum at a subsequent meeting.

Information in this memorandum is believed to be accurate. However, the information should not be relied upon in any legal proceeding.

SYSTEM OVERVIEW

The Fort Lyon Canal, Fort Lyon Storage Canal, Adobe Creek Reservoir, Horse Creek Reservoir and Thurston Reservoir are owned by the Fort Lyon Canal Company. These canals and reservoirs are operated together to provide irrigation supplies to lands in Otero, Bent and Prowers Counties. The Great Plains Reservoirs are owned by the Amity Mutual Irrigation Company and operated in cooperation with the Fort Lyon Canal Company.

The Fort Lyon Canal headgate is located on the Arkansas River between Swink, Colorado and La Junta, Colorado. The canal runs along the north bank of the Arkansas River for approximately 110 miles from above to below John Martin Reservoir.

The Fort Lyon Storage Canal headgate is located on the Arkansas River approximately three miles east of Manzanola, CO and 14 miles above the Fort Lyon Canal headgate. The storage canal runs along the north bank of the Arkansas River and turns north near Rocky Ford, CO. Water is carried up-gradient from the Holbrook Canal system and over Horse Creek before reaching Horse Creek Reservoir and ultimately Adobe Creek Reservoir. These reservoirs are located up-gradient from the Fort Lyon Canal and can deliver water via gravity for irrigation under the canal system.

In addition to providing water for direct irrigation, the Fort Lyon Canal is able to deliver storage diversions through the Kickingbird Canal to the Great Plains Reservoirs (Nee So Pah Reservoir, Nee Gronda Reservoir, Nee No She Reservoir and Nee Skah Reservoir, aka Queens Reservoir).

Although important to wildlife habitat, the Great Plains system has generally been dry since the early-2000s. A combination of high canal losses and high evaporation losses from the relatively shallow reservoirs make filling and keeping the reservoirs full problematic. In addition, the decree adjudicated in Case No. 80CW19 allows the Amity Mutual Irrigation Company to store water attributable to the Great Plains Reservoirs' storage rights in John Martin Reservoir, which has been practiced consistently since the early-1990s.

Approximately 93,000 acres are irrigated under the Fort Lyon Canal and reservoir systems. Direct flow and storage water is delivered to shareholders on a rotational basis to each of five divisions: La Junta and Horse Creek, located upstream of John Martin Reservoir, Las Animas to the north of the reservoir and Limestone and Lamar divisions, located downstream of John Martin Reservoir.

Key facilities identified in the Fort Lyon Canal and Reservoir System are as follows. Also listed below are ditches and reservoirs which are outside of the Fort Lyon Canal and Reservoir System, but are essential to system operation.

1) Fort Lyon Canal
2) Fort Lyon Storage Canal
3) Adobe Creek Reservoir
4) Horse Creek Reservoir
5) Queens Reservoir
6) Pueblo Reservoir
7) Lake Meredith and Meredith Outlet Canal
8) John Martin Reservoir

The contact information for the Fort Lyon Canal Company is:

Manny Torrez, Superintendent (retired)
750 Bent Avenue
Las Animas, Colorado
719.456.0720

The general locations of the Fort Lyon Canal, Fort Lyon Storage Canal, Adobe Creek Reservoir Horse Creek Reservoir and Great Plains Reservoir system and associated structures are shown on **Figure 1**. Irrigated parcels outlined in the figure are from the State of Colorado's Decision Support System (CDSS) 2003 GIS coverage.

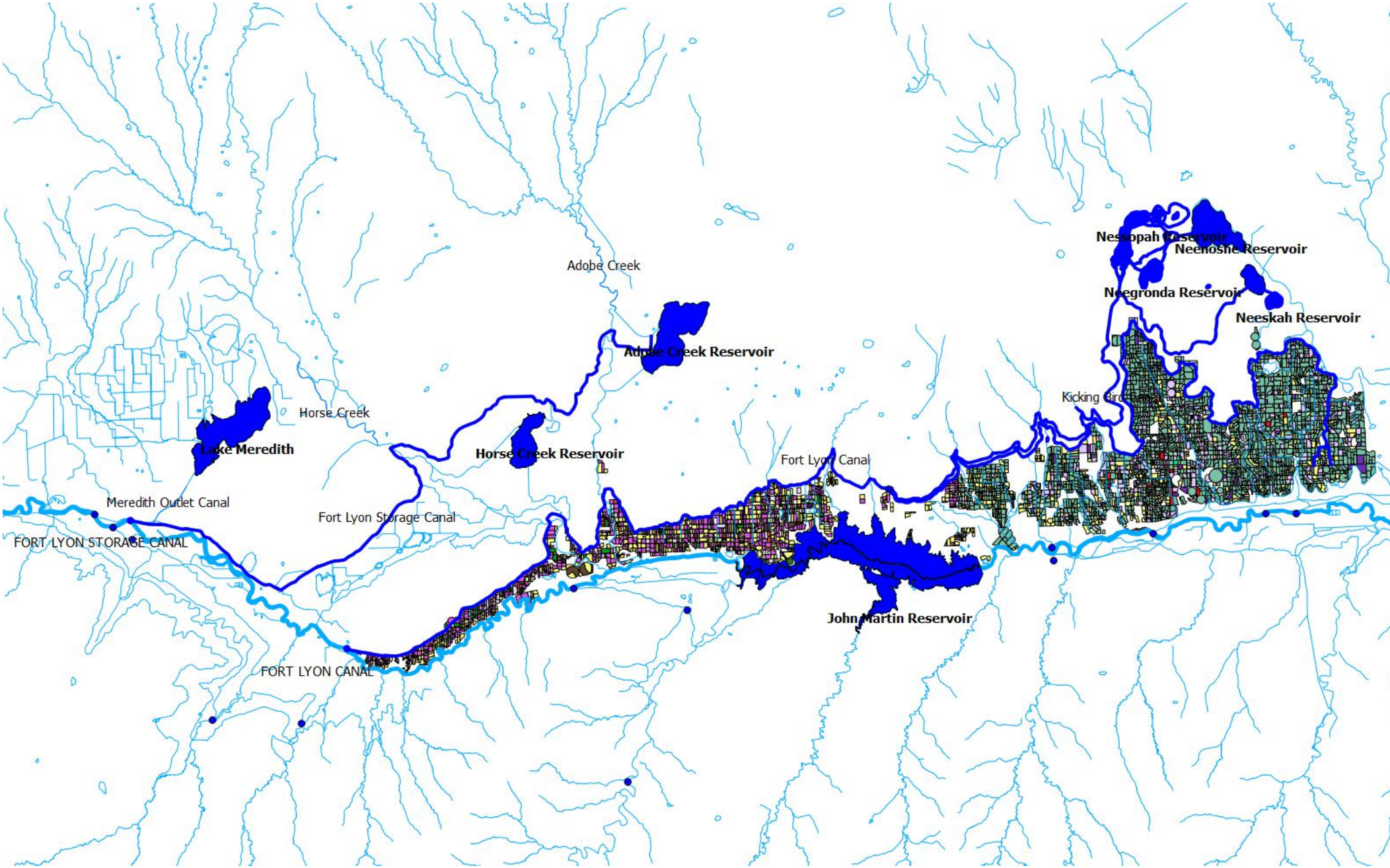

Figure 1: Fort Lyon Canal and Fort Lyon Storage Canal Systems

PHYSICAL INFORMATION

Infrastructure information related to the ditch headgate, ditch layout, reservoirs, and associated elements of the system are summarized below. The primary source for this information is the water resources data and GIS coverages available on the State of Colorado Decision Support System website (http://cdss.state.co.us/Pages/CDSSHome.aspx). These data were supplemented by the engineering report to support Colorado Beef's change of Fort Lyon shares in Case No. 08CW83

Sources of data and inputs from other basin models are also included. These data come predominantly from the Hydrological-Institutional (H-I) Model. A basin model was previously developed to support the Colorado Springs Utilities Southern Delivery System Environmental Impact Statement (EIS) analysis. This model is also being used for the Arkansas Valley Conduit EIS. Documentation summarizing the EIS models indicates the operations of the Fort Lyon Canal off-channel system is explicitly represented in detail in the models. The data from these models were not made available for this effort.

1) Fort Lyon Canal (Structure ID 1700553)

The Fort Lyon Canal runs along the north side of the Arkansas River generally parallel to the river. The Kickingbird Canal leaves the main canal near the midpoint of John Martin Reservoir and both canals turn north from the river near Hasty. Approximately two-thirds of the irrigated land is located below John Martin Reservoir in the Limestone and Lamar Divisions.

Length: The length of the Fort Lyon Canal is approximately 110 miles. The Kickingbird Canal bifurcation is located approximately 42 miles down the Fort Lyon Canal from where it travels approximately 37 miles to the Great Plains Reservoir System. The H-I Model lists a ditch length of 54 miles for the Fort Lyon Canal.

Capacity: The capacity of the Fort Lyon Canal is approximately 1,800 cfs. Review of daily records from 1911 to 2012 indicates a maximum diversion of 1,919 cfs was diverted past the Fort Lyon Canal recorder on June 29, 1983.

Conveyance Efficiency: Fort Lyon Canal Company personnel indicate ditch losses average approximately 38 percent to the ditch lateral turnouts in the Fort Lyon Canal system. Conveyance loss to the Kickingbird Canal bifurcation is estimated at 25 percent based on information outlined in the storage right decrees for the Great Plains Reservoirs that were transferred to John Martin Reservoir (Case No. 80CW19). Fort Lyon Canal Company personnel indicated water conveyed down the Kickingbird Canal experience an additional 20 to 30 percent of ditch loss. The H-I Model uses a ditch loss of 36.7 percent for the Fort Lyon Canal.

Irrigated Acreage and Crop Types: GIS coverages from the CDSS list approximately 92,191 acres under the Fort Lyon Canal in 2003. Approximately 23 percent of the acreage is identified as fallow in the 2003 GIS coverage, as summarized below in **Table 1**. The two primary crops that are irrigated under the Fort Lyon Canal are Alfalfa and Grass Pasture.

Table 1
Fort Lyon Canal 2003 Acreage

Crop	Acres	Crop	Acres
Alfalfa	54,261	Cereals	1,855
Corn Silage	658	Vegetables	65
Grass Pasture	12,555	Wheat	1,810
Fallow	20,987	Total	92,191

Source: http://cdss.state.co.us/GIS/Pages/Division2Arkansas.aspx.

The Division 2 office maintains more detailed coverages of total acreage, field verifications of dry up acreage, well associations, augmentation plan assignments, etc. This information may be helpful in analysis of system operations and subsequent studies.

Ground Water Use: GIS estimates for the 2003 irrigated lands coverage indicate approximately 11,000 acres total (9%) are supplied by supplemental wells.

Return Flow Locations: Return flows from the ditch system accrue to John Martin Reservoir and to the Arkansas River below the confluence with Big Sandy Creek and above the X-Y Graham Canal headgate.

Return flows in the StateMod model are differentiated for the ditch losses and farm losses, as shown in **Table 2**. The spatial distribution of canal losses is based on approximate ditch lengths in relation to locations of gages, reservoirs and ditch headgates included in the model network. The spatial distribution of irrigation return flows is based on the layout of the 2003 GIS acreage, with slight modifications to improve model simulation output (see Task 4 – Model Operations memorandum).

Table 2
Fort Lyon Canal
StateMod Model Return Flow Locations

Model Node	Structure ID	Canal Loss Return Percentage	Irrigated Lands Return Percentage
Arkansas River at La Junta gage	07123000	3%	---
Las Animas Consolidated	1700556	9%	5%
Horse Ck nr Hwy 194 gage	HRC194CO	3%	---
Arkansas River at Las Animas gage	07124000	13%	9%
John Martin Reservoir	1703512	17%	14%
Fort Bent Canal	6700610	9%	7%
Amity Canal	6700607	8%	11%
Lamar Canal	6700614	21%	28%
Arkansas River at Lamar gage	07133000	3%	6%
X-Y Graham Canal	6700617	14%	20%
TOTAL		100%	100%

HydroBase Data:

Fort Lyon Canal – Diversion data are available in HydroBase from the early-1910s to present. Total daily diversions (see **Figure 2** for data since 1980) and diversions to irrigation (Use 1) are complete over the 1986 to 2010 StateMod model study period. Diversions from storage (Source 2) are available sporadically for John Martin Reservoir (1990-1994, 1996-1997, 2002, 2004-2006, 2008 and 2010) and Adobe Creek Reservoir (1996, 2006 and 2008). Winter Water deliveries are recorded from Pueblo Reservoir (1980-1981 and 2003-2006) and Adobe Creek Reservoir (1990, 1993, 2003-2005 and 2008-2009). Fry-Ark Project deliveries are recorded for 1980-1982, 1984, 1988-1994, 1996 and 1998-2010.

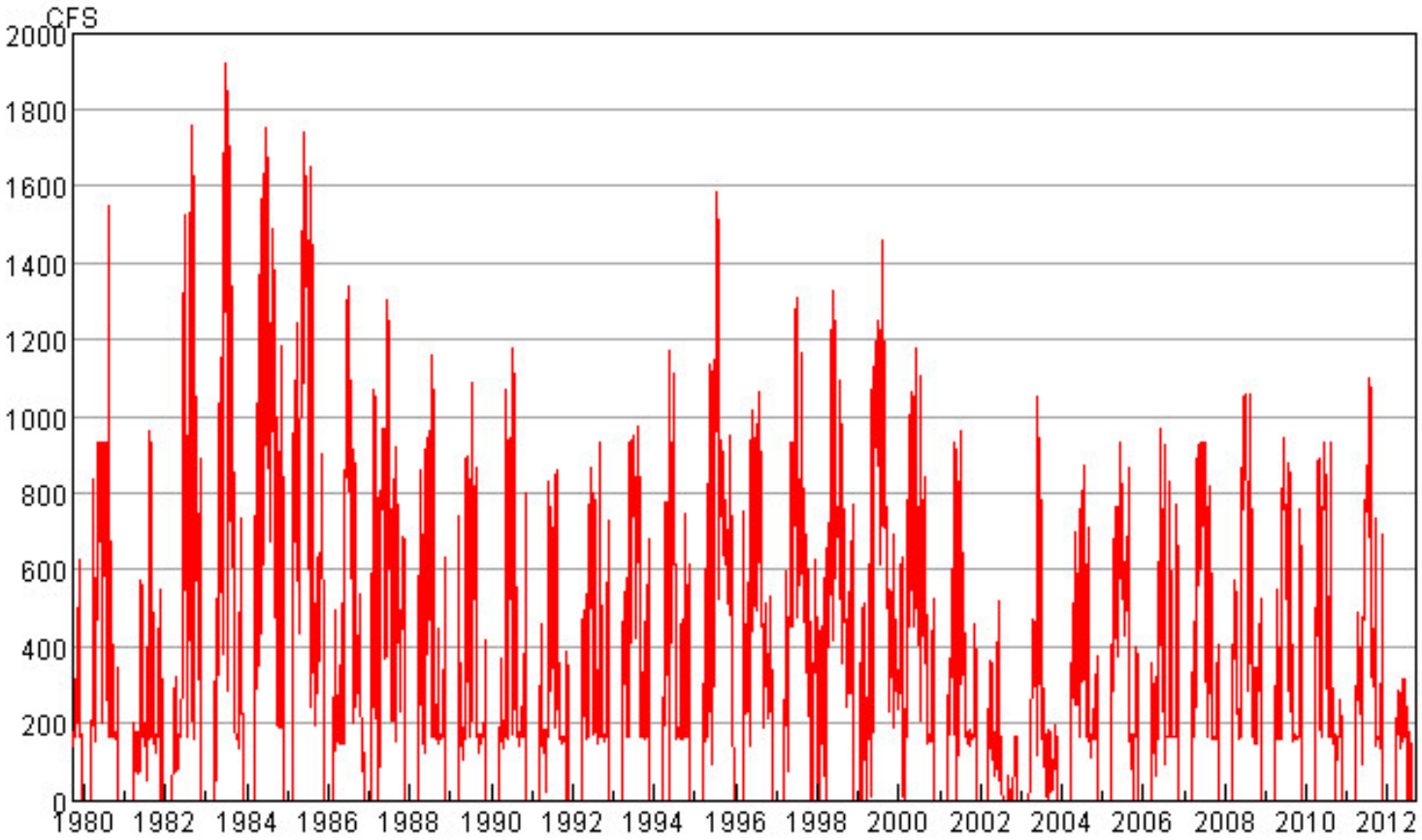

Figure 2: Fort Lyon Canal River Headgate Diversions

Kickingbird Canal – Diversion data are sporadically available in HydroBase from 1970 to present. These data are presumed to be recorded at the bifurcation, after the estimated 25 percent ditch loss down the Fort Lyon Canal (see red line in **Figure 3** for data since 1980). Water commissioner notes indicate Kickingbird Canal was "Not Used" during the 2001 through 2007 and 2009 – 2010 periods, which corresponds with the zeroes during those periods in Figure 3. These comments also correspond with the reduction in available storage contents for the Great Plains Reservoirs (see **Figure 7**).

