



HB16-1256 SOUTH PLATTE STORAGE STUDY

Final Report

Prepared for the Colorado General Assembly, in coordination with the Colorado Water Conservation Board, the Colorado Division of Water Resources, and the South Platte Basin and Metro Roundtables

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Appendix I – Cost Estimates TM

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1. EXECUTIVE SUMMARY

1.1 INTRODUCTION

The South Platte Storage Study (SPSS) was initiated as a result of House Bill 16-1256 titled “South Platte Storage Study.” It authorizes the Colorado Water Conservation Board, in collaboration with the State Engineer and the South Platte Basin and Metro Roundtables, to identify multi-purpose water storage options along the lower South Platte River to capture flows leaving Colorado in excess of the minimum legally required amounts. The study area for identifying storage options was the lower South Platte Basin between Greeley and the Nebraska State line. Water storage possibilities include new reservoirs, the enlargement/rehabilitation of existing reservoirs, and alternative storage mechanisms (e.g., underground storage).

The study tasks are summarized in [Figure 1-1](#). Study methods and preliminary results were reviewed by and coordinated with members of the Colorado Water Conservation Board, Colorado Division of Water Resources, and South Platte Basin and Metro Roundtables through a series of three workshops and informal reviews. Members of these groups reviewed and commented on draft technical memoranda and the final project report.

The SPSS study was conducted by Stantec Consulting Services Inc., with support from Leonard Rice Engineers, Inc. Funding for the study was provided from the Colorado Water Conservation Board Water Supply Reserve Fund.

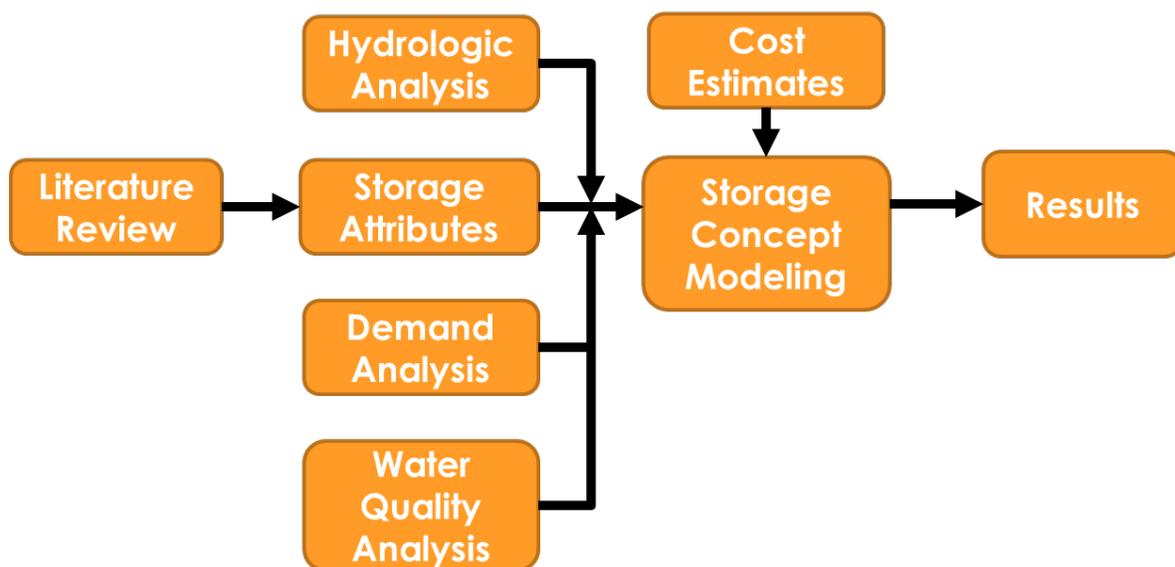


Figure 1-1 – South Platte Storage Study Approach

1.2 LITERATURE REVIEW

Past studies of storage options in the South Platte Basin were reviewed, and a database of storage options identified in these past studies was assembled. Storage options were categorized as new surface storage, existing surface storage enlargement, existing surface storage restoration, existing surface storage rehabilitation, gravel pit storage, and aquifer storage. After eliminating sites outside the SPSS study area and combining similar storage concepts, 73 surface storage options (excluding gravel pits) and 22 aquifer storage options were selected for evaluation.

1.3 LEGAL AND REGULATORY OVERVIEW

Federal, state and local regulations and permits that could affect the feasibility of storage options in the SPSS study area were reviewed and summarized. Key regulations and permits to consider during project development include: U.S. Army Corps of Engineers 404 permit, National Environmental Policy Act, Endangered Species Act, Platte River Recovery Implementation Program, South Platte River Compact, Colorado water rights administration, and local 1041 regulations.

1.4 HISTORICAL FLOW ANALYSIS

The historical flows at the Nebraska State line for the period 1996-2015 (water years) were analyzed to estimate the total amount of water leaving Colorado and the amount of water leaving Colorado in excess of the South Platte River Compact. [Table 1-1](#) shows statistics for total water leaving Colorado and water delivered to Nebraska in excess of the Compact for this 20-year period.

Table 1-1. Historical Annual Flow for 1996-2015 at Nebraska State Line

Statistic	Physical Water Leaving Colorado (Julesburg Gage)	Water Delivered to Nebraska in Excess of the Compact ⁽¹⁾⁽²⁾
Annual Median (ac-ft/yr)	331,000	293,000
Annual Average (ac-ft/yr)	436,000	397,000
Minimum Year (ac-ft/yr)	29,000	10,000
Maximum Year (ac-ft/yr)	1,957,000	1,904,000
Total for 20-yr Period 1996-2015 (ac-ft)	8,728,000	7,939,000

(1) Storable flow Julesburg gage

(2) Future environmental flow obligations could reduce legally available water.

1.5 AVAILABLE WATER FOR STORAGE

A daily point flow model was used to compute the amount of water that would be physically and legally available for storage in a new SPSS storage project. Available water was computed for two hydrologic conditions: (1) historical conditions for the 1996-2015 period of record in the point flow model; and (2) future conditions using the same basic hydrology. Future hydrology was estimated by reducing the historical point flow model results by an allowance for Identified Projects and Processes (IPPs) in Colorado's Water Plan and an allowance for existing conditional exchange water rights that have not been executed to date. Statistics defining water available for storage at five locations in the SPSS study area are given in [Table 1-2](#). Estimated future median annual available water is 20-30 percent less than median annual available water in the 20 years between 1996 and 2015. The median is a better statistic to describe typical conditions because there are a few high flow years that skew the average in the study period.

Table 1-2. Available Water for Selected Locations Based on Historical and Future Hydrology

Location	Median Annual Available Water (ac-ft)	Average Annual Available Water (ac-ft)	Available Water in Wet Year (ac-ft)	Available Water in Normal Year (ac-ft)	Available Water in Dry Year (ac-ft)
	All Years	All Years	1999	2010	2002
Historical Hydrology (1996-2015)					
South Platte River near Kersey	165,000	262,000	707,000	378,000	14,000
South Platte River near Weldona	179,000	281,000	731,000	411,000	18,000
South Platte River near Balzac	185,000	297,000	771,000	440,000	18,000
Lowline Ditch/Henderson Smith Ditch	200,000	314,000	799,000	476,000	33,000
South Platte River at Julesburg	289,000	397,000	951,000	627,000	79,000
Future Hydrology Based on IPP and Conditional Water Right Adjustments					
South Platte River near Kersey	116,000	214,000	580,000	275,000	6,000
South Platte River near Weldona	127,000	231,000	601,000	303,000	9,000
South Platte River near Balzac	144,000	246,000	641,000	326,000	9,000
Lowline Ditch/Henderson Smith Ditch	154,000	261,000	666,000	357,000	15,000
South Platte River at Julesburg	232,000	332,000	815,000	494,000	54,000

1.6 WATER DEMAND

Maximum potential water demands in the SPSS study area were estimated for use in the subsequent analysis to determine feasible sizes for conceptual SPSS storage projects. Agricultural and municipal & industrial (M&I) demands were estimated for four water districts and counties in the SPSS study area between Denver and Julesburg based on data from the Statewide Water Supply Initiative (SWSI 2010). Maximum demands on SPSS reservoirs were assumed to be equal to the future water supply gap or shortage (difference between demand and supply) for the lower South Platte Basin as reported in SWSI 2010. For purposes of the storage analysis, demands were aggregated at the five key locations on the South Platte River at which available water was estimated. **Figure 1-2** summarizes available supply and maximum potential demand values used for the SPSS analysis. Total median available supply is less than the total shortages in the upper part of the study area; for example, at the Denver gage the median available supply is 5,000 ac-ft compared to total M&I and agricultural water shortages of 106,000 ac-ft. In the lower part of the study area the median available water is greater than the total M&I and agricultural water shortages (232,000 ac-ft median available supply compared to 18,000 ac-ft shortages at the Julesburg gage).

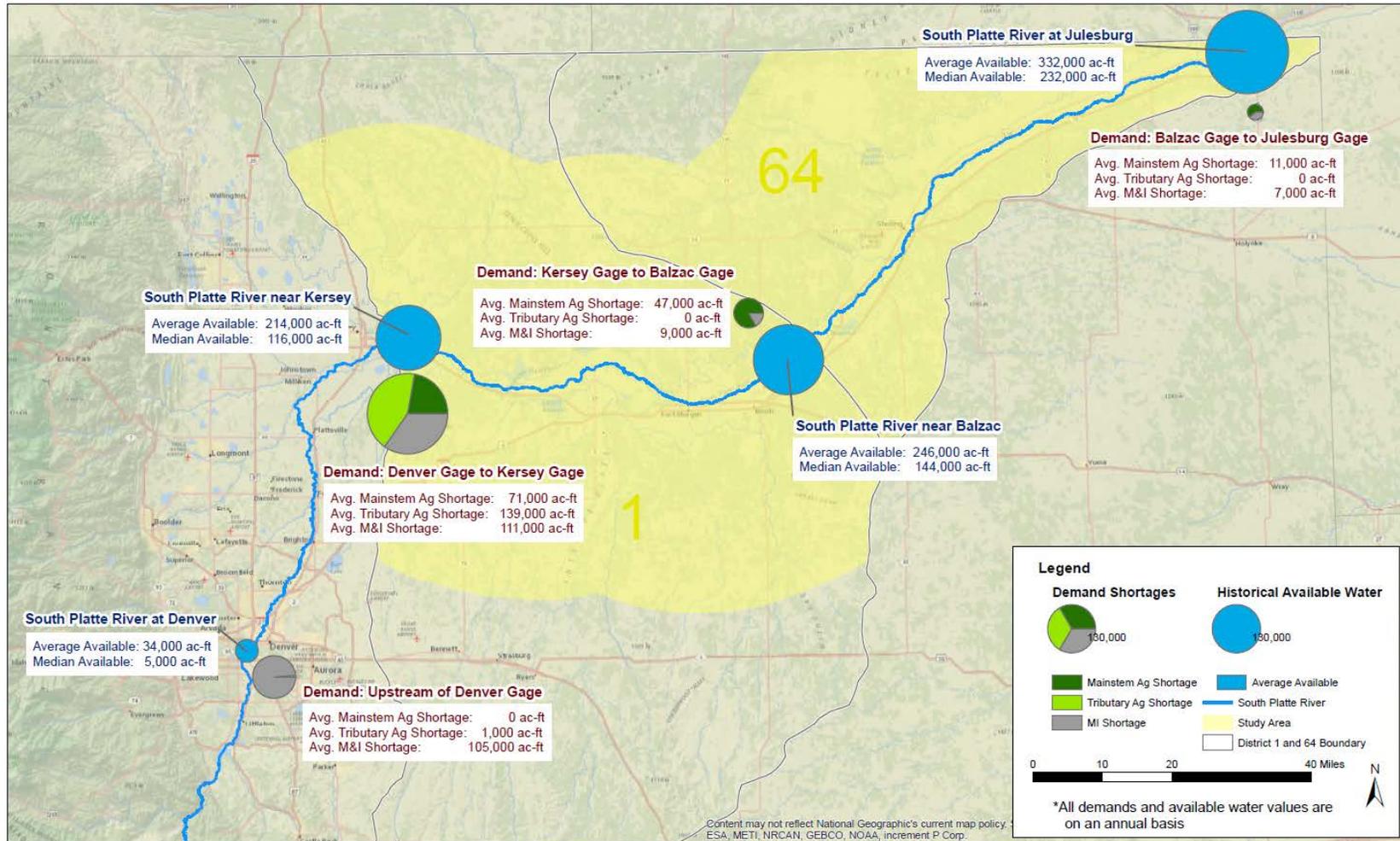


Figure 1-2. Summary of Available Water and Maximum Potential Demands at Key Locations in SPSS Study Area

1.7 WATER QUALITY

The quality of water available for a new storage project in the lower South Platte Basin could affect the feasibility of putting that water to beneficial use. Similarly, enlarging or rehabilitating existing reservoirs would only be feasible if water quality would be appropriate with treatment for the intended uses.

Existing water quality data for stream segments and reservoirs was reviewed and impaired water bodies based on the state’s water quality assessment were identified. Water diverted for storage in the SPSS study area would be adequate quality for irrigation use, as these sources are currently widely used for agricultural purposes. However, if used directly as a drinking water supply, water from any new SPSS storage project would require a high level of treatment (e.g., reverse osmosis, ion exchange) to remove a number of problematic constituents including arsenic, selenium, sulfate, total dissolved solids, and uranium. In addition, water used for aquifer storage in managed groundwater basins would have to be treated prior to recharge to protect existing groundwater quality.

1.8 STORAGE OPTIONS

The SPSS evaluation process involved analyzing storage options (individual reservoir or aquifer storage facilities) and more comprehensive storage concepts or solutions. Storage concepts include individual storage options or combinations of storage options integrated with all other infrastructure required to have an operational storage project. Storage options were analyzed first, and the most promising options were incorporated into storage concepts. The overall storage evaluation process is summarized in [Figure 1-3](#).

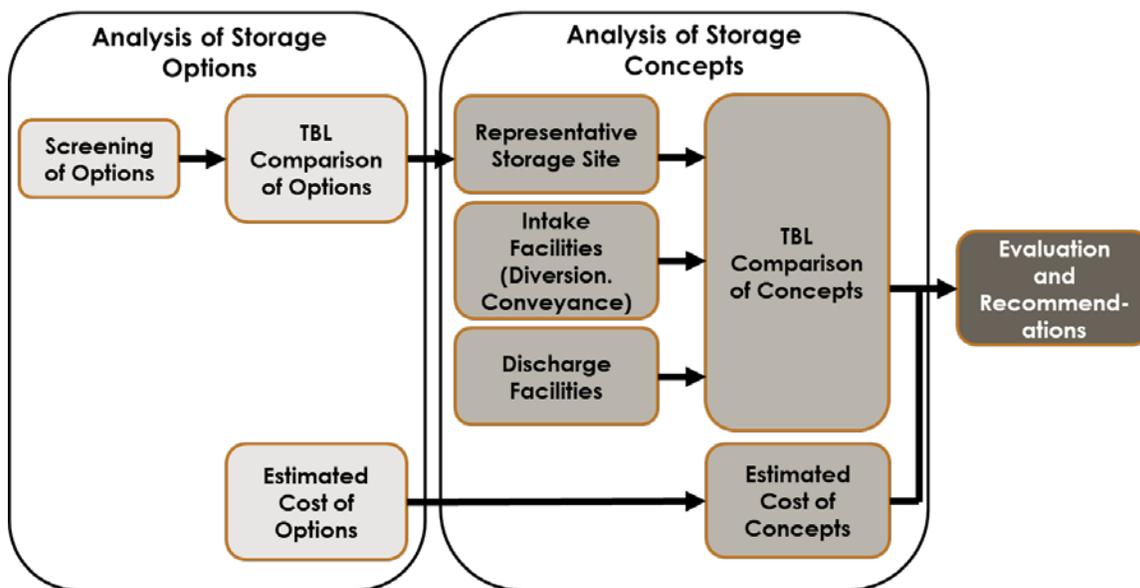


Figure 1-3. SPSS Storage Evaluation Process Overview

The long-list of possible storage sites in the SPSS study area was screened to identify those with the most potential for incorporating into SPSS storage concepts. Storage options not selected for use in creating storage concepts are not necessarily infeasible or inferior, depending on the particular application, and should be retained for consideration in any future studies. The storage site screening process is summarized in [Figure 1-4](#). Surface and aquifer storage options remaining after the screening process are shown in [Figure 1-5](#).

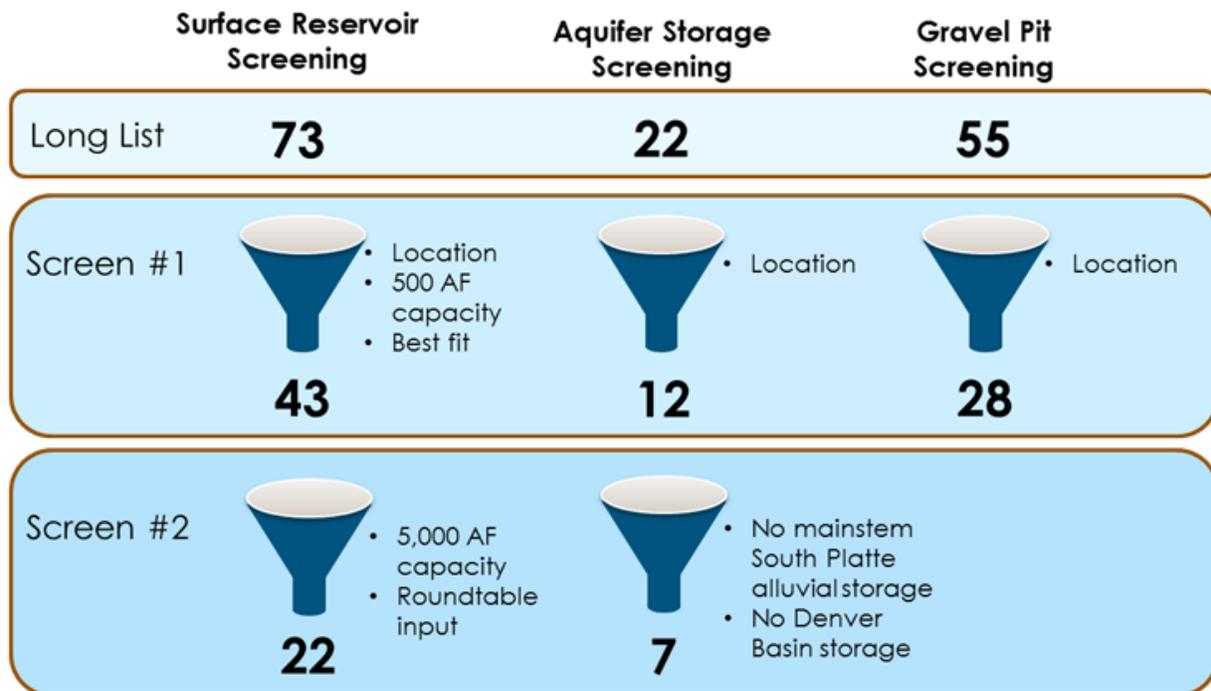


Figure 1-4. Summary of Storage Site Screening Process

Storage options were evaluated for 25 technical, environmental and social criteria based on available information on the sites and experience of the project team. Using this triple bottom line (TBL) type of evaluation process usually involves weighting categories of criteria in different ways to explore different value systems of stakeholder groups. For this study three criteria weighting scenarios were tested: equal weights, higher weighted technical criteria, and higher weighted environmental criteria. Most storage options ranked similarly regardless of the weighting scenario. [Table 1-3](#) lists the average of the scores under the three weighting scenarios. Because storage categories have different characteristics in terms of how they would be developed and operated, it is appropriate to compare sites within categories but not necessarily between categories.

Current cost estimates for surface storage options were developed based primarily on past studies supplemented by additional work by the consultant team. Costs were expressed in 2017 dollars and include permitting, design, land acquisition, and construction, with an accuracy of -50% to +100%. Results are summarized in [Table 1-3](#). Costs were not estimated for certain storage options that were not included in storage concepts described later in this report.

Aquifer storage concepts were assumed to be supplemental supply projects that would either work in conjunction with a surface reservoir or be smaller stand-alone projects. To standardize the comparative analysis they were assumed to have infiltration basins with 5,000 ac-ft/month (82 cfs) capacity for recharge and extraction wellfields with 4,000 ac-ft/month (65 cfs) capacity for recovery.

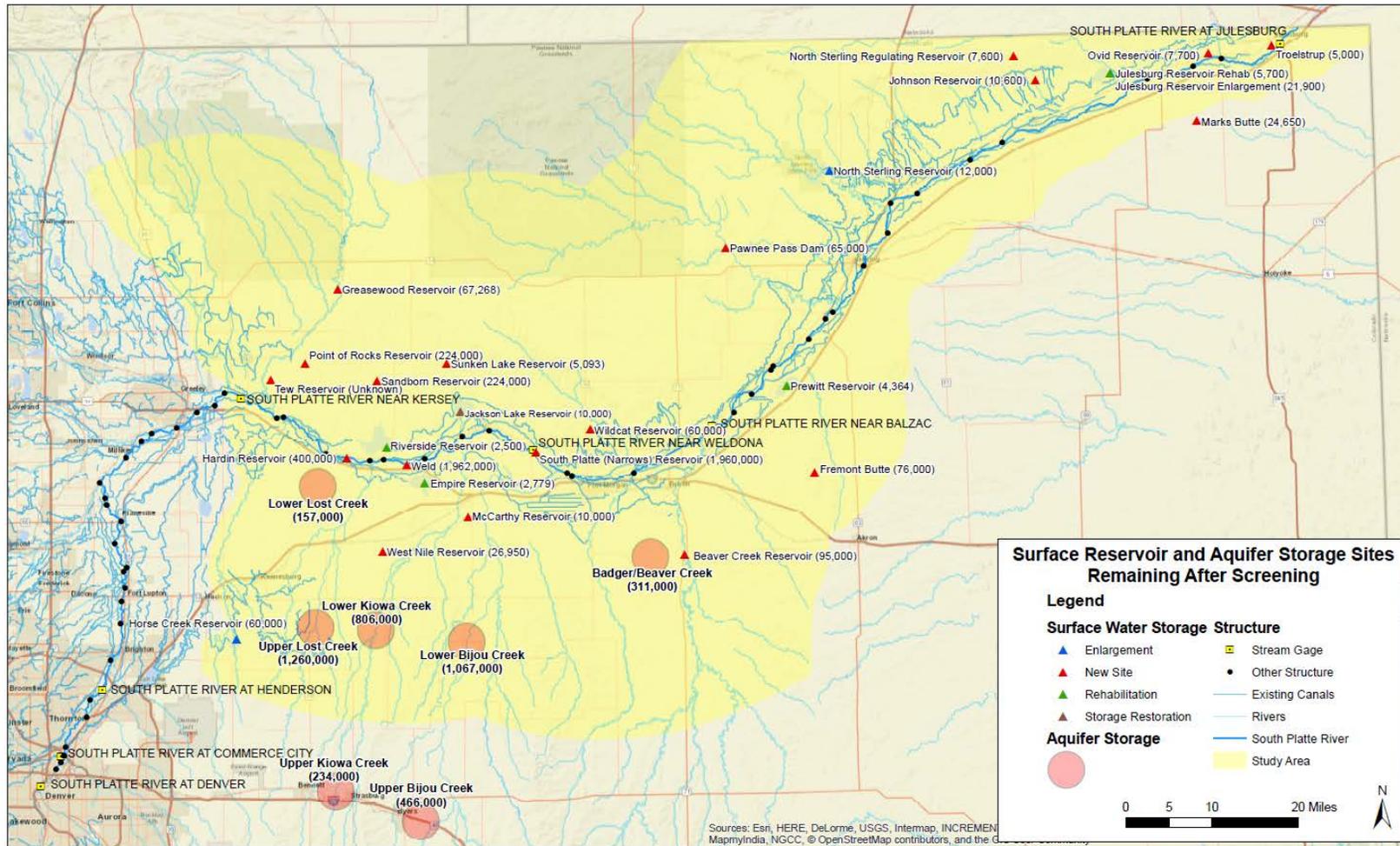


Figure 1-5. Surface Reservoir and Aquifer Storage Sites Remaining After Screening

Table 1-3. Storage Option Costs and Scores

Storage Type/Name	Storage Capacity (ac-ft)	Estimated 2017 Cost (\$ million)	Unit Cost (\$/ac-ft)	Average of Scores for 3 Weighting Scenarios ⁽¹⁾
New Site - Mainstem				
South Platte (Narrows) Reservoir	1,960,000	\$145	\$74	11.2
Hardin Reservoir	400,000	-	-	8.7
New Site – Off Chann				
Sandborn Reservoir	224,000	\$131	\$580	11.0
West Nile Reservoir	26,950	\$59	\$2,100	8.5
McCarthy Reservoir	10,000	\$27	\$2,500	9.3
Wildcat Reservoir	60,000	\$79	\$1,300	14.3
Pawnee Pass Dam	75,000	\$254	\$3,400	10.7
Fremont Butte Reservoir	76,000	\$74	\$980	11.2
North Sterling Regulating Reservoir	7,600	\$38	\$5,000	11.7
Johnson Reservoir	10,600	\$24	\$2,300	11.7
Ovid Reservoir	7,700	\$24	\$3,100	10.8
Troelstrup Reservoir	5,000	\$19	\$3,700	10.8
Beaver Creek Reservoir	95,000	\$66	\$690	13.2
Point of Rocks Reservoir	224,000	-	-	13.5
Sunken Lake Reservoir	5,100	-	-	10.2
Greasewood Reservoir	67,300	-	-	9.8
Enlargement				
North Sterling Reservoir Enlargement	12,000	\$22	\$1,800	11.7
Julesburg Reservoir Enlargement	21,900	\$44	\$2,000	13.7
Rehabilitation				
Empire Reservoir Rehab	2,779	\$14	\$5,000	16.0
Prewitt Reservoir Rehab	4,364	\$5.5	\$1,300	14.3
Julesburg Reservoir Rehab	5,700	\$31	\$5,400	17.8
Jackson Lake Reservoir Rehab	10,000	\$37	\$3,700	15.2
Riverside Reservoir Rehab	2,500	\$13	\$5,200	16.0

Storage Type/Name	Storage Capacity (ac-ft)	Estimated 2017 Cost (\$ million)	Unit Cost (\$/ac-ft)	Average of Scores for 3 Weighting Scenarios ⁽¹⁾
Aquifer Storage				
Lower Lost Creek Basin	157,000	\$39	N/A ⁽²⁾	19.2
Upper Lost Creek Basin	1,260,000	\$39	N/A ⁽²⁾	16.7
Lower Bijou Creek Basin	1,067,000	\$39	N/A ⁽²⁾	17.5
Upper Bijou Creek Basin	466,000	\$39	N/A ⁽²⁾	13.5
Lower Kiowa Creek Basin	806,000	\$39	N/A ⁽²⁾	16.0
Upper Kiowa Creek Basin	234,000	\$39	N/A ⁽²⁾	13.5
Badger/Beaver Creek Basin	311,000	\$39	N/A ⁽²⁾	15.8

(1) Range of possible scores is 0 – 34.

(2) Not applicable. Cost is a function of recharge and extraction hydraulic capacities, not storage capacity.

1.9 STORAGE CONCEPTS

Storage concepts were organized based on the reach of the lower South Platte River in which a storage project would be located, the reach from which water would be diverted, and whether storage would be achieved in a surface reservoir or groundwater basin. Storage concepts consisted of a specific storage option, an approach to capture water from the South Platte River, and an approach to deliver water to meet demands. While hundreds of possible storage concepts could be envisioned in the lower South Platte Basin, eight representative storage concepts were selected to investigate the range of practical storage projects in the region.

Each storage concept was simulated using a MODSIM water resources model developed for this project. To simplify the analysis and focus on differences due to storage options, surface storage concepts had the following consistent features:

- A representative storage option at the maximum physical capacity.
- New dedicated 800 cfs (520 mgd) river diversion with 10,000 ac-ft gravel pit for regulating storage. Although existing irrigation canals could be used to assist in filling some storage options, a detailed analysis of this opportunity was outside the SPSS scope.
- 400 cfs (260 mgd) bi-directional conveyance from intake to storage.
- Release back to river in the bi-directional pipeline to meet downstream demands or exchange to Kersey demand location.
- 150 cfs (100 mgd) conveyance to the Brighton area to meet demands in the Denver metro area.

ASR concepts were limited to a combined inflow rate of 82 cfs (54 mgd) based on the assumed recharge capacity and an outflow rate of 65 cfs (43 mgd) based on the assumed recovery wellfield capacity. All storage concepts were simulated to release water from storage to meet demands as follows.

- First, release to the South Platte River to meet downstream demands.
- Second, exchange to Kersey to meet northern Front Range demands.
- Third, pump to Brighton to meet Denver metro area demands.

No attempt was made in this study to optimize infrastructure or operational assumptions for any of the concepts. The new MODSIM model was used to estimate the firm yield for the eight selected storage concepts. **Table 1-4** provides a short description of each storage concept, and the annual firm yield (yield that can be delivered every year) with and without a pipeline to Brighton. This pipeline is an expensive component of any solution so firm yield with and without this component was computed.

Table 1-4. Storage Concept Annual Yield for Maximum Capacity of Representative Storage Sites

Storage Concept	Representative Storage Site(s)	Diversion Reach	Limiting Capacity	Annual Firm Yield with Pipeline to Brighton (ac-ft/yr)	Annual Firm Yield without Pipeline to Brighton (ac-ft/yr)
Surface Reservoir Concepts					
Mainstem Storage	South Platte (Narrows)	Greeley-Weldona	1,960,000 ac-ft	62,000	47,000
Upper Basin Storage	Sandborn	Greeley-Weldona	224,000 ac-ft	22,000	20,000
Mid Basin Storage North	Wildcat	Weldona-Balzac	60,000 ac-ft	9,000	7,000
Mid Basin Storage South	Beaver Creek	Weldona-Balzac	95,000 ac-ft	11,000	8,000
Lower Basin Storage	Julesburg, Ovid, Troelstrup	Balzac-Julesburg	40,300 ac-ft	24,000	24,000
Existing Reservoir Improvements	Riverside, Jackson, Prewitt, Julesburg, North Sterling	Greeley-Weldona Weldona-Balzac Balzac-Julesburg	56,464 ac-ft	17,000	15,000
Aquifer Storage Concepts					
Groundwater Basin Storage West – Recharge Limited	Lower Lost Creek Aquifer	Greeley-Weldona	5,000 ac-ft/month recharge	8,400	8,400
Groundwater Basin Storage East – Recharge Limited	Beaver/Badger Aquifer	Weldona-Balzac	5,000 ac-ft/month recharge	8,000	8,000

Similar to the evaluation of storage options, storage concepts were evaluated for 20 TBL criteria based largely on the criteria listed in HB16-1256, and total costs for all components included in the concepts. [Table 1-5](#) summarizes storage concept costs and TBL scores. Cost estimates include the following assumptions:

- No water treatment costs are included for water delivered to the Brighton or Kersey demand nodes for M&I use.
- Additional infrastructure needed to convey water from Brighton or Kersey to ultimate project beneficiaries is not included.
- All concepts only make use of new diversion structures and intakes. Any potential for use of existing irrigation canals is not considered.
- All concepts include an expensive pipeline and pumping system to Brighton in order to maximize the yield and allow for an even comparison of storage options. Eliminating the pipeline reduces firm yield by 0 to 15,000 ac-ft/yr, and reduces total storage concept cost by \$280M - \$780M.

Table 1-5. Summary of Storage Concept Costs for Maximum Representative Storage Sites

Storage Concept (Representative Sites)	Storage Capacity (ac-ft)	Storage Cost (\$M)	Intake System Cost (\$M) (Diversion, Gravel Pits, Pipes, Pump)	Delivery System Cost (\$M) (Pipe to Brighton, Kersey Gravel Pits)	Total Storage Concept Cost (\$M)	Total Unit Cost (\$/AFY Firm Yield)	TBL Score (Range: 0-20)
Surface Reservoir Concepts							
Mainstem Dam (Narrows)	1,960,000	\$145	\$0	\$380	\$525	\$8,500	11.5
Upper Basin Storage (Sandborn)	224,000	\$131	\$168	\$322	\$621	\$28,000	12
Mid Basin Storage North (Wildcat)	60,000	\$79	\$141	\$433	\$652	\$72,000	11
Mid Basin Storage South (Beaver)	95,000	\$66	\$407	\$437	910	\$83,000	11
Existing Reservoirs (Riverside, Jackson, Prewitt, Julesburg, North Sterling)	40,300	\$121	\$221	\$322	\$662	\$39,000	10
Lower Basin Storage (Julesburg, Ovid, Troelstrup)	56,464	\$118	\$92	\$826	\$1,037	\$43,000	8
Aquifer Storage Concepts							
Groundwater Storage West (Lost Creek) – Recharge Limited	157,000	\$39	\$238	\$158	\$435	\$52,000	12
Groundwater Storage East (Badger/Beaver) – Recharge Limited	311,000	\$39	\$160	\$270	\$469	\$59,000	10.5

1.10 CONCLUSIONS AND RECOMMENDATIONS

1.10.1. Conclusions

1.10.1.1 Available Water, Demand and Water Quality

The following conclusions relate to available water in the SPSS study area.

1. A large supply of water is available for beneficial use in the lower South Platte Basin. Between 1996 and 2015, an annual median of approximately 293,000 ac-ft/yr of water was delivered to Nebraska in excess of the South Platte Compact. Excess available water varied between 10,000 ac-ft/yr and 1,904,000 ac-ft/yr over this period.
2. Under future conditions, average annual water available for diversion to a new storage project would vary from approximately 214,000 ac-ft/yr at Kersey to 332,000 ac-ft/yr at Julesburg. Median annual available water would vary from approximately 116,000 ac-ft/yr at Kersey to 232,000 ac-ft/yr at Julesburg, highlighting the influence of a few high runoff years on streamflow statistics in the South Platte Basin.
3. Annual streamflows in the study area are characterized by a few very high flow years. A large mainstem dam or several off-stream dams with large diversion structures would be required to capture a large portion of the available streamflow.
4. Available water at Kersey is much less than at Julesburg due to return flows in the lower basin. A large lower basin reservoir(s) would be required as part of a storage scheme to capture a large portion of available flow upstream of the state line.
5. Because the vast majority of storage options are located off the main South Platte River channel, physically available water is constrained by the diversion capacity and the capacity of conveyance facilities from the river to the storage reservoir. Large diversion and conveyance structures would be needed to capture and convey water from the river to off-channel storage. At the Balzac gage near the middle of the SPSS study area, a diversion capacity of 550 cfs would be needed to capture 85 percent of the available water.
6. Future water shortages in the lower South Platte Basin based on the water supply gap estimated in SWSI 2010 are significant, and exceed the estimated available water in the future. Annual municipal and agricultural demands that could potentially be served by water from a SPSS storage project total over 502,000 ac-ft/yr for the Denver Metro Area, the Northern Front Range Region, and the lower South Platte basin below Greeley.
7. Water quality throughout the SPSS study area is adequate for agricultural use but would require advanced water treatment for direct municipal use.

1.10.1.2 Storage Options and Concepts

Conclusions related to the SPSS analysis of storage opportunities in the lower South Platte Basin are summarized as follows.

1. Many off-channel storage options are feasible and can be combined in a wide variety of water supply concepts.
2. Firm yields of 9,000 ac-ft/yr to 62,000 ac-ft/yr were estimated for the representative storage concepts analyzed for this study.
3. Capital costs for storage concepts range from \$7,400 to \$78,200/ac-ft/yr, exclusive of treatment costs, with a pipeline to Brighton. Without the pipeline to Brighton the concept costs range from \$3,300 to \$47,000/ac-ft/yr exclusive of treatment costs. The upper end of this range greatly exceeds the cost of recent water development projects in Colorado.
4. Not surprisingly, a large mainstem reservoir has the best performance in terms of putting the state's water to beneficial use. However, permitting obstacles may be insurmountable.
5. Aquifer storage projects are more limited by recharge and recovery rates rather than storage volume. Typical aquifer storage projects are designed as supplemental supply sources, not as projects to recharge large volumes of water diverted during peak spring snowmelt periods. This results in lower firm yield, and does not attempt maximize use of potential storage capacity as occurs with surface reservoirs. However, a related benefit is that aquifer storage projects are relatively low cost and can be scaled up over time (not constructed all at once). These unique characteristics make aquifer storage projects difficult to compare to surface water storage projects.
6. Storage options lower in the basin tend to be more efficient (better storage:yield ratio) because there is more water available. However they are further from the main demand centers.
7. Combinations of storage options working conjunctively can provide significantly more benefit than individual options. A combination of upper basin and lower basin storage concepts rivals the large mainstem dam option for firm yield benefits. However, there will be reduction in efficiency as the number of projects goes up, and even with multiple storage project a large amount of available water would leave Colorado.
8. No feasible storage concepts or reasonable combinations of concepts are capable of putting all the available flow in the lower South Platte River to beneficial use. This is shown in [Table 1-6](#). Therefore as a general principle, more storage will always be "better" in this region in terms of maximizing available supply for basin water users.

Table 1-6. Water Leaving the State under Future Hydrology for Simulated Storage Concepts

Storage Concept	Median Annual Water Leaving State (ac-ft)	Percentage of Available Water Contributing to Beneficial Use ⁽¹⁾
No Storage	249,000	-
Mainstem Storage	150,000	51%
Upper Basin Storage	210,000	19%
Mid Basin Storage North	196,000	21%
Mid Basin Storage South	192,000	22%
Lower Basin Storage	78,000	44%
Existing Reservoir Improvements	100,000	50%
Groundwater Basin Storage West	213,000 ⁽²⁾	18%
Groundwater Basin Storage East	196,000 ⁽²⁾	21%

(1) Includes evaporation losses and other losses which would not be beneficial uses

(2) Assumes maximum size to capture peak spring runoff. Actual projects would be smaller and leave more water at the state line.

9. Because nearly all concepts require off-channel storage and diversion from the South Platte River, intake capacity constraints can be important and there are benefits to having multiple off-channel storage projects to minimize the effects of these constraints.
10. Enlargements and rehabilitations of existing reservoirs tend to score higher than new reservoirs in the multi-criteria ranking process.
11. Triple bottom line scores for the storage sites analyzed in this study were fairly similar at this level of analysis without specific information on how the sites would be used in a water supply strategy; thus the triple bottom line scoring process should not be used to eliminate options at this time.
12. Any of the storage concepts could be candidates for further study in the future under the right circumstances. However, concepts with more storage higher in the basin generally offer a greater potential for benefits and could be more attractive to a broader variety of potential participants.
13. Multiple large storage projects, including one low in the basin, would be required to capture a substantial amount of the available water above the state line.
14. Even a combination of conjunctively operated storage projects would not be capable of addressing the majority of the combined overall M&I and agricultural water supply gaps in the South Platte Basin.

1.10.2. Recommendations

The SPSS team developed the following recommendations for future work.

1. Better estimates of future hydrology should be developed to refine the anticipated available water under future basin operations. Completion of the South Platte Decision Support System would facilitate further hydrologic and operational studies.
2. Exchanges will be important to making storage work cost effectively for many applications. A more robust method of estimating future exchange potential may be needed to refine this important aspect of the analysis.
3. Site-specific and owner-specific analyses will be needed when particular project opportunities are identified in the future. The work in the SPSS is a starting point for more specific alternative investigations, but substantial additional analysis will be required to test the feasibility of specific storage options based on points of diversion, intake systems, and methods of operating to meet demands.
4. Aquifer storage and recovery projects will require site specific aquifer characterization and pilot testing. Pilot testing and preliminary design can begin at a relatively low cost due to the scalability of ASR systems.
5. Using existing irrigation canals to fill storage sites could significantly reduce infrastructure costs for some concepts. Partnerships with irrigation companies and available canal capacities should be investigated further.
6. Cooperative storage projects with multiple users, multiple components and multiple purposes would have the best chance of success. The state, Roundtables and water users should continue to explore opportunities for cooperative multi-use storage projects in the lower South Platte Basin.
7. Gravel pit storage opportunities were not considered in detail in this study. Gravel pits have been used extensively for storage along the South Platte River upstream of Greeley. An investigation of gravel pit storage opportunities downstream of Greeley may be warranted.
8. Use of water from SPSS storage projects directly for M&I use would require advanced water treatment. Recharge into aquifer storage would also require treatment. Additional investigation is required into the feasibility of available advanced treatment processes on water quality from the study area, particularly in the further downstream reaches of the South Platte River.
9. Investigation is warranted into how storage could support future implementation of alternative transfer method (ATM) projects per recommendations in the South Platte Basin Implementation Plan. Most or even all ATM project would need storage to increase yield and project efficiency. Investigation is needed into how new storage projects could be utilized in combination with ATMs to efficiently store and deliver available water as well as water provided from ATM projects. This combination could potentially make both new storage and ATM projects more feasible and help meet the water supply gaps in the basin.
10. Future storage projects would have an impact on Colorado's water obligation to the PRRIP. Membership in SPWAP in addition to coordination with the State of

Colorado and SPWAP would be necessary to comply with all PRRIP mitigation requirements for new South Platte water storage projects. Further investigation into SPWRAP effects of new storage projects is recommended.

11. This study did not simulate conjunctive operation of a large surface storage project with an ASR project. Benefits of conjunctive use should be investigated.
12. This study did not evaluate potential supplies or storage opportunities upstream of Kersey on the South Platte River or Poudre River. Extending the water availability study and the investigation of potential storage options upstream of Kersey on the South Platte River and Cache la Poudre River should be considered.

2. INTRODUCTION

The South Platte Storage Study (SPSS) was initiated as a result of House Bill 16-1256 titled “South Platte Storage Study.” HB16-1256, provided in **Appendix A**, was signed into law by the Governor on June 9th, 2016. It authorizes the Colorado Water Conservation Board (CWCB), in collaboration with the State Engineer (SEO) and the South Platte Basin and Metro Roundtables, to identify multi-purpose water storage options along the lower South Platte River to capture flows leaving the state in excess of the minimum legally required amounts. The study area for identifying storage options was the lower South Platte Basin between Greeley and the state line. The study area is shown in **Figure 2-1**. Water storage possibilities include new reservoirs, the enlargement/rehabilitation of existing reservoirs, and alternative storage mechanisms (e.g., underground storage).

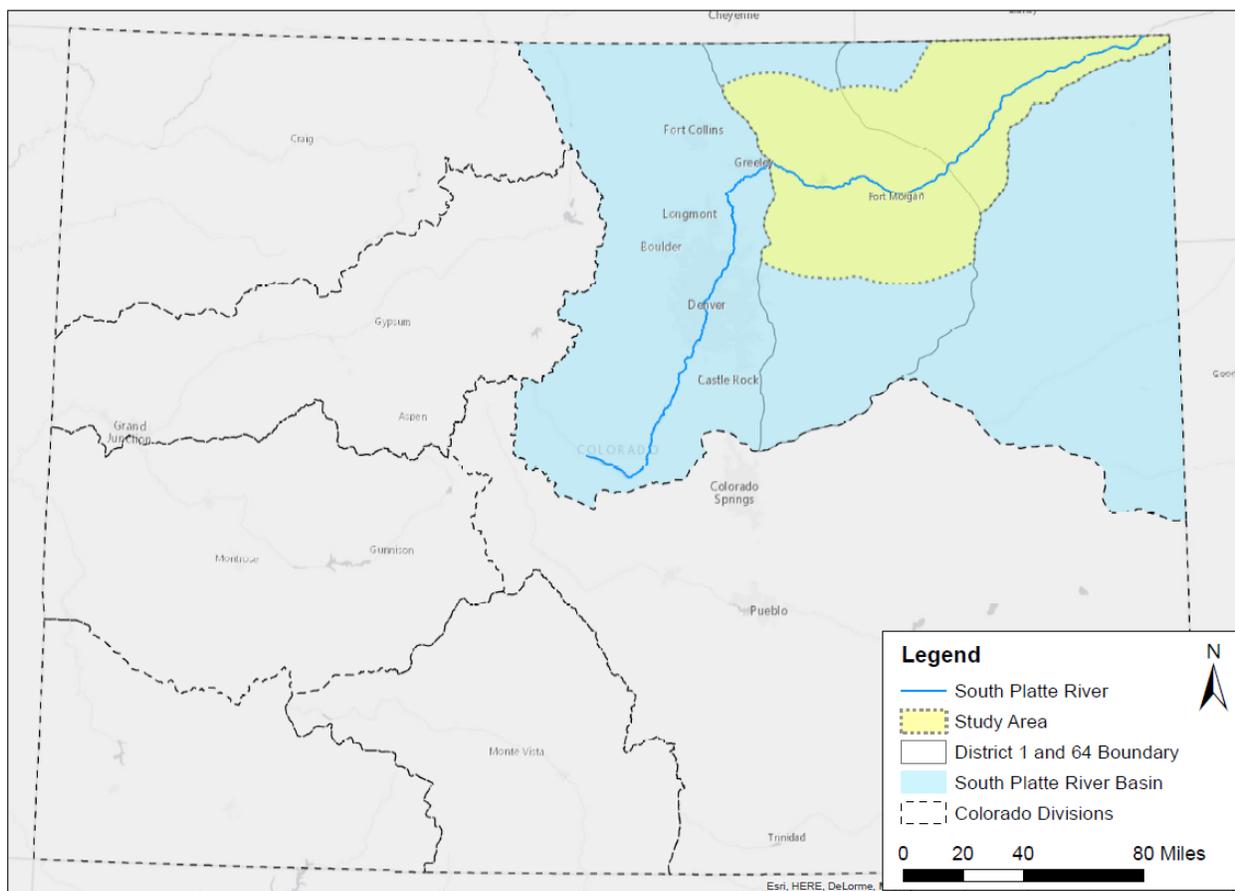


Figure 2-1. Study Area for South Platte Storage Study

This report presents a summary of the analysis and results of the SPSS. Detailed descriptions of technical approaches and preliminary results for specific topics were provided in technical memoranda (TM) during the course of the project. These TMs are included as appendices to this report. The study approach is summarized in **Figure 2-2**.

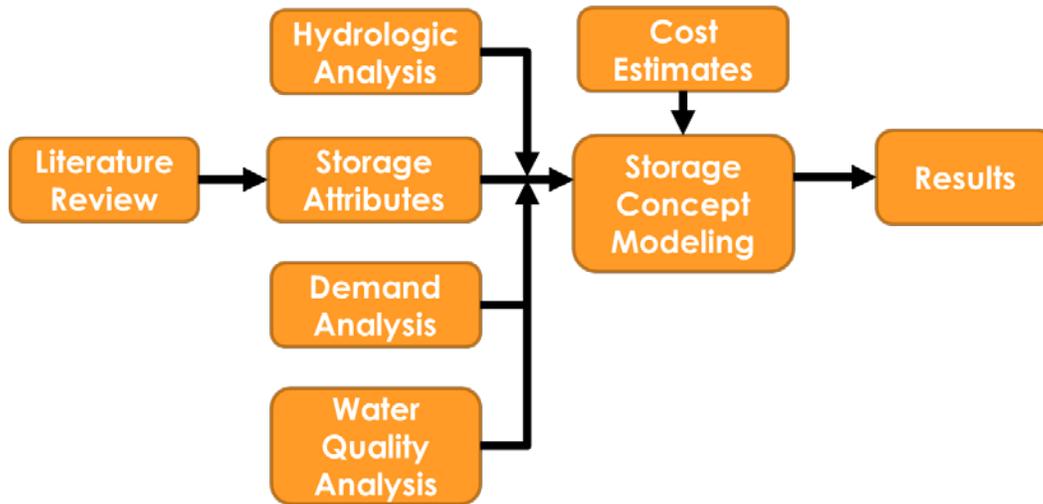


Figure 2-2. South Platte Storage Study Approach

Study methods and preliminary results were reviewed by and coordinated with representatives of the Colorado Water Conservation Board (CWCB), Colorado Division of Water Resources (CDWR), and the South Platte Basin and Metro Roundtables. Three workshops were held with representatives of these groups to present preliminary findings and receive direction on future tasks. They also provided reviews of draft technical memoranda and the final project report.

The SPSS study was conducted by Stantec Consulting Services Inc., with support from Leonard Rice Engineers, Inc. Funding for the study was provided from the Colorado Water Conservation Board Water Supply Reserve Fund.

3. PREVIOUS STUDIES

3.1 INTRODUCTION

Storage opportunities in the South Platte Basin have been studied by a variety of different agencies, including the state and individual water users. Some of these past studies sought to address broad regional water needs (e.g., the South Platte Basin Implementation Plan (HDR/West Sage, 2015)), while others were conducted by individual water users to meet their own storage needs. In some cases, those storage opportunities were part of water users' long term plans and are included in Colorado's Water Plan (CWCB, 2015) as Identified Projects and Processes (IPPs). In other cases, storage opportunities were ruled out by the water user that studied them because they did not meet the needs of the water user. These storage opportunities previously ruled out have been included herein because they could be an opportunity for others.

3.2 SOURCES OF INFORMATION

The sources of information reviewed for this study are listed in **Appendix B**. Pertinent information for storage sites was extracted from a variety of reports and databases. Reports covering areas throughout the basin were reviewed, but the emphasis was on storage options in the designated SPSS study area between Greeley and the state line.

3.3 STORAGE SITE CLASSIFICATION

Storage sites found in the literature review were separated into three main categories: surface storage sites, aquifer storage sites, and gravel pit sites. Gravel pit storage was separated from the surface storage category because it was treated differently in this study, as described below. For the purpose of this study, gravel pit storage was evaluated based on general geographic location, not as individual sites.

3.3.1. Surface Storage Sites

Surface storage sites were classified into four sub-categories to help identify opportunities for this project. Sub-categories for surface storage opportunities were enlargements of existing reservoirs, identified new reservoir sites, existing reservoirs with rehabilitation potential, and existing reservoirs with storage restoration potential. These categories are defined in [Table 2-3](#).

Storage sites identified as IPPs in Colorado's Water Plan are included in the inventory. Although the water users promoting these IPPs may be planning to use all the potential storage capacity, there may be opportunities for further enlargements of these reservoirs to incorporate the needs of additional partners. Additional analysis will need to be performed to determine if IPP sites can potentially be enlarged for use by others.

Storage projects identified in other studies that were screened out for that project purpose could still be feasible for this study and were included in the inventory.

Table 2-3. Surface Storage Category Definitions

Category	Description
Enlargement	This group includes existing reservoirs that have been previously studied to determine feasibility of an enlargement. If available, information such as enlarged capacity and enlargement feasibility from previous enlargement studies was captured for use in this investigation.
New Site	These are sites where a new surface storage facility could be feasible. Information such as potential reservoir capacity and feasibility from previous studies is usually available.
Rehabilitation	These sites are existing reservoirs that have a storage restriction imposed by the State of Colorado Dam Safety Branch. By rehabilitating the dams at these locations, the storage restrictions could be removed and additional storage would then become available.
Storage Restoration	Sites in this category include existing reservoirs that have reduced storage capacity due to sedimentation. Storage capacity at these sites could be recovered by dredging the sediment and disposing it.

3.3.2. Aquifer Storage Sites

This group of storage sites includes options that use deep confined or shallow unconfined aquifers to store water. For this summary these sites are represented by a single point on a map, but in reality aquifer storage could occur over a broad area in the aquifer porous space underground. These options require points of recharge and extraction that were analyzed when formulating the storage concepts.

3.3.3. Gravel Pit Storage

Gravel pit storage sites were separated from the surface water storage category because they were treated differently than the larger surface reservoir options in this study. The individual gravel pit storage options are small and were not considered for long term storage on their own; however, groups of individual gravel pits in the same general area could be combined into a larger storage complex that could provide sufficient capacity to meet the needs of this study. In addition, these sites may be used to support other storage solutions, for example by providing temporary storage to hold exchange water until it can be exchanged further upstream. For purposes of this storage site inventory, gravel pit locations were mapped separately from other surface reservoir options so locations of possible gravel pit complexes could be considered later in the project.

3.4 SUMMARY OF REVIEWED STORAGE SITES

The potential surface storage sites in the South Platte River Basin cataloged in this literature review are listed in **Appendix B**.

Figure 3-1 shows potential new, enlarged, rehabilitated and restored surface storage sites in the SPSS study area. **Figure 3-2** shows cataloged aquifer storage options for the SPSS study area. Locations indicated on the map are representative of the general aquifer locations; aquifer spatial boundaries are not depicted. **Figure 3-3** shows active permitted sand, gravel, sand and gravel, or construction borrow material mines in the SPSS study area that could be developed as gravel pit storage.

A total of 73 surface storage options (excluding gravel pits) and 22 aquifer storage options were found in the SPSS study area through the Literature Review. Individual surface storage options in the study area vary from 3 ac-ft to 1,962,000 ac-ft of additional storage capacity, and include sites on the South Platte mainstem, on primary tributaries, and in tributary drainage areas. The inventory includes:

- 62 new reservoir sites
- 6 existing reservoir enlargements
- 4 existing reservoir rehabilitations
- 1 existing reservoir restoration
- 22 aquifer storage options
- 55 permitted gravel mining sites

Some of these options are similar (e.g., different nearby reservoir sites on the same tributary) and were filtered into a single option during the storage site evaluation.

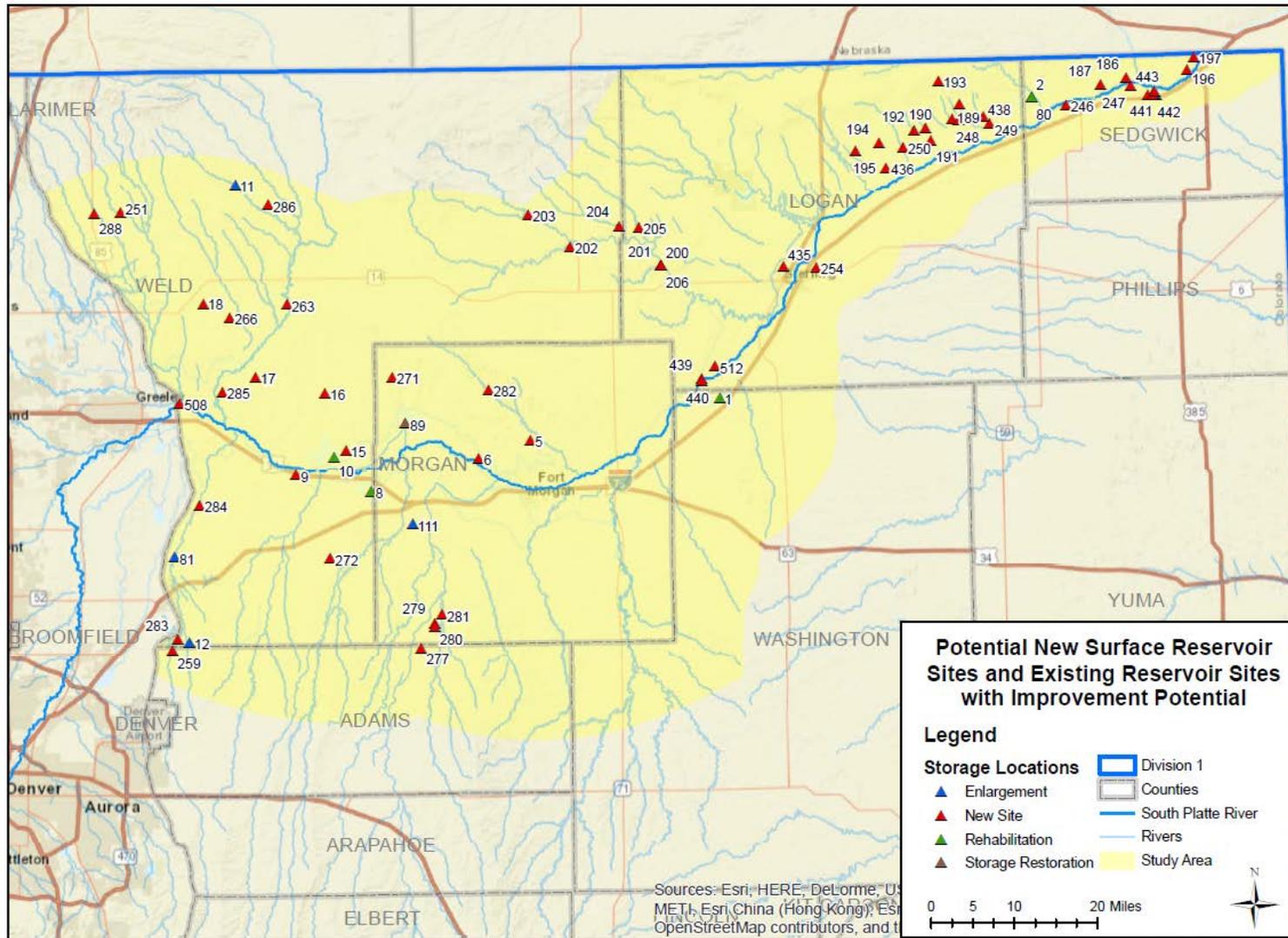


Figure 3-1. Cataloged Sites Where New Surface Storage Could be Developed in the Study Area

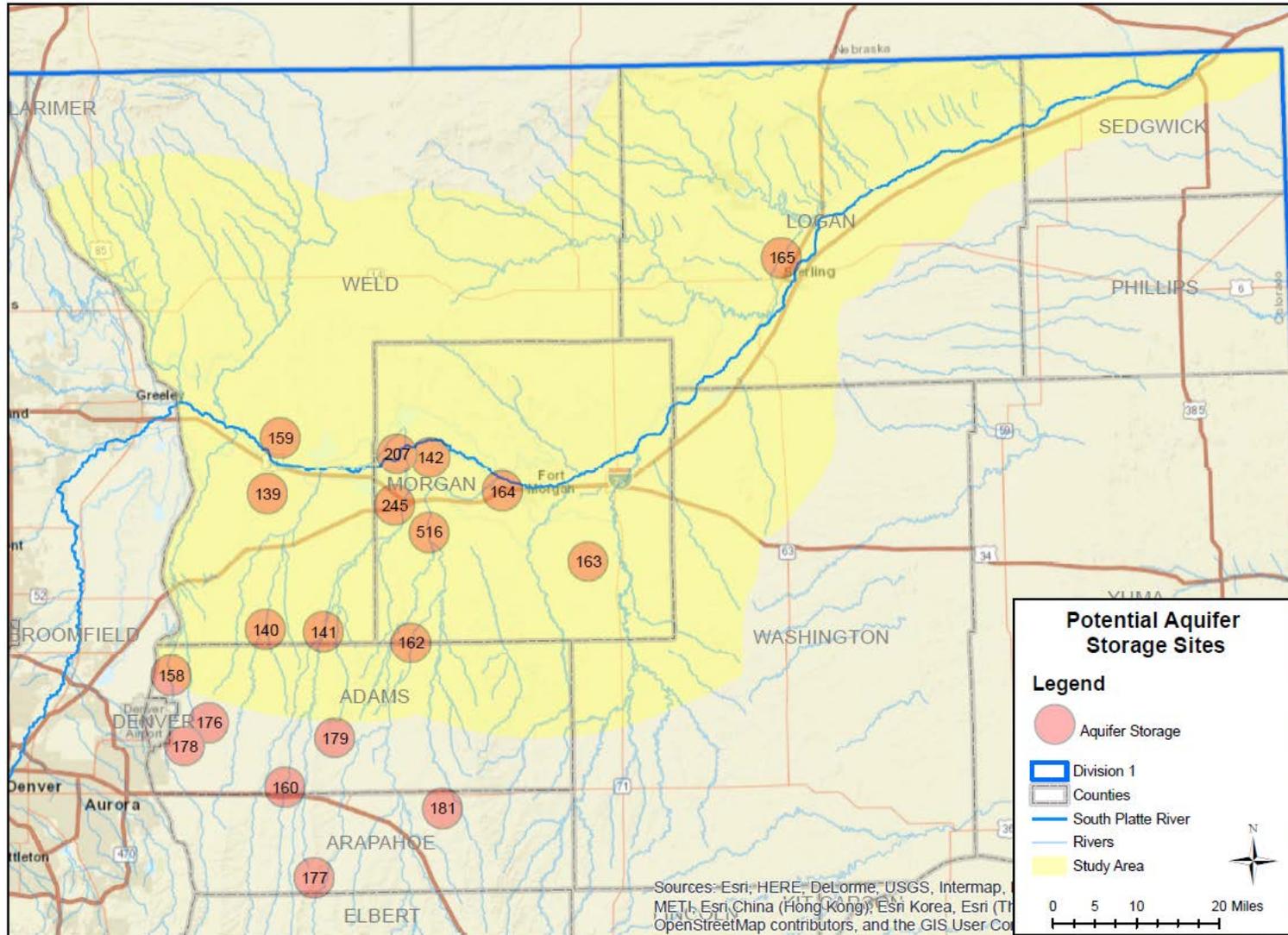


Figure 3-2. Cataloged Aquifer Storage Sites in or Near the Study Area

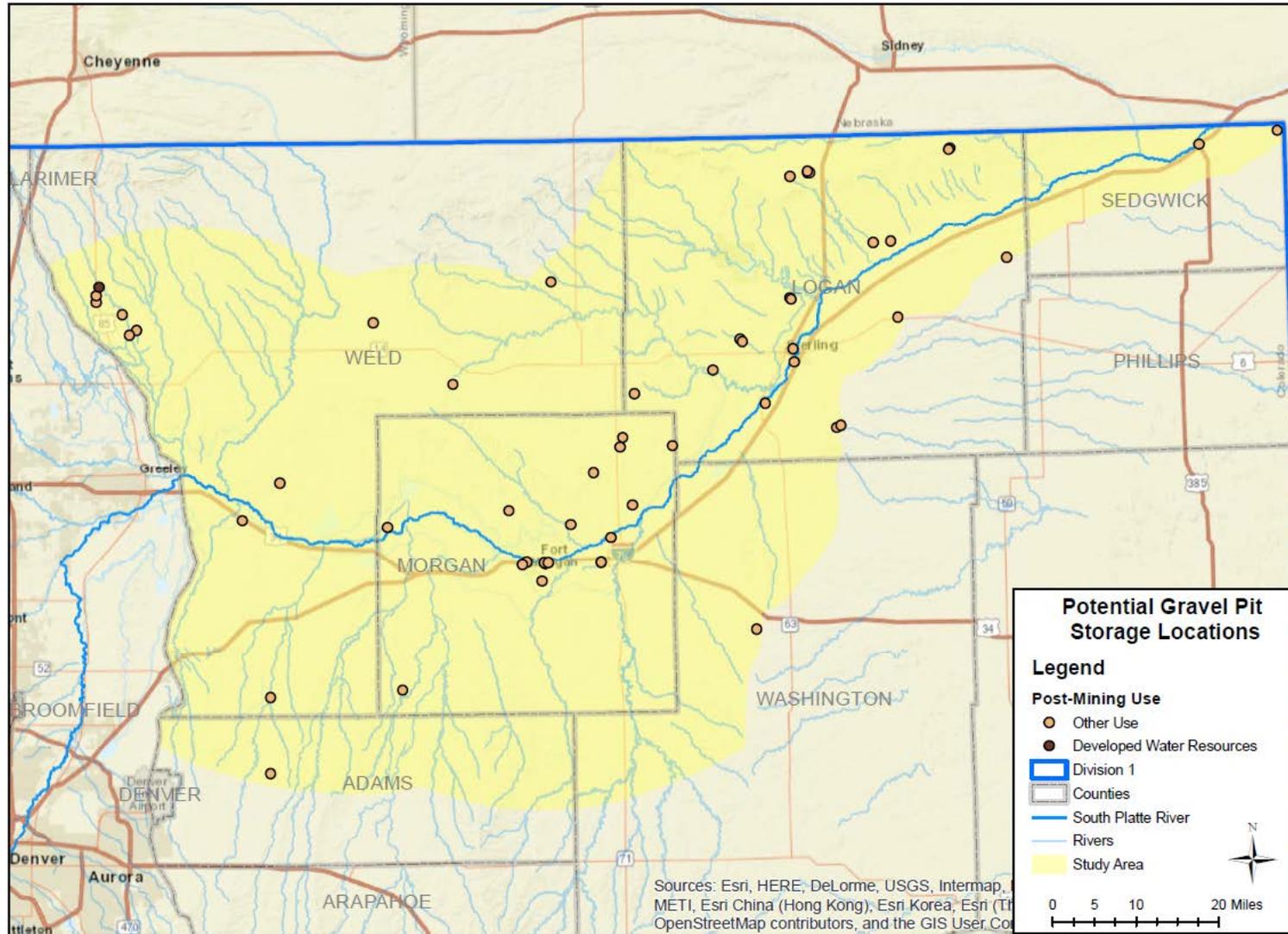


Figure 3-3. Potential Gravel Pit Storage Sites in the Study Area

4. LEGAL AND REGULATORY OVERVIEW

A review was performed of legal and regulatory factors affecting planning and implementation of potential water storage projects in the South Platte Basin. The review focused on how federal, state and local laws and regulations influence SPSS planning. Results are presented in detail in **Appendix C** and summarized below.

4.1 FEDERAL LAWS AND REGULATIONS

National Environmental Policy Act (NEPA) – NEPA requires environmental impact review and mitigation for projects involving a federal action. Several types of activities associated with development of storage projects can require federal actions triggering review under NEPA. These include the U.S. Army Corps of Engineers (USACE) issuing a 404 permit (see below); impacts to federally-listed threatened or endangered species requiring action by the U.S. Fish and Wildlife Service (USFWS); constructing projects on federal lands such as those managed by Bureau of Land Management (BLM) or the U.S. Forest Service (USFS); and connecting to federally owned facilities. An EIS can have significant impacts on project implementation schedule and budget, and in some extreme cases can render a project infeasible due to the inability to receive required federal permits.

Endangered Species Act (ESA) and Section 7 Consultation – Projects with a federal nexus require review for compliance with the ESA. Federal actions resulting in depletions to flows in the Platte River system are likely to jeopardize the continued existence of one or more federally-listed threatened or endangered species and adversely modify critical habitat. Analysis and mitigation of impacts would be required.

Platte River Recovery Implementation Program (PRRIP) – The PRRIP is a cooperative program between Colorado, Wyoming, Nebraska and the U.S. Department of Interior to provide streamlined ESA compliance for impacts of depletions in the Platte River Basin. In Colorado the South Platte Water Related Activities Program, Inc. (SPWRAP) is responsible for the operational costs of projects providing supplemental streamflows at the state line. SPWRAP would not cover a mainstem reservoir over 2,000 ac-ft, significantly complicating environmental permitting of a mainstem dam alternative.

Clean Water Act/Section 404 – Section 404 of the Clean Water Act regulates placement of dredge and fill material in waters of the US. The South Platte River and its tributaries are waters of the US, and construction of new dams or diversion structures on these water bodies would require 404 permits. The 404 review process triggers NEPA and ESA compliance as well as requiring its own permit review and mitigation.

National Historic Preservation Act – Archaeological and cultural surveys and management plans would be required for storage locations and other infrastructure.

South Platte River Compact – The Compact sets a minimum flow target at the Interstate Station (Julesburg gage) of 120 cfs between April 1 and October 15. This effectively limits new diversions in Water District 64 in this period such that a minimum of 120 cfs is left in the river.

4.2 STATE LAWS AND REGULATIONS

Water Right Determination and Administration Act – Water storage and diversion rights for a new SPSS project would have to be adjudicated per Colorado’s water rights system.

Colorado Department of Public Health and Environment (CDPHE) – The CDPHE Water Quality Control Division would require compliance with Section 401 of the Clean Water Act prohibiting degradation of the state’s water quality. This would involve an anti-degradation review and 401 certification from CDPHE.

Colorado Groundwater Management Act – This act regulates management of groundwater basins that could be used for groundwater storage in the South Platte Basin. Specific regulations apply to the designated basins considered for aquifer storage and recovery in the SPSS. Groundwater management policies require that aquifer storage projects not recharge or inject water that would degrade the water quality of the aquifer.

4.3 LOCAL

1041 Regulations - 1041 regulations allow local governments to describe and designate areas and activities which may be of state interest and encourages local governments to establish criteria for the administration of these areas and activities. 1041 regulations allow local governments to put permit conditions on water projects including reservoirs and pipelines. Local governments located within the SPSS study area known to have 1041 regulations in place include Adams County, Larimer County, Morgan County, and Weld County. A state or local government may choose to adopt 1041 regulations and guidelines for administration of matters of state interest at any time.

A host of other local regulations related to construction and floodplain administration would apply to water infrastructure projects such as those considered for the SPSS.

4.4 SUMMARY OF KEY LEGAL AND REGULATORY EFFECTS

Legal and regulatory issues could affect the feasibility of storage options in the SPSS study area in the following key ways.

- Environmental permitting for on-channel reservoirs would be extremely difficult, particularly for reservoirs on the mainstem of the South Platte River. Past permitting efforts for a mainstem dam at the Narrows site were unsuccessful, and

environmental regulations and policies are more challenging now than they were then. Permitting obstacles may be a fatal flow for mainstem storage options.

- Compatibility with the PRRIP and SPWRAP would greatly simplify regulatory compliance for any new storage project. Off-channel dams could be covered under these programs but not mainstem dams.
- Federal and state environmental compliance would be a significant cost and schedule driver for any new storage project.
- Cooperative, multi-purpose projects that have support of and create partnerships between local, state and federal agencies would be more likely to receive the necessary regulatory approvals.

5. HISTORICAL FLOW ANALYSIS

5.1 INTRODUCTION

HB 16-1256 included a requirement to determine historical flow that could have been captured and stored in the South Platte River at the state line. Specifically, the Bill states:

“The Board, in collaboration with the State Engineer, shall conduct or commission a hydrology study of the South Platte River Basin to estimate, for each of the previous twenty years, the volume of water that:

- i. Has been delivered to Nebraska in excess of the amount required to be delivered by the South Platte River Compact, Article 65 of this title; and
- ii. Could have otherwise been stored in the Lower South Platte River Basin.”

The South Platte Point Flow Model (PFM) was used to complete those two tasks. The PFM evaluates the historical daily flow passing structures on the mainstem of the South Platte River between the Burlington Ditch diversion (Henderson area) and the Nebraska State line based on hydrologic data, diversion records and reconstructed call records using a detailed point flow modeling approach. The point flow analysis calculates ungaged gains and losses between measured points by simple mass balance and estimates physical flow at 62 points along the river by redistributing the gains and losses according to their spatial distribution. The model does not account for existing conditional water rights that could be used more fully in the future as they are perfected nor does it consider unused reusable return flows that might be utilized in the future. The version of the PFM used in the South Platte Basin Implementation Plan was updated for this study to include a 20-year period of daily flow records from 1996 to 2015 (water years). Details of the PFM update process are provided in the “South Platte River Hydrologic Analysis TM” in **Appendix E**. Results of the historical flow analysis were presented previously in “Summary of South Platte River Historical Flow Leaving the State and Storable Water,” which is provided in **Appendix D**.

5.2 FINDINGS

Flow records and Point Flow Model results were analyzed at the South Platte River at Julesburg stream gage near the Nebraska State line to estimate: (1) physical flow in the river; and (2) water that could have been legally stored subject to South Platte River Compact requirements (referred to herein as “storable flow” or “available water”). Storable flow is the maximum potential water that could have been stored by a reservoir on the mainstem of the South Platte River. Storable flow in an off-channel reservoir that would depend on diversions and conveyance facilities similar to the current lower basin reservoirs and irrigation canals would be significantly less.

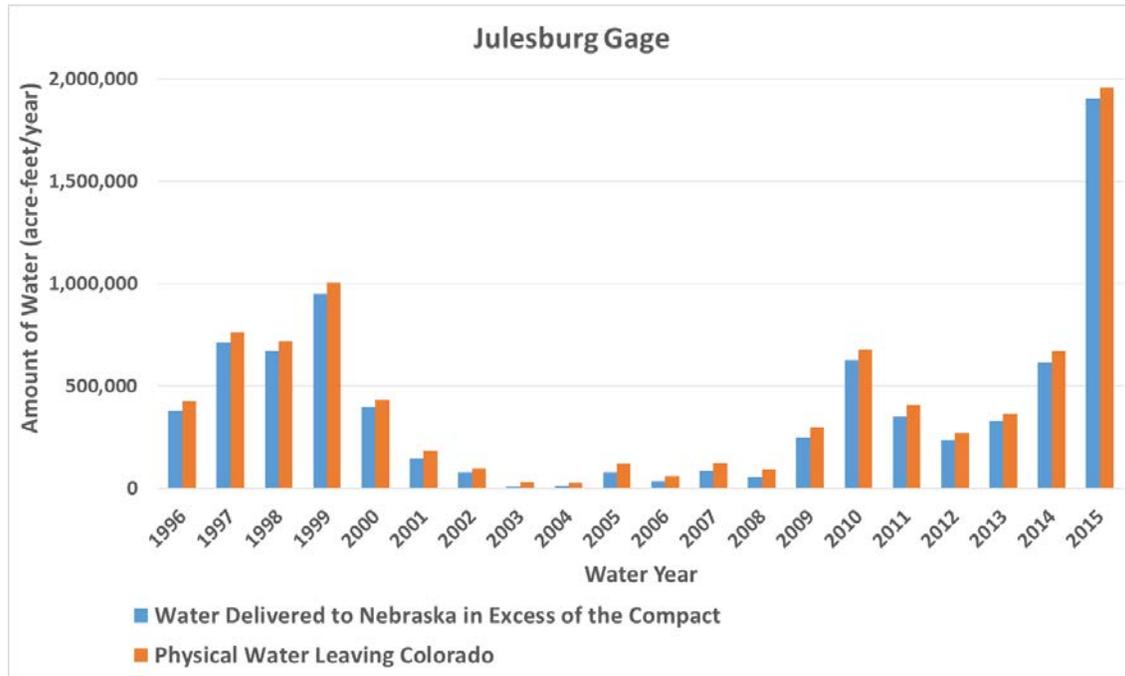
Figure 5-1 displays annual historical flow for the 20 years from 1996 to 2015 that was delivered to Nebraska. It shows the physical flow in the river (“Water Leaving Colorado”), and the water leaving the state that could have been physically and legally stored or put to beneficial use in Colorado (“Water Delivered to Nebraska in Excess of the Compact”). It is noted that legally available flow does not account for possible environmental flow obligations for mitigation of future Colorado water development projects, so actual available flow may be less than described in this section. Figure 5-1 shows that physical and storable flow vary significantly from year to year. Table 5-1 gives selected statistics for physical flow leaving the state and storable flow at the Julesburg gage for the 20-year period from 1996 to 2015. The large difference between the median and average statistics shows the effect of a few high flow years in the study period.

Table 5-1. Historical Annual Flow for 1996-2015 at Nebraska State Line

Statistic	Physical Water Leaving Colorado (Julesburg Gage)	Water Delivered to Nebraska in Excess of the Compact ⁽¹⁾⁽²⁾
Annual Median (ac-ft/yr)	331,000	293,000
Annual Average (ac-ft/yr)	436,000	397,000
Minimum Year (ac-ft/yr)	29,000	10,000
Maximum Year (ac-ft/yr)	1,957,000	1,904,000
Total for 20-yr Period 1996-2015 (ac-ft)	8,728,000	7,939,000

(1) Storable flow Julesburg gage

(2) Future environmental flow obligations could reduce legally available water.



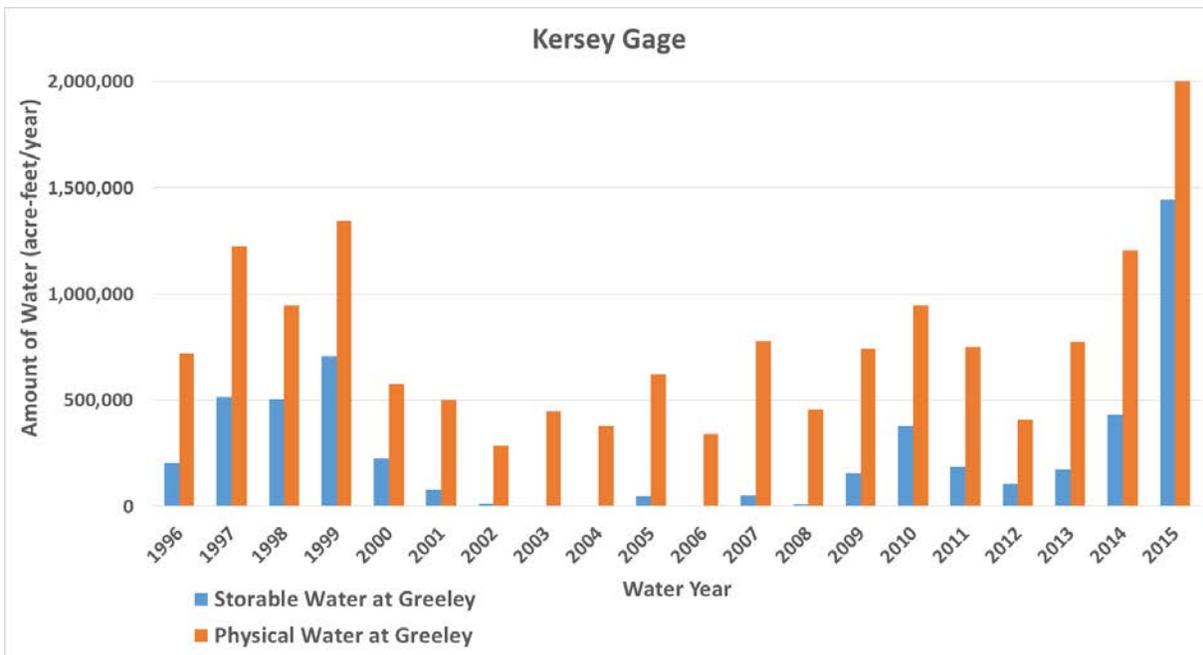
Note: Future environmental flow obligations could reduce legally available water.

Figure 5-1. South Platte River Water Delivered to Nebraska (Julesburg Gage), 1996-2015

Figure 5-2 displays the annual physical flow and storable flow at the South Platte River at Kersey stream gage from 1996 to 2015. Table 5-2 summarizes statistics for this data. This location is below the confluence of the South Platte River and the Cache la Poudre River in Greeley, and is the upstream end of the Lower South Platte River Basin as defined in the South Platte Storage Study. As with the analysis at the Julesburg gage, storable flow is the maximum potential storable flow assuming a mainstem reservoir that could capture all available water. Although physical flow in the river at Kersey is larger than at the state line due to the lack of major downstream tributaries and the significant diversions for lower South Platte Basin water users, storable flow is a smaller percentage of total flow at the Kersey gage compared to storable flow at the Julesburg gage because of the need to satisfy downstream water rights within Colorado. As with the analysis at the Julesburg gage, potential future environmental flow obligations are not accounted for in the estimate of storable water at Greeley.

Table 5-2. Historical Annual Flow for 1996-2015 at Greeley

Statistic	Physical Water at Greeley (Kersey Gage) (ac-ft/yr)	Storable Water at Greeley (Kersey Gage) (ac-ft/yr)
Annual Median	732,000	165,000
Annual Average	773,000	262,000
Minimum Year	285,000	0
Maximum Year	2,001,000	1,447,000



Note: Future environmental flow obligations could reduce legally available water.

Figure 5-2. Physical and Storable Flow at Greeley (Kersey Gage), 1996-2015

6. AVAILABLE WATER FOR STORAGE

6.1 INTRODUCTION

This section describes the analysis of water legally and physically available for storage in the lower South Platte River basin under future conditions. It represents water that could be stored in a mainstem dam or diverted from the mainstem for off-channel storage. The analysis was based on adjustments to the historical PFM described previously. Adjustments were made to estimate approximate storable flows under possible future hydrologic conditions based on discounting factors such as conditional water rights and the implementation of IPPs identified in Colorado's Water Plan.

Methods and results of the available water analysis are presented in detail in the "South Platte River Hydrologic Analysis TM" in **Appendix E**.

6.2 HISTORICAL HYDROLOGIC ANALYSIS AND RESULTS

Available water for the historical period 1996 to 2015 was calculated for all locations in the PFM by the following steps.

1. Daily historical flow that did not have a calling water right (available flow greater than 0), was reduced by the bypass flow required to satisfy downstream uses. With input from Division 1 staff, bypass flows in [Table 6-1](#) were adopted as reasonable estimates of the requirements.