Missing data in the late-1980s and early-1990s for the Kickingbird Canal were set to zero since Fort Lyon Canal diversions in HydroBase are equal to the estimated Fort Lyon Canal diversions from the H-I Model. Great Plains Reservoir contents data are not available during this period and these estimates should perhaps be re-visited in subsequent modeling efforts.

Kickingbird Canal diversions for the early-1980s were estimated to provide some coordination with the available storage contents in the Great Plains Reservoirs during that period. The data during this period (blue line in Figure 3) were filled based on a review of various data sources, including Fort Lyon Canal river headgate diversions from HydroBase and. These estimates were assigned ditch losses of 25% to arrive at a measurement at the Kickingbird Canal bifurcation and then compared to the total Fort Lyon Canal river diversion to ensure the data are consistent.

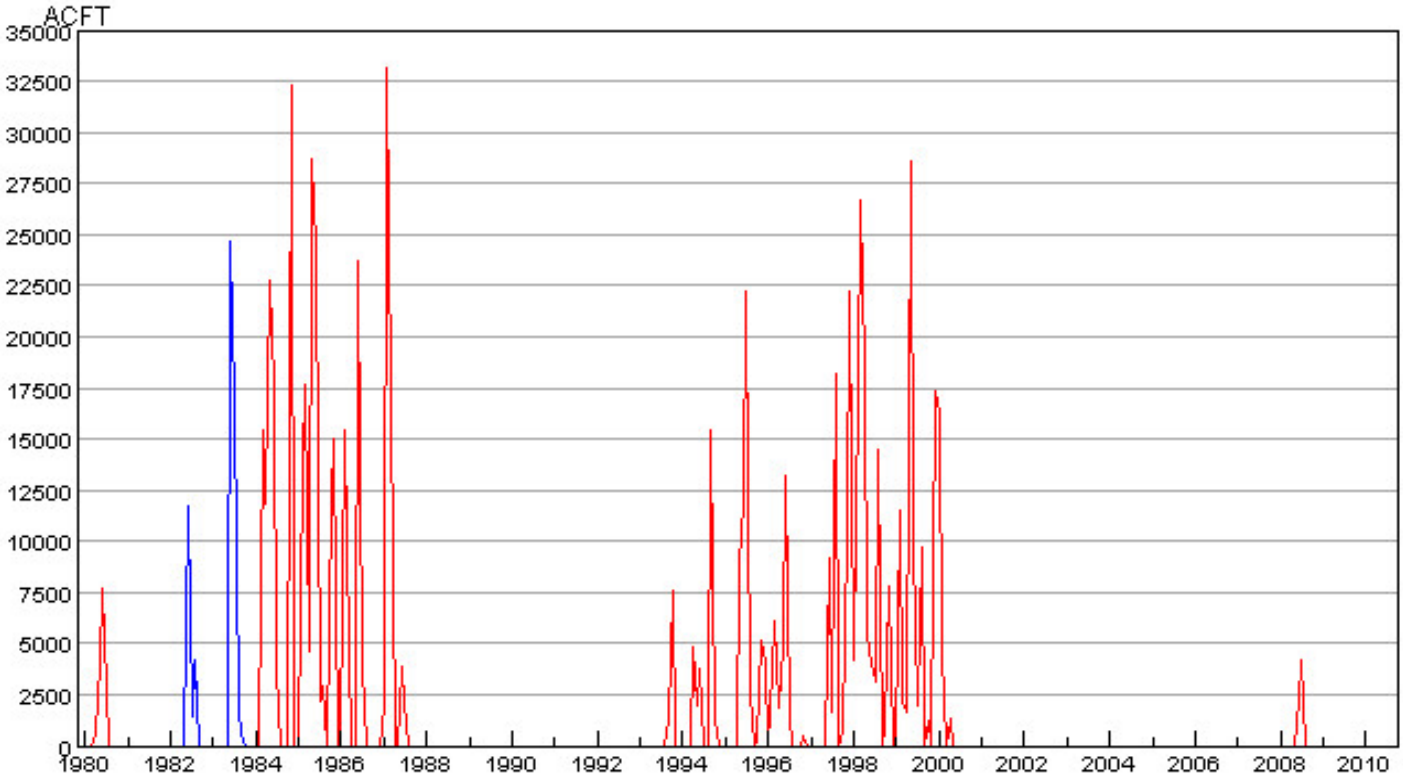

Figure 3: Kickingbird Canal Diversions

2) Fort Lyon Storage Canal (Structure ID 1700648)

The Fort Lyon Storage Canal runs along the north side of the Arkansas River generally parallel to the river east of Rocky Ford. The Storage Canal turns north from the river and travels over Horse Creek en route to Horse Creek Reservoir before terminating in Adobe Creek Reservoir.

Length: The length of the Fort Lyon Storage Canal is approximately 46 miles to Adobe Creek Reservoir. The H-I Model lists a ditch length of 26 miles for the Fort Lyon Storage Canal.

Capacity: The capacity of the Fort Lyon Storage Canal is approximately 1,500 cfs. Review of daily records from 1913 to 2012 indicates a number of diversions on the order of 1,800 cfs prior to 1958, up to a maximum diversion of 3,540 cfs on September 7, 1920.

Conveyance Efficiency: Estimates of seepage and evaporation losses from the Fort Lyon Storage Canal vary widely. Fort Lyon Canal Company personnel indicate ditch losses to Adobe Creek Reservoir are approximately 50 percent. The H-I Model uses a ditch loss of 19.8 percent for the Fort Lyon Storage Canal.

Return Flow Locations: Return flows from the canal system accrue to the Arkansas River above John Martin Reservoir, including losses to Horse Creek and losses tributary to Adobe Creek Reservoir.

Return flows in the StateMod model are shown in **Table 3**. The spatial distribution of canal losses is based on approximate ditch lengths in relation to locations of gages, reservoirs and ditch headgates included in the model network.

Table 3
Fort Lyon Storage Canal
StateMod Model Return Flow Locations

Model Node	Structure ID	Canal Loss Return Percentage
Arkansas River near Rocky Ford gage	ARKROCCO	12.5%
Fort Lyon Canal	1700553	12.5%
Holbrook Irrigators	1700554_I	25%
Horse Ck nr Hwy 194 gage	HRC194CO	25%
Fort Lyon Irrigators	170553_I	25%
TOTAL		100%

HydroBase Data: Diversion data are available in HydroBase from the early-1910s to present. Total diversions are complete over the 1986 to 2010 StateMod model study period (see **Figure 4** for data starting in 1980). Water commissioner notes indicate "Diversions Taken in Another Structure" during the 2003 through 2005 period, the location of which has not been identified.

Monthly diversions to storage from other sources are available sporadically for water from Lake Meredith (1983, 1993-1994, 1996, 2007 and 2009-2010; including separate entries for Lake Meredith Winter Water in 2007 and 2010) and Pueblo Reservoir (Winter Water 1982-1983 and Fry Ark Water 1988-1992 and 1998).

Note the Storage Canal diversion data and storage contents for Horse Creek Reservoir and Adobe Creek Reservoir are not always consistent. A number of months of input data were changed among the coordinated facilities during model calibration to make the various model input data consistent (see Task 4 – Model Operations memorandum).

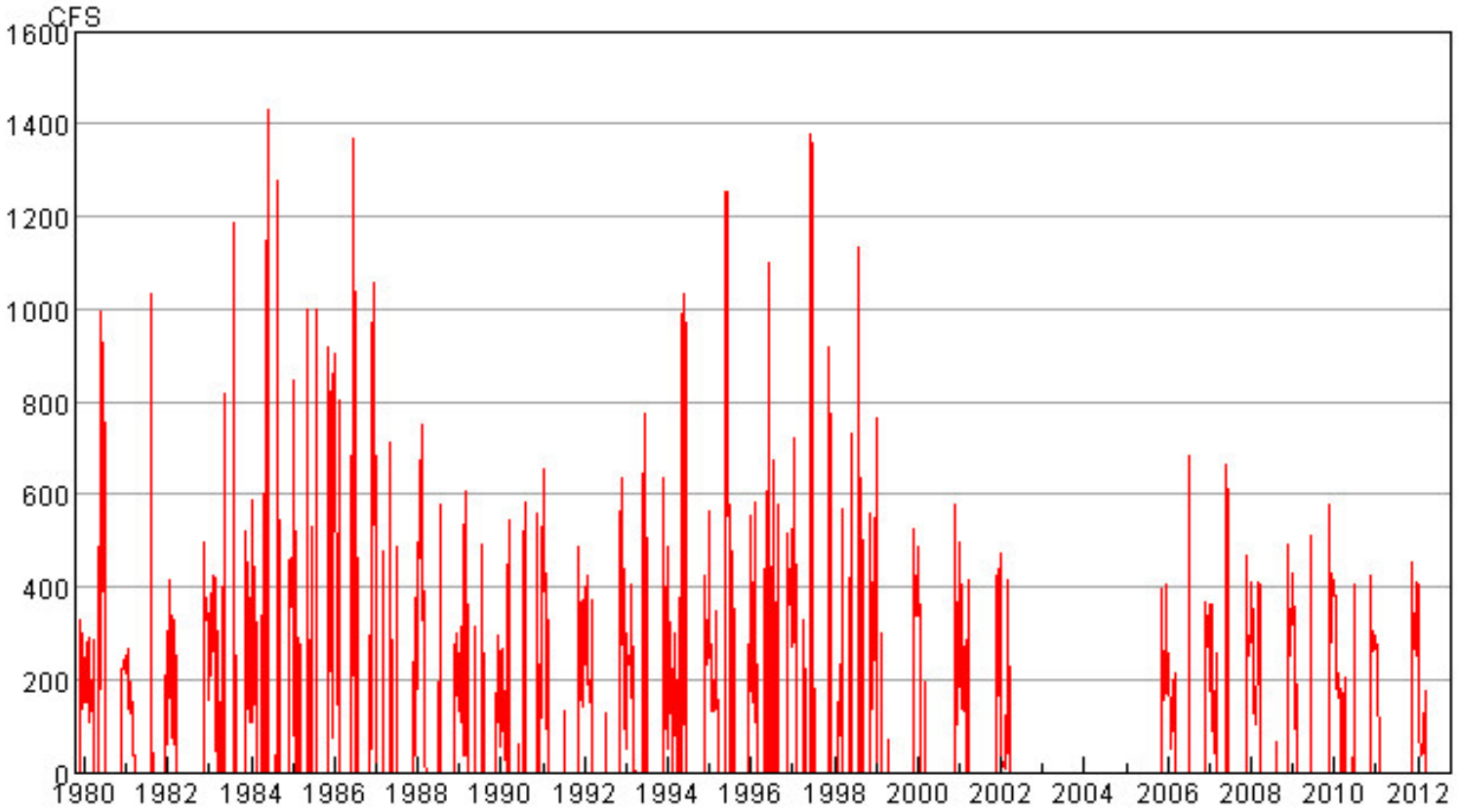

Figure 4: Fort Lyon Storage Canal River Headgate Diversions

3) Adobe Creek Reservoir (Structure ID 1703546)

Adobe Creek Reservoir is filled by the Fort Lyon Storage Canal. Water stored under the Adobe Creek Reservoir storage rights is available to Fort Lyon Canal Company shareholders. Releases from Adobe Creek Reservoir are delivered to the Horse Creek, Las Animas, Limestone and Lamar Divisions.

Inflows from Adobe Creek via the Adobe Creek Inlet Canal are minimal, outside of occasional high precipitation events.

In addition to storing the reservoir storage water right, Adobe Creek Reservoir is one of the off-channel reservoirs in the Winter Water storage program (see Task 3 – Winter Water Storage Program memorandum).

Capacity:

- Total Storage: 71,440 ac-ft, based on maximum storage contents in HydroBase
- Active Storage: 71,440 ac-ft

- Dead Storage: Unknown
- Area/Capacity Data: The area/capacity data in **Table 4** were obtained from Sheet 3 of the Supplementary Map and Statement of Claim of Adobe Creek Reservoir (approved by State Engineer 3/1/1910). The Canal Company provided a survey for the reservoir developed in 2005. Since 2005 the storage contents data measured by the transducer in the reservoir are slightly higher than the records – the latter assumedly based on the "older" survey. The older survey is used in the StateMod model since it was used during the majority of the StateMod model study period.

Table 4
Adobe Creek Reservoir Elevation – Area – Capacity

Gage Height (ft)	Surface Area (acres)	Cumulative Capacity (ac-ft)
0	-	-
1	2,227	22,760
2	2,309	4,429
3	2,394	6,781
4	2,477	9,216
5	2,549	11,729
6	2,648	14,328
7	2,747	17,025
8	2,846	19,822
9	2,945	22,717
10	3,057	25,718
11	3,156	28,824
12	3,255	32,030
13	3,354	35,335
14	3,453	38,738
15	3,556	42,242
16	3,686	45,863
17	3,680	49,615
18	3,946	53,497
19	4,052	57,497
20	4,105	61,575
21	4,266	65,760
22	4,426	70,106
23	4,587	74,612
24	4,747	79,279
25	4,908	84,107
26	5,068	89,083
27	5,229	94,231

Reservoir Storage Management: Until the mid-2000s, storage levels in Adobe Creek Reservoir were measured using a staff gauge. For the last ten years or so water elevation measurements have been measured with a transducer.