Table 6-1. Bypass Flows Applied to Available Water Analysis

Month	Burlington to Upstream of St. Vrain Creek (cfs)	Downstream of St. Vrain Creek to Riverside Canal (cfs)	Bijou Canal to State Line (cfs)
April - October	15	20	10
November - March	15	10	5

2. The South Platte River Compact requires flow at the state line to be 120 cubic feet per second (cfs) (238 ac-ft/day) or greater between April 1 and October 15. The available flow at the state line and at points throughout District 64 was reduced by 120 cfs during these dates. The Compact affects available flows in District 64 only.
3. Available water calculations were reduced by historically unused reusable return flows. These values were obtained from Aurora Water and Denver Water. It was assumed that both entities would reclaim all their reusable water supplies in the future and thus this water would not be available for downstream storage.

4. Available flow at any point along the South Platte River is affected by downstream water rights that must be satisfied. Sufficient water must be left in the river at any point to meet all downstream water rights and delivery obligations, including the South Platte River Compact.

Available water was compared between wet years, normal years, and dry years. Water year 1999 was chosen as a representative wet year, water year 2002 was chosen as a representative dry year, and water year 2010 was chosen as a representative normal year. For seasonal evaluations, February was chosen to be representative of the winter season, June was chosen to be representative of the runoff season, and August was chosen to be representative of the irrigation season.

Additionally, five locations along the South Platte River were chosen for further analysis. Four locations - South Platte River at Kersey, South Platte River at Weldona, South Platte River near Balzac, and South Platte River near Julesburg – are stream gage locations. The fifth location is the Lowline Ditch/Henderson Smith Ditch diversion, which is representative of flow in the river at Sterling. [Figure 6-1](#) shows these five points and their locations within the SPSS study area.

[Figure 6-2](#) shows historical average daily available water at all points in the Point Flow Model based on hydrologic year type. Available water increases in the downstream direction for all year types.

[Table 6-2](#) shows the average and median annual available water for the 1996-2015 historical period for the selected locations. The average annual available water is given as an average of all years and for a representative wet, normal, and dry year, and the median annual available water is given for all years. The significant differences between available water in wet and dry years and the significant differences between average and median statistics indicate the great variability in available water from year to year based on hydrologic conditions. These differences point to the value of storage in meeting regional demands from South Platte River flows, but also suggest that large storage capacities would be needed to generate substantial sustained yield from storage.

[Figure 6-3](#) and [Figure 6-4](#) are exceedance plots that show the percentage of time a given magnitude of available flow is equaled or exceeded in the Point Flow Model period of record for historical conditions. A daily flow exceedance plot for the Julesburg gage is shown in [Figure 6-3](#), and an annual flow exceedance plot is shown in [Figure 6-4](#). [Figure 6-3](#) shows the extreme variability in available water across the PFM period of record. On roughly half the days there is no available water at Julesburg. [Figure 6-4](#) shows that annual available water varies widely during the PFM period, with some years producing almost no available water. The average monthly physical flow is shown in [Figure 6-5](#), which demonstrates the strong seasonality of South Platte flows.

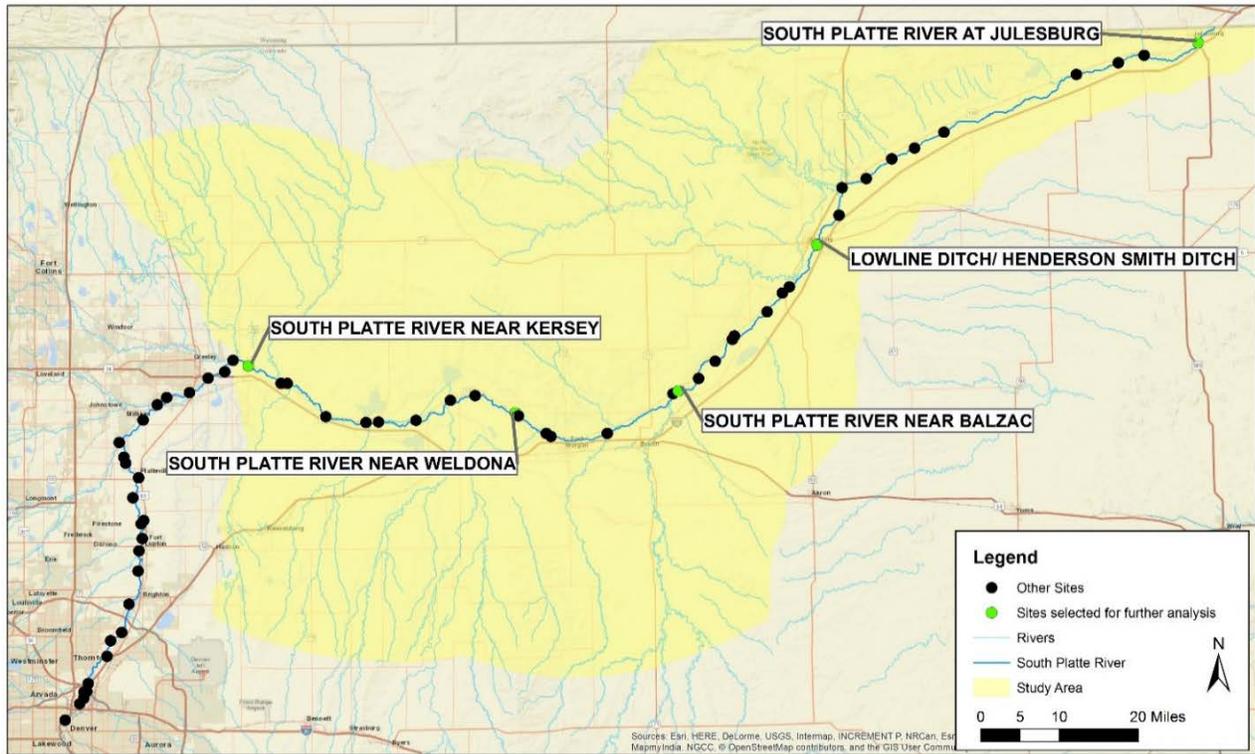


Figure 6-1. Selected Locations for Additional Analysis

Table 6-2. Annual Available Water for Selected Locations Based on Historical Hydrology

Location	Median Annual Available Water (ac-ft)	Average Annual Available Water (ac-ft)	Available Water in Wet Year (ac-ft)	Available Water in Normal Year (ac-ft)	Available Water in Dry Year (ac-ft)
	All Years	All Years	1999	2010	2002
South Platte River near Kersey	165,000	262,000	707,000	378,000	14,000
South Platte River near Weldona	179,000	281,000	731,000	411,000	18,000
South Platte River near Balzac	185,000	297,000	771,000	440,000	18,000
Lowline Ditch/ Henderson Smith Ditch	200,000	314,000	799,000	476,000	33,000
South Platte River at Julesburg	289,000	397,000	951,000	627,000	79,000

Notes: Based on 1996-2015 historical streamflows and river operations, adjusted to remove Denver Water and Aurora Water reusable return flows and account for all existing water rights and South Platte River Compact obligations. Available water" is water physically and legally available to be diverted to a new water supply project like SPSS.

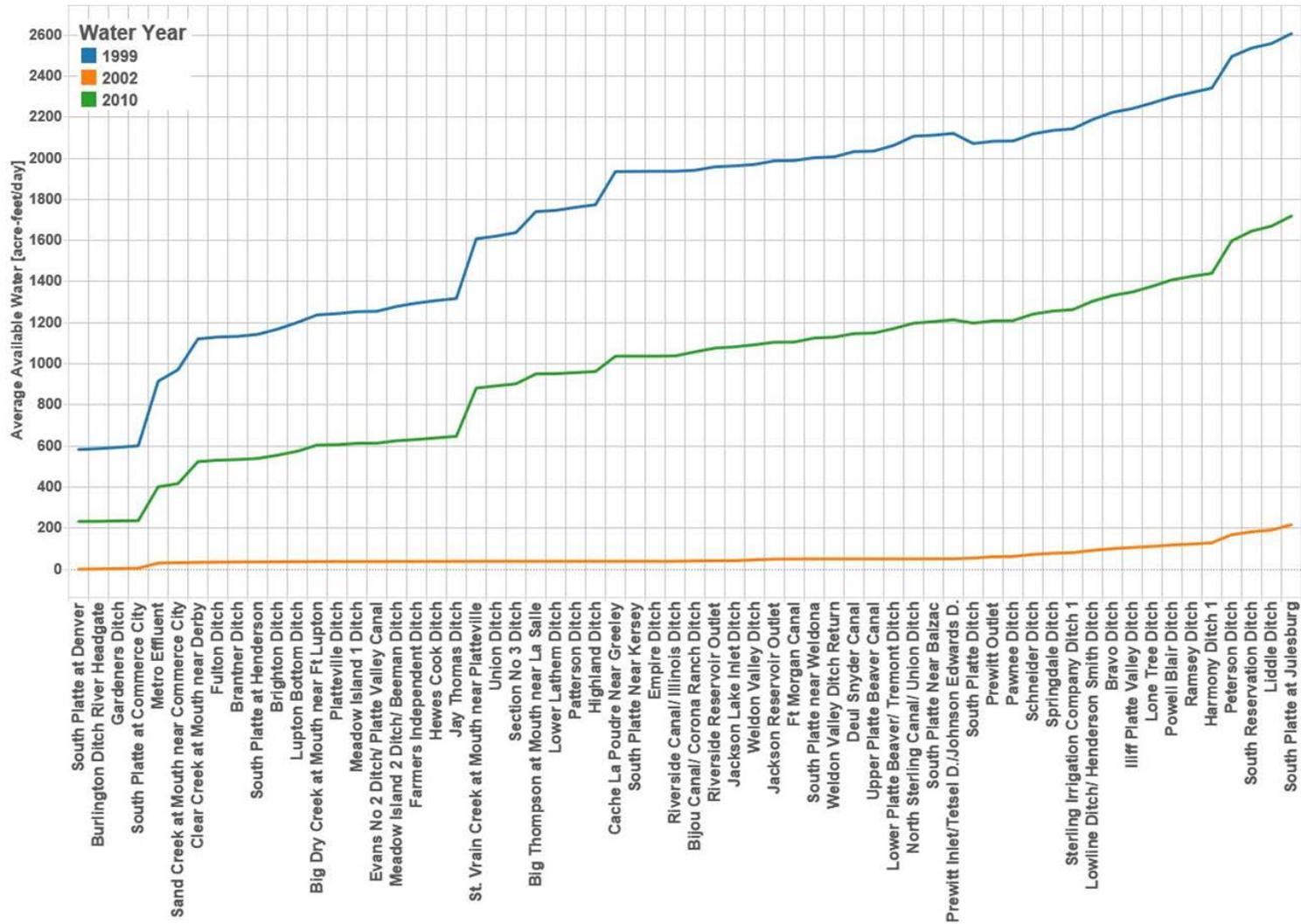


Figure 6-2. Historical Daily Average Available Water for Representative Wet, Normal, and Dry Years

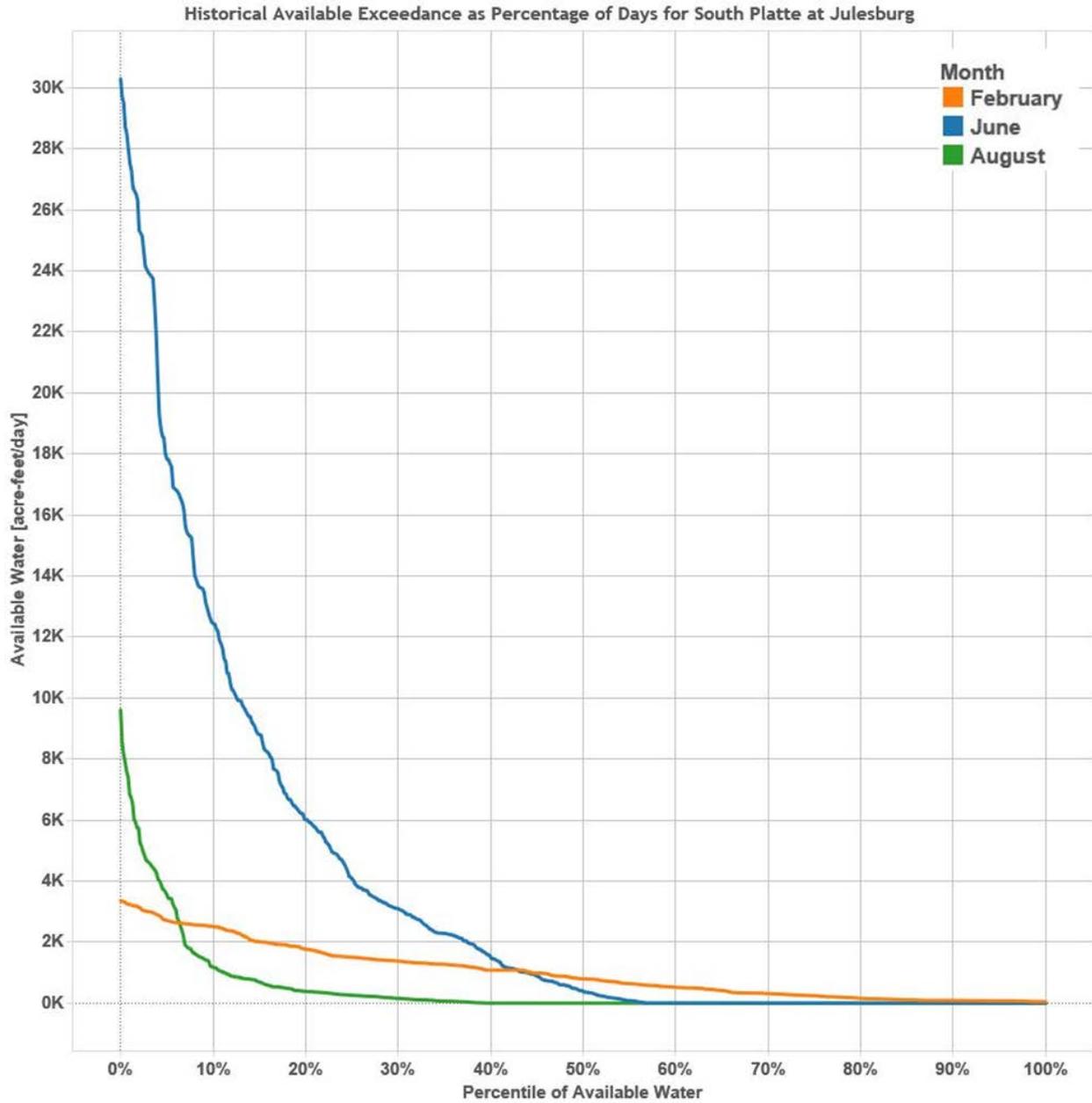


Figure 6-3. Historical Daily Available Water Exceedance for Representative Months, South Platte at Julesburg

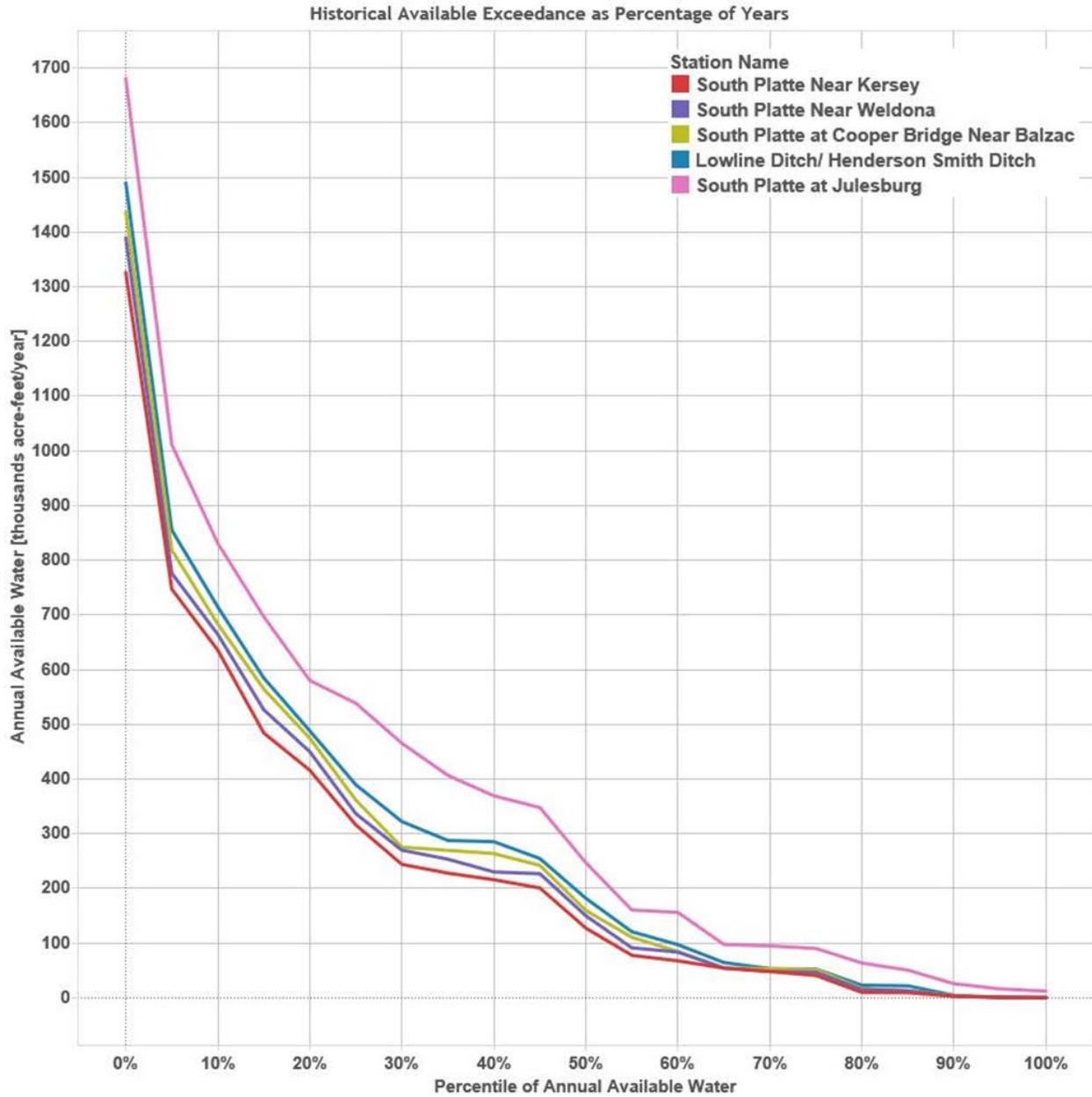


Figure 6-4. Historical Annual Available Water Exceedance at Five Key Locations

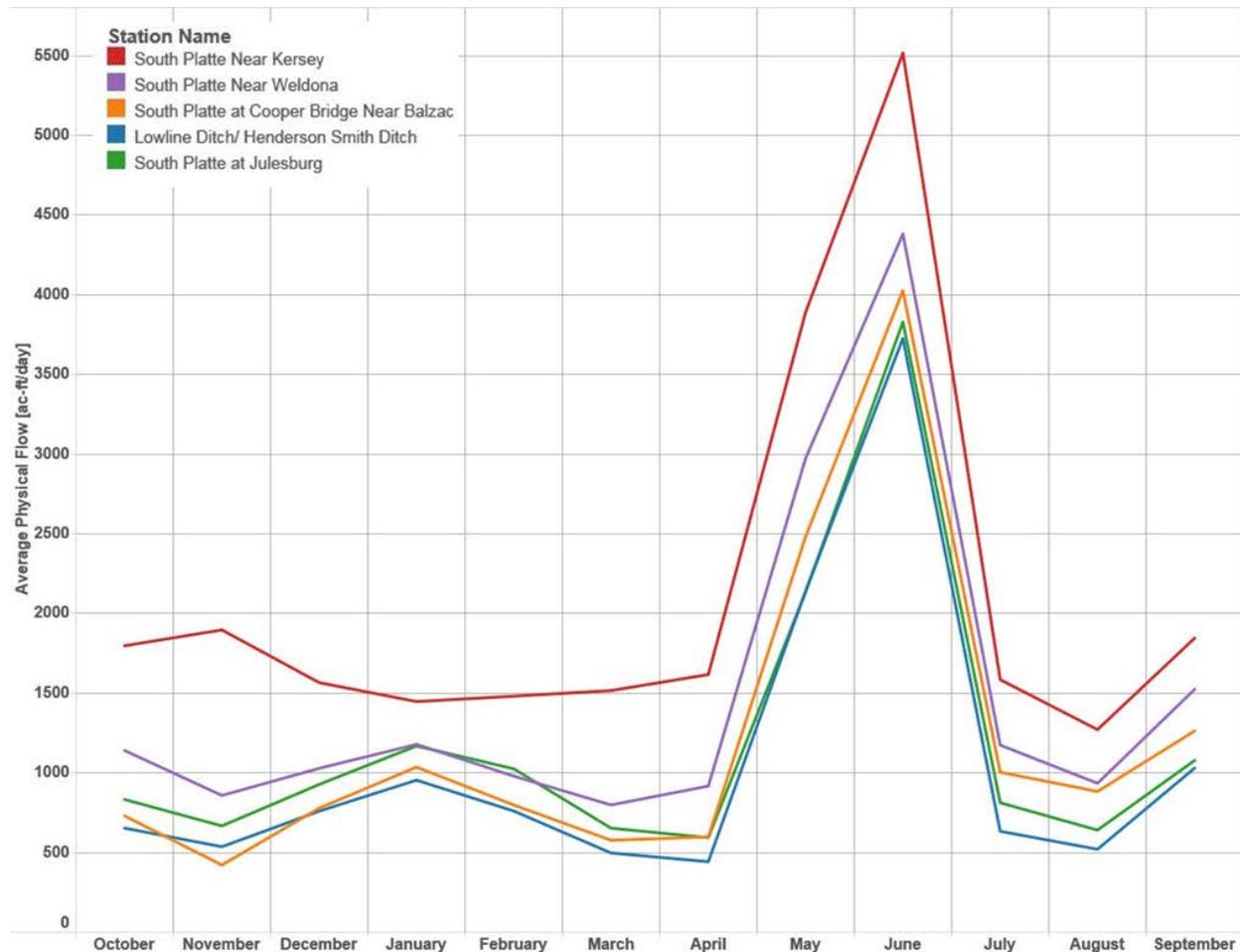


Figure 6-5. Average Monthly Physical Flows

6.3 FUTURE HYDROLOGIC ANALYSIS AND RESULTS

HB 16-1256 specified that this storage study should be based on historical hydrology to answer the question, “How much water could we have stored in recent years if storage had been in place?” However, it is recognized that future hydrologic conditions will not be the same as historical conditions due to development of conditional water rights, implementation of proposed IPPs from Colorado’s Water Plan, changed operations by water users, and a host of other factors. Based on direction from the CWCB, CDWR and Roundtables, SPSS planning was performed using future hydrology.

The SPSS used similar methods for adjusting historical hydrology to represent future conditions as were applied in the South Platte Basin Implementation Plan (BIP). In the BIP a routine was developed to reduce historical flows by diversions anticipated from

IPPs in Colorado's Water Plan. This routine used estimates of IPP annual yields obtained from the IPP proponents, and reduced available water equally in all months. The routine allowed the user to select individual IPPs or all IPPs for inclusion in the analysis, since the BIP acknowledges that not all IPPs are likely to be ultimately implemented.

For the SPSS the method of reducing available flows to account for implementation of IPPs from the BIP was modified by assuming a distribution of diversions between peak runoff months and the rest of the year for those proposed projects that would increase future diversions. It is recognized that many factors can affect the magnitude and timing of diversions for future projects, and detailed analyses of specific IPPs was not contemplated for this project. Estimates in this study were only developed to provide a rough order of magnitude of the effect of IPPs on water available for a new South Platte storage project. IPPs which are expected to reduce future demands were not considered in the adjustment of available flows. The IPPs, their estimated yield from the BIP, and the assumed distribution of their diversions between the peak runoff months of May/June and the rest of the year are listed in [Table 6-3](#).

Table 6-3. Assumed Seasonal Distribution of Future Diversions for IPPs

IPP Project	Provider	Annual Yield (ac-ft/yr)	May-June Diversions	July-April Diversions
ACWWA Reuse Flow Project	ACWWA, SMWSA	3,520	N/A	N/A
Alternative Northern Water Supply Project	Town of Castle Rock	2,500	80%	20%
ASR Future Storage	Town of Castle Rock	N/A	-	-
ASR Pilot Phase Storage	Town of Castle Rock	N/A	-	-
Chatfield Pump Station	Denver Water	3,000	50%	50%
Chatfield Reservoir Storage Reallocation Project	Colorado Water Conservation Board, Centennial Water and Sanitation District, Central Colorado Water Conservancy District, Castle Pines North Metro District, Colorado Parks and Wildlife, Castle Rock, Center of Colorado Water Conservancy District, Castle Pines Metro District	8,500	80%	20%
Conservation	Centennial Water and Sanitation District	1,764	N/A	N/A

IPP Project	Provider	Yield (ac-ft/yr)	May-June Diversions	July-April Diversions
Conservation	City of Greeley	3,000	N/A	N/A
Conservation	City of Northglenn	600	N/A	N/A
Conservation	City of Thornton	3,500	N/A	N/A
Conservation	Longmont	3,500	N/A	N/A
Conservation	Town of Castle Rock	3,350	N/A	N/A
Consolidated Mutual Water District Reservoir Construction	Consolidated Mutual Water Company	N/A	-	-
Denver Water Reuse	Denver Water	1,750	N/A	N/A
Downstream Reservoir Exchanges	Denver Water	12,000	70%	30%
Halligan Reservoir Enlargement	City of Fort Collins	7,000	80%	20%
Highway 93 Lakes	Arvada	500	80%	20%
Milton Seaman Reservoir Enlargement	City of Greeley	6,600	80%	20%
New Storage Projects	City of Northglenn	1,500	70%	30%
Northern Integrated Supply Project	Town of Erie, City of Lafayette, Left Hand Water District, City of Fort Morgan, City of Dacono, Town of Eaton, Town of Windsor, City of Fort Lupton, Fort Collins - Loveland Water District, Central Weld County Water District, Town of Evans, Morgan County Water Quality District, Town of Severance, Town of Frederick, Town of Firestone	40,000	70%	30%
Plum Creek Diversion & WPF Upgrades	Town of Castle Rock	4,100	80%	20%
Prairie Waters Project	Aurora	15,700	50%	50%
Reclaimed Water	Erie	5,390	N/A	N/A
Reuse	City of Thornton	2,000	N/A	N/A
Reuse Plan	City of Northglenn	700	N/A	N/A
Rueter Hess Reservoir Enlargement	Parker Water and Sanitation District, Castle Rock, Castle Pines North, Stonegate	14,810	80%	20%

IPP Project	Provider	Yield (ac-ft/yr)	May-June Diversions	July-April Diversions
South Platte and Beebe Draw Well Project - Reuse	City of Brighton	3,200	N/A	N/A
South Platte Protection Plan	Denver Water	N/A	-	-
Thornton Northern Project	City of Thornton	13,500	50%	50%
Union Pumpback Pipeline	Longmont	4,950	50%	50%
Union Reservoir Enlargement	Longmont	1,770	80%	20%
Westminster Agreement	City of Brighton	2,000	50%	50%
Westminster Gravel Storage	Westminster	N/A	-	-

Notes: Projects with N/A in the Diversions fields reduce future demand rather than increasing future diversions. Projects with N/A in Yield field did not have yield estimates available from the BIP. Projects with blanks in the Diversions fields did not have adequate yield information. Any potential influences of these IPPs on future storable flow was not accounted for in the SPSS analysis.

Future flows were also adjusted to account for conditional exchange rights that were not utilized in the historical period in the PFM but could be utilized in the future. Conditional water rights were tabulated and allocated to the major reaches in the SPSS study area. Based on input from the Division Engineer it was assumed 33 percent of conditional exchanges were not duplicative and would likely be perfected upstream of Kersey, and 25 percent of conditional exchanges were not duplicative and would likely be perfected downstream of Kersey. These are rough approximations but were considered adequate for this analysis. Daily flow reductions to reflect conditional exchange rights being perfected and exercised in the future are summarized in [Table 6-4](#).

Table 6-4. Reduction in Historical Daily Flows to Account for Conditional Exchange Rights

Reach	Total Conditional Exchanges (cfs)	Reductions to Daily Historical Flows	
		Conditional Exchanges Assuming 25% are Made Absolute and Operated Concurrently (cfs)	Conditional Exchanges Assuming 33% are Made Absolute and Operated Concurrently (cfs)
Above Denver	1,900	-	630
Denver to Kersey	7,600	-	2,500
Kersey to Balzac	1,100	280	-
Balzac to Julesburg	1,200	300	-

Table 6-5 shows historical average annual and median annual available water adjusted for IPP diversion estimates. These results assume all IPPs for which yield information was available in the BIP are implemented, while all IPPs without yield information in the BIP are not implemented. This is conceptually consistent with the scenario in Colorado’s Water Plan that assumes 60 percent of all IPPs will ultimately be implemented. Table 6-5 also shows the reduction in available water compared to the results of the historical hydrology analysis. Future average annual available water is 16-18 percent less than average annual available water in the 20 years between 1996 and 2015.

Figure 6-6 gives a comparison of the daily available water exceedance between the historical hydrology and the future hydrology adjusted for IPPs and conditional exchanges. Figure 6-7 shows the future average and median physical flow and available flow throughout the SPSS study area; these PFM results were used in the analysis of SPSS alternatives.

Table 6-5. Future Available Water for Selected Locations Based on Historical Hydrology and Adjustments

Location		Median Annual Available Water (ac-ft)	Average Annual Available Water (ac-ft)	Available Water in Wet Year (ac-ft)	Available Water in Normal Year (ac-ft)	Available Water in Dry Year (ac-ft)
		All Years	All Years	1999	2010	2002
South Platte River near Kersey	With IPP Adjustment	116,000	214,000	580,000	275,000	6,000
	Difference from Historical	-49,000	-48,000	-127,000	-103,000	-8,000
South Platte River near Weldona	With IPP Adjustment	127,000	231,000	601,000	303,000	9,000
	Difference from Historical	-52,000	-50,000	-130,000	-108,000	-9,000
South Platte River near Balzac	With IPP Adjustment	144,000	246,000	641,000	326,000	9,000
	Difference from Historical	-41,000	-51,000	-130,000	-114,000	-9,000
Lowline Ditch/Henderson Smith Ditch	With IPP Adjustment	154,000	261,000	666,000	357,000	15,000
	Difference from Historical	-46,000	-53,000	-133,000	-119,000	-18,000
South Platte River at Julesburg	With IPP Adjustment	232,000	332,000	815,000	494,000	54,000
	Difference from Historical	-57,000	-65,000	-136,000	-133,000	-25,000

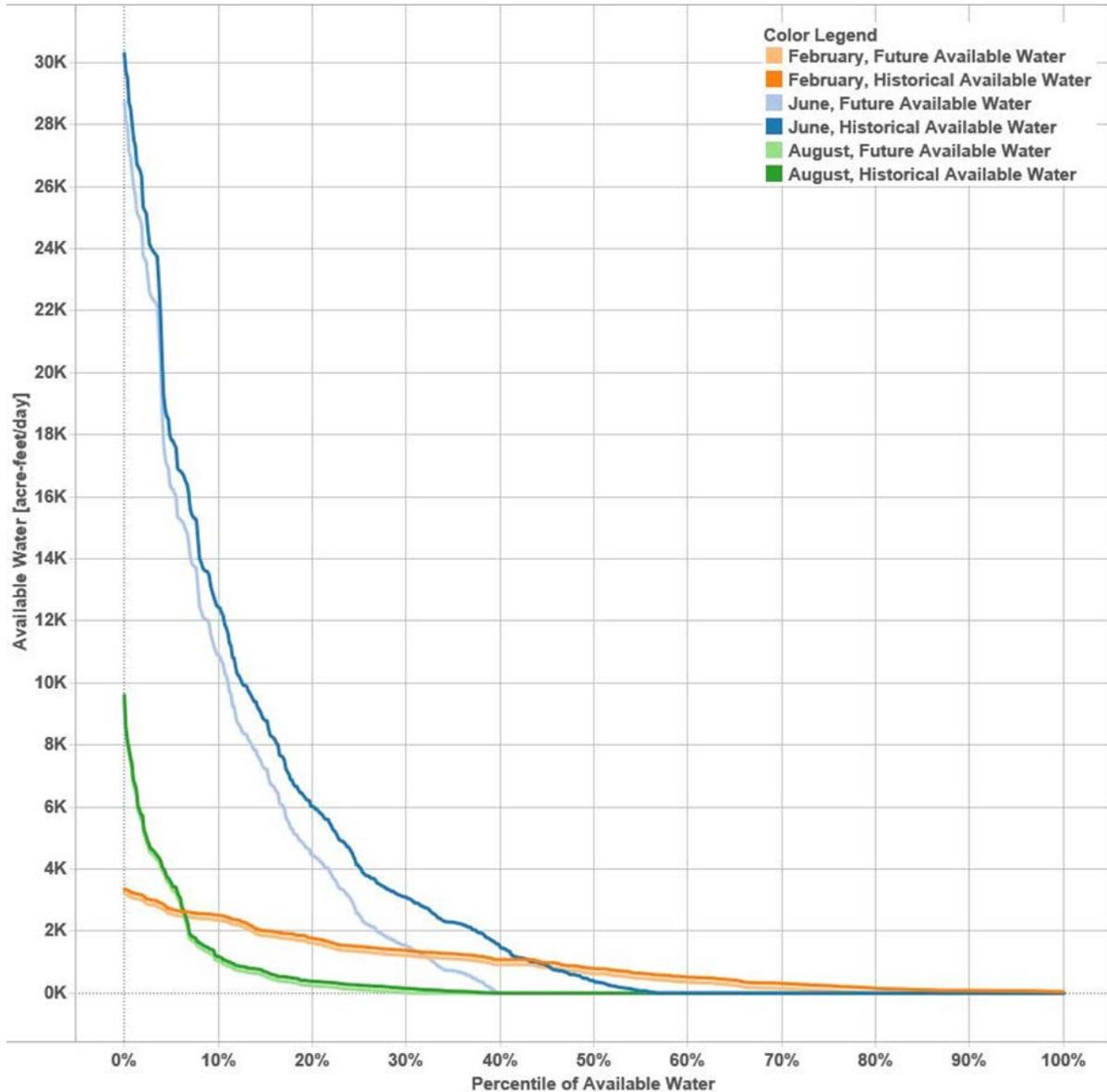


Figure 6-6. Historical and Future Available Water by Month for South Platte at Julesburg Gage

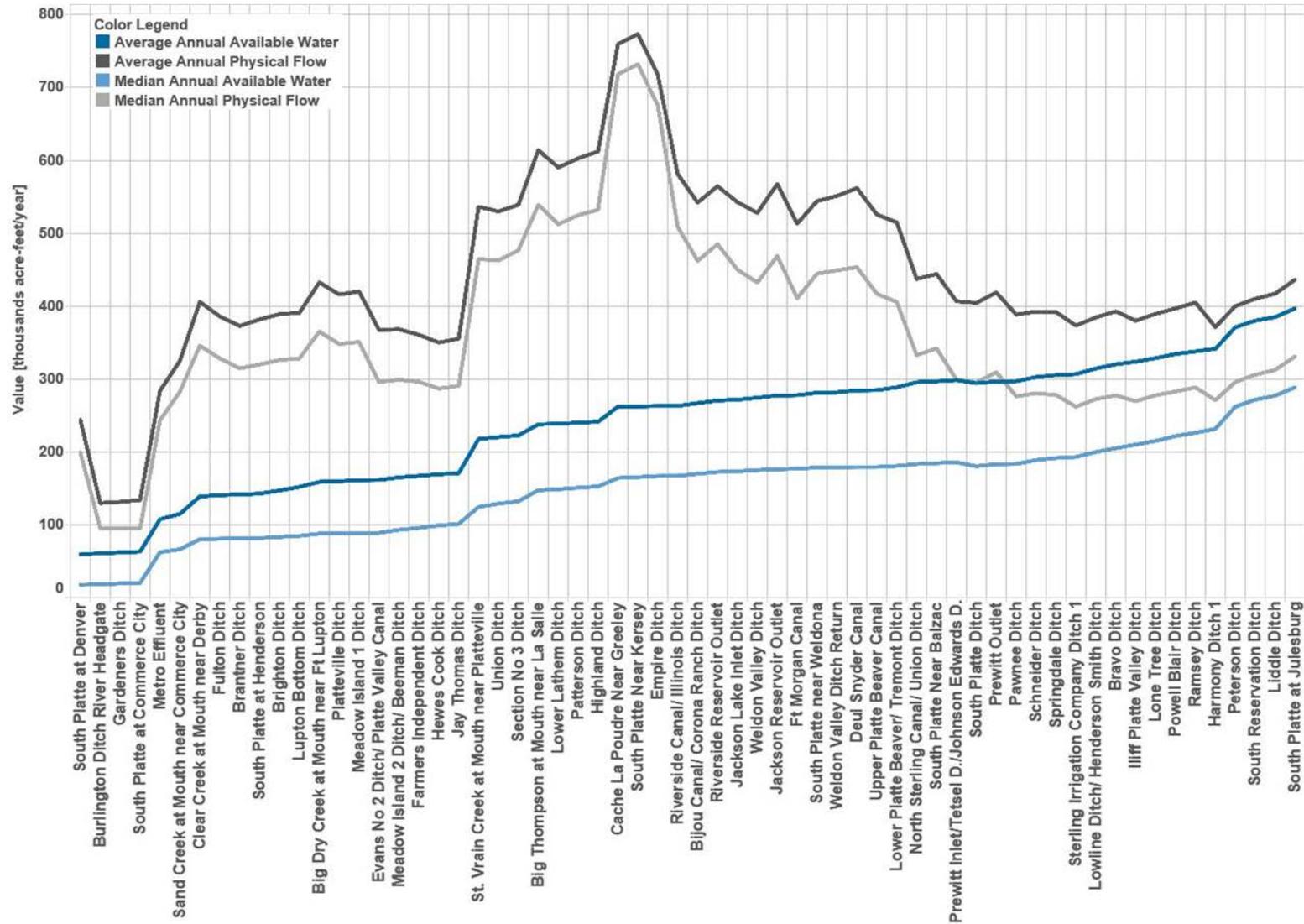


Figure 6-7. Future Average and Median Physical Flow and Available Water

6.4 DIVERSION CAPACITY CONSTRAINTS ON AVAILABLE WATER

Because nearly all potential SPSS storage options would be located off the mainstem of the South Platte River, effective available water would be constrained by the capacity of the diversion system conveying water from the river to storage. Future daily flows based on the adjusted 1996-2015 hydrology were analyzed to estimate the maximum potential volume of water that could be conveyed to storage as function of diversion capacity from three key points in the SPSS study area: the Kersey gage, the Balzac gage and the Julesburg gage. Results are shown in [Table 6-6](#), and indicate that large diversion and conveyance facilities would be required to capture significant portions of available water when storage is located off-channel. For example, at the Balzac gage a diversion capacity of 650 cfs would be needed to capture an average of 100,000 ac-ft/yr. Capturing 85 percent of available water would require diversion capacities from 450 cfs at Kersey to 800 cfs at Julesburg. These are large diversion capacities, but are within the range of existing diversion structures on the South Platte River.

Table 6-6. Diversion-Constrained Potential Yield to Off-Channel Storage Site

Percentage of Time the Full Daily Streamflow could be Diverted to Storage	Diversion Point					
	Kersey Gage		Balzac Gage		Julesburg Gage	
	Diversion Capacity (cfs)	Average Annual Yield (AFY)	Diversion Capacity (cfs)	Average Annual Yield (AFY)	Diversion Capacity (cfs)	Average Annual Yield (AFY)
85	450	75,300	550	93,800	800	162,900
90	700	97,600	900	124,600	1,100	189,400
95	1,100	118,100	1,400	149,800	1,700	219,400
97	1,900	140,300	2,100	168,000	2,400	238,500
98	3,100	161,100	3,500	191,700	3,800	262,900
99	5,500	186,300	6,400	220,700	7,400	299,300

7. DEMANDS

7.1 INTRODUCTION

Analysis of SPSS options required an assumption about demands the storage projects would potentially be operated to meet. A simplified approach for estimating water demands was adopted for the SPSS. Because no specific users of SPSS water have been identified, and because many different storage options were investigated, a standardized approach to determining demands for storage scenarios was needed. This approach allowed for a consistent comparison of storage scenarios on the basis of their ability to meet demands in the South Platte Basin.

For the purpose of the SPSS, total potential water demand for future storage projects is defined as the future agricultural and M&I gap or shortage in the lower South Platte Basin, assuming implementation of IPPs. Future demands were used rather than existing demands to match with the use of future condition hydrology for the SPSS supply analysis. The State of Colorado's 2010 Statewide Water Supply Initiative (SWSI 2010) (CDM, 2011) was utilized as the basis for information about the water demands within the SPSS study area.

To simplify the demand analysis, future demand estimates were aggregated by stream reach along the South Platte. From upstream to downstream, the demand reaches utilized for the SPSS were:

- Upstream of the South Platte River at Denver Gage (Upstream of Denver Gage)
- South Platte River at Denver gage to South Platte River Near Kersey gage (Denver to Kersey)
- South Platte River Near Kersey gage to South Platte River at Cooper Bridge near Balzac gage (Kersey to Balzac)
- South Platte River at Cooper Bridge near Balzac gage to South Platte River at Julesburg gage (Balzac to Julesburg)

Detailed documentation of the methods used to estimate demands is provided in **Appendix F**.

7.2 DEMAND ESTIMATION METHODS

Estimation of maximum potential demands that could be met by a SPSS storage project were developed using the approach shown in [Figure 7-1](#). Derivation of the SPSS agricultural demands was based on the SWSI 2010 analysis of estimated 2050 agricultural demand, which includes assumptions for reduction in irrigated acreage. The future agricultural shortage was assumed to be the maximum potential agricultural demand that could be met by a SPSS option. SWSI 2010 defines agricultural shortage as

the difference between the water supply-limited consumptive use and the irrigation water requirement of the irrigated lands.

Agricultural shortages for the recent 10-year historical period were computed by Water District in the SPSS study area. These were then adjusted to 2050 conditions based on the SWSI 2010 assumptions for reduced irrigated acreage. Shortages by Water District were then allocated to the four SPSS demand points.

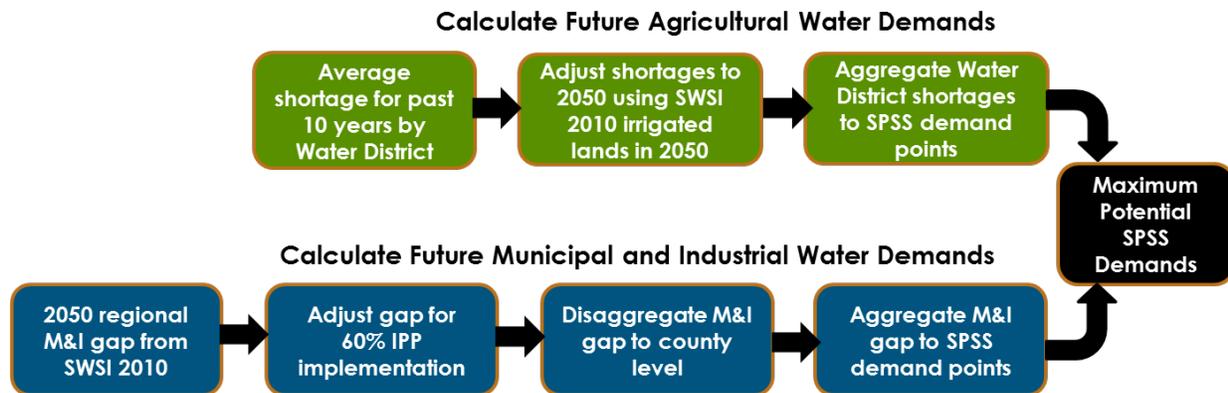


Figure 7-1. Demand Estimate Approach

Derivation of the SPSS municipal demands was based on the SWSI 2010 analysis of the 2050 M&I water supply gap. The SPSS adopted the 2050 M&I gap assuming the median demand forecast and 60 percent implementation of IPPs. SWSI 2010 data presented by region was disaggregated to the county level, then re-aggregated at each of the SPSS demand points.

7.3 RESULTS OF DEMAND ANALYSIS

Table 7-1 presents the results of the SPSS demand analysis. It lists the maximum potential demand that would be applied to storage options to assess their effectiveness in reducing excess flows at the state line and putting Colorado's water resources to beneficial use. Spatial distribution of the demands is shown in **Figure 7-2**, which also shows spatial distribution of available water in the SPSS study area.

In addition to total annual demand, the SPSS analysis required a monthly distribution of demand since both M&I and agricultural demands vary substantially throughout the year. M&I weekly demands as a percentage of total annual demand were taken from data available from Aurora Water; this was assumed to be representative of other municipal entities in the South Platte Basin. A monthly agricultural demand pattern was developed from historical data for applied water from both surface and groundwater sources since SPSS water could be used to augment well depletions. The weekly demand patterns for agricultural and M&I demands are shown in **Figure 7-3**.

The maximum potential demand exceeds the available water supply, particularly if the supply is limited by diversion capacity to off-channel storage projects. Thus the sizing of storage options is supply limited rather than demand limited on a basin-wide basis.

Table 7-1. Maximum Potential Demand Applied to SPSS Options

Reach	Ag Future Shortage			M&I Future Shortage		Total Demand
	Water District	Mainstem	Tributary	County	Total	
Upstream of Denver Gage	WD8		1,115	Denver	18,726	
	WD9		267	Arapahoe	40,439	
				Jefferson	15,215	
				Douglas	27,545	
				Elbert	3,516	
	<i>Reach Total</i>	-	1,382	<i>Reach Total</i>	105,441	106,823
Denver to Kersey	WD2	71,388		Weld	42,950	
	WD3		65,435	Adams	21,847	
	WD4		28,744	Larimer	28,122	
	WD5		29,394	Boulder	14,828	
	WD6		15,131	Broomfield	3,511	
	WD7		90			
	<i>Reach Total</i>	71,388	138,794	<i>Reach Total</i>	111,259	321,441
Kersey to Balzac	WD1	46,644		Morgan	9,486	
	<i>Reach Total</i>	46,644	-	<i>Reach Total</i>	9,486	56,130
Balzac to Julesburg	WD64	11,374		Logan	7,114	
				Sedgwick	0	
				Washington	0	
	<i>Reach Total</i>	11,374	-	<i>Reach Total</i>	7,114	18,488
BASIN TOTALS		129,406	140,176		233,300	502,882

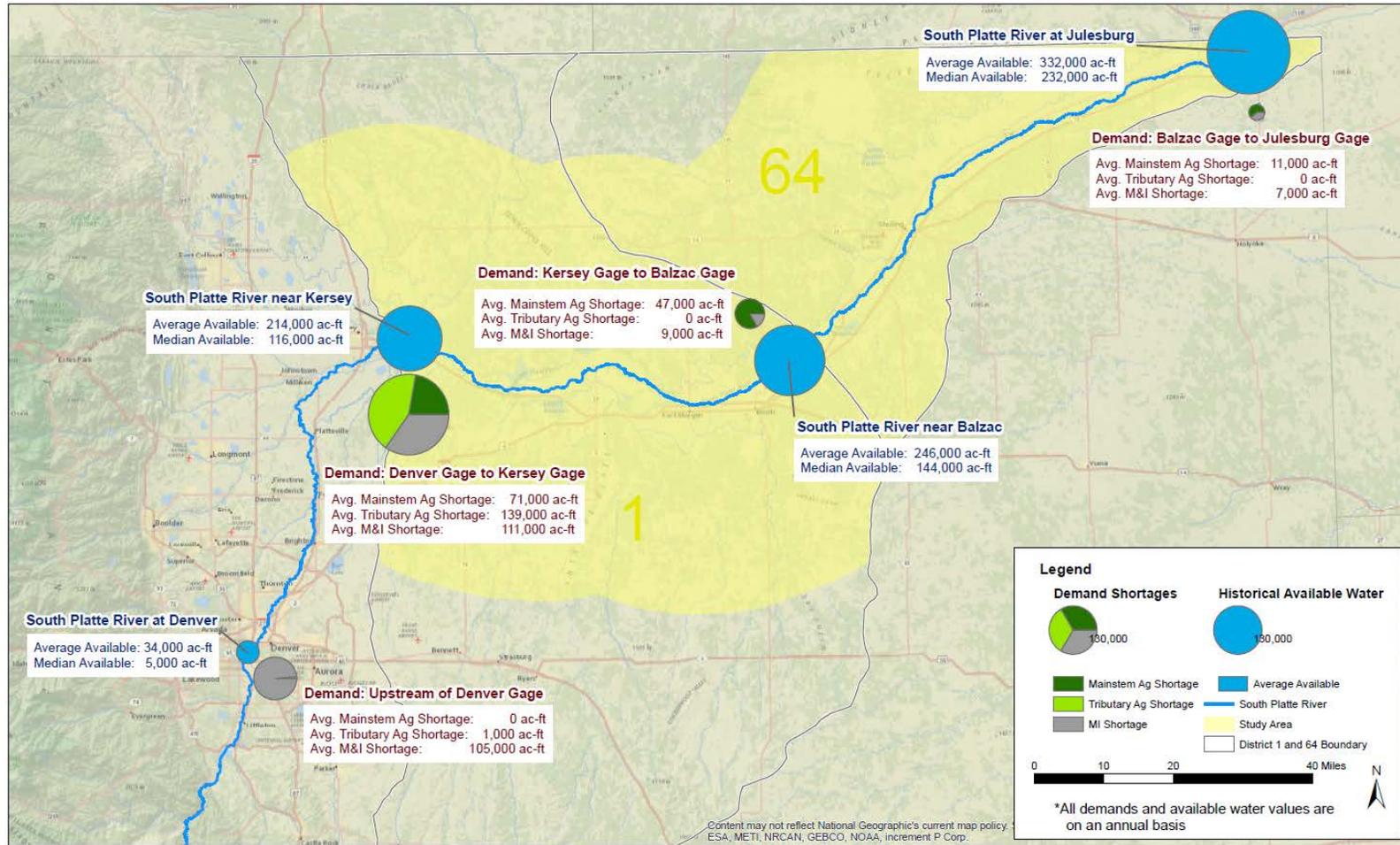


Figure 7-2. Summary of Available Water and Demands at Key Locations in SPSS Study Area

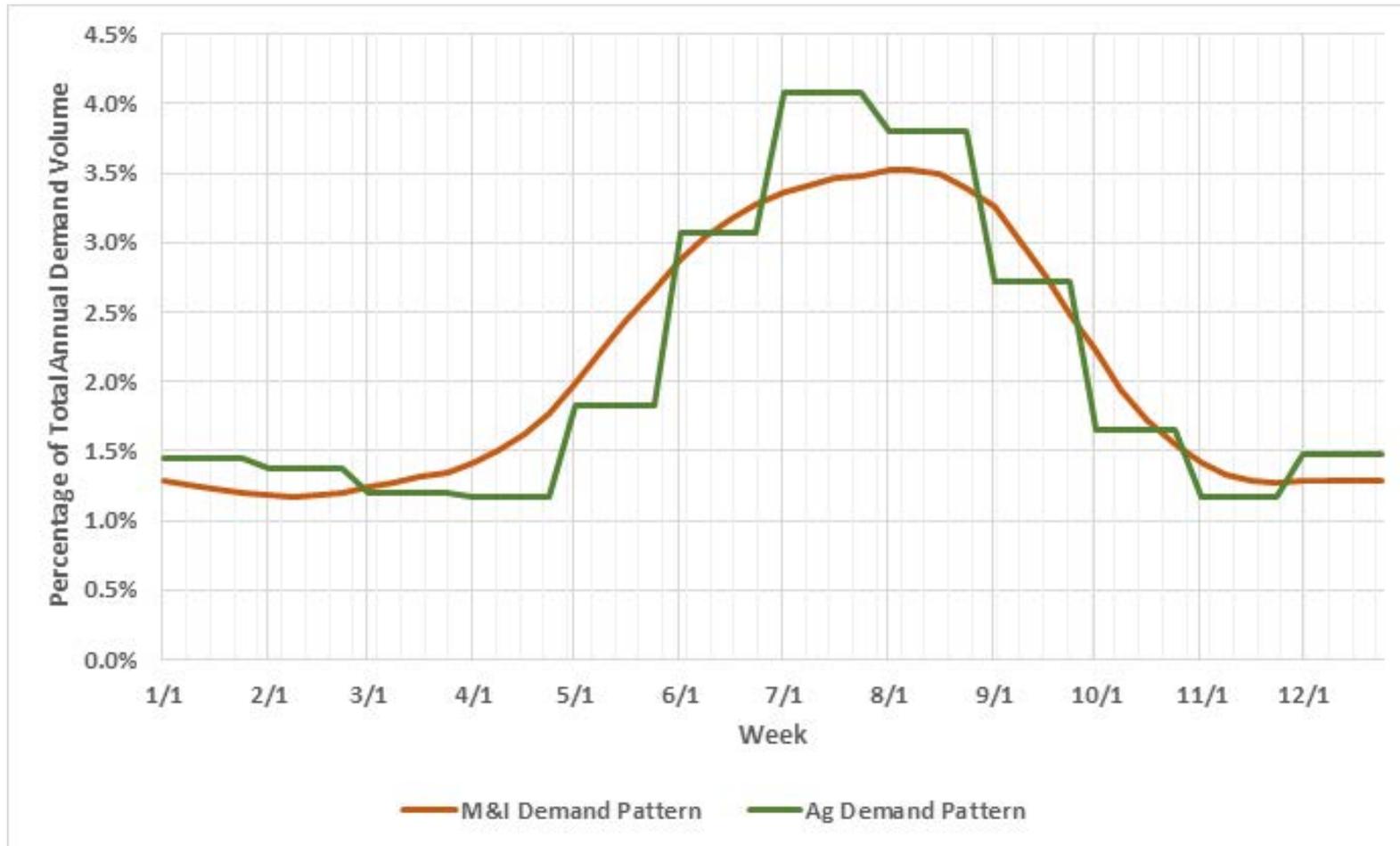


Figure 7-3. Weekly Distribution of Annual Demand

8. WATER QUALITY

The quality of water available for a new storage project in the lower South Platte Basin could affect the feasibility of putting that water to beneficial use. Similarly, enlarging or rehabilitating existing reservoirs would only be feasible if water quality would be appropriate for the intended uses.

Existing water quality data for stream segments and reservoirs was reviewed and impaired water bodies based on the state's water quality assessment were identified. Results of the water quality review are provided in **Appendix G**.

Table 8-1 summarizes the results of the water quality review for key parameters. Water diverted for storage in the SPSS study area would be adequate quality for irrigation use, as these sources are currently widely used for agricultural purposes. However, if used directly as a drinking water supply, water from any new SPSS storage project would require a high level of treatment (e.g., reverse osmosis, ion exchange) to remove a number of problematic constituents including arsenic, selenium, sulfate, total dissolved solids, and uranium. This level of treatment would add significant cost and complexity to a storage concept associated with construction of the treatment process itself, disposal of residuals, operational costs, and energy requirements. In addition, groundwater non-degradation policies would require treatment of any water delivered from the South Platte River below Greeley prior to performing aquifer recharge and underground storage to avoid adversely affecting existing groundwater quality.

Table 8-1. Summary of Water Quality Issues Affecting Storage Options

Key Parameter	Assumed Method of Use	Reach Impaired for Use	Potential Treatment Alternatives and Regulatory Needs
Arsenic	<i>Domestic Water Supply</i> – Direct feed to WTP	COSPMS01B	High Level Treatment Methods – High Cost Residuals Treatment and/or Disposal – High Cost
Dissolved Oxygen	<i>Agriculture, Aquatic Life, Recreation</i> – Surface water discharge to receiving water for direct use, augmentation use, or exchange <i>Domestic Water Supply</i> – Direct feed to WTP	COSPLS03 (North Sterling Reservoir)	Conventional Treatment Methods – Low Cost
E. Coli	<i>Recreation*</i> – Surface water discharge to receiving water for direct use, augmentation use, or exchange	COSPMS01B	Conventional Treatment Methods – Low Cost
Manganese	<i>Domestic Water Supply</i> – Direct feed to WTP	COSPMS01B COSPLS01	Medium Level Treatment Methods – Medium Cost (e.g., green sand filters, enhanced coagulation, etc.)

Key Parameter	Assumed Method of Use	Reach Impaired for Use	Potential Treatment Alternatives and Regulatory Needs
pH	<i>Aquatic Life*</i> – Surface water discharge to receiving water for direct use, augmentation use, or exchange <i>Domestic Water Supply</i> – Direct feed to WTP	COSPLS03 (Jackson Reservoir)	Conventional Treatment Methods – Low Cost
Selenium	<i>Domestic Water Supply</i> – Direct feed to WTP	COSPLS01 COSPLS03 (North Sterling Reservoir)	High Level Treatment Methods – High Cost Residuals Treatment and/or Disposal – High Cost
Sulfate	<i>Domestic Water Supply</i> – Direct feed to WTP	COSPMS01B COSPLS01	High Level Treatment Methods – High Cost
Total Dissolved Solids	<i>Domestic Water Supply</i> – Direct feed to WTP	COSPMS01B COSPLS01	High Level Treatment Methods – High Cost Residuals Treatment and/or Disposal – High Cost
Uranium	<i>Domestic Water Supply</i> – Direct feed to WTP	COSPLS01	High Level Treatment Methods – High Cost Residuals Treatment and/or Disposal – High Cost

Notes: COSPMS01B - Mainstem of the SPR from confluence with St Vrain Creek to the Weld/Morgan County Line
 COSPLS01 - Mainstem of the SPR from the Weld/Morgan County line to the CO/NE border
 High Level Treatment Needs could include reverse osmosis, ion exchange, activated alumina, etc.
 Residuals Treatment and/or Disposal could include permitted discharge to sewer, deep well injection, evaporation pond, land application, zero liquid discharge, etc.
 * Initial recommendation – obtain legal determination as to whether the use of water constitutes and “exercise of water rights”

9. STORAGE OPTIONS

The SPSS evaluation process involved analyzing storage options (individual reservoir or aquifer storage facilities) and more comprehensive storage concepts or solutions (individual storage options or combinations of storage options integrated with all other infrastructure required to have an operational storage project). Storage options were analyzed first, and the most promising options were incorporated into storage concepts. The overall storage evaluation process is summarized in [Figure 9-1](#).

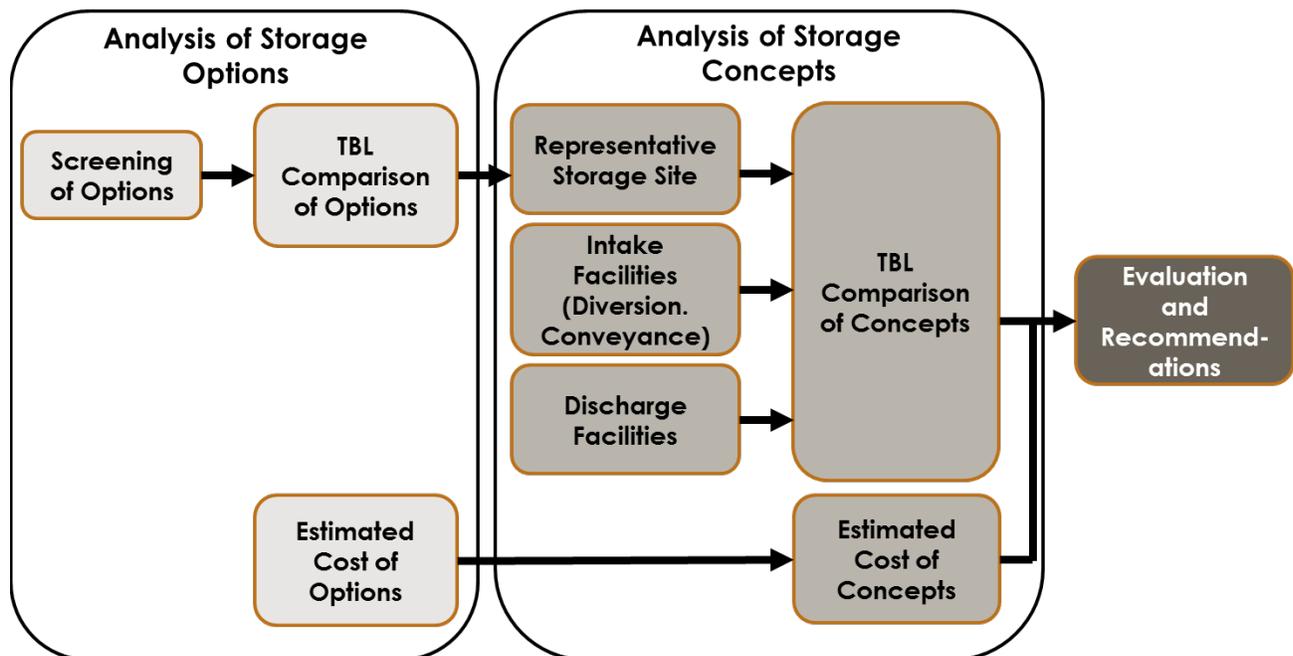


Figure 9-1. SPSS Storage Evaluation Process Overview

This section summarizes the process used to identify and evaluate individual storage options for the SPSS. It includes:

- Screening of storage options to eliminate infeasible and clearly inferior options
- Comparison of storage options based on technical and environmental criteria
- Estimation of cost of storage options

A more detailed discussion of the storage option analysis is provided in **Appendix H. Section 10.0** describes how individual storage options were incorporated into overall storage concepts for analysis.

Aquifer storage options are different from surface storage options. While many surface storage projects are designed to capture peak flows by diverting high flow rates for short periods of time, aquifer storage projects are limited by recharge capacity and thus

cannot directly store high flows. They are often combined with reservoir projects and operated conjunctively so the reservoir can feed water at a managed rate to the recharge area. Aquifer storage is often seen as a supplemental water source rather than a source for peaking or meeting high sustained demands. For this reason they were analyzed separately from surface reservoir options.

9.1 SCREENING OF STORAGE OPTIONS

Storage options were screened starting with a long-list resulting from the literature review to eliminate those options with fatal flaws or that did not meet minimum criteria related to SPSS project goals. The objective of this process was not to identify the best storage options, but to eliminate clearly inferior options that would not meet SPSS objectives. The storage option screening process was conducted collaboratively in a workshop attended by members of the South Platte and Metro Basin Roundtables and the Stantec consultant team. Subsequent refinements were made by the consultant team with concurrence of the CWCB, CDWR and Roundtables.

Figure 9-2 summarizes the storage site screening process for surface reservoirs, aquifer storage and gravel pits. Sites were screened out if they were located too far from the South Platte mainstem; did not meet minimum capacity criteria; were clearly inferior to other similar options; or were considered impractical for purposes of SPSS by the Roundtable members. Results of the storage site screening process are shown in Figure 9-3.

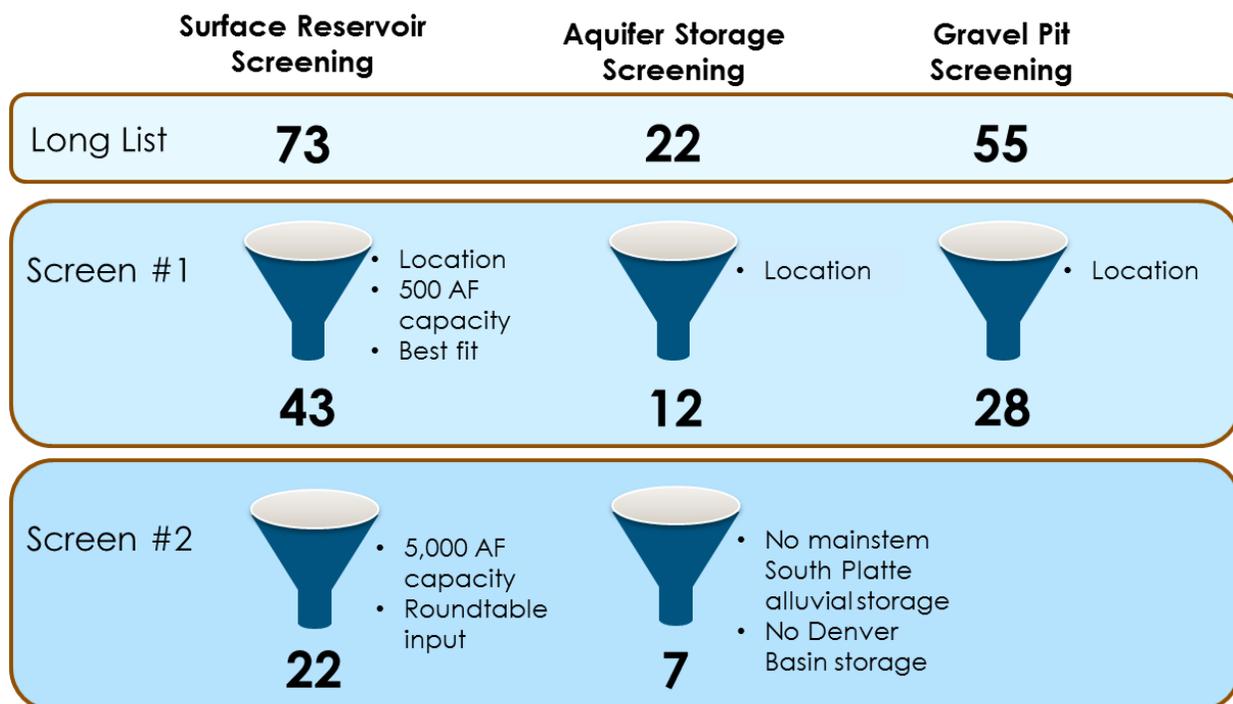


Figure 9-2. Summary of Storage Site Screening Process

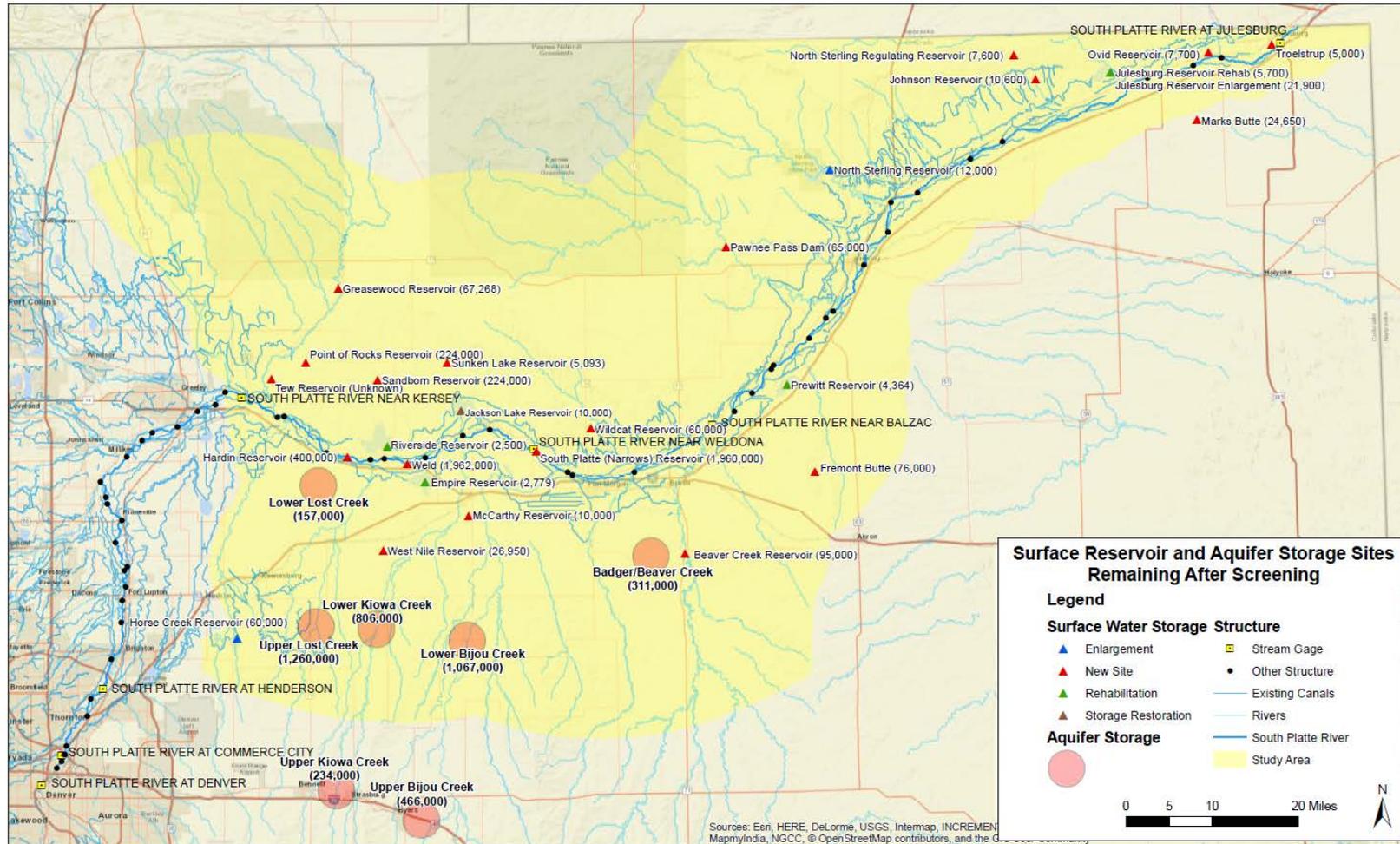


Figure 9-3. Surface Reservoir and Aquifer Storage Sites Remaining After Screening

9.2 COMPARISON OF STORAGE OPTIONS – SITE EVALUATION FRAMEWORK

Individual SPSS storage options were evaluated and compared based on technical, cost, and environmental factors. Technical and environmental data for all storage options remaining after the initial screening process were collected from the available sources described in **Appendix B**. Data were compiled in a Site Evaluation Framework (SEF) database. Database attributes (parameters, data types) and qualifiers (values, ratings) for the SEF are defined in **Appendix H**.

Where possible, data were collected from previous studies and reports. The SPSS study team used the best available maps, aerial photography and other resources to fill in the database attributes for each storage option. Professional judgment was used where necessary. For each surface reservoir storage option the descriptive data were based on the maximum storage capacity reported for that site in previous reports or based on a feasible dam alignment determined by the consultant team. ASR site characteristics were obtained from previous reports and combined with theoretical conceptual design for recharge and recovery facilities. Database entries for each storage option are shown in [Table 9-1](#).

Table 9-1. Database Entries for Storage Options

Site Name	Features									Benefits		
	Partnerships-Consumptive	Partnerships-Non-Consumptive	Regional Integration	Existing Water Quality	Source Water Quality	Construct-ability	Scalability	Use Existing Infrastructure	Ease To Use Existing Infrastructure	Flood Control Benefit	Migratory Bird Habitat	Solution Compatibility
Prewitt Reservoir Rehab	Yes	Unknown	Yes	No	Yes	High	Low	Yes	Easy	Low	Yes	Yes
Julesburg Reservoir Enlarge	Unknown	Unknown	Yes	Unknown	Yes	High	Low	Yes	Easy	Low	Yes	No
Wildcat Reservoir	Yes	Yes	Yes	N/A	Yes	High	Low	Yes	Medium	Low	Yes	Yes
South Platte (Narrows) Reservoir	Yes	Unknown	Yes	N/A	Yes	Low	Low	Yes	Easy	High	Yes	Yes
Hardin Reservoir	Unknown	Unknown	Yes	N/A	Yes	Low	Low	Yes	Easy	High	Yes	Yes
Riverside Reservoir Rehab	Unknown	Unknown	Yes	No	Yes	High	Low	Yes	Easy	Low	Yes	Yes
Empire Reservoir Rehab	Unknown	Unknown	Yes	No	Yes	High	Low	Yes	Easy	Low	Yes	Yes
Sandborn Reservoir	Unknown	Unknown	Yes	N/A	Yes	High	Low	Yes	Difficult	Low	Yes	Yes
Point of Rocks Reservoir	Unknown	Unknown	Yes	N/A	Yes	High	Low	Yes	Medium	Low	Yes	Yes
Julesburg Reservoir (Rehab)	Unknown	Unknown	Yes	Unknown	Yes	High	Low	Yes	Easy	Low	Yes	No
Jackson Lake Reservoir	Yes	Unknown	Yes	Yes	Yes	High	Low	Yes	Easy	Low	Yes	Yes
North Sterling Reservoir Enlarge	Unknown	Unknown	Yes	Yes	Yes	High	Low	Yes	Easy	Low	Yes	No
McCarthy Reservoir	Yes	Unknown	Yes	N/A	Yes	High	Low	No	N/A	Low	Yes	Yes
Upper Lost Creek	Unknown	Unknown	No	N/A	No	High	Medium	No	N/A	Low	No	Yes
Lower Lost Creek	Unknown	Unknown	Yes	No	No	High	Medium	No	N/A	Low	No	Yes
Upper Kiowa Creek	Unknown	Unknown	No	N/A	Yes	High	Medium	No	N/A	Low	No	Yes
Lower Kiowa Creek	Unknown	Unknown	Yes	Yes	Yes	High	Medium	No	N/A	Low	No	Yes
Upper Bijou Creek	Unknown	Unknown	No	N/A	Yes	High	Medium	No	N/A	Low	No	Yes
Lower Bijou Creek	Unknown	Unknown	Yes	Unknown	Unknown	High	Medium	No	N/A	Low	No	Yes
Badger/Beaver Creek	Unknown	Unknown	No	No	No	High	Medium	No	N/A	Low	No	Yes
Ovid Reservoir	Unknown	Unknown	Yes	N/A	Yes	High	Low	Yes	Medium	Low	Yes	No
Johnson Reservoir	Unknown	Unknown	Yes	N/A	Yes	High	Low	Yes	Medium	Low	Yes	No
North Sterling Regulating Res	Unknown	Unknown	Yes	N/A	Yes	High	Low	Yes	Difficult	Low	Yes	No
Troelstrup	Unknown	Unknown	Yes	N/A	Yes	High	Low	Yes	Medium	Low	Yes	No
Pawnee Pass Dam	Unknown	Unknown	Yes	N/A	Yes	High	Low	Yes	Difficult	Medium	Yes	Yes
Greasewood Reservoir	Unknown	Unknown	Yes	N/A	Yes	High	Low	No	N/A	Medium	Yes	Yes
Sunken Lake Reservoir	Unknown	Unknown	Yes	N/A	Yes	High	Low	No	N/A	Low	Yes	Yes
West Nile Reservoir	Unknown	Unknown	Yes	N/A	Yes	High	Low	No	N/A	Low	Yes	Yes
Fremont Butte	Yes	Unknown	Yes	N/A	Yes	High	Low	No	N/A	High	Yes	Yes
Beaver Creek Reservoir	Unknown	Unknown	Yes	N/A	Yes	High	Low	No	N/A	Medium	Yes	Yes

Site Name	Environmental							Permitting	
	National Wetland Inventory	Critical Habitat -ESA	Wildlife Habitat Impact	Wildlife Species Impact	Migratory Bird Impact	Bald Eagle Nests Impacts	Oil And Gas Wells	Federal Nexus	SPWRAP Potential
Prewitt Reservoir Rehab	Medium	No	Negative	Negative	Negative	Low	None	Yes	Yes
Julesburg Reservoir Enlarge	Medium	No	Negative	Negative	Negative	Low	None	Yes	Yes
Wildcat Reservoir	Medium	No	Negative	Negative	Negative	Low	None	Yes	Yes
South Platte (Narrows) Reservoir	High	No	Negative	Negative	Negative	Low	None	Yes	No
Hardin Reservoir	High	No	Negative	Negative	Negative	High	High	Yes	No
Riverside Reservoir Rehab	Medium	No	Neutral	Neutral	Neutral	High	Low	Yes	Yes
Empire Reservoir Rehab	Medium	No	Neutral	Neutral	Neutral	High	Low	Yes	Yes
Sandborn Reservoir	Low	No	Negative	Negative	Negative	Low	Low	Yes	Yes
Point of Rocks Reservoir	Low	No	Negative	Negative	Negative	Low	High	No	Yes
Julesburg Reservoir (Rehab)	High	No	Neutral	Neutral	Neutral	Low	None	Yes	Yes
Jackson Lake Reservoir	Low	No	Negative	Negative	Neutral	Medium	None	Yes	Yes
North Sterling Reservoir Enlarge	Medium	No	Negative	Negative	Negative	Low	None	Yes	Yes
McCarthy Reservoir	Low	No	Negative	Negative	Negative	Low	None	Yes	Yes
Upper Lost Creek	Low	No	Neutral	Neutral	Neutral	Low	None	Yes	No
Lower Lost Creek	Low	No	Neutral	Neutral	Neutral	Low	Low	No	No
Upper Kiowa Creek	Low	No	Neutral	Neutral	Neutral	Low	None	Maybe	No
Lower Kiowa Creek	Low	No	Neutral	Neutral	Neutral	Low	None	Yes	No
Upper Bijou Creek	Low	No	Neutral	Neutral	Neutral	Low	None	Maybe	No
Lower Bijou Creek	Medium	No	Neutral	Neutral	Neutral	Low	None	Yes	No
Badger/Beaver Creek	Low	No	Neutral	Neutral	Neutral	Low	Low	Yes	No
Ovid Reservoir	High	No	Negative	Negative	Negative	Low	None	Yes	Yes
Johnson Reservoir	Low	No	Negative	Negative	Negative	Low	None	Yes	Yes
North Sterling Regulating Res	Low	No	Negative	Negative	Negative	Low	None	Yes	Yes
Troelstrup	High	No	Negative	Negative	Negative	Low	None	Yes	Yes
Pawnee Pass Dam	Medium	No	Negative	Negative	Negative	Low	None	Yes	Yes
Greasewood Reservoir	Low	No	Negative	Negative	Negative	Low	None	Yes	Yes
Sunken Lake Reservoir	Medium	No	Negative	Negative	Negative	Low	None	Yes	Yes
West Nile Reservoir	Low	No	Negative	Negative	Negative	Low	None	Yes	Yes
Fremont Butte	Low	No	Negative	Negative	Negative	Low	None	Yes	Yes
Beaver Creek Reservoir	High	No	Neutral	Neutral	Neutral	Low	None	Yes	Yes

The information in the SEF was used to select the representative storage sites for modeling each storage concept as described in **Section 10.0** of this report. Representative sites were the sites that provided the best balance of technical feasibility and size while avoiding difficult environmental and social impacts to the extent possible. While the representative sites were selected as the “best fit” among the potential sites in each portion of the SPSS study area, further study could determine that other sites are as good or better. The data in the SEF can provide the starting point for future studies if desired.

Criteria and data from the SEF were used to compare short-listed storage sites using a simple scoring system. The purpose of the scoring system was to provide a means of identifying the more feasible storage options. At this level the comparison of sites is not a precise assessment, and results should be used only to identify overall trends or large differences between options.

Appendix H lists numerical values assigned to each of the qualifiers for the attributes. Assigning values to the qualifiers allowed for calculation of a triple bottom line evaluation score for each option.

Evaluation of alternatives using a triple bottom line scoring system with multiple criteria required assumptions for the weight of each of the criteria. For this analysis three weighting scenarios were tested:

- Equal Weights; all criteria received an equal weight of 1.
- Technical Weights; all criteria related to technical feasibility of the storage option (e.g., scalability, constructability, ability to use existing infrastructure) were given a weight of 3 and all other criteria were given a weight of 1.
- Environmental Weights; all criteria related to environmental parameters (e.g., wetlands, habitat impacts, permissibility) were given a weight of 3 and all other criteria were given a weight of 1.

Table 9-2 summarizes the results of the triple bottom line site evaluation process applied to the storage options for the three criteria weighting scenarios. The table shows the numerical score for the storage options separated by storage category. Because each type of storage project is different, it is most appropriate to compare scores within each category. In addition, the average of the scores was computed across the 3 weighting scenarios for each storage option to assess how the sites performed across all weightings. This is shown in **Table 9-3**, which again is separated by storage category. **Figure 9-4** shows the range of scores for combined surface reservoirs and aquifer storage sites for each of the weighting scenarios as well as the maximum possible score for each scenario.