Reservoir Seepage Information: Seepage from Adobe Creek Reservoir is not routinely monitored. Seepage from the reservoir accrues mostly to the Adobe Creek Reservoir Outlet Ditch.

The Adobe Creek Reservoir Outlet Canal is used to deliver water to Adobe Creek to be picked up by the Fort Lyon Canal for delivery to shareholders. The capacity of the outlet canal is unknown.

HydroBase Data: Historical storage contents data are mostly complete in HydroBase starting in water year 1988 (see red line in **Figure 5**). The Fort Lyon Canal Company provided a complete record of storage contents on a weekly basis for the January 1986 to present period (blue line). No diversions were made through the Fort Lyon Storage Canal during 2003 through 2005, which is consistent with the zero acre-foot storage contents provided for that period by the Canal Company. The Canal Company are generally consistent with the HydroBase data, with differences likely due to different days upon which staff gage readings were taken, minor differences in capacity estimates based on staff gage elevations, etc. As noted above, the post-2004 Canal Company data are greater than the HydroBase data.

The Canal Company data were chosen as the primary source of model input data since these data are more complete. The change in storage contents for Adobe Creek Reservoir and Horse Creek Reservoir were used with the Fort Lyon Canal diversion data to estimate total water supply for irrigation use. Some of the river headgate diversion data (total diversions and diversions to storage) and the storage contents and monthly release data for Adobe Creek Reservoir and Horse Creek Reservoir from the Fort Lyon Canal Company annual reports are not consistent. Therefore, some of the colors of water at the Fort Lyon Storage Canal river headgate were revised to develop a "best fit" to make the various model input data consistent.

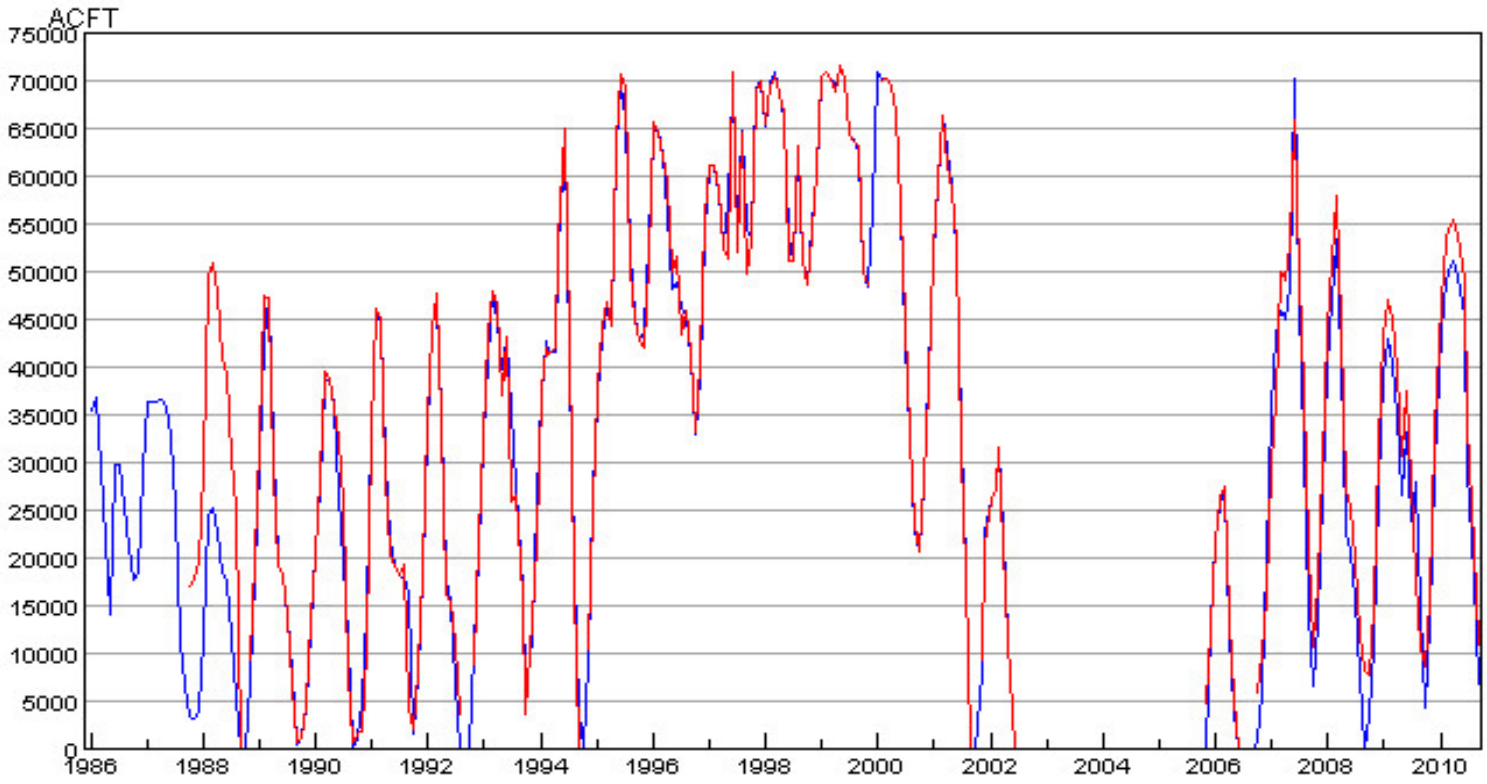

Figure 5: Adobe Creek Reservoir Storage Contents

4) Horse Creek Reservoir (Structure ID 1703546)

The Horse Creek Reservoir is filled by the Fort Lyon Storage Canal. Water stored under the Horse Creek Reservoir storage rights is available to Fort Lyon Canal Company shareholders. Releases from Horse Creek Reservoir are delivered to the Horse Creek, Las Animas, Limestone and Lamar Divisions.

Inflows from Horse Creek via the Horse Creek Supply Ditch are minimal, outside of occasional high precipitation events.

In addition to storing the reservoir storage water right, Horse Creek Reservoir is one of the off-channel reservoirs in the Winter Water storage program (see Task 3 – Winter Water Storage Program memorandum).

Capacity:

- Total Storage: 28,062 ac-ft, based on maximum storage contents in HydroBase
- Active Storage: 28,062 ac-ft
- Dead Storage: Unknown
- Area/Capacity Data: The area/capacity data in **Table 5** were obtained from The Amended Map of Horse Creek Reservoir (accepted by State Engineer 12/20/1907). The Canal Company provided a survey for the reservoir developed in 2005 but this survey has not been used during the latter years of the StateMod model study period as the reservoir has been empty during that period (2001 through 2010).

Table 5
Horse Creek Reservoir Elevation – Area – Capacity

Gage Height (ft)	Surface Area (acres)	Cumulative Capacity (ac-ft)
0	401	0
1	472	873
2	548	1,383
3	623	1,968
4	696	2,628
5	779	3,367
6	871	4,192
7	966	5,111
8	1,060	6,123
9	1,157	7,232
10	1,252	8,437
11	1,370	9,748
12	1,487	11,176
13	1,606	12,722
14	1,728	14,389
15	1,849	16,178
16	1,969	18,086
17	2,090	20,070
18	2,211	22,220
19	2,333	24,492
20	2,456	26,886

Reservoir Storage Management: Until the mid-2000s, storage levels in Horse Creek Reservoir were measured using a staff gauge. For the last ten years or so water elevation measurements have been measured with a transducer.

Reservoir Seepage Information: Seepage from Horse Creek Reservoir is not routinely monitored. Seepage from the reservoir accrues mostly to the Horse Creek Reservoir Outlet Ditch.

The Horse Creek Reservoir Outlet Canal is used to deliver water to Horse Creek to be picked up by the Fort Lyon Canal for delivery to shareholders. The capacity of the outlet canal is unknown.

HydroBase Data: Historical storage contents data are mostly complete in HydroBase starting in water year 1988 (see red line in **Figure 6**). The Fort Lyon Canal Company provided a complete record of storage contents on a weekly basis for the April 1985 to present period (blue line). No diversions were made through the Fort Lyon Storage Canal during 2003 through 2005 and In addition, water commissioner notes for Horse Creek Reservoir indicate "No Water is Available" during the 2001 and 2003 through 2010 period. These instances are consistent with the zero acre-foot storage contents provided for that period by the Canal Company. The Canal Company are generally consistent with the HydroBase data, with differences likely due to different days upon which staff gage readings were taken, minor differences in capacity estimates based on staff gage elevations, etc. As noted above, the post-2004 Canal Company data are greater than the HydroBase data.

As noted in the discussion above regarding Adobe Creek Reservoir contents data, the Canal Company data for Horse Creek Reservoir were chosen as the primary source of model input data.

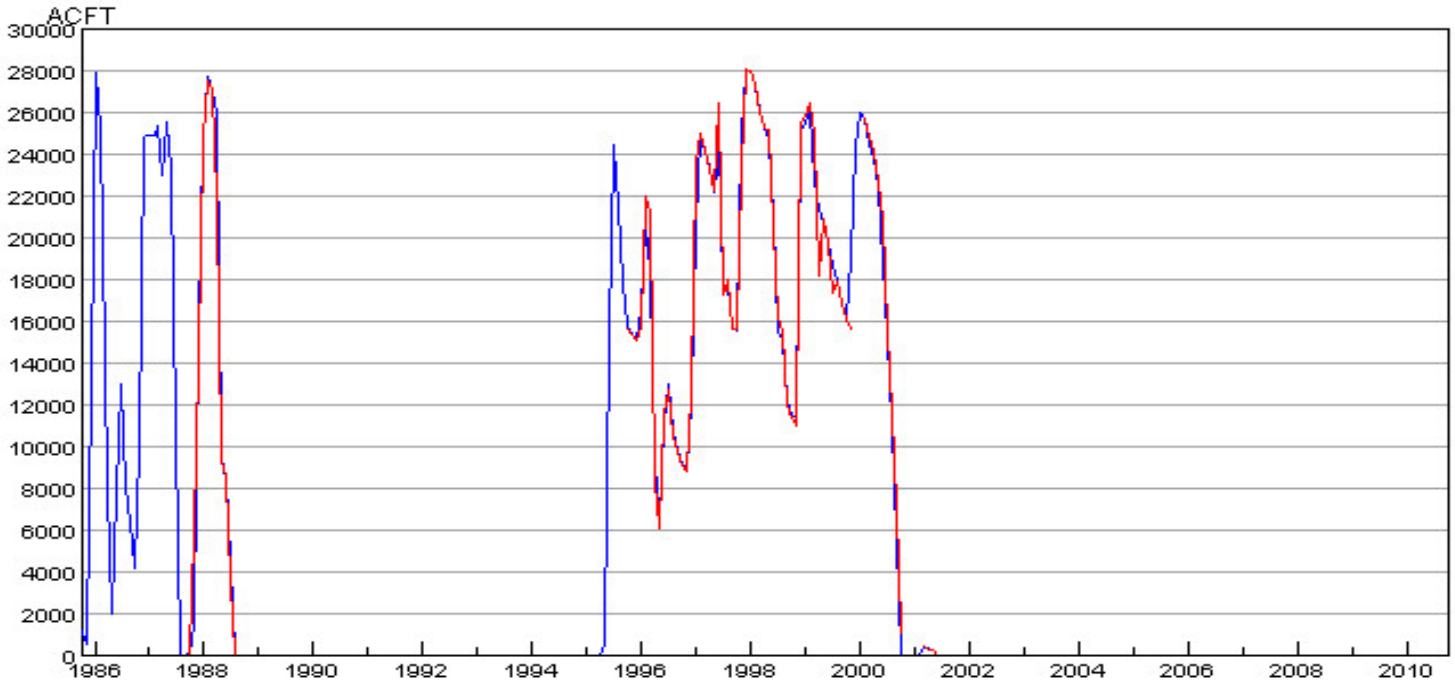

Figure 6: Horse Creek Reservoir Storage Contents

5) Queens Reservoir (Structure IDs 1703608 and 6703513)

Queens Reservoir (aka Nee Skah Reservoir) is filled by the Fort Lyon Storage Canal and Kickingbird Canal. Queens Reservoir is included here as the "key" storage unit in the Great Plains Reservoir system since it is the only one of the Great Plains Reservoirs identified in the Fort Lyon Canal Annual Reports. The other Great Plains Reservoirs – Black Water Reservoir (aka Nee So Pah Reservoir, Structure ID 1703605); Big Water Reservoir (aka Nee Gronda Reservoir, Structure ID 1703606); and Standing Water Reservoir (aka Nee No She Reservoir, Structure IDs 1703607 and 6703883) can also be filled via the Kickingbird Canal and can be operated in conjunction with Queens Reservoir.

Water stored under the Great Plains Reservoir storage rights is predominantly available to Amity Mutual Irrigation Company shareholders. In Civil Action 2158, the Fort Lyon Canal Company was granted preferential use of the first 5,483 ac-ft per year of Great Plains storage rights to compensate the company for use of its canals to convey water into the reservoirs. As noted above, use of the Great Plains Reservoirs is complicated by the significant amount of transit losses and evaporation involved in operations. Therefore, the Amity Mutual Irrigation Company entered into a decree (Case No. 80CW19) that adjudicated John Martin Reservoir as an alternate place of storage for the Great Plains Reservoir storage rights. The storage water is subject to the 1980 Operating Resolution and associated Revisions and Agreements. Under operation of the alternate place of storage, the Fort Lyon Canal Company has access to its preferential 5,483 ac-ft from the Amity Mutual Irrigation Company's accounts in John Martin Reservoir if the Fort Lyon Canal Company does not divert that water into Adobe Creek Reservoir during the winter.

Capacity:

- Total Storage: 35,890 ac-ft, based on maximum storage contents in HydroBase
- Active Storage: 35,890 ac-ft
- Dead Storage: Unknown
- Area/Capacity Data: No area/capacity data were located for Queens Reservoir. A two-point area-capacity curve in **Table 6**, assuming an average depth of 30 feet is input to the StateMod model.

Table 6
Queens Reservoir Elevation – Area – Capacity

Gage Height (ft)	Surface Area (acres)	Cumulative Capacity (ac-ft)
-	0	0
-	1,196	35,890

Reservoir Storage Management: The extent to which storage levels in Queens Reservoir and the other Great Plains Reservoirs are measured is unknown.

Reservoir Seepage Information: Seepage from Queens Reservoir and the other Great Plains Reservoirs is not routinely monitored.

Queens Reservoir has an outlet to the Pawnee Canal, which can deliver water to the Fort Lyon Canal or to the Amity Canal via the Comanche Canal. The other Great Plains

Reservoirs can deliver water to the Amity Canal via the Comanche Canal. The capacities of the outlet canals are unknown.

HydroBase Data: Historical end-of-month contents are available for the early-1980s and mid-1990s to late-2000s for the Great Plains Reservoirs (see **Figure 7**). Missing data were not available from SEO or the Fort Lyon Canal Company.

Preliminary review of the available data indicates the long-term records from Nee No She (blue line) and Queens Reservoir (green line) are additive, and the Great Plains Reservoir (red line – data for Structure ID 6703824) are the total contents after these two reservoir records cease.

Water commissioner notes indicate Kickingbird Canal was "Not Used" during the 2001 through 2007 and 2009 – 2010 periods. This corresponds with the steadily declining storage contents shown in Figure 7. No storage contents data for the Great Plains Reservoirs are available after August 2009 and are assumed to continue to decrease. The end-of-month contents over the 1986 through 2010 StateMod model study period were set to zero since a good amount of the Kickingbird Canal diversions were estimated and the available Great Plains Reservoir historical storage contents is limited. This approach is considered reasonable since the effects of model operations below John Martin Reservoir are not pivotal to the Super Ditch operations (see Task 4 – Model Operations memorandum).

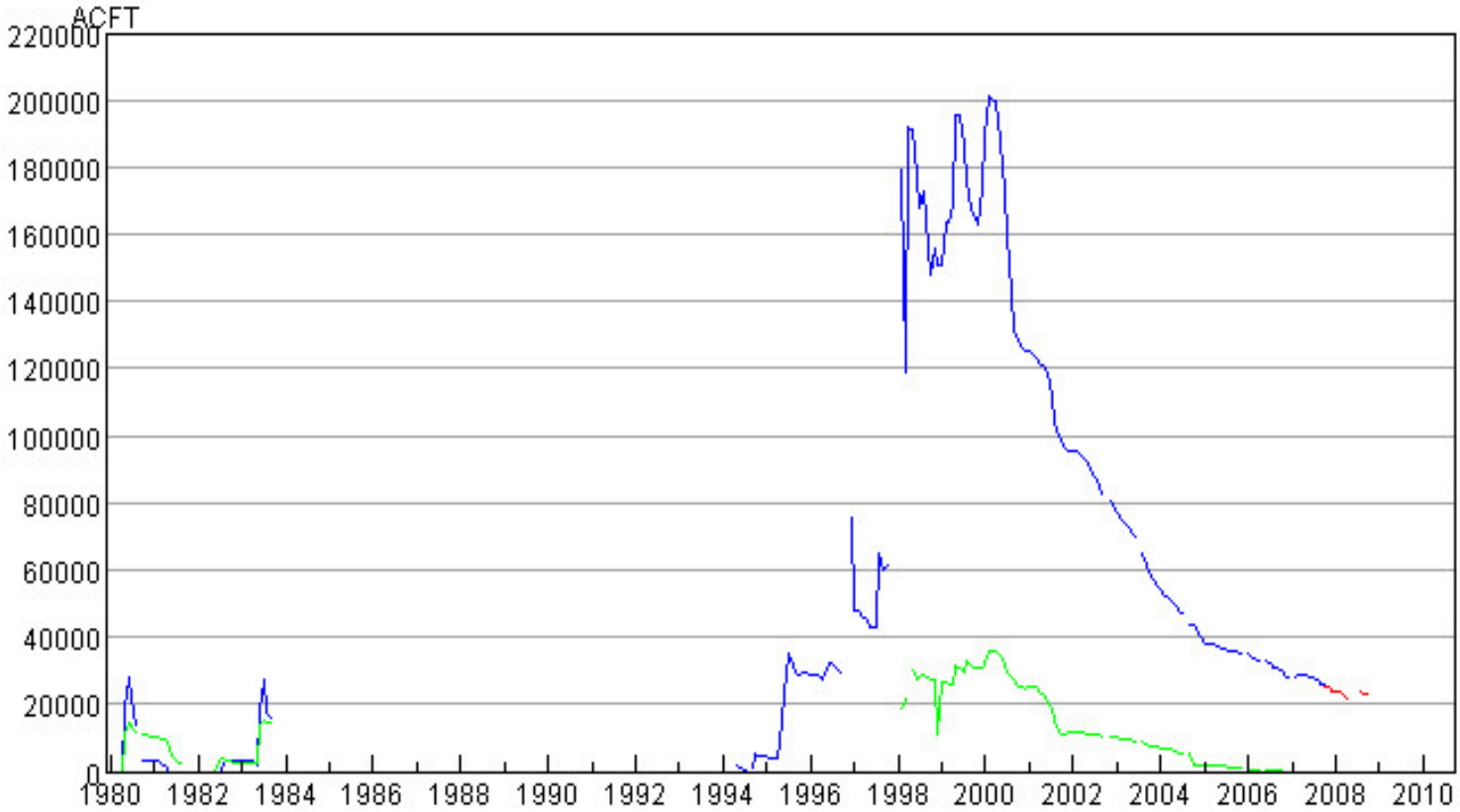

Figure 7: Great Plains Reservoir Storage Contents

WATER RIGHTS

Direct Flow Rights

The Fort Lyon Canal Diversion System has a total decreed flow rate of 933 cfs for irrigation uses, as summarized in **Table 7**. Also listed in Table 7 is the exchange rates from John Martin Reservoir, the filling rates for the Fort Lyon Storage Canal for the Horse Creek Reservoir and Adobe Creek Reservoir storage decrees (see Table 8) and the filling rate for the Kickingbird Canal for the Great Plains Reservoirs storage decrees (see Table 8).

Table 7
Direct Flow Rights – Fort Lyon Canal Company

Structure	Appropriation Date	Adjudication Date	Admin. No.	Decreed Amount (cfs)	Case No.	Notes
Fort Lyon Canal	4/15/1884	4/8/1905	12524.0	164.64	4/8/1905	Irrigation Use
	3/1/1887		13574.0	597.16		
	8/31/1893		15949.0	171.2		
			Total	933		
	8/12/1889	4/8/1905	14469.0	355.2	4/8/1905	Storage in Thurston Reservoir
	8/1/1896	2/3/1927	20186.17015	1,150	2/3/1927	Storage in Great Plains Reservoirs
	4/24/1980	12/31/1990	47596.0	544	90CW47	JMR Exch (Absolute)
			51134.47596	606		JMR Exch (Conditional)
Kickingbird Canal	8/1/1896	2/3/1927	20186.17015	1150	2/3/1927	Storage in Great Plains Reservoirs
Fort Lyon Storage Canal	1/25/1906	11/8/1928	20478.0	840	11/8/1928	Storage in Horse Creek and Adobe Creek Reservoirs
	6/12/1908		21347.0	840		Storage in Horse Creek Reservoir
	23/29/1908		21547.0	840		Storage in Adobe Creek Reservoir
	3/1/1910		21974.0	1466		Storage in Horse Creek and Adobe Creek Reservoirs

Source: Colorado Water Rights Tabulation.

Storage Rights

The storage rights associated with Adobe Creek Reservoir, Horse Creek Reservoir and the Great Plains Reservoirs are summarized in **Table 8**.

Adobe Creek Reservoir has undergone one enlargement from its initial decreed capacity of 61,575 ac-ft; the enlargement increased the decreed storage capacity by 25,425 ac-ft to its current decreed capacity of 87,000 acre-feet.

Horse Creek Reservoir has undergone two enlargements from its initial decreed capacity of 11,400 ac-ft. The first enlargement increased the decreed storage capacity by 15,487 ac-ft. The

second enlargement increased the decreed storage capacity by 1,113 ac-ft to its current decreed capacity of 28,000 acre-feet.

Table 8
Storage Rights – Fort Lyon Canal Company and Great Plains Reservoirs

Storage Unit	Appropriation Date	Adjudication Date	Admin. No.	Decreed Amount (ac-ft)	Case No.	Notes
Adobe Creek Reservoir *	8/1/1896	2/3/1927	20186.17015	5,483	89CW76	Queens Res. Alt Point
	1/25/1906	11/8/1928	20478.0	61,575	11/8/1928	Absolute (Irrig)
	12/29/1908		21547.0	25,425		
		Totals	87,000 (Storage)		5,483 (Alternate Point)	
Horse Creek Reservoir *	8/1/1896	2/3/1927	20186.17015	5,483	89CW76	Queens Res. Alt Point
	8/15/1900	11/8/1928	20186.18489	11,400	11/8/1928	Absolute (Irrig)
	1/25/1906		20478.0	15,487		
	6/12/1908		21347.0	1,113		
		Totals	28,000 (Storage)		5,483 (Alternate Point)	
Thurston Reservoir *	8/12/1889	4/8/1905	14469.0	1,515.15	W-27	Absolute (Irrig)
GREAT PLAINS RESERVOIRS **						
Nee Skah (Queens) Reservoir	8/1/1896	2/3/1927	20186.17015	35,657	2/3/1927	Absolute (Irrig)
Nee No She Reservoir				94,847		
Nee So Pah Reservoir				36,388		
Nee Gronda Reservoir				98,660		
			Total	265,552		

Source: Colorado Water Rights Tabulation
Notes: * Storage rights changed to include Commercial and Stock Water uses in Case No. 08CW83
** 48.37% of storage rights changed to include Storage, Commercial, Industrial, Fire, Domestic, Power, Recharge and Augmentation uses in Case No. 07CW74

Administration

Administration of the water rights associated with the Fort Lyon Canal Company involves interaction with the Commissioners for Water District 17 and 67 and the Division 2 Engineer. The Superintendent of the canal company is more often in contact with these individuals during periods of storage and during periods when direct flow calls have been placed downstream on the Arkansas River.

OPERATIONAL INFORMATION

The general operating strategy for the Fort Lyon Canal and Reservoir System in a typical year is as follows:

Non-Irrigation Season
Once the irrigation season has finished, Fort Lyon Canal Company flows are focused on its Winter Water. The canal company's pro-rata share amounts to 38.16 percent of the first 100,000 ac-ft of Winter Water and a similar percentage of amounts stored beyond 103,106 ac-ft. As noted above, these supplies were historically stored under the Fort Lyon Storage Canal but the canal company has stored its pro-rata share in Lake Meredith for the last approximately 10 years.

The Fort Lyon Canal Company generally takes delivery of its Winter Water in Lake Meredith early in the irrigation season since its water will be booked out if the Lake Henry or Lake Meredith storage rights come into priority during the spring runoff.

Irrigation Season

The Fort Lyon Canal has relatively senior direct flow rights. The 1884 priority is generally in priority and the 1887 cfs direct flow right is typically in priority to divert a certain amount, depending on the amount of return flows and demands associated with the large senior 1887 rights at the Amity Canal and Oxford Farmers Ditch.

Historically, irrigators under the ditch benefitted from Winter Water stored in Adobe Creek Reservoir and Horse Creek Reservoir and in its John Martin Reservoir Article III Account (20,000 acre-feet maximum), since the 1980 Operating Plan for said reservoir was established. Since the early-2000s drought, the Fort Lyon Company tries to store its Winter Water in Lake Meredith since conveyance losses down the Colorado Canal are less than losses down the Fort Lyon Storage Canal. Water stored in Lake Meredith can be released to the river via the Meredith Outlet Canal and re-diverted at the Fort Lyon Canal headgate. Alternately, water released from Adobe Creek Reservoir can be picked up in the Fort Lyon Storage Canal prior to Outlet Canal releases reaching the Arkansas River. These releases from Lake Meredith are then typically stored in Adobe Creek Reservoir and later released to the Fort Lyon Canal.

In addition to the direct flow rights and Winter Water supplies stored upstream, the Fort Lyon Canal typically takes delivery, by exchange, of the 5,483 ac-ft of Amity Mutual Canal Company water and Fort Lyon Article III water stored in John Martin Reservoir. The choice of the source of delivery of Winter Water is contingent on available river flows and estimated transit losses. There is approximately 1,500 cfs of direct flow rights in Water District 67 senior to the Fort Lyon Canal 1893 direct flow right. The Fort Lyon Canal can divert river flows in exchange for releases from John Martin Reservoir when river flows past the Fort Lyon Canal headgate and downstream gains are insufficient to meet the District 67 senior rights. Other operations can also be used to deliver water into the Fort Lyon Canal, including occasional releases from Queens Reservoir or storage of Great Plains storage rights otherwise to be bypassed to John Martin Reservoir, both of which may occur via an internal book over of water from Fort Lyon Canal's Article III account into the Amity Mutual Irrigation Company's John Martin Reservoir accounts.

Fry-Ark Project water released from Pueblo Reservoir is also diverted into the Fort Lyon Canal.

Although the sequence of delivery each year varies based on hydrologic conditions, ditch operational issues and locations of storage of its Winter Water and other supplies, a general order of operations for water supplies into the Fort Lyon Canal is as follows:

1. Direct Flow Water
2. Winter Water from Lake Meredith if available
3. Winter Water from Adobe Creek Reservoir
4. 5,483 Water from John Martin Reservoir
5. Article III Water stored in John Martin Reservoir
6. Winter Water and Storage Rights from Adobe Creek Reservoir and Horse Creek Reservoir
7. Fry-Ark Project Water from Pueblo Reservoir

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LAVWCD Memorandum
Final

To: Jay Winner

From: Rick Parsons

Subject: Lower Arkansas Valley Water Conservancy District, Super Ditch Engineering Task 2 – Pueblo Reservoir

Date: July 31, 2014

INTRODUCTION

Some of the Task 2 objectives are to:

> *Review and document an understanding of the key operations of Pueblo Reservoir and how the reservoir accounts are organized and accounted. The distribution of Fry-Ark Project water, native water and other supplies delivered and stored in the reservoir and the relative spill priorities of the associated accounts will be investigated to determine how a new account for storage of Super Ditch water supplies might factor into reservoir operations. Gathering and review of available data, including comparison to input data and variables from other modeling efforts will be used to develop input data and operational parameters for representation of Pueblo Reservoir in the StateMod model representation of the Lower Arkansas River basin. This understanding will be developed through interviews with Division 2 personnel, Southeastern Colorado Water Conservancy District personnel and representatives of federal facilities.*

Pueblo Reservoir is part of the transmountain diversion Fryingpan – Arkansas (Fry-Ark) Project developed by the U.S. Bureau of Reclamation (Reclamation). Completed in the 1970s, the reservoir is the Project's terminal storage facility and operations are coordinated with the Upper Basin Project Reservoirs (Turquoise Reservoir and Twin Lakes) and transmountain water deliveries from the Roaring Fork and Fryingpan River basins. The Fry-Ark Project provides supplemental water for municipal, industrial, domestic, irrigation, hydroelectric power, flood control, and incidental fish, wildlife, and recreational uses. Other transmountain water supplies are also stored in Pueblo Reservoir.

The Southeastern Colorado Water Conservancy District (SECWCD) is the entity responsible for repayment of the reimbursable portion of the Fry-Ark Project. SECWCD also holds the water rights for the Fry-Ark Project and allocates Project water for use by various municipal and industrial (M&I) and agricultural users. The SECWCD extends along the Arkansas River from Buena Vista to Lamar, and along Fountain Creek from Colorado Springs to Pueblo. In addition to providing water supplies for municipal and industrial users, approximately 280,600 acres of irrigated land

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can receive supplemental irrigation water from the Fry-Ark Project.