Table 9-2. Summary of Storage Site Evaluation Scores for Different Criteria Weighting Scenarios

Name	Storage Category	Site Score-Equal Weighting	Site Score-Feasibility Weighting	Site Score-Environmental Weighting
Range of Possible Scores (Min / Max)		0 / 20.5	0 / 43.5	0 / 37.5
New Reservoirs				
Beaver Creek Reservoir	New Site	8.5	18.5	12.5
Fremont Butte	New Site	7.5	18.5	7.5
Greasewood Reservoir	New Site	6.5	16.5	6.5
Hardin Reservoir	New Site	6	20	0
Johnson Reservoir	New Site	7	21	7
McCarthy Reservoir	New Site	6	16	6
North Sterling Reg Res	New Site	7	21	7
Ovid Reservoir	New Site	6.5	21.5	4.5
Pawnee Pass Dam	New Site	7	19	6
Point of Rocks Reservoir	New Site	8.5	21.5	10.5
Sandborn Reservoir	New Site	7	19	7
South Platte (Narrows) Res	New Site	7.5	22.5	3.5
Sunken Lake Reservoirs	New Site	6.5	18.5	5.5
Troelstrup	New Site	6.5	21.5	4.5
West Nile Reservoir	New Site	5.5	14.5	5.5
Wildcat Reservoir	New Site	9	26	8
Modified Existing Reservoirs				
Jackson Lake Reservoir	Rehabilitation	9.5	25.5	10.5
Julesburg Reservoir (Enlrg)	Enlargement	8	25	8
Julesburg Reservoir (Rehab)	Rehabilitation	10.5	27.5	15.5
North Sterling Reservoir	Enlargement	7	22	6
Prewitt Reservoir	Rehabilitation	9	26	8
Riverside Reservoir	Rehabilitation	10	25	13
Empire Reservoir	Rehabilitation	10	25	13
Aquifer Storage				
Badger/Beaver Creek	Aquifer	9.5	24.5	13.5
Lower Bijou Creek	Aquifer	10.5	28.5	13.5
Lower Kiowa Creek	Aquifer	10	26	12
Lower Lost Creek	Aquifer	11.5	28.5	17.5
Upper Bijou Creek	Aquifer	8.5	20.5	11.5
Upper Kiowa Creek	Aquifer	8.5	20.5	11.5
Upper Lost Creek	Aquifer	10	26	14

Table 9-3. Average of Scores across Three Weighting Scenarios for Reservoir Storage Options

Storage Options Sorted by Average Score	Storage Category	Average of Scores for 3 Weighting Scenarios ⁽¹⁾
New Reservoirs		
Wildcat Reservoir	New – Off Channel	14.3
Point of Rocks Reservoir	New – Off Channel	13.5
Beaver Creek Reservoir	New – Off Channel	13.2
Johnson Reservoir	New – Off Channel	11.7
North Sterling Regulating Reservoir	New – Off Channel	11.7
Fremont Butte	New – Off Channel	11.2
South Platte (Narrows) Reservoir	New - Mainstem	11.2
Sandborn Reservoir	New – Off Channel	11.0
Ovid Reservoir	New – Off Channel	10.8
Troelstrup	New – Off Channel	10.8
Pawnee Pass Dam	New – Off Channel	10.7
Sunken Lake Reservoir	New – Off Channel	10.2
Greasewood Reservoir	New – Off Channel	9.8
McCarthy Reservoir	New – Off Channel	9.3
Hardin Reservoir	New – Mainstem	8.7
West Nile Reservoir	New – Off Channel	8.5
Modified Existing Reservoirs		
Julesburg Reservoir (Rehabilitation)	Rehabilitation	17.8
Riverside Reservoir	Rehabilitation	16.0
Empire Reservoir	Rehabilitation	16.0
Jackson Lake Reservoir	Rehabilitation	15.2
Prewitt Reservoir	Rehabilitation	14.3
Julesburg Reservoir (Enlargement)	Enlargement	13.7
North Sterling Reservoir	Enlargement	11.7
Aquifer Storage		
Lower Lost Creek	Aquifer	19.2
Lower Bijou Creek	Aquifer	17.5
Upper Lost Creek	Aquifer	16.7
Lower Kiowa Creek	Aquifer	16.0
Badger/Beaver Creek	Aquifer	15.8
Upper Bijou Creek	Aquifer	13.5
Upper Kiowa Creek	Aquifer	13.5

(1) Range of possible averaged scores is 0 – 34

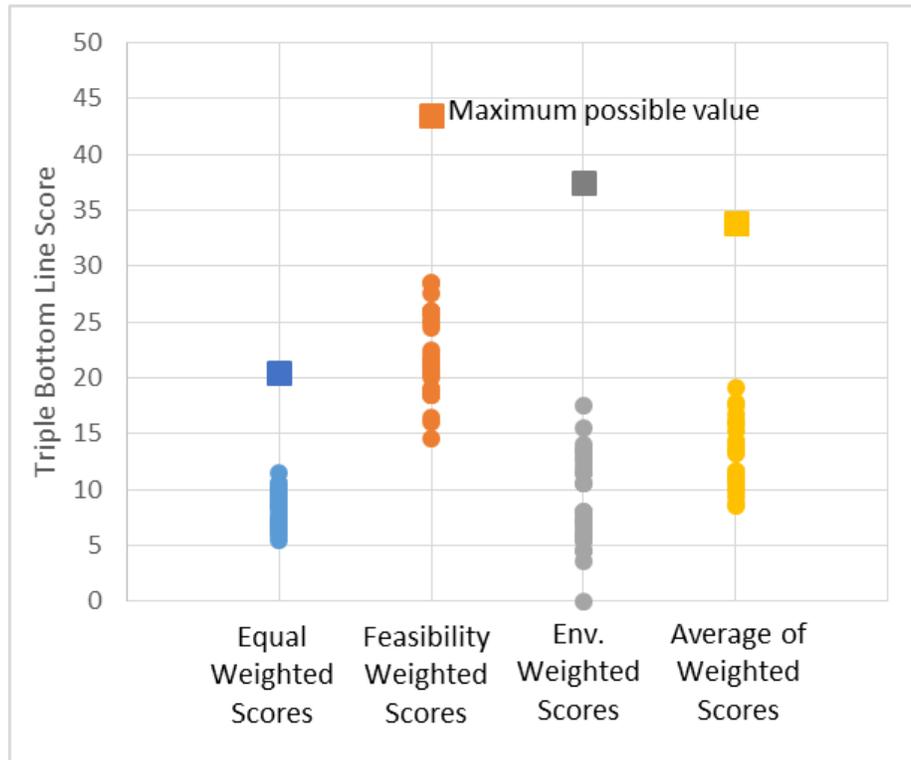


Figure 9-4. Range of Storage Site Scores for Different Weighting Scenarios

Results of the multi-criteria comparison of sites can be summarized as follows:

- Sites that tend to rise to the top of the scoring process tend to do so regardless of the weights assigned to the criteria. Similarly, sites that tend to fall to the bottom of the scoring process tend to do so regardless of the weights assigned to the criteria. This is helpful in that the relative scoring of most sites is fairly independent of the weight assigned to the criteria in the SEF.
- As expected, the on-channel storage options (Narrows Reservoir and Hardin Reservoir) score poorly relative to most other options.
- Of the new off-channel reservoir options, the sites with the most promise appear to be Wildcat, Point of Rocks, Beaver Creek, Johnson, North Sterling Regulating, and Sandborn.
- Of the aquifer storage sites, Lower Lost Creek and Lower Bijou Creek score better than the other sites because of their closer proximity to the South Platte (simplifying diversions into storage and releases back to the river) and closer proximity to the major demand centers at Denver and Kersey.
- Scores are clustered over a relatively narrow range compared to the maximum possible score for each weighting scenario, and no storage options had a score close to the maximum possible score. Differences among storage options are small, and at this level of analysis the triple bottom line scoring process should not be used to eliminate options.

At this level of analysis, the storage option scoring process is very approximate and is based on conceptual information and considerable professional judgment. Significant information about individual sites was unknown at this stage. Refinement of site specific data could change scores of options significantly. In addition, sites were scored without regard for how they could be used in a specific solution that could be formulated by a specific water user. When considering how storage sites would be incorporated into a particular alternative and integrated into the operations of a particular water user, results for the scoring process could vary considerably from this generic approach.

9.3 STORAGE COST ESTIMATES

Conceptual (ACEE Class V) construction cost estimates were prepared for the remaining surface reservoir sites and for two of the aquifer storage sites with the most potential for SPSS storage. Details of the cost estimating process for dams and other infrastructure are contained in **Appendix I**. Where possible cost estimates from past studies were adopted for this study and were escalated to 2017 dollars using accepted construction cost indexes. For new sites or sites for which no data were available, unit costs (\$/ac-ft) were estimated based on unit costs of other reservoir storage projects in the SPSS study area.

Surface reservoir costs are summarized in [Table 9-4](#). These include costs for permitting, design, land acquisition and construction. The reservoirs with the lowest unit cost are the most cost-effective in terms of storage provided per dollar spent. For new surface reservoirs, unit cost is generally inversely correlated with capacity such that the largest reservoirs have the lowest unit cost. This is shown in [Figure 9-5](#); data in the figure include design and construction but not permitting costs. Enlarged or rehabilitated existing reservoirs have more variable unit costs because the type of work required to achieve the additional storage varies considerably from site to site.

Table 9-4. Summary of Surface Reservoir Costs

Dam Type/Name	Storage Capacity (ac-ft)	Estimated 2017 Cost (\$ million)	Unit Cost (\$/ac-ft)
New Site			
Sandborn Reservoir	224,000	\$131	\$580
West Nile Reservoir	26,950	\$59	\$2,100
McCarthy Reservoir	10,000	\$27	\$2,500
South Platte (Narrows) Reservoir	1,960,000	\$145	\$74
Wildcat Reservoir	60,000	\$79	\$1,300
Pawnee Pass Dam	75,000	\$254	\$3,400
Fremont Butte	76,000	\$74	\$980
North Sterling Regulating Reservoir	7,600	\$38	\$5,000
Johnson Reservoir	10,600	\$24	\$2,300
Ovid Reservoir	7,700	\$24	\$3,100
Troelstrup	5,000	\$19	\$3,700
Beaver Creek	95,000	\$66	\$690
Enlargement			
North Sterling Reservoir Enlargement	12,000	\$22	\$1,800
Julesburg Reservoir Enlargement	21,900	\$46	\$2,100
Rehabilitation			
Empire Reservoir Rehab	2,779	\$14	\$5,000
Prewitt Reservoir Rehab	4,364	\$5.5	\$1,300
Julesburg Reservoir Rehab	5,700	\$31	\$5,400
Jackson Lake Reservoir Rehab	10,000	\$37	\$3,700
Riverside Reservoir Rehab	2,500	\$13	\$5,200

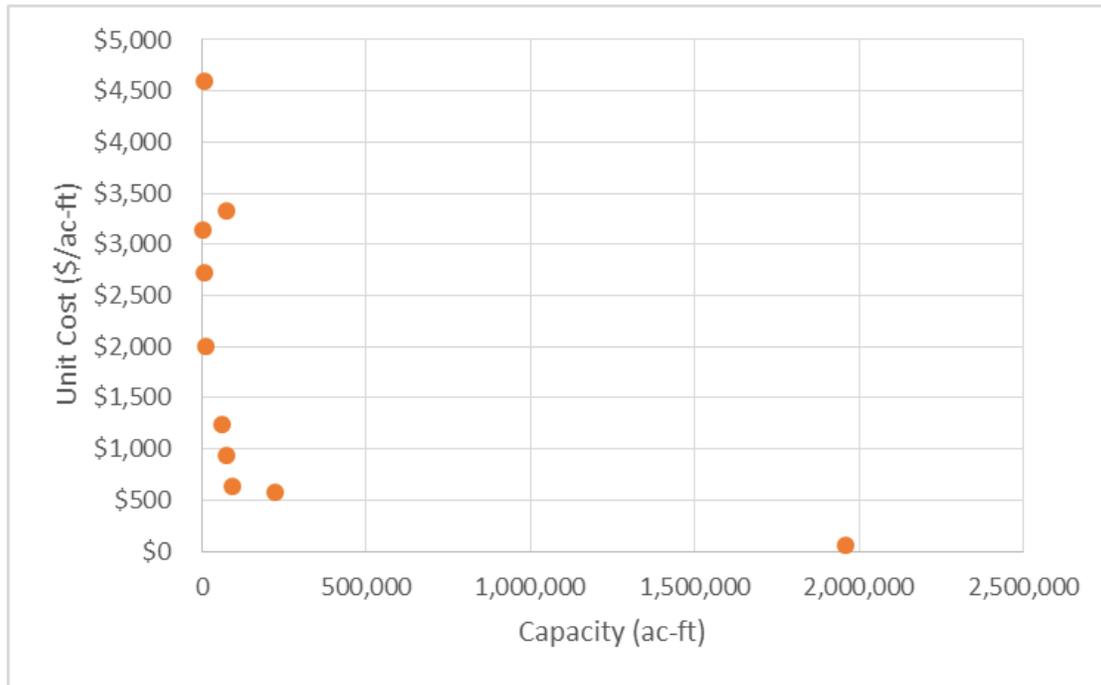


Figure 9-5. Unit Cost of Surface Storage vs Capacity for New Reservoirs

Aquifer storage costs were based on conceptual designs for infiltration basin recharge and recovery within an alluvial aquifer. Conceptual designs included components required to recharge and recover water at a site, but not the conveyance to and from the site.

Aquifer storage and recovery concept costs are more correlated to recharge and recovery rates than total storage volumes. Because of this, [Table 9-5](#) presents the same total cost estimate for Lower Lost Creek Basin and Badger/Beaver Basin. These costs were developed on a unit basis so future cost estimates can be scaled to different recharge and recovery scenarios.

Table 9-5. Aquifer Storage and Recovery Costs

Storage Concept	Storage Capacity (ac-ft)	Recharge Rate (ac-ft per month)	Recovery Rate (ac-ft per month)	Estimated 2017 Cost (\$ million)	Unit Cost (\$/ac-ft/month)
Lower Lost Creek Aquifer	157,000	5,000	4,000	\$39	\$9,750
Beaver/Badger Aquifer	311,000	5,000	4,000	\$39	\$9,750

The aquifer storage cost estimates were based on SPSS delivery and demand scenarios with 10,000 ac-ft of gravel pit regulating storage near the river diversion (see discussion of concepts in the next section). Aquifer storage concepts were modeled with a capacity of 5,000 ac-ft per month of inflow/recharge and 4,000 ac-ft per month of outflow/recovery. It is possible that these scenarios would not represent achievable rates of alluvial aquifer recharge and recovery for all alluvial ASR sites, but these rates were used to provide a reasonable scale for ASR site components and associated costs. It was assumed that land availability and hydrogeologic conditions would not constrain site construction or operations for recharge or recovery. Comparison to surface water storage options is challenging because of fundamental differences in how ASR sites would be constructed and operated.

9.4 SUMMARY OF STORAGE OPTION ANALYSIS

The analysis of storage options was necessarily high level at this stage of analysis, but supports the following conclusions.

- Many feasible surface and aquifer storage options exist in the lower South Platte Basin.
- Cost of surface reservoir storage varies widely, and is very dependent on the specific site being considered and its size based on the needs of the particular application. Nonetheless, many potentially cost-effective reservoir storage options exist in the study area.
- Aquifer storage projects are more limited by recharge and recovery rates rather than storage volume. Typical aquifer storage projects are designed as supplemental supply sources, not as projects to recharge large volumes of water diverted during peak spring snowmelt periods. This results in lower firm yield, and does not attempt to maximize use of potential storage capacity as occurs with surface reservoirs. However, a related benefit is that aquifer storage projects are relatively low cost and can be scaled up over time (not constructed all at once). These unique characteristics make aquifer storage projects difficult to compare to surface water storage projects.
- Factors besides cost such as environmental impacts, permissibility, land requirements, infrastructure conflicts, etc. will be important in evaluating specific storage options. These would need to be reviewed in the context of a particular storage project to determine how they could affect project feasibility.
- Based on the high level evaluation in this study it is not recommended that any potential storage options be eliminated from further consideration. However, mainstem dams may prove infeasible due to insurmountable permitting obstacles.
- Mainstem dam options (e.g., Narrows and Hardin sites) are technically feasible and cost-effective but would face significant new permitting challenges and present extensive social challenges related to property acquisition and landowner impacts.

10. STORAGE CONCEPTS

Storage sites cannot be evaluated in a vacuum, but must be integrated with assumed basin water supply, demand and operations to assess their potential effectiveness. The SPSS used the term “storage concept” or “storage solution” to describe how individual storage options would be tied to the overall basin operations in the South Platte River. Conceptual storage solutions were generalized approaches to developing additional storage of South Platte River water in the SPSS study area below Greeley.

Storage concepts were organized based on the reach of the lower South Platte River in which a storage project would be located, the reach from which water would be diverted, and whether storage would be achieved in a surface reservoir or groundwater basin. Each concept was required to have at least one actual storage site identified in the inventory of storage options described in **Section 2.0**. Storage concepts consisted of a specific storage option, an approach to capture water from the South Platte River, and an approach to deliver water to meet demands.

Aquifer storage concepts were fit to the aquifer recharge and recovery capacities described previously. For purposes of comparison with similar surface storage concepts, alternate aquifer storage concepts were also evaluated with similar intake and discharge assumptions, even though in most cases designing and operating aquifer storage projects under those conditions would be extremely challenging.

Surface reservoir storage concepts were modeled using a simplified MODSIM water resources model of the SPSS study area developed for this project. The features of storage concepts and the assumptions used to model them are described below. Aquifer storage options were not simulated in the same way because they would typically be used in conjunction with surface reservoirs and not as stand-alone projects; modeling of surface-groundwater conjunctive use concepts was beyond the scope of this study.

While hundreds of possible storage concepts could be envisioned in the lower South Platte Basin, a manageable number of representative storage concepts was selected to investigate the range of possible storage opportunities in the region.

10.1 SELECTION OF STORAGE CONCEPTS

The following eight representative storage concepts were selected for analysis. Evaluating these concepts will give the state an indication of the range of alternatives, feasibility issues, costs, etc. associated with a new storage project in the SPSS study area.

1. Mainstem Storage – surface reservoir on the mainstem of the South Platte River
2. Upper Basin Storage – surface storage with a reservoir and river diversion between Greeley and the South Platte River near Weldona stream gage
3. Mid Basin Storage North – surface storage with a reservoir and river diversion on the north side of the river between the South Platte River near Weldona stream gage and the South Platte River near Balzac stream gage
4. Mid Basin Storage South – surface storage with a reservoir and river diversion on the south side of the river between the South Platte River near Weldona stream gage and the South Platte River near Balzac stream gage
5. Lower Basin Storage – surface storage with a reservoir and river diversion downstream of the South Platte River near Balzac stream gage
6. Existing Reservoir Improvements – enlargements or rehabilitations of existing reservoirs anywhere in the study area
7. Groundwater Storage Basin West – groundwater aquifer storage and recovery in a groundwater basin in the western portion of the study area
8. Groundwater Storage Basin East – groundwater aquifer storage and recovery in a groundwater basin in the eastern portion of the study area

10.2 DEFINITION OF COMPONENTS ASSOCIATED WITH STORAGE CONCEPTS

In order to analyze the relative benefits of the identified storage concepts, the common components necessary to implement the concepts were defined at a conceptual level. These components are described below and include storage, diversion, intake, and outlet infrastructure. Standard assumptions were adopted for surface storage concepts and another set of standard assumptions were adopted for groundwater storage concepts so as to avoid biasing the results. No optimization or other special consideration was given to any of the storage concepts.

10.2.1. Storage Components

Table 10-1 lists the specific surface and groundwater storage options remaining after the previously described screening process and connects them with each storage concept. Representative storage sites used for analysis are highlighted in bold.

Table 10-1. Specific Storage Options Linked to Generalized Storage Solution Concepts

Storage Solution Concepts	Potential Storage Sites and Maximum Capacities
Mainstem Storage	South Platte (Narrows) Reservoir Site (1,960,000 ac-ft) Hardin Reservoir Site (400,000 ac-ft)
Upper Basin Storage	Sandborn Reservoir Site (224,000 ac-ft) Point of Rocks Reservoir Site (224,000 ac-ft) Sunken Lake Reservoir Site (5,093 ac-ft) Greasewood Reservoir Site (67,268 ac-ft) Jackson Lake Reservoir Rehabilitation (10,000 ac-ft)
Mid Basin Storage North	Wildcat Reservoir Site (60,000 ac-ft) Pawnee Pass Reservoir Site (75,000 ac-ft)
Mid Basin Storage South	Beaver Creek Reservoir Site (95,000 ac-ft) Fremont Butte Reservoir Site (75,000 ac-ft) West Nile Reservoir Site (26,950 ac-ft) McCarthy Reservoir Site (10,000 ac-ft)
Lower Basin Storage	Julesburg Reservoir Enlargement/Rehabilitation (27,600 ac-ft) Ovid Reservoir Site (7,700 ac-ft) Troelstrup Reservoir Site (5,000 ac-ft) North Sterling Reservoir Enlargement (12,000 ac-ft) North Sterling Regulation Reservoir (7,600 ac-ft) Johnson Reservoir (10,600 ac-ft)
Existing Reservoir Improvements	Julesburg Reservoir Enlargement/Rehabilitation (27,600 ac-ft) North Sterling Reservoir Enlargement (12,000 ac-ft) Prewitt Reservoir Rehabilitation (4,364 ac-ft) Riverside Reservoir Rehabilitation (2,500 ac-ft) Jackson Lake Reservoir Rehabilitation (10,000 ac-ft) Empire Reservoir Rehabilitation (2,779 ac-ft)
Groundwater Basin Storage West	Upper Lost Creek Aquifer (1,260,000 ac-ft) Lower Lost Creek Aquifer (157,000 ac-ft) Upper Kiowa Creek Aquifer (234,000 ac-ft) Lower Kiowa Creek Aquifer (806,000 ac-ft) Upper Bijou Creek Aquifer (466,000 ac-ft) Lower Bijou Creek Aquifer (1,067,000 ac-ft)
Groundwater Basin Storage East	Beaver/Badger Aquifer (311,000 ac-ft)

Note: Representative storage sites used for analysis are highlighted in bold.

Representative storage options were selected for use in each of the storage concepts. This allowed realistic elevation-area-capacity data, evaporation data, and diversion and delivery configurations to be used in the simulations. The study team performed a best-fit evaluation to select a representative storage option for each storage concept. The best-fit option was selected based on data in the Site Evaluation Framework

described previously, including physical, environmental and social attributes of the candidate reservoir and groundwater sites in each region of the SPSS study area.

Table 10-1 highlights the representative storage options selected for simulating each storage concept. The locations of these representative storage options are shown in **Figure 10-1**. **Figures 10-2** through **Figures 10-9** present maps of the representative storage options used for each storage concept, and the location of conceptual inlet-outlet facilities (intake pipelines, use of existing irrigation canals, or both).

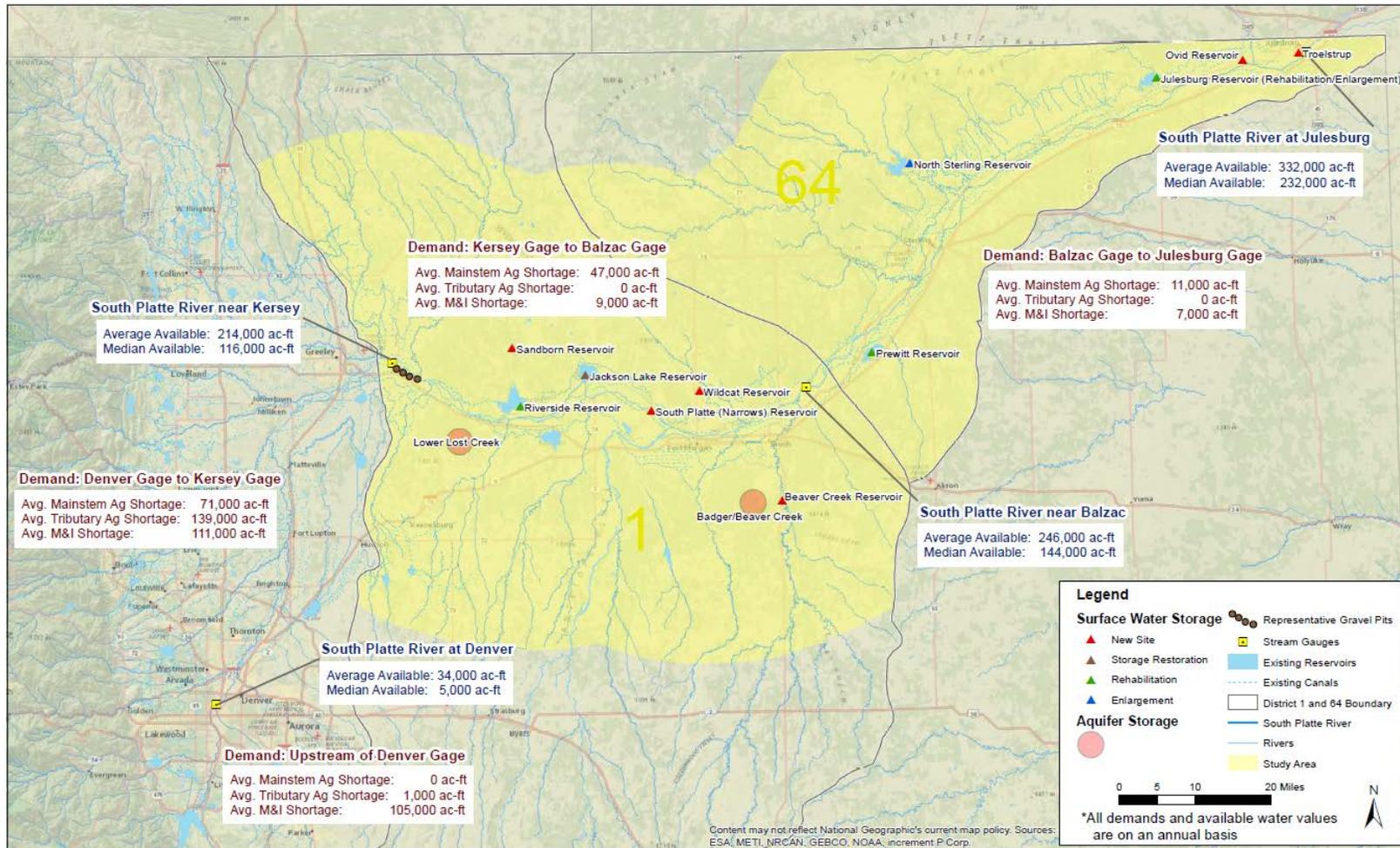


Figure 10-1. Representative Storage Options Used to Model Storage Concepts



Figure 10-2. Upper Basin Storage Conceptual Design for Sandborn Reservoir



Figure 10-3. Mainstem Storage Conceptual Design for South Platte (Narrows) Reservoir

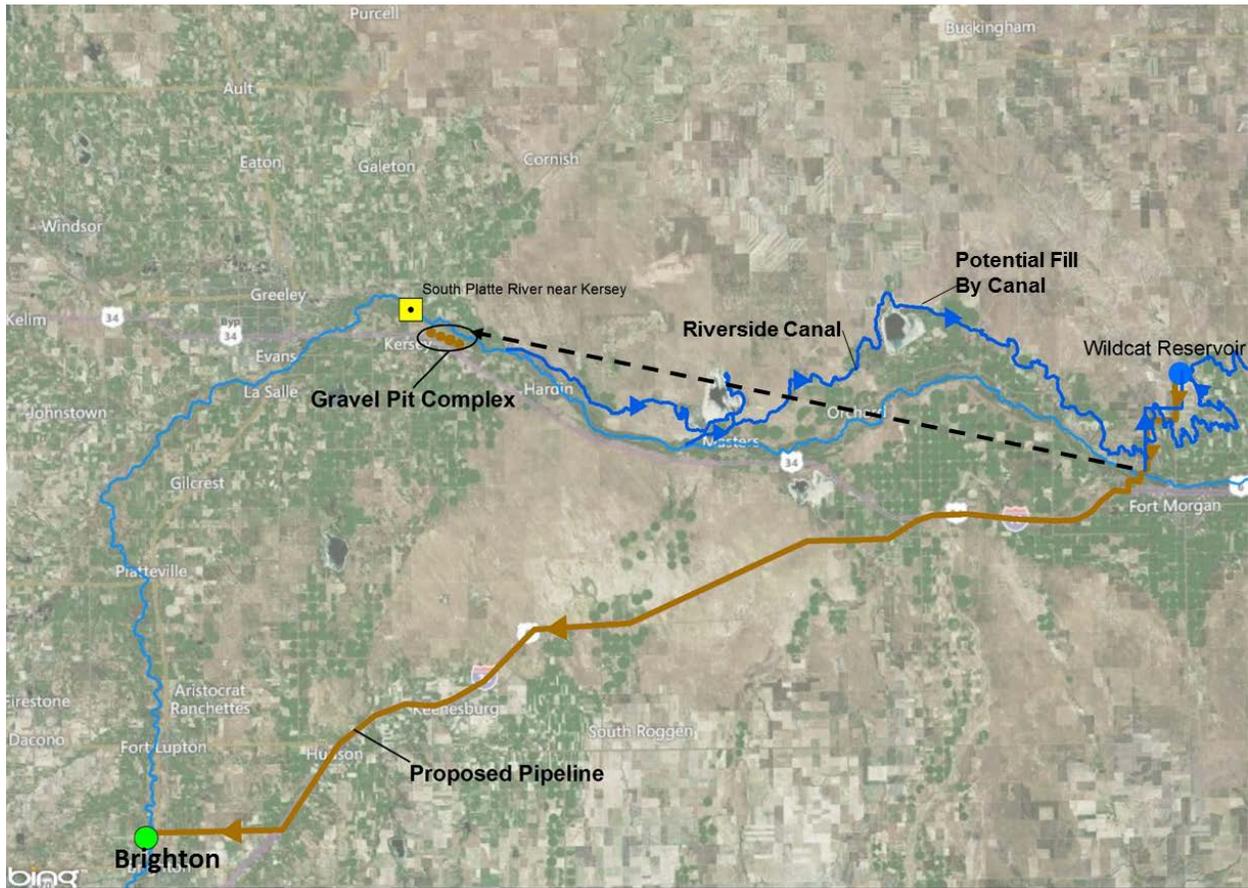


Figure 10-4. Mid Basin North Conceptual Design for Wildcat Reservoir



Figure 10-5. Mid Basin South Conceptual Design for Beaver Creek Reservoir

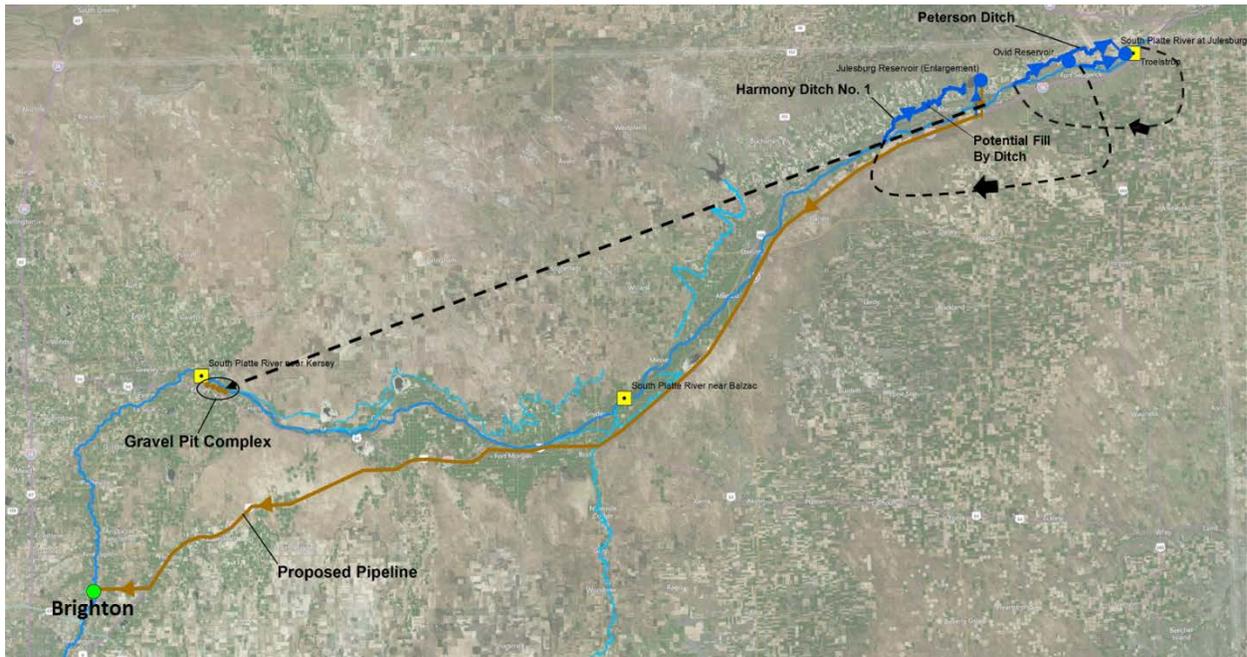


Figure 10-6. Lower Basin Storage Conceptual Design for Julesburg, Ovid, Troelstrup Reservoirs



Figure 10-7. Existing Reservoir Improvements Conceptual Design for Julesburg, North Sterling, Prewitt, Jackson Lake, and Riverside Reservoirs

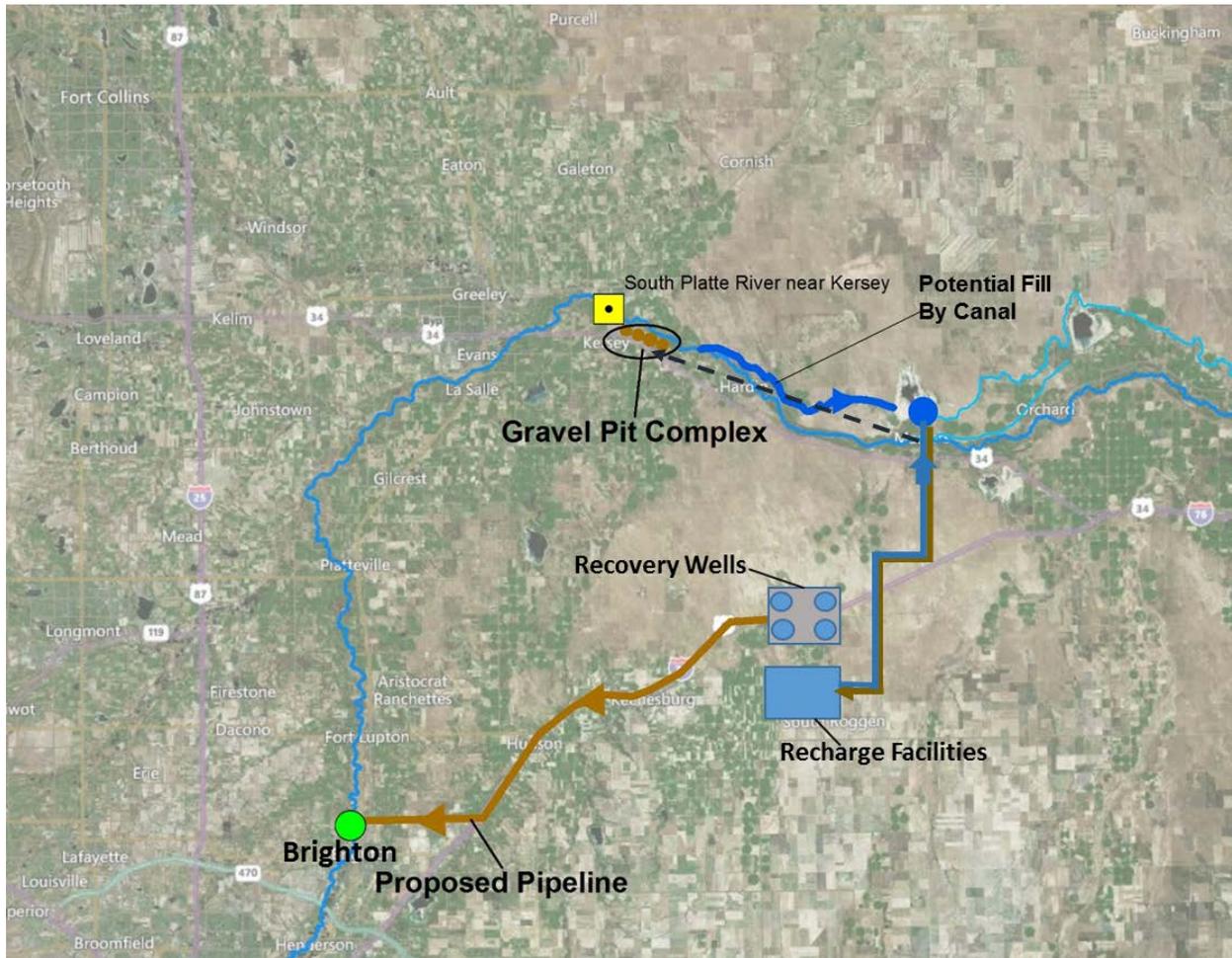


Figure 10-8. Groundwater Storage Basin West Conceptual Design for Lower Lost Creek Basin

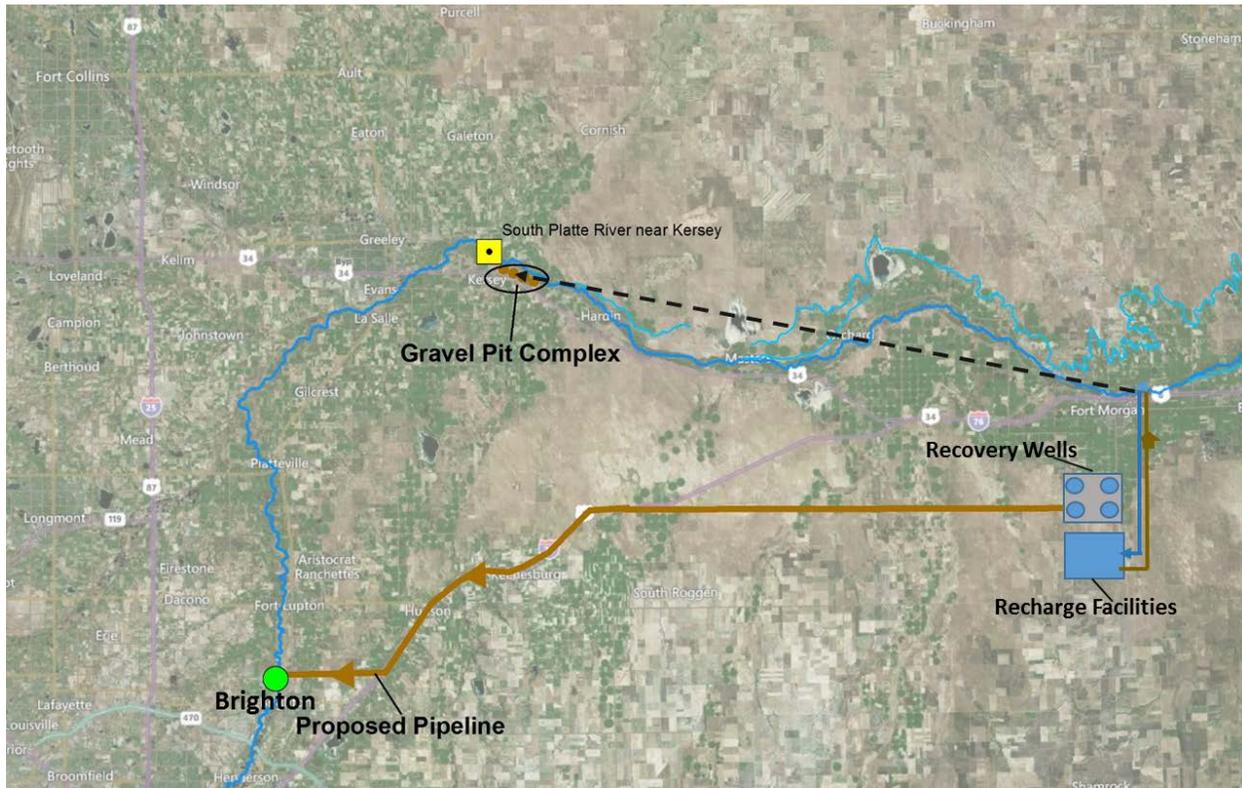


Figure 10-9. Groundwater Basin East Conceptual Design for Badger/Beaver Creek Basin

10.2.2. Surface Reservoir Concept Components

10.2.2.1 River Diversion and Intake Components

With the exception of the Mainstem Storage concept, all concepts require diversion of water from the South Platte River and conveyance to an off-channel storage facility. For any off-channel storage option, the water supply yield would be constrained by the capacity of the diversion and conveyance facilities used to fill the reservoir. Based on review of historical diversion data and conceptual engineering analysis of potential conveyance options, standard assumptions were made for analyzing storage concepts. All storage concepts included the following diversion and intake components.

- A new 800 cfs (520 mgd) diversion structure on the South Platte River at a location close to the storage option. This is close to the maximum historical river diversion and balances size and cost of the structure against frequency of bypassing potentially divertable flows due to limited diversion capacity (see **Section 6.4**). Available divertable flow in the South Platte River would exceed this capacity about 8-15 percent of the time, depending on the location.
- A 10,000 ac-ft gravel pit complex at the diversion point. This would allow the capacity of the intake conveyance facilities to be sized at 50 percent of the river diversion capacity. This was an estimated size for regulating storage; it was not simulated in the modeling of storage concepts or optimized.
- A new 96-inch pipeline and system of pump stations from the diversion structure to the reservoir or aquifer recharge area with a capacity of 400 cfs (260 mgd). It is possible that existing irrigation diversion structures and canals could be used to fill new storage sites depending on their location and available capacity at the time SPSS water rights would be in priority. Because of the great uncertainty around use of existing irrigation systems for new storage when the owner/operator is not defined, this study assumed new infrastructure would be required.

10.2.2.2 Outlet Components

For purposes of comparing SPSS storage concepts, it was assumed that any storage project would be operated to meet demands in three ways: (1) make releases to the South Platte and exchange up to Kersey to meet demands in the Northern Front Range area; (2) make releases to the South Platte River to meet demands downstream of the discharge point; and (3) make releases to a new pipeline to Brighton to meet demands in the Denver Metro/Northern Front Range area. To make these releases each storage concept included the same standard outlet components:

- Release of water back to the South Platte in the same pipeline used to fill the reservoir (bi-directional pipeline), with an unconstrained capacity.
- 100 mgd pipeline to Brighton. A capacity of 100 mgd (150 cfs) was selected because it is similar to the ultimate capacity of the Prairie Waters pipeline that delivers water from the Brighton area to Aurora and WISE participants.
- A 20,000 ac-ft gravel pit complex near Kersey to serve as the exchange-to point for the exchange alternative. The size of this storage was not optimized but was standard for all storage concepts.

10.2.3. Aquifer Storage Concept Components

The ASR site components were conceptually designed to recharge alluvial aquifers through surface infiltration basins with downgradient recovery wells. The ASR site components included associated instrumentation/controls, conveyance piping, and site excavation costs. ASR sites will also require similar intake components (diversion structure, gravel pit storage, pipeline) and outlet components (pipeline, gravel pit storage), as those described above.

10.3 ASSUMED OPERATIONS FOR STORAGE CONCEPT ANALYSIS

In order to simulate operation of each surface reservoir storage concept to estimate the water supply yield it could produce, a MODSIM operations model was constructed for the Lower South Platte River. The model used the infrastructure components described in the previous section. This section describes the other input data and assumptions used to create the MODSIM model and perform that analysis.

10.3.1. Hydrology

The MODSIM operations model used the daily estimate of available water under future river conditions for the period 1996-2015 from the Point Flow Model. The estimates of future available water account for effects of full use of reusable water by Denver Water and Aurora Water; IPPs from Colorado's Water Plan; and decreed but unexercised exchanges that would not have been reflected in the historical data in the Point Flow Model.

10.3.2. Demands

The same demands were applied to each storage concept, regardless of where it was located in the SPSS study area. This provided a standard basis of comparison for all the storage concepts. The maximum potential demands as well as their temporal distribution through the year were described in **Section 6.0** based on the SWSI gap analysis for the lower South Platte Basin.

All storage concepts were simulated to concurrently meet the three demand scenarios according to the following logic.

1. Priority 1: Exchange to Kersey. Water was exchanged to the assumed 20,000 ac-ft gravel pit complex at Kersey to meet the M&I and agricultural demands aggregated at the Kersey gage. Demands at the Kersey gage represent M&I and agricultural shortages for areas primarily east and north of this point. It is recognized that infrastructure would be required to deliver water from Kersey to M&I or agricultural customers upstream of this point. That infrastructure has not been conceptualized and has not been included in the SPSS costs described in this report.
2. Priority 2: Release to River. Water was released back to the South Platte River to meet downstream agricultural and municipal demands. This would include use of the SPSS water to meet augmentation commitments.
3. Priority 3: Pipe to Brighton. Water delivered by pipeline to the Brighton area could meet demands for municipal customers upstream of the Denver gage and municipal and agricultural customers upstream of the Kersey gage. This was given the lowest priority among the demand scenarios because it would have the highest capital and operating costs. It is recognized that infrastructure would be required to deliver water from Brighton to M&I or agricultural customers upstream of this point. That infrastructure has not been conceptualized and has not been included in the SPSS costs described in this report.

10.3.3. System Losses

Losses in pipelines and pump stations were set at 5 percent of the flow conveyed. Net evaporation at all the reservoir sites was set at 34 inches/year, based on a typical value for the lower South Platte Basin.

10.3.4. Groundwater Storage Options

To simplify the initial comparison of options, all groundwater storage options were assumed to be operated in an aquifer storage and recovery mode in which recharge would occur in surface infiltration basins and recovery would occur through a gallery of extraction wells.

The primary assumptions used to simulate groundwater storage options were developed based on review of available documentation for hydrogeologic characteristics and are listed in [Table 10-2](#). Year-to-year carryover storage was allowed as it would be in a surface reservoir. Deliveries from the river were assumed to occur from new river diversions and dedicated pipelines including 10,000 ac-ft of regulating storage (e.g., gravel lakes), similar to operation of the surface storage options.

10.3.5. Reservoir Operations

Reservoir storage could be operated in many different ways depending on the needs of the owners. Conceptually, water from storage could be:

- used as a base supply with a constant amount taken every year;
- used as a supplemental dry year supply with water withdrawn only in drought periods;
- used as a primary supply with water taken whenever it is available; or
- used as a mitigation supply to augment diversions from other sources.

Table 10-2. Aquifer Storage Modeling Assumptions

Characteristic	Lower Lost Creek Basin	Badger/Beaver Basin
Storage Capacity (ac-ft)	157,000	311,000
Storage per Acre (ac-ft/ac)	5.7	4.4
Maximum Inflow (ac-ft/month)	5,000	5,000
Maximum Outflow (ac-ft/month)	4,000	4,000
Dominion and Control / Residence Time	Challenging	Challenging
Multi-year Storage	Challenging	Challenging
Infiltration Rate (ft/day)	1.0	1.0
Extraction Well Capacity (gpm)	500	500
Approximate Well Count	60	60
Losses in Aquifer (% of inflow)	10	10

Because SPSS reservoir ownership is unknown and the demands the reservoir could be operated to meet are unknown, a standard operating approach was adopted for each storage concept such that the performance of the concepts could be compared against the same set of conditions. Two operating approaches were considered.

1. Firm Yield Analysis. Firm yield is the maximum yield that could be delivered in every year, for all years of the simulation. In this approach the firm yield for each concept was determined by varying the total demand on a trial-and-error basis until the maximum demand that could be met in every year was determined.
2. As-Available Analysis. This approach estimated the yield that could be delivered if the water would be taken from the river into storage whenever available and delivered from storage to a demand center whenever there is demand. It assumes SPSS water would be the primary supply for the user and would be taken whenever it is available.

Results from simulations of storage concepts using both approaches to reservoir operations were investigated to assure that the selection of a particular operating assumption would not bias the comparison of storage concepts.

10.4 STORAGE CONCEPT WATER SUPPLY ANALYSIS RESULTS

10.4.1. Basic Firm Yield Analysis

The firm yield for each of the storage concepts was estimated for the maximum capacity of the representative storage options. Results are shown in [Table 10-3](#). As an example of the firm yield simulations, [Figure 10-10](#) shows a plot of daily MODSIM model results for the Upper Basin – Sandborn Reservoir simulation. The figure shows the demand met on a daily basis by a 224,000 ac-ft reservoir diverting from the Upper Basin portion of the SPSS study area. The firm yield is met on almost every day of the simulation; the shortages are due to the tolerance in the iterative routine used to estimate firm yield in the MODSIM model. The plot shows the reservoir emptying during the critical drought in the model period.

Table 10-3. Storage Concept Firm Yield for Maximum Capacity of Representative Storage Sites

Storage Concept	Representative Storage Site(s)	Reservoir Capacity (ac-ft)	Firm Yield with Pipeline to Brighton (ac-ft/yr)	Firm Yield without Pipeline to Brighton (ac-ft/yr)
Mainstem Storage	South Platte (Narrows)	1,960,000	62,000	47,000
Upper Basin Storage	Sandborn	224,000	22,000	20,000
Mid Basin Storage North	Wildcat	60,000	9,000	7,000
Mid Basin Storage South	Beaver Creek	95,000	11,000	8,000
Lower Basin Storage	Julesburg, Ovid, Troelstrup	40,300	24,000	24,000
Existing Reservoir Improvements	Riverside, Jackson, Prewitt, Julesburg, North Sterling	56,464	17,000	15,000

[Figure 10-11](#) plots the demand locations receiving deliveries of firm yield for each of the storage concepts. Recall that the Kersey demand is met through a combination of exchange and pipeline deliveries, the Denver demand is met through pipeline deliveries alone, and the Balzac and Julesburg demands are met by direct releases to the South Platte. Kersey demands receive the majority of the firm yield for most concepts. Exchanges have the highest priority in the model when attempting to satisfy demands, so those are exercised first and remaining water is released to the river or piped to Brighton. For concepts with some or all of the storage in the lower basin (Lower Basin Storage, Existing Reservoir Improvements), direct releases are the primary mechanism for meeting demands because of the constraints of limited exchange potential. Different reservoir operation assumptions would give different results for distribution of demands being met; for this analysis, the total firm yield is the most important parameter for comparing storage concepts.

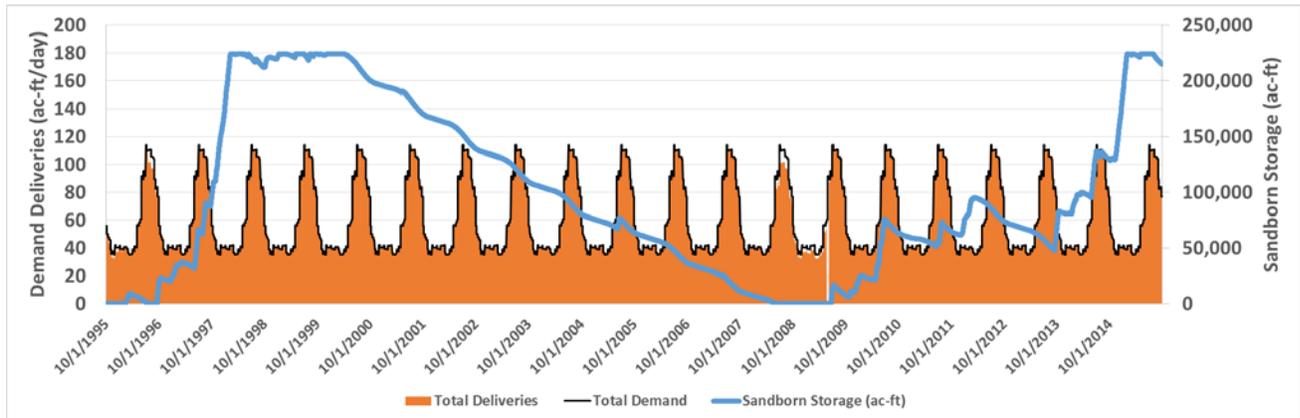
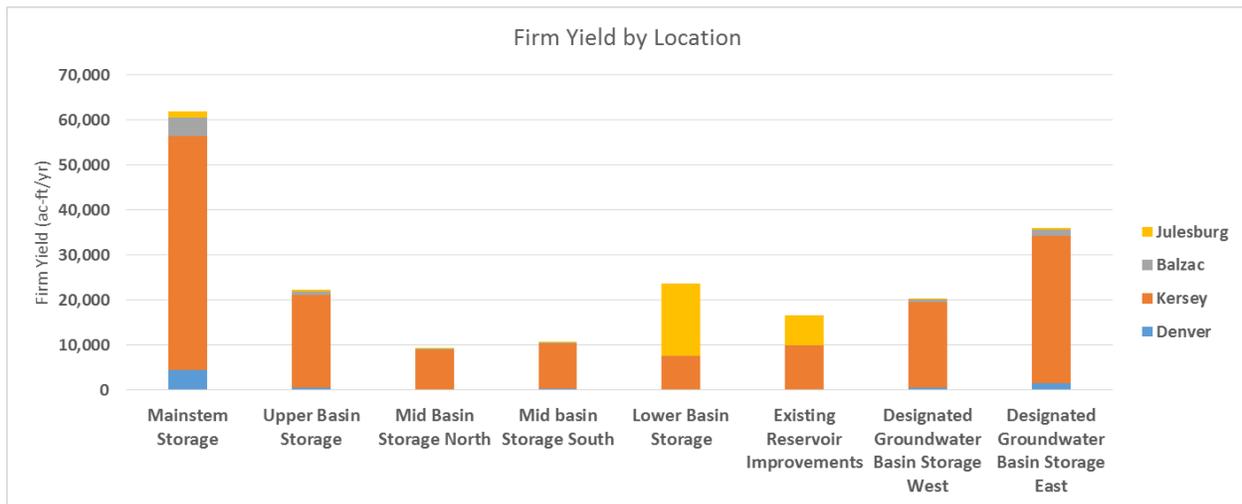


Figure 10-10. Demand Met and Storage Contents for Sandborn Reservoir Firm Yield Analysis

It is noted that any concept in which water is exchanged or piped to Brighton would benefit greatly from terminal storage at the delivery point. As noted previously, this SPSS analysis did not evaluate infrastructure needed to store or convey water beyond Kersey or Brighton.



Note: Groundwater storage concepts were simulated based on sizing to capture large peak flows from South Platte River for purposes of comparing to surface reservoirs. Feasible recharge constraints would produce much smaller firm yields.

Figure 10-11. Distribution of Firm Yield to Demand Points for Storage Concepts with Maximum Capacity of Representative Storage Site

The results depicted in Figure 10-11 show that for the firm yield simulation most storage concepts do not utilize the Brighton Pipeline to meet demands at the Denver demand node because they do not have water remaining after the higher priority demands are satisfied. This raises the question of how much the Brighton Pipeline is being used in the

simulations. The water delivered in the Brighton Pipeline can meet demands at the Denver demand node but can also be discharged to the South Platte River to meet demands at the Kersey demand node that could not be met through exchanges due to limited exchange potential. **Table 10-4** summarizes the average annual water conveyed in the Brighton Pipeline for each surface reservoir concept. The Mainstem Storage concept makes significant the most use of the Brighton Pipeline. **Figure 10-12** is a plot of the daily flow in the Brighton Pipeline for the firm yield simulation of the Upper Basin storage concept with Sandborn Reservoir. This shows that the pipeline is used at a high flow rate only infrequently. As shown later in this section, this pipeline is a very expensive infrastructure component. For comparison the firm yields without the pipeline are shown in **Table 10-3**.

Table 10-4. Average Flow through Brighton Pipeline for Firm Yield Simulations

Solution Name	Representative Storage Site(s)	Average Annual Flow through Pipeline to Brighton (AF/Y)
Mainstem Storage	Narrows	15,000
Upper Basin Storage	Sandborn	2,000
Mid Basin Storage North	Wildcat	2,000
Mid basin Storage South	Beaver Creek	3,000
Lower Basin Storage	Julesburg, Ovid, Troelstrup	0
Existing Reservoir Improvements	Riverside, Jackson, Prewitt, Julesburg, North Sterling	2,000

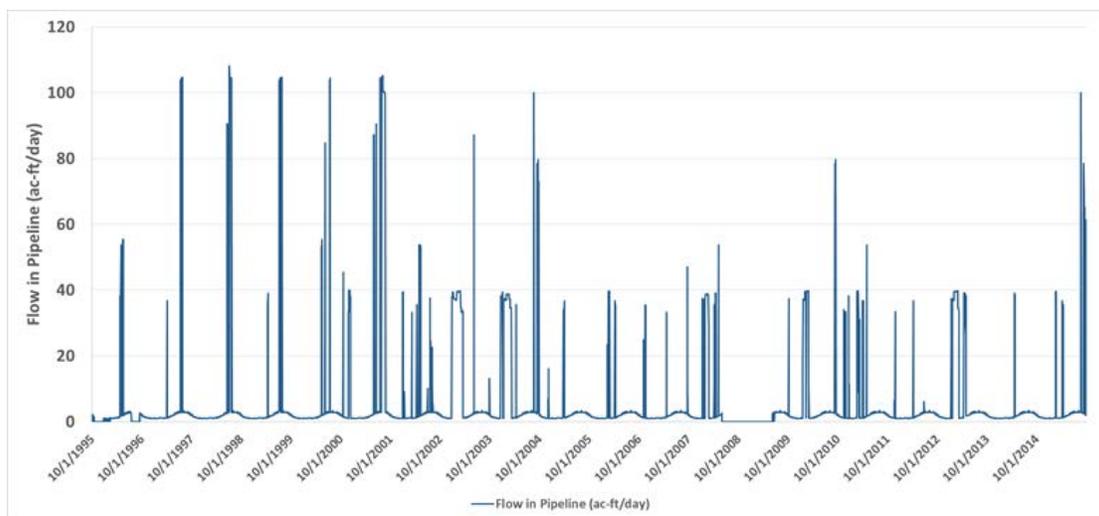


Figure 10-12. Daily Flow in Brighton Pipeline for Upper Basin Storage Concept (Sandborn Reservoir) Firm Yield Simulation

10.4.2. Firm Yield Sensitivity Analyses

A firm yield sensitivity analysis was performed in which selected alternative sizes of storage capacity for certain storage concepts were simulated to assess the effect of capacity on firm yield.

Mainstem Storage Concept. Table 10-5 and Figure 10-13 compare firm yield at the South Platte (Narrows) Dam site for reservoir capacities of 1,960,000 ac-ft, 500,000 ac-ft and 250,000 ac-ft. Results show firm yield is strongly correlated to reservoir capacity. Although the storage efficiency (storage-to-yield ratio) is better for the smaller reservoir, in general bigger is better for the mainstem dam sizes investigated.

Table 10-5. Mainstem Storage Concept Sensitivity Analysis Results

Reservoir Capacity (ac-ft)	Firm Yield (ac-ft/yr)	Storage:Yield Ratio
1,960,000	61,700	16:1
500,000	38,000	13:1
250,000	20,300	12:1

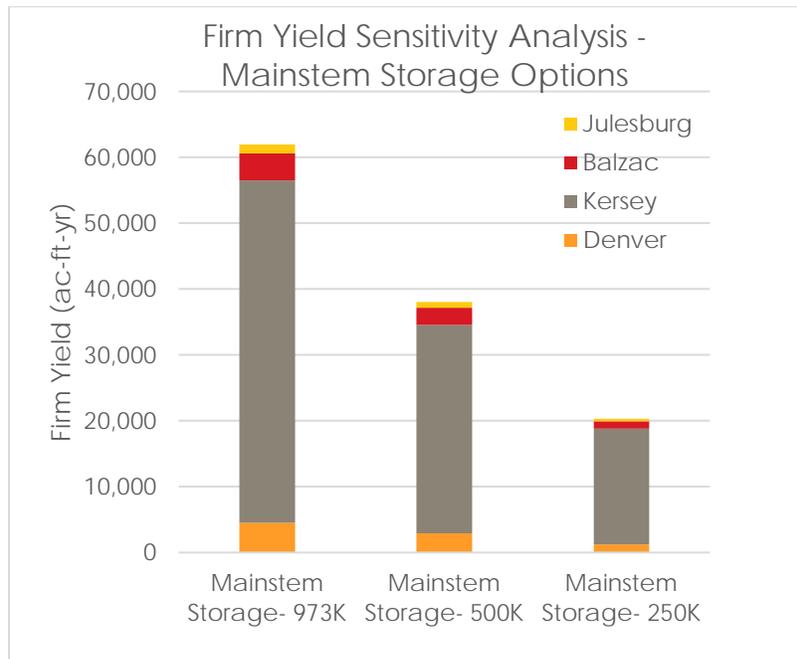


Figure 10-13. Mainstem Storage Concept Sensitivity Analysis Results

Mid Basin Storage Concept. A larger storage capacity than the two identified Mid Basin sites was simulated to estimate potential benefits from additional storage in this region. A 150,000 ac-ft capacity was simulated at the Wildcat Reservoir location. Results are

shown in [Table 10-6](#). A larger storage capacity provides a significant increase in firm yield in this region even with off-channel storage options. Because of the high variability in annual flow the storage:yield ratio is better for smaller reservoir sizes.

Table 10-6. Mid Basin Concept Sensitivity Analysis

Storage Site	Capacity (ac-ft)	Firm Yield (ac-ft/yr)	Storage:Yield Ratio
Wildcat	60,000	9,300	6:1
Beaver Creek	95,000	10,700	9:1
Wildcat	150,000	17,200	9:1

Aquifer Storage vs Surface Storage. To compare relative benefits of surface storage and aquifer storage for similar operations, the Upper Basin Storage Concept using Sandborn Reservoir was simulated with a capacity of 150,000 ac-ft, and the Groundwater Basin West aquifer storage option was simulated with the Lost Basin ASR capacity of 157,000 ac-ft. To be comparable to the surface reservoir options, in this case the Lost Creek Basin concept was expanded such that the inflow/outflow facilities would be similar to those used for surface reservoirs; this would not only require the large intake and delivery pipelines and pump stations but also extremely large recharge basins and extraction wellfields. Results are shown in [Table 10-7](#). The ASR concept gives a higher firm yield and better storage:yield ratio for essentially the same storage capacity. This is likely due primarily to the elimination of evaporation losses in the aquifer storage concept (although the simulation does include some groundwater losses). However, it is noted that designing and operating an aquifer storage project in this manner on such a large scale would be extremely challenging and may be infeasible.

Table 10-7. Surface Storage vs Aquifer Storage Comparison in Upper Basin

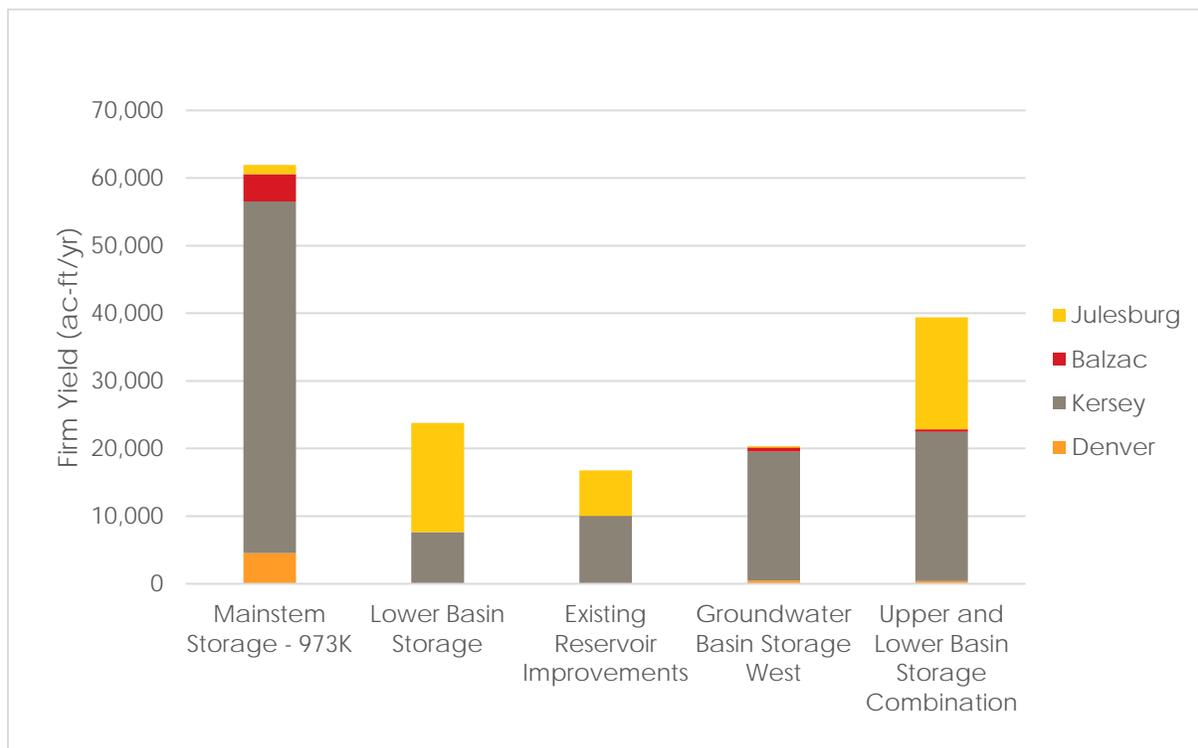
Storage Option	Capacity (ac-ft)	Firm Yield (ac-ft/yr)	Storage:Yield Ratio
Upper Basin Surface Storage	224,000	22,200	10:1
Upper Basin Surface Storage	150,000	16,200	9:1
Upper Basin Aquifer Storage	157,000	20,100	8:1

Note: Recharge and extraction capacities would be extremely large in this concept compared to most ASR projects in Colorado and may be infeasible.

Combination of Upper Basin + Lower Basin Concepts. Benefits of combining an Upper Basin project with a Lower Basin project were investigated by simulating a combination of Lost Creek ASR in the Upper Basin with the three surface reservoirs in the Lower Basin Storage concept. Results are shown in [Table 10-8](#) and [Figure 10-14](#). The benefits are significant; firm yield of this combination is exceeded only by the large Mainstem Dam concept.

Table 10-8. Firm Yield for Combined Upper and Lower Basin Storage Concepts

Storage Concept	Storage Options Simulated	Total Capacity (ac-ft)	Firm Yield (ac-ft/yr)	Storage:Yield Ratio
Lower Basin Storage Alone	Julesburg Enlargement/ Rehabilitation, Ovid, Troelstrup	40,300	23,500	2:1
Upper Basin Storage Alone	Lower Lost Creek ASR	157,000	20,100	8:1
Combined Upper and Lower Basin Storage	All of above	197,300	39,200	5:1



Note: Groundwater basin concepts with displayed in this chart were sized to capture peak flows from the South Platte River. Yield is greater than simulated for the more feasible aquifer storage concepts.

Figure 10-14. Comparison of Firm Yield for Combined Upper and Lower Basin Storage Concept with Other Concepts

10.4.3. As-Available Analysis of Storage Concepts

As noted previously, actual operations of any of the SPSS storage concepts are unknown because the ownership is unknown. Reservoir owners could choose to

operate their storage in something other than a firm yield approach. To test the sensitivity of the comparison of storage concepts to operating assumptions, two other operational scenarios were simulated that assumed the storage would be operated to meet as much demand as possible whenever that demand occurred. These scenarios varied only in the amount of demand applied to the storage reservoirs.

- Scenario 1 – Demand on the reservoir was set to the total demand estimated based on the future M&I and agricultural South Platte Basin gap at the four demand centers as described in **Section 7.0** (annual demand = 502,900 AFY).
- Scenario 2 – Gap demand was scaled-back to force reservoirs to hold more water in storage during wet periods (annual demand = 97,000 AFY).

Modeling results are summarized in **Table 10-9** for the maximum potential capacities at each of the representative storage sites for the SPSS storage concepts. The average annual deliveries under this kind of operating assumption are much higher than the firm yields shown in **Table 10-3**. However, the reliability (percentage of days the full applied demand was completely satisfied) was very low. For the Upper Basin Storage simulation in **Figure 10-15**, the reliability is only 1 percent. For the Mainstem Storage concept the reliability is higher – 9 percent – because the storage volume is larger and there are no constraints in diversion and intake capacities. (Recall firm yield has a reliability of 100 percent.) **Figure 10-15** also shows that the storage is rarely used because demands are so high water is moved directly from the river to the demand centers. The simulation of this type of operation does not highlight the value of storage, but does demonstrate that there is a large amount of available water in the river to meet high demands on a very infrequent basis.

Table 10-9. Yield of Storage Concepts Based on As-Available Operations

Solution Name	Representative Storage Site(s)	Reservoir Capacity (AF)	Full Gap Demand (502,882 AFY) – Average Annual Delivery (AF/Y)	Scaled Demand (97,000 AFY) – Average Annual Delivery (AF/Y)
Mainstem Storage	Narrows	1,960,000	118,000	81,000
Upper Basin Storage	Sandborn	224,000	74,000	48,000
Mid Basin Storage North	Wildcat	60,000	82,000	43,000
Mid Basin Storage South	Beaver Creek	95,000	85,000	46,000
Lower Basin Storage	Julesburg, Ovid, Troelstrup	40,300	129,000	48,000
Existing Reservoir Improvements	Riverside, Jackson, Prewitt, Julesburg, North Sterling	56,464	143,000	59,000

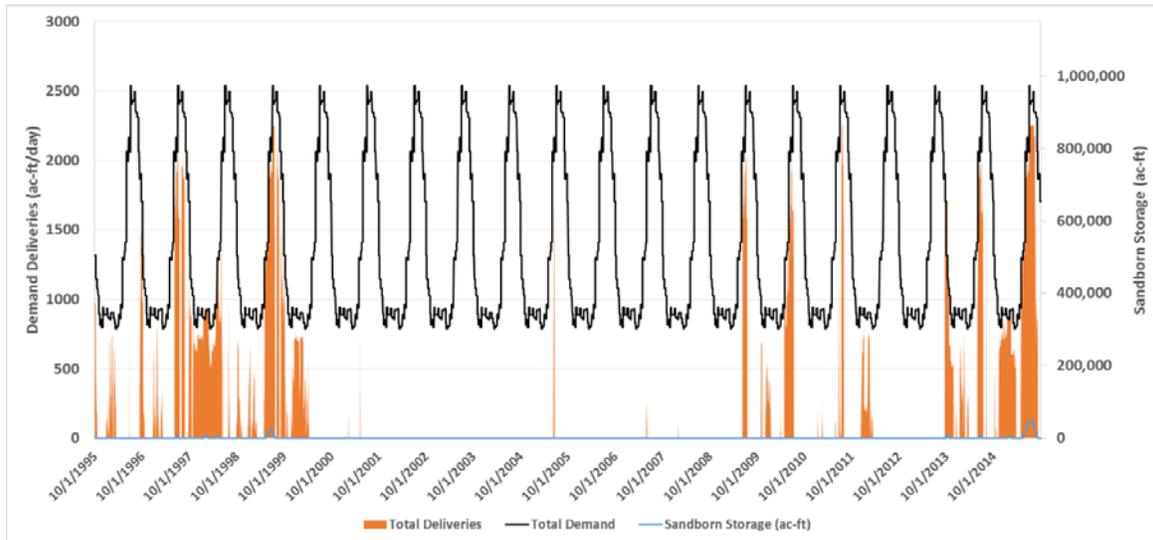


Figure 10-15. Simulation of Sandborn Reservoir with Full Gap Demand Applied in As-Available Operation Mode

Simulation of the scaled-back demands is summarized for each concept in [Table 10-9](#), and is displayed for the Upper Basin (Sandborn) concept in [Figure 10-16](#). The scaled-back demands are 97,000 ac-ft/yr compared to 502,900 ac-ft/yr for the full gap demands. Average annual deliveries are less than for the full gap scenario (because less water is demanded) and the benefits of storage are more evident. In addition, [Figure 10-16](#) shows that the reliability for this condition is approaching 50 percent, which is much better than when the full gap demands were applied.

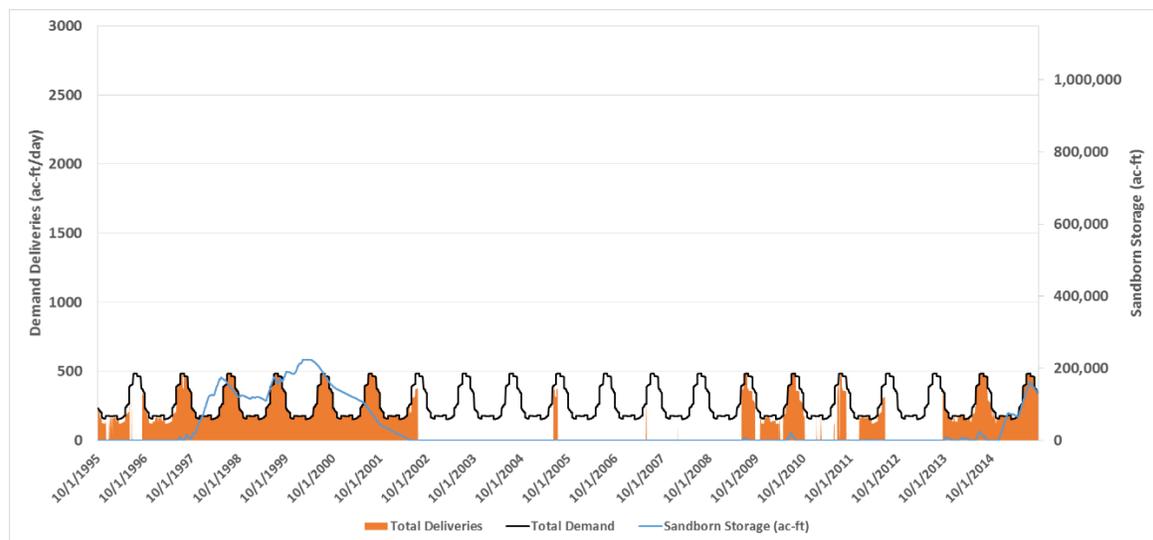


Figure 10-16. Simulation of Sandborn Reservoir with Scaled-Back Demand Applied in As-Available Operation Mode

10.5 SUMMARY OF STORAGE CONCEPT SIMULATIONS

The key findings of the storage concept simulation analysis are as follows.

1. The Firm Yield results are the most useful for this analysis and have an easier message to convey. Thus the firm yield results will be used to draw conclusions.
2. Firm yields of 9,000 ac-ft/yr to 62,000 ac-ft/yr were estimated for the representative storage concepts analyzed for this study.
3. Not surprisingly, the large mainstem reservoir has the best performance. Smaller mainstem reservoirs have significantly less firm yield and are comparable to other off-channel options.
4. Aquifer storage projects are more limited by recharge and recovery rates rather than storage volume. Typical aquifer storage projects are designed as supplemental supply sources, not as projects to recharge large volumes of water diverted during peak spring snowmelt periods. This results in lower firm yield, and does not attempt to maximize use of potential storage capacity as occurs with surface reservoirs. However, a related benefit is that aquifer storage projects are relatively low cost and can be scaled up over time (not constructed all at once). These unique characteristics make aquifer storage projects difficult to compare to surface water storage projects.
5. Average annual available water under future conditions varies from about 160,000 ac-ft/yr at Greeley to about 290,000 ac-ft/yr at Julesburg. Firm yields are much less than these values even for the large storage options due to the significant year-to-year variability in streamflow. Substantially more storage would be required to significantly increase firm yields from the alternatives.
6. Storage options lower in the basin tend to be more efficient (better storage:yield ratio) because there is more water available. This is biased by the fact that the lower basin concepts simulated in this study have multiple storage buckets and hence multiple inlets, so there is more diversion capacity, but the additional water is still an important factor in performance of storage options.
7. A combination of upper basin and lower basin storage concepts rivals the large mainstem dam for firm yield benefits.
8. No feasible storage concepts or reasonable combinations of concepts are capable of putting all the available flow in the lower South Platte River to beneficial use. Therefore as a general principle, more storage will always be "better" in this region in terms of maximizing available supply for basin water users.
9. Because nearly all concepts require off-channel storage and diversion from the South Platte River, intake capacity constraints can be important and there are benefits to having multiple off-channel storage projects to minimize these effects.

10.6 SUMMARY OF COSTS BY STORAGE CONCEPT

Conceptual (ACEE Class V) cost estimates were prepared for the surface reservoir storage concepts including components for storage (maximum size), intake system (new 800 cfs diversion structure, new 10,000 ac-ft gravel pit, new 400 cfs bi-directional conveyance system), and delivery system (conveyance system to Brighton, 20,000 ac-ft Kersey gravel pits). Aquifer storage concept costs were estimated based on the assumptions described earlier with recharge capacities of 5,000 ac-ft/month and extraction wellfield capacities of 4,000 ac-ft/month.

Table 10-10 summarizes capital costs for SPSS storage concepts. These costs are based on the largest feasible storage capacity for the surface reservoir, and the assumed modest size of an ASR project. No alignment studies or cost optimization were performed for this analysis. It is noted that cost estimates assume construction of all new intake and delivery system components; the ability to utilize existing diversion structures or irrigation canals to some degree for certain storage options would reduce the estimated cost. Use of SPSS water directly for M&I purposes at any of the demand centers in the analysis would require advanced water treatment; the cost of facilities to provide this treatment is not included in the storage concept costs. Storage concept costs do not include O&M costs for items such as energy for pumping or maintenance and replacement of mechanical equipment. Energy costs could be significant for pumpback components and aquifer storage and recovery projects.

Table 10-10. Summary of Storage Concept Costs for Maximum Representative Storage Site Including Pipeline to Brighton

Storage Concept (Representative Site)	Storage Capacity (ac-ft)	Storage Cost (\$M)	Intake System Cost (\$M) (Diversion, Gravel Pits, Pipes, Pump)	Delivery System Cost (\$M) (Pipe to Brighton, Kersey Gravel Pits)	Total Storage Concept Cost (\$M)	Firm Yield (AFY)	Total Unit Cost (\$/AFY)
Surface Reservoir Storage Concepts							
Mainstem Dam (Narrows)	1,960,000	\$145	-	\$380	\$525	62,000	\$8,500
Upper Basin Storage (Sandborn)	224,000	\$131	\$168	\$322	\$621	22,000	\$28,000
Mid Basin Storage North (Wildcat)	60,000	\$79	\$141	\$433	\$652	9,000	\$72,000
Mid Basin Storage South (Beaver)	95,000	\$66	\$407	\$437	\$910	11,000	\$83,000
Existing Reservoirs	40,300	\$121	\$221	\$322	\$664	17,000	\$39,000
Lower Basin Storage	56,464	\$118	\$92	\$826	\$1,037	24,000	\$43,000

Storage Concept (Representative Site)	Storage Capacity (ac-ft)	Storage Cost (\$M)	Intake System Cost (\$M) (Diversion, Gravel Pits, Pipes, Pump)	Delivery System Cost (\$M) (Pipe to Brighton, Kersey Gravel Pits)	Total Storage Concept Cost (\$M)	Firm Yield (AFY)	Total Unit Cost (\$/AFY)
Groundwater Storage Concepts							
Groundwater Storage West (Lost Creek)	157,000	\$39	\$238	\$ 158	\$435	8,400	52,000
Groundwater Storage East (Badger/Beaver)	311,000	\$39	\$160	\$270	\$469	8,000	59,000

Note: Aquifer storage concepts are smaller than surface reservoir concepts, consistent with common existing projects.

As described in the discussion of storage concept modeling results, the pipeline to Brighton is used infrequently when it has lowest priority after exchanges and releases to the river have been performed. This pipeline is a very expensive component of any storage concept in the lower South Platte River. [Table 10-11](#) shows storage concept costs without the pipeline to Brighton. It is noted that without the pipeline the performance of any storage concept is very dependent on exchange potential in the South Platte River. While exchange potential was simulated in the reaches below Kersey, many factors could reduce this exchange potential in the future. In addition, the exchange potential between Kersey and Denver is very limited, and substantial demands at the Denver location could only be met using direct conveyance.