Pueblo Reservoir is a multi-purpose facility that is pivotal in Arkansas River basin administration and is the uppermost storage facility associated with the Winter Water Storage Program (WWSP; see Task 3 – Winter Water Storage Program memorandum). Pueblo Reservoir also stores non-Project water for various entities under the terms of contracts with Reclamation for excess capacity storage. Water supply operations are coordinated by the Division of Water Resources and Reclamation. Flood control operations are directed by the U.S. Army Corps of Engineers-Albuquerque District.

Pueblo Reservoir has a 1939 priority storage right administered pursuant to a 1962 adjudication date. The junior right enables storage of native water for the Project during periods of high flow in the Arkansas River Basin. The storage right is only in priority when the conservation pool in John Martin Reservoir is full (approximately 350,000 acre-feet).

A draft of this memorandum was provided to the Division 2 office and Reclamation's Pueblo Field Office (PFO). Comments were provided by PFO staff on the draft memorandum.

The information provided in this memorandum was developed from publicly accessible sources and discussions and meetings with Division 2, Bureau of Reclamation and SECWCD personnel. Information in this memorandum is believed to be accurate. However, the information should not be relied upon in any legal proceeding.

RESERVOIR ACCOUNTS

Pueblo Reservoir has a total storage capacity of 349,940 acre-feet: including 28,121 acre-feet of dead and inactive capacity that comprises most of a 30,000 acre-foot reserve maintained for recreation and fishery protection; 228,828 acre-feet of conservation capacity; 66,000 acre-feet of joint use capacity; and 26,991 acre-feet of exclusive flood control capacity.

The Conservation Pool provides designated storage space for domestic and municipal users (163,100 acre-feet total, of which no more than 159,000 acre-feet can be Project water). Winter Water is also stored in the conservation and joint use storage pools. Excess capacity in the Conservation Pool is available for storage of Project water for irrigation users, unallocated Project water, Winter Water in excess of 70,000 acre-feet and Excess Capacity contracts. The Excess capacity contracts are temporary or long term leases for storage. These contracts, also known as If and When contracts, are available to entities inside and outside of SECWCD boundaries and are typically used to store non-Project water and Project return flows that are used directly, by exchange, for well augmentation replacement, etc. Conservation storage may encroach into the Joint Use pool can also be used for conservation storage but this storage space (66,000 acre-feet) must be evacuated between April 15 and November 1 to provide additional flood control capacity in the reservoir.

The sum of all storage accounts total more than the capacity of the reservoir, which is typical of multiuse facilities. The repayment contract between SECWCD and the United States was modified in 1984 to protect Fry-Ark Project beneficiaries. The Spill Order resulted from negotiations related to the 1984 water court applications for the WWSP (Case No. 84CW179)

and for reuse of wastewater return flows controlled by Colorado Springs Utilities (CSU; Case Nos. 84CW202 and 84CW203). The storage account categories to be evacuated are listed below with the first account category in the list spilled first. Note that transmountain Project Water is not spilled.

1. Excess Capacity storage leased by entities outside of SECWCD boundaries
2. Excess Capacity storage leased by entities within SECWCD boundaries
3. Winter Water stored in excess of 70,000 acre-feet
4. Pro-rata evacuation of municipal non-Project water stored beyond the designated municipal allowance in the Conservation Pool.
5. Stored Winter Water less than 70,000 acre-feet
6. Native east slope Fry-Ark supplies (1939 priority storage)

Inclusion of a Super Ditch account in Pueblo Reservoir in the model will be represented in the context of the existing Spill Order. The Super Ditch account will provide for storage and release of changed irrigation water rights but will be among the earlier categories of accounts to be spilled.

The number of lessees and amount of leased excess capacity storage space has changed over time. A 2012 snapshot of excess capacity account holders provided by Reclamation's PFO included six (6) Long Term accounts (total 44,650 acre-feet) and 21 Temporary accounts (total 21,467 acre-feet), with a combined total of 66,117 acre-feet. The Long Term accounts represented about two-thirds of the total leased excess capacity storage. CSU was the largest lessee in 2012, with 22,000 acre-feet.

Project Water accounts in 2012 included Current Year Allocated and Carryover accounts for 46 municipal users and 37 agricultural users. Winter Water accounts (Current and Carryover) for 10 users were also included.

According to Reclamation personnel, there is significant accounting of bookovers of water between storage accounts in Pueblo Reservoir each year. These bookovers occur, in part, because there are a number of large municipal interests in the basin that share storage space in reservoirs (Pueblo Reservoir, the Upper Basin Reservoirs and the Colorado Canal system reservoirs), share pipelines (Otero Canal and Joint Use Pipeline / Fountain Valley Pipeline) and share supplies from transmountain supplies and changed shares in a number of ditch and reservoir companies. This overlap in supplies and infrastructure facilitates trading water stored in various locations to the desired delivery locations for the trading partners.

Reclamation personnel indicated individual account owners request the bookovers and do not typically provide reasoning for the requests other than the assumed general motivations listed above. Requested bookovers are explicitly accounted for and result in a diminished amount in the donor account and an increased amount in the recipient's account, with the inverse of the trade in other Pueblo Reservoir accounts and/or other locations pursuant to appropriate transit, evaporation, and other losses. Agreements between account owners may or may not include monetary compensation.

Storage within specific accounts over time was not reviewed for this effort. As discussed in the StateMod Model section of this memorandum, the number of Pueblo Reservoir accounts represented in the model will be simplified due to the limited geographical extent of the model

network and the degree to which the supply operations for water users is represented in the model.

FRYINGPAN-ARKANSAS RIVER PROJECT ALLOCATION

SECWCD allocates Fry-Ark Project water in May of each year. Allocations are available for purchase from the SECWD by municipal and irrigation users. Fry-Ark Project water is allocated such that domestic use has preference over agricultural use; therefore, a minimum of 51 percent of the Project yield is allocated to municipal and domestic use. The pro-rata yield available to municipal and domestic use has increased to about 54 percent as irrigated lands have been dried up in the basin and the associated Project water is re-allocated to other entities.

As outlined in the SECWCD Allocation Principles, the municipal and domestic use is split among the Fountain Valley Authority (FVA; 25 percent); entities east of Pueblo (12 percent); Pueblo Board of Water Works (PBWW – 10 percent); and entities west of Pueblo (4 percent). The 163,100 acre-feet of storage space is similarly split among these entities: FVA (79,900 acre-feet); entities east of Pueblo (38,400 acre-feet); PBWW (32,000 acre-feet); and entities west of Pueblo (12,800 acre-feet). FVA includes CSU, Stratmoor Hills and Widefield Water and Sanitation Districts, Security Water District and the City of Fountain, all located within the Fountain Creek basin.

The remaining Project allocation is available for agricultural users based on the extent of irrigated acreage under the particular irrigation system. Irrigation use is subject to the 80/20 rule whereby 80 percent of the purchased Project allocation must be used by November 15 and the remaining 20 percent must be used by the following May 1. Project water not allocated or not purchased by Project entities is re-allocated to other entities based on their requests for water.

Although Fry-Ark Project water is delivered to Pueblo Reservoir throughout the year, releases are typically made from the Upper Basin Reservoirs during the winter to prepare for the import of transmountain diversions available during the spring runoff. In addition, Upper Basin Reservoir releases are also made during the summer to increase streamflows above Pueblo Reservoir as part of the Upper Arkansas Voluntary Flow Management Program (VFMP). The VFMP began in the early-1990s to improve river conditions to support the fishery and recreation industries in the upper basin.

RESERVOIR DATA

Data related to Pueblo Reservoir are summarized below. The primary sources for this information are the water resources data available on the State of Colorado Decision Support System website (http://cdss.state.co.us/Pages/CDSSHome.aspx) and material provided by personnel at the Division 2 office and Reclamation's PFO.

Sources of data and inputs from other basin models are also included. These data come predominantly from the Hydrological-Institutional (H-I) Model. A basin model was previously developed to support the Colorado Springs Utilities Southern Delivery System Environmental Impact Statement (EIS) analysis. This same basin model was also used to analyze potential impacts in the Arkansas Valley Conduit EIS. Documentation summarizing the EIS models indicates the operations of the Fry-Ark Project, including deliveries and releases, is explicitly

represented in detail in the models. The Bureau of Reclamation input data for these models, prior to the manipulation of those data for use in the EIS models, were provided by the EIS model developer, MWH Global, for this effort.

STORAGE CONTENTS

Historical storage contents data are available in HydroBase for water years 1978 through 1984. The Division 2 office provided Daily Balance Reports, including storage and releases by account, for the 1997 through 2012 period. Pueblo Reservoir daily storage contents data starting in May 1974 (see **Figure 1**) are available on Reclamation's reservoir data website (http://www.usbr.gov/gp-bin/arcweb_puer.pl). The Reclamation data are consistent with the HydroBase data and were chosen as the primary source of model input data since these data are complete.

The storage contents records appear to represent a combination of the Conservation Pool and the Joint Use Pool (total of 294,828 acre-feet). Maximum storage contents of approximately 295,000 acre-feet were recorded in January 1985 and February 1985.

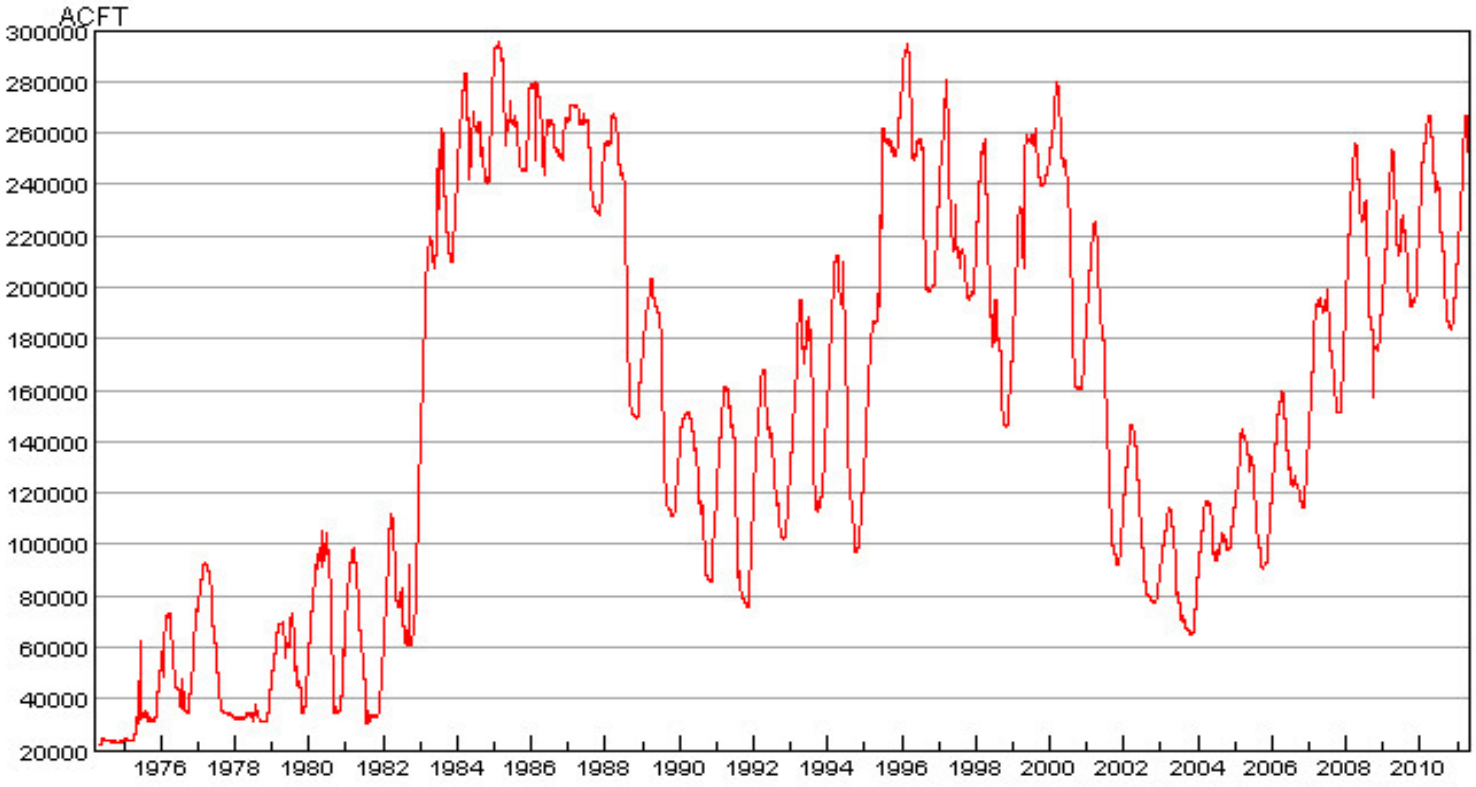

Figure 1
Pueblo Reservoir Storage Contents

RESERVOIR INFLOWS

Inflows to the reservoir are comprised of Fry-Ark Project water deliveries from the Upper Basin Reservoirs and non-Project water. Non-Project water deliveries include other transmountain imports (Twin Lakes Reservoir and Canal Company, Busk-Ivanhoe and Columbine, Wurtz and Ewing Ditches) and east slope water supplies from the Arkansas River and storage releases. Water is either stored in Pueblo Reservoir or bypassed through the reservoir to meet downstream water user obligations.

Streamflow above the reservoir is recorded at the Arkansas River at Portland gage (USGS ID 00907000). The Portland gage is located approximately 10 miles upstream from the reservoir and is considered a good indication of inflows to Pueblo Reservoir except during precipitation events when unmeasured inflows from the areas below the gage accrue to the reservoir.