Table 10-11. Summary of Storage Concept Costs for Maximum Potential Storage Site without Pipeline to Brighton

Storage Concept (Representative Site)	Storage Capacity (ac-ft)	Storage Cost (\$M)	Intake System Cost (\$M) (Diversion, Gravel Pits, Pipes, Pump)	Delivery System Cost (\$M) (Kersey Gravel Pits)	Total Storage Concept Cost (\$M)	Firm Yield (AFY)	Total Unit Cost (\$/AFY)
Surface Reservoir Storage Concepts							
Mainstem Dam (Narrows)	1,960,000	\$145	-	\$45	\$190	58,000	\$ 3,300
Upper Basin Storage (Sandborn)	224,000	\$131	\$168	\$45	\$344	21,000	\$26,000
Mid Basin Storage North (Wildcat)	60,000	\$79	\$141	\$45	\$265	9,000	\$29,000
Mid Basin Storage South (Beaver)	95,000	\$66	\$407	\$45	\$518	11,000	\$47,000
Existing Reservoirs	40,300	\$121	\$221	\$45	\$387	17,000	\$23,000
Lower Basin Storage	56,464	\$118	\$92	\$45	\$255	24,000	\$11,000
Aquifer Storage Concepts							
Groundwater Storage West (Lost Creek)	157,000	\$39	\$238	\$45	\$322	8,400	\$38,000
Groundwater Storage East (Badger/Beaver)	311,000	\$39	\$160	\$45	\$244	8,000	\$31,000

Note: Aquifer storage concepts are smaller than surface reservoir concepts, consistent with common existing projects.

10.7 COMPARISON OF STORAGE CONCEPTS

The SEF for the SPSS contains many attributes that apply to the overall solutions and storage concepts. Many of the storage concept attributes are based on the specific criteria listed in HB 16-1256 for evaluating SPSS alternatives. Others were developed by the study team to assist in comparing the storage concepts on a relative basis.

Table 10-12 shows the attribute values for the eight SPSS storage concepts considered in this study. It also lists the cumulative scores for each storage concept when numerical values are assigned to the attribute qualifiers (e.g., 1.0, 0.5, 0). For many of the attributes, particularly those associated with the HB 16-1256 criteria, the storage concepts have very similar performance. They were formulated to meet demands in a

variety of locations in the basin and thus have similar capabilities of providing water supply benefits listed in HB 16-1256. The storage concepts relying on reservoirs lower in the South Platte basin (e.g., Lower Basin Storage, Existing Storage) have lower scores due to the relatively greater difficulty in providing water supply and flood management benefits for large portions of the basin when storage is located downstream.

It is noted that this comparison is based on the storage concepts and representative storage sites simulated in the MODSIM model. For the SPSS analysis it was necessary to select a limited number of concepts for analysis. Many variations of these concepts would be feasible, including use of different storage options, increased storage capacity, and different operating assumptions. Variations in these storage concept definitions could result in substantial differences in scores exceeding the variability in the scores in [Table 10-12](#). Furthermore, none of the concepts or individual site designs were optimized at this level because ownership of storage projects is not known. Results in this table should be used only for a high-level comparison of storage concepts. The fact that the comparison produces fairly similar scores for all of the storage concepts suggests that none should be eliminated based on this analysis.

It was not possible to monetize project benefits at this level of analysis to support a numerical benefit-cost comparison of storage concepts. Information in [Table 10-11](#) and [Table 10-11](#) allows for qualitative comparisons of benefits and costs of the limited number of storage concepts analyzed in this study. Storage concepts developed to meet the needs of specific water users could have very different costs and benefits based on their particular application and the ability to optimize size and performance to meet the specific project needs.

Table 10-12. Site Evaluation Framework Attribute Values for Storage Concepts

Attribute	Description	Mainstem Dam	Upper Basin Storage	Mid Basin Storage - North	Mid Basin Storage - South	Lower Basin Storage	Existing Storage	Aquifer Storage West	Aquifer Storage East	Comments
Water Supply Gap Solution	The storage solution could capture water to meet demands in the basin.	High	Medium	Low	Medium	Medium	Medium	Medium	Medium	Based on firm yield
Reduce TransBasin Diversions	The storage solution could yield additional supplies from in-basin sources, reducing the need for future transbasin diversions.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Any in-basin yield substitutes for transbasin diversions
Multiple Users Supply	The storage solution could supply water to various municipal, industrial, environmental, and agricultural water users in the basin.	High	High	High	High	Low	Medium	High	Medium	Upstream is good. Far downstream with no pipeline is bad.
Augmentation Plan Operation Enhancement	The storage solution could be used to optimize the operation of existing or future augmentation plans.	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Any storage concept can release to river so all those above Lower Basin could be operated for augmentation

SOUTH PLATTE STORAGE STUDY



STORAGE CONCEPTS
FINAL REPORT

Attribute	Description	Mainstem Dam	Upper Basin Storage	Mid Basin Storage - North	Mid Basin Storage - South	Lower Basin Storage	Existing Storage	Aquifer Storage West	Aquifer Storage East	Comments
Aquifer Recharge Operations	The storage solution is an aquifer recharge facility, directly delivers water to aquifer recharge facilities, or facilitates conjunctive use.	Medium	Medium	Medium	Medium	Low	Medium	High	High	Lower Basin would be below aquifer recharge facilities
ATM Partnership	A storage solution would have available storage for temporary leased water to be stored to help the ATM operations and partnerships.	High	High	High	High	High	High	High	High	All could do this
Exchange Potential Enhancement	The storage solution adds storage capacity for interim storage or "leap-frogging" exchanges, or could add streamflows that would increase exchange potential in the river.	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes for all except Lower Basin
Recreation Benefit	The storage solution would increase recreational opportunities.	Positive	Positive	Positive	Positive	Positive	Neutral	Neutral	Neutral	Positive for new surface sites; neutral for GW and existing storage sites

SOUTH PLATTE STORAGE STUDY



STORAGE CONCEPTS
FINAL REPORT

Attribute	Description	Mainstem Dam	Upper Basin Storage	Mid Basin Storage - North	Mid Basin Storage - South	Lower Basin Storage	Existing Storage	Aquifer Storage West	Aquifer Storage East	Comments
Enhance Streamflow	The storage solution could deliver water to downstream users via natural channels, enhancing stream flow.	Medium	High	High	High	Medium	Medium	High	High	All could release to South Platte; some could release to tribs
Compact Compliance	The storage solution could increase low flows at the state line and reduce frequency of compact calls.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	All would do this
Increase Ag Production	The storage solution could help meet the agricultural demand gap in the basin.	Low	Low	Low	Low	High	Low	Low	Low	
Reduce Buy&Dry	The storage solution could yield additional M&I supplies from in-basin sources, reducing the pressure to buy Ag water rights.	High	Medium	Low	Medium	Medium	Medium	Medium	Medium	Based on firm yield and applicability to potential M&I users

SOUTH PLATTE STORAGE STUDY



STORAGE CONCEPTS
FINAL REPORT

Attribute	Description	Mainstem Dam	Upper Basin Storage	Mid Basin Storage - North	Mid Basin Storage - South	Lower Basin Storage	Existing Storage	Aquifer Storage West	Aquifer Storage East	Comments
Delivery Water Quality	The storage solution would deliver raw water requiring advance treatment to achieve primary and/or secondary drinking water standards.	Low	Low	Low	Low	Low	Low	Low	Low	All water in SPSS study area would need advanced treatment for potable use
Permitting Feasibility	The potential permitting feasibility of site and solution.	Low	Medium	Medium	Medium	Medium	High	High	High	On channel is worst; existing dams and GW are best
Water Rights	Measure of the perceived ease in obtaining the water rights/decrees required to operate the solution.	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Set all to medium. All will have some issues.
Combined Permitting	Captures the potential increase in permitting complexity for the solutions compared to storage sites alone.	Same	Same	Same	More	More	More	Same	More	Used "More" for concepts requiring longer pipelines to Brighton
Estimated Permit Timeline	The probability that permits would be secured quickly.	Low	Medium	Medium	Medium	Medium	High	Medium	Medium	Mainstem dam is longest. Modifications to existing reservoirs is shortest.

SOUTH PLATTE STORAGE STUDY



STORAGE CONCEPTS
FINAL REPORT

Attribute	Description	Mainstem Dam	Upper Basin Storage	Mid Basin Storage - North	Mid Basin Storage - South	Lower Basin Storage	Existing Storage	Aquifer Storage West	Aquifer Storage East	Comments
Combined Impact	Captures the potential increase in environmental impacts for the solutions compared to individual sites alone.	More	More	More	More	More	More	More	More	All require facilities outside the storage footprint
River Reach	River reach where the solution is predominantly located.	Kersey-Balzac	Kersey-Balzac	Kersey-Balzac	Kersey-Balzac	Balzac-Julesburg	Balzac-Julesburg	Kersey-Balzac	Balzac-Julesburg	
Meet Demands	Ability of a solution to meet demands, either upstream or downstream	US and DS	US and DS	US and DS	US and DS	US and DS	US and DS	US and DS	US and DS	All concepts were formulated to meet demands throughout Basin
Total Score (Unweighted)		11.5	12	11	11	8	10	12	10.5	

10.8 BENEFICIAL USE OF COLORADO'S AVAILABLE SOUTH PLATTE WATER

The ability of the simulated storage concepts to put Colorado's South Platte River water to beneficial use is summarized in [Table 10-13](#). This analysis used future hydrology, and shows that while a significant amount of water that would otherwise leave Colorado could contribute to in-state beneficial uses, considerably more storage would be required to use all the state's available South Platte water resources. A plot of daily flows at the state line for the Upper Basin Storage Concept is shown in [Figure 10-17](#). Similar plots for all of the storage concepts are contained in [Appendix J](#).

Table 10-13. Water Leaving the State under Future Hydrology for Simulated Storage Concepts

Storage Concept	Average Annual Water Leaving State (ac-ft)	Median Annual Water Leaving State (ac-ft)	Percentage of Available Water Contributing to Beneficial Use ⁽¹⁾
No Storage	343,000	249,000	-
Mainstem Storage	169,000	150,000	51%
Upper Basin Storage	279,000	210,000	19%
Mid Basin Storage North	272,000	196,000	21%
Mid Basin Storage South	269,000	192,000	22%
Lower Basin Storage	193,000	78,000	44%
Existing Reservoir Improvements	173,000	100,000	50%
Groundwater Basin Storage West (sized and operated similar to surface reservoirs)	280,000	213,000 ⁽²⁾	18%
Groundwater Basin Storage East (sized and operated similar to surface reservoirs)	271,000	196,000 ⁽²⁾	21%

(1) Includes evaporation losses and other losses which would not be beneficial uses.

(2) Assumes maximum size to capture peak spring runoff. Actual projects would be smaller and leave more water at the state line.

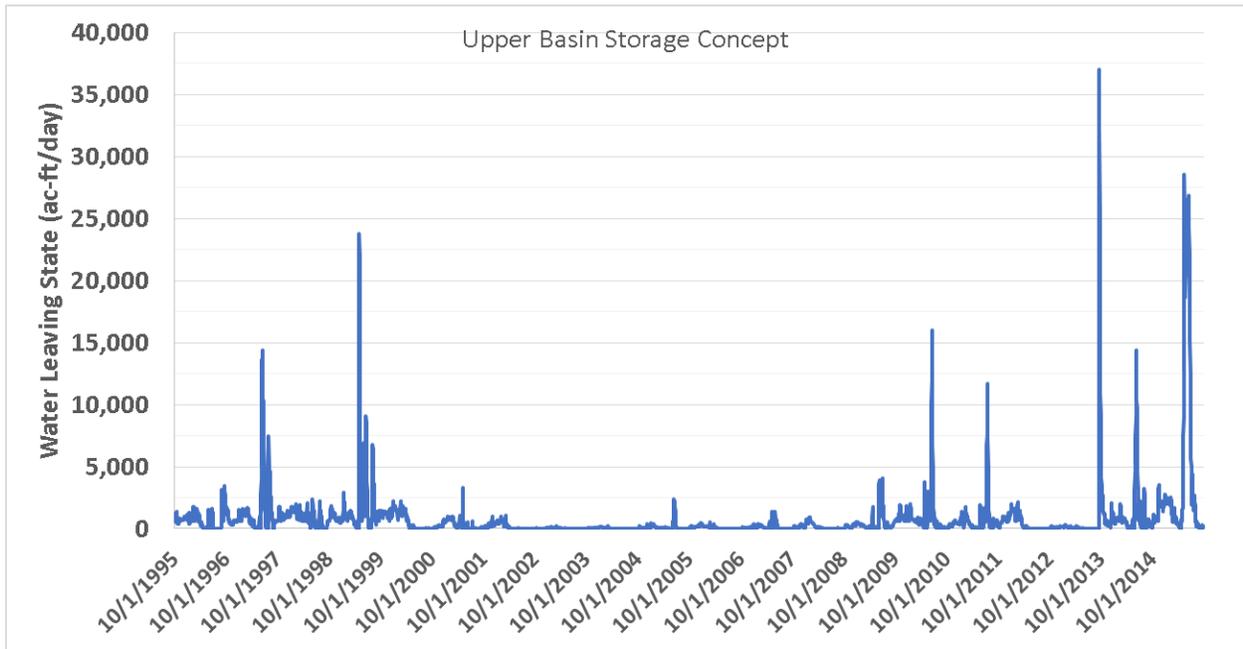


Figure 10-17. Timeseries of Water Leaving the State for Upper Basin Storage Concept under Future Hydrology

11. CONCLUSIONS AND RECOMMENDATIONS

11.1 CONCLUSIONS

11.1.1. Available Water, Demand and Water Quality

The following conclusions relate to available water in the SPSS study area.

1. A large supply of water is available for beneficial use in the lower South Platte Basin. Between 1996 and 2015, an annual median of approximately 293,000 ac-ft/yr of water was delivered to Nebraska in excess of the South Platte Compact. Excess available water varied between 10,000 ac-ft/yr and 1,904,000 ac-ft/yr over this period.
2. Under future conditions, average annual water available for diversion to a new storage project would vary from approximately 214,000 ac-ft/yr at Kersey to 332,000 ac-ft/yr at Julesburg. Median annual available water would vary from approximately 116,000 ac-ft/yr at Kersey to 232,000 ac-ft/yr at Julesburg, highlighting the influence of a few high runoff years on streamflow statistics in the South Platte Basin.
3. Annual streamflows in the study area are characterized by a few very high flow years. A large mainstem dam or several off-stream dams with large diversion structures would be required to capture a large portion of the available streamflow.
4. Available water at Kersey is much less than at Julesburg due to return flows in the lower basin. A large lower basin reservoir(s) would be required as part of a storage scheme to capture a large portion of available flow upstream of the state line.
5. Because the vast majority of storage options are located off the main South Platte River channel, physically available water is constrained by the diversion capacity and the capacity of conveyance facilities from the river to the storage reservoir. Large diversion and conveyance structures would be needed to capture and convey water from the river to off-channel storage. At the Balzac gage near the middle of the SPSS study area, a diversion capacity of 550 cfs would be needed to capture 85 percent of the available water.
6. Future water shortages in the lower South Platte Basin based on the water supply gap estimated in SWSI 2010 are significant, and exceed the estimated available water in the future. Annual municipal and agricultural demands that could potentially be served by water from a SPSS storage project total over 502,000 ac-ft/yr for the Denver Metro Area, the Northern Front Range Region, and the lower South Platte basin below Greeley.
7. Water quality throughout the SPSS study area is adequate for agricultural use but would require advanced water treatment for direct municipal use.

11.1.2. Storage Options and Concepts

Conclusions related to the SPSS analysis of storage opportunities in the lower South Platte Basin are summarized as follows.

1. Many off-channel storage options are feasible and can be combined in a wide variety of water supply concepts.
2. Firm yields of 9,000 ac-ft/yr to 62,000 ac-ft/yr were estimated for the representative storage concepts analyzed for this study.
3. Capital costs for storage concepts range from \$7,400 to \$78,200/ac-ft/yr, exclusive of treatment costs, with a pipeline to Brighton. Without the pipeline to Brighton the concept costs range from \$3,300 to \$47,000/ac-ft/yr exclusive of treatment costs. The upper end of this range greatly exceeds the cost of recent water development projects in Colorado.
4. Not surprisingly, a large mainstem reservoir has the best performance in terms of putting the state's water to beneficial use. However, permitting obstacles may be insurmountable.
5. Aquifer storage projects are more limited by recharge and recovery rates rather than storage volume. Typical aquifer storage projects are designed as supplemental supply sources, not as projects to recharge large volumes of water diverted during peak spring snowmelt periods. This results in lower firm yield, and does not attempt maximize use of potential storage capacity as occurs with surface reservoirs. However, a related benefit is that aquifer storage projects are relatively low cost and can be scaled up over time (not constructed all at once). These unique characteristics make aquifer storage projects difficult to compare to surface water storage projects.
6. Storage options lower in the basin tend to be more efficient (better storage:yield ratio) because there is more water available. However they are further from the main demand centers.
7. Combinations of storage options working conjunctively can provide significantly more benefit than individual options. A combination of upper basin and lower basin storage concepts rivals the large mainstem dam option for firm yield benefits. However, there will be reduction in efficiency as the number of projects goes up, and even with multiple storage project a large amount of available water would leave Colorado.
8. No feasible storage concepts or reasonable combinations of concepts are capable of putting all the available flow in the lower South Platte River to beneficial use. This is shown in [Table 11-1](#). Therefore as a general principle, more storage will always be "better" in this region in terms of maximizing available supply for basin water users.

Table 11-1. Water Leaving the State under Future Hydrology for Simulated Storage Concepts

Storage Concept	Median Annual Water Leaving State (ac-ft)	Percentage of Available Water Contributing to Beneficial Use ⁽¹⁾
No Storage	249,000	-
Mainstem Storage	150,000	51%
Upper Basin Storage	210,000	19%
Mid Basin Storage North	196,000	21%
Mid Basin Storage South	192,000	22%
Lower Basin Storage	78,000	44%
Existing Reservoir Improvements	100,000	50%
Groundwater Basin Storage West	213,000 ⁽²⁾	18%
Groundwater Basin Storage East	196,000 ⁽²⁾	21%

(1) Includes evaporation losses and other losses which would not be beneficial uses

(2) Assumes maximum size to capture peak spring runoff. Actual projects would be smaller and leave more water at the state line.

10. Because nearly all concepts require off-channel storage and diversion from the South Platte River, intake capacity constraints can be important and there are benefits to having multiple off-channel storage projects to minimize the effects of these constraints.
11. Enlargements and rehabilitations of existing reservoirs tend to score higher than new reservoirs in the multi-criteria ranking process.
12. Triple bottom line scores for the storage sites analyzed in this study were fairly similar at this level of analysis without specific information on how the sites would be used in a water supply strategy; thus the triple bottom line scoring process should not be used to eliminate options at this time.
13. Any of the storage concepts could be candidates for further study in the future under the right circumstances. However, concepts with more storage higher in the basin generally offer a greater potential for benefits and could be more attractive to a broader variety of potential participants.
14. Multiple large storage projects, including one low in the basin, would be required to capture a substantial amount of the available water above the state line.
15. Even a combination of conjunctively operated storage projects would not be capable of addressing the majority of the combined overall M&I and agricultural water supply gaps in the South Platte Basin.

11.2 RECOMMENDATIONS

The SPSS team developed the following recommendations for future work.

1. Better estimates of future hydrology should be developed to refine the anticipated available water under future basin operations. Completion of the South Platte Decision Support System would facilitate further hydrologic and operational studies.
2. Exchanges will be important to making storage work cost effectively for many applications. A more robust method of estimating future exchange potential may be needed to refine this important aspect of the analysis.
3. Site-specific and owner-specific analyses will be needed when particular project opportunities are identified in the future. The work in the SPSS is a starting point for more specific alternative investigations, but substantial additional analysis will be required to test the feasibility of specific storage options based on points of diversion, intake systems, and methods of operating to meet demands.
4. Aquifer storage and recovery projects will require site specific aquifer characterization and pilot testing. Pilot testing and preliminary design can begin at a relatively low cost due to the scalability of ASR systems.
5. Using existing irrigation canals to fill storage sites could significantly reduce infrastructure costs for some concepts. Partnerships with irrigation companies and available canal capacities should be investigated further.
6. Cooperative storage projects with multiple users, multiple components and multiple purposes would have the best chance of success. The state, Roundtables and water users should continue to explore opportunities for cooperative multi-use storage projects in the lower South Platte Basin.
7. Gravel pit storage opportunities were not considered in detail in this study. Gravel pits have been used extensively for storage along the South Platte River upstream of Greeley. An investigation of gravel pit storage opportunities downstream of Greeley may be warranted.
8. Use of water from SPSS storage projects directly for M&I use would require advanced water treatment. Recharge into aquifer storage would also require treatment. Additional investigation is required into the feasibility of available advanced treatment processes on water quality from the study area, particularly in the further downstream reaches of the South Platte River.
9. Investigation is warranted into how storage could support future implementation of alternative transfer method (ATM) projects per recommendations in the South Platte Basin Implementation Plan. Most or even all ATM project would need storage to increase yield and project efficiency. Investigation is needed into how new storage projects could be utilized in combination with ATMs to efficiently store and deliver available water as well as water provided from ATM projects. This combination could potentially make both new storage and ATM projects more feasible and help meet the water supply gaps in the basin.
10. Future storage projects would have an impact on Colorado's water obligation to the PRRIP. Membership in SPWAP in addition to coordination with the State of

Colorado and SPWAP would be necessary to comply with all PRRIP mitigation requirements for new South Platte water storage projects. Further investigation into SPWRAP effects of new storage projects is recommended.

11. This study did not simulate conjunctive operation of a large surface storage project with an ASR project. Benefits of conjunctive use should be investigated.
12. This study did not evaluate potential supplies or storage opportunities upstream of Kersey on the South Platte River or Poudre River. Extending the water availability study and the investigation of potential storage options upstream of Kersey on the South Platte River and Cache la Poudre River should be considered.

12. REFERENCES

CDM. Statewide Water Supply Initiative. Prepared for Colorado Water Conservation Board and Colorado Department of Natural Resources. January 2011.

Colorado Water Conservation Board. Colorado's Water Plan. 2015.

HDR/West Sage. South Platte Basin Implementation Plan. Prepared for South Platte and Metro Basin Roundtables. 2015

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APPENDIX A – HB 16-1256

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Second Regular Session
Seventieth General Assembly
STATE OF COLORADO

INTRODUCED

LLS NO. 16-0630.01 Jennifer Berman x3286

HOUSE BILL 16-1256

HOUSE SPONSORSHIP

Brown, Humphrey, Priola, Roupe, Nordberg, Windholz, Everett, Lundeen, Klingenschmitt, Thurlow, Wist, Sias, Dore, DelGrosso, Leonard, Willett, Van Winkle, Wilson, Rankin, Arndt, Becker J., Conti, Coram, Landgraf, Navarro, Saine, Singer, Vigil

SENATE SPONSORSHIP

Sonnenberg,

House Committees

Agriculture, Livestock, & Natural Resources
Appropriations

Senate Committees

A BILL FOR AN ACT

101 **CONCERNING A STUDY REGARDING THE CREATION OF ADDITIONAL**
102 **WATER STORAGE IN THE SOUTH PLATTE RIVER BASIN.**

Bill Summary

(Note: This summary applies to this bill as introduced and does not reflect any amendments that may be subsequently adopted. If this bill passes third reading in the house of introduction, a bill summary that applies to the reengrossed version of this bill will be available at <http://www.leg.state.co.us/billsummaries>.)

Section 1 of the bill requires the Colorado water conservation board (board), in collaboration with the state engineer, to conduct or commission a hydrology study of the South Platte river basin to determine, for each of the previous 20 years, the amount of water that has been delivered to Nebraska from the river in excess of the amount required under the South Platte river compact. The study must also

Shading denotes HOUSE amendment. Double underlining denotes SENATE amendment.
Capital letters indicate new material to be added to existing statute.
Dashes through the words indicate deletions from existing statute.

include a list of locations that have been identified as possible sites for the construction of a reservoir along the mainstem and tributaries of the South Platte river between Greeley, Colorado, and Julesburg, Colorado. For each listed location, the study must include information on the amount of water that could have been stored in a reservoir at the site, a list of any property that the federal bureau of reclamation or another government agency has purchased for construction of the site, an estimate of the cost to construct a reservoir at the site, and a cost-benefit analysis for constructing a reservoir at the site. The board, in collaboration with the state engineer, is required to provide a report summarizing the study to the committees of reference in the house of representatives and the senate that have jurisdiction over natural resources matters.

Section 2 transfers \$250,000 from the severance tax perpetual base fund to the Colorado water conservation board construction fund on July 1, 2016.

1 *Be it enacted by the General Assembly of the State of Colorado:*

2 **SECTION 1.** In Colorado Revised Statutes, 37-60-115, **add** (11)
3 as follows:

4 **37-60-115. Water studies - rules - repeal. (11) South Platte**
5 **river storage study - report - repeal. (a) Legislative declaration.**

6 (I) THE GENERAL ASSEMBLY HEREBY FINDS THAT:

7 (A) COLORADO'S WATER PLAN IDENTIFIES INCREASED WATER
8 STORAGE AS AN IMPORTANT GOAL AND SETS FORTH AN OBJECTIVE TO
9 ATTAIN AN ADDITIONAL FOUR HUNDRED THOUSAND ACRE FEET OF WATER
10 STORAGE IN COLORADO BY 2050; AND

11 (B) IN 2015, MORE THAN TWO MILLION ACRE FEET OF WATER THAT
12 WERE DELIVERED TO NEBRASKA BY THE SOUTH PLATTE RIVER COULD
13 HAVE BEEN STORED AND USED IN COLORADO.

14 (II) THE GENERAL ASSEMBLY FURTHER DETERMINES THAT WATER
15 STORAGE PROVIDES NUMEROUS BENEFITS, INCLUDING:

16 (A) AN INCREASED ABILITY TO ADDRESS COLORADO'S PREDICTED
17 FUTURE WATER SUPPLY GAPS;

- 1 (B) PROVIDING AQUIFER RECHARGE;
- 2 (C) REDUCING THE NEED TO IMPORT WATER FROM ONE WATER
- 3 BASIN TO ANOTHER WATER BASIN THROUGH A TRANSBASIN DIVERSION;
- 4 (D) REDUCING RELIANCE ON THE PRACTICE OF BUYING
- 5 AGRICULTURAL WATER RIGHTS AND DRYING UP THE AGRICULTURAL LAND
- 6 SERVED BY THE WATER RIGHTS;
- 7 (E) RECREATIONAL BENEFITS;
- 8 (F) FLOOD CONTROL;
- 9 (G) INCREASING PRODUCTION BY ALLOWING AGRICULTURAL
- 10 PUMPING OF WELLS, WHICH WILL LOWER THE WATER LEVELS IN AREAS
- 11 WHERE WELLS HAVE BEEN SHUT OFF DUE TO HIGH GROUNDWATER LEVELS;
- 12 (H) INCREASED MUNICIPAL, INDUSTRIAL, AND AGRICULTURAL
- 13 WATER SUPPLY; AND
- 14 (I) INCREASED AGRICULTURAL PRODUCTION.

15 (III) THEREFORE, THE GENERAL ASSEMBLY DECLARES THAT A
16 STUDY SHOULD BE CONDUCTED TO IDENTIFY POSSIBLE WATER STORAGE
17 SITES ALONG THE SOUTH PLATTE RIVER BASIN.

18 (b) THE BOARD, IN COLLABORATION WITH THE STATE ENGINEER,
19 SHALL CONDUCT OR COMMISSION A HYDROLOGY STUDY OF THE SOUTH
20 PLATTE RIVER BASIN TO ESTIMATE, FOR EACH OF THE PREVIOUS TWENTY
21 YEARS, THE VOLUME OF WATER THAT:

22 (I) HAS BEEN DELIVERED TO NEBRASKA IN EXCESS OF THE
23 AMOUNT REQUIRED TO BE DELIVERED BY THE SOUTH PLATTE RIVER
24 COMPACT, ARTICLE 65 OF THIS TITLE; AND

25 (II) COULD HAVE OTHERWISE BEEN STORED IN THE LOWER SOUTH
26 PLATTE RIVER BASIN.

27 (c) THE STUDY MUST INCLUDE A LISTING OF THE LOCATIONS THAT

1 HAVE BEEN IDENTIFIED AS POSSIBLE SITES FOR THE CONSTRUCTION OF A
2 NEW RESERVOIR ON THE MAINSTEM AND TRIBUTARIES OF THE SOUTH
3 PLATTE RIVER BETWEEN GREELEY, COLORADO, AND JULESBURG,
4 COLORADO.

5 (d) FOR EACH POSSIBLE SITE IDENTIFIED PURSUANT TO PARAGRAPH
6 (c) OF THIS SUBSECTION (11), THE STUDY MUST INCLUDE:

7 (I) AN ESTIMATE OF THE VOLUME OF WATER THAT COULD HAVE
8 BEEN STORED ANNUALLY;

9 (II) USING RELEVANT RECORDS TO WHICH THE PERSONS
10 CONDUCTING THE STUDY MAY ACCESS, INCLUDING RECORDS OF THE
11 FEDERAL BUREAU OF RECLAMATION AND OTHER FEDERAL AGENCIES, A
12 LISTING OF ANY PROPERTY THAT THE FEDERAL BUREAU OF RECLAMATION
13 OR OTHER GOVERNMENT AGENCY HAS PURCHASED FOR CONSTRUCTION OF
14 THE SITE;

15 (III) AN ESTIMATE OF THE COST TO CONSTRUCT A RESERVOIR AT
16 THE SITE, INCLUDING THE ESTIMATED COSTS OF OBTAINING NECESSARY
17 PERMITS AND ACQUIRING PROPERTY; AND

18 (IV) A COST-BENEFIT ANALYSIS FOR CONSTRUCTING A RESERVOIR
19 AT THE SITE, INCLUDING CONSIDERATION OF POTENTIAL ENVIRONMENTAL,
20 FINANCIAL, AND LEGAL CONSTRAINTS AND POTENTIAL BENEFITS,
21 INCLUDING:

22 (A) ADDRESSING COLORADO'S PREDICTED FUTURE WATER SUPPLY
23 GAPS;

24 (B) PROVIDING AQUIFER RECHARGE;

25 (C) REDUCING THE NEED TO IMPORT WATER INTO THE SOUTH
26 PLATTE RIVER BASIN FROM OTHER WATER BASINS;

27 (D) REDUCING RELIANCE ON THE PRACTICE OF BUYING

1 AGRICULTURAL WATER RIGHTS AND DRYING UP THE AGRICULTURAL LAND
2 SERVED BY THE WATER RIGHTS;

3 (E) RECREATIONAL BENEFITS;

4 (F) FLOOD CONTROL;

5 (G) INCREASING PRODUCTION BY ALLOWING AGRICULTURAL
6 PUMPING OF WELLS, WHICH WILL LOWER THE WATER LEVELS IN AREAS
7 WHERE WELLS HAVE BEEN SHUT OFF DUE TO HIGH GROUNDWATER LEVELS;

8 (H) INCREASED MUNICIPAL, INDUSTRIAL, AND AGRICULTURAL
9 WATER SUPPLY;

10 (I) INCREASED AGRICULTURAL PRODUCTION; AND

11 (J) ANY OTHER BENEFIT.

12 (e) THE BOARD, IN COLLABORATION WITH THE STATE ENGINEER,
13 SHALL:

14 (I) COMPLETE THE STUDY AS EXPEDITIOUSLY AS PRACTICABLE,
15 BUT NOT LATER THAN NOVEMBER 30, 2016; AND

16 (II) ON OR BEFORE JANUARY 20, 2017, PROVIDE A REPORT
17 SUMMARIZING THE STUDY TO THE COMMITTEES OF REFERENCE IN THE
18 HOUSE OF REPRESENTATIVES AND THE SENATE WITH JURISDICTION OVER
19 NATURAL RESOURCES.

20 (f) THE BOARD MAY ACCEPT AND EXPEND GIFTS, GRANTS, AND
21 DONATIONS FOR THE PURPOSES OF THIS SUBSECTION (11), BUT THE
22 IMPLEMENTATION OF THIS SUBSECTION (11) IS NOT DEPENDENT ON THE
23 RECEIPT OF GIFTS, GRANTS, AND DONATIONS. THE BOARD SHALL TRANSMIT
24 ALL MONEY RECEIVED THROUGH GIFTS, GRANTS, OR DONATIONS TO THE
25 STATE TREASURER, WHO SHALL CREDIT THEM TO THE COLORADO WATER
26 CONSERVATION BOARD CONSTRUCTION FUND CREATED IN SECTION
27 37-60-121.

1 (g) THIS SUBSECTION (11) IS REPEALED, EFFECTIVE JULY 1, 2018.

2 **SECTION 2.** In Colorado Revised Statutes, 39-29-109, **amend**
3 (2) introductory portion; and **add** (2) (a) (XV) as follows:

4 **39-29-109. Severance tax trust fund - created - administration**
5 **- distribution of money - repeal.** (2) State severance tax receipts shall
6 be credited to the severance tax trust fund as provided in section
7 39-29-108. Except as otherwise set forth in section 39-29-109.5, all
8 income derived from the deposit and investment of the ~~moneys~~ MONEY
9 in the fund shall be credited to the fund. At the end of any fiscal year, all
10 unexpended and unencumbered ~~moneys~~ MONEY in the fund ~~remain~~
11 ~~therein~~ REMAINS IN THE FUND and shall not be credited or transferred to
12 the general fund or any other fund. All ~~moneys~~ MONEY in the fund ~~are~~ IS
13 subject to appropriation by the general assembly for the following
14 purposes:

15 (a) **The severance tax perpetual base fund.**
16 (XV) NOTWITHSTANDING ANY PROVISION OF THIS PARAGRAPH (a) TO THE
17 CONTRARY, ON JULY 1, 2016, THE STATE TREASURER SHALL TRANSFER
18 TWO HUNDRED FIFTY THOUSAND DOLLARS FROM THE FUND TO THE
19 COLORADO WATER CONSERVATION BOARD CONSTRUCTION FUND,
20 CREATED IN SECTION 37-60-121 (1) (a), C.R.S., FOR USE BY THE
21 COLORADO WATER CONSERVATION BOARD, CREATED IN SECTION
22 37-60-102, C.R.S., TO IMPLEMENT THE SOUTH PLATTE RIVER WATER
23 STORAGE STUDY PURSUANT TO SECTION 37-60-115 (11), C.R.S.

24 **SECTION 3. Safety clause.** The general assembly hereby finds,
25 determines, and declares that this act is necessary for the immediate
26 preservation of the public peace, health, and safety.

APPENDIX B – LITERATURE REVIEW TM

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HB 1256 - South Platte Storage Study (SPSS)



TECHNICAL MEMORANDUM

To: Joe Frank, Andy Moore
Lower South Platte Water Conservancy District, Colorado Water Conservation Board

From: Samantha Mauzy, Enrique Triana and Chip Paulson
MWH Now Part of Stantec

Subject: **South Platte Storage Opportunities Literature Review** Date: March 13, 2017

INTRODUCTION AND BACKGROUND

The South Platte Storage Study (SPSS) was initiated as a result of House Bill 16-1256 titled “South Platte Storage Study.” HB16-1256, signed into law by the Governor on June 9th, 2016, authorizes the Colorado Water Conservation Board (CWCB), in collaboration with the State Engineer (SEO), and the South Platte Basin and Metro Roundtables, to identify multi-purpose water storage options along the lower South Platte River to capture flows leaving the state in excess of the legally required amounts. These water storage possibilities will include new reservoirs, the enlargement/rehabilitation of existing reservoirs, and alternative storage mechanisms (e.g., underground storage).

The first task of the SPSS project is a literature review of storage studies in the South Platte River basin. The objective of the literature review is to identify and document previously studied storage sites and catalog opportunities for additional expansion, partnerships and multiuse possibilities.

Storage opportunities in the South Platte basin have been studied by a variety of different agencies, including the State and individual water users. Some of these past studies sought to address broad regional water needs (e.g., the South Platte Basin Implementation Plan), while others were conducted by individual water users to meet their own storage needs. In some cases, those storage opportunities are part of water users’ long term plans and are included in the State Water Plan as Identified Projects and Processes (IPP). In other cases, storage opportunities were ruled out by the water user that studied them because they did not meet the needs of the water user. These storage opportunities previously ruled out have been included herein because they could be an opportunity for others.

This technical memorandum presents the results of the SPSS Literature Review. It contains an overview of potential storage sites identified thus far. It outlines the sources that have been reviewed and how the identified sites have been categorized. A working draft of this technical memorandum was distributed and presented to interested parties on January 12, 2017. The feedback, comments, and clarifications received were incorporated into this version of the memorandum.

SOURCES OF INFORMATION

The sources reviewed for this study are shown in Table 1. Pertinent information for storage sites was extracted from these reports and databases. HB 16-1256 asked for a review of previously identified storage sites throughout the South Platte Basin. Reports covering areas throughout the basin were reviewed, but the emphasis was on storage options in the designated SPSS study area between Greeley and the state line.

Table 1. Information Sources Used in the Literature Review

Source Name	Entity	Author	Year
2015 South Platte Basin Implementation Plan	South Platte Basin Roundtable	HDR/ West Sage	2015
2015 South Platte Basin Surface Water Availability Analysis - Appendix G	South Platte Basin Roundtable	MWH/ HDR	2015
Active Construction DRMS Permits Shapefile from State of Colorado			2017
Addendum No. 2 to Definite Plan Report	US Bureau of Reclamation		1983
Analysis of managed aquifer recharge for retiming streamflow in an alluvial river	Journal of Hydrology	Michael J. Ronayne, Jason A. Roudebush, John D. Stednick	2016
Artificial Aquifer Recharge in the Colorado Portion of the Ogallala Aquifer	Colorado Water Resources Research Institute	Robert Longenbaugh, Donald Miles, Earl Hess, James Rubingh	1984
Artificial Recharge of Ground Water in Colorado - A Statewide Assessment	Colorado Geological Survey	Ralf Topper, Peter E. Barkmann, David A. Bird, and Matthew A. Sares	2004
Cache la Poudre Water and Hydropower Resources Management Study	Colorado Water Resources and Power Development Authority	Harza Engineering Company	1987
CDSS Reservoirs GIS Shapefile, Division 1			2017
Chatfield Reservoir Reallocation Final Integrated Feasibility Report and Environmental Impact Statement		US Army Corps of Engineers	2013
Colorado Water Conservation Board SB-193 Underground Water Storage Study	Colorado Water Conservation Board		2007
Colorado's Water Plan	Colorado Water Conservation Board	Colorado Water Conservation Board	2015
Final Draft Alternative Descriptions for Moffat Collection System EIS	Denver Water	MWH	2005
GIS Dam Site Inventory from State of Colorado			
Legal and Institutional Opportunities for Aquifer Recharge and Storage in Colorado --An Interactive Forum		Aqua Engineering, Inc., El Paso County Water Authority	2008
Lost Creek Basin Aquifer Recharge and Storage Study	Lost Creek Ground Water Management District	Colorado Geological Survey	2011
Multi-Basin Water Supply Investigation	Northern Colorado Water Conservancy District	Black and Veatch	2006
Northern Integrated Supply Project Final Technical Memorandum 5D: Existing Reservoirs with Enlargement and Rehabilitation Potential	Northern Colorado Water Conservancy District	MWH	2004
Northern Integrated Supply Project Phase II Alternative Evaluation	Northern Colorado Water Conservancy District	MWH	2004
Northern Integrated Supply Project Technical Memorandum 5E Upper Saint Vrain Yield Analysis	Northern Colorado Water Conservancy District	MWH	2004
Ovid Reservoir and Dam Preliminary Design Report		Applegate Group	2003

Source Name	Entity	Author	Year
Pawnee Creek Flood Control Project - Phase 1 Project Scoping Report		W. W. Wheeler and Associates	2011
Preliminary Conceptual Plan for Proposed Pawnee Pass Dam and Reservoir in Logan County Colorado	Platte River Hydrologic Research Center	Charles Leaf	
River Water Management and Storage Sites	Colorado Water Conservation Board	GEI Consultants	2001
SB06-193 Underground Water Storage Study	Colorado Water Conservation Board	Camp Dresser and McKee Inc.	2007
SPSS Project - CCWCD Interview Notes	Colorado Water Conservation Board	MWH	2016
Statewide Water Supply Initiative Technical Memoranda	Colorado Water Conservation Board		2010
Windy Gap Firming Project, Alternative Plan Formulation Report	Northern Colorado Water Conservancy District	Boyle Engineering Corporation	2003

STORAGE SITE CLASSIFICATION

Storage sites found in the literature review were separated into three (3) main categories: surface storage sites; aquifer storage sites; and gravel pit sites. Gravel pit storage was separated from the surface storage category because of the way gravel pit storage is evaluated herein. For the purpose of this study, gravel pit storage is evaluated based on general geographic location, not as individual sites.

SURFACE STORAGE SITES

Surface storage sites were classified into four (4) sub-categories to help identify opportunities for this project. Sub-categories for surface storage opportunities were enlargements of existing reservoirs, identified new reservoir sites, existing reservoirs with rehabilitation potential, and existing reservoirs with storage restoration potential. These categories are defined in Table 2.

Table 2. Surface Storage Category Definitions

Category	Description
Enlargement	This group includes existing reservoirs that have been previously studied to determine feasibility of an enlargement. If available, information such as enlarged capacity and enlargement feasibility from previous enlargement studies was captured for use in this investigation.
New Site	These are locations where a new surface storage facility could be feasible. Information such as potential reservoir capacity and feasibility from previous studies is usually available.
Rehabilitation	These sites are existing reservoirs that have a storage restriction imposed by the State of Colorado Dam Safety Branch. By rehabilitating the dams at these locations, the storage restrictions could be removed and additional storage would then become available.
Storage Restoration	Locations in this category include existing reservoirs that have reduced storage capacity due to sedimentation. Storage capacity at these sites could be recovered by dredging the sediment and disposing it.

Storage sites identified as IPPs in the State Water Plan are included in the inventory. Although the water users promoting these IPPs might be planning to use all the potential storage capacity, there may be opportunities for further enlargements of these reservoirs to incorporate the needs of additional partners. Additional analysis will need to be performed to determine if IPP sites can potentially be enlarged for the purpose of this study. Storage projects identified in other studies that were screened out for that project purpose could still be feasible for this study. If available, the reasons for sites being screened out in previous studies were compiled in this literature review.

Sites included in the GIS Dam Site Inventory Shapefile from the State of Colorado that were not included in the comprehensive CDSS Division 1 Reservoirs Shapefile of existing sites were categorized as *Potential New Sites*. The potential for reservoir sites in this category within the SPSS study area to meet needs of this study will have to be evaluated in detail later in the project.

AQUIFER STORAGE SITES

This group of storage sites includes options that use deep confined or shallow unconfined aquifers to store water. For this summary these sites are represented by a single point on a map, but in reality aquifer storage could occur over a broad area in the aquifer porous space underground. These options will require points of recharge and extraction that will be analyzed when formulating the storage concepts later in the project.

GRAVEL PIT STORAGE

Gravel pit storage sites were separated from the surface water storage category because they will be treated differently than the larger surface reservoir options in this study. The individual gravel pit storage options are small and will not be considered for long term storage on their own; however, groups of individual gravel pits in the same general area could be combined into a larger storage complex that could provide sufficient capacity to meet the needs of this study. In addition, these sites may be used to support other storage solutions, for example by providing temporary storage to hold exchange water until it can be exchanged further upstream. For purposes of this storage site inventory, gravel pit locations were mapped separately from other surface reservoir options so locations of possible gravel pit complexes can be considered later in the project.

SUMMARY OF REVIEWED STORAGE SITES

The potential surface storage sites in the South Platte River Basin cataloged in this literature review are listed in Table 3, and potential aquifer storage sites are presented in Table 4. *Additional Storage* represents the estimated volume that the site could contribute to new storage in the basin (i.e., excluding existing storage for enlargement, rehabilitation and restoration options). Readily available information was collected and summarized for storage options in the entire South Platte Basin. Information was not verified, but was taken directly from previous studies or inventories. Additional information will be developed for sites within the SPSS study area that are candidates for including in this study in future phases of the work.

Potential for Consumptive Partnerships and *Potential for Non-Consumptive Partnerships* are key factors in determining which sites have potential to be considered for this project as an option to develop additional storage in the basin. A site with Potential Consumptive Partnerships refers to future storage concepts for which the current reservoir owner could consider opportunities to split both financial costs and additional storage space at the site with other water users for consumptive water uses. A site with potential non-consumptive partnerships refers to a storage opportunity for which the current owner could consider cooperating with additional entities to split financial costs, providing non-consumptive use benefits (i.e. recreation, wildlife habitat, etc.). This factor is important because, although it may be physically feasible to enlarge or rehabilitate an existing reservoir, without cooperation from the current owner and a commitment to make a portion of the additional storage space available to the State or other water users the additional storage capacity would not benefit this project. Similarly for a new reservoir, if the water user proposing it intends to develop the full site capacity for its own purposes then there would be no opportunity to acquire storage for purposes of the SPSS. Limited information on potential partnership opportunities was obtained through the literature review and therefore this information is incomplete; it will be refined for reservoir options in the SPSS study area as the project progresses and the number of candidate sites is reduced through the screening process.

Figure 1 shows the location of the cataloged surface storage sites for the entire South Platte Basin. It includes potential new reservoir sites and existing reservoirs that could be enlarged, rehabilitated, or restored. Figure 2 shows potential new, enlarged, rehabilitated and restored surface storage sites in the SPSS study area. Figure 3 shows the cataloged aquifer storage options in the South Platte Basin; Figure 4 shows the same information for the SPSS study area. Locations indicated on the map are representative of the general aquifer locations; aquifer spatial boundaries are not depicted.

Figure 5 and Figure 6 show active sand, gravel, sand and gravel, or construction borrow material mines in Division 1 and the SPSS study area, respectively. These sites are color-coded according to the current post-mining use designation. Those with the designation “developed water resources” have been identified as sites that will be reclaimed for the purpose of water storage use after mining is completed. Note that there is potential for mines not designated as “developed water resources” to change designation after mining is completed, so all permitted gravel mining operations are shown.

A total of 70 surface storage options (excluding gravel pits) and 22 aquifer storage options were found in the SPSS study area through the Literature Review. Individual surface storage options in the study area vary from 3 ac-ft to 1,962,000 ac-ft of additional storage capacity, and include sites on the South Platte mainstem, on primary tributaries, and in tributary drainage areas. The inventory includes:

- Fifty-nine (59) new reservoir sites
- Six (6) existing reservoir enlargements
- Four (4) existing reservoir rehabilitations

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- One (1) existing reservoir restoration
- Twenty-two (22) aquifer storage options
- Fifty-five (55) permitted gravel mining sites

Some of these options are similar (e.g., different nearby reservoir sites on the same tributary) and may be filtered into a single option in the next step of the storage site evaluation.

The next phase of the work will include assessing the storage options in the study area and developing a long-list of options that warrant further study based on their size, location, ownership, permitability, and other attributes.

Table 3. Potential Surface Storage Sites in the South Platte Basin

Site ID	Site Name	Category	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
Primary Source: 2015 South Platte Basin Implementation Plan								
114	Box Creek Reservoir	New Site	25,000	Unknown	Unknown	Yes		
137	Consolidated Mutual Water District Reservoir Construction	New Site		Unknown	Unknown	Yes		
194	Corral Creek A	New Site	9,000	Unknown	Unknown		Yes	
250	Corral Creek B	New Site	2,500	Unknown	Unknown		Yes	
247	Cottonwood Creek	New Site	4,000	Unknown	Unknown		Yes	
197	Gerk	New Site	5,000	Unknown	Unknown		Yes	
107	Greeley Flatiron Reservoir	New Site	3,100	Unknown	Unknown			Enlarged capacity is combined Greeley Flatiron and Overland Trail and 25th Ave Lakes
189	Harmony Ditch West	New Site	10,000	Unknown	Unknown		Yes	
248	Hawk Springs	New Site	3,500	Unknown	Unknown		Yes	
110	Highway 93 Lakes	New Site	500	Unknown	Unknown	Yes		
89	Jackson Lake Reservoir	Storage Restoration	10,000	Yes	Unknown		Yes	Potential partnerships to recapture storage by dredging (front range city, oil/gas industry, or State Parks Dept.) Info updated 2/21/17 based on email communication with Cynthia Lefever (fmrico@outlook.com)
199	Johnson Lake Enlargement	Enlargement	5,400	Unknown	Unknown		Yes	
198	Johnson Lake West	New Site	3,500	Unknown	Unknown		Yes	
188	Johnson Reservoir	New Site	10,600	Unknown	Unknown		Yes	
97	Little Thompson Reservoir	New Site	305,000	Unknown	Unknown			

Table 3. Potential Surface Storage Sites in the South Platte Basin

Site ID	Site Name	Category	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
138	New Storage Projects (Northglenn)	New Site	1,500	Unknown	Unknown	Yes		
193	North Sterling Regulating Reservoir	New Site	7,600	Unknown	Unknown		Yes	
249	Ramsey Draw	New Site	2,900	Unknown	Unknown		Yes	
133	Reuter Hess Reservoir Enlargement	Enlargement	14,810	Unknown	Unknown	Yes		
187	Sedgwick	New Site	2,230	Unknown	Unknown		Yes	
246	Site A	New Site	1,580	Unknown	Unknown		Yes	
195	Skinner Draw	New Site	5,400	Unknown	Unknown		Yes	
190	Sterling Lateral East	New Site	4,900	Unknown	Unknown		Yes	
191	Sterling Lateral South	New Site	6,600	Unknown	Unknown		Yes	
192	Sterling Lateral West	New Site	6,900	Unknown	Unknown		Yes	
196	Troelstrup	New Site	5,000	Unknown	Unknown		Yes	
134	Union (Calkins) Reservoir Enlargement	Enlargement	1,770	Unknown	Unknown	Yes		>5 residences impacted
Primary Source: CDSS Reservoirs GIS Shapefile, Division 1								
427	A C Rupp Reservoir No 2	New Site	22	Unknown	Unknown			
431	Alma Reservoir	New Site		Unknown	Unknown			
367	Bakerville Reservoir 1	New Site	70	Unknown	Unknown			
368	Bakerville Reservoir 2	New Site	80	Unknown	Unknown			
370	Bald Mountain Reservoir	New Site	110,000	Unknown	Unknown			
364	Ball Placer Reservoir	New Site	110	Unknown	Unknown			
489	Barnes Park Pond Reservoir	New Site		Unknown	Unknown			

Table 3. Potential Surface Storage Sites in the South Platte Basin

Site ID	Site Name	Category	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
340	Behrmann Reservoir	New Site	2,869	Unknown	Unknown			
507	Bickling Reservoir	New Site		Unknown	Unknown			
277	Bijou Valley D & R Sys A	New Site	487	Unknown	Unknown		Yes	
474	Bokelman Reservoir 1	New Site	345	Unknown	Unknown			
414	Boksmati Reservoir	New Site		Unknown	Unknown			
484	Boomerang Reservoir 1	New Site	581	Unknown	Unknown			
485	Boomerang Reservoir 2	New Site	481	Unknown	Unknown			
462	Brinkmann-Woodward Reservoir	New Site		Unknown	Unknown			
331	Buckhorn Reservoir	New Site	1,190	Unknown	Unknown			
312	Cache La Poudre Forebay	New Site	55,000	Unknown	Unknown			
499	Carbon Valley Water Storage Cell Reservoir	New Site	1,600	Unknown	Unknown			
394	Centennial Lake	New Site	680	Unknown	Unknown			
458	Centennial Ponds	New Site	2,172	Unknown	Unknown			
369	Centennial Reservoir	New Site	110,000	Unknown	Unknown			
509	Central City Chase Gulch Reservoir	New Site		Unknown	Unknown			
490	Cgrw Investments Pond Reservoir	New Site		Unknown	Unknown			
358	Clear Creek Reservoir 2	New Site	30	Unknown	Unknown			
359	Clear Creek Reservoir 3	New Site	65	Unknown	Unknown			
360	Clear Creek Reservoir 4	New Site	55	Unknown	Unknown			
430	Columbine Reservoir	New Site		Unknown	Unknown			

Table 3. Potential Surface Storage Sites in the South Platte Basin

Site ID	Site Name	Category	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
432	Como Reservoir 2	New Site	7,900	Unknown	Unknown			
444	Corliss No 1 Reservoir	New Site		Unknown	Unknown			
436	Couch Aug Pond D	New Site		Unknown	Unknown		Yes	
479	Cpnmr Reservoir 1	New Site	5,500	Unknown	Unknown			
281	D T Reservoir 1	New Site	138	Unknown	Unknown		Yes	
279	D T Reservoir 2	New Site	112	Unknown	Unknown		Yes	
280	D T Reservoir 3	New Site	125	Unknown	Unknown		Yes	
393	Dancing Deer Pond	New Site		Unknown	Unknown			
354	Donald Reservoir	New Site	264	Unknown	Unknown			
361	Douglas Mountain Reservoir 2	New Site	525	Unknown	Unknown			
288	Dover Reservoir	New Site		Unknown	Unknown		Yes	
273	Duke Pond	New Site		Unknown	Unknown			
421	Eagle Rock Park Reservoir	New Site	7	Unknown	Unknown			
453	East Reservoir Complex	New Site	45,761	Unknown	Unknown			
466	East Wabash Underground Storage Structure	New Site	101	Unknown	Unknown			
422	Eitel North Dam	New Site	1	Unknown	Unknown			
423	Eitel South Dam	New Site	10	Unknown	Unknown			
460	Emj Squaw Pass Upper Reservoir No 1	New Site	3	Unknown	Unknown			
470	Emj Squaw Pass Upper Reservoir No 2	New Site	2	Unknown	Unknown			
505	Everist No 2 Reservoir	New Site	10,163	Unknown	Unknown			

Table 3. Potential Surface Storage Sites in the South Platte Basin

Site ID	Site Name	Category	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
506	Everist No 3 Reservoir	New Site	1,767	Unknown	Unknown			
374	Everist Reservoir	New Site	990	Unknown	Unknown			
304	Ferguson Reservoir	New Site		Unknown	Unknown			
318	Firesteine Reservoir	New Site	1,000	Unknown	Unknown			
486	Flyfisher Reservoir	New Site	25	Unknown	Unknown			
512	Fritzler Reservoir 2	New Site		Unknown	Unknown		Yes	
319	Gray Reservoir 3A	New Site	15	Unknown	Unknown			
320	Gray Reservoir 3B	New Site	20	Unknown	Unknown			
321	Gray Reservoir 3C	New Site	20	Unknown	Unknown			
322	Gray Reservoir 3D	New Site	10	Unknown	Unknown			
323	Gray Reservoir 3E	New Site	10	Unknown	Unknown			
324	Gray Reservoir 3F	New Site	15	Unknown	Unknown			
325	Gray Reservoir 3G	New Site	10	Unknown	Unknown			
326	Gray Reservoir 3H	New Site	10	Unknown	Unknown			
327	Gray Reservoir 3I	New Site	10	Unknown	Unknown			
467	Great Western Reservoir 1	New Site		Unknown	Unknown			
468	Great Western Reservoir 2	New Site		Unknown	Unknown			
469	Great Western Reservoir 3	New Site		Unknown	Unknown			
287	Grover Reservoir	New Site	2,506	Unknown	Unknown			
372	Guy Gulch Reservoir	New Site	35,000	Unknown	Unknown			
316	Hansen Stenzel Reservoir	New Site		Unknown	Unknown			

Table 3. Potential Surface Storage Sites in the South Platte Basin

Site ID	Site Name	Category	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
448	Happy Canyon Reservoir & Recharge Area	New Site		Unknown	Unknown			
413	Harden Reservoir 2	New Site	3	Unknown	Unknown			
310	Harris Reservoir A	New Site	350	Unknown	Unknown			
426	High Chaparral Pond	New Site		Unknown	Unknown			
416	Hiwan Reservoir 10	New Site	206	Unknown	Unknown			
415	Hiwan Reservoir 9	New Site	230	Unknown	Unknown			
305	Home Place Pond No 14	New Site		Unknown	Unknown			
306	Home Place Pond No 15	New Site		Unknown	Unknown			
282	Jackpot Reservoir	New Site		Unknown	Unknown		Yes	
398	Jackson Cr Prop Pond 1	New Site		Unknown	Unknown			
407	Jackson Cr Prop Pond 11	New Site		Unknown	Unknown			
408	Jackson Cr Prop Pond 12	New Site		Unknown	Unknown			
396	Jackson Cr Prop Pond 13	New Site		Unknown	Unknown			
399	Jackson Cr Prop Pond 2A	New Site		Unknown	Unknown			
395	Jackson Cr Prop Pond 2B	New Site		Unknown	Unknown			
400	Jackson Cr Prop Pond 3	New Site		Unknown	Unknown			
401	Jackson Cr Prop Pond 4	New Site		Unknown	Unknown			
402	Jackson Cr Prop Pond 5	New Site		Unknown	Unknown			
403	Jackson Cr Prop Pond 6	New Site		Unknown	Unknown			
404	Jackson Cr Prop Pond 7	New Site		Unknown	Unknown			
405	Jackson Cr Prop Pond 8	New Site		Unknown	Unknown			

Table 3. Potential Surface Storage Sites in the South Platte Basin

Site ID	Site Name	Category	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
406	Jackson Cr Prop Pond 9	New Site		Unknown	Unknown			
329	Kammerzell Lake	New Site	14	Unknown	Unknown			
409	Keats Pond 1	New Site	25	Unknown	Unknown			
410	Keats Pond 2	New Site	20	Unknown	Unknown			
284	Klug Reservoir 3	New Site	715	Unknown	Unknown		Yes	
417	Krain Pond 1	New Site	33	Unknown	Unknown			
418	Krain Pond 2	New Site	36	Unknown	Unknown			
452	Kurtz Reservoir	New Site	10,500	Unknown	Unknown			
350	Lafayette Reservoirs 1&2	New Site	180	Unknown	Unknown			
385	Lake Roxborough	New Site		Unknown	Unknown			
481	Lasalle Reservoir	New Site	36	Unknown	Unknown			
365	Leavenworth Reservoir 1	New Site	155	Unknown	Unknown			
366	Leavenworth Reservoir 2	New Site	160	Unknown	Unknown			
450	Lone Tree Reservoir & Recharge No 2	New Site		Unknown	Unknown			
449	Lone Tree Reservoir No 1	New Site		Unknown	Unknown			
433	Lost Park Reservoir	New Site		Unknown	Unknown			
482	Lower Equalizer Reservoir 1	New Site	900	Unknown	Unknown			
483	Lower Equalizer Reservoir 2	New Site	760	Unknown	Unknown			
501	Lower Sandstone Reservoir	New Site	60	Unknown	Unknown			
330	Maitland/Loveland Reservoir	New Site		Unknown	Unknown			
351	Mary E Miller Reservoir	New Site		Unknown	Unknown			

Table 3. Potential Surface Storage Sites in the South Platte Basin

Site ID	Site Name	Category	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
375	Mcdonald Reservoir 1	New Site	8	Unknown	Unknown			
376	Mcdonald Reservoir 2	New Site	12	Unknown	Unknown			
377	Mcdonald Reservoir 3	New Site	10	Unknown	Unknown			
378	Mcdonald Reservoir 4	New Site	5	Unknown	Unknown			
379	Meadow Ranch Reservoir 1	New Site	145	Unknown	Unknown			
380	Meadow Ranch Reservoir 2	New Site	145	Unknown	Unknown			
381	Meadow Ranch Reservoir 3	New Site	145	Unknown	Unknown			
382	Meadow Ranch Reservoir 4	New Site	145	Unknown	Unknown			
383	Meadow Ranch Reservoir 5	New Site	145	Unknown	Unknown			
384	Meadow Ranch Reservoir 6	New Site	145	Unknown	Unknown			
386	Meadow Ranch Reservoir 7	New Site	145	Unknown	Unknown			
297	Miracle Lake	New Site	95	Unknown	Unknown			
283	Moonshine Reservoir	New Site		Unknown	Unknown		Yes	
492	Morey Pond Reservoir	New Site		Unknown	Unknown			
438	N Sterling Harmony W Reservoir	New Site		Unknown	Unknown		Yes	
335	Neighbors Pond 1	New Site	123	Unknown	Unknown			
333	Neighbors Pond 2	New Site	105	Unknown	Unknown			
508	New Cache Agricultural Pond 1	New Site		Unknown	Unknown		Yes	
278	Noonen Seep Reservoir	New Site	176	Unknown	Unknown			
313	North Lone Pine Reservoir	New Site		Unknown	Unknown			
295	Northglenn Reservoir	New Site		Unknown	Unknown			

Table 3. Potential Surface Storage Sites in the South Platte Basin

Site ID	Site Name	Category	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
292	Oar Reservoir A	New Site	6,200	Unknown	Unknown			
294	Oar Reservoir B	New Site	10,200	Unknown	Unknown			
463	Oar Reservoir C	New Site	4,500	Unknown	Unknown			
293	Oar Reservoir D	New Site	4,000	Unknown	Unknown			
343	Oleson No 1 Reservoir	New Site		Unknown	Unknown			
344	Oleson No 2 Reservoir	New Site		Unknown	Unknown			
345	Oleson No 3 Reservoir	New Site		Unknown	Unknown			
355	Opalair Reservoir	New Site	30	Unknown	Unknown			
363	Paradise Valley Reservoir No 2	New Site	50	Unknown	Unknown			
362	Paradise Valley Reservoir No 3	New Site	50	Unknown	Unknown			
412	Petersburg Reservoir	New Site	5	Unknown	Unknown			
437	Phillips-Sedgwick Reservoir # 2	New Site		Unknown	Unknown			
435	Pioneer Reservoir	New Site	200	Unknown	Unknown		Yes	
456	Pisano Illegal Pond	New Site		Unknown	Unknown			
307	Platte Valley Pit	New Site		Unknown	Unknown			
309	Platte Valley Reservoir 1	New Site	300	Unknown	Unknown			
459	Platte Valley Trust Reservoir	New Site		Unknown	Unknown			
491	Pond North Of Service Center Reservoir	New Site		Unknown	Unknown			
488	Probasco Pit Reservoir	New Site		Unknown	Unknown			
502	Quartz Valley Reservoir	New Site	1,660	Unknown	Unknown			
388	Ramsour Bros Pond No 1	New Site		Unknown	Unknown			

Table 3. Potential Surface Storage Sites in the South Platte Basin

Site ID	Site Name	Category	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
389	Ramsour Bros Pond No 2	New Site		Unknown	Unknown			
390	Ramsour Bros Pond No 3	New Site		Unknown	Unknown			
420	Red Hill Reservoir	New Site		Unknown	Unknown			
455	Richardson Illegal Pond	New Site		Unknown	Unknown			
334	Rock N Wp Ranch Lake 5	New Site	1,820	Unknown	Unknown			
397	Roxborough Village Reservoir 2	New Site	61	Unknown	Unknown			
510	Rumsey Reservoir 1	New Site	1,250	Unknown	Unknown			
511	Rumsey Reservoir 2	New Site	1,250	Unknown	Unknown			
411	Sandifer Pond 1	New Site	2	Unknown	Unknown			
439	Scalva Replacement Reservoir C	New Site	9	Unknown	Unknown		Yes	
440	Scalva Replacement Reservoir D	New Site	8	Unknown	Unknown		Yes	
352	Section No 9 Reservoir	New Site		Unknown	Unknown			
392	Sellers Gulch Reservoir 1	New Site		Unknown	Unknown			
391	Sellers Gulch Reservoir 2	New Site		Unknown	Unknown			
314	Sleeping Ute Reservoir	New Site		Unknown	Unknown			
317	South Eighty Reservoir	New Site		Unknown	Unknown			
346	South Flat Reservoir	New Site	656	Unknown	Unknown			
500	South Shaw Lake No 1	New Site	372	Unknown	Unknown			
342	Southdown Reservoir Field	New Site	5,900	Unknown	Unknown			
428	Spruce Grove Reservoir	New Site	110,000	Unknown	Unknown			
339	St Vrain Portland 1 Reservoir	New Site	13,292	Unknown	Unknown			

Table 3. Potential Surface Storage Sites in the South Platte Basin

Site ID	Site Name	Category	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
387	Stevens Jackson Reservoir 4	New Site	1	Unknown	Unknown			
311	Taft Hill Reservoir	New Site	1,080	Unknown	Unknown			
347	Tahosa Park Reservoir	New Site		Unknown	Unknown			
301	Tani Lake 1	New Site		Unknown	Unknown			
298	Tani Lake 2	New Site		Unknown	Unknown			
299	Tani Lake 3	New Site		Unknown	Unknown			
300	Tani Lake 5	New Site		Unknown	Unknown			
429	Tarryall Reservoir	New Site	107,000	Unknown	Unknown			
285	Tew Reservoir	New Site		Unknown	Unknown		Yes	
514	The Pinery Lsp East Pond	New Site		Unknown	Unknown			
515	The Pinery Lsp North Pond	New Site		Unknown	Unknown			
513	The Pinery Lsp West Pond	New Site		Unknown	Unknown			
308	Thornton Doeringsfeld Pit	New Site	6,000	Unknown	Unknown			
476	Thornton Ncci Reservoir	New Site		Unknown	Unknown			
315	Trap Lake li	New Site	3,800	Unknown	Unknown			
419	Trout Creek Ranch Pond	New Site		Unknown	Unknown			
356	Trucksess Pond	New Site		Unknown	Unknown			
291	Tucson South Reservoirs	New Site	5,200	Unknown	Unknown			
373	Tunnel No 1 Reservoir	New Site	110,000	Unknown	Unknown			
371	Tunnel No 3 Reservoir	New Site	110,000	Unknown	Unknown			
425	Venture 73 Reservoir	New Site		Unknown	Unknown			

Table 3. Potential Surface Storage Sites in the South Platte Basin

Site ID	Site Name	Category	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
480	W W Farms Lake 1	New Site	3,514	Unknown	Unknown			
441	W6 Irr Pond	New Site	5	Unknown	Unknown		Yes	
443	W6 New Reservoir	New Site	5	Unknown	Unknown		Yes	
442	W6 Trout Pond	New Site	3	Unknown	Unknown		Yes	
504	Walker Reservoir	New Site	2,000	Unknown	Unknown			
472	Walters Reservoir 1	New Site	480	Unknown	Unknown			
473	Walters Reservoir 2	New Site	160	Unknown	Unknown			
471	Warren Gulch Reservoir No 1	New Site	48	Unknown	Unknown			
303	Water Hazard Pond No 1	New Site	5	Unknown	Unknown			
302	Water Hazard Pond No 2	New Site	9	Unknown	Unknown			
296	Wattensburg Lake	New Site	2,966	Unknown	Unknown			
434	Wears Ditch Reservoir	New Site		Unknown	Unknown			
348	Welty Lake	New Site		Unknown	Unknown			
464	West Wabash Storage & Recharge Structure	New Site	125	Unknown	Unknown			
424	Widdofield Reservoir	New Site		Unknown	Unknown			
286	Willow Creek Reservoir 2	New Site		Unknown	Unknown		Yes	
451	Windmill Reservoir No 1	New Site		Unknown	Unknown			
447	Woodside Reservoir	New Site	50	Unknown	Unknown			
445	Wray-2 Hatchery Ponds	New Site	160	Unknown	Unknown			
446	Wray-2 Reservoir	New Site	150	Unknown	Unknown			

Table 3. Potential Surface Storage Sites in the South Platte Basin

Site ID	Site Name	Category	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
Primary Source: Chatfield Reservoir Reallocation Final Integrated Feasibility Report and Environmental Impact Statement								
208	Penley Reservoir	New Site	12,725	Unknown	Unknown			
Primary Source: GIS Dam Site Inventory Shapefile from State of Colorado								
257	Altona Dam & Reservoir	New Site	26,720	Unknown	Unknown			
210	Big John Reservoir	Potential New Site	30,000	Unknown	Unknown			
259	Bootleg Reservoir	New Site	6,194	Unknown	Unknown		Yes	
260	Bradley Ranch Reservoir	New Site	77,000	Unknown	Unknown			
211	Buck Gulch Reservoir	Potential New Site	67,000	Unknown	Unknown			
213	Cone Mountain Reservoir	Potential New Site	33,300	Unknown	Unknown			
261	Craig Meadows Reservoir	New Site	15,000	Unknown	Unknown			
214	Crescent Reservoir	Potential New Site	11,300	Unknown	Unknown			
262	Dowe Flats Reservoir	New Site	119,000	Unknown	Unknown			
215	East Bijou Reservoir	Potential New Site	219,600	Unknown	Unknown			
216	Estabrook Res. Site No. 1	Potential New Site	233,000	Unknown	Unknown			
217	Estabrook Res. Site No. 2	Potential New Site	405,000	Unknown	Unknown			
218	Ferndale Reservoir	Potential New Site	785,000	Unknown	Unknown			
263	Greasewood Reservoir	New Site	67,268	Unknown	Unknown		Yes	
252	Hackett Reservoir	Potential New Site	55,200	Unknown	Unknown			
264	Hall Reservoir	New Site	49,464	Unknown	Unknown			
220	Idlewilde Reservoir	Potential New Site	200,000	Unknown	Unknown			
221	Inion Reservoir	Potential New Site	28,000	Unknown	Unknown			

Table 3. Potential Surface Storage Sites in the South Platte Basin

Site ID	Site Name	Category	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
265	Link Slater Reservoir	New Site	58,190	Unknown	Unknown			
223	Little S. St. Vrain Res.	Potential New Site	37,000	Unknown	Unknown			
224	Livermore Reservoir	Potential New Site	394,000	Unknown	Unknown			
225	Longmont Sugar Plant	Potential New Site	44,000	Unknown	Unknown			
226	Lookout Reservoir	Potential New Site	43,000	Unknown	Unknown			
266	March Reservoir	New Site	15,863	Unknown	Unknown		Yes	
228	Middle Bijou Reservoir	Potential New Site	111,700	Unknown	Unknown			
229	Muddy Creek Reservoir	Potential New Site	72,000	Unknown	Unknown			
230	New Cheesman Reservoir	Potential New Site	743,000	Unknown	Unknown			
231	North Sheep Mountain Res.	Potential New Site	150,000	Unknown	Unknown			
267	Northern W-Y Reservoir	New Site	30,000	Unknown	Unknown			
232	Orodell Reservoir	Potential New Site	55,000	Unknown	Unknown			
268	Park Reservoir	New Site	6,767	Unknown	Unknown			
269	Phillips-Sedgwick Reservoir #1	New Site	18,200	Unknown	Unknown			
233	Rowell Hill Reservoir	Potential New Site	150,000	Unknown	Unknown			
253	Shawnee Reservoir	Potential New Site	50,000	Unknown	Unknown			
270	Southern W-Y Reservoir	New Site	50,000	Unknown	Unknown			
236	Steamboat Mountain Res.	Potential New Site	55,000	Unknown	Unknown			
254	Sterling Recharge Reservoir	Potential New Site	35,000	Unknown	Unknown		Yes	Need to confirm site does not exist
237	Stone Canyon Reservoir	Potential New Site	31,800	Unknown	Unknown			
271	Sunken Lake Reservoir	New Site	5,093	Unknown	Unknown		Yes	

Table 3. Potential Surface Storage Sites in the South Platte Basin

Site ID	Site Name	Category	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
238	Thorodin Reservoir	Potential New Site	33,000	Unknown	Unknown			
239	Toll Gate Reservoir	Potential New Site	34,300	Unknown	Unknown			
240	Tungsten Reservoir	Potential New Site	74,000	Unknown	Unknown			
255	Two Forks Reservoir	New Site	1,100,000	Unknown	Unknown			
241	Upper Poudre Reservoir	Potential New Site	97,000	Unknown	Unknown			
243	West Bijou Reservoir	Potential New Site	111,700	Unknown	Unknown			
272	West Nile Reservoir	New Site	26,950	Unknown	Unknown		Yes	
256	West Plum Creek	Potential New Site	730,000	Unknown	Unknown			
Primary Source: Multi-Basin Water Supply Investigation								
251	Little Owl Creek Reservoir	New Site	75,000	Unknown	Unknown		Yes	
Primary Source: Northern Integrated Supply Project Final Technical Memorandum 5D: Existing Reservoirs with Enlargement and Rehabilitation Potential								
75	Bear Creek Lake	Enlargement	32,000	Unknown	Unknown			
52	Beaver Park Reservoir	Enlargement	7,000	Unknown	Unknown			>5 residences impacted
78	Big Kammerzell Reservoir	Enlargement	215,000	Unknown	Unknown			
40	Big Windsor Reservoir	Enlargement	29,200	Unknown	Unknown			
56	Boulder Reservoir	Enlargement	11,000	Unknown	Unknown			
46	Carter Lake Reservoir	Enlargement	108,400	Unknown	Unknown			
45	Chimney Hollow Pond	Enlargement	65,500	Unknown	Unknown			
25	Cobb Lake	Enlargement	39,500	Unknown	Unknown			>5 residences impacted
26	Douglass Reservoir	Enlargement	53,400	Unknown	Unknown			>5 residences impacted
8	Empire Reservoir	Rehabilitation	2,779	Unknown	Unknown		Yes	

Table 3. Potential Surface Storage Sites in the South Platte Basin

Site ID	Site Name	Category	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
59	Foothills Reservoir	Enlargement	4,260	Unknown	Unknown			
68	Foster Reservoir	Enlargement	3,500	Unknown	Unknown			
54	Gold Lake	Enlargement	400	Unknown	Unknown			
50	Great Western Reservoir	Enlargement	18,400	Unknown	Unknown			
47	Green Ridge Glade Reservoir	Enlargement	5,440	Unknown	Unknown			Pursued by City of Loveland
71	Gross Reservoir	Enlargement	72,000	No	Unknown			
27	Halligan Reservoir	Enlargement	15,000	No	Unknown	Yes		Subject of current EIS by City of Fort Collins
43	Hertha Reservoir	Enlargement	74,300	Unknown	Unknown			
55	Highland Reservoir Number 2	Enlargement	3,300	Unknown	Unknown			
87	Hilsboro Reservoir	Enlargement	5,000	Unknown	Unknown			
22	Horsetooth Reservoir	Enlargement		Unknown	Unknown			
79	Howlet Reservoir	New Site	4,000	Unknown	Unknown			
73	Idaho Springs Reservoir	Enlargement	950	Unknown	Unknown			
2	Julesburg Reservoir	Enlargement	21,900	Unknown	Unknown		Yes	
80	Julesburg Reservoir	Rehabilitation	5,700	Unknown	Unknown		Yes	
81	Klug Reservoir	Enlargement		Unknown	Unknown		Yes	
53	Left Hand Valley Reservoir	Enlargement	3,000	Unknown	Unknown			>5 residences impacted
82	Little Kammerzell Reservoir	Enlargement	6,964	Unknown	Unknown			
83	Lower Latham Reservoir	Enlargement		Unknown	Unknown			
70	Marshall Lake	Enlargement	15,200	Unknown	Unknown			
60	McIntosh Lake	Enlargement	1,500	Unknown	Unknown			Significant impact on existing residences

Table 3. Potential Surface Storage Sites in the South Platte Basin

Site ID	Site Name	Category	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
51	Milton Reservoir	Enlargement	72,000	Unknown	Unknown			
84	Mose Davis Reservoir	Enlargement	3,600	Unknown	Unknown			
24	North Poudre Reservoir Number 5 and 6	Enlargement	48,470	Unknown	Unknown			>5 residences impacted
44	Pinewood Springs Reservoir	Enlargement	2,740	Unknown	Unknown			
1	Prewitt Reservoir	Rehabilitation	4,634	Yes	Unknown		Yes	Info updated on 2/9/17 based on email conversation with Jim Yahn (jim@northsterling.org)
58	Ralph Price/Button Rock Reservoir	Enlargement	12,500	Unknown	Unknown			
74	Ralston Reservoir	Enlargement	4,800	Unknown	Unknown			
10	Riverside Reservoir	Rehabilitation	2,500	Unknown	Unknown		Yes	
28	Seaman Reservoir	Enlargement	38,000	Unknown	Unknown	Yes		Subject of current EIS by City of Greeley. Possibility for enlargement of 120,000 ac-ft, but would require new dam at that size
69	Silver Lake	Enlargement	5,000	Unknown	Unknown			
85	Spomer Reservoir	Enlargement	5,000	Unknown	Unknown			
57	Terry Lake (Pleasant Valley)	Enlargement	4,000	Unknown	Unknown			>5 residences impacted
86	Thomas Reservoir	Enlargement	10,200	Unknown	Unknown			
21	Trap Lake	Enlargement	5,600	Unknown	Unknown			
5	Wildcat Reservoir	New Site	60,000	Unknown	Unknown		Yes	
11	Willow Creek Reservoir	Enlargement	32,000	Unknown	Unknown		Yes	
Primary Source: Northern Integrated Supply Project Phase II Alternative Evaluation								
61	Antelope Park	New Site	7,000	Unknown	Unknown			

Table 3. Potential Surface Storage Sites in the South Platte Basin

Site ID	Site Name	Category	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
48	Berts Corner	New Site	10,000	Unknown	Unknown			
41	Black Hollow Reservoir	New Site	10,700	Unknown	Unknown			
31	Box Elder	New Site	20,300	Unknown	Unknown			
72	Broomfield	New Site	21,900	Unknown	Unknown			Designed by City of Broomfield
66	Buckingham	New Site	35,000	Unknown	Unknown			
42	Cactus Hill	New Site	104,071	Unknown	Unknown			
32	Calloway Hill	New Site	63,000	Unknown	Unknown			
49	Chimney Hollow	New Site	110,000	No	Unknown			
18	Galeton Reservoir	New Site	80,000	No	No		Yes	Subject of current EIS by Northern Water
34	Glade East	New Site	303,000	No	Unknown			Subject of current EIS by Northern Water
33	Glade West	New Site	303,000	No	Unknown			Subject of current EIS by Northern Water
36	Grey Mountain	New Site	204,000	Unknown	Unknown			
9	Hardin Reservoir	New Site	400,000	Unknown	Unknown		Yes	
12	Horse Creek Reservoir	Enlargement	60,000	Unknown	Unknown		Yes	
63	Little Narrows	New Site	23,000	Unknown	Unknown			
13	Lone Tree Creek	New Site	14,000	Unknown	Unknown			
64	Lykins Gulch	New Site	20,000	Unknown	Unknown			
17	Point of Rocks Reservoir	New Site	224,000	Unknown	Unknown		Yes	
35	Portal	New Site	310,000	Unknown	Unknown			
37	Poudre	New Site	143,000	Unknown	Unknown			
30	Rawhide Creek	New Site	30,300	Unknown	Unknown			

Table 3. Potential Surface Storage Sites in the South Platte Basin

Site ID	Site Name	Category	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
29	Rawhide North	New Site	140,000	Unknown	Unknown			
39	Rockwell	New Site	39,000	Unknown	Unknown			
16	Sandborn Reservoir	New Site	224,000	Unknown	Unknown		Yes	
62	Smithy Mountain	Enlargement	73,800	Unknown	Unknown			
6	South Platte (Narrows) Reservoir	New Site	1,960,000	Unknown	Unknown		Yes	
14	Spring Creek	New Site	27,500	Unknown	Unknown			
65	Table Mountain	New Site	5,000	Unknown	Unknown			
38	Trailhead	New Site	24,200	Unknown	Unknown			
15	Weld	New Site	1,962,000	Unknown	Unknown		Yes	
Primary Source: Northern Integrated Supply Project Technical Memorandum 5E Upper Saint Vrain Yield Analysis								
244	Coffintop Reservoir	New Site	115,900	Unknown	Unknown			
Primary Source: Ovid Reservoir and Dam Preliminary Design Report								
186	Ovid Reservoir	New Site	7,700	Unknown	Unknown		Yes	Can be built at 11,100 ac-ft capacity with a ring dike and excavation
Primary Source: Pawnee Creek Flood Control Project - Phase 1 Project Scoping Report								
202	P3	New Site	50,700	Unknown	Unknown		Yes	
204	P6	New Site	10,900	Unknown	Unknown		Yes	
205	P7	New Site	15,400	Unknown	Unknown		Yes	
203	W-NP2	New Site	24,400	Unknown	Unknown		Yes	
Primary Source: Preliminary Conceptual Plan for Proposed Pawnee Pass Dam and Reservoir in Logan County Colorado								
200	Pawnee Pass Dam	New Site		Unknown	Unknown		Yes	

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Table 3. Potential Surface Storage Sites in the South Platte Basin

Site ID	Site Name	Category	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
Primary Source: South Wiggins Recharge Project								
111	McCarthy Reservoir	Enlargement	10,000	Unknown	Unknown		Yes	

Table 4. Potential Aquifer Storage Sites in the South Platte Basin

Site ID	Site Name	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
Primary Source: 2015 South Platte Basin Surface Water Availability Analysis - Appendix G							
131	ASR Future Storage		Unknown	Unknown	Yes		
132	ASR Pilot Phase Storage		Unknown	Unknown	Yes		
Primary Source: Colorado Water Conservation Board SB-193 Underground Water Storage Study							
176	Arapahoe Confined - East	690,000	Unknown	Unknown		Yes	
150	Arapahoe Confined - Northwest	511,000	Unknown	Unknown			
152	Arapahoe Confined - Southwest	204,000	Unknown	Unknown			
177	Arapahoe Unconfined - East	324,000	Unknown	Unknown		Yes	
153	Arapahoe Unconfined - West	324,000	Unknown	Unknown			
163	Badger/Beaver Creek	311,000	Unknown	Unknown		Yes	
157	Cache la Poudre River Basin	291,000	Unknown	Unknown			
171	Dawson Unconfined - East	520,000	Unknown	Unknown		Yes	
149	Dawson Unconfined - West	1,169,000	Unknown	Unknown			
173	Denver Confined - East	60,000	Unknown	Unknown			
172	Denver Confined - West	87,000	Unknown	Unknown		Yes	
175	Denver Unconfined - East	770,000	Unknown	Unknown		Yes	
174	Denver Unconfined - West	387,000	Unknown	Unknown			
179	Laramie-Fox Hills Confined - East	1,059,000	Unknown	Unknown		Yes	
178	Laramie-Fox Hills Confined - West	900,000	Unknown	Unknown		Yes	
181	Laramie-Fox Hills Unconfined - East	85,000	Unknown	Unknown		Yes	
180	Laramie-Fox Hills Unconfined - West	122,000	Unknown	Unknown			

Table 4. Potential Aquifer Storage Sites in the South Platte Basin

Site ID	Site Name	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
143	Lower Beebe Draw/ Box Elder Creek	61,000	Unknown	Unknown			
162	Lower Bijou Creek	1,067,000	Unknown	Unknown		Yes	
141	Lower Kiowa Creek	806,000	Unknown	Unknown		Yes	
139	Lower Lost Creek	157,000	Unknown	Unknown		Yes	
151	Ogallala - North	89,412,000	Unknown	Unknown			
165	South Platte River - Balzac to State Line	890,000	Unknown	Unknown		Yes	
155	South Platte River - Denver Metro	353,000	Unknown	Unknown			
142	South Platte River - Fort Morgan Area	968,000	Unknown	Unknown		Yes	
164	South Platte River - Fort Morgan to Balzac	890,000	Unknown	Unknown		Yes	
159	South Platte River - Greeley to Fort Morgan	94,000	Unknown	Unknown		Yes	
156	South Platte River - Metro to Greeley	169,000	Unknown	Unknown			
166	South Platte River - South Park	899,000	Unknown	Unknown			
158	Upper Beebe Draw/ Box Elder Creek	268,000	Unknown	Unknown		Yes	
161	Upper Bijou Creek	466,000	Unknown	Unknown			
160	Upper Kiowa Creek	234,000	Unknown	Unknown		Yes	
140	Upper Lost Creek	1,260,000	Unknown	Unknown		Yes	
Primary Source: SPSS Project - CCWCD Interview Notes							
207	New Aquifer Storage Near Orchard Recharge Project		Yes	Unknown		Yes	Recharge project described with 100 cfs diversion from the South Platte River, with potential for aquifer storage partnerships

Table 4. Potential Aquifer Storage Sites in the South Platte Basin

Site ID	Site Name	Additional Storage (ac-ft)	Potential for Consumptive Partnerships	Potential for Non-Consumptive Partnerships	IPP	In Study Area	Notes
Primary Source: 2015 South Platte Basin Implementation Plan							
245	Bijou/Empire System ASR		Unknown	Unknown		Yes	
Primary Source: CDSS Reservoirs GIS Shapefile, Division 1							
290	Aurora Underground Reservoir B	920	Unknown	Unknown			
465	West Wabash Underground Storage Structure	110	Unknown	Unknown			
Primary Source: South Wiggins Recharge Project							
516	South Wiggins Recharge Project	24,000	Unknown	Unknown		Yes	

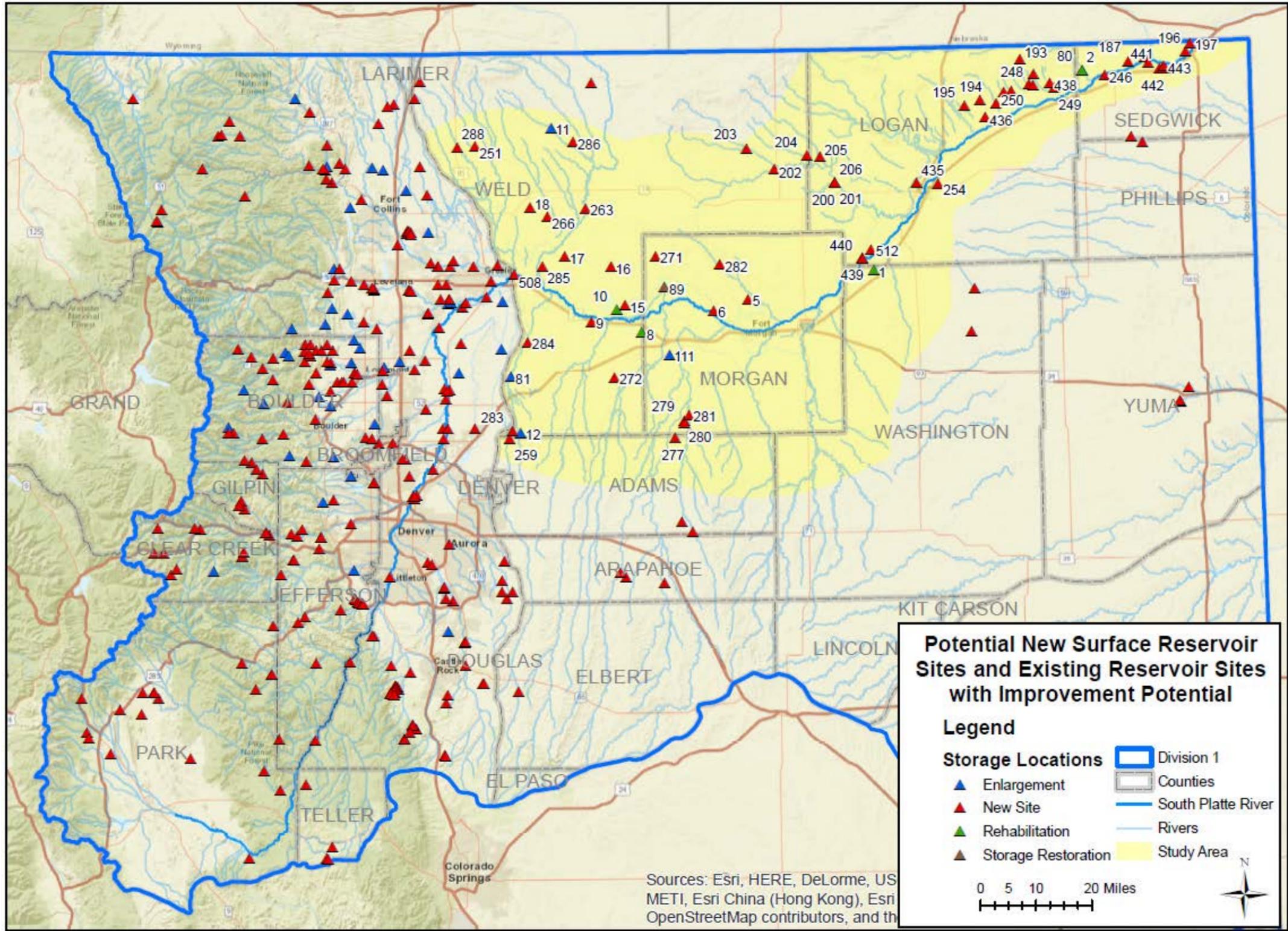


Figure 1. Cataloged Sites Where New Surface Storage Could Be Developed in Division 1

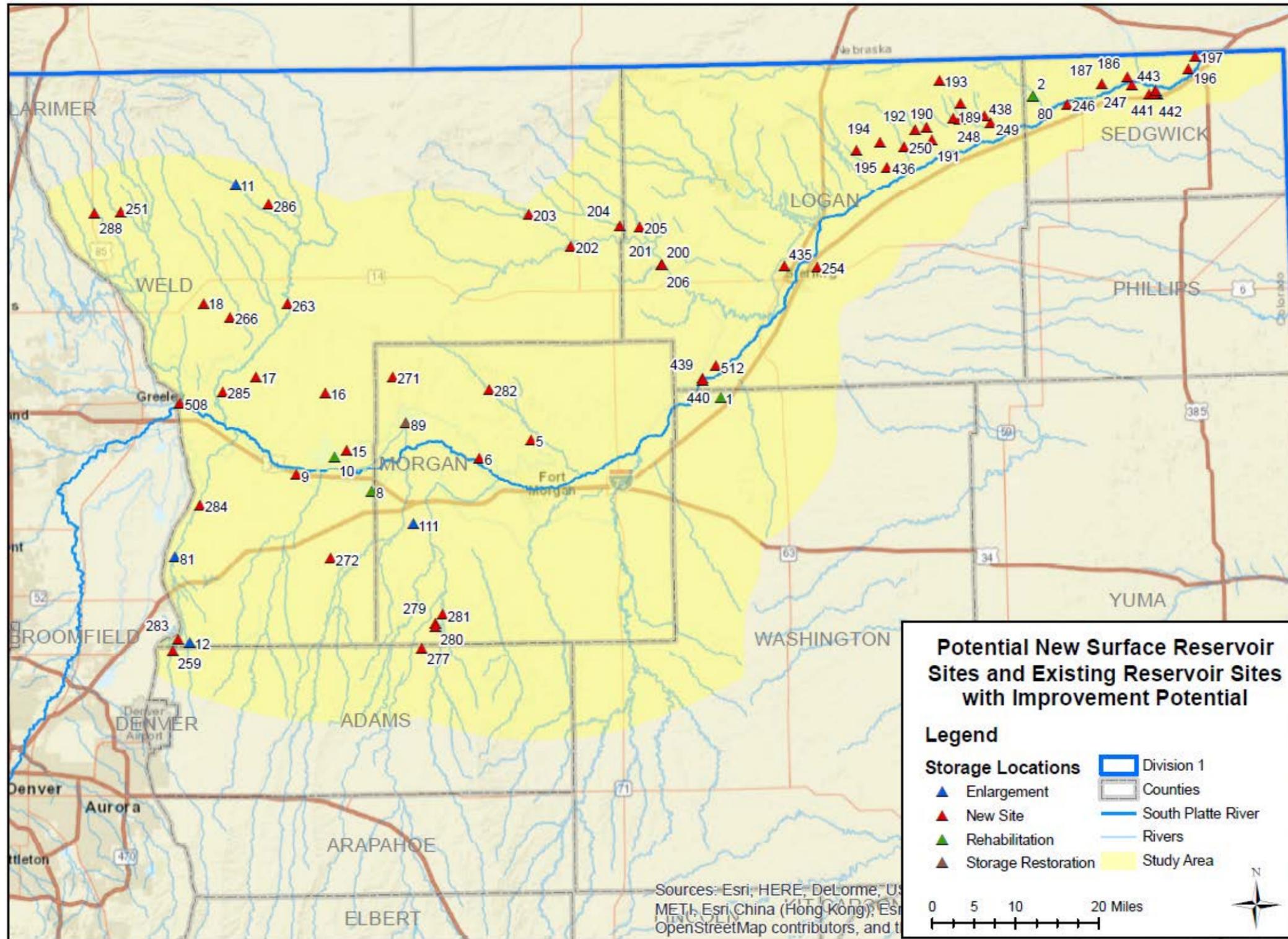


Figure 2. Cataloged Sites Where New Surface Storage Could be Developed in the Study Area

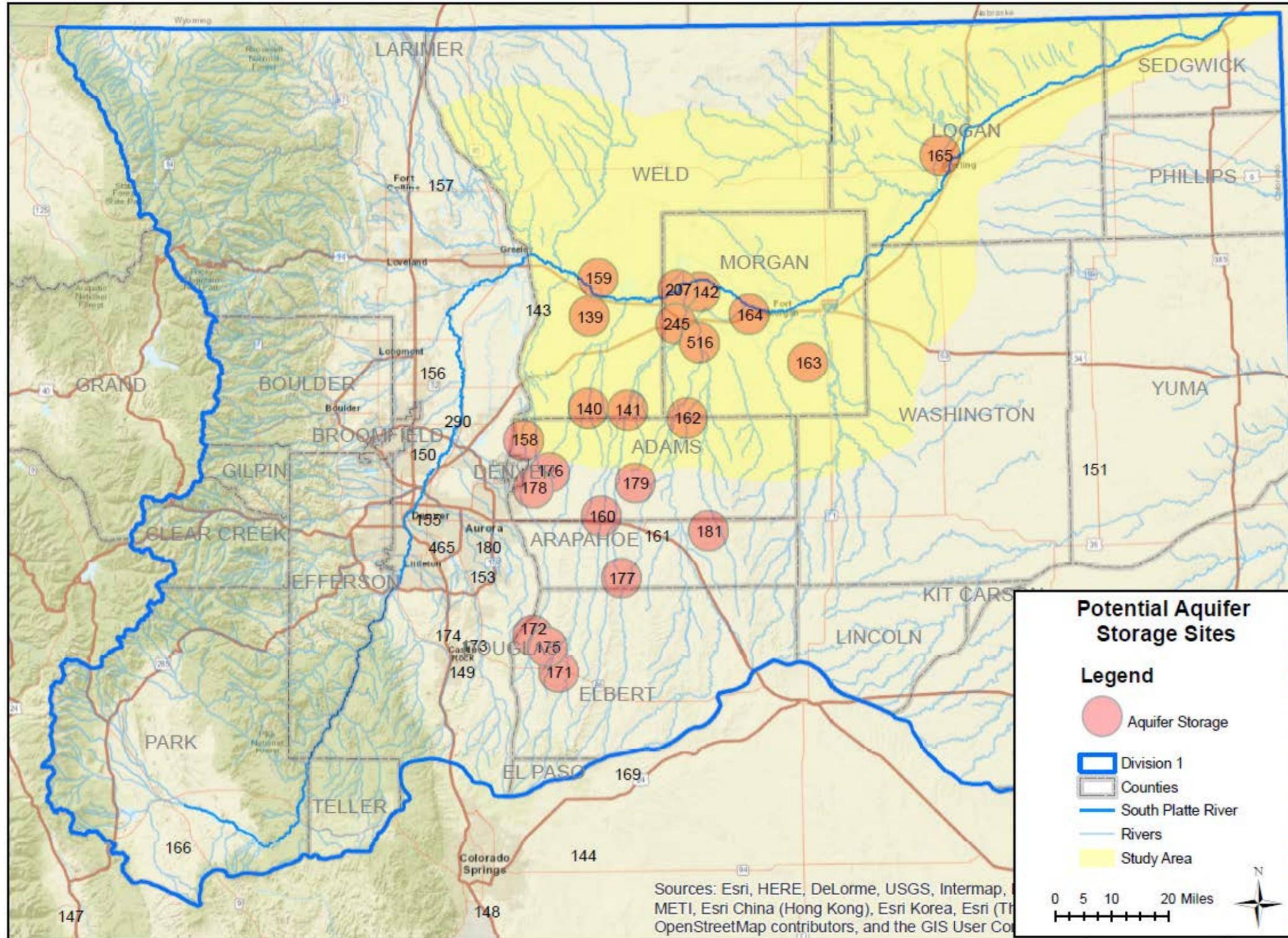


Figure 3. Cataloged Aquifer Storage Sites in Division 1

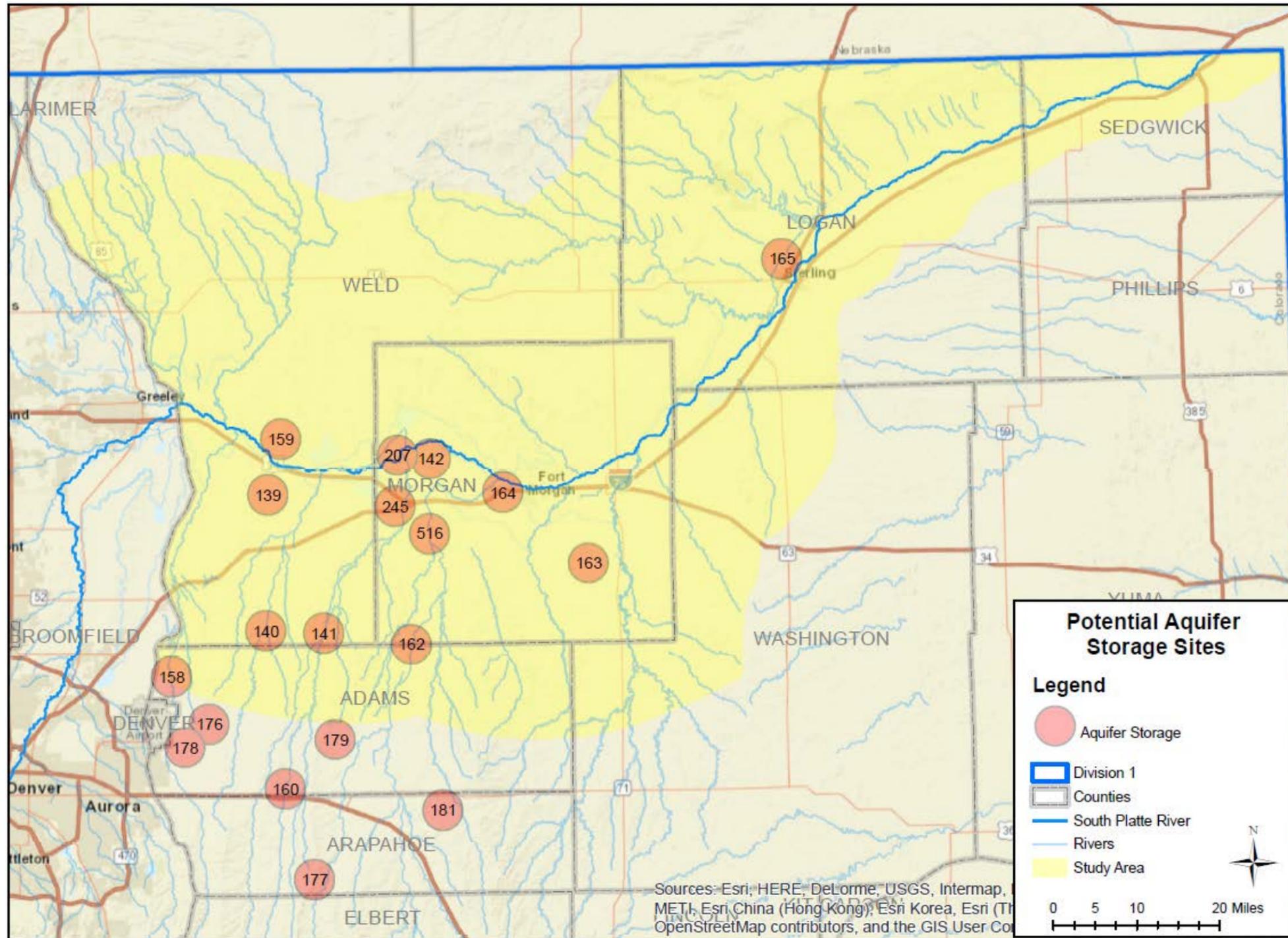


Figure 4. Cataloged Aquifer Storage Sites in or Near the Study Area

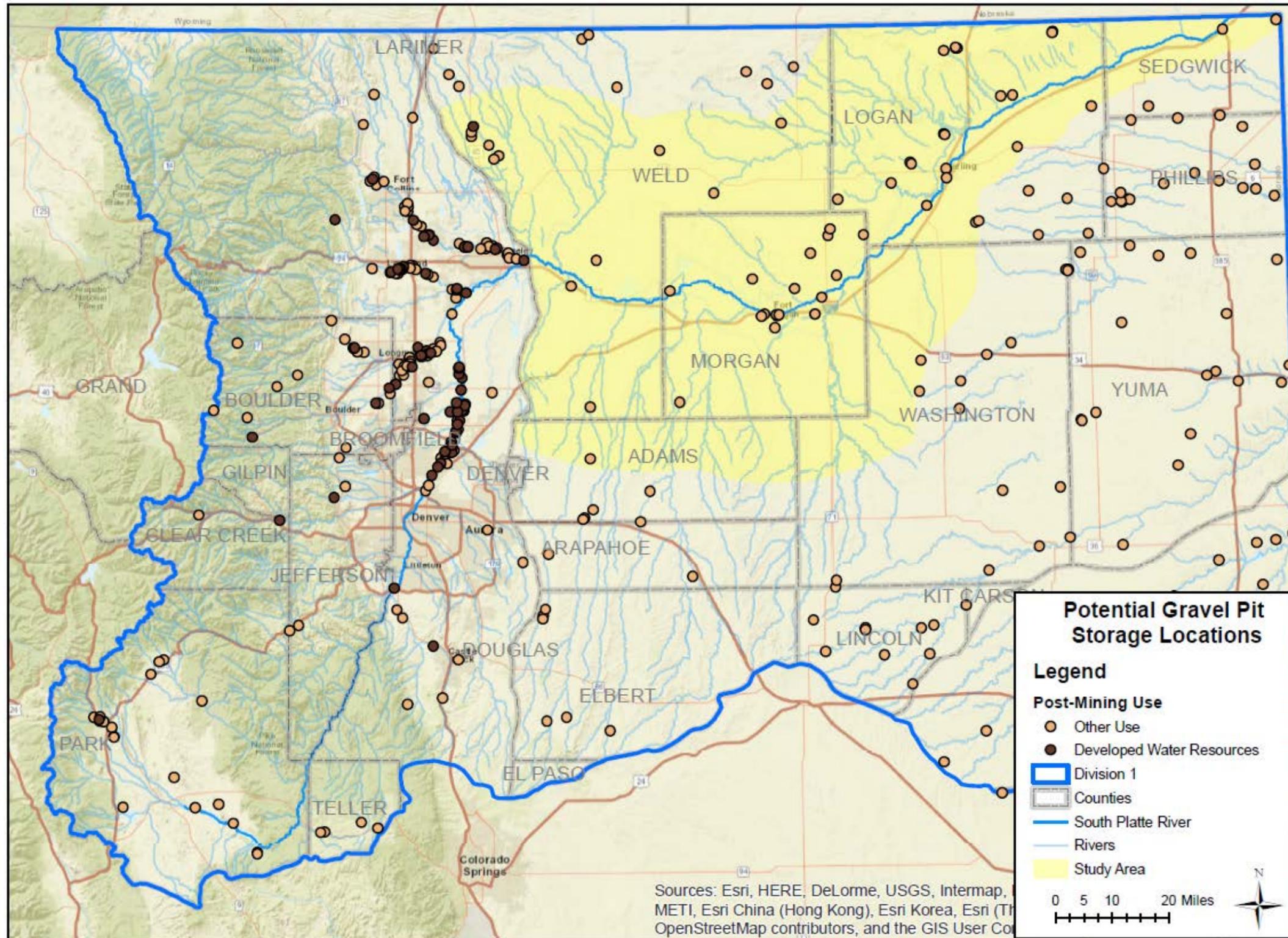


Figure 5. Potential Gravel Pit Storage Sites in Division 1

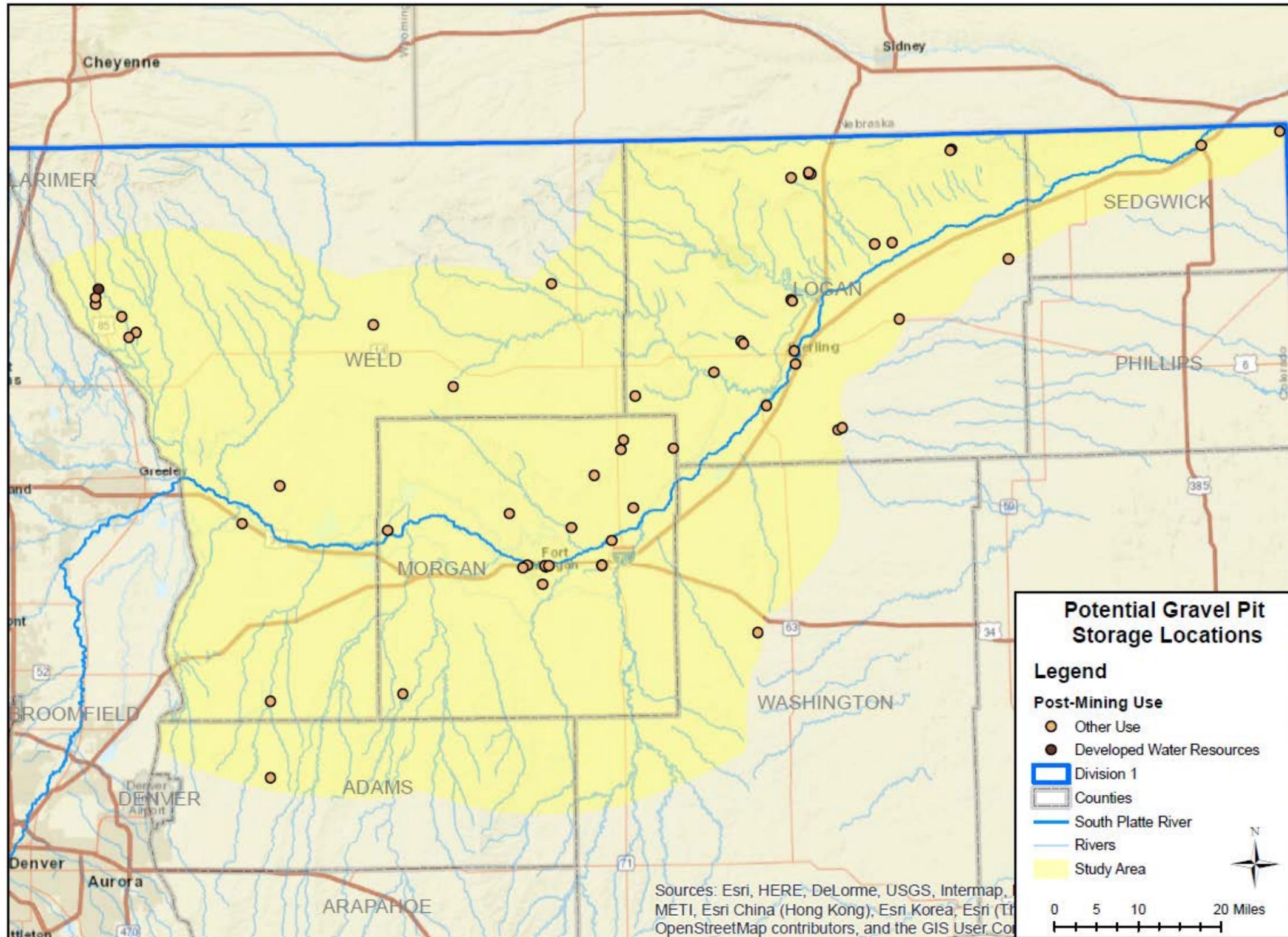


Figure 6. Potential Gravel Pit Storage Sites in the Study Area

**APPENDIX C – LEGAL AND REGULATORY
REVIEW TM**

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SPSS Final Memorandum

To: Chip Paulson, Enrique Triana, and Joshua Cowden - Stantec
From: Leonard Rice Engineers
Date: November 30, 2017
Subject: Literature Review for South Platte Storage Study

Leonard Rice Engineers, Inc. (“LRE”), has performed a high level review of the legal framework that may impact the South Platte Storage Study (“SPSS”) being performed in connection with HB-1256 2016. According to HB-1256-2016, the legislature is interested in computing the amount of water that could have been stored in the South Platte Basin in Colorado but rather went down stream to Nebraska. This interest appears to be focused on storm flows, excess runoff, and other water events wherein current water rights are being fulfilled and excess water is available that can then be stored for future use (hereinafter the “Excess Water”). Under LRE’s final Scope of Work we were tasked to review and provide a written description of applicable laws and agreements that will affect the estimation of storable water in the South Platte, including the 1928 South Platte River Compact required flows, constraints associated with Platte River Recovery Implementation Program (PRRIP), Tamarack recharge credits, augmentation plans, groundwater pumping administration, and the Rules and Regulations for the Management and Control of Designated Ground Water.

The following memorandum summarizes the major federal, state, and local legal and administrative factors that impact the ability to divert and store excess water and therefore, should be considered in the planning and permitting of any future water storage project within the South Platte drainage. In addition to the factors summarized below, there are additional federal, state, and local legal and administrative factors that may apply to the environmental, land use, construction, and operation components of a future water storage project. These additional legal and administrative factors will be considered in the later phases of the project.

Federal

Depending on the type of storage project identified, the following Federal factors may influence the ability to divert and store excess water.

1. South Platte River Compact (C.R.S. § 37-65-101)
2. Endangered Species Act – Section 7 Consultation (ESA Section 7))
3. Platte River Recovery Implementation Program (PRRIP)

South Platte River Compact (C.R.S. § 37-65-101)

- a. Between Nebraska and Colorado
- b. Signed April 23, 1923
- c. Within Colorado there are two sections of the South Platte River
 - i. Upper Section west of the intersection of the river and the Washington County Line

- ii. Lower Section which is east of the intersection of the river and the Washington County Line downstream to the intersection of the river and the State line.
- d. Interstate Station is a gauging station near Julesburg Colorado above the Western Irrigation District of Nebraska canal diversion.
 - i. Interstate Station is the gauging station to determine compliance with the compact (daily mean flow of 120 cfs between April 1 and October 15)¹
- e. Colorado shall not permit diversions in the Lower Section between April 1 and October 15 to supply Colorado appropriators with priority subsequent to June 14, 1897 if said diversions will diminish flow at the Interstate Station below the daily mean of 120 cfs.
- f. Colorado may use all the waters of the river flowing within Colorado during October 15 and April 1 of the next year²
- g. Colorado shall have the right to all diversions in the Upper Section.

Between April 1 and October 15 the water right owners in Water District 64 collectively strive to keep the daily mean flow at the Interstate Station at or above 120 cfs thereby preventing the June 14, 1897 Compact call. If the Compact call is in effect, water rights junior to June 14, 1897 are not diverting in the Lower Section, and augmentation plans are being operated in accordance with decrees, Colorado is considered acting in compliance with the terms and condition of the South Platte Compact³. When Colorado is active in compliance³ with the South Platte Compact, and flow at the Interstate Station is still less than 120 cfs, Colorado is not obligated to deliver water to the South Platte River.

Under the South Platte River Compact there is the opportunity to capture and use of the 35,000 acre-feet of water that may be available during October 15 and April 1 of the next year under the South Platte River Compact. Under the South Platte River Compact Article VI, Paragraph 2(a), Colorado has reserved the right to store, use and to have in storage in readiness for use on and after April 1 each year an aggregate of 35,000 acre-feet of water to be diverted from the river in the Lower Section between October 15 and April 1. Further discussion needs to occur as to whether (i) the state of Colorado has ever diverted South Platte River water under this provision of the compact, (ii) the PRRIP is affected by this diversion, and (iii) if able to be diverted where would/could the water be stored and how would/could this water be used in the future.

Endangered Species Act – Section 7 Consultation (ESA Section 7) and Platte River Recovery Implementation Program (“PRRIP”)

If an action or project, that has a federal nexus, is likely to adversely affect any listed endangered or threatened species, a Section 7 consultation under the Endangered Species Act (ESA) will be required. Since 1978, the U.S. Fish and Wildlife Service (the “Service”) has consistently found,

¹ This flow is subject to variable climatic conditions and other conditions that may affect the daily flow in a minor way.

² The use of this water is subject to Article VI which allows Nebraska to divert 500 cfs through the Perkins County Canal during this time so long as water is available after Colorado meets all diversions in the Upper Section, meets all diversions in the Lower Section with a priority date before December 17, 1921, and satisfies the removal of 35, 000 acre-feet of water to storage.

³ Per conversation with Water Division 1 Engineer Dave Nettles.

through formal ESA Section 7 consultations with Federal agencies, that federal actions resulting in depletions to flows in the Platte River system are likely to jeopardize the continued existence of one or more federally-listed threatened or endangered species and adversely modify critical habitat.⁴

In 2006, a landmark agreement was signed between the governors of Colorado, Nebraska, and Wyoming and the U.S. Secretary of the Interior (the “Interior”) to implement a basin-wide Platte River Recovery Implementation Program (the “PRRIP Program”). The purpose of the PRRIP Program is to provide streamlined ESA compliance for water users in the Platte River basin. The PRRIP Program went into effect on January 1, 2007.

Colorado’s plan under the agreement and the PRRIP Program is to account for depletions within the South Platte drainage for water-related activities implemented prior to July 1, 1997 (Existing water related activities) and to identify mechanisms to allow the implementation of water-related activities after July 1, 1997 (New water-related projects). Colorado is meeting its obligations under the plan through re-regulating flows of water within the South Platte River west of the state line with Nebraska. This is done on the Tamarack Ranch and Pony Express State Wildlife Areas.⁵ The operator of the State Wildlife Areas is the Colorado Department of Wildlife, but through an MOU, the South Platte Water Related Activities Program, Inc. (“SPWRAP”) is responsible for the operational costs.

While compliance with the Program is the burden of the State of Colorado, the SPWRAP is the non-profit entity that assists the state in compliance with the Program. Under the Colorado plan, all existing water-related activities are covered including irrigation wells that were augmented prior to June 30, 1997. Moreover, new water-related activities will be covered by the plan so long as the new project is (i) operated on behalf of Colorado water users; (ii) does not involve a major on-stream reservoir (greater than 2,000 acre-feet⁶) located on the mainstem of the South Platte anywhere downstream of Denver; (iii) not a hydropower diversion/return project anywhere downstream of Denver; and (iv) within the average annual water supply of 98,010 acre-feet to serve Colorado’s population increase during February through July. Per the PRRIP Program definition of Major On-Stream Reservoirs, reservoirs, including gravel pit reservoirs, adjacent to the main stem of the South Platte River and reservoirs on tributaries to the South Platte River are not considered to be located on the “mainstem⁷.”

To be covered by the plan, the participant must comply with the SPWRAP’s member criteria, which includes applying for and paying for corresponding assessments. Standardized reporting forms are available to help prospective members calculate corresponding assessments. These assessments reflect the costs of operating this non-profit corporation. SPWRAP’s first year of

⁴ Information review at www.platteriver.org.

⁵ See Colorado’s Initial Water Project (Tamarack I), December 7, 2005, Colorado’s Plan for Future Depletions (Tamarack II), October 24, 2006, Updated December 1, 2015, Memorandum of Understanding (MOU) for the Planning, Development and Operation of the Managed Groundwater Recharge Facilities on the State Wildlife Areas in the Lower South Platte River (March 19, 2009).

⁶ PRRIP Attachment 5, Section 9, Colorado’s Plan for Future Depletions. October 24, 2006, Updated December 1, 2015.

⁷ Id.

operation was 2007. Project proponents can become members immediately, or at a future date. However, entities that become members in later years will be assessed at a rate that addresses SPWRAP costs from Year 1.⁸

Once an entity becomes a member of SPWRAP, Colorado’s plan will cover a project that involves a Federal nexus. The entity (the member of SPWRAP) will work with the federal agency(s) involved and file a request for formal Section 7 consultation. This process will be streamlined and the FWS will issue a Tiered Biological Opinion authorizing the project if the aforementioned criteria are met. If an entity is not covered by SPWRAP (the aforementioned criteria are not met) then the entity must still comply with Section 7 of the ESA and develop a stand-alone biological opinion addressing the incremental effects associated with the individual project. This can be laborious, time consuming, and very expensive.

Item for Further Consideration: It is unclear whether or not projects within the designated basins of the South Platte River drainage that have a federal nexus are included under the PRRIP. If designated basins are excluded from the South Platte River drainage and therefore excluded under the PRRIP, compliance with Section 7 of the Endangered Species Act may not be possible under the SPWRAP framework.

State

In addition to meeting the federal issues outlined above, the following state laws and guidelines will need to be complied with for new projects within the South Platte River basin.

1. Water Right Determination and Administration Act (C.R.S. § 37-92)
2. Reservoirs (C.R.S. § 37-87)
3. Colorado Groundwater Management Act (C.R.S. § 37-90)
4. Rules and Regulations for the Management and Control of Designated Ground Water (2 C.C.R. 410-1.)
5. Proposed changes to Designated Basin Rules 5.6 and 5.8. (12/23/2016 Draft)
6. Denver Basin Artificial Recharge Extraction Rules (2 C.C.R. 402-11)
 - a. Denver Basin Rules (2 C.C.R. 402-6)
 - b. Statewide Nontributary Ground Water Rules (2 C.C.R. 402-7)
7. Supreme Court Rulings – *Bd. Of County Comm’rs v. Park County Sportsman’s Ranch , LLP*, 45 P.3d 693 (Colo. 2002)[Listing the conditions that the owner of an underground storage project would have to prove to establish a right in water court]
8. Operation and Accounting for Porosity Storage Reservoirs – State Engineer Guideline found at <http://water.state.co.us/SurfaceWater/SWRights/Pages/default.aspx>
9. Administrative Statement Regarding the Management of Storm Water Detention Facilities and Post-Wildland Fire Facilities in Colorado February 11, 2016. Found at <http://water.state.co.us/DWRIPub/Documents/DWR%20Storm%20Water%20Statement.pdf>

⁸ The basis for annual assessments, and corresponding reporting forms are available via the SPWRAP Website (www.spwrap.org).

The following section highlights key elements of the above mentioned State laws and guidelines.

Water Right Determination and Administration Act (C.R.S. § 37-92)

Under the State of Colorado Constitution of 1876, Article XVI outlines that water within the borders of the state is the property of the state to be used by the citizens of the state. Moreover, the Constitution provides the backbone of the prior appropriation system (first in time, first in right). Presently, the provisions of the Constitution are codified in the Water Right Determination and Administration Act (C.R.S. § 37-92), which was passed by the Colorado Legislature in 1969. Under this legislation water courts and water referees were established and their functions defined. It is the water courts that adjudicate new water rights (including storage rights) and approve permanent changes to water rights.⁹ Furthermore, duties of the State Engineer as administrator of water within the state was clarified. This legislation also set forth augmentation plans to replace out of priority depletions (protecting senior rights from junior diversions), the relationship between groundwater and surface water in the state, key definitions regarding water administration, and the establishment of water divisions and division engineers.¹⁰

With respect to “storage,” the Water Right Determination and Administration Act defines “storage” as “the impoundment, possession, and control of water by means of a dam.”¹¹ A water storage right is almost always confirmed by a court decree. The basic elements of a water storage right include:

- 1) Identification of a structure where the water is stored;
- 2) An annual amount of storage (normally expressed in acre-feet), which, in modern decrees, includes active and dead storage, exposed surface acreage and fill rate;
- 3) A legal description of the axis of the dam;
- 4) Identification of the point of diversion from the stream or tributary from which the storage water is diverted, including the means of conveyance by ditch or pipeline if this is an off-channel reservoir;
- 5) A priority date for purposes of administration; and
- 6) Often, there are limitations on type and place of use; such as a description of the lands or a location where the stored water may be used after impoundment.¹²

A water storage right, like any other water right, can be changed, but the applicant risks re-quantification of the water right based upon historical and legal usage limitations applied after the fact.¹³

Underground storage outside the boundary of a designated ground water basin is also recognized under Colorado law if such water is placed in an aquifer “by other than natural means” by an

⁹ The State Engineer has certain powers to issue Substitute Water Supply Plans (C.R.S. § 37-92-308),

¹⁰ Section 37-92 is a complex statute that covers more than the issues listed. This literature review is intended to outline the applicable laws, rules and policy that would affect new storage in the South Platte. Additional legal and technical analysis will be required.

¹¹ C.R.S. § 37-92-103(10.8).

¹² *Id.*

¹³ *Id.*

application with a right.¹⁴ This definition was reviewed by the Sportsman’s Ranch II Supreme Court to determine what conditions an owner of an underground storage project would have to prove to establish a storage right. As the Court noted, an owner must:

- 1) Capture, possess, and control the water it intends to put into the aquifer;
- 2) Not injure other water use rights, either surface or underground, by appropriating the water for recharge;
- 3) Not injure water use rights, either surface or underground, as a result of recharging the aquifer and storing water in it;
- 4) Show that the aquifer is capable of accommodating the stored water without injuring other water use rights;
- 5) Show that the storage will not tortiously interfere with overlying landowners’ use and enjoyment of their property;
- 6) Not physically invade the property of another by activities such as directional drilling, or occupancy by recharge structures or extraction wells, without proceeding under the procedures for eminent domain;
- 7) Have the intent and ability to recapture and use the stored water; and
- 8) Have an accurate means for measuring and accounting for the water stored and extracted from storage in the aquifer.¹⁵

C.R.S. Section 37-87, Reservoirs

C.R.S. § 37-87 addresses the construction of reservoirs, inspections of reservoirs, and enforcement for violations. These statutory obligations generally apply after the planning phase of a reservoir project. Therefore, a study to determine the ability to divert and store excess water would not be impacted by these obligations.

Underground aquifers are not considered reservoirs within the meaning of C.R.S. § 37-87 except to the extent such aquifers are filled by other than natural means with water diverted under a conditional or decreed right. As such, aspects of C.R.S. § 37-87 could apply to the construction and operation of alternative storage mechanisms that utilize underground aquifers.

Colorado Groundwater Management Act (C.R.S. § 37-90), Rules and Regulations for the Management and Control of Designated Ground Water (2 C.C.R. 410-1), and Proposed Changes to Designated Basin Rules 5.6 and 5.8

The Colorado Groundwater Management Act (“GMA”) created designated ground water, the Colorado Ground Water Commission (“Commission”), ground water management districts for local control and management of designated ground water, and a statutory scheme to allocate and administer designated ground water.

Under Colorado law there are four (4) types of groundwater; tributary groundwater, nontributary groundwater, Denver Basin groundwater, and designated groundwater.

¹⁴ C.R.S. § 37-92-103(10.8).

¹⁵ *Bd. of County Comm’rs v. Park County Sportsman’s Ranch, LLP*, 45 P.3d 693, 705, n. 19 (Colo. 2002) (*Sportsman’s Ranch II*)

Designated ground water is a separate and unique resource that has been created by the General Assembly.¹⁶ Designated ground water is not considered “nontributary” ground water, as is commonly misunderstood.¹⁷ The GMA defines designated ground water as:

[g]round water which in its natural course would not be available to and required for the fulfillment of decreed surface rights, or ground water in areas not adjacent to a continuously flowing natural stream wherein ground water withdrawals have constituted the principal water usage for at least fifteen years preceding the date of the first hearing on the proposed designation of the basin, and which in both cases is within the geographic boundaries of a designated ground water basin.

“Designated ground water” shall not include any ground water within the Dawson-Arkose, Denver, Arapahoe, or Laramie-Fox Hills formation located outside the boundaries of any designated ground water basin that was in existence on January 1, 1983.¹⁸

The statutes, rules, and regulations of the commission and the local district govern the allocation and administration of designated ground water. Once the Commission designates a basin under its statutory authority, the ground water within that basin typically all becomes designated ground water.¹⁹ For example, within the South Platte drainage designated basins of interest in this phase of the SPSS project (i.e., Lost Creek, Kiowa-Bijou, Upper Crow Creek, and Camp Creek), numerous ground water aquifers exist below each designated basin boundary. While all of these different aquifers are different sources of ground water, they are all collectively referred to as designated ground water and are regulated under the GMA and the Commission Rules. This concept is important because within its statutory authority, the Commission can define how each specific source should be allocated and administered.²⁰

Under the current Rules and Regulations for Management and Control of Designated Ground Water, Aquifer Storage and Recovery (ASR) is not expressly allowed. Rule 5.8 currently allows for the practice of artificial recharge in the designated basins, however, the rule is general in nature and makes the application unclear. The Commission is currently evaluating whether to remove Rule 5.8 and expand Rule 5.6, the Replacement Plan rule, to allow for ASR. With the proposed rule changes, the Commission is proposing that ASR within the designated basins would operate as a

¹⁶ See *Goss*, 993 P.2d at 1182-83.

¹⁷ While the Denver Basin aquifers encompass both designated and non-designated ground water, Denver Basin ground water within the boundaries of a designated basin is still designated ground water and should not be confused with nontributary ground water, which, pursuant to a 2000 Colorado Supreme Court decision, is a separate category of ground water. See *Upper Black Squirrel Creek Groundwater Mgmt. Dist. v. Goss*, 993 P.2d 1177, 1182 (Colo. 2000).

¹⁸ C.R.S. § 37-90-103(6).

¹⁹ See C.R.S. § 37-90-106. The designation of a basin is premised on a designated basin geological and hydrogeological report. This report would be the basis of designating the basin, and in this author’s experience, all the aquifers within each designated basin to date are considered designated ground water.

²⁰ For a detailed analysis of designated ground water please refer to William H. Fronczak, “Designated Groundwater: Colorado’s Unique Way of Administering its Underground Resources,” 7 *U. Denv. Water L. Rev.* 111 (Fall 2004) and *Colorado Water Law Benchmark*, Second Ed. (Carrie I. Ciliberto and Timothy J. Flanagan eds., CLE in Colo., Inc. 2016) Chap. 8 Designated Basins.

replacement plan subject to the general replacement plan criteria and specific criteria for alluvial, bedrock, and Denver Basin aquifers.

Water that is withdrawn and exported out of a designated basin as designated ground water is considered fully consumable and can be used and reused to extinction once exported. The current Rules and Regulations for Management and Control of Designated Ground Water are not explicit as to the nature of free river water that is diverted from the South Platte River and placed in the designated basin for later withdrawal and export.

Denver Basin Artificial Recharge Extraction Rules

In 1995 the State Engineer, pursuant to statutory authority, promulgated the Denver Basin Artificial Recharge Extraction Rules (2 C.C.R. 402-11). These rules work together with the Denver Basin Rule and the Statewide Non-Tributary Rules regarding the placement of water into and the extraction of such placed water out of unconfined and confined aquifers within the Denver Basin aquifers outside the boundaries of a designated basin. These rules do expressly allow for the practice of ASR within the Denver Basin. The Denver Basin and Statewide Non-Tributary Rules are referenced in the Denver Basin Artificial Recharge Extraction Rules because cylinders of appropriation, existing withdrawals, and new withdrawals of naturally occurring groundwater out of the Denver Basin may occur as a part of or in addition to the artificial recharge.

State Engineer Administrative Guidelines and Statements

Two guidelines were reviewed that would have a potential impact on storage either above or below ground within the South Platte Drainage. The first is a State Engineer Guideline regarding the Operation and Accounting for Porosity Storage Reservoirs and the second is an Administrative Statement Regarding the Management of Storm Water Detention Facilities and Post-Wildland Fire Facilities in Colorado February 11, 2016.

Porosity Storage Reservoirs are a defined term for vessels that store water underground in shallow alluvial deposits that are intentionally isolated from the surrounding alluvial deposits. The preferred method of containment is with the use of slurry walls (i.e. City of Aurora Prairie Waters Project). The difference with porosity storage, compared to gravel pit storage, is that the material within the slurry walls is not mined and the natural alluvial deposit is used as the storage media. Benefits of porosity storage includes (i) elimination of evaporative losses associated with traditional storage reservoirs, (ii) use of the alluvial material as a filter media; (iii) minimal impact to overlying land; and (iv) isolation of the water stored from the surrounding aquifer and streams. Porosity Storage has been recognized by the State Engineer and allows complete use of the stored water without impacting the surrounding water systems or natural habitats. The State has developed guidelines for the operation and accounting required for these vessels. These guidelines for operation and accounting would have minimal impact at the planning level of this study.

The State previously administered storm water detention facilities pursuant to the 2011 “Administrative Approach for Storm Water Management.” However, in 2015 the Colorado Legislature passed Senate Bill 15-212, which directs administrative requirements for storm water

management.²¹ Essentially this statute, as referenced and explained in the Administrative Statement Regarding the Management of Storm Water Detention Facilities and Post-Wildland Fire Facilities in Colorado, February 11, 2016 outlines the criteria that storm water detention facilities must meet to be exempt from administration under the Colorado water law. Since it is anticipated that the storage vessels contemplated under the SPSS would have to be administered under Colorado water law, these criteria most likely would not apply to a SPSS project.

Local

The local regulations and laws (besides land use which is beyond the scope of this literature review) that would impact the SPSS would be (i) the Designated Basin Ground Water District Rules for the Lost Creek Designated Basin and the Kiowa-Bijou Designated Basin; and (ii) 1041 regulations.

Lost Creek Designated Basin Rules

In addition to being controlled by the Rules and Regulations for Management and Control of Designated Ground Water, the use and management of designated groundwater within Lost Creek designated basin and Kiowa-Bijou designated basin is regulated by local regulations and laws specific to the basins.

The Regulations for the Use, Control and Conservation of Ground Water within the Lost Creek Ground Water Management District (“Lost Creek District”) were amended on March 28, 2013. These Regulations outline the Lost Creek Ground Water District Rules regarding issuance of new wells by the Commission, changes to existing wells, restrictions on replacement wells and exporting water outside the Lost Creek District, injection of water into the groundwater within the basin for recharge, and small capacity wells (less than 15 gallons per minute).

Of interest is Regulation 10 wherein the Lost Creek District outlines criteria for the “injection of water, gases, effluent, liquids or solid into any fresh water aquifer.” The Lost Creek District prohibits such activity “except for fresh water recharge purposes approved by the Board of Directors of the Lost Creek District.” The Lost Creek District requires that all such projects comply with the standards and procedures applicable to “Domestic Use-Quality” and “Agricultural Use-Quality” groundwater set forth in the then current Colorado Department of Public Health and Environment Water Quality Control Commission Regulation No. 41, “Basic Standards for Groundwater” (5 CCR 1002-41). The Lost Creek District also defines point or points of compliance for each recharge site or project as a monitoring well(s) in close proximity to the recharge site or project, as established by the district.

North Kiowa-Bijou Designated Basin Rules

The Regulations for the Use, Control and Conservation of Ground Water within the North Kiowa Bijou Management District (“Kiowa-Bijou District”) has similar regulations as to the Lost Creek District rules regarding issuance of new wells by the Commission, changes to existing wells,

²¹ C.R.S. § 37-92-602(8).

restrictions on replacement wells and exporting water outside the Kiowa-Bijou District. However, these regulations do not address injection for recharge or small capacity wells.

1041 Regulations

The Colorado General Assembly enacted measures to further define the authority of state and local governments in making planning decisions for matters of statewide interest in 1974. The creation of 1041 regulations by state and local governments was approved in HB 74-1041 and is found in C.R.S. § 24-65.1-101. The purpose of the Act is to describe and designate areas and activities which may be of state interest and to encourage local governments to establish criteria for the administration of these areas and activities. Activities of state interest, as defined by Colorado Statute, may include, and are not limited to:

- Site selection and construction of major new domestic water and sewage treatment systems and major extension of existing domestic water and sewage treatment systems;
- Site selection and construction of major facilities of a public utility;
- Efficient utilization of municipal and industrial water projects;

The 1041 permit application process is extensive and includes the submission of detailed specifications concerning the affected environments and impacts of the proposed development.

As of the date of this memo, the local governments located within the SPSS study area known to have 1041 regulations in place include Adams County, Larimer County, Morgan County, and Weld County. A state or local government may choose to adopt 1041 regulations and guidelines for administration of matters of state interest at any time.

APPENDIX D – HISTORICAL FLOW TM

NOTE: SOME OF THE INFORMATION IN THIS TM WAS CHANGED DURING
PREPARATION OF THE FINAL REPORT

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HB 1256 - South Platte Storage Study (SPSS)



TECHNICAL MEMORANDUM

To: Joe Frank, Andy Moore
Lower South Platte Water Conservancy
District, Colorado Water Conservation
Board

From: Chip Paulson, Samantha Mauzy
MWH Now Part of Stantec

Subject: **Summary of South Platte River
Historical Flow Leaving the State and
Storable Water**

Date: July 21, 2017

INTRODUCTION

HB 16-1256, which authorized the South Platte Storage Study (SPSS), included a requirement to determine historical flow that could have been captured and stored in the South Platte River at the state line. Specifically, the Bill states:

“The Board, in collaboration with the State Engineer, shall conduct or commission a hydrology study of the South Platte River Basin to estimate, for each of the previous twenty years, the volume of water that:

- i. Has been delivered to Nebraska in excess of the amount required to be delivered by the South Platte River Compact, Article 65 of this title; and
- ii. Could have otherwise been stored in the Lower South Platte River Basin.”

The South Platte Point Flow Model was used to complete those two tasks. The Point Flow Model was updated for this study to include a 20-year period of daily flow records from 1996 to 2015. Details of the SPSS hydrologic analysis are provided in the “South Platte River Hydrologic Analysis TM”.

FINDINGS

Flow records and Point Flow Model results were analyzed at the South Platte River at Julesburg stream gage near the Nebraska state line to estimate: (1) physical flow in the river; and (2) water that could have been legally stored subject to South Platte River Compact requirements (referred to herein as “storable flow”). Storable flow is the maximum potential water that could have been stored by a reservoir on the mainstem of the South Platte River. Storable flow in an off-channel reservoir that would depend on diversions and conveyance facilities similar to the current lower basin reservoirs and irrigation canals would be significantly less.

Figure 1 displays annual historical flow for the 20 years from 1996 to 2015 that was delivered to Nebraska. It shows the physical flow in the river (“Water Leaving Colorado”), and the water leaving the state that could have been stored or put to beneficial use in Colorado (“Water Delivered to Nebraska in Excess of the Compact”). Figure 1 shows that physical and storable flow vary significantly from year to year. Table 1 gives selected statistics for physical flow leaving the state and storable flow at the Julesburg gage for the 20-year period from 1996 to 2015.

Table 1. Historical Annual Flow for 1996-2015 at Nebraska State Line

Statistic	Physical Water Leaving Colorado (Julesburg gage)	Water Delivered to Nebraska in Excess of the Compact (Julesburg gage)
Annual Average (ac-ft/yr)	436,000	397,000
Annual Median (ac-ft/yr)	331,000	293,000
Minimum Year (ac-ft/yr)	29,000	10,000
Maximum Year (ac-ft/yr)	1,957,000	1,904,000
Total for 20-yr Period 1996-2015 (ac-ft)	8,728,000	7,939,000

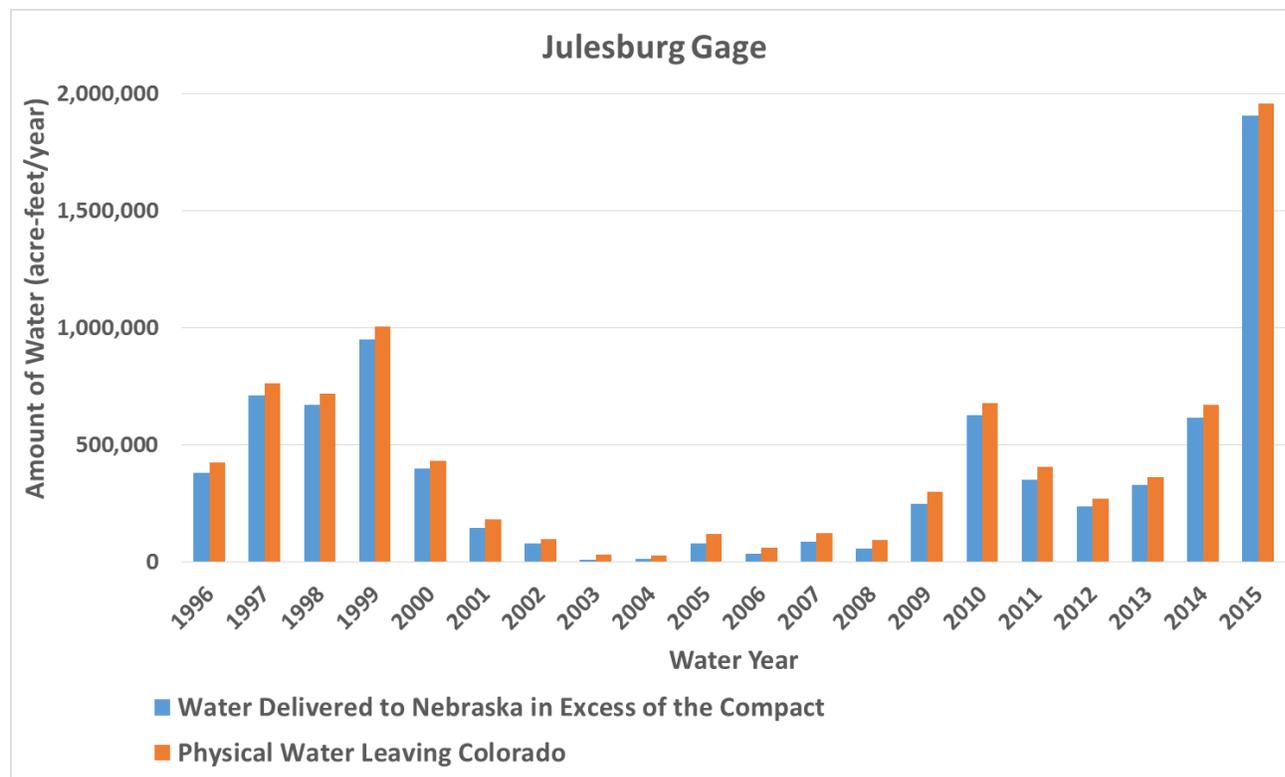


Figure 1. South Platte River Water Delivered to Nebraska (Julesburg Gage), 1996-2015

Figure 2 displays the annual physical flow and storable flow at the South Platte River at Kersey stream gage from 1996 to 2015. This location is below the confluence of the South Platte River and the Cache la Poudre River in Greeley, and is the upstream end of the Lower South Platte River Basin as defined in the South Platte Storage Study. As with the analysis at the Julesburg gage, storable flow is the maximum potential storable flow assuming a mainstem reservoir that can capture all available water. Although physical flow in the river at Kersey is larger than at the State line, storable flow is a smaller percentage of total flow at the Kersey gage compared to storable flow at the Julesburg gage because of the need to satisfy downstream water rights within Colorado.

Selected statistics for physical flow and storable flow at the Kersey gage are presented in Table 2. Physical flow decreases but storable flow increases in the Lower South Platte River between the Kersey gage and the State line. Physical flow decreases due to the lack of major tributaries and the significant diversions for Lower South Platte Basin water users. Storable flow increases because less water must be reserved in the stream for downstream water rights.

Table 2. Historical Annual Flow for 1996-2015 at Greeley

Statistic	Physical Water at Greeley (Kersey gage) (ac-ft/yr)	Storable Water at Greeley (Kersey gage) (ac-ft/yr)
Annual Average	773,000	262,000
Annual Median	732,000	165,000
Minimum Year	285,000	0
Maximum Year	2,001,000	1,447,000

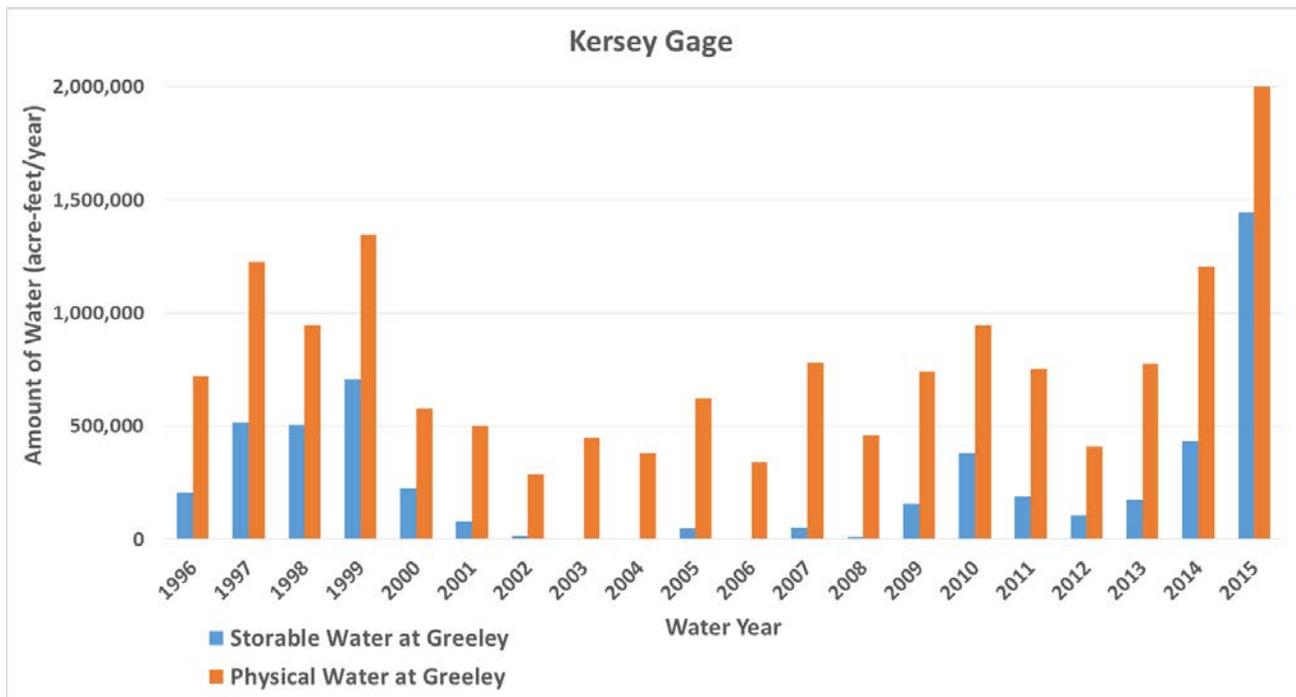


Figure 2. Physical and Storable Flow at Greeley (Kersey Gage), 1996-2015

APPENDIX E – WATER AVAILABILITY TM

NOTE: SOME OF THE INFORMATION IN THIS TM WAS CHANGED DURING
PREPARATION OF THE FINAL REPORT

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HB 1256 - South Platte Storage Study (SPSS)



TECHNICAL MEMORANDUM

To: Joe Frank, Andy Moore
Lower South Platte Water Conservancy
District, Colorado Water Conservation
Board

From: Samantha Mauzy, Lisa Fardal and Chip Paulson
MWH Now Part of Stantec

Subject: **South Platte River Hydrologic Analysis**

Date: June 26, 2017

INTRODUCTION AND BACKGROUND

The South Platte Storage Study (SPSS) was initiated as a result of House Bill 16-1256 titled “South Platte Storage Study.” HB16-1256, signed into law by the Governor on June 9th, 2016, authorizes the Colorado Water Conservation Board (CWCB), in collaboration with the State Engineer (SEO), and the South Platte Basin and Metro Roundtables, to identify multi-purpose water storage options along the lower South Platte River to capture flows leaving the state in excess of the legally required amounts. These water storage possibilities will include new reservoirs, the enlargement/rehabilitation of existing reservoirs, and alternative storage mechanisms (e.g., underground storage).

The third task of the SPSS project is a hydrologic flow analysis of the South Platte River basin, which includes an analysis of historical and future flows. The objective of the historical flow analysis is to estimate the amount of water that was physically and legally available for storage in the lower South Platte River based on historical hydrologic records. For the analysis of future flows, rough adjustments were made to estimate storable flows under possible future hydrologic conditions based on discounting factors such as conditional diversion or storage rights or the implementation of Identified Projects and Processes (IPPs) identified in Colorado’s Water Plan.

This technical memorandum presents the results of the historical and future available flow analyses. It contains a brief overview of the updates performed on the point flow model and a description of how the available flows were estimated from the point flow model results.

POINT FLOW MODEL

The Point Flow Model was initially developed by Ken Fritzier for Brown and Caldwell for the Lower South Platte Water Conservancy District under a Water Supply Reserve Account (WSRA) grant with the State of Colorado. The model evaluates the daily flow passing structures on the mainstem of the South Platte River between the Burlington Ditch diversion (Henderson area) and the Nebraska state line based on hydrologic data, diversion records and reconstructed call records using a detailed point flow modeling approach. The point flow analysis calculates ungaged gains and losses between measured points by simple mass balance and estimates physical flow at 62 points along the river by redistributing the gains and losses according to their spatial distribution. The model does not account for existing conditional water rights that could be used more fully in the future as they are perfected nor does it consider unused reusable return flows that might be utilized in the future.

The Point Flow Model version dated February 23, 2017 was updated to meet the needs of the SPSS project. The model was previously updated for the South Platte Basin Implementation Plan. Details of the historical flow dataset update can be found in the memorandum dated March 10, 2017 from Leonard Rice Engineers, Inc. to Stantec entitled “Task 3: Historical Point Flow Dataset Update (WY1996-WY2015).” This

memorandum is provided in Appendix B. Using this data, the Point Flow Model was updated by the original developer, Ken Fritzler. The following updates were implemented:

- Daily time series in the original Point Flow Model was water years 2000 to 2013. This was extended to include water years 1996 to 2015.
- Daily call chronology was updated for the new time period.
- The Metro Effluent dataset was updated. The original Metro Effluent time series used in the Point Flow Model was obtained. This dataset (WY1994 – WY2014) provided the template for recreating the time series using publicly available data from HydroBase and Colorado Division of Water Resources (CDWR) website. Russel Stroud (Division 1 Lead Hydrographer) was also consulted to help understand the available public data for gage METSEWCO discharges operated by CDWR. The original Metro time series used in the Point Flow Model included releases back to the Burlington Canal. The final Metro time series was reconstructed using both Metro Sewer (0200700) historical diversion classes and gaged discharges from METSEWCO (discharge 1 and discharge 3) to match the proprietary dataset from Metro Wastewater without Burlington Canal releases. The resulting dataset differs from the original, but should be considered more accurate.
- Water District 2 diversion totals were updated by using administrative records (S:X F: U:Q T:0 G:) from November 1, 2010 forward instead of diversion totals as these data were not compiled correctly due to a change in both the Water Commissioner and diversion class coding requirements.
- Daily streamflow records directly from the Colorado Division of Water Resources website were used to fill missing streamflow records in HydroBase in September 2013 for several stations.
- Due to new release class protocols implemented in 2012, several new release classes (S: F: U:Q T:7 G:) not in the original dataset were identified in HydroBase for the more recent period for the Jackson Reservoir outlet, Weldon Valley Ditch return, and the Prewitt outlet.

Table 1 gives the names and types of structures used in the Point Flow Model in order from most upstream to most downstream. Figure 1 shows the location of each point in the Point Flow Model along the South Platte River. Figure 2 shows the average annual flow in the South Platte River after the updates described were made for water years 1996 to 2015. (All figures are presented at the end of this document.)

Table 1. Points Analyzed in Point Flow Model

ID	Location Name	Type
1	South Platte River at Denver	Stream Gage
2	Burlington Ditch River Headgate	Diversion Structure
3	Gardeners Ditch	Diversion Structure
4	South Platte River at Commerce City	Stream Gage
5	Metro Effluent	Tributary
6	Sand Creek at Mouth Near Commerce City	Tributary
7	Clear Creek at Mouth Near Derby	Tributary
8	Fulton Ditch	Diversion Structure
9	Brantner Ditch	Diversion Structure
10	South Platte River at Henderson	Stream Gage

ID	Location Name	Type
11	Brighton Ditch	Diversion Structure
12	Lupton Bottom Ditch	Diversion Structure
13	Big Dry Creek at Mouth Near Fort Lupton	Tributary
14	Platteville Ditch	Diversion Structure
15	Meadow Island 1 Ditch	Diversion Structure
16	Evans No 2 Ditch/ Platte Valley Canal (Shared Headgate)	Diversion Structure
17	Meadow Island 2 Ditch/ Beeman Ditch (Shared Headgate)	Diversion Structure
18	Farmers Independent Ditch	Diversion Structure
19	Hewes Cook Ditch	Diversion Structure
20	Jay Thomas Ditch	Diversion Structure
21	St. Vrain Creek at Mouth, Near Platteville	Tributary
22	Union Ditch	Diversion Structure
23	Section No 3 Ditch	Diversion Structure
24	Big Thompson River at Mouth, near La Salle	Tributary
25	Lower Latham Ditch	Diversion Structure
26	Patterson Ditch	Diversion Structure
27	Highland Ditch	Diversion Structure
28	Cache La Poudre River Near Greeley	Tributary
29	South Platte River Near Kersey	Stream Gage
30	Empire Ditch	Diversion Structure
31	Riverside Canal/ Illinois Ditch (Shared Headgate)	Diversion Structure
32	Bijou Canal/ Corona Ranch Ditch (Shared Headgate)	Diversion Structure
33	Riverside Reservoir Outlet	Tributary
34	Jackson Lake Inlet Ditch	Diversion Structure
35	Weldon Valley Ditch	Diversion Structure
36	Jackson Reservoir Outlet	Tributary
37	Ft Morgan Canal	Diversion Structure
38	South Platte River Near Weldona	Stream Gage
39	Weldon Valley Ditch Return	Tributary
40	Deuel Snyder Canal	Diversion Structure
41	Upper Platte Beaver Canal	Diversion Structure
42	Lower Platte Beaver Ditch/Tremont Ditch (Same Point From Diversion On South Platte River)	Diversion Structure
43	North Sterling Canal/ Union Ditch (Assumes Shared Headgate)	Diversion Structure
44	South Platte River at Cooper Bridge, Near Balzac	Stream Gage
45	Prewitt Inlet Canal/ Tetsel Ditch/ Johnson Edwards Ditch (Shared Headgate)	Diversion Structure
46	South Platte Ditch	Diversion Structure
47	Prewitt Outlet	Tributary

ID	Location Name	Type
48	Pawnee Ditch	Diversion Structure
49	Schneider Ditch	Diversion Structure
50	Springdale Ditch	Diversion Structure
51	Sterling Irrigation Company Ditch 1	Diversion Structure
52	Lowline Ditch/ Henderson Smith Ditch	Diversion Structure
53	Bravo Ditch	Diversion Structure
54	Iliff Platte Valley Ditch	Diversion Structure
55	Lone Tree Ditch	Diversion Structure
56	Powell Blair Ditch	Diversion Structure
57	Ramsey Ditch	Diversion Structure
58	Harmony Ditch 1	Diversion Structure
59	Peterson Ditch	Diversion Structure
60	South Reservation Ditch	Diversion Structure
61	Liddle Ditch	Diversion Structure
62	South Platte River at Julesburg	Stream Gage

HISTORICAL HYDROLOGIC ANALYSIS RESULTS

Available water for the historical period 1995 to 2015 was calculated for all locations in the Point Flow Model by the following steps.

1. Daily historical flow that did not have a calling water right (available flow greater than 0), was reduced by the bypass flow required to satisfy downstream uses. With input from Division 1 staff, bypass flows in Table 2 were adopted as reasonable estimates of the requirements.

Table 2. Bypass Flows Applied to Available Water Analysis

Month	Burlington to upstream of St Vrain Creek (cfs)	Downstream of St Vrain Creek to Riverside Canal (cfs)	Bijou Canal to state line (cfs)
Apr - Oct	15	20	10
Nov - Mar	15	10	5

2. The South Platte River Compact requires flow at the state line to be 120 cubic feet per second (cfs) [238 ac-ft/day) or greater between April 1 and October 15. The available flow at the state line was reduced by 120 cfs during these dates. The Compact affects available flows in District 64 only.
3. Available water calculations were reduced by historically unused reusable return flows. These values were obtained from Aurora Water and Denver Water. It was assumed that both entities would reclaim all their reusable water supplies in the future.

4. Available flow at any point along the South Platte River is affected by downstream water rights that must be satisfied. Sufficient water must be left in the river at any point to meet all downstream water rights and delivery obligations. Thus, the available flow is constrained by the minimum flow that must remain in the river to assure that all downstream water rights are satisfied. If there was a call at one point in the river, it was assumed that there was no available water at that point or at any points upstream. In District 64, the 120 cfs Compact requirement could reduce the available flow to zero in the entire district. Figure 3 shows, as an example, physical flow and available water for June 20, 2005. This date was chosen arbitrarily to demonstrate how the calculation of available water was performed.

To compare available water between wet years, normal years, and dry years, water year 1999 was chosen as a representative wet year, water year 2002 was chosen as a representative dry year, and water year 2010 was chosen as a representative normal years. Figure 4 shows annual available water at all points in the Point Flow Model based on year type.

Further analysis was done seasonally for the representative wet, dry, and normal years. Average available water and physical flow in the river was plotted for February, June, and August. February was chosen to be representative of the winter season, June was chosen to be representative of the runoff season, and August was chosen to be representative of the irrigation season.

Figures 5 to 13 show available water and physical flow in the South Platte for all combinations of year type and season. See Table 3 for a summary of the conditions presented in these figures.

Table 3. Index to Available Water and Physical Flow Figures

	Winter Season (February)	Runoff Season (June)	Irrigation Season (August)
Wet Year (WY 1999)	Figure 5	Figure 6	Figure 7
Dry Year (WY 2002)	Figure 8	Figure 9	Figure 10
Normal Year (WY 2010)	Figure 11	Figure 12	Figure 13

Additionally, five locations along the South Platte River were chosen for further analysis. Four locations - South Platte River at Kersey, South Platte River at Weldona, South Platte River near Balzac, and South Platte River near Julesburg – are stream gage locations. The fifth location is the Lowline Ditch/Henderson Smith Ditch diversion, which is representative of flow in the river at Sterling. Figure 14 shows these five points and their locations within the SPSS study area.

Table 4 shows the average and median annual available water for the 1995-2015 historical period for the selected locations. The average annual available water is given as an average of all years and for a representative wet, normal, and dry year, and the median of all years is given.

Table 4. Annual Available Water for Selected Locations Based on Historical Hydrology

Location	Average Annual Available Water [ac-ft]				Median Annual Available Water [ac-ft]
	All Years	Wet Year (1999)	Normal Year (2010)	Dry Year (2002)	All Years
South Platte River near Kersey	262,000	707,000	378,000	14,000	165,000
South Platte River near Weldona	281,000	731,000	411,000	18,000	179,000
South Platte River near Balzac	297,000	771,000	440,000	18,000	185,000
Lowline Ditch/Henderson Smith Ditch	314,000	799,000	476,000	33,000	200,000
South Platte River at Julesburg	397,000	951,000	627,000	79,000	289,000

Notes:

1. Based on 1995-2015 historical streamflows and river operations, adjusted to remove Denver Water and Aurora Water reusable return flows and account for all existing water rights and South Platte River Compact obligations.
2. "Available water" is water physically and legally available to be diverted to a new water supply project like SPSS.

Average available water calculated from the Point Flow Model was compared to CDWR historical stream gage data. According to CDWR historical stream gage data, on average, 407,000 acre-feet of water passed the Julesburg gage on an annual basis during the full period of record from 1903 to 2016. According to the Point Flow Model, on average, only 397,000 acre-feet is available for diversion. The difference is due to a combination of differences in period of record, consideration for Denver Water and Aurora Water reusable return flows, adjustments for all existing water rights, and South Platte Compact obligations. The stream gage flow average was calculated based on water years 1903 to 2016 (all years with adequate streamflow data available), whereas the Point Flow Model available water calculations are done based on water years 1996 to 2015. Available water calculations take into account the effect of Denver Water and Aurora Water reusable return flows, adjustments for all existing water rights and Compact calls, while stream gage flows do not.

Figures 15 to 20 are exceedance plots that show the percentage of time a given magnitude of available flow is equaled or exceeded in the Point Flow Model period of record for historical conditions. Daily flow exceedance plots are shown in Figures 15 to 19, an annual flow exceedance plot is shown in Figure 20, and the average monthly physical flow is shown in Figure 21.

Exchange potential between any two given points along the river can be estimated by the minimum available flow within the reach. Exchange potential is used to analyze the general exchange conditions in the South Platte River and identify points that would potentially limit or control future exchanges. The legally and physically available flow shown in Figure 22 represents the exchange potential as the minimum available flow between any two selected points of interest. Figure 23 shows a map of the location of the two points used as an example in Figure 22.

FUTURE HYDROLOGIC CONDITIONS

HB 16-1256 specified that this storage study should be based on historical hydrology to answer the question, "how much water could we have stored in recent years if storage had been in place?" However, it is recognized that future hydrologic conditions will not be the same as historical conditions due to development of conditional water rights, implementation of proposed Identified Projects and Processes (IPPs) from the Colorado Water Plan, changed operations by water users, and a host of other factors. Per the direction of the

SPSS Review Committee, the SPSS planning will be performed using future hydrology, the effect of the unaltered historical hydrology on the performance of potential storage solutions will also be investigated.

The scope of work for the SPSS indicated that future hydrology would be developed using the same methods as were applied in the South Platte Basin Implementation Plan (BIP). In the BIP a routine was developed to reduce historical flows by diversions anticipated from IPPs in the Colorado Water Plan. This routine uses estimates of IPP annual yields obtained from the IPP proponents, and reduces available water equally in all months. The routine allows the user to select individual IPPs or all IPPs for inclusion in the analysis, since the BIP acknowledges that not all IPPs are likely to be ultimately implemented.

An alternate approach to estimate future hydrology would be to reduce the historical flows by the current conditional water right filings in the basin. Some of the conditional diversion and storage water rights are associated with IPPs, but not all of them. Both approaches involve significant speculation about future water development in the basin. The selected approach based on IPPs is assumed to give a reasonable estimate of the order of magnitude of impacts of future water development on historical hydrology.

For the SPSS the method of reducing available flows to account for implementation of IPPs was modified by assuming a monthly pattern of diversions for those proposed projects which would increase future diversions. These rough estimates were developed by the study team and were not verified with the IPP proponents. It is recognized that many factors can affect the magnitude and timing of diversions for future projects, and detailed analyses of specific IPPs was not contemplated for this project. Estimates in this study are only developed to provide a rough order of magnitude of the effect of IPPs on water available for a new South Platte storage project. IPPs which are expected to reduce future demands were not considered in the adjustment of available flows.

For IPPs with increased future diversions, it was assumed that most IPPs would divert a majority of their water during the spring runoff months when the most water is available and when junior water rights would be in priority. Assumptions were made as to the percentage of diversions that would be made during spring runoff months (May and June) and the percentage of diversions that would be made during the rest of the year (July to April). Table 5 shows the IPPs, their estimated yield from the BIP, and the assumed distribution of their diversions.

Table 5. Seasonal Distribution of Future Diversions for IPPs

IPP Project	Provider	Yield (ac-ft/year)	May-June Diversions	July-April Diversions
ACWWA Reuse Flow Project	ACWWA, SMWSA	3,520	n/a	n/a
Alternative Northern Water Supply Project	Town of Castle Rock	2,500	80%	20%
ASR Future Storage	Town of Castle Rock	n/a	-	-
ASR Pilot Phase Storage	Town of Castle Rock	n/a	-	-
Chatfield Pump Station	Denver Water	3,000	50%	50%
Chatfield Reservoir Storage Reallocation Project	Colorado Water Conservation Board, Centennial Water and Sanitation District, Central Colorado Water Conservancy District, Castle Pines North Metro District, Colorado Parks and Wildlife, Castle Rock, Center of Colorado Water Conservancy District, Castle Pines Metro District	8,500	80%	20%
Conservation	Centennial Water and Sanitation District	1,764	n/a	n/a

IPP Project	Provider	Yield (ac-ft/year)	May-June Diversions	July-April Diversions
Conservation	City of Greeley	3,000	n/a	n/a
Conservation	City of Northglenn	600	n/a	n/a
Conservation	City of Thornton	3,500	n/a	n/a
Conservation	Longmont	3,500	n/a	n/a
Conservation	Town of Castle Rock	3,350	n/a	n/a
Consolidated Mutual Water District Reservoir Construction	Consolidated Mutual Water Company	n/a	-	-
Denver Water Reuse	Denver Water	1,750	n/a	n/a
Downstream Reservoir Exchanges	Denver Water	12,000	70%	30%
Halligan Reservoir Enlargement	City of Fort Collins	7,000	80%	20%
Highway 93 Lakes	Arvada	500	80%	20%
Milton Seaman Reservoir Enlargement	City of Greeley	6,600	80%	20%
New Storage Projects	City of Northglenn	1,500	70%	30%
Northern Integrated Supply Project	Town of Erie, City of Lafayette, Left Hand Water District, City of Fort Morgan, City of Dacono, Town of Eaton, Town of Windsor, City of Fort Lupton, Fort Collins - Loveland Water District, Central Weld County Water District, Town of Evans, Morgan County Water Quality District, Town of Severance, Town of Frederick, Town of Firestone	40,000	70%	30%
Plum Creek Diversion & WPF Upgrades	Town of Castle Rock	4,100	80%	20%
Prairie Waters Project	Aurora	15,700	50%	50%
Reclaimed Water	Erie	5,390	n/a	n/a
Reuse	City of Thornton	2,000	n/a	n/a
Reuse Plan	City of Northglenn	700	n/a	n/a
Rueter Hess Reservoir Enlargement	Parker Water and Sanitation District, Castle Rock, Castle Pines North, Stonegate	14,810	80%	20%
South Platte and Beebe Draw Well Project - Reuse	City of Brighton	3,200	n/a	n/a
South Platte Protection Plan	Denver Water	n/a	-	-
Thornton Northern Project	City of Thornton	13,500	50%	50%
Union Pumpback Pipeline	Longmont	4,950	50%	50%
Union Reservoir Enlargement	Longmont	1,770	80%	20%
Westminster Agreement	City of Brighton	2,000	50%	50%
Westminster Gravel Storage	Westminster	n/a	-	-

Notes:

1. Projects with n/a in the Diversions fields reduce future demand rather than increasing future diversions. Projects with n/a in Yield field did not have yield estimates available from the BIP.
2. Projects with blanks in the Diversions fields did not have adequate yield information. It is assumed these projects will not be built.