The Reclamation PFO provided daily records (see **Figure 2**) of Project Water and Twin Lakes Reservoir and Canal Company inflows to Pueblo Reservoir over the 1985 through 2008 period. Homestake Project inflows to Pueblo Reservoir are typically very minor as are waters stored from other transbasin diversions

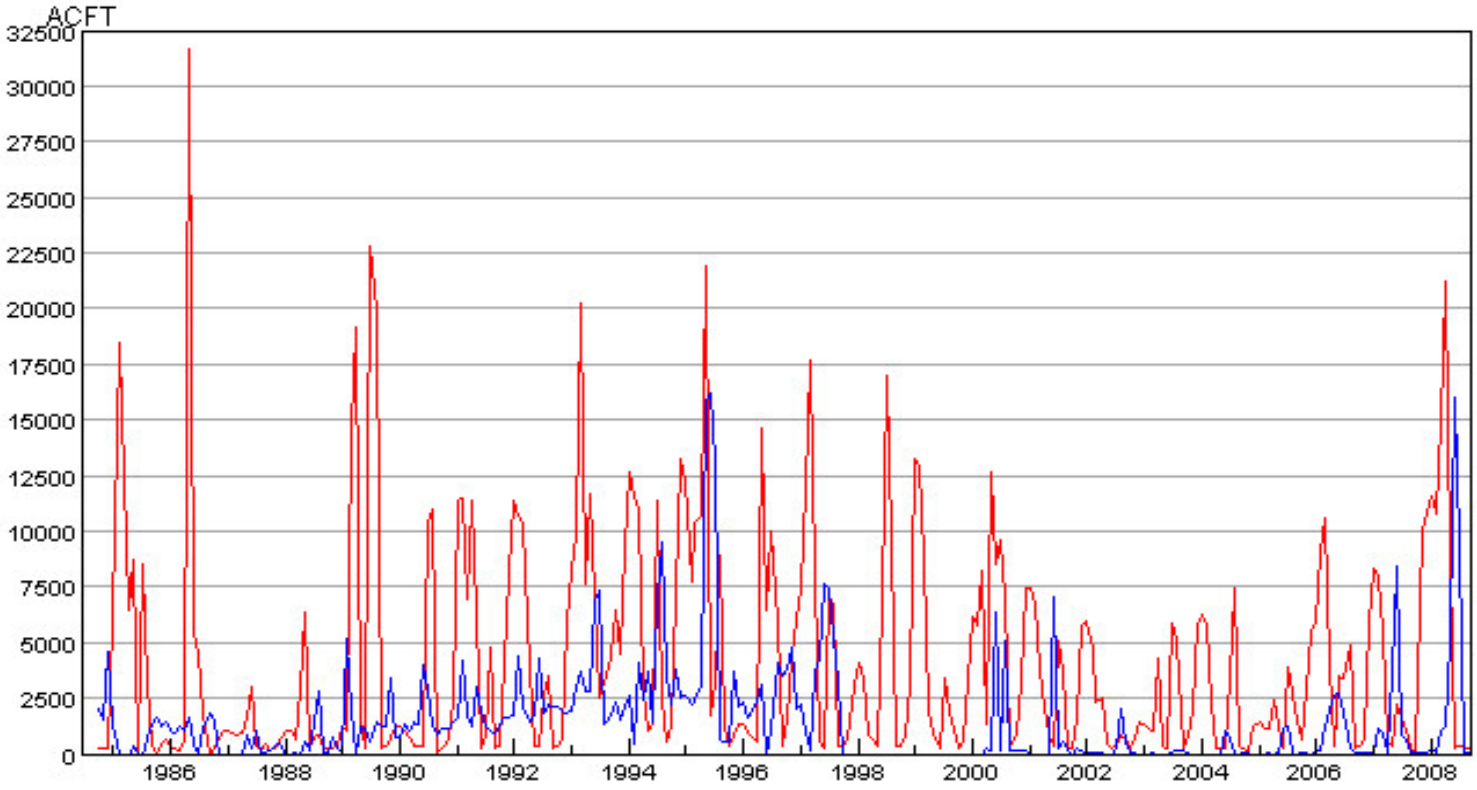

Figure 2
Pueblo Reservoir Transmountain Inflows from
Fry-Ark Project (red line) and Twin Lakes Reservoir & Canal Company (blue line)

The Project Water annual inflows during this period range between about 11,000 acre-feet (1987) and 100,000 acre-feet (1995) with an average of 50,470 acre-feet over the 24-year period. The Twin Lakes Reservoir and Canal Company inflows during this period range between zero acre-feet (1998 and 1999) and 65,000 acre-feet (1995) with an average of 17,467 acre-feet over the 24-year period. For comparison, the average annual flow recorded at the Portland stream gage over the same period was 553,338 acre-feet.

Native water diversions into Pueblo Reservoir ("East Slope Project water") have occurred over seven (7) years: 1985 – 1987, 1995 and 1998 – 2000. These storage amounts typically correspond with high water years, as illustrated by the Portland streamflows (red line) in **Figure 3**. Although 1998 through 2000 could be characterized as average to below average water years, East Slope storage occurred during those periods since John Martin Reservoir was full (blue line

in Figure 3). Water year storage amounts ranged between approximately 2,000 acre-feet (1986) to over 100,000 acre-feet (1995 and 1999).

Other sources of Arkansas River basin supplies are also stored in Pueblo Reservoir. These may include direct storage of changed water rights and storage releases located above Pueblo Reservoir. Water supplies are also stored by exchange from downstream locations. The exchanged water supplies include CSU reusable return flows from Fountain Creek; CSU and Aurora Winter Water and changed water rights from Lake Meredith; and Aurora changed water rights from the Rocky Ford Ditch. The downstream water supplies may be exchanged against native inflows to Pueblo Reservoir or may be exchange via in-reservoir bookovers between storage accounts. Specifics regarding ditch shares stored directly in the reservoir or particular water that was exchanged up to the reservoir were not identified. Review of the HydroBase data provides some insight into water exchanged into the reservoir but the data are not complete.

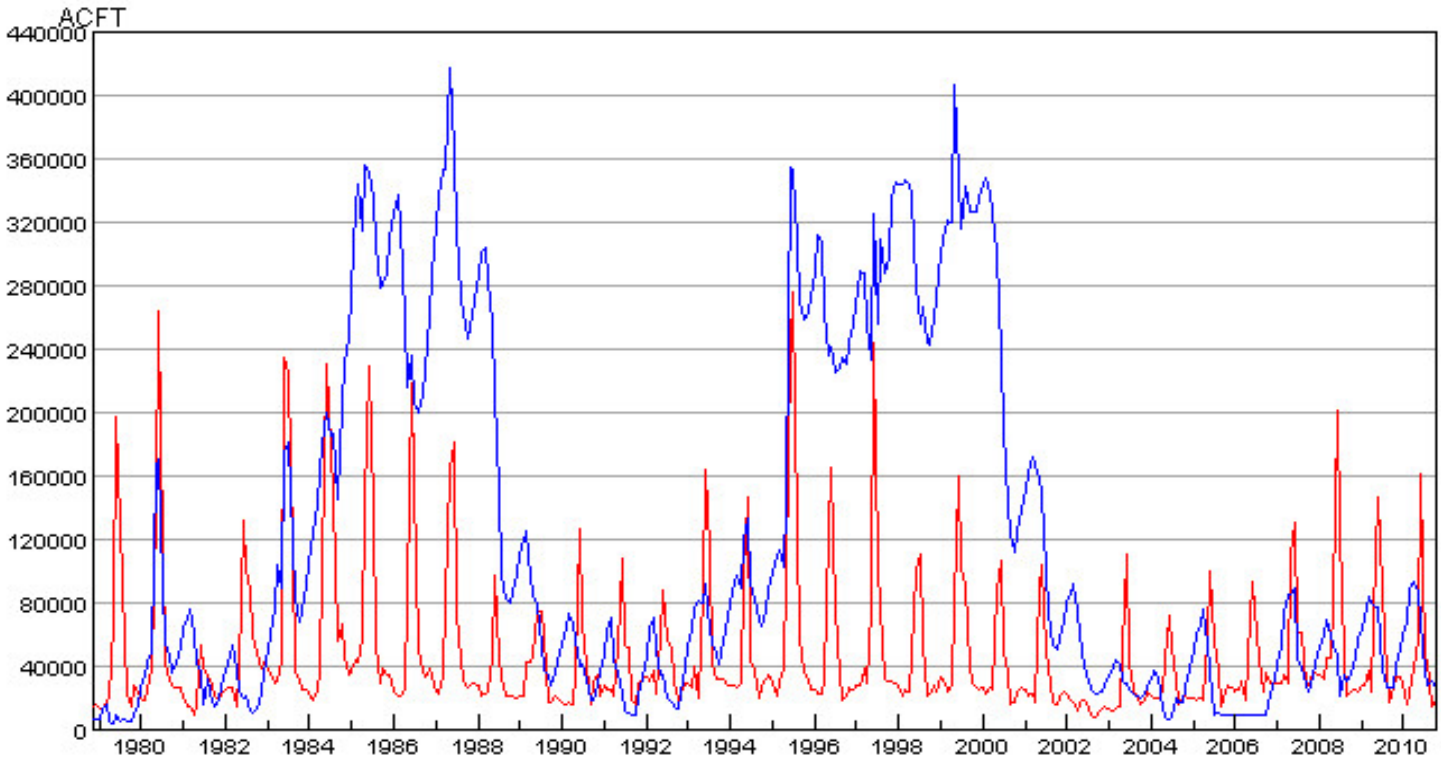

Figure 3
Arkansas River at Portland Streamflow (red line)
and John Martin Reservoir Storage Contents (blue line)

RESERVOIR OUTFLOWS

Pueblo Reservoir and the Fry-Ark Project are operated so as not to affect the Arkansas River Compact of 1948. Unless Fry-Ark Project east slope Arkansas Basin water rights are in priority, native water is bypassed for downstream delivery to satisfy senior water rights, including the John Martin Reservoir storage right. Releases from storage in Pueblo Reservoir are comprised of Fry-Ark Project and other transmountain water released to the Arkansas River for irrigation and municipal purposes, Winter Water releases for irrigation purposes, pipeline / outlet works releases to the FVA, PBWW and Pueblo West Metropolitan District (Pueblo West) for municipal

purposes, direct releases to the Bessemer Ditch for irrigation and to the Pueblo Fish Hatchery for the fishery.

Project water releases are available in the Division 2 Daily Balance Reports for the 1997 through 2012 period. The release data appear to be coded for some but perhaps not all Project recipients. Records of Aurora and CSU exchanges against Twin Lake Canal Company water in storage in Pueblo Reservoir are coded in the Daily Balance Reports. No data regarding Twin Lakes Reservoir and Canal Company releases to the river were identified within HydroBase.

Some records of Fry-Ark Project deliveries to ditches are available in HydroBase. These diversions are recorded as From: Pueblo Res Fry-Ark Project structure (ID 1403537) under Diversion Classes for the various recipient ditches. The available release data over the 1975 through 2010 period for the ditches located above John Martin Reservoir are summarized in **Table 1**. These data are likely most useful as a comparison to releases in model simulation output. Note there are a few other structures with a year or two or three of Fry-Ark delivery data in HydroBase. These recipients are not included in Table 1 (St Charles Mesa Water District, PBWW, Hobson Ditch, Comanche Power Plant, Fort Bent Canal, Canady Ditch, Herman Klinkerman Ditch and Crowley County Well No. 3).

Table 1
Fry-Ark Project Release Data from Pueblo Reservoir
1975 – 2010

Participant	HydroBase Data	
	Years Available	Average Annual Release (ac-ft)
Bessemer Canal	20	4,105
Excelsior Ditch	9	478
Collier Ditch	3	38
Colorado Canal	12	2,525
Highline Canal	19	7,283
Oxford Canal	18	1,146
Otero Canal	26	930
Catlin Canal	24	3,575
Holbrook Canal	27	3,886
Fort Lyon Storage Canal	5	6,623
Fort Lyon Canal	26	14,914

Source: HydroBase Database version 20130903.
Note: Averages based on number of years with available data.

The releases from Winter Water and excess capacity accounts are represented in the Daily Balance Reports for some but perhaps not all Program recipients. Winter Water release data are available in HydroBase. The ditch-specific records in HydroBase cover about two-thirds of the period between 1976 and 2010 reviewed for this effort. Winter Water releases are input to the H-I Model. The H-I Model data are complete over the 1976 through 2006 period and are likely similarly available for subsequent years. As discussed in the Task 3 – Winter Water Storage Program memorandum, the HydroBase and the H-I Model data are only somewhat consistent.

Daily records of the release and storage amounts of Winter Water Carryover storage was provided by Reclamation PFO for the 1997 to 2014 period. These data indicate no Carryover water is stored in Pueblo Reservoir after April 30 of each year. One exception to this Winter

Water Carryover storage protocol was identified. In 1998, Carryover water from the 1996 – 1997 storage season was allowed in Pueblo Reservoir because Pueblo Dam structural concerns precluded Winter Water storage during the 1997 – 1998 storage season.

CSU provided daily deliveries to FVA over the May 1986 through April 2010 period. The annual FVA deliveries range from about 3,100 acre-feet (1987) to 13,600 acre-feet (2003) with an average of about 6,800 acre-feet over the 23 years with record. Annual FVA deliveries over the last 10 years have averaged approximately 8,600 acre-feet. Diversions in HydroBase for the Fountain Valley Pipeline structure (ID 100859) are available for 1990 through 1994. On an annual basis, the HydroBase data are about 5 to 10 percent higher than those provided by CSU.

Annual deliveries to PBWW through the dam outlet (ID 1400639) started in mid-2002, subsequent to when water was predominantly diverted to the PBWW municipal system through its Northside Intake (ID 1400589) and Southside Intake (ID 1400590), located on the Arkansas River downstream from the dam. Annual deliveries through the dam outlet through 2010 were consistently about 26,000 acre-feet.

Annual deliveries to Pueblo West recorded in the Daily Balance Reports average approximately 3,600 acre-feet over the 1997 through 2010 period.

Releases of storage water to the Bessemer Ditch are on the order of 15,000 acre-feet per year. The storage releases are available in HydroBase and include Project Water, Winter Water and excess capacity (If and When) account water. These releases supplement the approximately 53,000 acre-feet per year of river diversions that are also carried through the reservoir to the Bessemer Ditch.

Reclamation provided daily release data for the Pueblo Fish Hatchery for calendar years 2008 and 2009. Releases range from about 30 cfs to 40 cfs and averaged approximately 37 cfs during the two-year period.

The Pueblo RICD flows range from 100 cfs during the winter and 500 cfs in June and July. The RICD extends from Aquila Energy diversion dam down to the Arkansas River at Moffat Street gage (USGS ID 07099970), at which point the RICD flows are administered. The RICD is typically satisfied by native flows bypassed at Pueblo Reservoir and other account releases from the reservoir. Water users in the basin have agreed to forego senior storage diversions and exchanges into Pueblo Reservoir during periods the RICD flows are not satisfied. The Foregone Diversions may be stored in locations downstream of the Moffat stream gage and exchanged back into Pueblo Reservoir at a later time evidenced by higher streamflows.

RESERVOIR OPERATIONS and STATEMOD MODEL

Storage and release of water from Pueblo Reservoir is discussed in the sections above.

The representation of Pueblo Reservoir in the model focuses on understanding how water moves into and out of the reservoir. This is necessary since the StateMod program uses a demand-driven algorithm whereby water is only diverted, stored, released, booked over, et cetera in response to meeting an unmet demand. For instance, a water right located on the Arkansas River will trigger

in July to divert to meet an irrigation demand. That same water right will not trigger in February since there is no irrigation demand in February. The same is true for modeling the movement of water into and out of reservoir accounts. Again, water is simulated to move only if there is a destination demand. For example, a storage release of Winter Water or Fry-Ark Project water to meet a July irrigation demand can be simulated if the irrigator is water short after the direct flow rights trigger. An upstream exchange of Aurora's water in Lake Meredith, though, is more difficult to represent. These exchanges are executed in accord with other trades of water, exchange potential to Pueblo Reservoir, Otero Canal or other locations and/or Aurora's demands for diversion of Arkansas River water supplies. Representation of the dynamic movement of water in operations like these is complicated in a model network that does not extend upstream of Pueblo Reservoir and does not explicitly represent the full demand, supply and operations of Aurora's demands. Ultimately, the representation of different operations outside of the model network will need to be simplified or not explicitly addressed until the model is expanded to cover a larger portion of the Arkansas River basin.