Table 6 shows historical average annual and median annual available water adjusted for IPP diversion estimates. These results assume all IPPs for which yield information was available in the BIP are implemented, while all IPPs without yield information in the BIP are not implemented. This is conceptually consistent with the assumption in the Colorado Water Plan that not all IPPs will ultimately be implemented. The table also shows the reduction in available water compared to the results of the historical hydrology analysis shown in Table 4. Figure 24 shows South Platte at Julesburg as an example of historical available water and how it might be affected by IPPs in the future. Plots showing the same information at the other South Platte stream gages look very similar. Figure 25 gives a comparison of the daily available water exceedance between the historical hydrology and the future hydrology adjusted for IPPs.

Table 6. Future Available Water for Selected Locations Based on Historical Hydrology and IPP Adjustment

Location		Average Annual Available Water, After IPPs [ac-ft]				Median Annual Available Water [ac-ft]
		All Years	Wet Year (Based on 1999)	Normal Year (Based on 2010)	Dry Year (Based on 2002)	All Years
South Platte River near Kersey	With IPP Adjustment	214,000	580,000	275,000	6,000	116,000
	<i>Difference from Historical</i>	<i>-48,000</i>	<i>-127,000</i>	<i>-103,000</i>	<i>-8,000</i>	<i>-49,000</i>
South Platte River near Weldona	With IPP Adjustment	231,000	601,000	303,000	9,000	127,000
	<i>Difference from Historical</i>	<i>-50,000</i>	<i>-130,000</i>	<i>-108,000</i>	<i>-9,000</i>	<i>-52,000</i>
South Platte River near Balzac	With IPP Adjustment	246,000	641,000	326,000	9,000	144,000
	<i>Difference from Historical</i>	<i>-51,000</i>	<i>-130,000</i>	<i>-114,000</i>	<i>-9,000</i>	<i>-41,000</i>
Lowline Ditch/Henderson Smith Ditch	With IPP Adjustment	261,000	666,000	357,000	15,000	154,000
	<i>Difference from Historical</i>	<i>-53,000</i>	<i>-133,000</i>	<i>-119,000</i>	<i>-18,000</i>	<i>-46,000</i>
South Platte River at Julesburg	With IPP Adjustment	332,000	815,000	494,000	54,000	232,000
	<i>Difference from Historical</i>	<i>-65,000</i>	<i>-136,000</i>	<i>-133,000</i>	<i>-25,000</i>	<i>-57,000</i>

FINDINGS AND CONCLUSIONS

Figure 26 summarizes the results of the historical water availability analysis by showing the historical average annual available water and physical flow along with the historical median annual available water and physical flow in the SPSS study area. Figure 27 summarizes the results of the future water availability analysis by showing the future average annual available water and historical physical flow along with the future median annual available water and historical physical flow.

The results from this hydrologic analysis will be used to estimate the amount of water available to a new SPSS storage project at various locations along the South Platte River and to guide the amount of storage that could be beneficial at those locations.

It is noted that the results for estimates of available water assume water is diverted at only one point on the South Platte mainstem. If multiple diversions were to occur, the results of this analysis could be used to estimate yield from the upstream diversion but the point flow model would have to be recalculated to determine available water at a subsequent downstream diversion.

In general, available water in the South Platte mainstem increases in the downstream direction because of fewer senior water rights to constrain available water, tributary inflows, and more return flows entering the South Platte. Siting SPSS storage options further downstream will generally result in greater available water. However, the increase in available water between the Kersey gage and Sterling is relatively modest – the mean annual available water increases by 20 percent and the median annual available water increases by 30 percent between these points. Thus water availability will be an important but not a critical differentiator in siting of SPSS storage options in the majority of the study area.

Several choke points exist along the river profile that would affect exchange potential; the majority of these occur upstream of Kersey and the Poudre River confluence. While these are outside the SPSS study area for storage projects, the choke points affect the ability to exchange water from downstream storage to upstream demand centers closer to the Front Range urban corridor.

From the hydrologic analysis, it can be concluded that in general, when water is available, there is a large amount of water available for a short period of time. This confirms the expected findings based on experience in the basin. It is likely that the most feasible new storage options for capturing excess flows on the South Platte will have to be capable of “scalping” and storing high flows that occur during the annual Spring runoff period in wet years. This would require large diversion structures and/or large storage capacities with significant carry-over storage.

Future divertible flow will be less than historical divertible flow due to development of IPPs, conditional water rights and new water supply projects. For purposes of this study, IPPs for which yield estimates were available were assumed to be implemented to provide a rough order of magnitude estimate of future hydrology. Applying this adjustment to the historical point flow model reduced available annual available water by 16-18 percent throughout the study area, and reduced median available flow by 20-30 percent.

APPENDIX A: FIGURES

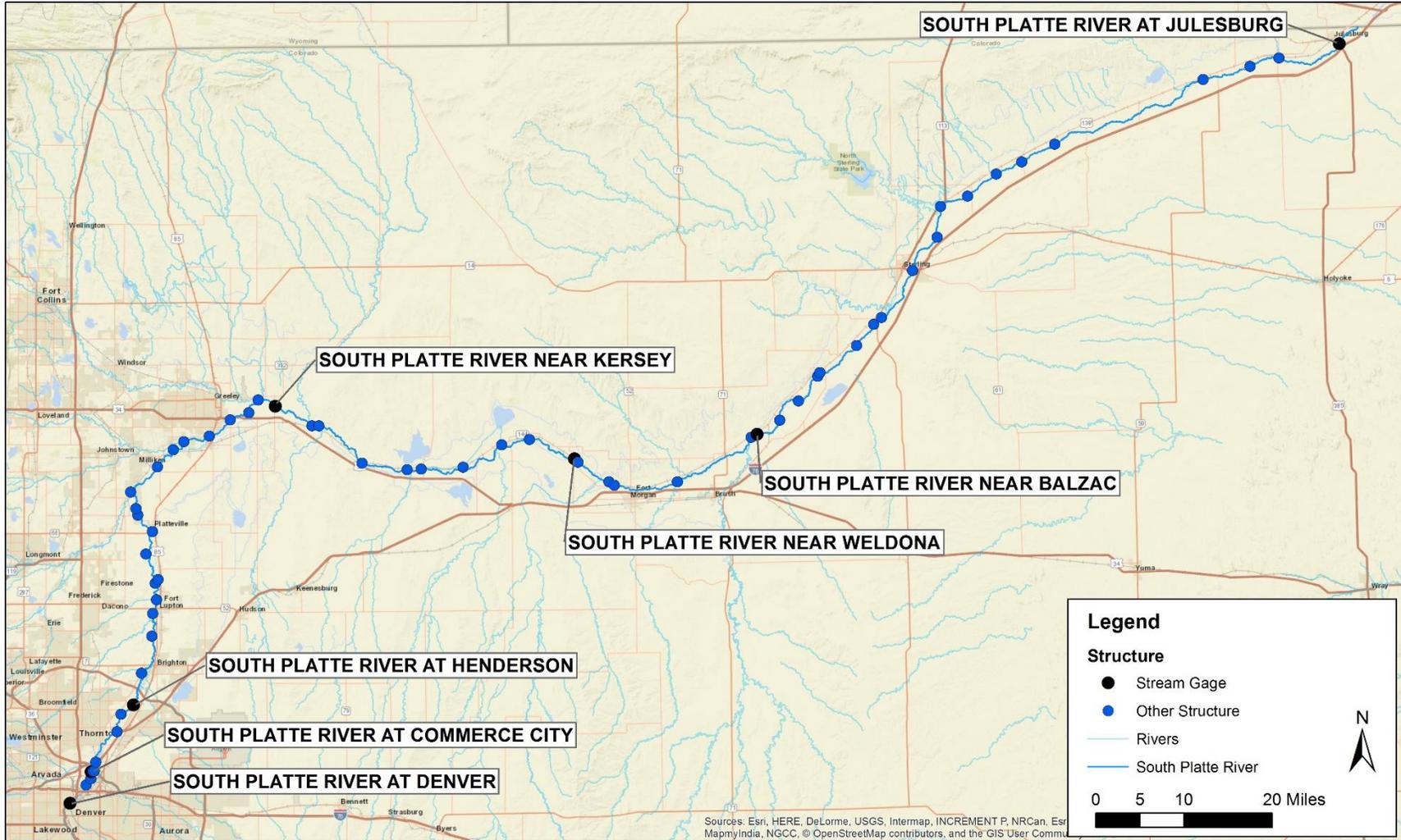


Figure 1. Point Flow Model Analysis Locations

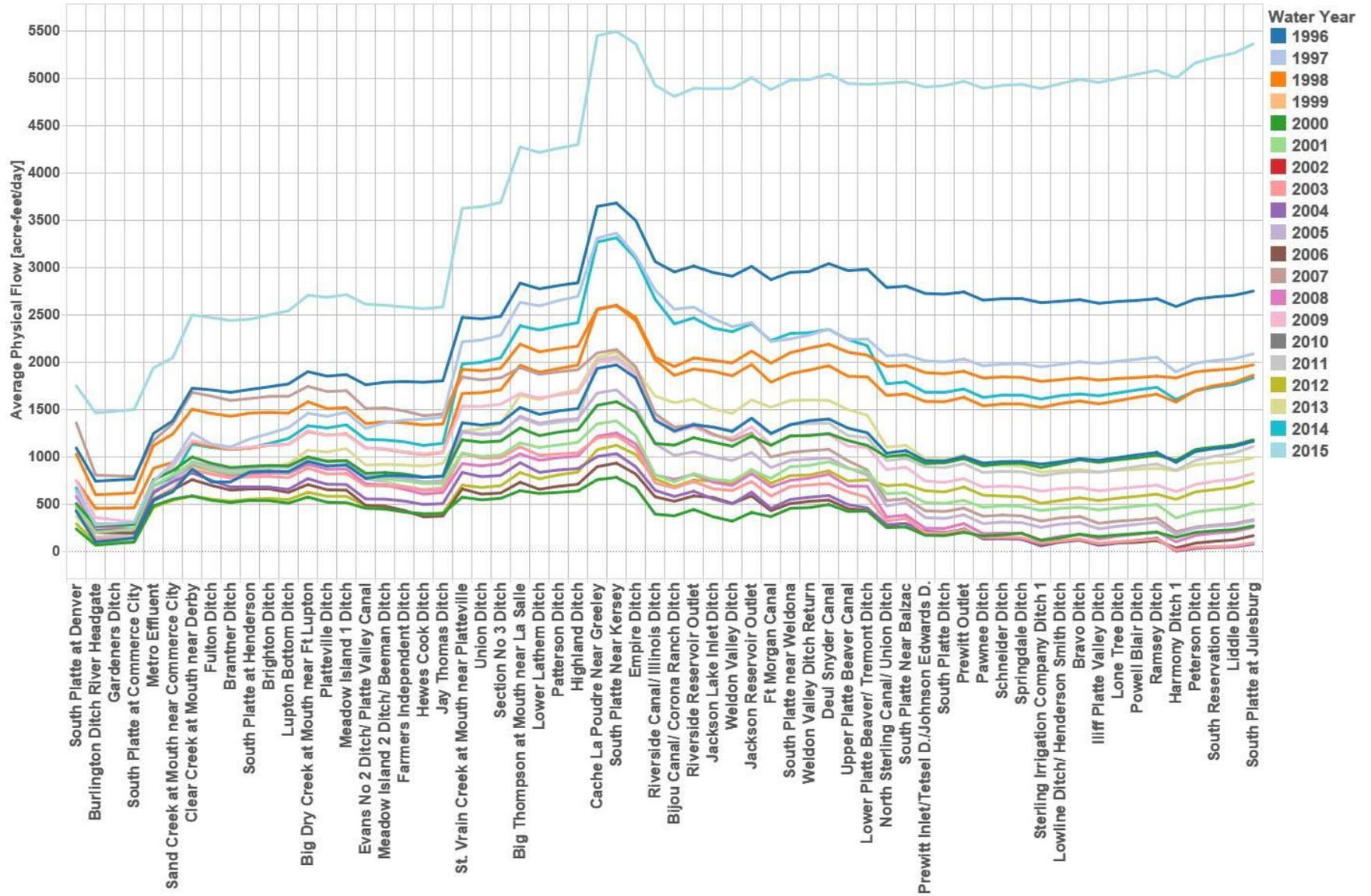


Figure 2. Historical Average Physical Flow after Point Flow Model Updates

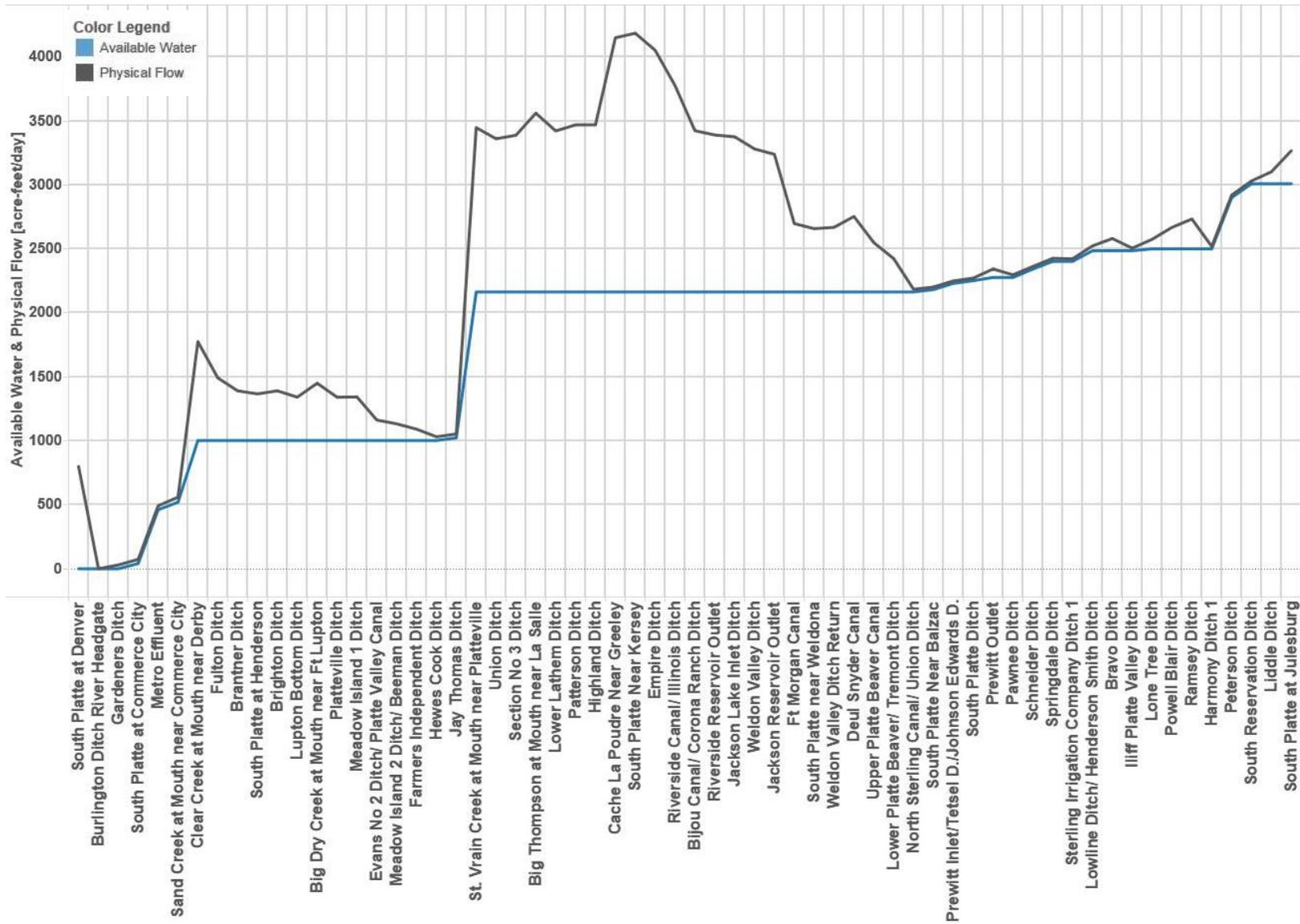


Figure 3. Sample Daily Available Water Calculation Method – June 20, 2005

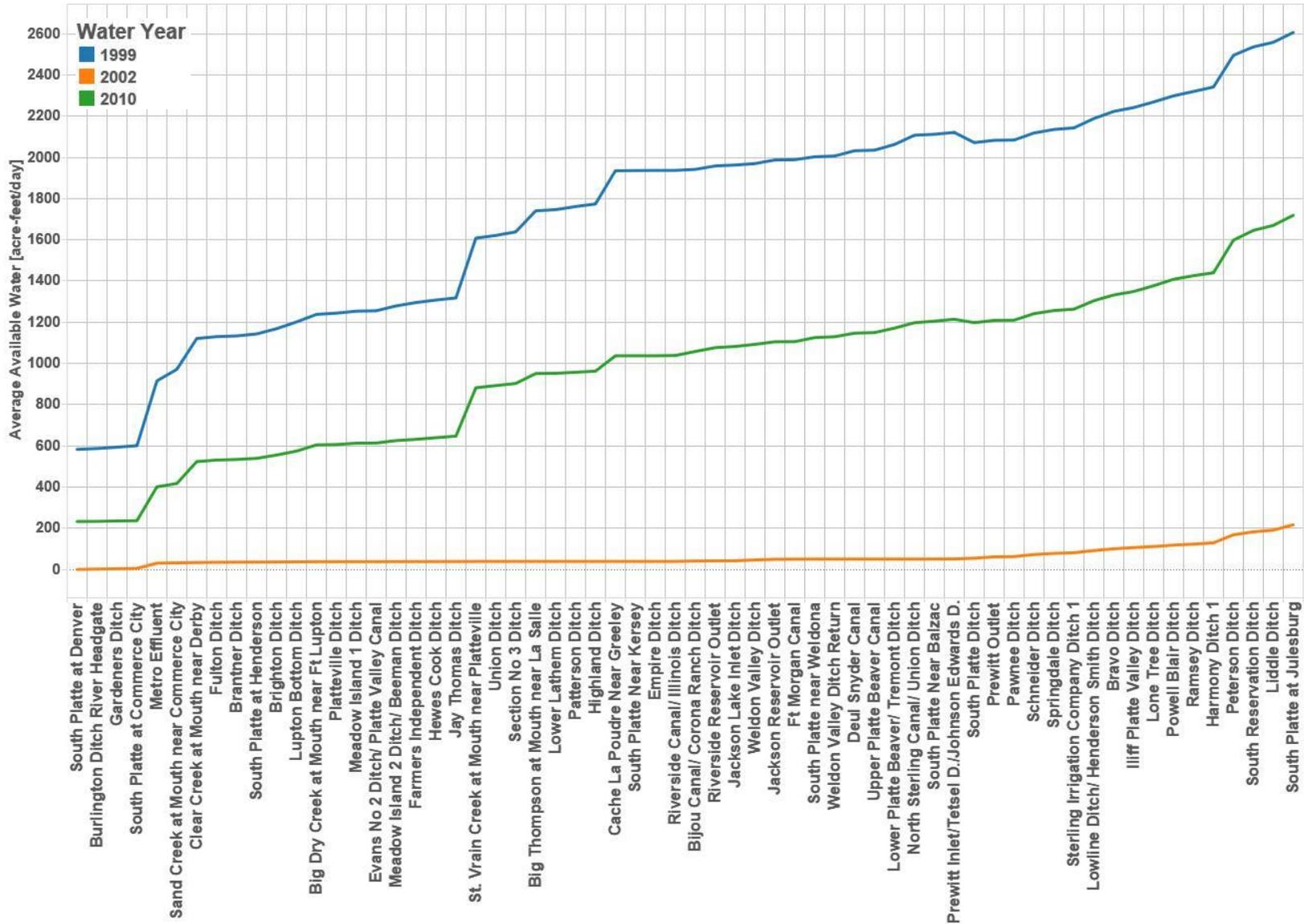


Figure 4. Historical Daily Average Available Water for Representative Wet, Normal, and Dry Years

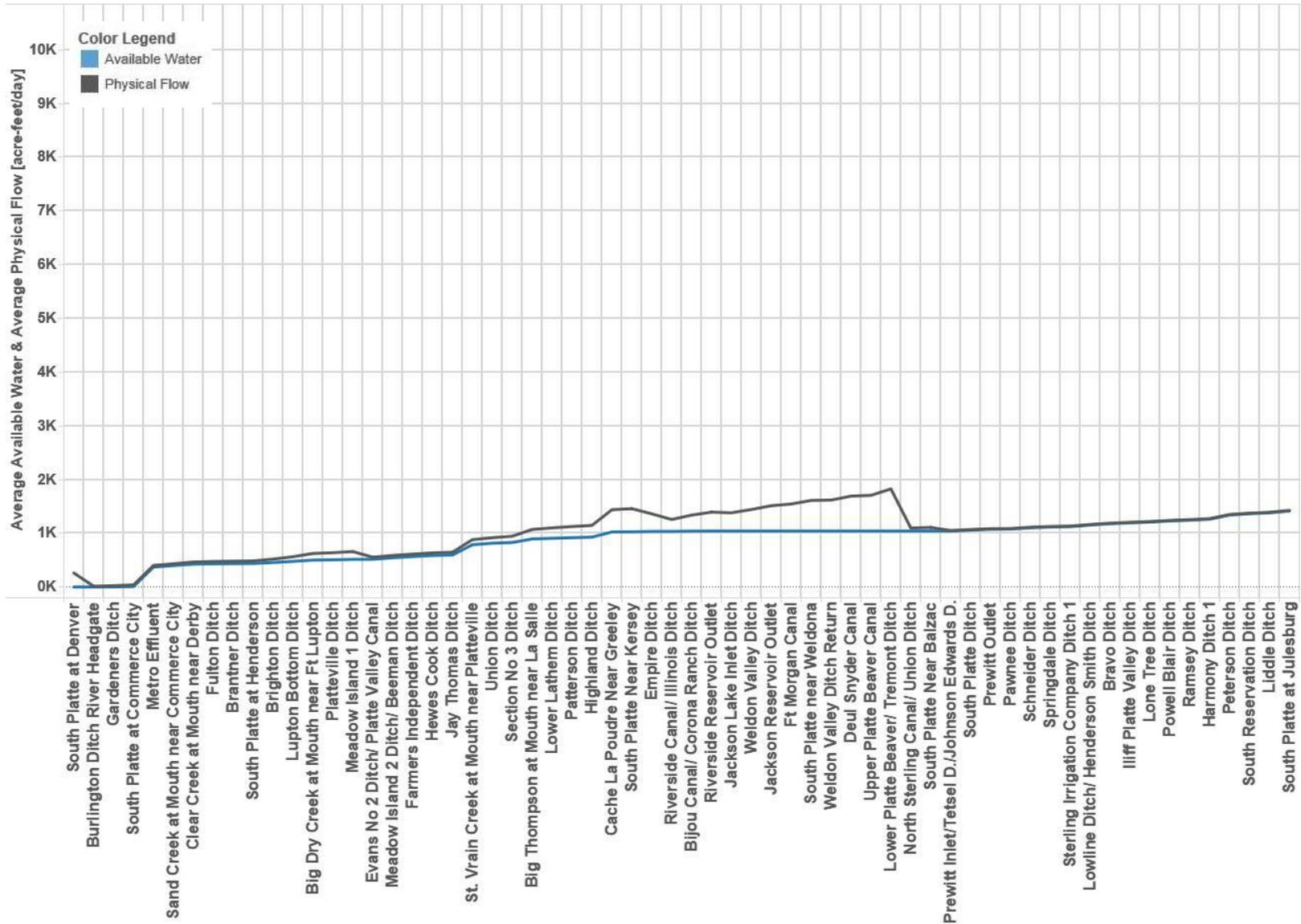


Figure 5. Historical Available Water and Physical Flow for Wet Winter Season (February 1999)

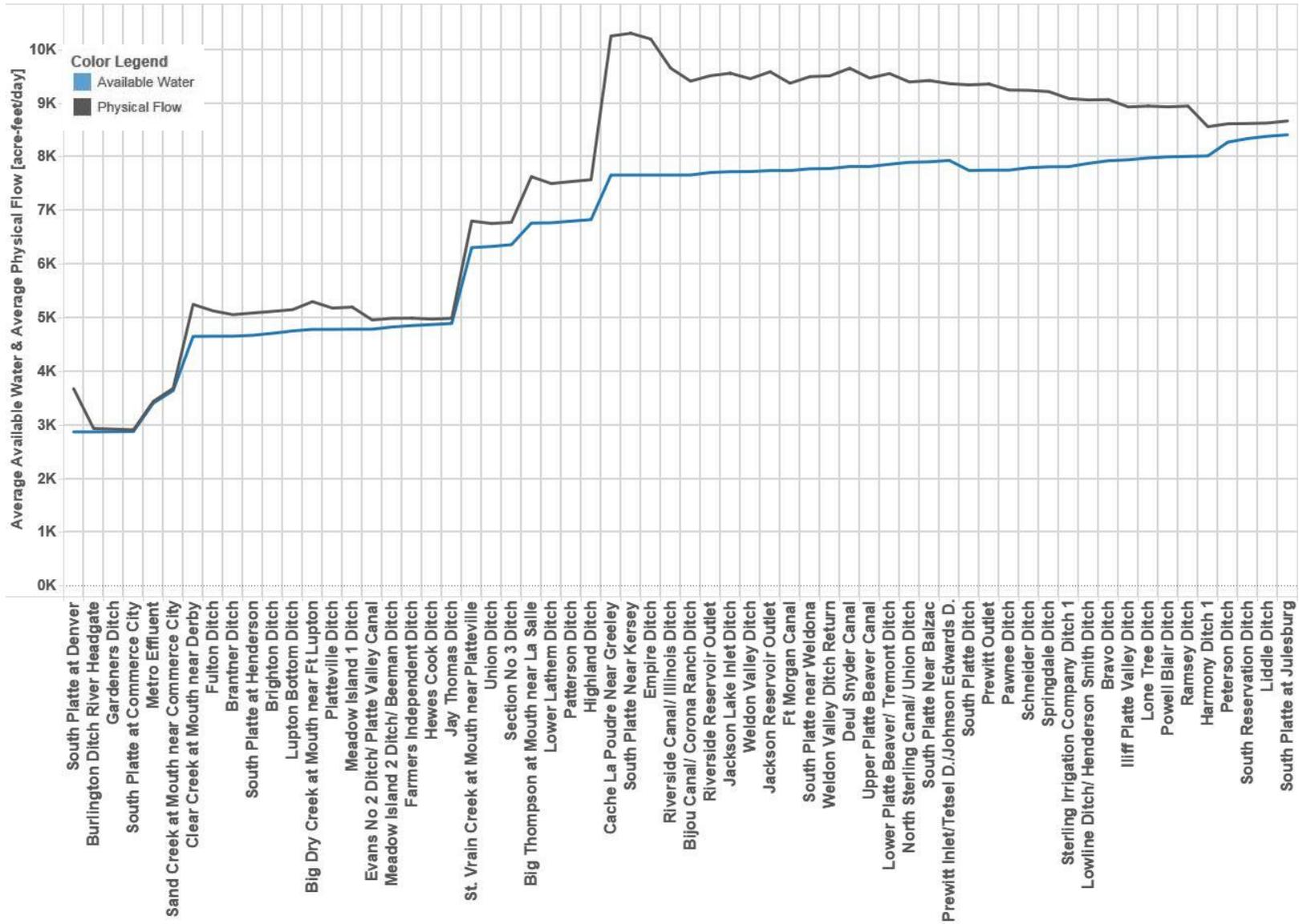


Figure 6. Historical Available Water and Physical Flow for Wet Runoff Season (June 1999)

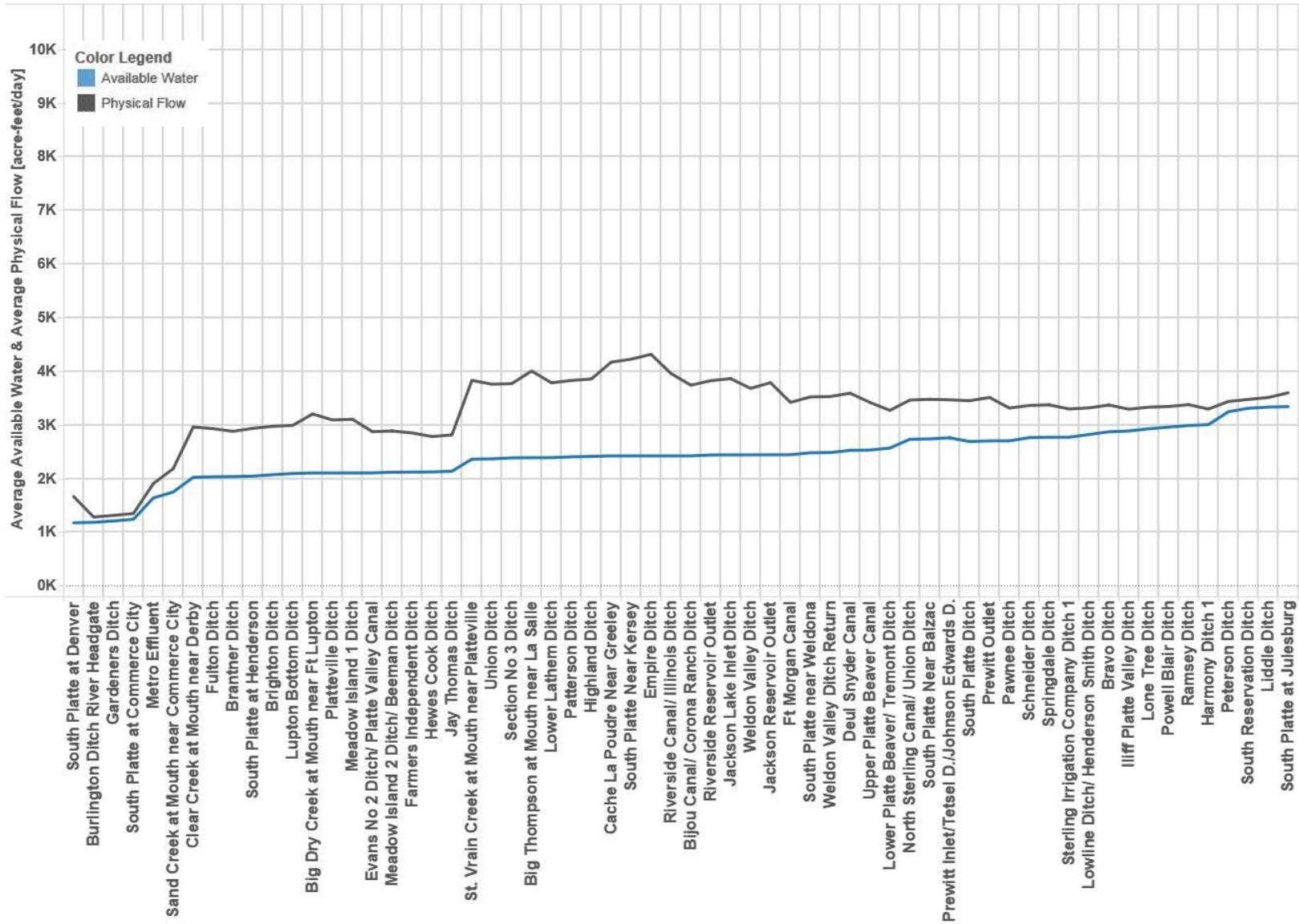


Figure 7. Historical Available Water and Physical Flow for Wet Irrigation Season (August 1999)

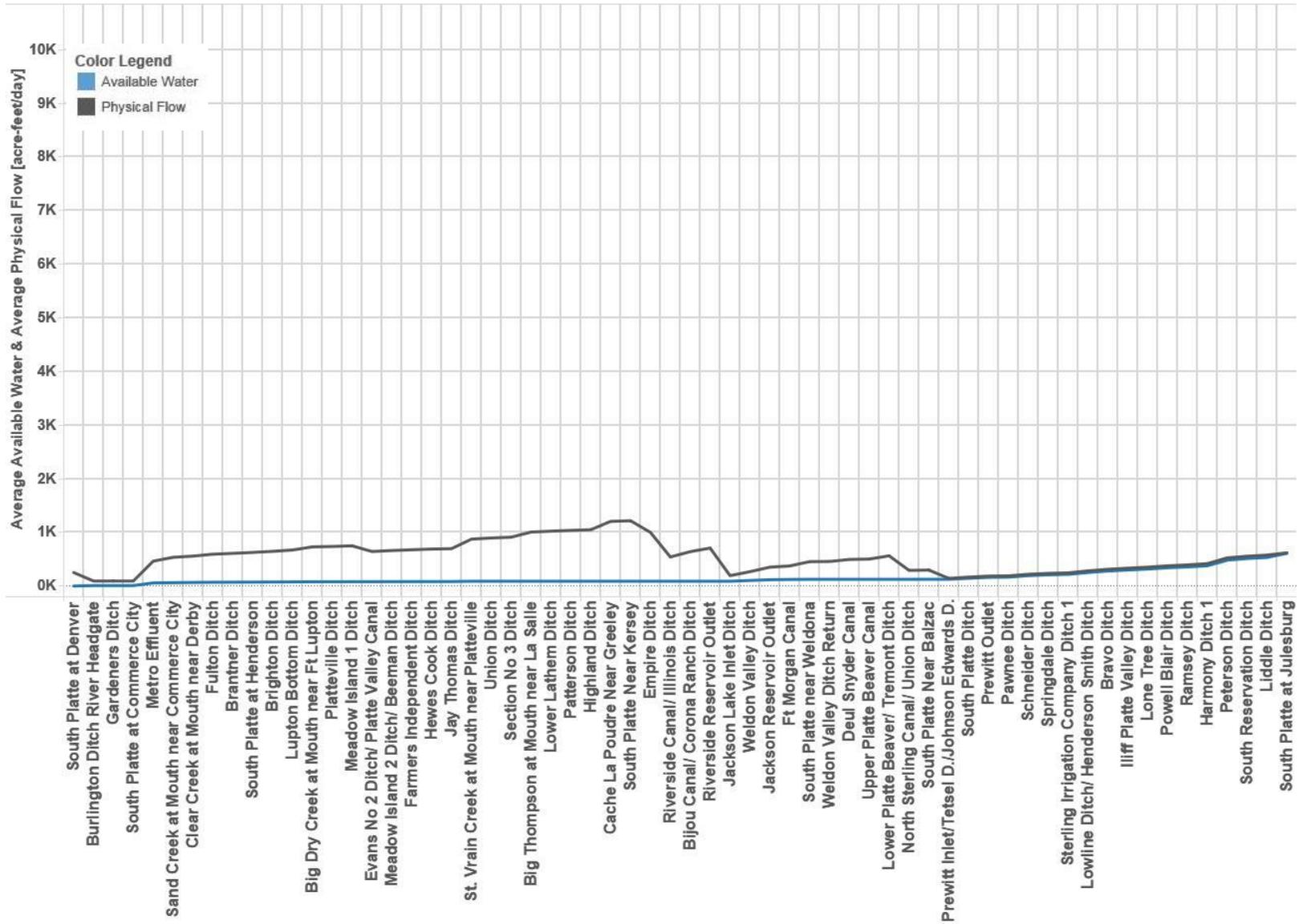


Figure 8. Historical Available Water and Physical Flow for Dry Winter Season (February 2002)

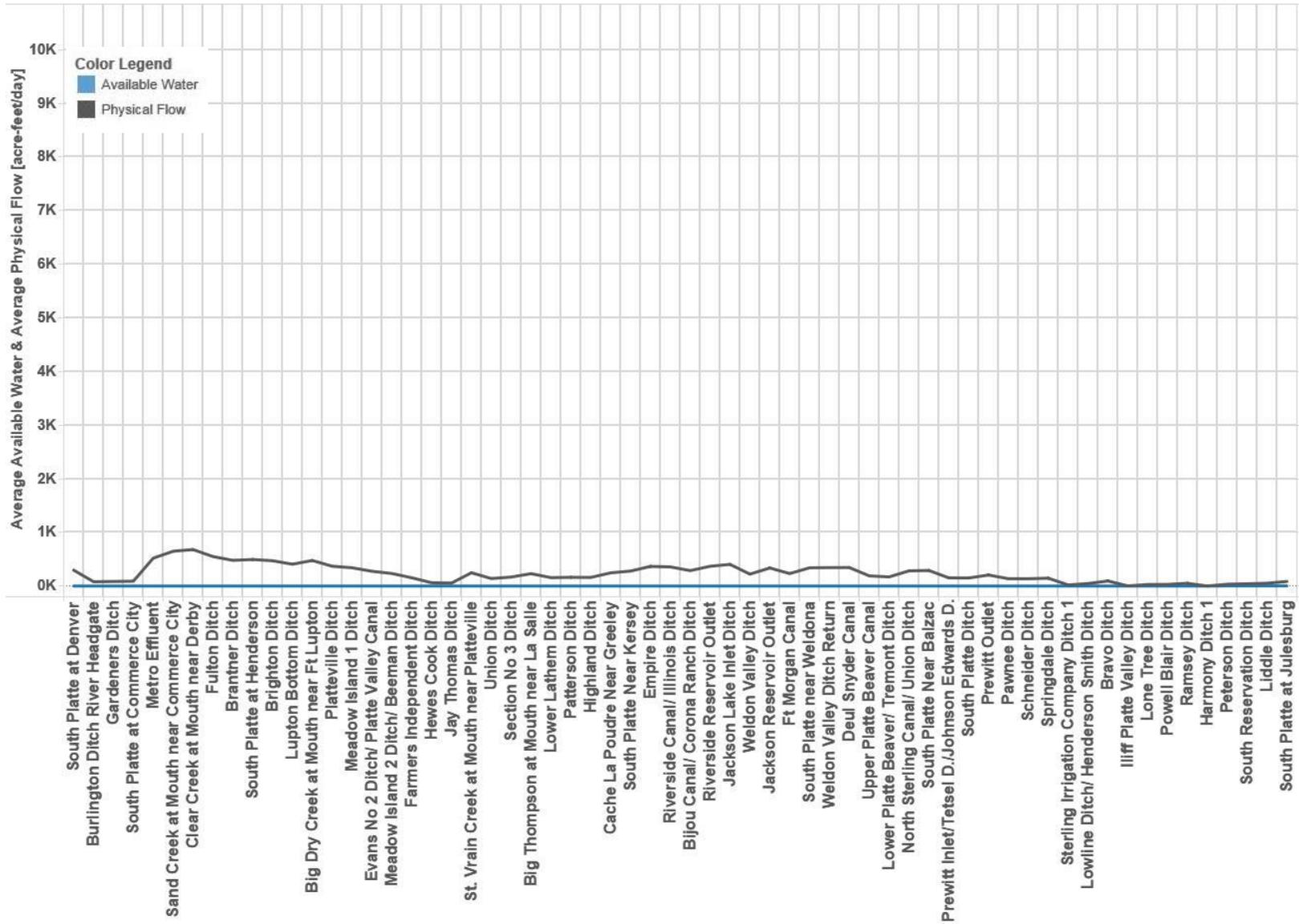


Figure 9. Historical Available Water and Physical Flow for Dry Runoff Season (June 2002)

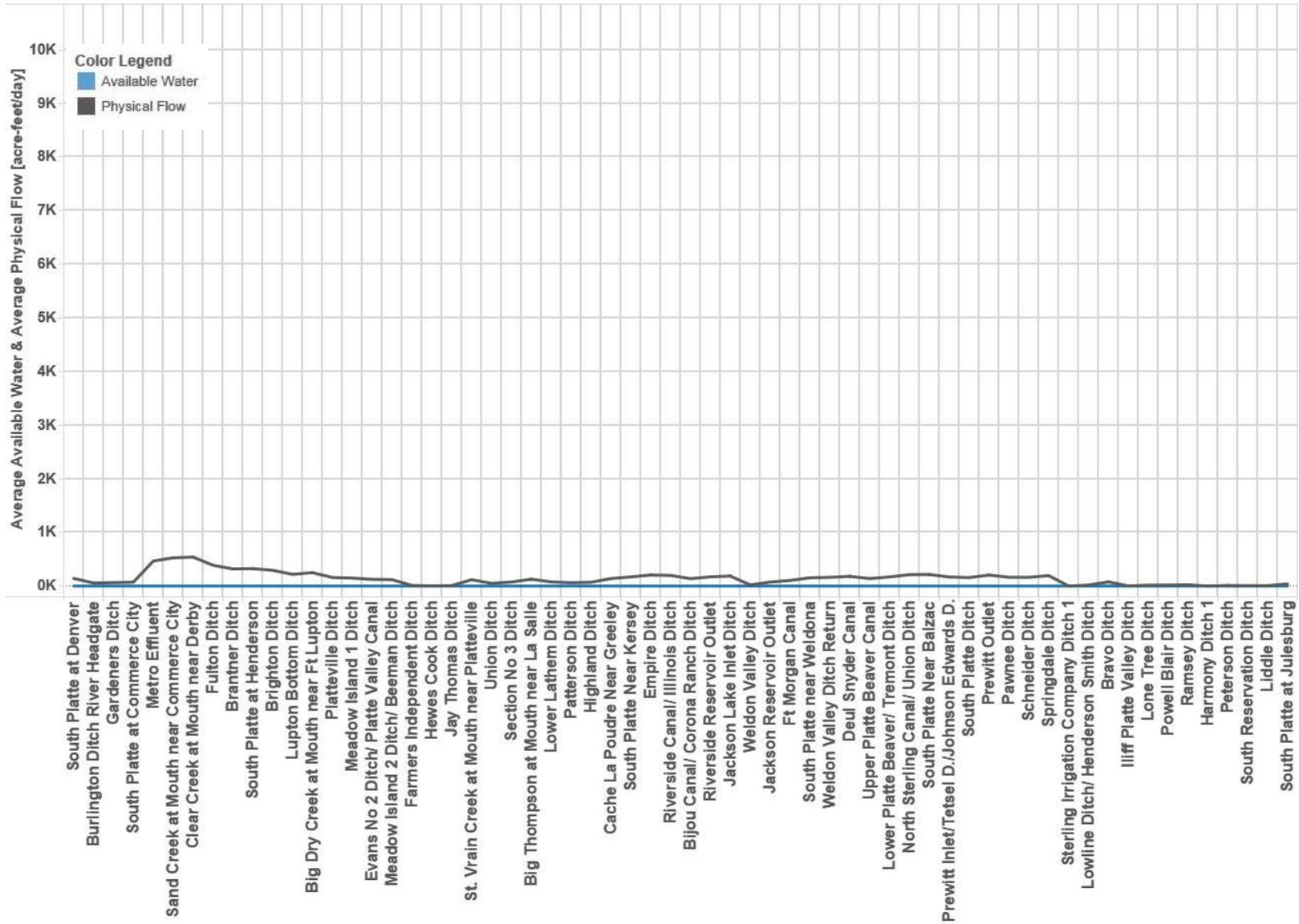


Figure 10. Historical Available Water and Physical Flow for Dry Irrigation Season (August 2002)

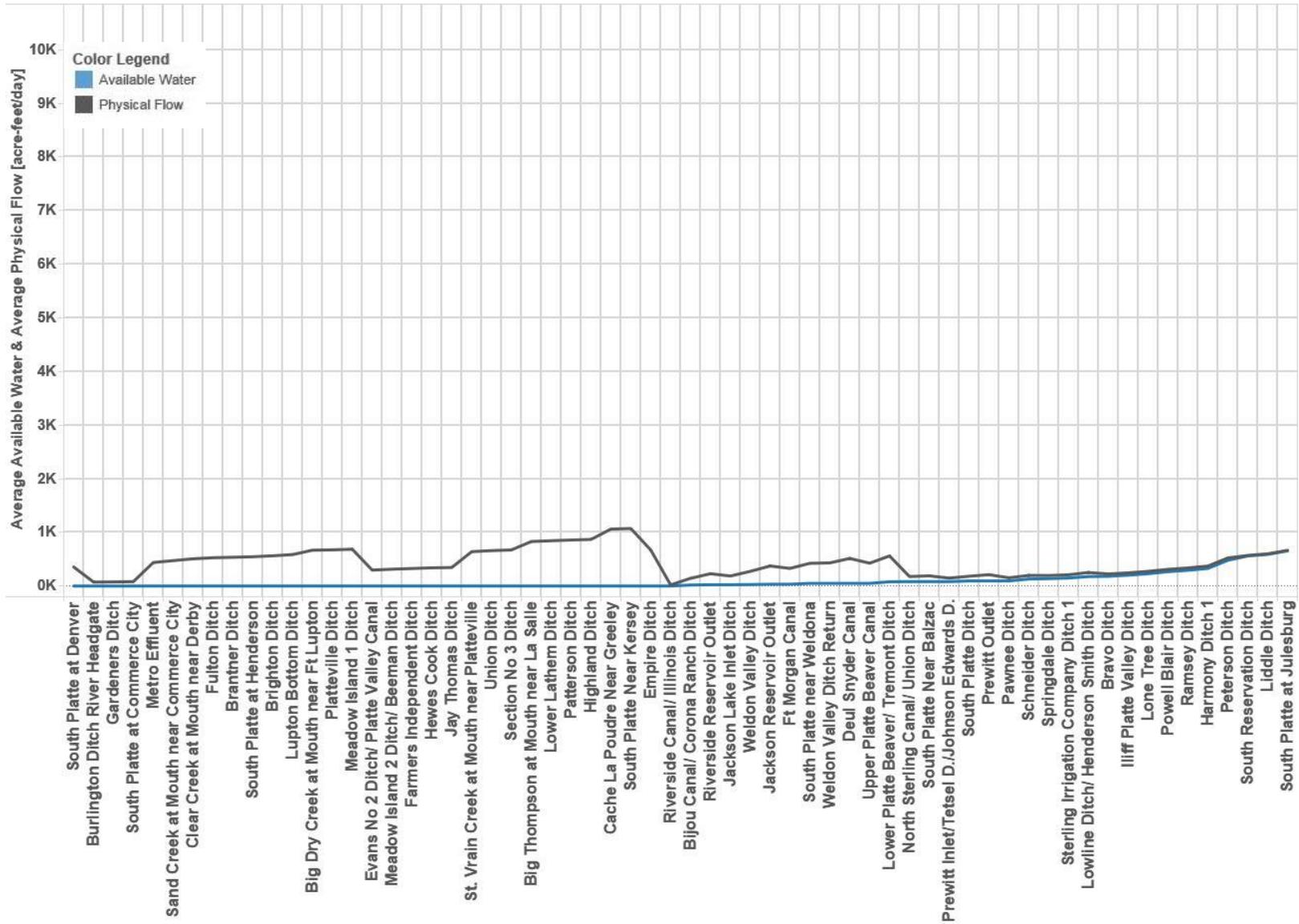


Figure 11. Historical Available Water and Physical Flow for Normal Winter Season (February 2010)

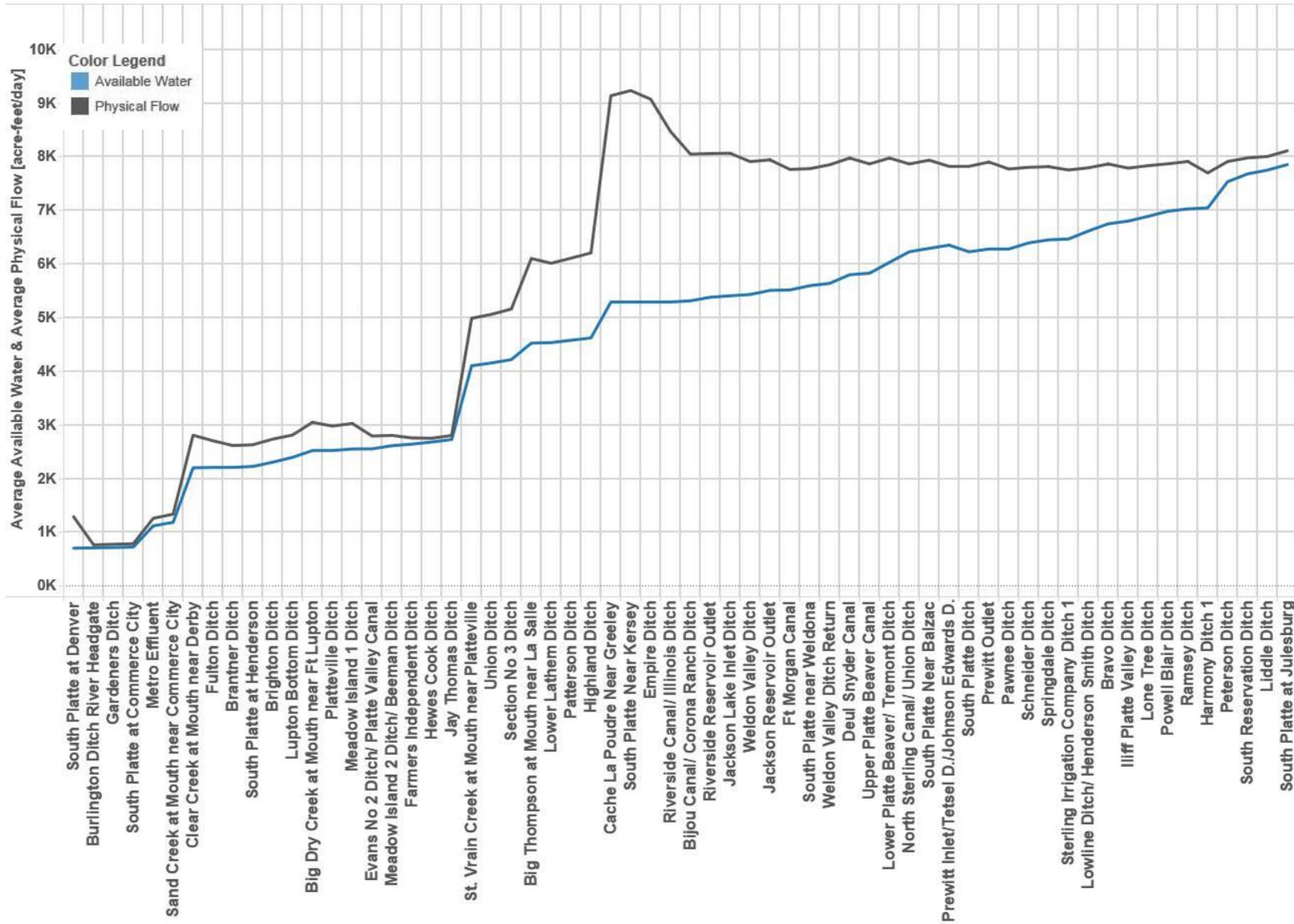


Figure 12. Historical Available Water and Physical Flow for Normal Runoff Season (June 2010)

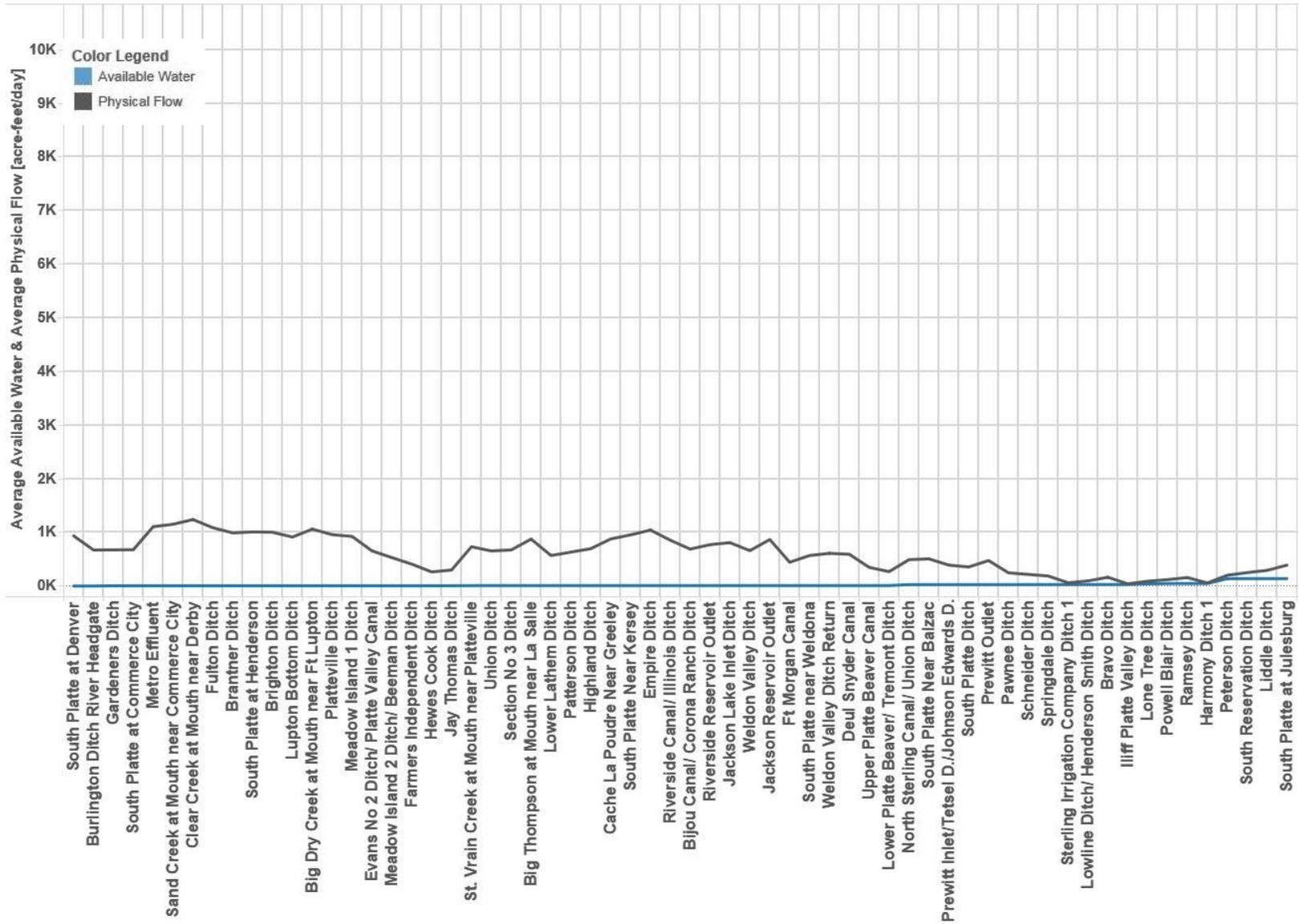


Figure 13. Historical Available Water and Physical Flow for Normal Irrigation Season (August 2010)

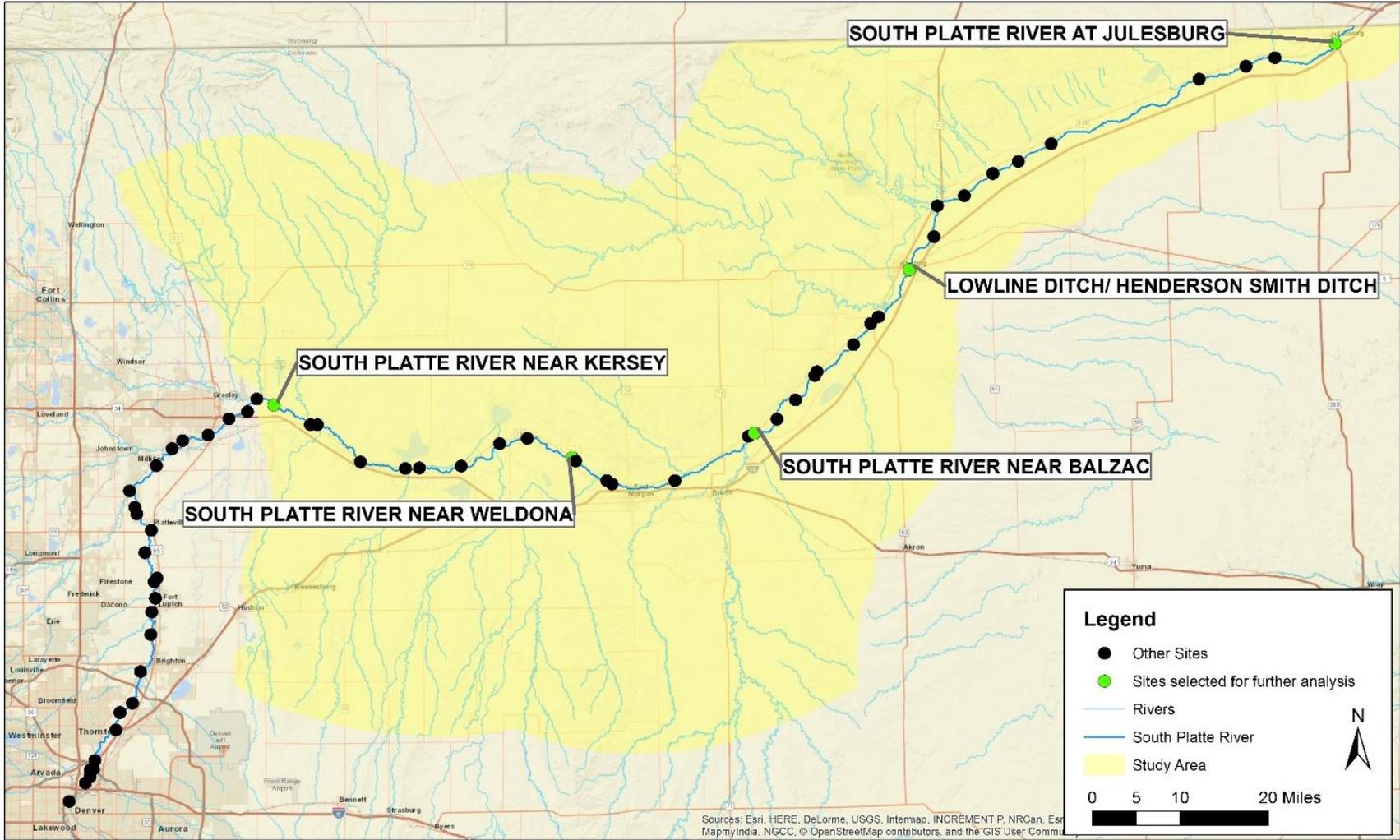


Figure 14. Selected Locations for Additional Analysis

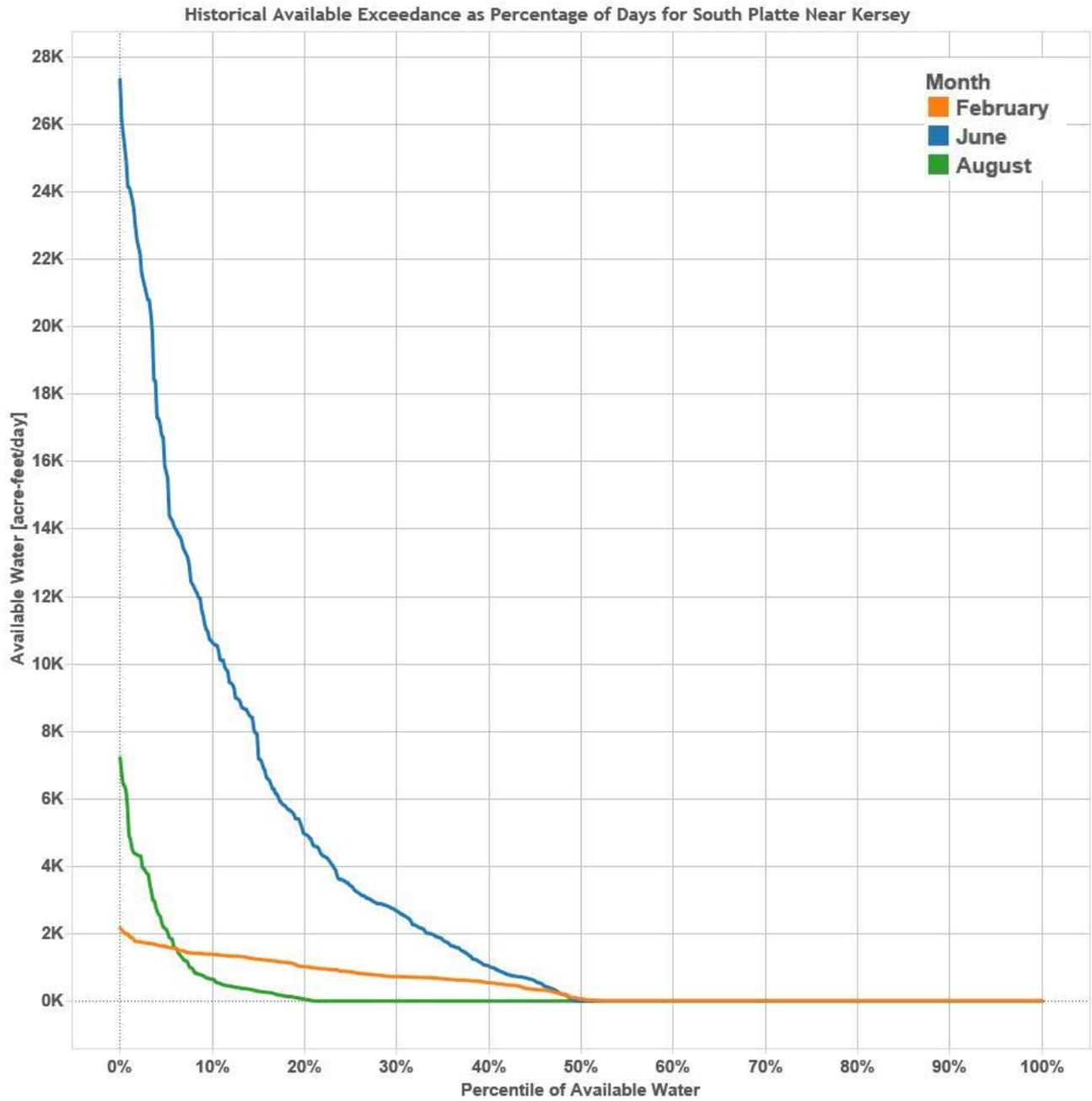


Figure 15. Historical Daily Available Water Exceedance, South Platte near Kersey

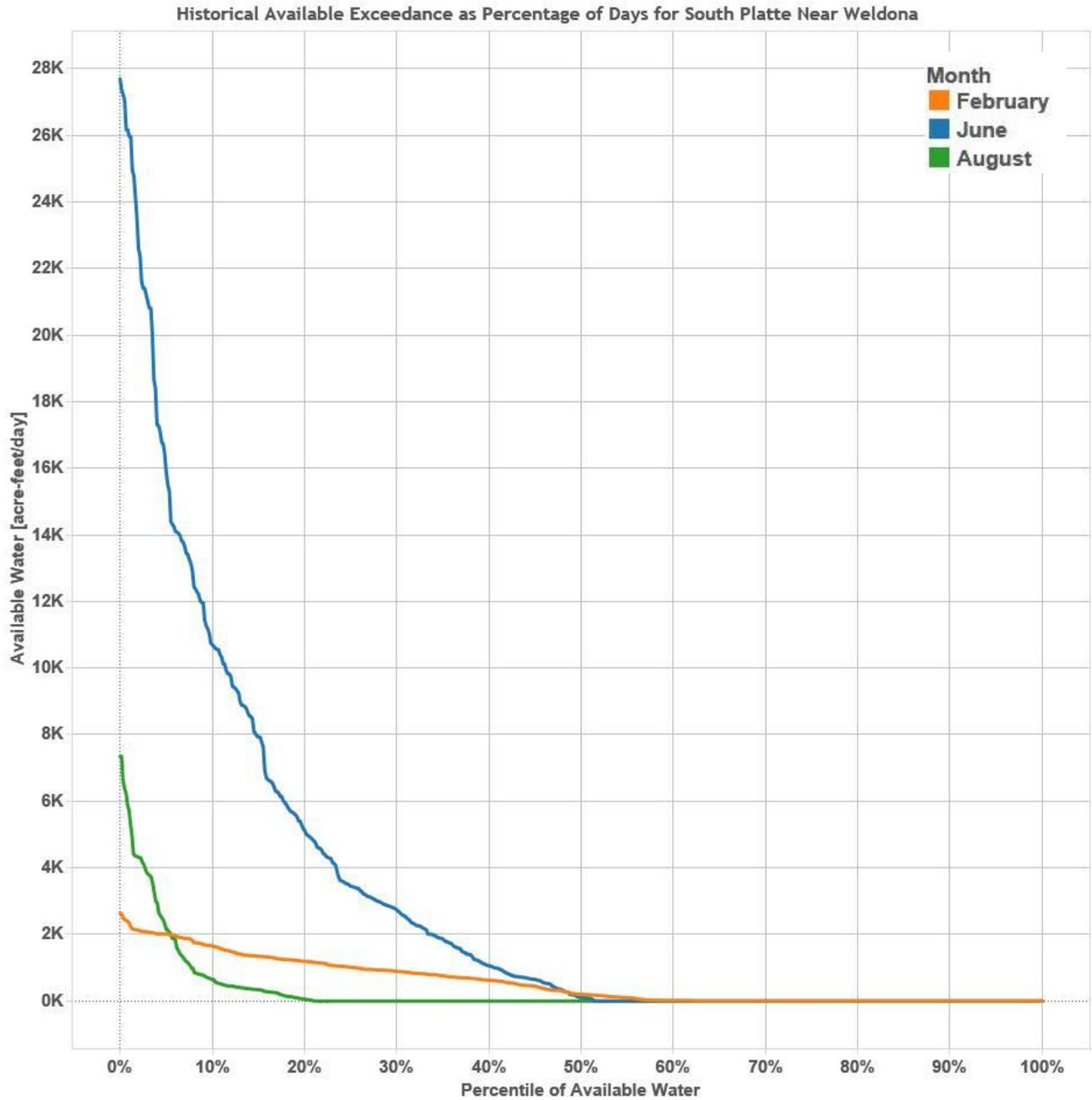


Figure 16. Historical Daily Available Water Exceedance, South Platte near Weldona

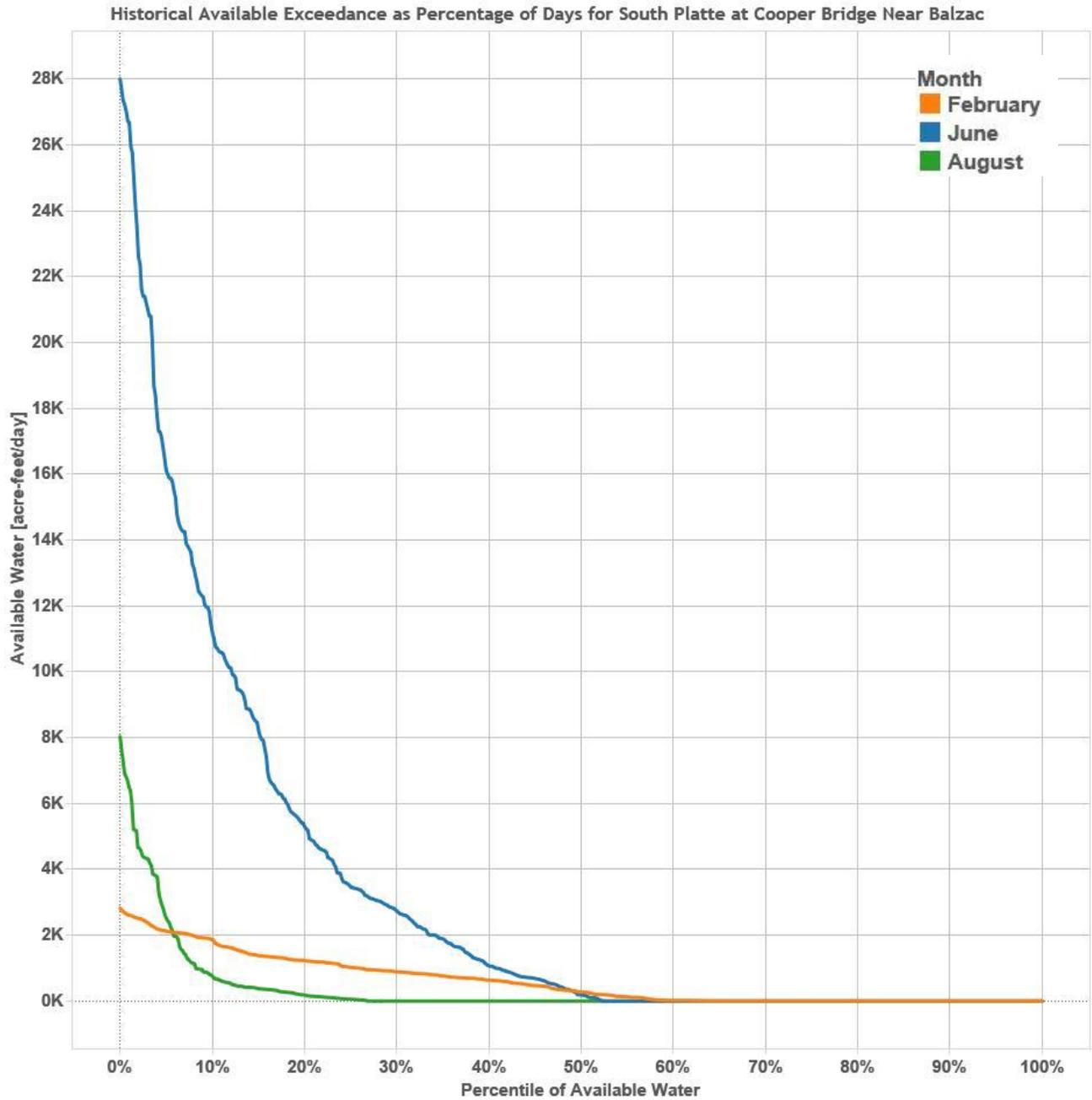


Figure 17. Historical Daily Water Exceedance, South Platte near Balzac

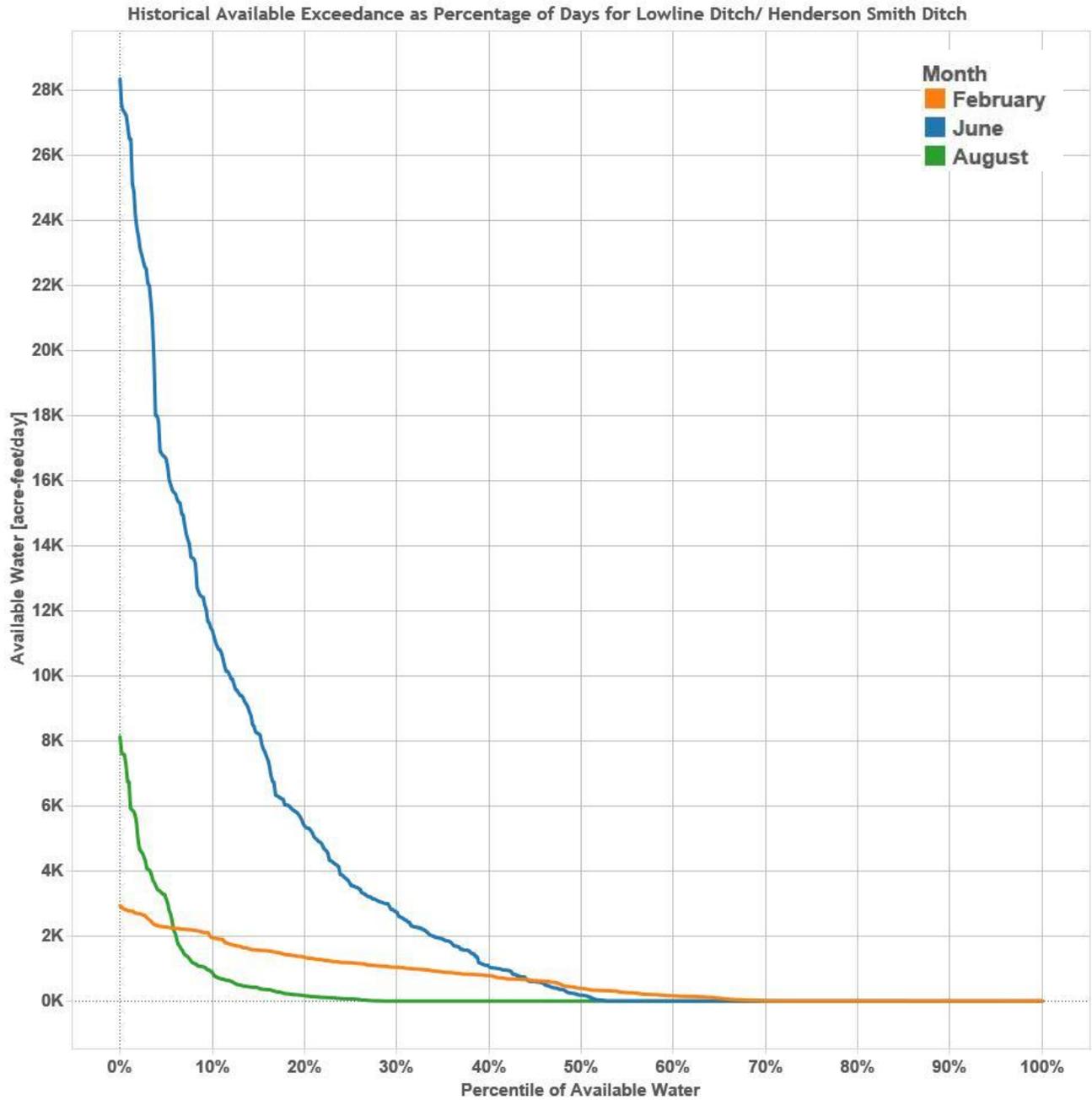


Figure 18. Historical Daily Available Water Exceedance, Lowline Ditch/ Henderson Smith Ditch

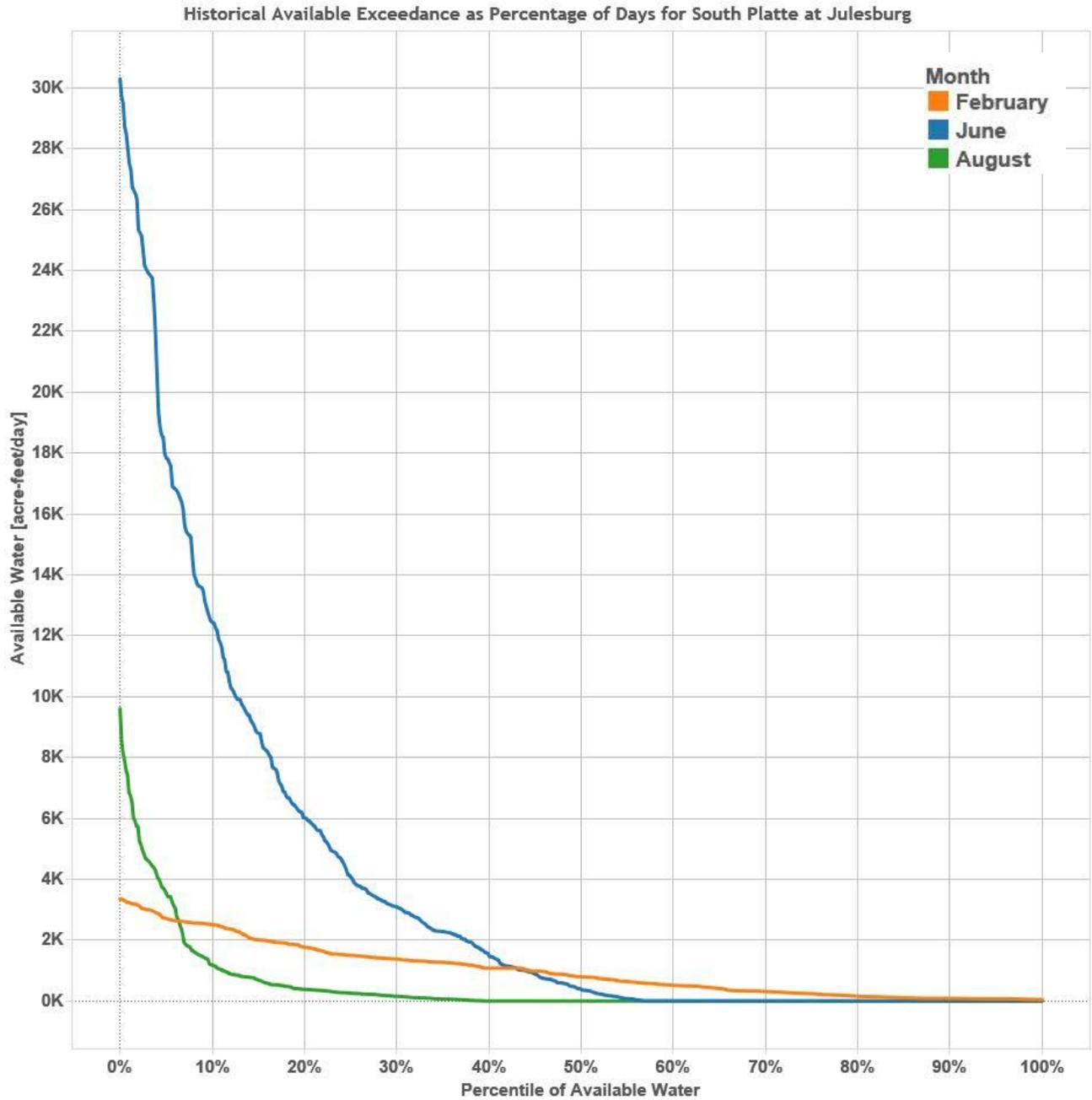


Figure 19. Historical Daily Available Water Exceedance, South Platte at Julesburg

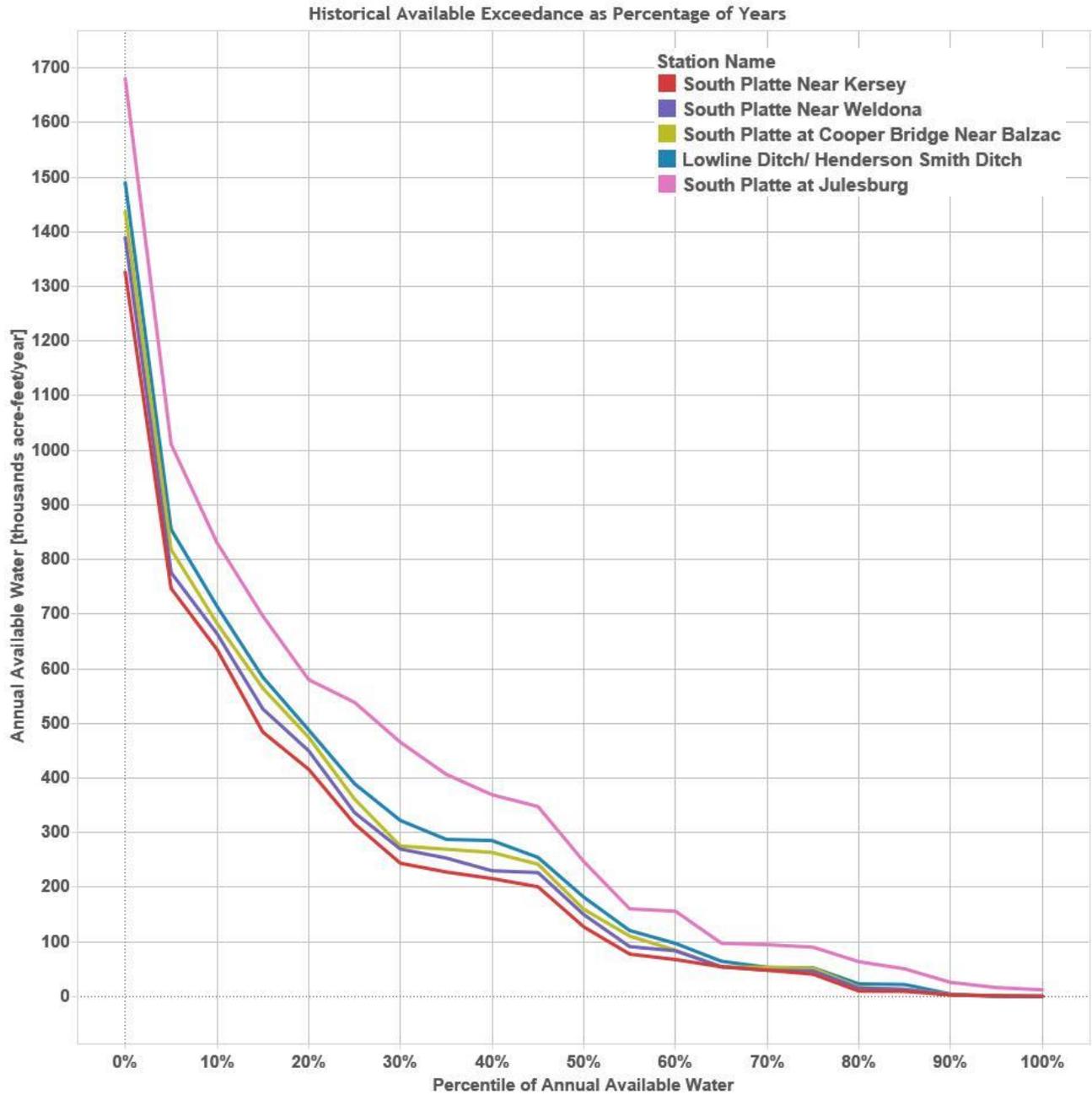


Figure 20. Historical Annual Available Water Exceedance

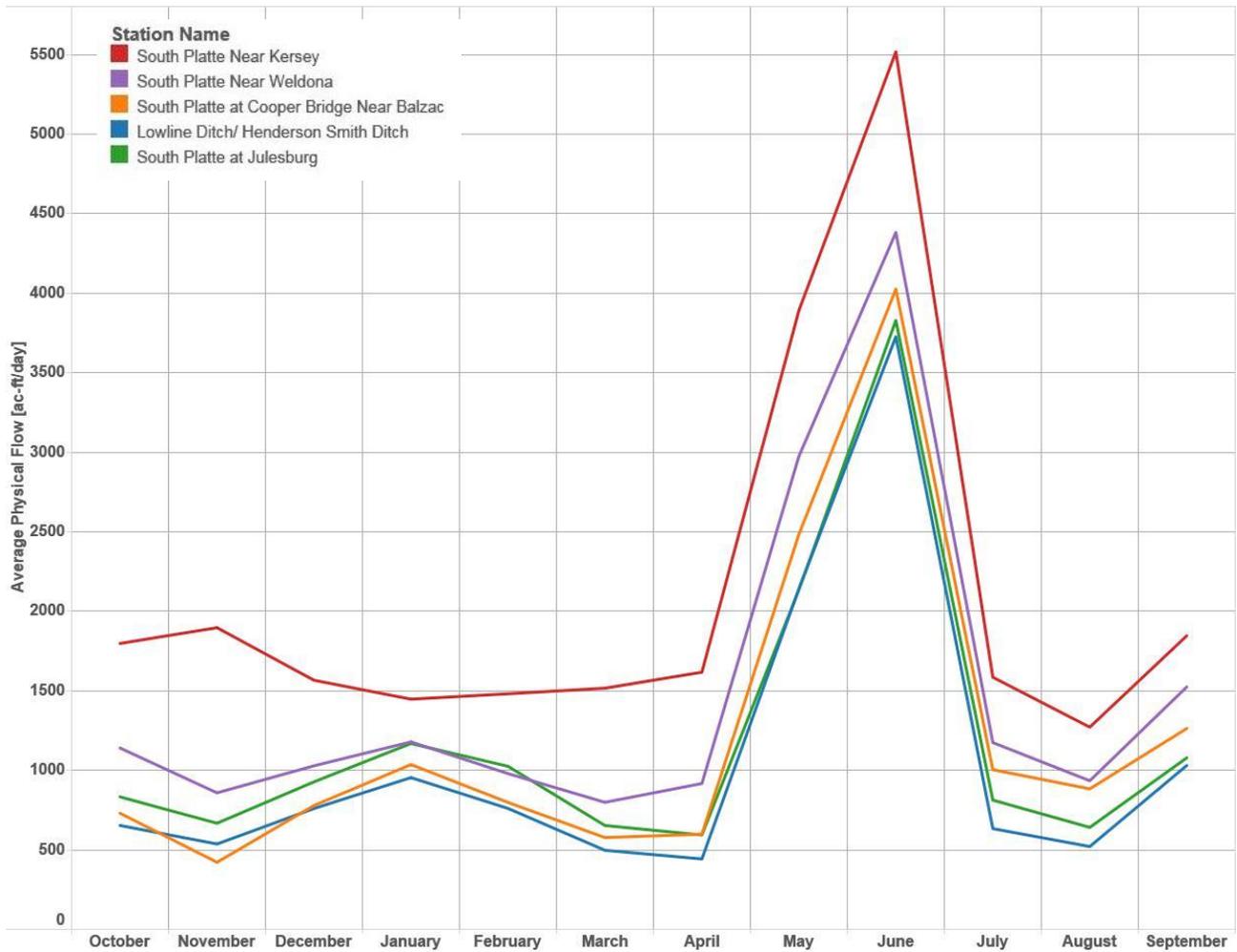


Figure 21. Average Monthly Physical Flows

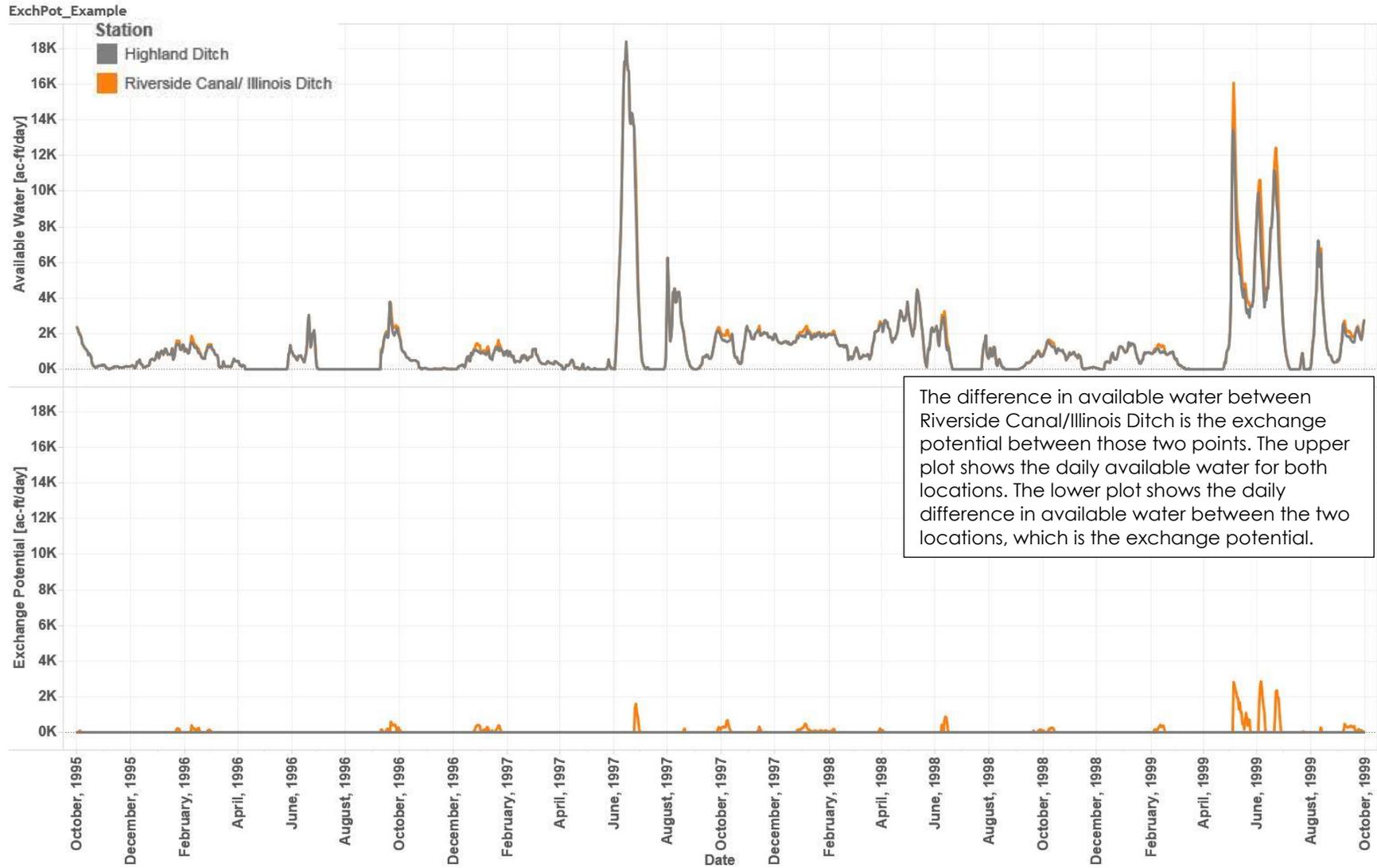


Figure 22. Example Exchange Potential between Highland Ditch and Riverside Canal/ Illinois Ditch

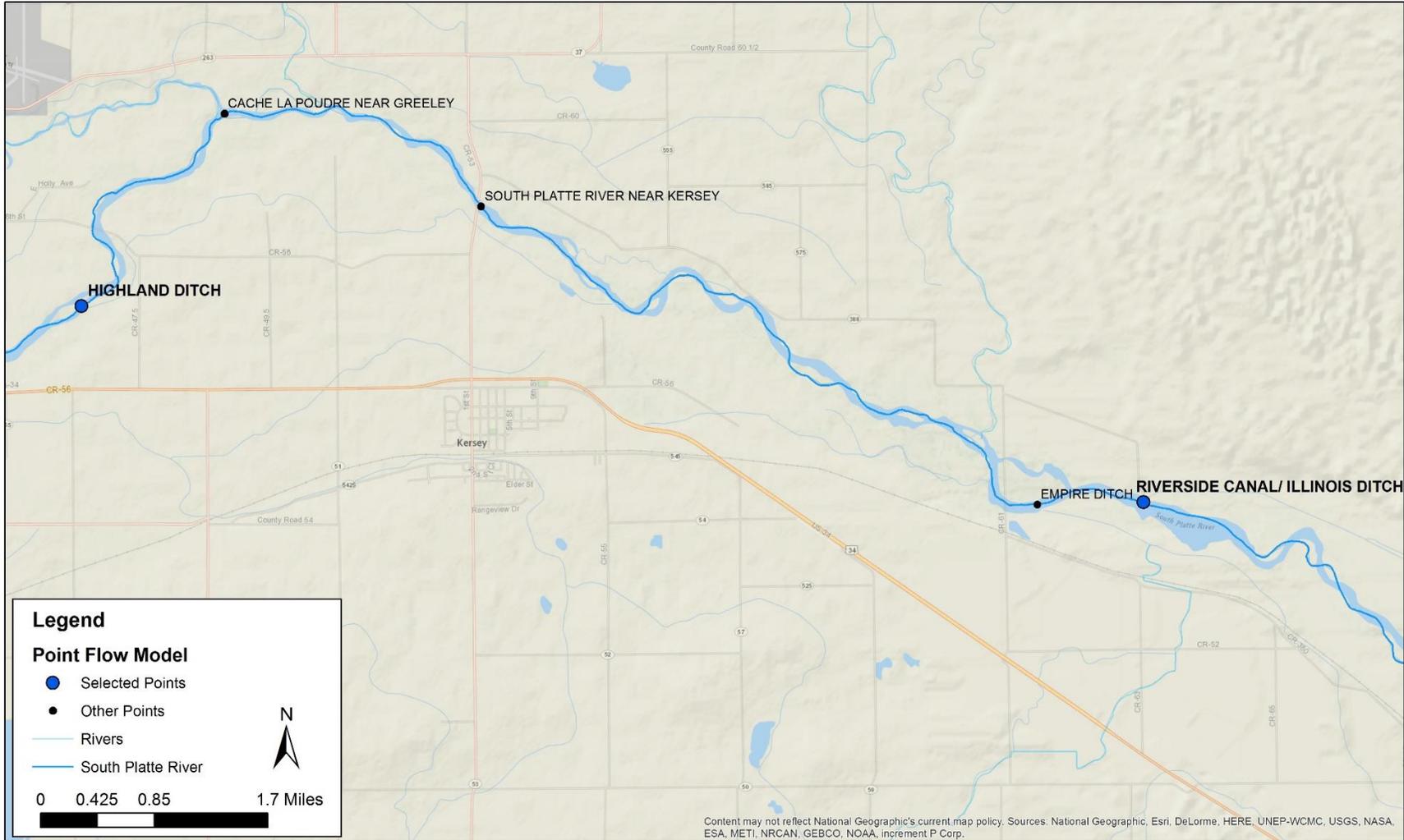


Figure 23. Highland Ditch and Riverside Canal/ Illinois Ditch Locations

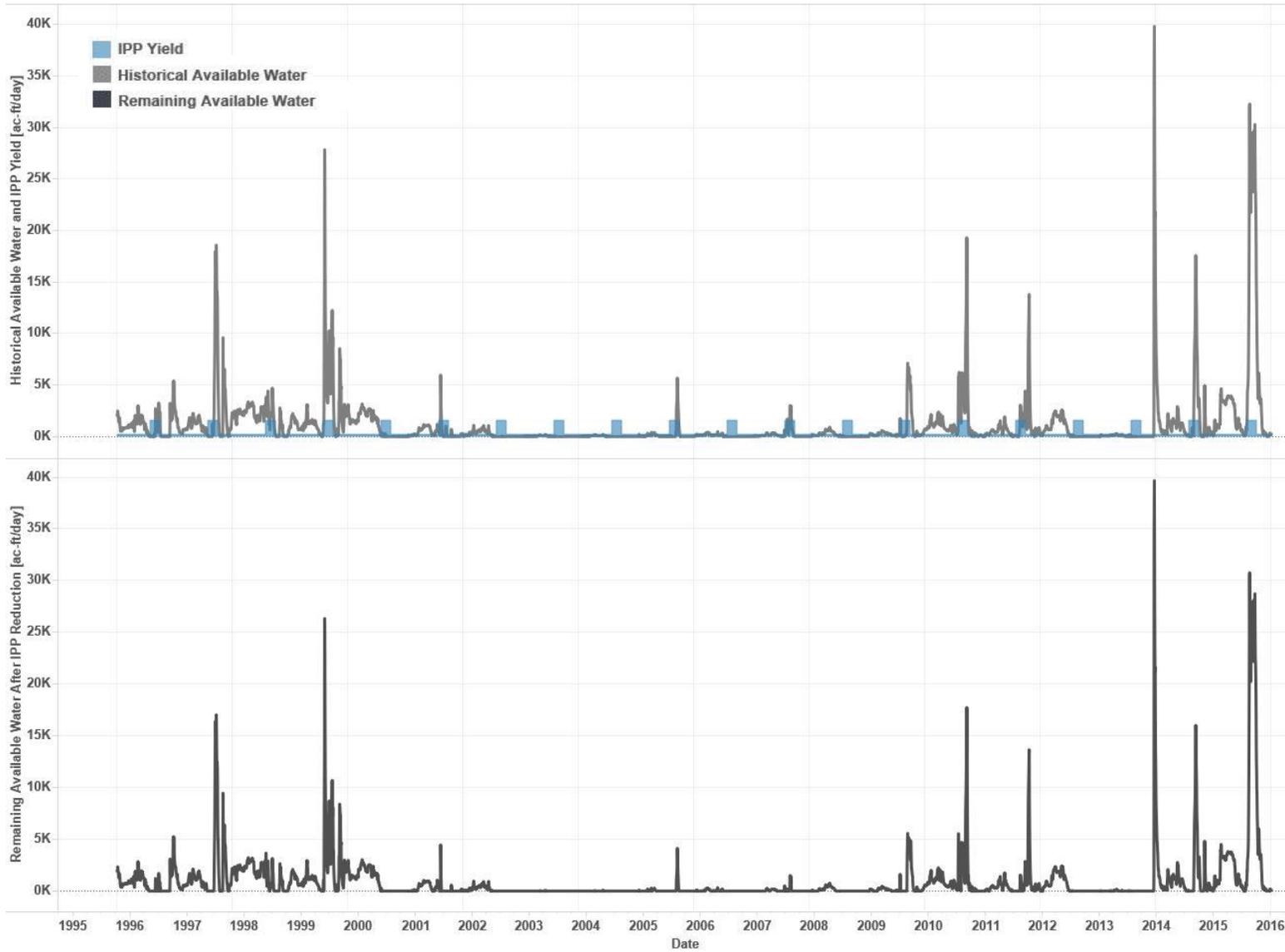


Figure 24. Remaining Available Water after IPP Adjustment for South Platte at Julesburg

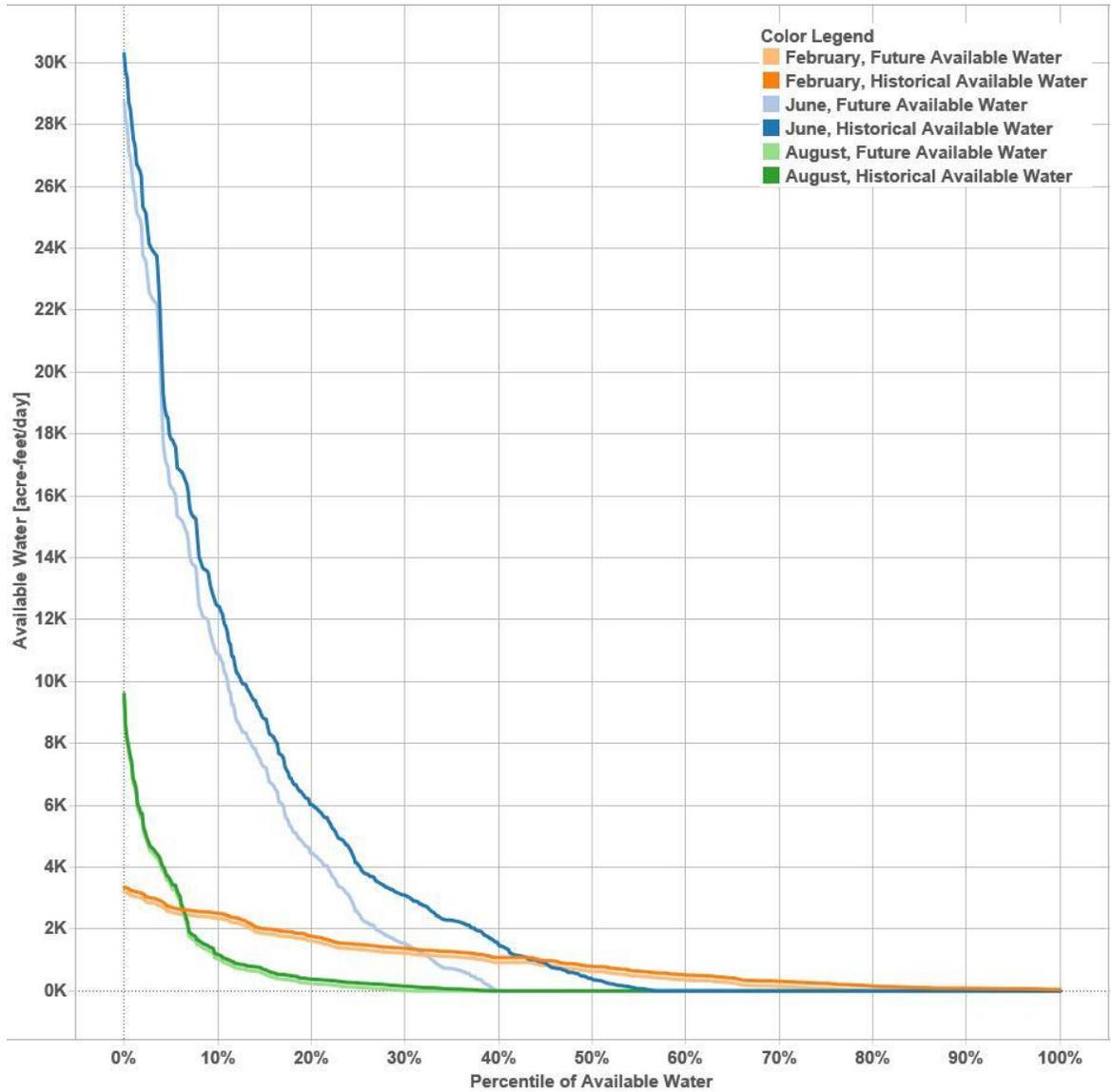


Figure 25. Historical and Future Available Water by Month for South Platte at Julesburg Gage

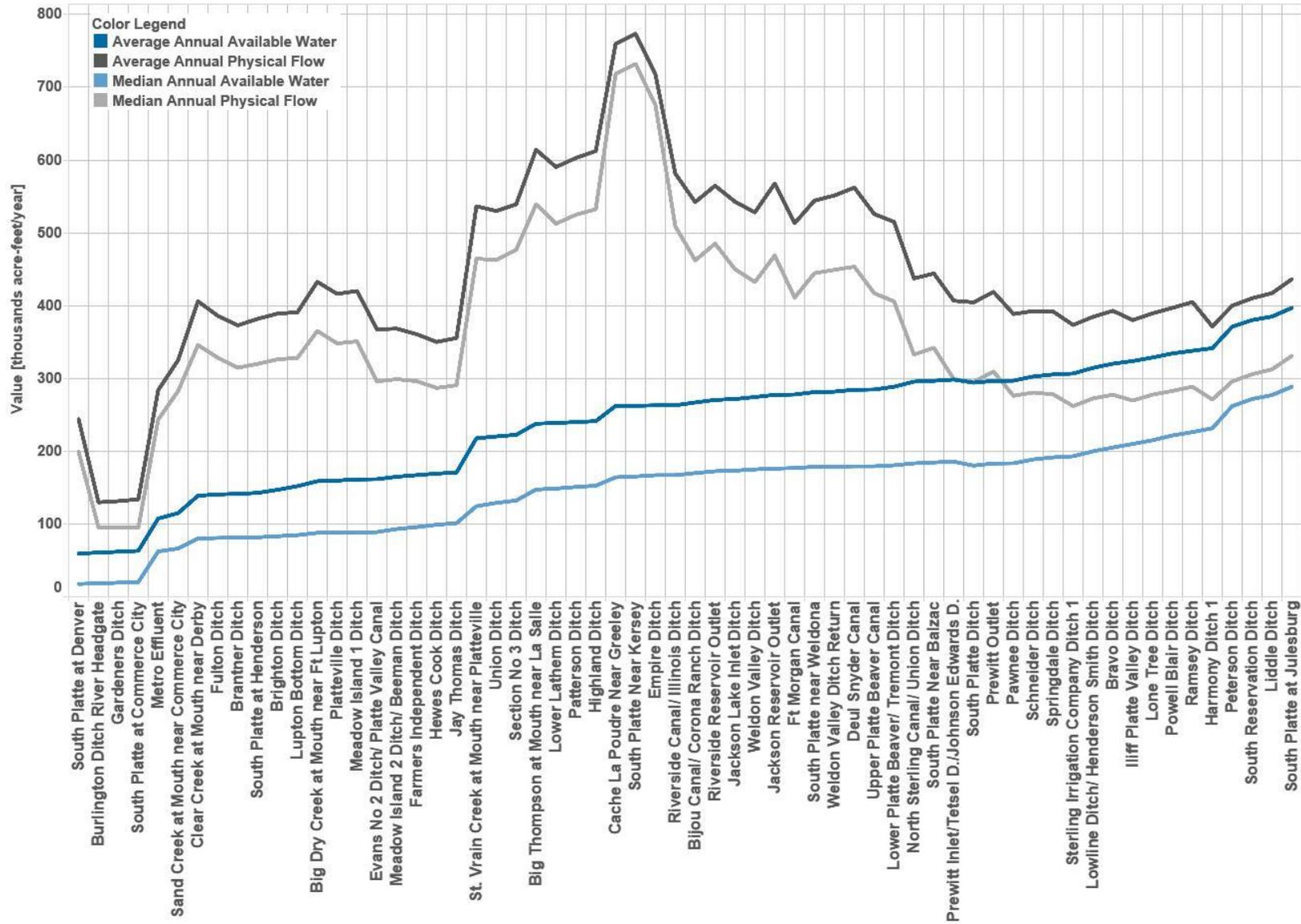


Figure 26. Historical Average and Median Physical Flow and Available Water

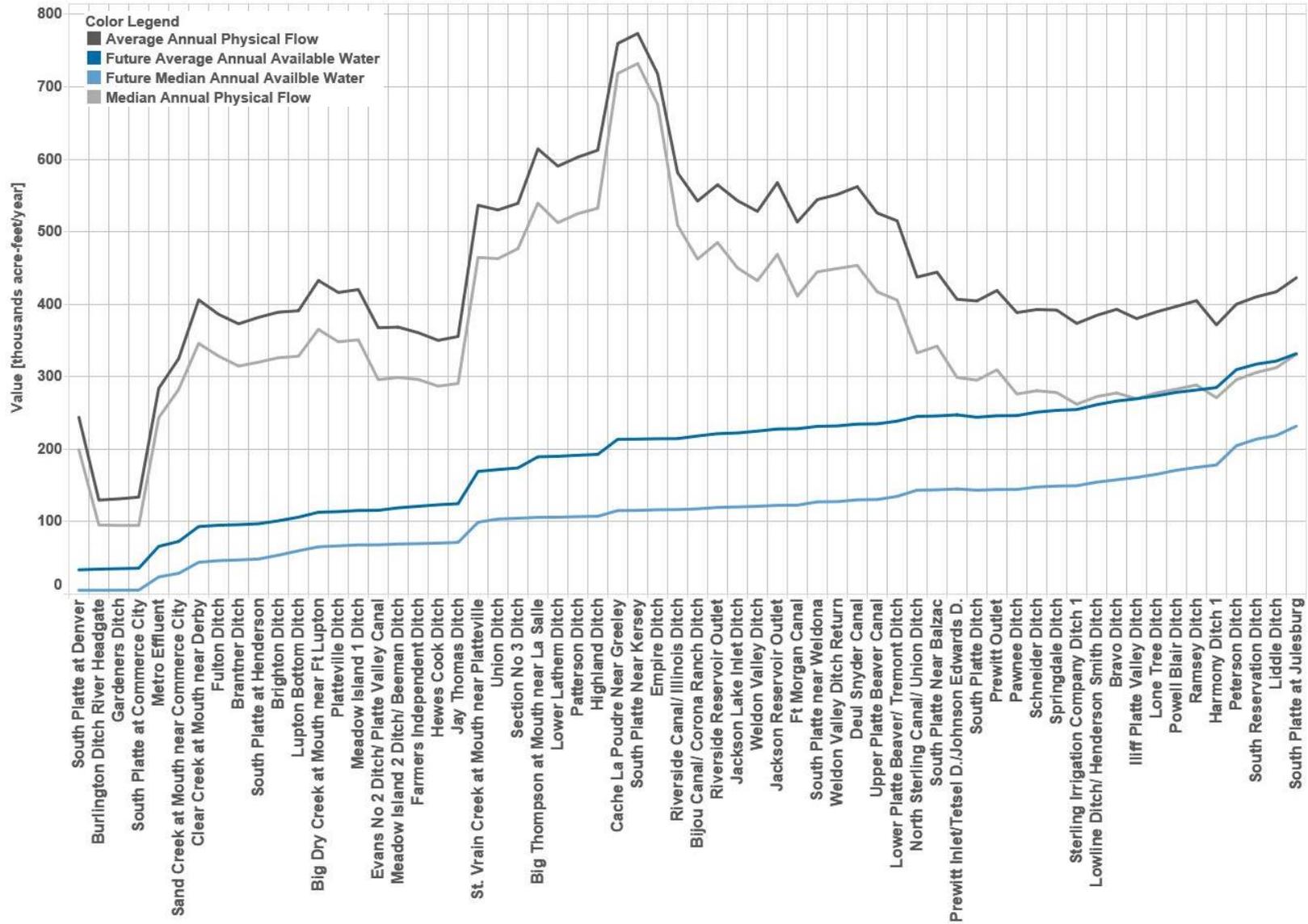


Figure 27. Future Average and Median Physical Flow and Available Water

APPENDIX F – DEMANDS TM

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SPSS Draft Memorandum

To: Chip Paulson, Stantec
From: Leonard Rice Engineers, Inc.
Date: July 7, 2017
Project: South Platte Storage Study
Subject: Task 2.1: Water Demands

The purpose of this memo is to document the methodology used to quantify agricultural and municipal & industrial (M&I) water demands for the South Platte Storage Study (SPSS). Estimates of the magnitude and location of water demand were needed for the feasibility analysis of potential storage sites.

Approach

A simplified approach for estimating water demands was adopted for the SPSS. Because no specific users of SPSS water have been identified, and because many different storage options were investigated, a standardized approach to determining demands for storage scenarios was needed. This approach allowed for a consistent comparison of storage scenarios on the basis of their ability to meet demands in the South Platte Basin.

For the purpose of the SPSS, water demand is defined as the future agricultural or M&I gap or shortage, assuming implementation of select identified projects and processes (IPPs). Future demands were used rather than existing demands to match with the use of future condition hydrology for the SPSS supply analysis.

The State of Colorado's 2010 Statewide Water Supply Initiative (SWSI 2010) was utilized as the basis for information about the water demands within the SPSS study area. Once the potential South Platte Basin water demands were quantified, the agricultural and M&I demands were distributed along the South Platte River into demand reaches based on major stream gages.

Demand Reaches

To simplify the analysis of demands that could be met from SPSS storage sites, future demand estimates were aggregated by stream reach along the South Platte. From upstream to downstream, the demand reaches utilized for the SPSS include:

- Upstream of the South Platte River at Denver Gage (Upstream of Denver Gage)
- South Platte River at Denver gage to South Platte River Near Kersey gage (Denver to Kersey)
- South Platte River Near Kersey gage to South Platte River at Cooper Bridge near Balzac gage (Kersey to Balzac)
- South Platte River at Cooper Bridge near Balzac gage to South Platte River at Julesburg gage (Balzac to Julesburg)

Agricultural Demand

Derivation of the SPSS agricultural demands was based on the SWSI 2010 analysis of estimated 2050 agricultural demand by basin as described in SWSI 2010 Appendix I – Technical Memorandum State of Colorado Current and 2050 Agricultural Demands. According to SWSI 2010, future irrigated acres in the South Platte basin may decrease by 47,000 to 58,000 acres due to urbanization alone, under low and high population growth scenarios, respectively. The South Platte basin is one of the basins wherein the largest expected loss of irrigated acres due to urbanization is expected to occur.

2050 agricultural demands in SWSI 2010 consider a number of factors including, but not limited to, historical agricultural water use and irrigated acreage, urbanization of existing irrigated lands, agricultural to municipal water transfers, and water management decisions. The impact of these factors on future agricultural demands was quantified in SWSI 2010 based on future growth estimates, municipal water demand gaps that will be met by 2050, and interviews with water management agencies across the state. Based on the factors considered in developing the 2050 agricultural demands and shortages, we have assumed that implementation of IPPs is implicit in the 2050 shortages.

SWSI 2010 defines agricultural shortage as the difference between the water supply limited consumptive use and the irrigation water requirement of the irrigated lands. Within the South Platte Basin, SWSI 2010 found the current agricultural shortage to be 379,000 AF and the 2050 agricultural shortage to be 274,000 AF. Based on these results, SWSI 2010 concluded that the 2050 agricultural shortage in the South Platte Basin would be 72.3% ($274,000/379,000 = 72.3\%$) of the current agricultural shortage.

To determine current agricultural demand, SWSI 2010 considered the current extent of irrigated acreage and the associated irrigation water requirement and shortage within each Water District. The Water District specific current agricultural demands were then summed to determine the agricultural demands and shortages for the South Platte Basin. The methodology used for estimating the 2050 agricultural shortage in SWSI 2010 did not look at the individual Water Districts', instead it looked at the South Platte Basin as a whole.

Therefore for the SPSS, following process was used to develop and distribute the future agricultural shortage by SPSS demand reach:

1. The 10-year average agricultural demand shortages by Water District were obtained from Appendix B to *Appendix I – Technical Memorandum State of Colorado Current and 2050 Agricultural Demands* of SWSI 2010.
2. The 10-year average current agricultural demand shortage for each Water District was then multiplied by 72.3% to calculate the future agricultural demand.
3. Each Water District was associated with a SPSS demand reach based on the location of irrigated area. The agricultural demand was further broken out as being mainstem or tributary based on the sources of water used to satisfy a majority of the irrigated area within each District.

The calculation of future agricultural demand by SPSS demand reach is presented in Table 1 below.

TABLE 1
Calculation of Future Agricultural Demands
 (all values in AFY)

Demand Reach	SWSI 2010 Current Ag Demand			Calculated Future Ag Demand		
	Water District	Mainstem	Tributary	Water District	Mainstem	Tributary
Upstream of Denver Gage	WD8		1,542	WD8		1,115
	WD9		369	WD9		267
	<i>Reach Total</i>	-	1,911	<i>Reach Total</i>	-	1,382
Denver to Kersey	WD2	98,738		WD2	71,388	
	WD3		90,505	WD3		65,435
	WD4		39,756	WD4		28,744
	WD5		40,656	WD5		29,394
	WD6		20,928	WD6		15,131
	WD7		125	WD7		90
	<i>Reach Total</i>	98,738	191,970	<i>Reach Total</i>	71,388	138,794
Kersey to Balzac	WD1	64,515		WD1	46,644	
	<i>Reach Total</i>	64,515	-	<i>Reach Total</i>	46,644	-
Balzac to Julesburg	WD64	15,732		WD64	11,374	
	<i>Reach Total</i>	15,732	-	<i>Reach Total</i>	11,374	-
BASIN TOTALS		178,985	193,881		129,406	140,176

Scaling Factor 72.3%

The demand for agricultural water is not consistent throughout the year; instead it varies based on factors such as crop demand for water, outside temperatures, and well pumping and corresponding depletions. For the purpose of SPSS we determined the monthly distribution for agricultural water in wet, dry, and average years based on the irrigation water requirement for irrigated lands in Water Division 1 and representative depletion patterns for irrigation well users.

Development of the monthly distribution for agricultural water started with an evaluation of the amount of irrigated lands satisfied by surface water supplies versus the amount of irrigated lands satisfied by both surface water and ground water supplies. Our analysis found that, of the average annual 512,081 acres irrigated in Water Districts 1, 2, and 64, 41% of irrigated lands are supplied by surface water sources alone and 59% of irrigated lands are supplied by both surface water and ground water sources.

To determine the agricultural demand pattern for irrigated lands satisfied by surface water supplies alone, we relied upon data contained in the State of Colorado's SP2008 StateCU model. This model utilizes a study period of 1950 through 2006 and provides information to calculate, among other things, the irrigation water requirement for irrigated lands throughout the South Platte basin. For the purpose of SPSS, 2002 was selected as a representative dry year and 1983 was selected as a representative wet year. Utilizing the SP2008 StateCU model we developed an average annual agricultural demand pattern for irrigated lands based on the irrigation water requirements for all irrigated area as well as the agricultural demand pattern for irrigated lands in the representative dry and wet years.

To determine the agricultural demand pattern for irrigated lands satisfied by surface water and ground water supplies, we obtained the projected well depletion patterns, prior to application of replacement supplies, from Central Colorado Water Conservancy District (CCWCD) and Lower South Platte Water Conservancy District (LSPWCD). Utilizing projected well depletion patterns for the two Districts we developed an aggregated pattern of well depletions representative of well users throughout the SPSS study area.

Finally, to develop a single agricultural demand pattern representative of all irrigated lands within the SPSS study area we assumed that 41% of the agricultural demand pattern would be represented by the wet, dry, and average irrigation water requirement demand patterns for lands satisfied by surface water supplies alone, and 59% of the agricultural demand pattern would be represented by the aggregated pattern of well depletions for lands satisfied by surface water and ground water supplies.

Table 2 provides the monthly agricultural demand pattern for the South Platte basin in wet, dry and average years, presented as a percentage of the total annual agricultural demand.

TABLE 2
Agricultural Demand Pattern
 (all values are % of total demand)

Month	Average Year	Dry Year (2002)	Wet Year (1983)
Jan	5.8%	6.3%	5.3%
Feb	5.5%	6.0%	5.1%
Mar	4.8%	5.2%	4.4%
Apr	4.7%	5.8%	3.7%
May	7.3%	8.2%	3.9%
Jun	12.3%	12.8%	7.3%
Jul	16.3%	15.7%	20.0%
Aug	15.2%	12.7%	20.5%
Sep	10.9%	9.8%	14.0%
Oct	6.6%	6.2%	6.1%
Nov	4.7%	5.1%	4.3%
Dec	5.9%	6.4%	5.4%

Municipal Demand

Derivation of the SPSS municipal demands was based on the SWSI 2010 analysis of 2050 M&I gap analysis as described in SWSI 2010 *Appendix H – State of Colorado 2050 Municipal & Industrial Water Use Projections* and SWSI 2010 *Appendix J – Technical Memorandum 2050 Municipal and Industrial Gap*

Analysis. According to SWSI 2010, the 2050 M&I and self-supplied industrial (SSI) water supply gap is a function of the 2050 net new water needs minus the 2050 IPPs.

SWSI 2010 presents the South Platte Basin M&I demands in terms of regions. The SWSI South Platte regions which represent the SPSS study area include Lower South Platte Region, Northern Region, Denver Metro, and South Metro. For the purpose of SPSS, the SWSI 2010 M&I demands were disaggregated by County, then assigned to a SPSS demand reach based on the Counties within each reach. The following details the process used to develop and distribute the future M&I demands by SPSS demand reach:

1. For the SPSS study area, the SWSI regions and counties represented in each of those regions were identified.
2. The medium M&I gap at alternative IPP success rate of 60% for each SWSI region represented in the SPSS study area was obtained from *Appendix J – Technical Memorandum 2050 Municipal and Industrial Gap Analysis* of SWSI 2010
3. Based on the data available in Table 3-2 of SWSI 2010 *Appendix H – State of Colorado 2050 Municipal & Industrial Water Use Projections*, the amount of demand gap by county was calculated as the difference between the 2050 high water demand with passive conservation minus the 2008 water demand with passive conservation.
4. The SWSI 2010 medium gap at alternative IPP success rate was then distributed by county based on the percentage of demand gap by the counties within each SWSI region.
5. Based on the location of the majority of the population and future growth within each county, each county and the associated M&I demand was assigned to a specific SPSS demand reach.

The calculation of future M&I demands by county is presented in Table 3 below. Table 4 shows the association of county by SPSS demand reach.

TABLE 3
Calculation of Future M&I Demands
 (all values in AFY)

SWSI Region	Medium Gap at Alternative IPP Success Rate (60%)	Counties Represented	2050 High Water Demand w/ Passive Conservation	2008 Water Demand w/ Passive Conservation	2050 Demand minus 2008 Demand	% of Demand Gap by County w/in SWSI Region	Distribute Gap Based on Difference Between 2008 and 2050 Demand
Lower Platte Region	16,600	Morgan	16,000	8,000	8,000	57.1%	9,486
		Logan	14,000	8,000	6,000	42.9%	7,114
		Sedgwick	1,000	1,000	-	0.0%	-
		Washington	2,000	2,000	-	0.0%	-
Northern	85,900	Boulder	88,000	59,000	29,000	17.3%	14,828
		Larimer	114,000	59,000	55,000	32.7%	28,122
		Weld	137,000	53,000	84,000	50.0%	42,950
Denver Metro	59,300	Adams	125,000	69,000	56,000	36.8%	21,847
		Broomfield	20,000	11,000	9,000	5.9%	3,511
		Denver	160,000	112,000	48,000	31.6%	18,726
		Jefferson	133,000	94,000	39,000	25.7%	15,215
South Metro	71,500	Arapahoe	173,000	104,000	69,000	56.6%	40,439
		Douglas	93,000	46,000	47,000	38.5%	27,545
		Elbert	9,000	3,000	6,000	4.9%	3,516
TOTAL	233,300						233,300

The typical monthly pattern for M&I demands will be calculated by others.

Results

Table 4 below presents a summary of the agricultural and M&I future demands by SPSS reach.

TABLE 4
SPSS Agricultural and M&I Demands by SPSS Demand Reach
 (all values in AFY)

Demand Reach	Ag Future Demand			M & I Future Demand		Total Demand
	Water District	Mainstem	Tributary	County	Total	
Upstream of Denver Gage	WD8		1,115	Denver	18,726	
	WD9		267	Arapahoe	40,439	
				Jefferson	15,215	
				Douglas	27,545	
				Elbert	3,516	
	<i>Reach Total</i>	-	1,382	<i>Reach Total</i>	105,441	106,823
Denver to Kersey	WD2	71,388		Weld	42,950	
	WD3		65,435	Adams	21,847	
	WD4		28,744	Larimer	28,122	
	WD5		29,394	Boulder	14,828	
	WD6		15,131	Broomfield	3,511	
	WD7		90			
	<i>Reach Total</i>	71,388	138,794	<i>Reach Total</i>	111,259	321,440
Kersey to Balzac	WD1	46,644		Morgan	9,486	
	<i>Reach Total</i>	46,644	-	<i>Reach Total</i>	9,486	56,130
Balzac to Julesburg	WD64	11,374		Logan	7,114	
				Sedgwick	0	
				Washington	0	
	<i>Reach Total</i>	11,374	-	<i>Reach Total</i>	7,114	18,489
BASIN TOTALS		129,406	140,176		233,300	502,882

Source of Data:

- Agricultural demand based on the following parts of SWSI 2010:

- Appendix I – Technical Memorandum State of Colorado Current and 2050 Agricultural Demands
- Appendix B to Appendix I - South Platte and Rio Grande Basins Agricultural Demands Methodology
- Table 2. South Platte Basin 10-year Average Agricultural Demand

- M&I demand based on the following parts of SWSI 2010:

- Appendix H - State of Colorado 2050 Municipal & Industrial Water Use Projections
- Table 3-2 M&I Forecast by County with Passive Conservation
- Appendix J - Technical Memorandum 2050 Municipal and Industrial Gap Analysis

APPENDIX G – WATER QUALITY TM

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SPSS Memorandum

To: Chip Paulson - Stantec
From: Leonard Rice Engineers, Inc.
Date: September 18, 2017
Subject: Task 2.2 - Water Quality Analysis for South Platte Storage Study Water Demands

In support of Subtask 2.2 of the South Platte Storage Study (“SPSS”), Leonard Rice Engineers, Inc. (“LRE”), has performed a high level analysis of water quality requirements for demand types within the study area. The elements included in this water quality analysis include:

- The identification of Colorado Water Quality Control Commission’s (“WQCC”) stream segments within the Study Area and those stream segments further analyzed as part of SPSS.
- A categorization of water demand types and associated water quality requirements consistent with the WQCC State Use Classification (e.g., domestic water supply, recreation, agriculture, aquatic life).
- A review of water quality indicators for the water use categories and review of the WQCC Regulation 93 list of impaired waters to identify segments where water quality requirements are not met.
- A summary of the WQCC List of Impaired Waters data by identified segments, and selection of key indicators to be used for screening water quality for future potential storage projects.
- And a list of treatment needs to be considered when storing and utilizing South Platte sources for multi-use benefits.

WQCC Stream Segments within the Study Area

The SPSS Study Area overlaps portions or the entirety of nine counties as shown on Figure 1. Throughout the State of Colorado, WQCC has adopted designated use classifications and numeric water quality standards for the State’s streams, lakes, and reservoirs. Segments are divided by designated use classifications and numeric water quality standards.

Stream segment use classifications are to protect uses of the respective stream segment. In Colorado there are five use classification groups: (1) agriculture; (2) aquatic life; (3) domestic water supply; (4) recreation; and (5) wetlands. Aquatic life classifications include (1) cold water aquatic life class 1; (2) warm water aquatic life class 1; or (3) class 2 waters which can be either cold and warm water aquatic life. The classification use for recreation is further subdivided into class “E” (existing primary contact use), class “P” (potential primary contact use), class “N” (not primary contact use), and class “U” (undetermined use).

LRE identified seven stream segments: two river segments on the mainstem of the South Platte River, two segments containing associated tributaries of the South Platte River, and three segments for lakes and reservoirs in the SPSS Study Area. LRE then assessed each segment to determine if it should be included or excluded from further consideration in this phase of the SPSS. Table 1 shows the seven

individual stream segments in the Study Area, descriptions, designated use classifications, and reasoning for inclusion or exclusion of the segment from further review in this memo. Figure 1 shows the location of each of these seven segments.

Of the seven identified stream segments reviewed in Table 1, three segments were found to be key stream segments for the water quality review for selecting indicators to use as a screening-level assessment of water quality for the SPSS. The three stream segments identified for further review are:

- Mainstem of South Platte River from confluence with St. Vrain to Weld/Morgan County line (COSPMS01B);
- Mainstem of South Platte River from Weld/Morgan County line to the Colorado/Nebraska border (COSPLS01); and
- Jackson and North Sterling Reservoirs (a subset of COSPLS03).

Segments COSPLS02A, COSPLS02B, COSPLS04, COSPLS05, and portions of COSPLS03 which cover tributaries and smaller lakes/reservoirs to the South Platte River, were removed from further review because of the likelihood that the majority of the water to be diverted and stored in the storage projects evaluated as part of the SPSS will use water from the mainstem of the South Platte River. Further, the potential for expansion of existing reservoirs is greatest at the existing major lakes and reservoirs included in stream segment COSPLS03.

**Table 1
 Summary of Potential Steam Segments Considered for Review**

WQCC Segment ID	Description of Stream Segment	Designated Uses ^a	Need for Further Review
COSPMS01B	Mainstem of the South Platte River from a point immediately below the confluence with St. Vrain Creek to the Weld/Morgan County Line	<ul style="list-style-type: none"> • Agriculture • Aquatic Life Warm 2 • Recreation E • Water Supply 	Yes , segment covers portion of mainstem.
COSPLS01 ^b	Mainstem of the South Platte River from the Weld/Morgan County line to the Colorado/Nebraska border	<ul style="list-style-type: none"> • Agriculture • Aquatic Life Warm 2 • Recreation E • Water Supply 	Yes , segment covers portion of mainstem.
COSPLS02A	All tributaries to the South Platte River, including all wetlands, from the Weld/Morgan County line to the Colorado/Nebraska border, except for the specific listings in Segment 2b	<ul style="list-style-type: none"> • Agriculture • Aquatic Life Warm 2 • Recreation E • Water Supply 	No, tributaries were excluded from review due to lower likelihood of site selection on tributaries.
COSPLS02B	All tributaries to the South Platte River, including all wetlands, north of the South Platte River and below 4,500 feet in elevation in Morgan County, north of the South Platte River in Washington County, north of the South Platte River and below 4,200 feet in elevation in Logan County, north of the South Platte River and below 3,700 feet in elevation in Sedgwick County, and the mainstems of Beaver Creek, Bijou Creek and Kiowa Creek from their sources to the confluence with the South Platte River, except for the portion of Beaver Creek from its source to the Fort Morgan Canal.	<ul style="list-style-type: none"> • Agriculture • Aquatic Life Warm 2 • Recreation E 	No, tributaries were excluded from review due to lower likelihood of site selection on tributaries.
COSPLS03	Jackson Reservoir, Prewitt Reservoir, North Sterling Reservoir, Jumbo (Julesburg), Riverside Reservoir, Empire Reservoir, and Vancil Reservoir.	<ul style="list-style-type: none"> • Agriculture • Aquatic Life Warm 1 • Recreation E • Water Supply 	Yes , segment includes lakes and reservoirs within which expansion or further site development may occur.
COSPLS04	All lakes and reservoirs tributary to the South Platte River from the Weld/Morgan County line to the Colorado/Nebraska border, except for specific listings in Segments 3 and 5.	<ul style="list-style-type: none"> • Agriculture • Aquatic Life Warm 2 • Recreation P • Water Supply 	No. The storage sites in this segment would primarily be filled with water from the South Platte River mainstem.
COSPLS05	All lakes and reservoirs tributary to the South Platte River north of the South Platte River and below 4,500 feet in elevation in Morgan county, north of the South Platte river in Washington County, north of the South Platte River and below 4,200 feet in elevation in Logan County, north of the South Platte River and below 3,700 feet in elevation in Sedgwick County, and the mainstems of Beaver Creek, Bijou Creek and Kiowa Creek from their sources to the confluence with the South Platte River, except for those specific listings in Segment 3.	<ul style="list-style-type: none"> • Agriculture • Aquatic Life Warm 2 • Recreation E • Water Supply 	No. The storage sites in this segment would primarily be filled with water from the South Platte River mainstem.

^a Description of Uses:

Table 1
Summary of Potential Steam Segments Considered for Review

WQCC Segment ID	Description of Stream Segment	Designated Uses ^a	Need for Further Review
	<p>Agriculture - These surface waters are suitable or intended to become suitable for irrigation of crops usually grown in Colorado and which are not hazardous as drinking water for livestock.</p> <p>Aquatic Life Warm 1 - These are waters that (1) currently are capable of sustaining a wide variety of warm water biota, including sensitive species, or (2) could sustain such biota but for correctable water quality conditions. Waters shall be considered capable of sustaining such biota where physical habitat, water flows or levels, and water quality conditions result in no substantial impairment of the abundance and diversity of species.</p> <p>Aquatic Life Warm 2 - These are waters that are not capable of sustaining a wide variety of cold or warm water biota, including sensitive species, due to physical habitat, water flows or levels, or uncorrectable water quality conditions that result in substantial impairment of the abundance and diversity of species.</p> <p>Recreation E - These surface waters are used for primary contact recreation or have been used for such activities since November 28, 1975.</p> <p>Recreation P - These surface waters have the potential to be used for primary contact recreation. This classification shall be assigned to water segments for which no use attainability analysis has been performed demonstrating that a recreation class N classification is appropriate, if a reasonable level of inquiry has failed to identify any existing primary contact uses of the water segment, or where the conclusion of a use attainability analysis is that primary contact uses may potentially occur in the segment, but there are no existing primary contact uses.</p> <p>Water Supply - These surface waters are suitable or intended to become suitable for potable water supplies. After receiving standard treatment (defined as coagulation, flocculation, sedimentation, filtration, and disinfection with chlorine or its equivalent) these waters will meet Colorado drinking water regulations and any revisions, amendments, or supplements thereto.</p> <p>^b Qualifiers for segment are Water + Fish Standards.</p>		

Source: Regulation #38 Stream Classifications and Water Quality Standards Appendix 38-1, pp. 88, 124-126 and Regulation 31, Section 31.13 State Use Classifications.

Data Sources

Water Quality Standards

Statewide numeric water quality criteria have been adopted by the WQCC as recommended levels that are protective of the different designated uses. Different uses may require different levels of protection; for example, aquatic life is more sensitive to zinc (e.g., 400 μ /L) than domestic water supply (e.g., 5,000 μ /L) or agriculture (2,000 μ /L). A copy of Regulation 31 *Basic Standards and Methodologies for Surface Water* is presented in Appendix A. Table I in Regulation 31 includes criteria for physical and biological parameters, Table II covers inorganics, and Tables III and IV cover metals. These statewide criteria are usually applied as water quality standards for individual segments. These criteria only become enforceable if they are adopted by WQCC as water quality standards for a specific segment.

In cases where the WQCC decides the statewide criteria are not appropriate values to assign to a particular segment, it can develop site-specific standards for that respective segment. These site-specific standards by stream segment are summarized in WQCC's Regulation 38, *Classifications and Numeric Standards*. Regulation 38 contains a table for each stream segment in the State, and identifies the use classifications for that reach, and show each water quality parameter as either (1) TVS (Regulation 31 Basic Standard) or (2) having an ambient quality-based standard or site-specific criteria for the particular stream segment. Figures 2-4 shows each of the three stream segments and the corresponding WQCC's Regulation 38 stream classifications and water quality standards associated for the respective segment. A copy of Regulation 38 and the site-specific standard tables for the three stream segments evaluated as part of SPSS are presented in Appendix B.

The Regulation 38 Water Quality Standards presented in Appendix B are highlighted to show and support the identification of key parameters to be used for the screening-level assessment presented herein. LRE recommends using the most stringent criteria under all of the designated use classifications in the stream segment for each parameter because of the high likelihood that the project evaluated and screened as part of the SPSS projects will be used for multiple types of beneficial use.

Impaired Waters

Under Section 303(d) of the Federal Clean Water Act, the State of Colorado is required to list waters where water quality standards are not met. Section 303(d) Impairment List integrates the WQCC stream segments to identify areas of impaired waters based on an evaluation of biological, chemical, and/or physical data. An additional list, the Monitoring and Evaluation List (M&E List), is comprised of waters for which there is some data available suggesting water quality problems may exist; however, the data are inadequate to support a determination of nonattainment at the time of evaluation by the State of Colorado. WQCC's Regulation 93, *Colorado's Section 303(d) List of Impaired Waters and Monitoring and Evaluation List*, identifies all parameters by stream segments that do not meet water quality standards (i.e., 303(d) Impairment List) and/or have been placed on the M&E list. Figures 2-4 show each of the three stream segments and the identification of waters included on the Section 303(d) Impairment List. Copies of the Standard Attainment Assessment Summaries from Regulation 93 for the stream segments evaluated herein are included in Appendix C.

WQCC Stream Segments Review of Classifications and Water Quality Standards

The information obtained from the data sources described above was compiled and used to identify key parameters within each SPSS stream segment. In addition, LRE reviewed publically available water quality data within each of the SPSS stream segments to understand the ambient water quality and to compare the ambient water quality to the water quality standards and the water quality criteria for each of the associated use classifications. Additional information about each stream segment and the selection of key parameters for the stream segments are further described below and summarized in Table 2. A detailed table compiling key information and selection of key parameters for each stream segment is presented in Appendix D.

COSPMS01B Stream Segment

COSPMS01B comprises the mainstem of the South Platte River from a point immediately below the confluence with St. Vrain Creek to the Weld/Morgan County Line, as shown on Figure 2. The stream segment has agriculture, aquatic life warm 2, recreation E, and water supply as classified uses, as described in Table 1. COSPMS01B is listed as impaired for *E. coli* (physical and biological parameter) and two metal parameters: arsenic and manganese. No parameters are listed on the M&E List. Arsenic does have temporary modification for the stream segment which is set to expire in 2021 under Regulation 38.

WQCD has determined that the water is segment COSPMS01B does not meet the water quality standard for three constituents. COSPMS01B does not meet the chronic water quality standard for domestic water supply for arsenic and manganese, nor does it meet the *E. coli* standard for recreation.

Review of ambient water quality data for stream segment COSPMS01B found that, while water quality does meet the domestic water use water quality criteria for sulfate, it only barely meets the water quality standard. For this reason, sulfate has been added to the list of key parameters for COSPMS01B.

The WQCD found segment COSPMS01B was in attainment of acute water quality standards for aquatic life, water supply, and agriculture for aluminum, ammonia, arsenic, nitrate + nitrite, cadmium, copper, lead, manganese, nickel, selenium, silver, uranium, and zinc.

The WQCD found segment COSPMS01B was in attainment of chronic water quality standards for aquatic life, water supply, recreation, and agriculture for pH, dissolved oxygen, aluminum, cadmium, copper, iron, lead, molybdenum, nickel, selenium, silver, sulfate, uranium, zinc, and ammonia.

COSPLS01 Stream Segment

COSPLS01 covers the mainstem of the South Platte River from the Weld/Morgan County line to the Colorado/Nebraska border, as shown on Figure 3. The stream segment has agriculture, aquatic life warm 2, recreation E, and water supply as classified uses, as described in Table 1. COSPLS01 is listed as impaired for three metal parameters: manganese, selenium, and uranium. Sulfate is listed on the M&E List. Arsenic does have temporary modification for the stream segment which is set to expire in 2021.

WQCD has determined that the water in segment COSPLS01 does not meet the water quality standard for four (4) constituents. COSPLS01 does not meet the chronic water quality standard for domestic water supply for manganese, selenium, uranium, and sulfate. In addition, the water quality in COSPLS01 does not meet the selenium water quality standard for agriculture.

Review of ambient water quality data for stream segment COSPLS01 found that, while water quality does meet the aquatic life warm 2 water quality criteria for selenium, it only barely meets the water quality standard. For this reason, selenium has been added to the list of key parameters for COSPLS01.

The WQCD found segment COSPLS01 was in attainment of acute water quality standards for aquatic life, water supply, and agriculture for aluminum, ammonia, arsenic, nitrate + nitrite, cadmium, copper, lead, manganese, nickel, selenium, silver, uranium, and zinc. However, the segment was retained on the 303(d) list in 2016 for selenium by the WQCC.

The WQCD found segment COSPLS01 was in attainment of chronic water quality standards for aquatic life, water supply, recreation, and agriculture for pH, dissolved oxygen, aluminum, arsenic, cadmium, copper, iron, lead, manganese, nickel, selenium, silver, zinc, and ammonia.

COSPLS03 Stream Segment

COSPLS03 includes the Jackson Reservoir, Prewitt Reservoir, North Sterling Reservoir, Jumbo (Julesburg), Riverside Reservoir, Empire Reservoir, and Vancil Reservoir, as shown on Figure 4. The stream segment has agriculture, aquatic life warm 1, recreation E, and water supply as classified uses, as described in Table 1. COSPLS03 is listed as impaired at Jackson and North Sterling. Jackson Reservoir is listed as 303(d) impaired list for pH only and North Sterling is listed on the 303(d) impairment list for Dissolved Oxygen and selenium. Jumbo (Julesburg) Reservoir is listed for selenium on the M&E List.

WQCD has determined that the water in segment COSPLS03 does not meet the water quality standard for three (3) constituents. The water in North Sterling Reservoir does not meet the chronic water quality standard for domestic water supply Dissolved Oxygen. The water in Jackson Reservoir does not meet the acute standard for agriculture, aquatic life, recreation, or water supply for pH. The water in North Sterling Reservoir does not meet the chronic selenium water quality standard for aquatic life.

The WQCD found that Jackson Reservoir in section COSPLS03 was in attainment of the selenium standard, for which it had previously been listed for non-compliance.

Summary

Based on the review of WQCC's Regulations 31, 38, and 93, LRE has identified the key water quality parameters to be considered when screening SPSS sites and solutions. These key parameters and the designated uses for which the parameter are identified as being key, are summarized in Table 2 below. The impact of the water quality on the eventual use of these waters captured in a future storage site is further described below.

Table 2 – Key Water Quality Parameters by WQCC Stream Segment

WQCC Stream Segment	Description	Key Parameter and Designated Use
COSPMS01B	Mainstem of the SPR from point immediately below confluence w/ St Vrain Creek to the Weld/Morgan County Line	Arsenic – Domestic Water Supply E. Coli – Recreation Manganese – Domestic Water Supply Sulfate – Domestic Water Supply
COSPLS01	Mainstem of the SPR from the Weld/Morgan County line to the CO/NE border	Manganese – Domestic Water Supply Selenium – Aquatic Life Uranium – Domestic Water Supply Sulfate – Domestic Water Supply
COSPLS03	Jackson Reservoir	pH – Aquatic Life & Domestic Water Supply
COSPLS03	North Sterling Reservoir	Dissolved Oxygen – Agriculture, Aquatic Life, Domestic Water Supply, & Recreation Selenium – Aquatic Life

Treatment and Use Considerations

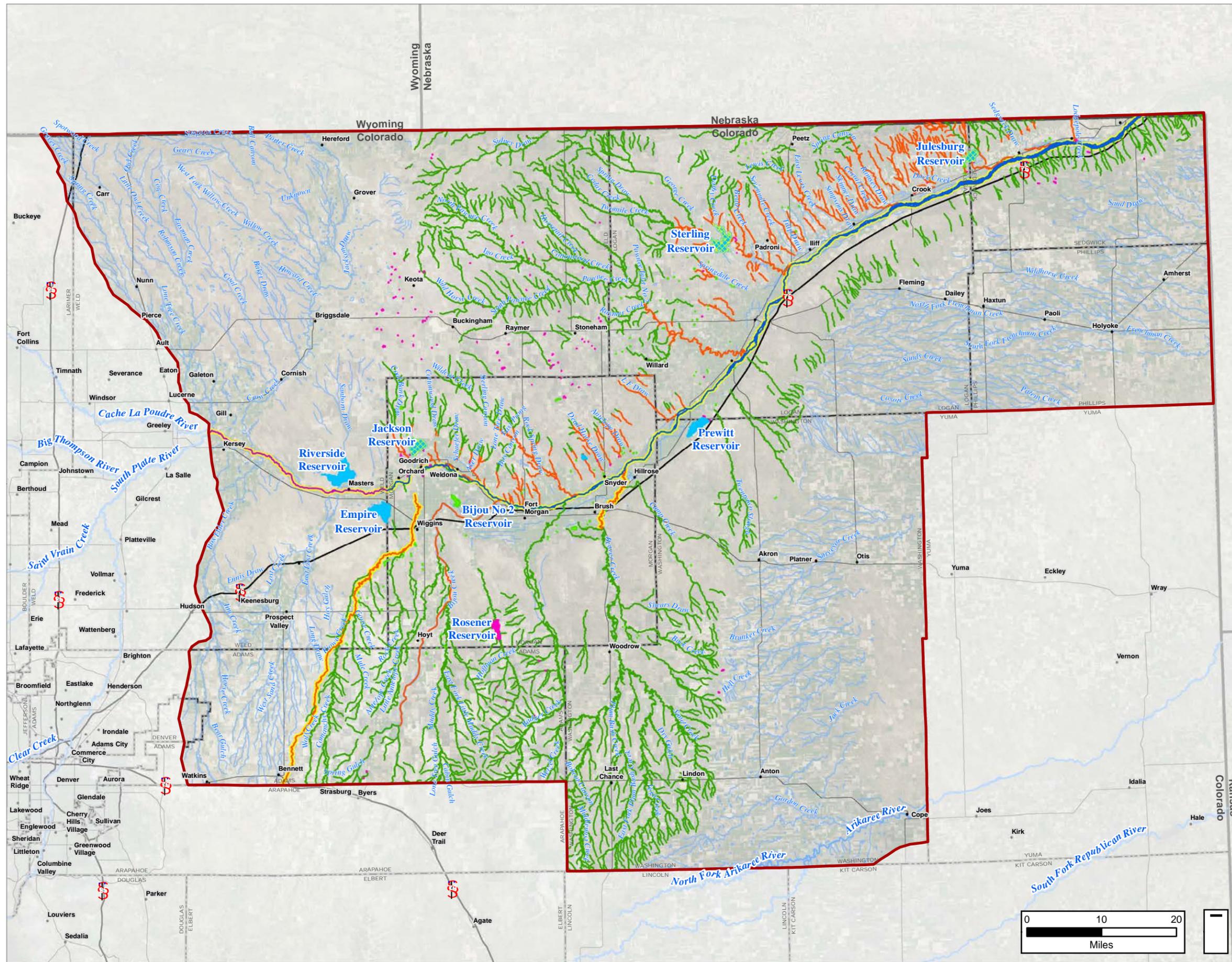
Utilizing the list of key parameters summarized in Table 2, we next considered the potential methods of use and associated treatment and use considerations. Table 3 below summarizes the treatment and regulatory considerations that should be considered for each of the key parameters as well as a relative cost of the potential treatment options.

Table 3 below provides insight into potential constraints of water sources for specific beneficial use types. While LRE cannot provide confirmation as to the exact form/type of treatment that would be required by impaired use(s), it is understood arsenic, selenium, and uranium could require costly treatment methods when the source water is used for domestic water supply. Sulfate is a secondary standard largely based on physical properties (e.g., taste, color, odor), unlike arsenic, selenium, and uranium which have direct impacts to human and/or aquatic health based on contact. Sulfate is classified under the secondary maximum contaminate level standards; therefore, while high levels of sulfate are not as serve to health, the impacts on taste, color, odor can be costly to treat prior to use as a domestic water supply.

Table 3 – Potential Treatment and Use Considerations

Key Parameter	Method of Use	Potential Treatment Alternatives And Regulatory Needs
Arsenic	<i>Domestic Water Supply – Assumed direct feed to WTP</i>	HIGH LEVEL TREATMENT NEEDS - HIGH COST (e.g., reverse osmosis, ion exchange, activated alumina, etc.) RESIDUALS TREATMENT &/OR DISPOSAL - HIGH COST (e.g., permitted discharge to sewer, deep well injection, evaporation pond, land application, zero liquid discharge, etc.)
Dissolved Oxygen	<i>Agriculture, Aquatic Life, Recreation – Assumed surface water discharge to receiving water for direct use, augmentation use, or exchange</i> <i>Domestic Water Supply – Assumed direct feed to WTP</i>	CONVENTIONAL TREATMENT METHODS - LOW COST
E. Coli	<i>Recreation – Assumed surface water discharge to receiving water for direct use, augmentation use, or exchange</i>	* Initial recommendation – Obtain legal determination as to whether or not the use of water constitutes an “exercise of water rights.” CONVENTIONAL TREATMENT METHODS - LOW COST
Manganese	<i>Domestic Water Supply – Assumed direct feed to WTP</i>	MEDIUM LEVEL TREATMENT NEEDS - MEDIUM COST (e.g., green sand filters, enhanced coagulation, etc.)
pH	<i>Aquatic Life – Assumed surface water discharge to receiving water for direct use, augmentation use, or exchange</i> <i>Domestic Water Supply – Assumed direct feed to WTP</i>	* Initial recommendation – Obtain legal determination as to whether or not the use of water constitutes an “exercise of water rights.” CONVENTIONAL TREATMENT METHODS - LOW COST
Selenium	<i>Domestic Water Supply – Assumed direct feed to WTP</i>	HIGH LEVEL TREATMENT NEEDS - HIGH COST (e.g., reverse osmosis, ion exchange, activated alumina, etc.) RESIDUALS TREATMENT &/OR DISPOSAL - HIGH COST (e.g., permitted discharge to sewer, deep well injection, evaporation pond, land application, zero liquid discharge, etc.)
Sulfate	<i>Domestic Water Supply – Assumed direct feed to WTP</i>	HIGH LEVEL TREATMENT NEEDS - HIGH COST (e.g., reverse osmosis, ion exchange, activated alumina, etc.)
Uranium	<i>Domestic Water Supply – Assumed direct feed to WTP</i>	HIGH LEVEL TREATMENT NEEDS - HIGH COST (e.g., reverse osmosis, ion exchange, activated alumina, etc.) RESIDUALS TREATMENT &/OR DISPOSAL - HIGH COST (e.g., permitted discharge to sewer, deep well injection, evaporation pond, land application, zero liquid discharge, etc.)

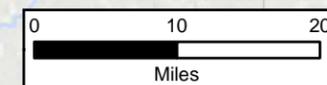
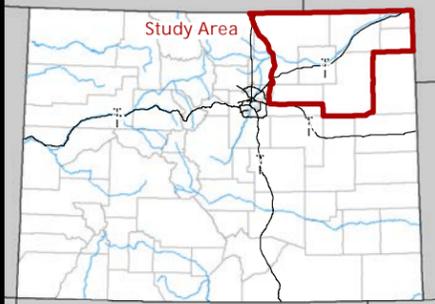
FIGURE 1
WATER QUALITY BY
WQCC STREAM SEGMENTS



SOUTH PLATTE STORAGE
STUDY

- Study Area
- WQCC Stream Segments Within Study Area**
- Other Stream Segments
- COSPLS01
- COSPLS02a
- COSPLS02b
- COSPMS01b
- COSPLS03
- COSPLS04
- COSPLS05
- List of Impaired Waters (303d Features)**
- 303d Waterways
- 303d Lakes/Reservoirs

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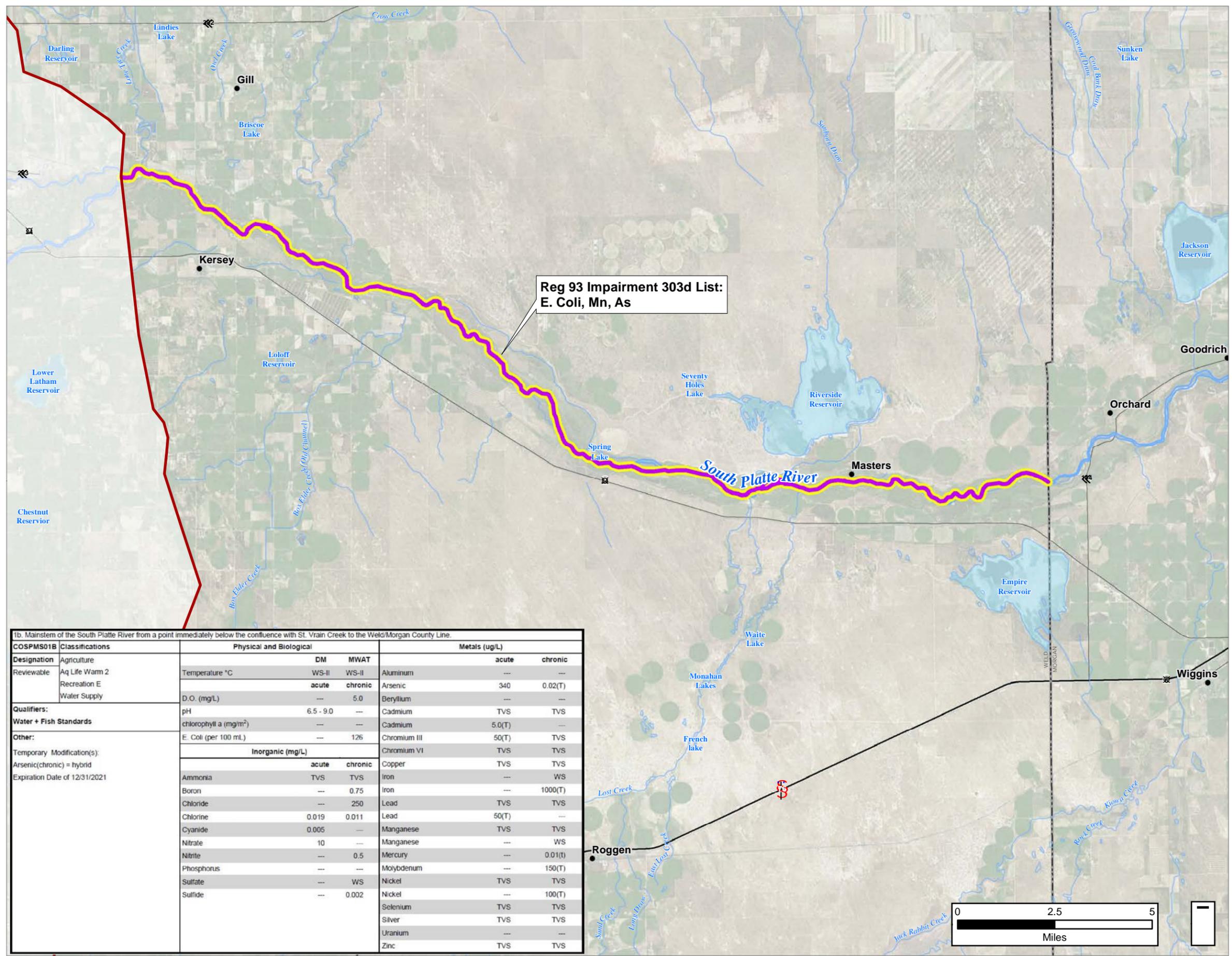


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FIGURE 2
COSPMS01B
STREAM SEGMENT

SOUTH PLATTE STORAGE
STUDY

- Study Area
- WQCC Stream Segment**
- COSPMS01b
- List of Impaired Waters (303d Features)**
- 303d Waterways



1b. Mainstem of the South Platte River from a point immediately below the confluence with St. Vrain Creek to the Weld/Morgan County Line.