The following approach represents how water is simulated into and out of Pueblo Reservoir in the StateMod model. The description below illustrates the representation of Pueblo Reservoir at this time. Changes are likely to model set up as model calibration efforts continue; more information is learned about Pueblo Reservoir operations and different approaches used to improve system representation are incorporated. Any changes will be discussed in the Task 4 – Model Operations memorandum.

Fry-Ark Project Water

The Fry-Ark allocations for irrigation users have changed over time as has the amount of allocated water that was actually purchased. The allocations by ditch over the 1972 through 2013 period were provided by SECWCD personnel. These data were used to develop a rough estimate of annual averages for use in distributing Project Water to agricultural users during the 1986 through 2010 StateMod model study period. These percentages coincide with magnitude of Project delivery recorded in HydroBase summarized in Table 1.

- Bessemer – 14 percent
- Colorado – 3 percent
- High Line – 13 percent
- Oxford – 3 percent
- Otero – 3 percent
- Catlin – 10 percent
- Holbrook – 11 percent
- Fort Lyon – 43 percent

The historical deliveries of Project Water from the Upper Basin Reservoirs provided by Reclamation are distributed in the model 51 percent to Municipal Users and 49 percent to Agricultural Users. The municipal deliveries are distributed to reservoir accounts for FVA, PBWW and municipalities east and west of Pueblo. The agricultural allocations are distributed to ditch-specific Fry-Ark storage accounts based on the percentages listed above.

The municipal accounts are used to supply the associated municipal demands. The FVA demands are set equal to the historical deliveries provided by CSU. After 2002, the PBWW demands are set to meet the Joint Use Pipeline deliveries recorded in HydroBase. Prior to 2002, the PBWW Fry-Ark Project Water is released to meet the historical diversions at the PBWW Northside and Southside Intakes. Note the representation of PBWW is simplified based on these

demands and Fry-Ark Project Water as its sole supply. The details of all the Arkansas River basin senior rights held by PBWW and transmountain imports and Clear Creek Reservoir operations are beyond the scope of this modeling effort.

The demands for the municipalities located east and west of Pueblo were developed based on the 2000 and 2010 municipal demands developed for the SDS EIS model, as outlined in Tables 39 and 44 of the SDS EIS Hydrologic Model Documentation Report ➔ East of Pueblo – 15,545 ac-ft/yr (2000) and 17,892 ac-ft/yr (2010); West of Pueblo – 9,165 ac-ft/yr (2000) and 10,871 ac-ft/yr (2010); and Cañon City (represented separately) – 5,876 ac-ft/yr (2000) and 7,150 ac-ft/yr (2010).

The agricultural accounts are used to release water to meet downstream irrigation demands when demands are not satisfied by direct flow rights. In order to differentiate the water supply by season and by year, the Fry-Ark Project Water not used at the end of one season is booked over to ditch-specific Fry-Ark Project Water Carryover accounts in November. The water carried over is used at the beginning of the following irrigation season since Project Water carried over but not used before May 1 is available for re-allocation to other participants.

Twin Lakes Reservoir and Canal Company Water
The historical deliveries of Twin Lakes Water provided by the Reclamation are split in the model to CSU (55 percent), Aurora (30 percent) and Colorado Canal Irrigators (15 percent) based roughly on the pro-rata ownership of shares in the Colorado Canal (see Task 1 – Colorado Canal Operations memorandum, Table 1).

Twin Lakes water is released to the Colorado Canal Irrigators from its account in Pueblo Reservoir after the direct flow rights trigger and supplemental releases are made from Lake Henry (direct) and Lake Meredith (by exchange) to meet the irrigation demands.

A destination demand is required in the model to trigger movement of the municipalities' Twin Lakes water out of Pueblo Reservoir. Although the two municipalities are represented in the Colorado Canal system and with accounts in Pueblo Reservoir, the demands for CSU and Aurora are not explicitly represented in the StateMod model. This is because extent of the model network is limited and includes neither the Arkansas River above Pueblo Reservoir nor Fountain Creek and the associated water supplies and infrastructure involved in municipal operations in those areas. Without these municipal demands in the model, a surrogate demand for the Twin Lakes and Colorado Canal system water is input. The municipalities' Twin Lakes water is moved out of Pueblo Reservoir to meet those demands. This operation effectively causes the Twin Lakes water destined for municipal uses not explicitly represented in the model to be removed after delivery into Pueblo Reservoir.

Winter Water
Simulated storage of Winter Water is held in an aggregate account in Pueblo Reservoir between November 15 and March 15 of each year. Winter Water is diverted and stored in similar accounts under the Colorado Canal reservoirs, Fort Lyon Storage Canal reservoirs and in John Martin Reservoir. At the end of the Winter Water season, the total yield for the year is added and distributed to Program participants amongst the different storage locations.
The agricultural Winter Water accounts are used to release water to meet irrigation demands when demands are not satisfied by direct flow rights. These releases are made after Fry-Ark

Project Water releases since 80 percent of the Fry-Ark water must be used by the end of the irrigation season, which is considered more likely to be reduced than Winter Water supplies that can be carried over, in total, until the following year.

In order to differentiate the water by year in Pueblo Reservoir, the Winter Water not used at the end of one season is booked over to ditch-specific Winter Water Carryover accounts at the end of the irrigation season. The water carried over is used at the beginning of the following storage season since Winter Water carried over but not used before May 1 is released to the river.

At this time, representation of Winter Water operations in the StateMod model is ongoing, specifically the distribution of total yield to project participants. The ultimate method for representing Winter Water to illustrate how future operations may impact existing operations will be discussed in the Task 4 – Model Operations memorandum.

As noted above, future scenarios with the StateMod model will include a Super Ditch account in Pueblo Reservoir. The representation of the account and related river exchanges vis-à-vis other exchange rights will be discussed in the Task 4 memorandum. The discussion will present how operations of future scenarios under which the consumptive use portions of Lower Arkansas River basin ditch shares can be exchanged to the reservoir, either during the summer or after accretions or releases from interim storage, and how that storage will inter with other accounts and the Spill Order in Pueblo Reservoir.

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To: Jay Winner

From: Rick Parsons

Subject: Lower Arkansas Valley Water Conservancy District, Super Ditch Engineering
Task 3 – Winter Water Storage Program

Date: July 10, 2014

INTRODUCTION

Some of the Task 3 objectives are to:

> *Review and document an understanding of the key operations of the Winter Water Storage Program and its concepts, components and administrative constraints. Decisions that go into each canal company's placement of Winter Water, the constraints placed on that storage and the conditions that prompt storage releases will be investigated. Gathering and review of available data, including comparison to input data and variables from other modeling efforts will be used to develop complete input data sets for the StateMod model representation of the Lower Arkansas River basin. This understanding will be developed through interviews with Division 2 personnel, Southeastern Colorado Water Conservancy District personnel and operators of large canal and reservoir systems, and representatives of federal facilities.*

The key reservoir systems identified in Task 1 of the Lower Arkansas Valley Water Conservancy District (LAVWCD) Super Ditch Engineering that are involved with the Winter Water Storage Program include:

- Pueblo Reservoir (addressed in Task 2)
- Lake Meredith and Lake Henry (Colorado Canal System, addressed in Task 1)
- Holbrook Reservoir (Holbrook Canal System, addressed in Task 1)
- Adobe Creek Reservoir, Horse Creek Reservoir and Great Plains Reservoirs (Fort Lyon Canal System, addressed in Task 1)
- John Martin Reservoir (addressed in Task 1)

A major use of Pueblo Reservoir since the late 1970s has been the Winter Water Storage Program (WWSP). The program stores irrigation water that was historically diverted in the winter under direct flow rights and stores the water in Pueblo Reservoir, John Martin Reservoir and other off-channel reservoirs in the Lower Arkansas River Basin. Program participants include all major canal and reservoir companies located between Pueblo Reservoir and John Martin Reservoir, with the exception of the Rocky Ford Ditch Company and Otero Ditch Company. The Amity Mutual

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Irrigation Company, which diverts from the Arkansas River below John Martin Reservoir, is also a Program participant due to its ownership interest in the Great Plains Reservoir system located under the Fort Lyon Canal and Kickingbird Canal diversion system. The purpose of this Task 3 memorandum is to document operational aspects of the WWSP and to develop complete input data sets for use in the StateMod modeling effort.

The information provided in this memorandum was developed from publicly accessible sources, discussions with Division 2 personnel, Bureau of Reclamation personnel, Southeastern Colorado Water Conservancy District personnel and meetings with canal company representatives. A draft of this memorandum was provided to the Division 2 office for review. No comments were provided on the draft memorandum.

Information in this memorandum is believed to be accurate. However, the information should not be relied upon in any legal proceeding.

PROGRAM OVERVIEW

Agricultural users have the most senior rights on the river. These rights have historically been diverted during the wintertime to store water in the soil underlying fields. This soil moisture content is important for spring planting and winter wheat.

Construction of Pueblo Reservoir in the 1970s and operations of the reservoir complicated administration of the Arkansas River in the lower basin. The reservoir, though, also provides opportunities to enhance the flexibility of operations for the benefit of water users. The concept of Winter Water is that completion of Pueblo Reservoir could allow carryover storage to benefit farming and ranching communities in the Lower Arkansas Valley.

The Winter Water Storage Program grew out of negotiations amongst agricultural water users, the Bureau of Reclamation, the Division 2 Engineer and associated water users. The need for a process of fairly diverting and dividing the amount of Winter Water resulted in the 1987 Decree (84CW179) that officially recognized the Winter Water Storage Program. Modifications to the Program, including alternate accounting have been made over time to enhance the flexibility of the Program (e.g., Restoration of Yield, Aurora-Holbrook 2006 Agreement, etc.).

The resultant storage program provides the majority of agricultural water users under ditches located between Pueblo Reservoir and John Martin Reservoir the opportunity to work in concert to store water over the winter for release during the summer. The Program is administered by the Division 2 Engineer. The call on the river during the Winter Water season (November 15 through March 14) is artificially set at March 1, 1910, which allows non-participants, including upper basin storage rights to divert water during the winter.

The flow of the Arkansas River, including the Winter Water Storage Program, is subject to the Kansas – Colorado compact of 1948. The Winter Water Storage Program allows storage of some water in John Martin Reservoir and the Compact Administration has approved resolutions permitting use of John Martin Reservoir for this purpose. The Winter Water Storage Program is operated in compliance with these resolutions and the Compact.

OPERATIONAL INFORMATION

WWSP Participants typically cease diversions by November 14, prior to the start of the Winter Water season. In addition, the off-channel storage rights for the Program Participants are not operated during the Winter Water season but do turn on after March 15. Canal Companies that do not participate in the Winter Water Storage Program continue winter diversions pursuant to their respective direct flow rights. Program Participants occasionally divert after November 14 and, if they do, those diversions are counted as part of their pro rata Winter Water amounts.

The outlet gates at Pueblo Reservoir are essentially closed starting November 15 to allow storage of Winter Water. Pueblo Reservoir dries up the river except for the Pueblo bypass flows. Currently, a Flow Management Program directs the bypass of the lesser of 100 cfs or natural inflows to provide instream flows for riparian habitat and recreation through the City of Pueblo, when possible. This operation is based upon the Preferred Storage Options Plan (PSOP) and is a result of the riparian restoration as part of the City of Pueblo's Recreational In-Channel Diversion water right adjudicated in Case No. 01CW160 and the settlement of various water resources issues between the signatories.

Between November 15 and March 14, river flows in excess of the amount necessary to supply senior priorities of entities not participating in the Winter Water Storage Program can be stored in Pueblo Reservoir, John Martin Reservoir and off-channel storage facilities of Program participants. Overall, water is stored and released as prescribed by the decree entered in 84CW179.

BASEFLOW DETERMINATION and JOHN MARTIN RESERVOIR OPERATIONS

At the end of the summer, irrigation return flows accruing to the river are the primary component of streamflows above John Martin Reservoir. The outlet gates at John Martin Reservoir are essentially closed during the winter. Reservoir inflows to John Martin Reservoir are quantified at the beginning of the storage season to ensure the operations of the Program is adequately balanced between the Colorado – Kansas Interstate Compact storage and Winter Water storage in John Martin Reservoir and other upstream locations of storage (Pueblo Reservoir and off-channel facilities).

The Winter Baseflow is defined as the average inflow to John Martin Reservoir during the second week of November, as measured at the Las Animas stream gage (USGS ID 07124000). Cessation of diversions by Program Participants in mid-November results in increased flows at the Las Animas gage. The average inflow to John Martin Reservoir during the third week of November less the Winter Baseflow amount represents the Enhanced Baseflow.

Inflows to John Martin Reservoir continue throughout the winter from irrigation return flows and winter storm events. The Baseflow and Enhanced Baseflow amounts are used to differentiate the winter storage in John Martin Reservoir. Storage up to the Baseflow amount is considered Article II Water. Storage up to the Enhanced Baseflow amount is considered Article III Water. The ratio of Baseflow : Enhanced Baseflow is used to differentiate John Martin Reservoir inflows and storage in excess of the Enhanced Baseflow amount.

The Article II Water is accounted as storage under the Interstate Compact (aka Conservation Storage). The Article III Water is available to the Fort Lyon Canal, Las Animas Consolidated Canal and Amity Canal in their Other Water accounts.

STORAGE PROTOCOL

Program participants include entities both with and without off-channel reservoir storage reservoirs. Although the location of Winter Water storage varies based on hydrologic conditions, available reservoir storage capacity, ditch operational issues and other issues, a general sequence of storage of Winter Water is as follows:

1. Canal systems located at the top of the lower Arkansas Valley without off-channel storage typically store their Winter Water in Pueblo Reservoir.
    a. Bessemer Ditch
    b. West Pueblo Ditch
    c. Riverside Dairy Ditch
    d. High Line Canal
    e. Oxford Farmers Ditch

2. Canal systems with off-channel storage historically stored water in the reservoirs under the system.
    a. Colorado Canal – Lake Meredith and Lake Henry
    b. Holbrook Canal – Holbrook Reservoir
    c. Fort Lyon Canal – Adobe Creek Reservoir via the Fort Lyon Storage Canal
        The Fort Lyon Canal Company may also divert 5,483 acre-feet of the Amity Mutual Irrigation Company's Winter Water at the Fort Lyon Storage Canal

3. Program participants at the lower part of the system have space in John Martin Reservoir where their Winter Water can be stored (the Article III Accounts, including Fort Lyon Canal – 20,000 ac-ft capacity; Las Animas Consolidated Canal – 5,000 ac-ft capacity; and Amity Canal – 50,000 ac-ft capacity).
    a. All of the Amity Canal's pro rata Winter Water is stored in John Martin Reservoir. The canal company also diverts the Great Plains Reservoir storage rights into John Martin Reservoir pursuant to the alternate place of storage adjudicated in Case No. 80CW19.
    b. Although generally not too significant in magnitude, all of the Purgatoire River inflows to John Martin Reservoir (on the order of about 25 cfs during the winter) are also stored in the Article III accounts.

As discussed further below, some Program participants submit requests each year to the Division Engineer and to the companies with off-channel storage regarding the location of storage of their respective Winter Water amounts. In addition, operations for some of the systems have been modified over time.

Much of the off-channel reservoir storage of Winter Water is controlled at the Colorado Canal headgate. The Colorado Canal company tends to wait for diversions in excess of 200 cfs due to conveyance losses down the Colorado Canal on the order of 30 percent of diversions. Although

operations may change every year the Colorado Canal tends to wait until the latter part of the storage season to start Winter Water diversions. This provides more of the early winter season irrigation return flows in the Arkansas River to be diverted by canal companies in the lower reaches of the Arkansas Valley.

Unlike the other off-channel diversions, the Winter Water diversions in the Colorado Canal are accounted by gage height (i.e., at Lake Meredith and Lake Henry) rather than at the river headgate. Water in storage in Lake Meredith is fairly easily accessed by others through releases from the Meredith Outlet Canal either directly into their system (Holbrook Canal) or by re-diversion of water after delivery to the Arkansas River (Fort Lyon Canal and Las Animas Consolidated Canal). These operations are advantageous to the lower ditches since transit losses assigned to releases from Lake Meredith are not as high as the losses assigned to releases from Pueblo Reservoir. In addition, the conveyance losses down the Fort Lyon Storage Canal and evaporation from the relatively shallow Adobe Creek Reservoir are much higher than the losses attributable to the storage and release of water from Lake Meredith.

The storage of water under the Colorado Canal by non-shareholders is governed by agreements between the canal and reservoir companies involved. Any water stored under the Colorado Canal pursuant to these agreements will typically be released to the non-shareholders early in the spring since this water would get booked out of storage if the Lake Meredith and / or Lake Henry storage rights come into priority during the spring runoff.

Releasing Winter Water from Lake Meredith to the Las Animas Consolidated and Fort Lyon Canal Companies also benefits the recipients since the Article III water is subject to the loss of 35 percent of the stored water into the Kansas Article II account. Nonetheless, these two canal companies do have portions of their Winter Water in John Martin Reservoir. The Fort Lyon Canal Company takes its summer delivery of Winter Water in John Martin Reservoir by exchange. The Fort Lyon Canal Company operation is subject to the exchange right adjudicated in Case No. 90CW47. The Las Animas Consolidated Ditch Company often takes its summer delivery of Winter Water directly from the Purgatoire River in trade for the release to Water District 67 of a like amount of water from the Las Animas Consolidated Article III account in John Martin Reservoir.

The Holbrook Canal historically stored its pro rata Winter Water in Holbrook Reservoir. In addition to the potential storage of its Winter Water in Lake Meredith, as discussed above, the Holbrook Canal Company's pattern of Winter Water storage has changed somewhat in recent years since an intergovernmental agreement (IGA) with the City of Aurora was executed in 2006. Operation under the IGA results in Holbrook Canal Company Winter Water stored in Pueblo Reservoir in exchange for a like amount of Aurora's Rocky Ford Ditch consumptive use credits stored in Holbrook Reservoir the following summer. Winter Water storage in Holbrook Reservoir may also be modified in the future as part of the Restoration of Yield operations, under which the Pueblo Reservoir bypass water is captured below the instream flow reach and the confluence with Fountain Creek.

The Restoration of Yield (ROY) program is an IGA between the Cities of Pueblo, Aurora, Fountain, Colorado Springs and Pueblo and Southeastern Colorado Water Conservancy District. The ROY provides for the recapture and storage of the streamflows bypassed through Pueblo Reservoir to accommodate the Flow Management Program ("Foregone Diversions"). The ROY

program provides for the storage of Foregone Diversions in Lake Meredith and other off-channel storage facilities, including lined gravel pits. Future off-channel locations for ROY storage may be the proposed Stonewall Springs Reservoir, located off of the Excelsior Ditch system north of the Arkansas River near the Pueblo Ordnance Depot. The ROY storage to date has been within Lake Meredith through the Colorado Canal system.

WINTER WATER USE

Program Participants typically release their Winter Water to supplement their direct flow rights. Therefore, the releases are made during the latter part of the irrigation season.

Winter Water in Pueblo Reservoir not used during the summer after it was stored can be carried over to the following year. This Carryover Winter Water must be used prior to May 1 after the winter it was carried over. On May 1, the Division Engineer orders all Carryover Winter Water to be released from Pueblo Reservoir to the Arkansas River of the year after it was carried over. This water becomes river water is not shepherded to any particular ditch headgates. One exception to the carryover protocol was identified based on the review of available records and discussions with various entities. Structural issues on the face of Pueblo Dam were identified in 1997 and Winter Water was not stored from November 1997 through March 1998. Winter Water from the 1996 – 1997 storage season was carried over into 1998 and a portion of it was not released until after May 1, 1998.

Note the Carryover Winter Water protocol discussed above applies only to water stored in Pueblo Reservoir. Winter Water originally stored at other locations is not subject to this protocol.

STORAGE ACCOUNTING

Accounting of the Winter Water program is conducted throughout the storage season at Pueblo Reservoir, John Martin Reservoir and off-channel storage facilities. The Winter Water is balanced each year among Program participants on March 15, dependent on the total yield, amounts of water in storage in various facilities and requests for locations of storage by Program participants.

The total yield of the Winter Water Program since its inception in 1976, gathered from various sources, is summarized in **Table 1**. Data missing from the 1984 through 2001 period indicate bi-weekly reporting sheets published on March 15 of the year in question were not available. The right-most column includes both Storage and Canal Diversions. The Canal Diversions include those diverted at through the Bessemer, Rocky Ford Highline, Oxford, Catlin, Las Animas Consolidated, Riverside, Holbrook, Fort Lyon Storage Canal and Amity systems. The extent of diversions from the above list of canals that do not have off-channel storage is fairly limited (approximately five years, total) during the last 30 years for which these records are available,

Table 1
Winter Water Storage Program Yield
March 15th acre-foot values

Year	Pueblo Reservoir	Lake Meredith	John Martin Reservoir	Cumulative Storage and Diversion
1976	32,179	unknown	unknown	unknown
1977	35,768	unknown	unknown	unknown
1978	No Program	unknown	unknown	unknown
1979	37,809	unknown	unknown	unknown
1980	39,713	unknown	unknown	unknown
1981	49,755	unknown	unknown	unknown
1982	45,241	unknown	unknown	unknown
1983	75,628	unknown	unknown	unknown
1984	82,396	unknown	unknown	unknown
1985	49,912	unknown	unknown	unknown
1986	30,000	unknown	22,350	179,520
1987	20,179	unknown	unknown	unknown
1988	38,050	unknown	unknown	unknown
1989	40,991	15,724	26,479	148,072
1990	36,023	12,950	23,249	129,584
1991	43,340	unknown	unknown	144,625
1992	46,112	16,086	27,556	159,335
1993	48,014	16,619	28,782	163,409
1994	46,122	16,059	28,118	154,289
1995	42,627	15,843	24,541	153,749
1996	34,100	22,379	34,374	177,590
1997	46,505	13,143	34,858	161,706
1998	Limitation	16,090	0	124,607
1999	51,986	11,677	41,819	174,646
2000	23,200	17,150	4,384	178,579
2001	44,867	unknown	unknown	158,390
2002	38,702	19,278	25,024	134,665
2003	31,871	24,589	13,896	74,775
2004	28,378	38,129	13,570	81,439
2005	40,557	46,595	26,064	116,465
2006	38,304	13,219	15,630	111,384
2007	51,140	17,565	21,461	149,577
2008	52,329	17,580	22,155	153,035
2009	48,037	18,672	23,099	140,356
2010	50,012	19,108	23,336	150,077
2011	44,555	22,040	11,411	121,484
2012	41,352	20,346	16,938	121,377

Sources: Pueblo Reservoir – USBR
Bi-Weekly Reports
1984 - 2001 Div 2 Winter Water File Cabinets
2002 - Present Div 2 Electronic Files
Notes: 1986 yield in Pueblo Reservoir limited for unknown reason.
1998 Winter Water Storage in Pueblo Reservoir evacuated due to dam seepage issues.

The pro rata entitlements to the Winter Water pursuant to the Case No. 84CW179 decree are summarized in **Table 2**.

Table 2
Winter Water Storage Program Yield
Canal Company Pro Rata Ownership

Participant	First 100,000 ac-ft	Next 3,106 ac-ft	More than 103,106 ac-ft
Bessemer Canal	6.297%	---	5.2475%
Highline Canal	8.457%	---	7.0475%
Oxford Canal	2.040%	---	1.7000%
Catlin Canal	9.300%	---	7.7500%
Last Animas Consolidated Canal	2.799%	---	2.3325%
Otero Canal	0.699%	---	0.5825%
Riverside Dairy Ditch - West Pueblo Ditch	0.408%	---	0.3400%
Colorado, Henry and Lake Meredith	11.137%	---	12.8025%
Holbrook Canal	8.876%	356 ac-ft	10.5375%
Fort Lyon Canal	38.157%	---	38.1600%
Amity Canal	11.830%	2,750 ac-ft	13.5000%
Total	100%		100%

Source: 84CW179 decree.

HydroBase Data and H-I Model Data:

Pueblo Reservoir releases are an input to the H-I Model and are available from 1976 to 2006. Data subsequent to 2006 are likely available as input to the H-I Model but have not been collected for this effort. The H-I Model data are complete over the 31-year period.

Pueblo Reservoir release data (recorded as From the Pueblo Reservoir Winter Water WDID 1403528) is available in HydroBase from 1976 to present for most of the ditches located between Pueblo Reservoir and John Martin Reservoir. The HydroBase data are available for available for about two-thirds to three-quarters of the 35-year period (1976-2010) reviewed for this effort, as summarized in **Table 3**.

The consistency of data between HydroBase and the H-I Model is dependent on the particular canal system. For most of the canals, about one-third to one-half of the annual values from the H-I Model are within 10 percent of the HydroBase release data. The reasons for the inconsistencies between the two data sources are unknown. Unlike the lower ditches, the Bessemer Canal data are almost wholly consistent between the two sources.

Many of the years where HydroBase data are missing are set to zero in the H-I Model. Setting the missing HydroBase data to zero results in mostly complete records of Pueblo Reservoir Winter Water release data for use in the StateMod modeling effort.

Table 3
Winter Water Release Data from Pueblo Reservoir
1976 – 2010

Participant	HydroBase Data		H-I Model Zero Releases when HydroBase Data Missing	HydroBase and H-I Model	
	Years Available	Average Annual Release (ac-ft)		Average Annual Release (ac-ft)	Total Years Available
Bessemer Canal	29	6,195	5	5,284	34
Highline Canal	32	7,876	1	7,637	33
Oxford Canal	29	1,680	5	1,433	34
Catlin Canal	31	6,994	3	6,377	34
Last Animas Consolidated Canal	5	1,699	25	283	30
Otero Canal	4	434	24	62	28
Riverside Dairy Ditch - West Pueblo Ditch	n/a				
Colorado, Henry and Lake Meredith	22	4,744	9	3,367	31
Holbrook Canal	22	5,373	10	3,694	32
Fort Lyon Canal *	12	1,653	23	567	35
Amity Canal	n/a				

Sources: HydroBase Database version 20130903 and H-I Model input files <WINTER.DAT> and <UPDATE.DAT>.
Note: * Two years (1982-1983) of mostly winter month's releases to Fort Lyon Storage Canal also included in HydroBase (58,454 ac-ft/yr average).

In addition to the Pueblo Reservoir release records there are records of releases of Winter Water stored in Lake Meredith to the Holbrook Canal (1990-1993 and 2006), Fort Lyon Canal (1990, 1993, 2003-2005 and 2008-2009) and Fort Lyon Storage Canal (2007 and 2010). These releases are recorded as Meredith Winter Water WDID 1403598.

It should be noted that, in addition to not being complete, the diversion coding in HydroBase is not always consistent, which may result in diversions and release data from a Source structure not being the same as the Destination structure. For example, there are records of Lake Meredith releases to the three canals listed in the previous paragraph that may or may not be releases of Winter Water.

Despite the possible differences in HydroBase diversion coding and differences with the H-I Model input, the availability of Winter Water release data in HydroBase is considered good. These data can be used for comparison to model simulation output and to help with modifying model input parameters to improve historical calibration efforts.

Restoration of Yield Data:

HydroBase records of ROY operations are not easily accessed. In conjunction with the Division Engineer's Office, records were queried to provide some information for storage of ROY supplies in Lake Meredith. The ROY program has been operated from 2007 through 2011 and has an average diversion of 5,472 acre-feet of water from the Arkansas River for storage in Lake Meredith. The maximum was in 2008 where 10,950 acre-feet was stored and to date over 27,000 acre-feet have been diverted. The typical diversion

was between 50 and 100 cfs into the Colorado Canal and the maximum recorded was 195 cfs.

Aurora-Holbrook 2006 Agreement Data:

The HydroBase records related to the Aurora-Holbrook Agreement are sporadic. A few years of data were identified that may be related to the Agreement. Diversion records to the Holbrook Canal from the Rocky Ford Wasteway (2005-2006, recorded under WDID 170668) and Rocky Ford Ditch Headgate Augmentation Station (2005, recorded under WDID 1700802) are available.

STATEMOD MODEL

The StateMod model is set up so that water is delivered to various destinations (e.g., irrigation demands, storage fills and instream / bypass flows) based on decreed water rights and user-input operating rules. Use of the planning model to represent current and future operations is enhanced if the model is set up such that all supplemental operations (e.g., storage releases, reservoir storage bookovers, etc.) are dynamically simulated, dependent on the amount the input demands are not satisfied by their senior direct flow and storage water rights. Therefore, fixed inputs such as Pueblo Reservoir releases of Winter Water are not desirable.

Nonetheless, the Arkansas River administration and operations is complex and the distribution of Winter Water to Participants is done after the Storage Season concludes. The StateMod program is a deterministic model, in which the developer provides a set of inputs and the program distributes and accounts for water to the different demands based on those fixed inputs. The model only looks forward and does not simulate decisions after the fact. Successive model simulations as part of the historical calibration effort allows the developer to vary different inputs, including the priorities assigned to operating rules in the effort to match historical operations (e.g., simulated streamflows, diversions and storage contents).

At this time, representation of Winter Water operations in the StateMod model is ongoing, specifically the distribution of total yield to project participants. The ultimate method for representing Winter Water to illustrate how future operations may impact existing operations will be discussed in the Task 4 – Model Operations memorandum.

REFERENCES

1) John van Oort, Division 2 River Operation Coordinator. 719.542.3368 x2103.
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4) Kelley Thompson. SEO Decision Support System Modeling group. 303.866.3581 x8261.
5) Roy Vaughan, Theresa Dawson, Valda Terauds and Linda Hopkins. U.S. Bureau of Reclamation, Pueblo Field Office. 719.591.9855.
6) Division of Water Resources. Winter Water Storage Program Synopsis.
7) HydroBase Database. State of Colorado official water resources database developed under the Colorado Decision Support System.