COSPMS01B Classifications		Physical and Biological		Metals (ug/L)	
Designation	Agriculture	DM	MWAT	acute	chronic
Reviewable	Aq Life Warm 2 Recreation E Water Supply	WS-II	WS-II	Aluminum	---
Qualifiers:		acute	chronic	Arsenic	340
Water + Fish Standards		---	5.0	Beryllium	---
Other:		pH	6.5 - 9.0	Cadmium	TVS
Temporary Modification(s):		chlorophyll a (mg/m ²)	---	Cadmium	5.0(T)
Arsenic(chronic) = hybrid		E. Coli (per 100 mL)	---	Chromium III	50(T)
Expiration Date of 12/31/2021		Inorganic (mg/L)		Chromium VI	TVS
		acute	chronic	Copper	TVS
		TVS	TVS	Iron	---
		---	0.75	Iron	1000(T)
		---	250	Lead	TVS
		0.019	0.011	Lead	50(T)
		0.005	---	Manganese	TVS
		10	---	Manganese	---
		---	0.5	Mercury	---
		---	---	Molybdenum	---
		---	WS	Nickel	TVS
		---	0.002	Nickel	---
				Selenium	TVS
				Silver	TVS
				Uranium	---
				Zinc	TVS

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1. Mainstem of the South Platte River from the Weld/Morgan County line to the Colorado/Nebraska border.							
COSPLS01	Classifications	Physical and Biological		Metals (ug/L)			
		DM	MWAT	acute	chronic		
Designation	Agriculture	Temperature °C	WS-II	WS-II	Aluminum	---	
	Recreation E		acute	chronic	Arsenic	340	
Water + Fish Standards	Water Supply	D.O. (mg/L)	---	5.0	Beryllium	---	
		pH	6.5 - 9.0	---	Cadmium	TVS	
Other:		chlorophyll a (mg/m ²)	---	---	Cadmium	5.0(T)	
		E. Coli (per 100 mL)	---	126	Chromium III	50(T)	
Temporary Modification(s)		Inorganic (mg/L)		Chromium VI	TVS	TVS	
	Arsenic(chronic) = hybrid		acute	chronic	Copper	TVS	TVS
Expiration Date of 12/31/2021		Ammonia	TVS	TVS	Iron	---	WS
		Boron	---	0.75	Iron	---	1000(T)
		Chloride	---	250	Lead	TVS	TVS
		Chlorine	0.019	0.011	Lead	50(T)	---
		Cyanide	0.005	---	Manganese	TVS	TVS
		Nitrate	10	---	Manganese	---	WS
		Nitrite	---	0.5	Mercury	---	0.01(t)
		Phosphorus	---	---	Molybdenum	---	150(T)
		Sulfate	---	WS	Nickel	TVS	TVS
		Sulfide	---	0.002	Nickel	---	100(T)
					Selenium	TVS	TVS
					Silver	TVS	TVS
					Uranium	---	---
					Zinc	TVS	TVS

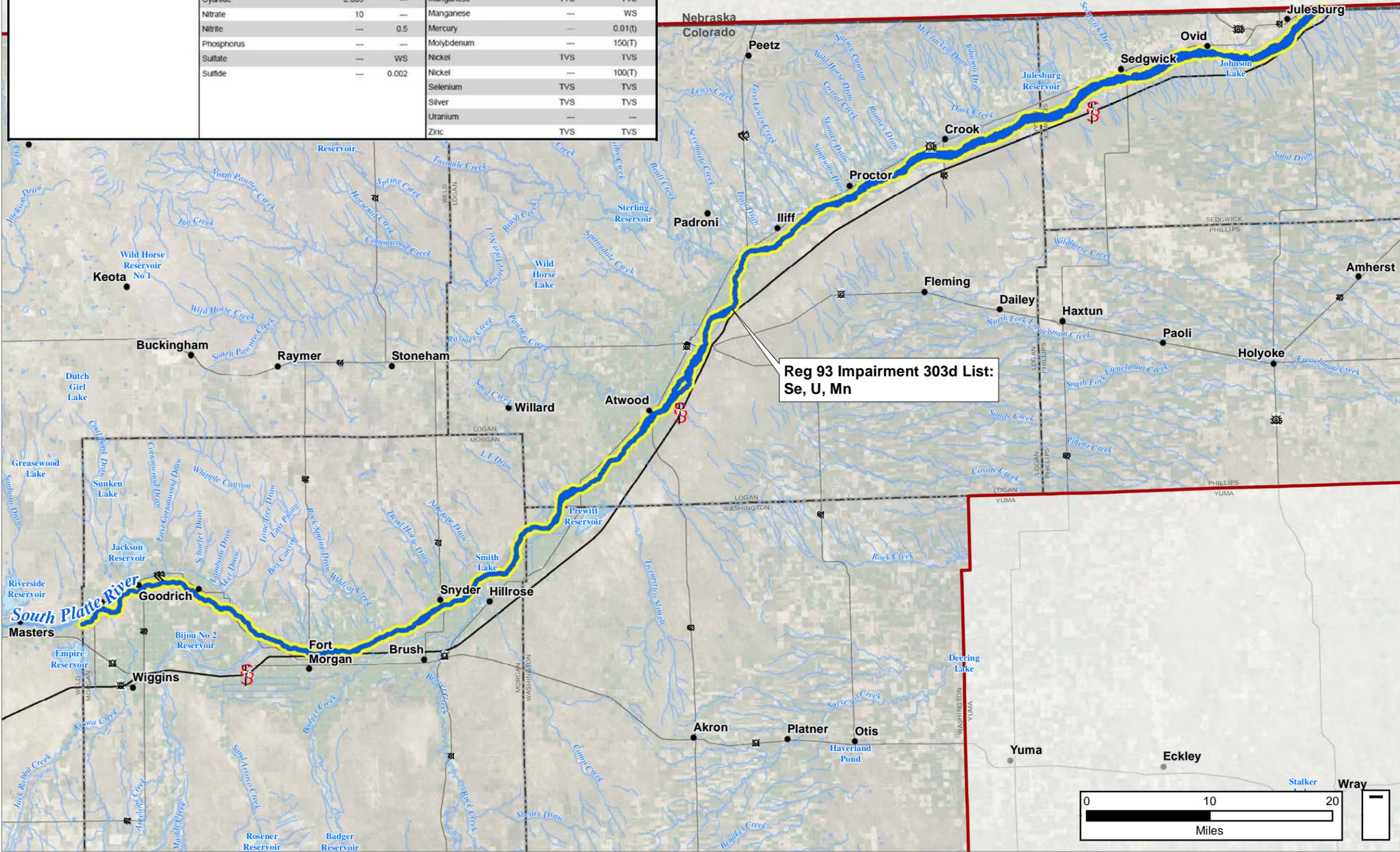


FIGURE 3
COSPLS01
STREAM SEGMENT

SOUTH PLATTE STORAGE
STUDY

- Study
- WQCC Stream Segment
- COSPLS01
- List of Impaired Waters (303d Features)
- 303d Waterways

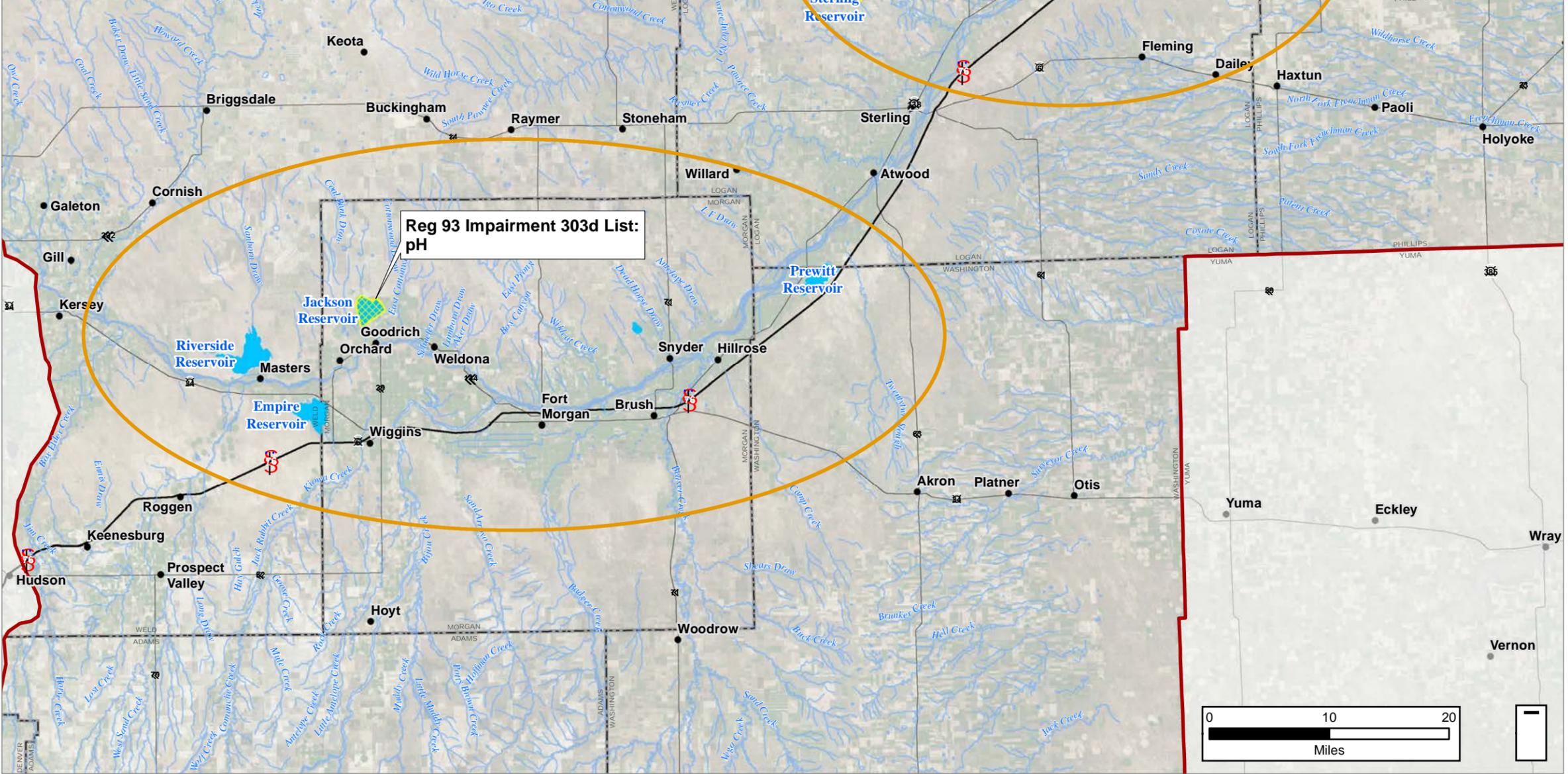
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3 Jackson Reservoir, Prewitt Reservoir, North Sterling Reservoir, Jumbo (Julesburg), Riverside Reservoir, Empire Reservoir, and Vancil Reservoir		Physical and Biological		Metals (ug/L)	
COSPLS03	Classifications	DM	MWAT	acute	chronic
UP	Agriculture	WL	WL	Aluminum	---
	Aq Life Warm 1	4/1 - 12/31	26.1*	Arsenic	340
	Recreation E	4/1 - 12/31	27*	Beryllium	---
	Water Supply	4/1 - 12/31	28.1*	Cadmium	TVS
Qualifiers:				Cadmium	5.0(T)
Other:				Chromium III	50(T)
*chlorophyll a (ug/L)(chronic) = applies only above the facilities listed at 38.5(4), applies only to lakes and reservoirs larger than 25 acres surface area.				Chromium VI	TVS
*Phosphorus(chronic) = applies only above the facilities listed at 38.5(4), applies only to lakes and reservoirs larger than 25 acres surface area.				Copper	TVS
*Temperature(4/1 - 12/31) = North Sterling Res. (MWAT=26.1)				Iron	---
*Temperature(4/1 - 12/31) = Jumbo Reservoir (MWAT=27)				Iron	1000(T)
*Temperature(4/1 - 12/31) = Jackson Reservoir (MWAT=28.1)				Lead	TVS
				Lead	50(T)
				Manganese	TVS
				Manganese	---
				Mercury	0.01(t)
				Molybdenum	150(T)
				Nickel	TVS
				Nickel	100(T)
				Selenium	TVS
				Selenium	TVS
				Silver	TVS
				Silver	TVS
				Uranium	---
				Uranium	---
				Zinc	TVS
				Zinc	TVS



Reg 93 Impairment 303d List:
None Listed

Reg 93 Impairment 303d List:
D.O., Se

Reg 93 Impairment 303d List:
pH

FIGURE 4
COSPLS03
LAKES/RESERVOIRS

SOUTH PLATTE STORAGE
STUDY

- Study
- WQCC**
- Lakes/Reservoirs**
- COSPLS03
- WQCC 303d Lakes/Reservoirs

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**SPSS Subtask 2.2 -
Water Quality Analysis**

**Appendix A
WQCC Regulation 31**

COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT
WATER QUALITY CONTROL COMMISSION

REGULATION NO. 31

**THE BASIC STANDARDS AND
METHODOLOGIES
FOR SURFACE WATER
(5 CCR 1002-31)**

ADOPTED: May 22, 1979	EFFECTIVE: July 10, 1979
AMENDED: December 12, 1983	EFFECTIVE: January 30, 1984
AMENDED: June 2, 1987	EFFECTIVE: July 31, 1988
AMENDED: June 6, 1988	EFFECTIVE: July 31, 1988
AMENDED: August 1, 1988	EFFECTIVE: September 30, 1988
AMENDED: August 7, 1989	EFFECTIVE: September 30, 1989
AMENDED: October 8, 1991	EFFECTIVE: November 30, 1991
AMENDED: May 4, 1993	EFFECTIVE: June 30, 1993
AMENDED: August 2, 1993	EFFECTIVE: September 30, 1993
AMENDED: October 4, 1993	EFFECTIVE: November 30, 1993
AMENDED: December 6, 1993	EFFECTIVE: January 31, 1994
AMENDED: January 10, 1995	EFFECTIVE: March 2, 1995
AMENDED: January 8, 1996	EFFECTIVE: March 1, 1996
AMENDED: January 13, 1997	EFFECTIVE: March 3, 1997
AMENDED: July 14, 1997	EFFECTIVE: August 30, 1997
AMENDED: January 12, 1998	EFFECTIVE: March 2, 1998
AMENDED: January 11, 1999	EFFECTIVE: March 2, 1999
AMENDED: August 15, 2000	EFFECTIVE: December 22, 2000
AMENDED: November 7, 2000	EFFECTIVE: March 20, 2001
EMERGENCY AMENDMENT: November 8, 2000	EFFECTIVE: November 8, 2001
AMENDED: February 13, 2001	EFFECTIVE: March 30, 2001
EMERGENCY AMENDMENT: May 14, 2001	EFFECTIVE: May 14, 2001
AMENDED: September 10, 2001	EFFECTIVE: October 30, 2001
AMENDED: November 8, 2004	EFFECTIVE: March 22, 2005
AMENDED: August 8, 2005	EFFECTIVE: December 31, 2005
AMENDED: August 8, 2005	EFFECTIVE: December 31, 2007
AMENDED: February 12, 2007	EFFECTIVE: July 1, 2007
AMENDED: January 14, 2008	EFFECTIVE: May 31, 2008
AMENDED: October 13, 2009	EFFECTIVE: November 30, 2009
AMENDED: August 9, 2010	EFFECTIVE: January 1, 2011
AMENDED: June 13, 2011	EFFECTIVE: January 1, 2012
AMENDED: June 11, 2012	EFFECTIVE: September 30, 2012
AMENDED: September 11, 2012	EFFECTIVE: January 31, 2013
AMENDED: May 9, 2016	EFFECTIVE: June 30, 2016
AMENDED: August 8, 2016	EFFECTIVE: December 31, 2016

TABLE I PHYSICAL AND BIOLOGICAL PARAMETERS								
Parameter	Recreational			Aquatic Life			Agriculture	Domestic Water Supply
	CLASS E (Existing Primary Contact) and CLASS U (Undetermined Use)	CLASS P (Potential Primary Contact Use)	CLASS N (Not Primary Contact Use)	CLASS 1 COLD WATER BIOTA	CLASS 1 WARM WATER BIOTA	CLASS 2		
PHYSICAL								
D.O. (mg/l) ⁽¹⁾⁽⁹⁾	3.0(A)	3.0(A)	3.0(A)	6.0 ⁽²⁾ (G) 7.0(spawning)	5.0 ⁽²⁾ (G)	5.0(A)	3.0(A)	3.0(A)
pH (Std. Units) ⁽³⁾	6.5–9.0 (Bm)	6.5–9.0 (Bm)	6.5–9.0 (Bm)	6.5–9.0(A)	6.5–9.0(A)	6.5–9.0(A)		5.0–9.0(A)
Suspended Solids ⁽⁴⁾								
Temperature (°C) ⁽⁵⁾				Rivers & Streams: Tier I^{a,g}: June-Sept = 17.0 (ch), 21.7 (ac) Oct–May = 9.0 (ch), 13.0 (ac) Tier II^{b,g}: Apr-Oct = 18.3 (ch), 24.3 (ac) Nov-Mar = 9.0 (ch), 13.0 (ac) Lakes & Res^h: Apr-Dec = 17.0 (ch), 21.2 (ac) Jan-Mar = 9.0 (ch), 13.0 (ac) Large Lakes & Res^{c,h}: Apr-Dec = 18.3 (ch), 24.2 (ac) Jan-Mar = 9.0 (ch), 13.0 (ac)	Rivers & Streams: Tier I^d: Mar-Nov = 24.2 (ch), 29.0 (ac) Dec-Feb = 12.1 (ch), 24.6 (ac) Tier II^e: Mar-Nov = 27.5 (ch), 28.6(ac) Dec-Feb = 13.8 (ch), 25.2 (ac) Tier III^f: Mar-Nov = 28.7 (ch), 31.8 (ac) Dec-Feb = 14.3 (ch), 24.9 (ac) Lakes & Res: Apr-Dec = 26.2 (ch), 29.3 (ac) Jan-Mar = 13.1 (ch), 24.1 (ac)	Same as Class 1		

TABLE I PHYSICAL AND BIOLOGICAL PARAMETERS								
Parameter	Recreational			Aquatic Life			Agriculture	Domestic Water Supply
	CLASS E (Existing Primary Contact) and CLASS U (Undetermined Use)	CLASS P (Potential Primary Contact Use)	CLASS N (Not Primary Contact Use)	CLASS 1 COLD WATER BIOTA	CLASS 1 WARM WATER BIOTA	CLASS 2		
BIOLOGICAL:								
<i>E. coli</i> per 100 ml	126 ^(f)	205 ^(f)	630 ^(f)					630
Note: Capital letters in parentheses refer to references listed in section 31.16(3); Numbers in parentheses refer to Table 1 footnotes.								
<p>Temperature Definitions</p> <p>^a Cold Stream Tier I temperature criteria apply where cutthroat trout and brook trout are expected to occur.</p> <p>^b Cold Stream Tier II temperature criteria apply where cold-water aquatic species, excluding cutthroat trout or brook trout, are expected to occur.</p> <p>^c Large Cold Lakes temperature criteria apply to lakes and reservoirs with a surface area equal to or greater than 100 acres surface area.</p> <p>^d Warm Stream Tier I temperature criteria apply where common shiner, johnny darter, or orangethroat darter, or stonecat are expected to occur.</p> <p>^e Warm Stream Tier II temperature criteria apply where brook stickleback, central stoneroller, creek chub, finescale dace, longnose dace, mountain sucker, Nnorthern redbelly dace, razorback sucker, or white sucker are expected occur, and none of the more thermally sensitive species in Tier I are expected to occur.</p> <p>^f Warm Stream Tier III temperature criteria apply where warm-water aquatic species are expected to occur, and none of the more thermally sensitive species in Tiers I and II are expected to occur.</p> <p>^g Mountain whitefish-based summer temperature criteria [16.9 (ch), 21.2 (ac)] apply when and where spawning and sensitive early life stages of this species are known to occur.</p> <p>^h Lake trout-based summer temperature criteria [16.6 (ch), 22.4 (ac)] apply where appropriate and necessary to protect lake trout from thermal impacts.</p>								

Table I – Footnotes

- (1) Standards for dissolved oxygen are minima, unless specified otherwise. For the purposes of permitting, dissolved oxygen may be modeled for average conditions of temperature and flow for the worst case time period. Where dissolved oxygen levels less than these levels occur naturally, a discharge shall not cause a further reduction in dissolved oxygen in receiving water. (For lakes, also see footnote 9.)
- (2) A 7.0 mg/liter standard (minimum), during periods of spawning of cold water fish, shall be set on a case-by-case basis as defined in the NPDES or CDPS permit for those dischargers whose effluent would affect fish spawning.
- (3) The pH standards of 6.5 (or 5.0) and 9.0 are an instantaneous minimum and maximum, respectively to be applied as effluent limits. In determining instream attainment of water quality standards for pH, appropriate averaging periods may be applied, provided that beneficial uses will be fully protected.
- (4) Suspended solid levels will be controlled by Effluent Limitation Regulations, Basic Standards, and Best Management Practices (BMPs).
- (5) Temperature shall maintain a normal pattern of diel and seasonal fluctuations and spatial diversity with no abrupt changes and shall have no increase in temperature of a magnitude, rate, and duration deleterious to the resident aquatic life. These criteria shall not be interpreted or applied in a manner inconsistent with section 25-8-104, C.R.S.
 - a. The MWAT of a waterbody shall not exceed the chronic temperature criterion more frequently than one event in three years on average.
 - b. The DM of a waterbody shall not exceed the acute temperature criterion more frequently than one event in three years on average.
 - c. The following shall not be considered an exceedance of the criteria:
 - i. Air temperature excursion: ambient water temperature may exceed the criteria in Table 1 or the applicable site-specific standard when the daily maximum air temperature exceeds the 90th percentile value of the monthly maximum air temperatures calculated using at least 10 years of air temperature data.
 - ii. Low-flow excursion: ambient water temperature may exceed the criteria in Table 1 or the applicable site-specific standard when the daily stream flow falls below the acute critical low flow or monthly average stream flow falls below the chronic critical low flow, calculated pursuant to Regulation 31.9(1)
 - iii. Winter shoulder-season excursion: For the purposes of assessment, ambient water temperatures in cold streams may exceed the winter criteria in Table 1 or applicable site-specific winter standard for 30-days before the winter/summer transition, and 30-days after the summer/winter transition, provided that the natural seasonal progression of temperature is maintained and that temperature exceedances during these periods are not the result of anthropogenic activities in the watershed.
- (6) Deleted

- (7) *E.coli* criteria and resulting standards for individual water segments, are established as indicators of the potential presence of pathogenic organisms. Standards for *E. coli* are expressed as a two-month geometric mean. Site-specific or seasonal standards are also two-month geometric means unless otherwise specified.
- (8) Deleted
- (9) The dissolved oxygen standard applies to lakes and reservoirs as follows.
- a. Recreation: In the upper portion of a lake or reservoir, dissolved oxygen shall not be less than the criteria in Table 1 or the applicable site-specific standard. In the lower portion of a lake or reservoir, dissolved oxygen may be less than the applicable standard except where a site-specific standard has been adopted. A site-specific dissolved oxygen standard will be established for the lower portion of a lake or reservoir where there is evidence that primary contact occurs within the lower portion.
 - b. Agriculture: In the upper portion of a lake or reservoir, dissolved oxygen shall not be less than the criteria in Table 1 or the applicable site-specific standard. In the lower portion of a lake or reservoir, dissolved oxygen may be less than the applicable standard except where a site-specific standard has been adopted. A site-specific dissolved oxygen standard will be established for the lower portion of a lake or reservoir where there is evidence that livestock watering or irrigation water is pumped from the lower portion.
 - c. Aquatic Life: In the upper portion of a lake or reservoir, dissolved oxygen shall not be less than the criteria in Table I or the applicable site-specific standard. In the lower portion of a lake or reservoir, dissolved oxygen may be less than the applicable standard as long as there is adequate refuge. Adequate refuge means that there is concurrent attainment of the applicable Table I temperature and dissolved oxygen criteria. A site-specific dissolved oxygen standard will be established for the lower portion of a lake or reservoir where the expected aquatic community has habitat requirements within the lower portion.
 - i. Fall turnover exclusion: Dissolved oxygen may drop 1 mg/l below the criteria in Table 1 in the upper portion of a lake or reservoir for up to seven consecutive days during fall turnover provided that profile measurements are taken at a consistent location within the lake or reservoir 7-days before, and 7-days after the profile with low dissolved oxygen. The profile measurements taken before and after the profile with low dissolved oxygen must attain the criteria in Table 1 in the upper portion of the lake or reservoir. The fall turnover exclusion does not apply to lakes or reservoirs with fish species that spawn in the fall unless there are data to show that adequate dissolved oxygen is maintained in all spawning areas, for the entire duration of fall turnover.
 - d. Water Supply: The dissolved oxygen criteria is intended to apply to the epilimnion and metalimnion strata of lakes and reservoirs. Dissolved oxygen in the hypolimnion may, due to the natural conditions, be less than the table criteria. No reductions in dissolved oxygen levels due to controllable sources is allowed.

TABLE II INORGANIC PARAMETERS							
PARAMETER	AQUATIC LIFE				AGRICULTURE		DOMESTIC WATER SUPPLY
	CLASS 1 Cold Water Biota	CLASS 1 Warm Water Biota		CLASS 2			
INORGANICS:							
Ammonia (mg/l as N) Total	chronic = elsp or elsa ⁽¹⁾ acute = sp ⁽¹⁾ (N)		chronic = Apr 1-Aug 31=elsp ⁽¹⁾ Sept 1-Mar 29=elsa ⁽¹⁾ acute = sa ⁽¹⁾ (N)		Class 2 Cold/Warm have the same standards as Class 1 Cold/Warm (N)		
Total residual Chlorine (mg/l)	0.019 (L) (1-day)	0.011 (L) (30-day)	0.019 (L) (1-day)	0.011 (L) (30-day)	0.019 (L) (1-day)	0.011 (L) (30-day)	
Cyanide - Free (mg/l)	0.005(H) (1-day)		0.005(H) (1-day)		0.005(H) (1-day)		0.2(G) (1-day)
Fluoride (mg/l)							2.0 ⁽³⁾ (E) (1-day)
Nitrate (mg/l as N)						100 ⁽²⁾ (B)	10 ⁽⁴⁾ (K) (1-day)
Nitrite (mg/l as N)	TO BE ESTABLISHED ON A CASE BY CASE BASIS ⁽³⁾			A CASE BY CASE BASIS ⁽³⁾		10 ⁽²⁾ (B) (1-day)	1.0(2) ⁽⁴⁾ (K) (1-day)
Sulfide as H ₂ S (mg/l)	0.002 undissociated(A) (30-day)		0.002 undissociated(A) (30-day)		0.002 undissociated(A) (30-day)		0.05(F) (30-day)
Boron (mg/l)						0.75(A,B) (30-day)	
Chloride (mg/l)							250(F) (30-day)
Sulfate (mg/l)							250(F) (30-day)
Asbestos							7,000,000 fibers/L ⁽⁵⁾
NOTE: Capital letters in parentheses refer to references listed 31.16(3); numbers in parentheses refer to table II footnotes.							

Table II – Footnotes

(1)

Chronic:

For Fish Early Life Stage Present (elsp):

$$chronic\ elsp = \left(\frac{0.0577}{1 + 10^{7.688 - pH}} + \frac{2.487}{1 + 10^{pH - 7.688}} \right) * MIN \left(2.85, 1.45 * 10^{0.028(25 - T)} \right)$$

For Fish Early Life Stage Absent (elsa):

$$chronic\ elsa = \left(\frac{0.0577}{1 + 10^{7.688 - pH}} + \frac{2.487}{1 + 10^{pH - 7.688}} \right) * 1.45 * 10^{0.028 * (25 - MAX(T, 7))}$$

Acute:

For salmonids present (sp):

$$acute\ sp = \frac{0.275}{1 + 10^{7.204 - pH}} + \frac{39.0}{1 + 10^{pH - 7.204}}$$

For salmonids absent (sa):

$$acute\ sa = \frac{0.411}{1 + 10^{7.204 - pH}} + \frac{58.4}{1 + 10^{pH - 7.204}}$$

(2) In order to provide a reasonable margin of safety to allow for unusual situations such as extremely high water ingestion or nitrite formation in slurries, the NO₃-N plus NO₂-N content in drinking waters for livestock and poultry should be limited to 100ppm or less, and the NO₂-N content alone be limited to 10ppm or less.

(3) Salmonids and other sensitive fish species present:

$$Acute = 0.10 (0.59 * [Cl^-] + 3.90) \text{ mg/l NO}_2\text{-N}$$

$$Chronic = 0.10 (0.29 * [Cl^-] + 0.53) \text{ mg/l NO}_2\text{-N}$$

(upper limit for Cl⁻ = 40 mg/l)

Salmonids and other sensitive fish species absent:

$$Acute = 0.20 (2.00 * [Cl^-] + 0.73) \text{ mg/l NO}_2\text{-N}$$

$$Chronic = 0.10 (2.00 * [Cl^-] + 0.73) \text{ mg/l NO}_2\text{-N}$$

[Cl⁻] = Chloride ion concentration

(upper limit for Cl⁻ = 22 mg/l)

- (4) The nitrate limit shall be calculated to meet the relevant standard in accordance with the provisions of Section 31.10 of this regulation, unless (this subsection 4 is repealed effective 12/31/2022):
- a. The permittee provides documentation that a reasonable level of inquiry demonstrates that there is no actual domestic water supply use of the waters in question or of hydrologically connected ground water, or
 - b. The combined total of nitrate plus nitrite at the point of intake to the domestic water supply will not exceed 10 mg/l as demonstrated through modeling or other scientifically supportable analysis
- (5) Asbestos standard applies to fibers 10 micrometers or longer.

TABLE III METAL PARAMETERS (Concentration in µg/l)						
METAL ⁽¹⁾	AQUATIC LIFE ^{(1)(3)(4)(J)}		AGRICULTURE ⁽²⁾	DOMESTIC WATER-SUPPLY ⁽²⁾	WATER + FISH ⁽⁷⁾	FISH INGESTION ⁽¹⁰⁾
	ACUTE	CHRONIC				
Aluminum	$e^{(1.3695[\ln(\text{hardness}))+1.8308]}$ (tot.rec.)	87 or $e^{(1.3695[\ln(\text{hardness}))-0.1158]}$ (tot.rec.) ⁽¹¹⁾			---	---
Antimony				6.0 (30-day)	5.6	640
Arsenic	340	150	100 ^(A) (30-day)	0.02 – 10 ⁽¹³⁾ (30-day)	0.02	7.6
Barium				1,000 ^(E) (1-day) 490 (30-day)	---	---
Beryllium			100 ^(A,B) (30-day)	4.0 (30-day)	---	---
Cadmium	$(1.136672-[\ln(\text{hardness}) \times e^{0.9151[\ln(\text{hardness})]-3.1485}]) \times e^{(0.041838)}$ (Trout) = $(1.136672-[\ln(\text{hardness}) \times e^{0.9151[\ln(\text{hardness})]-3.6236}]) \times e^{(0.041838)}$	$(1.101672-[\ln(\text{hardness}) \times e^{0.7998[\ln(\text{hardness})]-4.4451}]) \times e^{(0.041838)}$	10 ^(B) (30-day)	5.0 ^(E) (1-day)	---	---
Chromium III ⁽⁵⁾	$e^{(0.819[\ln(\text{hardness}))+2.5736]}$	$e^{(0.819[\ln(\text{hardness}))+0.5340]}$	100 ^(B) (30-day)	50 ^(E) (1-day)	---	---
Chromium VI ⁽⁵⁾	16	11	100 ^(B) (30-day)	50 ^(E) (1-day)	100(30-day)	---
Copper	$e^{(0.9422[\ln(\text{hardness})]-1.7408)}$	$e^{(0.8545[\ln(\text{hardness})]-1.7428)}$	200 ^(B)	1,000 ^(F) (30-day)	1,300	---
Iron		1,000(tot.rec.) ^(A,C)		300(dis) ^(F) (30-day)	---	---
Lead	$(1.46203-[(\ln(\text{hardness}))^* (0.145712)]) \times e^{(1.273[\ln(\text{hardness})]-1.46)}$	$(1.46203-[(\ln(\text{hardness}))^* (0.145712)]) \times e^{(1.273[\ln(\text{hardness})]-4.705)}$	100 ^(B) (30-day)	50 ^(E) (1-day)	—	---
Manganese	$e^{(0.3331[\ln(\text{hardness}))+6.4676]}$	$e^{(0.3331[\ln(\text{hardness}))+5.8743]}$	200 ^(B) (30-day) ⁽¹²⁾	50(dis) ^(F) (30-day)	—	---
Mercury		FRV(fish) ⁽⁶⁾ = 0.01 (Total)		2.0 ^(E) (1-day)	—	---
Molybdenum			300 ^(O) (30-day) ⁽¹⁵⁾	210 (30-day)		

TABLE III METAL PARAMETERS (Concentration in µg/l)						
METAL ⁽¹⁾	AQUATIC LIFE ^{(1)(3)(4)(J)}		AGRICULTURE ⁽²⁾	DOMESTIC WATER-SUPPLY ⁽²⁾	WATER + FISH ⁽⁷⁾	FISH INGESTION ⁽¹⁰⁾
	ACUTE	CHRONIC				
Nickel	$e^{(0.846[\ln(\text{hardness})]+2.253)}$	$e^{(0.846[\ln(\text{hardness})]+0.0554)}$	200 ^(B) (30-day)	100 ^(E) (30-day)	610	4,600
Selenium ⁽⁹⁾	18.4	4.6	20 ^(B,D) (30-day)	50 ^(E) (30-day)	170	4,200
Silver	$\frac{1}{2}e^{(1.72[\ln(\text{hardness})]-6.52)}$	$e^{(1.72[\ln(\text{hardness})]-9.06)}$ (Trout) = $e^{(1.72[\ln(\text{hardness})]-10.51)}$		100 ^(F) (1-day)	—	---
Thallium		15 ^(C)		0.5 (30-day)	0.24	0.47
Uranium ⁽¹⁶⁾	$e^{(1.1021[\ln(\text{hardness})]+2.7088)}$	$e^{(1.1021[\ln(\text{hardness})]+2.2382)}$		16.8 – 30 ⁽¹³⁾ (30-day)	---	---
Zinc	$0.978 * e^{(0.9094[\ln(\text{hardness})]+0.9095)}$	$0.986 * e^{(0.9094[\ln(\text{hardness})]+0.6235)}$ (sculpin) ⁽¹⁴⁾ = $e^{(2.140[\ln(\text{hardness})]-5.084)}$	2000 ^(B) (30-day)	5,000 ^(F) (30-day)	7,400	26,000

NOTE: Capital letters in parentheses refer to references listed in section 31.16(3); Numbers in parentheses refer to Table III footnote

Table III – Footnotes

- (1) Metals for aquatic life use are stated as dissolved unless otherwise specified.
- Where the hardness-based equations in Table III are applied as table value water quality standards for individual water segments, those equations define the applicable numerical standards. As an aid to persons using this regulation, Table IV provides illustrative examples of approximate metals values associated with a range of hardness levels. This table is provided for informational purposes only.
- (2) Metals for agricultural and domestic uses are stated as total recoverable unless otherwise specified.
- (3) Hardness values to be used in equations are in mg/l as calcium carbonate and shall be no greater than 400 mg/l. The exception is for aluminum, where the upper cap on calculations is a hardness of 220 mg/l. For permit effluent limit calculations, the hardness values used in calculating the appropriate metal standard should be based on the lower 95 percent confidence limit of the mean hardness value at the periodic low flow criteria as determined from a regression analysis of site-specific data. Where insufficient site-specific data exists to define the mean hardness value at the periodic low flow criteria, representative regional data shall be used to perform the regression analysis. Where a regression analysis is not possible, a site-specific method should be used, e.g., where hardness data exists without paired flow data, the mean of the hardness during the low flow season established in the permit shall be used. In calculating a hardness value, regression analyses should not be extrapolated past the point that data exist. For determination of standards attainment, where paired metal/hardness data is available, attainment will be determined for individual sampling events. Where paired data is not available, the mean hardness will be used.
- (4) Both acute and chronic numbers adopted as stream standards are levels not to be exceeded more than once every three years on the average.
- (5) Unless the stability of the chromium valence state in receiving waters can be clearly demonstrated, the standard for chromium should be in terms of chromium VI. In no case can the sum of the instream levels of hexavalent and trivalent chromium exceed the water supply standard of 50 µg/l chromium in those waters classified for domestic water use.
- (6) FRV means Final Residue Value and should be expressed as "Total" because many forms of mercury are readily converted to toxic forms under natural conditions. The FRV value of 0.01 µg/liter is the maximum allowed concentration of total mercury in the water. This value is estimated to prevent bioaccumulation of methylmercury in edible fish or shellfish tissue above the fish tissue standard for methylmercury of 0.3 mg/kg.

In waters supporting populations of fish or shellfish with a potential for human consumption, the Commission can adopt the FRV as the stream standard to be applied as a 30-day average. Alternatively, the Commission can adopt site-specific ambient based standards for mercury in accordance with section 31.7(1)(b)(ii) and (iii). Site-specific water-column standards shall be calculated from the site-specific bioaccumulation factor, using measured water column concentrations of total mercury and measured fish tissue concentrations of methylmercury. Fish tissue data shall be collected from species of the highest trophic level present in the water body. Fish tissue samples should include older, larger individuals present in the water body. A bioaccumulation factor should be calculated separately for each species sampled, and the highest bioaccumulation factor should be used to calculate the site-specific water column standard in order to prevent the average fish tissue concentrations from exceeding 0.3 mg/kg for all species.

- (7) Applicable to all Class 1 aquatic life segments which also have a water supply classification or Class 2 aquatic life segments which also have a water supply classification designated by the Commission after rulemaking hearing. These Class 2 segments will generally be those where fish of a catchable size and which are normally consumed are present, and where there is evidence that fishing takes place on a recurring basis. The Commission may also consider additional evidence that may be relevant to a determination whether the conditions applicable to a particular segment are similar enough to the assumptions underlying the water plus fish ingestion criteria to warrant the adoption of water plus fish ingestion standards for the segment in question.
- (8) The use of 0.1 micron pore size filtration for determining dissolved iron is allowed as an option in assessing compliance with the drinking water standard.
- (9) Selenium is a bioaccumulative metal and subject to a range of toxicity values depending upon numerous site-specific variables.
- (10) Applicable to the following segments which do not have a water supply classification: all Class 1 aquatic life segments or Class 2 aquatic life segments designated by the Commission after rulemaking hearing. These class 2 segments will generally be those where fish of a catchable size and which are normally consumed are present, and where there is evidence that fishing takes place on a recurring basis. The Commission may also consider additional evidence that may be relevant to a determination whether the conditions applicable to a particular segment are similar enough to the assumptions underlying the fish ingestion criteria to warrant the adoption of fish ingestion standards for the segment in question.
- (11) Where the pH is equal to or greater than 7.0 in the receiving water after mixing, the chronic hardness-dependent equation will apply. Where pH is less than 7.0 in the receiving water after mixing, either the 87 µg/l chronic total recoverable aluminum criterion or the criterion resulting from the chronic hardness-dependent equation will apply, whichever is more stringent.
- (12) This standard is only appropriate where irrigation water is applied to soils with pH values lower than 6.0.
- (13) Whenever a range of standards is listed and referenced to this footnote, the first number in the range is a strictly health-based value, based on the Commission's established methodology for human health-based standards. The second number in the range is a maximum contaminant level, established under the federal Safe Drinking Water Act that has been determined to be an acceptable level of this chemical in public water supplies, taking treatability and laboratory detection limits into account. Control requirements, such as discharge permit effluent limitations, shall be established using the first number in the range as the ambient water quality target, provided that no effluent limitation shall require an "end-of-pipe" discharge level more restrictive than the second number in the range. Water bodies will be considered in attainment of this standard, and not included on the Section 303(d) List, so long as the existing ambient quality does not exceed the second number in the range.
- (14) The chronic zinc equation for sculpin applies in areas where mottled sculpin are expected to occur and hardness is less than 102 ppm CaCO₃. The regular chronic zinc equation applies in areas where mottled sculpin are expected to occur, but the hardness is greater than 102 ppm CaCO₃.
- (15) In determining whether adoption of a molybdenum standard is appropriate for a segment, the Commission will consider whether livestock or irrigated forage is present or expected to be present. The table value assumes that copper and molybdenum concentrations in forage are 7 mg/kg and 0.5 mg/kg respectively, forage intake is 6.8 kg/day, copper concentration in water is 0.008 mg/l, water intake is 54.6 l/day, copper supplementation is 48 mg/day, and that a Cu:Mo ratio of 4:1 is appropriate with a 0.075 mg/l molybdenum margin of safety. Numeric standards different than the table-value may be adopted on a site-specific basis where appropriate

justification is presented to the Commission. In evaluating site-specific standards, the relevant factors that should be considered include the presence of livestock or irrigated forage, and the total intake of copper, molybdenum, and sulfur from all sources (i.e., food, water, and dietary supplements). In general, site-specific standards should be based on achieving a safe copper:molybdenum total exposure ratio, with due consideration given to the sulfur exposure. A higher Cu:Mo ratio may be necessary where livestock exposure to sulfur is also high. Species specific information shall be considered where cattle are not the most sensitive species.

- (16) When applying the table value standards for uranium to individual segments, the Commission shall consider the need to maintain radioactive materials at the lowest practical level as required by Section 31.11(2) of the Basic Standards regulation.

Table IV Table Value Standards for Selected Hardnesses (concentration in ug/L, dissolved)											
		Mean Hardness in mg/L calcium carbonate									
		25	50	75	100	150	200	250	300	350	400
Aluminum	Acute	512	1324	2307	3421	5960	8838	10071	10071	10071	10071
	Chronic	73	189	329	488	851	1262	1438	1438	1438	1438
Cadmium	Acute trout	0.5	0.9	1.3	1.7	2.4	3.1	3.8	4.4	5.1	5.7
	Acute	0.8	1.5	2.1	2.7	3.9	5.0	6.1	7.1	8.1	9.2
Chromium III	Chronic	.15	.25	0.34	0.42	0.58	0.72	0.85	0.97	1.1	1.2
	Acute	183	323	450	570	794	1005	1207	1401	1590	1773
Copper	Chronic	24	42	59	74	103	131	157	182	207	231
	Acute	3.6	7.0	10	13	20	26	32	38	44	50
Lead	Chronic	2.7	5.0	7.0	9.0	13	16	20	23	26	29
	Acute	14	30	47	65	100	136	172	209	245	281
Manganese	Chronic	0.5	1.2	1.8	2.5	3.9	5.3	6.7	8.1	9.5	11
	Acute	1881	2370	2713	2986	3417	3761	4051	4305	4532	4738
Nickel	Chronic	1040	1310	1499	1650	1888	2078	2238	2379	2504	2618
	Acute	145	260	367	468	660	842	1017	1186	1351	1513
Silver	Chronic	16	29	41	52	72	94	113	132	150	168
	Acute	0.19	0.62	1.2	2.0	4.1	6.7	9.8	13	18	22
Uranium	Chronic Trout	0.01	0.02	0.05	0.08	0.15	0.25	0.36	0.50	0.65	0.81
	Chronic	0.03	0.10	0.20	0.32	0.64	1.0	1.6	2.1	2.8	3.5
Zinc	Acute	521	1119	1750	2402	3756	5157	6595	8062	9555	11070
	Chronic	326	699	1093	1501	2346	3221	4119	5036	5968	6915
Chronic sculpin	Acute	45	85	123	160	231	301	368	435	500	565
	Chronic	6.1	27	64	118	N/A	N/A	N/A	N/A	N/A	N/A
Chronic	Chronic	34	65	93	121	175	228	279	329	379	428

Shaded values exceed drinking water supply standards.

**SPSS Subtask 2.2 -
Water Quality Analysis**

**Appendix B
WQCC Regulation 38**

COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT
WATER QUALITY CONTROL COMMISSION

5 CCR 1002-38

REGULATION NO. 38
CLASSIFICATIONS AND NUMERIC STANDARDS
FOR
SOUTH PLATTE RIVER BASIN, LARAMIE RIVER BASIN
REPUBLICAN RIVER BASIN, SMOKY HILL RIVER BASIN

ADOPTED:	April 6, 1981	EFFECTIVE:	May 16, 1981
AMENDED:	April 12, 1982	EFFECTIVE:	May 16, 1982 through May 30, 1982
AMENDED:	December 6, 1982	EFFECTIVE:	January 30, 1983
SEPARATELY AMENDED:	December 6, 1982	EFFECTIVE:	January 30, 1983
AMENDED:	May 9, 1983	EFFECTIVE:	July 16, 1983
AMENDED:	December 12, 1983	EFFECTIVE:	January 30, 1984
AMENDED:	May 15, 1984	EFFECTIVE:	June 30, 1984
AMENDED:	August 14, 1984	EFFECTIVE:	September 30, 1984
AMENDED:	April 1, 1985	EFFECTIVE:	May 30, 1985
AMENDED:	March 7, 1986	EFFECTIVE:	April 30, 1986
AMENDED:	April 8, 1986	EFFECTIVE:	May 30, 1986
AMENDED:	May 9, 1986	EFFECTIVE:	June 30, 1986
AMENDED:	September 18, 1986	EFFECTIVE:	October 30, 1986
AMENDED:	August 4, 1987	EFFECTIVE:	September 30, 1987
AMENDED:	November 3, 1987	EFFECTIVE:	December 30, 1987
AMENDED:	May 2, 1988	EFFECTIVE:	June 30, 1988
AMENDED:	February 6, 1989	EFFECTIVE:	March 30, 1989
EMERGENCY AMENDED:	February 6, 1989	EFFECTIVE:	February 6, 1989 through August 30, 1989
AMENDED:	March 6, 1989	EFFECTIVE:	April 30, 1989
AMENDED:	June 5, 1989	EFFECTIVE:	July 30, 1989
EMERGENCY AMENDED:	July 11, 1989	EFFECTIVE:	July 11, 1989 through March 30, 1990
AMENDED:	February 5, 1990	EFFECTIVE:	March 30, 1990
AMENDED:	September 5, 1991	EFFECTIVE:	October 30, 1991
AMENDED:	January 6, 1992	EFFECTIVE:	March 1, 1992
AMENDED:	June 2, 1992	EFFECTIVE:	July 30, 1992
AMENDED:	July 6, 1992	EFFECTIVE:	August 30, 1992
AMENDED:	December 7, 1992	EFFECTIVE:	January 30, 1993
AMENDED:	March 1, 1993	EFFECTIVE:	April 30, 1993
AMENDED:	August 2, 1993	EFFECTIVE:	September 30, 1993
AMENDED:	September 7, 1993	EFFECTIVE:	October 30, 1993
AMENDED:	March 7, 1994	EFFECTIVE:	April 30, 1994
AMENDED:	May 2, 1994	EFFECTIVE:	June 30, 1994
AMENDED:	February 13, 1995	EFFECTIVE:	March 30, 1995
AMENDED:	June 12, 1995	EFFECTIVE:	July 30, 1995
AMENDED:	July 10, 1995	EFFECTIVE:	August 30, 1995
AMENDED:	December 11, 1995	EFFECTIVE:	January 30, 1996

AMENDED:	May 13, 1996	EFFECTIVE:	June 30, 1996
AMENDED:	August 12, 1996	EFFECTIVE:	September 30, 1996
AMENDED:	January 13, 1997	EFFECTIVE:	March 3, 1997
AMENDED:	April 14, 1997	EFFECTIVE:	May 30, 1997
AMENDED:	May 12, 1997	EFFECTIVE:	June 30, 1997
AMENDED:	July 14, 1997	EFFECTIVE:	August 30, 1997
AMENDED:	November 9, 1998	EFFECTIVE:	December 30, 1998
AMENDED:	May 11, 1999	EFFECTIVE:	June 30, 1999
AMENDED:	October 10, 2000	EFFECTIVE:	February 20, 2001
AMENDED:	February 13, 2001	EFFECTIVE:	June 20, 2001
EMERGENCY AMENDMENT:	May 14, 2001	EFFECTIVE:	May 14, 2001
AMENDED:	September 10, 2001	EFFECTIVE:	October 30, 2001
AMENDED:	December 10, 2001	EFFECTIVE:	January 30, 2002
AMENDED:	September 13, 2004	(Clear Creek seg. 5 and Middle South Platte segs. 1a & 1b)	EFFECTIVE:
			November 1, 2004
AMENDED:	September 13, 2004	(all other segments)	
			EFFECTIVE:
			January 20, 2005
AMENDED:	December 12, 2005	EFFECTIVE:	March 2, 2006
AMENDED:	August 14, 2006	EFFECTIVE:	September 30, 2006
AMENDED:	February 12, 2007	EFFECTIVE:	July 1, 2007
AMENDED:	April 9, 2007	EFFECTIVE:	September 1, 2007
AMENDED:	August 13, 2007	EFFECTIVE:	September 30, 2007
AMENDED:	January 14, 2008	EFFECTIVE:	March 1, 2008
AMENDED:	February 9, 2009	EFFECTIVE:	March 30, 2009
AMENDED:	August 10, 2009	EFFECTIVE:	January 1, 2010
AMENDED:	February 8, 2010	EFFECTIVE:	June 30, 2010
AMENDED:	April 12, 2010	EFFECTIVE:	June 30, 2010
AMENDED:	July 12, 2010	EFFECTIVE:	November 30, 2010
AMENDED:	January 10, 2011	EFFECTIVE:	June 30, 2011
EMERGENCY AMENDMENT:	December 13, 2011	EFFECTIVE:	December 13, 2011
AMENDED:	June 13, 2011	EFFECTIVE:	January 1, 2012
AMENDED:	August 13, 2012	EFFECTIVE:	December 31, 2012
AMENDED:	October 9, 2012	EFFECTIVE:	March 1, 2013
AMENDED:	January 14, 2013	EFFECTIVE:	June 30, 2013
EMERGENCY AMENDMENT:	May 13, 2013	EFFECTIVE:	May 13, 2013
AMENDED:	May 1, 2013	EFFECTIVE:	September 30, 2013
AMENDED:	March 11, 2014	EFFECTIVE:	April 30, 2014
AMENDED:	March 11, 2014	EFFECTIVE:	June 30, 2014
AMENDED:	January 12, 2015	EFFECTIVE:	June 30, 2015
AMENDED:	August 10, 2015	EFFECTIVE:	December 31, 2015
AMENDED:	January 11, 2016	EFFECTIVE:	March 1, 2016
AMENDED:	January 11, 2016	EFFECTIVE:	June 30, 2016

WATER QUALITY CONTROL COMMISSION

5 CCR 1002-38

REGULATION NO. 38 CLASSIFICATIONS AND NUMERIC STANDARDS FOR SOUTH PLATTE RIVER BASIN, LARAMIE RIVER BASIN REPUBLICAN RIVER BASIN, SMOKY HILL RIVER BASIN

38.1 AUTHORITY

These regulations are promulgated pursuant to section 25-8-101 et seq C.R.S., as amended, and in particular, 25-8-203 and 25-8-204.

38.2 PURPOSE

These regulations establish classification and numeric standards for the South Platte River, the Laramie River, the Republican River and the Smoky Hill River, including all tributaries and standing bodies of water as indicated in section 38.6. The classifications identify the actual beneficial uses of the water. The numeric standards are assigned to determine the allowable concentrations of various parameters. Discharge permits will be issued by the Water Quality Control Division to comply with basic, narrative, and numeric standards and control regulations so that all discharges to waters of the state protect the classified uses. (See section 31.14). It is intended that these and all other stream classifications and numeric standards be used in conjunction with and be an integral part of Regulation 31.0 - BASIC STANDARDS AND METHODOLOGIES FOR SURFACE WATER.

38.3 INTRODUCTION

These regulations and Tables present the classifications and numeric standards assigned to stream segments listed in the attached Tables (See section 38.6). As additional stream segments are classified and numeric standards for this drainage system are adopted, they will be added to or replace the numeric standards in the Tables in section 38.6. Any additions or revisions of classifications or numeric standards can be accomplished only after public hearing by the Commission and proper consideration of evidence and testimony as specified by the statute and the "basic regulations".

38.4 DEFINITIONS

See the Colorado Water Quality Control Act and the codified water quality regulations for definitions.

38.5 BASIC STANDARDS

(1) TEMPERATURE

All waters of the South Platte, Laramie, Republican and Smoky Hill River Basins are subject to the following standard for temperature. (Discharges regulated by permits, which are within the permit limitations, shall not be subject to enforcement proceedings under this standard.)

Temperature shall maintain a normal pattern of diurnal and seasonal fluctuations with no abrupt changes and shall have no increase in temperature of a magnitude, rate, and duration deemed deleterious to the resident aquatic life. This standard shall not be interpreted or applied in a manner inconsistent with section 25-8-104, C.R.S.

(2) QUALIFIERS

See Basic Standards and Methodologies for Surface Water for a listing of organic standards at 31.11 and metal standards found at 31.16 Table III. The column in the tables headed "Water + Fish" are presumptively applied to all aquatic life class 1 streams which also have a water supply classification, and are applied to aquatic life class 2 streams which also have a water supply classification, on a case-by-case basis as shown in the Tables 38.6. The column in the tables at 31.11 headed "Fish Ingestion" is presumptively applied to all aquatic life class 1 streams which do not have a water supply classification, and are applied to aquatic life class 2 streams which do not have a water supply classification, on a case-by-case basis, as shown in the Tables in 38.6.

(3) URANIUM

- (a) All waters of the South Platte River Basin are subject to the following basic standard for uranium, unless otherwise specified by a water quality standard applicable to a particular segment. However, discharges of uranium regulated by permits which are within these permit limitations shall not be a basis for enforcement proceedings under this basic standard.
- (b) Uranium level in surface waters shall be maintained at the lowest practicable level.
- (c) In no case shall uranium levels in waters assigned a water supply classification be increased by any cause attributable to municipal, industrial, or agricultural discharges so as to exceed 16.8-30 µg/l or naturally-occurring concentrations (as determined by the State of Colorado), whichever is greater.
 - (i) The first number in the 16.8-30 µg/l range is a strictly health-based value, based on the Commission's established methodology for human health-based standards. The second number in the range is a maximum contaminant level, established under the federal Safe Drinking Water Act that has been determined to be an acceptable level of this chemical in public water supplies, taking treatability and laboratory detection limits into account. Control requirements, such as discharge permit effluent limitations, shall be established using the first number in the range as the ambient water quality target, provided that no effluent limitation shall require an "end-of-pipe" discharge level more restrictive than the second number in the range. Water bodies will be considered in attainment of this standard, and not included on the Section 303(d) List, so long as the existing ambient quality does not exceed the second number in the range.

(4) NUTRIENTS

Prior to May 31, 2022, interim nutrient values will be considered for adoption only in the limited circumstances defined at 31.17(e). These circumstances include headwaters, Direct Use Water Supply (DUWS) Lakes and Reservoirs, and other special circumstances determined by the Commission. Additionally, prior to May 31, 2017, only total phosphorus and chlorophyll a will be considered for adoption. After May 31, 2017, total nitrogen will be considered for adoption per the circumstances outlined in 31.17(e).

Prior to May 31, 2022, nutrient criteria will be adopted for headwaters on a segment by segment basis for the South Platte River Basin. Moreover, pursuant to 31.17(e), nutrient standards will only be adopted for waters upstream of all permitted domestic wastewater treatment facilities discharging prior to May 31, 2012 or with preliminary effluent limits requested prior to May 31, 2012, and any non-domestic facilities subject to Regulation 85 effluent limits and discharging prior to May 31, 2012. The following is a list of all permitted domestic wastewater treatment facilities discharging prior to May 31, 2012 or with preliminary effluent limits requested prior to May 31,

2012, and any non-domestic facilities subject to Regulation 85 effluent limits and discharging prior to May 31, 2012 in the South Platte River Basin:

Segment	Permittee	Facility name	Permit No.
COSPUS01a	Alma Town of	ALMA, TOWN OF	CO0035769
COSPUS01a	Fairplay Sanitation District	FAIRPLAY SANITATION DISTRICT WWTF	CO0040088
COSPUS01a	Boy Scouts of America Pikes Peak Council	CAMP ALEXANDER	COG588036
COSPUS02a	Florissant Water and San Dist	FLORISSANT WATER & SAN DIST	CO0041416
COSPUS02a	Teller County	TELLER COUNTY WW UTILITY BOARD	CO0044211
COSPUS03	Woodland Park City of	WOODLAND PARK, CITY OF	CO0043214
COSPUS03	YMCA Camp Shady Brook	CAMP SHADY BROOK	CO0045993
COSPUS03	Lost Valley Ranch Corporation	LOST VALLEY RANCH	COG588122
COSPUS04	Will-O-Wisp Metro District	WILL-O-WISP METRO DISTRICT	CO0041521
COSPUS04	Bailey WSD	BAILEY WSD WWTF	COG588056
COSPUS04	Platte Canyon School Dist 1	PLATTE CANYON SCHOOL DIST 1	COG588114
COSPUS05c	Mountain Water and Sanitation District	MOUNTAIN WATER & SAN DISTRICT	CO0022730
COSPUS06a	Roxborough Water and Sanitation District	ROXBOROUGH PARK WATER & SAN WWTF	CO0041645
COSPUS10a	Plum Creek Water Reclamation Authority	PLUM CREEK WW AUTHORITY WWTF	CO0038547
COSPUS10a	Perry Park Water and Sanitation District	SAGEPORT WWTF	CO0043044
COSPUS11b	Perry Park Water and Sanitation District	WAUCONDAH WWTP	CO0022551
COSPUS14	Littleton/Englewood Cities of	LITTLETON/ENGLEWOOD, CITIES OF	CO0032999
COSPUS15	Metro Waste Water Reclamation District	METRO WASTEWATER RECLAM DIST	CO0026638
COSPUS15	Brighton City of	BRIGHTON WWTF	CO0021547
COSPUS15	South Adams County WSD	WILLIAMS MONOCO WWTF	CO0026662
COSPUS15	Metro Waste Water Reclamation District	NORTHERN TREATMENT PLANT	CO0048959
COSPUS16c	Ascentia Real Estate Holding Company LLC	FOX RIDGE FARMS MH COMMUNITY	CO0028908
COSPUS16c	SouthWest Water Company	HI-LAND ACRES W&SD WWTF	COG589072
COSPUS16c	Mile High Racing and Enter dba Arapahoe Park	ARAPAHOE PARK RACETRACK	COG589073
COSPUS16c	Rangeview Metro District	COAL CREEK WW RECLAMATION FAC	COG589108
COSPUS16g	Centennial Water and San Dist	MARCY GULCH WWTF	CO0037966
COSPUS16i	Aurora City of - Aurora Water	SAND CREEK WATER REUSE FACILITY	CO0026611
COSPCH01	Stonegate Village Metropolitan District	STONEGATE VILLAGE WWTF	CO0040291

Segment	Permittee	Facility name	Permit No.
COSPCH01	Pinery Water and Wastewater District	PINERY WWTF	CO0041092
COSPCH01	Parker Water and Sanitation District	PARKER NORTH WRF	CO0046507
COSPCH04	Arapahoe County W and WW Authority	LONE TREE CREEK WWTP	CO0040681
COSPBE01a	Amen Real Estate LLC	SINGIN' RIVER RANCH WWTF	CO0035971
COSPBE01b	Morrison Town of	MORRISON TOWN OF	CO0041432
COSPBE01e	Kittredge Sanitation and Water District	KITTREDGE SAN & WATER DISTRICT	CO0023841
COSPBE01e	Bruce & Jayne Hungate DBA Bear Creek Cabins	BEAR CREEK CABINS	CO0030856
COSPBE01e	Evergreen Metropolitan District	EVERGREEN METROPOLITAN DIST WWTF	CO0031429
COSPBE04a	Genesee WSD	GENESEE WATER & SAN DISTRICT	CO0022951
COSPBE04a	Forest Hills Metro District	FOREST HILLS METROPOLITAN DIST	CO0037044
COSPBE05	West Jefferson County MD	W. JEFFERSON COUNTY METRO DIST	CO0020915
COSPBE05	Historic Brook Forest Inn LLC	BROOK FOREST INN	CO0030261
COSPBE06a	Tiny Town Foundation Inc	TINY TOWN	CO0036129
COSPBE06a	Aspen Park Metropolitan District	ASPEN PARK METROPOLITAN DISTRICT	CO0000001
COSPBE06b	Jefferson County Public Schools R-1	CONIFER HIGH SCHOOL WW REC PLT	CO0047988
COSPCL01	Colorado Dept of Transportation	EISENHOWER/JOHNSON MEMORIAL TUNNELS	CO0026069
COSPCL01	Clear Creek Skiing Corp	LOVELAND SKI AREA WWTF	CO0040835
COSPCL02a	Georgetown Town of	GEORGETOWN WWTF	CO0027961
COSPCL02c	Central Clear Creek SD	CENTRAL CLEAR CREEK SD WWTF	COG588055
COSPCL05	Empire Town of	EMPIRE TOWN OF	COG588065
COSPCL09a	St Marys Glacier WSD	ST. MARYS GLACIER WSD	CO0023094
COSPCL10	Shwayder Camp Wastewater	SHWAYDER CAMP WWTF	CO0047473
COSPCL11	Idaho Springs City of	IDAHO SPRINGS WWTF	CO0041068
COSPCL12	Clear Creek WWTP	CLEAR CREEK WWTP	CO0046574
COSPCL13b	Black Hawk/Central City Sanitation District	BLACK HAWK/CENTRAL CITY SD WWTF	CO0046761
COSPCL14a	MillerCoors LLC	MILLERCOORS GOLDEN FACILITY	CO0001163
COSPBD01	Westminster City of	BIG DRY CREEK WWTF	CO0024171
COSPBD01	Broomfield City and County	BROOMFIELD WWTF	CO0026409
COSPBD01	Northglenn City of	NORTHGLENN WWTF	CO0036757
COSPBO02b	San Lazaro Park Properties LLP c/o	SAN LAZARO MHP WWTF	CO0020184
COSPBO02b	BaseCamp Ventures LLC	BOULDER MOUNTAIN LODGEWWTF	CO0040819

Segment	Permittee	Facility name	Permit No.
COSPBO02b	Mueller Red Lion Inn	RED LION INN WWTF	COG588118
COSPBO03	Nederland Town of	NEDERLAND TOWN OF WWTF	CO0020222
COSPBO04b	Eldorado Springs Wastewater	ELDORADO SPRINGS WWTF	CO0047651
COSPBO04b	San Souci MHP	SAN SOUCI MHP	COG588101
COSPBO07b	Louisville City of	LOUISVILLE WWTF	CO0023078
COSPBO07b	Lafayette City of	LAFAYETTE WWTF	CO0023124
COSPBO07b	Erie Town of	ERIE WWTF	CO0045926
COSPBO08	Superior Metropolitan District No 1	SUPERIOR METROPOLITAN DIST NO1	CO0043010
COSPBO09	Boulder City of	75TH ST WWTP	CO0024147
COSPBO10	Erie Town of	ERIE NORTH WATER RECLAMATION FACILITY	CO0048445
COSPBO10	B & B Mobile Home and RV Park	B & B MOBILE HOME & RV PARK	COG588107
COSPBO14	Lake Eldora WSD	LAKE ELDORA WSD WWTF	CO0020010
COSPSV02a	Peaceful Valley Ranch LLC	PEACEFUL VALLEY RANCH WWTF	CO0048828
COSPSV02a	Seventh-Day Adventist Assoc of Colorado	GLACIER VIEW RANCH	CO0030112
COSPSV02a	Aspen Lodge at Estes Park Corp	ASPEN LODGE AT ESTES PARK CORP	CO0042820
COSPSV02b	Lyons Town of	LYONS TOWN OF	CO0020877
COSPSV03	Longmont City of	LONGMONT WWTF	CO0026671
COSPSV03	St Vrain Sanitation District	ST VRAIN SANITATION DISTRICT	CO0041700
COSPSV06	Niwot Sanitation District	NIWOT SANITATION DISTRICT	CO0021695
COSPSV06	Mead Town of	LAKE THOMAS SUBDIVISION WWTF	CO0046868
COSPSV06	Mead Town of	MEAD, TOWN OF	CO0046876
COSPSV06	Fairways Metro Dist	FAIRWAYS WWTF	CO0048411
COSPMS01a	Fort Lupton City of	FORT LUPTON WWTF	CO0021440
COSPMS01b	Evans City of	EVANS CITY OF WWTF	CO0020508
COSPMS01b	Kersey Town of	KERSEY WWTF	CO0021954
COSPMS01b	Platteville Town of	PLATTEVILLE WWTF	CO0040355
COSPMS01b	Evans City of	HILL-N-PARK SANITATION DIST.	CO0047287
COSPMS01b	La Salle Town of	LA SALLE TOWN OF	COG588058
COSPMS01b	Gilcrest Town of	GILCREST WWTF	COG588121
COSPMS03a	Elizabeth Town of	GOLD CREEK	COG589037
COSPMS03a	Galeton Water and Sanitation District	GALETON WATER & SAN DISTRICT	CO0043320
COSPMS03a	Orica USA Inc	ORICA USA, INC.	CO0046221
COSPMS03a	Spring Valley Ranch	SPRING VALLEY RANCH WWTF	CO0046965

Segment	Permittee	Facility name	Permit No.
COSPMS03a	Front Range Airport WWTF	FRONT RANGE AIRPORT WWTF	CO0047741
COSPMS04	Lochbuie Town of	LOCHBUIE TOWN OF	CO0047198
COSPMS05a	Swift Beef Company	SWIFT BEEF - LONE TREE	CO0027707
COSPMS05c	Hudson WWTF	HUDSON MECHANICAL WWTF	COG589104
COSPMS06	Keenesburg Town of	KEENESBURG TOWN OF	CO0041254
COSPMS06	Bennett Town of	BENNETT TOWN OF	COG589069
COSPBT02	Estes Park Sanitation District	ESTES PARK SANITATION DISTRICT	CO0020290
COSPBT02	Upper Thompson Sanitation District	UTSD WWTF	CO0031844
COSPBT04c	Loveland City of	LOVELAND WWTP	CO0026701
COSPBT05	Milliken Town of	MILLIKEN SANITATION DISTRICT	CO0042528
COSPBT05	Johnstown Town of	LOW POINT WWTP	CO0047058
COSPBT07	Hidden View Estates HOA	HIDDEN VIEW ESTATES HOA WWTF	CO0048861
COSPBT09	Johnstown Town of	JOHNSTOWN CENTRAL WWTF	CO0021156
COSPBT09	Riverglen Homeowners Assoc	RIVERGLEN HOA WWTF	CO0029742
COSPBT09	Berthoud Town of	BERTHOUD, TOWN OF	CO0046663
COSPBT10	Berthoud Town of	SERENITY RIDGE WWTF	CO0047007
COSPBT10	Western Mini-Ranch/Vaquero Estates Sewer Assoc.	WESTERN MINI-RANCH/VAQUERO EST	COG589095
COSPBT10	Berthoud Estates Community Assoc	BERTHOUD ESTATES WWTF	COG589097
COSPCP08	Fox Acres Community Services Corp	FOX ACRES WWTF	COG589112
COSPCP08	Girl Scouts of Colorado	MAGIC SKY RANCH G.S. CAMP	CO0047317
COSPCP11	Fort Collins City of	MULBERRY WWTP	CO0026425
COSPCP11	Fort Collins City of	DRAKE WWTP	CO0047627
COSPCP12	Windsor, Town of	WINDSOR TOWN OF WWTF	CO0020320
COSPCP12	Greeley City of	GREELEY CITY OF	CO0040258
COSPCP12	Leprino Foods Company	LEPRINO GREELEY FACILITY WWTF	CO0048860
COSPCP13a	Anheuser Busch Inc	NUTRI-TURF, INC.	CO0039977
COSPCP13a	Eaton Town of	EATON, TOWN OF	CO0047414
COSPCP13a	Saddler Ridge Metro Dist Water Reclamation Facility	SADDLER RIDGE METRO DIST WATER RECLAMATION FACILITY	COG589107
COSPCP13b	Boxelder Sanitation District	BOXELDER SANITATION DISTRICT WWTF	CO0020478
COSPCP13b	Wellington Town of	WELLINGTON WWTF	CO0046451
COSPCP22	South Fort Collins Sanitation District	SOUTH FORT COLLINS SAN DIST	CO0020737
COSPLS01	Western Sugar Cooperative	FORT MORGAN FACILITY	CO0041351

Segment	Permittee	Facility name	Permit No.
COSPLS01	Cargill Meat Solutions	FORT MORGAN BEEF PLANT	CO0044270
COSPLS01	Julesburg Town of	JULESBURG TOWN OF	CO0021113
COSPLS01	Brush City of	BRUSH CITY OF	CO0021245
COSPLS01	Sterling City of	STERLING CITY OF	CO0026247
COSPLS01	Fort Morgan City of	FORT MORGAN CITY OF	CO0044849
COSPLS01	Snyder Sanitation District	SNYDER SANITATION DISTRICT	COG588016
COSPLS01	Morgan Heights WSD	MORGAN HEIGHTS WATER&SEWER INC	COG588040
COSPLS01	Ovid Town of	OVID TOWN OF	COG588106
COSPLS02a	Leprino Foods Company	FORT MORGAN CHEESE FACILITY	CO0043958
COSPLS02a	Deer Trail Town of	DEER TRAIL WWTF	COG589002
COSPLS02a	Hillrose Town of	HILLROSE WWTF	COG589030
COSPLS02a	Byers Water and Sanitation District	BYERS WATER AND SANITATION DISTRICT	COG589033
COSPLS02a	Eastern Adams County Metro District	EASTERN ADAMS CO METRO DIST WWTF	COG589035
COSPLS02b	Kiowa Town of	KIOWA WWTF	CO0033405
COSPLS02b	Elbert Water Sanitation District	ELBERT WATER & SANITATION DIST WWTF	COG589065
COSPRE03	Wray City of	WRAY CITY OF	CO0023833
COSPRE06	Flagler Town of	FLAGER WWTF	COG589036
COSPRE06	Arriba Town of	ARRIBA WWTF	COG589055
COSPRE06	Holyoke City of	HOLYOKE, CIY OF	COG589059
COSPRE06	Akron Town of	AKRON WWTF	COG589061
COSPRE06	Haxtun Town of	HAXTUN, TOWN OF	COG589062
COSPRE06	Stratton Town of	STRATTON WWTF	COG589100
COSPRE06	Burlington City of	BURLINGTON CITY OF WWTF	COG589114
COSPRE06	Seibert Town of	SEIBERT WWTF	COG589120
COSPRE07	Cheyenne Wells Sanitation District No 1	CHEYENNE WELLS SANITATION DIST	COG589039
Unclassified	Silco Oil Co	TOMAHAWK TRUCK STOP	COG589003

Prior to May 31, 2022:

- For segments located entirely above these facilities, nutrient standards apply to the entire segment.
- For segments with portions downstream of these facilities, *nutrient standards only apply above these facilities*. A footnote was added to the total phosphorus and chlorophyll a standards in these segments. The footnote references the table of qualified facilities at 38.5(4).
- For segments located entirely below these facilities, nutrient standards do not apply.

A footnote was added to the total phosphorus and chlorophyll a standards in lakes segments as nutrients standards apply only to lakes and reservoirs larger than 25 acres surface area.

38.6 TABLES

(1) Introduction

The numeric standards for various parameters in this regulation and in the tables in Appendix 38-1 were assigned by the Commission after a careful analysis of the data presented on actual stream conditions and on actual and potential water uses.

Numeric standards are not assigned for all parameters listed in the Tables attached to 31.0. If additional numeric standards are found to be needed during future periodic reviews, they can be assigned by following the proper hearing procedures.

(2) Abbreviations:

(a) The following abbreviations are used in this regulation and in the tables in Appendix 38-1:

ac	=	acute (1-day)
°C	=	degrees celsius
ch	=	chronic (30-day)
CL	=	cold lake temperature tier
CLL	=	cold large lake temperature tier
CS-I	=	cold stream temperature tier one
CS-II	=	cold stream temperature tier two
D.O.	=	Dissolved oxygen
DM	=	daily maximum
DUWS	=	direct use water supply
E. coli	=	Eschericia coli
mg/l	=	milligrams per liter
MWAT	=	maximum weekly average temperature
OW	=	outstanding waters
sp	=	Spawning
SSE	=	site-specific equation
T	=	total recoverable
t	=	total
tr	=	trout
TVS	=	table value standard
µg/l	=	micrograms per liter
UP	=	use-protected
WAT	=	weekly average temperature
WL	=	warm lake temperature tier
WS	=	water supply
WS-I	=	warm stream temperature tier one
WS-II	=	warm stream temperature tier two
WS-III	=	warm stream temperature tier three

(b) In addition, the following abbreviations are used:

Fe(ch)	=	WS
Mn(ch)	=	WS
SO ₄	=	WS

These abbreviations mean: For all surface waters with an actual water supply use, the less restrictive of the following two options shall apply as numerical standards, as specified in the Basic Standards and Methodologies at 31.11(6);

- (i) existing quality as of January 1, 2000; or
- (ii)

Iron	=	300 µg/l (dissolved)
Manganese	=	50 µg/l (dissolved)
SO ₄	=	250 mg/l

For all surface waters with a “water supply” classification that are not in actual use as a water supply, no water supply standards are applied for iron, manganese or sulfate, unless the Commission determines as the result of a site-specific rulemaking hearing that such standards are appropriate.

(c) Temporary Modification for Water + Fish Chronic Arsenic Standard

- (i) The temporary modification for chronic arsenic standards applied to segments with an arsenic standard of 0.02 µg/l that has been set to protect the Water+Fish qualifier is listed in the temporary modification and qualifiers column as As(ch)=hybrid.
- (ii) For discharges existing on or before 6/1/2013, the temporary modification is: As(ch)=current condition, expiring on 12/31/2021.
- (iii) For new or increased discharges commencing on or after 6/1/2013, the temporary modification is: As(ch)=0.02-3.0 µg/l (Trec), expiring on 12/31/2021.
 - (a) The first number in the range is the health-based water quality standard previously adopted by the Commission for the segment.
 - (b) The second number in the range is a technology based value established by the Commission for the purpose of this temporary modification.
 - (c) Control requirements, such as discharge permit effluent limitations, shall be established using the first number in the range as the ambient water quality target, provided that no effluent limitation shall require an “end-of-pipe” discharge level more restrictive than the second number in the range.

(3) Table Value Standards

In certain instances in the tables in Appendix 38-1, the designation “TVS” is used to indicate that for a particular parameter a “table value standard” has been adopted. This designation refers to numerical criteria set forth in the Basic Standards and Methodologies for Surface Water. The criteria for which the TVS are applicable are on the following table.

**TABLE VALUE STANDARDS
(Concentrations in µg/l unless noted)**

PARAMETER ⁽¹⁾	TABLE VALUE STANDARDS ⁽²⁾⁽³⁾
Aluminum (T)	Acute = $e^{(1.3695[\ln(\text{hardness})]+1.8308)}$ pH equal to or greater than 7.0

	<p>Chronic=$e^{(1.3695[\ln(\text{hardness})]-0.1158)}$</p> <p>pH less than 7.0</p> <p>Chronic=$e^{(1.3695[\ln(\text{hardness})]-0.1158)}$ or 87, whichever is more stringent</p>
Ammonia ⁽⁴⁾	<p>Cold Water = (mg/l as N)Total</p> $acute = \frac{0.275}{1 + 10^{7.204 - pH}} + \frac{39.0}{1 + 10^{pH - 7.204}}$ $chronic = \left(\frac{0.0577}{1 + 10^{7.688 - pH}} + \frac{2.487}{1 + 10^{pH - 7.688}} \right) * MIN \left(2.85, 1.45 * 10^{0.028(25 - T)} \right)$ <p>Warm Water = (mg/l as N)Total</p> $acute = \frac{0.411}{1 + 10^{7.204 - pH}} + \frac{58.4}{1 + 10^{pH - 7.204}}$ $chronic \text{ (Apr 1 - Aug 31)} = \left(\frac{0.0577}{1 + 10^{7.688 - pH}} + \frac{2.487}{1 + 10^{pH - 7.688}} \right) * MIN \left(2.85, 1.45 * 10^{0.028(25 - T)} \right)$ $chronic \text{ (Sep 1 - Mar 31)} = \left(\frac{0.0577}{1 + 10^{7.688 - pH}} + \frac{2.487}{1 + 10^{pH - 7.688}} \right) * 1.45 * 10^{0.028 * (25 - MAX(T, 7))}$
Cadmium	<p>Acute = $(1.136672 - [\ln(\text{hardness}) \times (0.041838)]) * e^{(0.9151[\ln(\text{hardness})] - 3.1485)}$</p> <p>Acute(Trout) = $(1.136672 - [\ln(\text{hardness}) \times (0.041838)]) * e^{(0.9151[\ln(\text{hardness})] - 3.6236)}$</p> <p>Chronic = $(1.101672 - [\ln(\text{hardness}) \times (0.041838)]) * e^{(0.7998[\ln(\text{hardness})] - 4.4451)}$</p>
Chromium III ⁽⁵⁾	<p>Acute = $e^{(0.819[\ln(\text{hardness})] + 2.5736)}$</p> <p>Chronic = $e^{(0.819[\ln(\text{hardness})] + 0.5340)}$</p>
Chromium VI ⁽⁵⁾	<p>Acute = 16</p> <p>Chronic = 11</p>
Copper	<p>Acute = $e^{(0.9422[\ln(\text{hardness})] - 1.7408)}$</p> <p>Chronic = $e^{(0.8545[\ln(\text{hardness})] - 1.7428)}$</p>
Lead	<p>Acute = $(1.46203 - [\ln(\text{hardness}) * (0.145712)]) * e^{(1.273[\ln(\text{hardness})] - 1.46)}$</p> <p>Chronic = $(1.46203 - [\ln(\text{hardness}) * (0.145712)]) * e^{(1.273[\ln(\text{hardness})] - 4.705)}$</p>
Manganese	<p>Acute = $e^{(0.3331[\ln(\text{hardness})] + 6.4676)}$</p> <p>Chronic = $e^{(0.3331[\ln(\text{hardness})] + 5.8743)}$</p>
Nickel	<p>Acute = $e^{(0.846[\ln(\text{hardness})] + 2.253)}$</p> <p>Chronic = $e^{(0.846[\ln(\text{hardness})] + 0.0554)}$</p>

Selenium ⁽⁶⁾	Acute = 18.4						
	Chronic = 4.6						
Silver	Acute = $\frac{1}{2} e^{(1.72[\ln(\text{hardness})]-6.52)}$						
	Chronic = $e^{(1.72[\ln(\text{hardness})]-9.06)}$						
	Chronic(Trout) = $e^{(1.72[\ln(\text{hardness})]-10.51)}$						
Temperature	TEMPERATURE TIER	TIER CODE	SPECIES EXPECTED TO BE PRESENT	APPLICABLE MONTHS	TEMPERATURE STANDARD (°C)		
					(MWAT)	(DM)	
	Cold Stream Tier I	CS-I	brook trout, cutthroat trout	June – Sept.	17.0	21.7	
				Oct. - May	9.0	13.0	
	Cold Stream Tier II	CS-II	all other cold-water species	April – Oct.	18.3	23.9	
				Nov. - March	9.0	13.0	
	Cold Lake	CL	brook trout, brown trout, cutthroat trout, lake trout, rainbow trout, Arctic grayling, sockeye salmon	April – Dec.	17.0	21.2	
				Jan. - March	9.0	13.0	
	Temperature	Cold Large Lake (>100 acres surface area)	CLL	brown trout, lake trout, rainbow trout	April – Dec.	18.3	23.8
					Jan. - March	9.0	13.0
Warm Stream Tier I		WS-I	common shiner, Johnny darter, orangethroat darter	March – Nov.	24.2	29.0	
				Dec. – Feb.	12.1	14.5	
Warm Stream Tier II		WS-II	brook stickleback, central stoneroller, creek chub, longnose dace, Northern redbelly dace, finescale dace, razorback sucker, white sucker	March – Nov.	27.5	28.6	
				Dec. – Feb.	13.8	14.3	
Warm Stream Tier III		WS-III	all other warm-water species	March – Nov.	28.7	31.8	
				Dec. – Feb.	14.3	15.9	
Warm Lakes		WL	Yellow perch, walleye, pumpkinseed, smallmouth bass, striped bass, white bass, largemouth bass, bluegill, spottail shiner, Northern pike, tiger muskellunge, black crappie, common carp, gizzard shad, sauger, white crappie, wiper	April – Dec.	26.3	29.5	
				Jan. - March	13.2	14.8	
Uranium	Acute = $e^{(1.1021[\ln(\text{hardness})]+2.7088)}$						
	Chronic = $e^{(1.1021[\ln(\text{hardness})]+2.2382)}$						
Zinc	Acute = $0.978 * e^{(0.9094[\ln(\text{hardness})]+0.9095)}$						
	Chronic = $0.986 * e^{(0.9094[\ln(\text{hardness})]+0.6235)}$						

TABLE VALUE STANDARDS - FOOTNOTES

- (1) *Metals are stated as dissolved unless otherwise specified.*
- (2) *Hardness values to be used in equations are in mg/l as calcium carbonate and shall be no greater than 400 mg/L except for aluminum for which hardness shall be no greater than 220 mg/L. The hardness values used in calculating the appropriate metal standard should be based on the lower 95 per cent confidence limit of the mean hardness value at the periodic low flow criteria as determined from a regression analysis of site-specific data. Where insufficient site-specific data exists to define the mean hardness value at the periodic low flow criteria, representative regional data shall be used to perform the regression analysis. Where a regression analysis is not appropriate, a site-specific method should be used. In calculating a hardness value, regression analyses should not be extrapolated past the point that data exist.*
- (3) *Both acute and chronic numbers adopted as stream standards are levels not to be exceeded more than once every three years on the average.*
- (4) *For acute conditions the default assumption is that salmonids could be present in cold water segments and should be protected, and that salmonids do not need to be protected in warm water segments. For chronic conditions, the default assumptions are that early life stages could be present all year in cold water segments and should be protected. In warm water segments the default assumption is that early life stages are present and should be protected only from April 1 through August 31. These assumptions can be modified by the Commission on a site-specific basis where appropriate evidence is submitted.*
- (5) *Unless the stability of the chromium valence state in receiving waters can be clearly demonstrated, the standard for chromium should be in terms of chromium VI. In no case can the sum of the instream levels of Hexavalent and Trivalent Chromium exceed the water supply standard of 50 µg/l total chromium in those waters classified for domestic water use.*
- (6) *Selenium is a bioaccumulative metal and subject to a range of toxicity values depending upon numerous site-specific variables.*
- (7) *E.coli criteria and resulting standards for individual water segments, are established as indicators of the potential presence of pathogenic organisms. Standards for E. coli are expressed as a two-month geometric mean. Site-specific or seasonal standards are also two-month geometric means unless otherwise specified.*
- (8) *All phosphorus standards are based upon the concentration of total phosphorus.*
- (9) *The pH standards of 6.5 (or 5.0) and 9.0 are an instantaneous minimum and maximum, respectively to be applied as effluent limits. In determining instream attainment of water quality standards for pH, appropriate averaging periods may be applied, provided that beneficial uses will be fully protected.*

(4) Assessment Criteria

The following criteria shall be used when assessing whether a specified waterbody is in attainment of the specified standard.

- (a) Upper South Platte Segment 6b, Chatfield Reservoir: Assessment Thresholds

chlorophyll = 11.2 µg/l, summer average, 1 in 5 year allowable exceedance frequency
 phosphorus(Tot) = 0.035 mg/l, summer average, 1 in 5 year allowable exceedance frequency.
- (b) Upper South Platte Segment 16h: Selenium Standards and Assessment Locations

Selenium Standards:

REGULATION #38 STREAM CLASSIFICATIONS and WATER QUALITY STANDARDS

Middle South Platte River Basin

1a. Mainstem of the South Platte River from a point immediately below the confluence with Big Dry Creek to the confluence with St. Vrain Creek.						
COSPM01A	Classifications	Physical and Biological			Metals (ug/L)	
Designation	Agriculture	DM	MWAT	acute chronic		
UP	Aq Life Warm 2	Temperature °C	WS-II	WS-II	Aluminum	--- ---
	Recreation E	acute	chronic	Arsenic	340 0.02(T) ^A	
	Water Supply	D.O. (mg/L)	varies*	varies*	Beryllium	--- ---
Qualifiers:		pH	6.5 - 9.0	---	Cadmium	TVS TVS
Water + Fish Standards		chlorophyll a (mg/m ²)	---	---	Cadmium	5.0(T) ---
Other:		E. Coli (per 100 mL)	---	126	Chromium III	50(T) TVS
Temporary Modification(s):		Inorganic (mg/L)			Chromium VI	TVS TVS
Arsenic(chronic) = hybrid		acute	chronic	Copper	--- 23.5*	
Expiration Date of 12/31/2021		Ammonia	TVS*	TVS*	Copper	35.1* ---
*Ammonia(acute) = See attached table for site-specific standards.		Boron	---	0.75	Iron	--- WS
*Ammonia(chronic) = See attached table for site-specific standards.		Chloride	---	250	Iron	--- 1000(T)
*Copper(acute) = Copper BLM-based FMB		Chlorine	0.019	0.011	Lead	TVS TVS
Cu FMB(ac)=35.1 ug/l		Cyanide	0.005	---	Lead	50(T) ---
*Copper(chronic) = Copper BLM-based FMB		Nitrate	10	---	Manganese	TVS TVS
Cu FMB(ch)= 23.5 ug/l		Nitrite	---	0.5	Manganese	--- WS
*D.O. (mg/L)(acute) = See attached table for site-specific standards.		Phosphorus	---	---	Mercury	--- 0.01(t)
*D.O. (mg/L)(chronic) = See attached table for site-specific standards.		Sulfate	---	WS	Molybdenum	--- 150(T)
		Sulfide	---	0.002	Nickel	TVS TVS
					Nickel	--- 100(T)
					Selenium	TVS TVS
					Silver	TVS TVS
					Uranium	--- ---
					Zinc	TVS TVS

1b. Mainstem of the South Platte River from a point immediately below the confluence with St. Vrain Creek to the Weld/Morgan County Line.						
COSPM01B	Classifications	Physical and Biological			Metals (ug/L)	
Designation	Agriculture	DM	MWAT	acute chronic		
Reviewable	Aq Life Warm 2	Temperature °C	WS-II	WS-II	Aluminum	--- ---
	Recreation E	acute	chronic	Arsenic	340 0.02(T)	
	Water Supply	D.O. (mg/L)	---	5.0	Beryllium	--- ---
Qualifiers:		pH	6.5 - 9.0	---	Cadmium	TVS TVS
Water + Fish Standards		chlorophyll a (mg/m ²)	---	---	Cadmium	5.0(T) ---
Other:		E. Coli (per 100 mL)	---	126	Chromium III	50(T) TVS
Temporary Modification(s):		Inorganic (mg/L)			Chromium VI	TVS TVS
Arsenic(chronic) = hybrid		acute	chronic	Copper	TVS TVS	
Expiration Date of 12/31/2021		Ammonia	TVS	TVS	Iron	--- WS
*Ammonia(acute) = See attached table for site-specific standards.		Boron	---	0.75	Iron	--- 1000(T)
*Ammonia(chronic) = See attached table for site-specific standards.		Chloride	---	250	Lead	TVS TVS
*Copper(acute) = Copper BLM-based FMB		Chlorine	0.019	0.011	Lead	50(T) ---
Cu FMB(ac)=35.1 ug/l		Cyanide	0.005	---	Manganese	TVS TVS
*Copper(chronic) = Copper BLM-based FMB		Nitrate	10	---	Manganese	--- WS
Cu FMB(ch)= 23.5 ug/l		Nitrite	---	0.5	Mercury	--- 0.01(t)
*D.O. (mg/L)(acute) = See attached table for site-specific standards.		Phosphorus	---	---	Molybdenum	--- 150(T)
*D.O. (mg/L)(chronic) = See attached table for site-specific standards.		Sulfate	---	WS	Nickel	TVS TVS
		Sulfide	---	0.002	Nickel	--- 100(T)
					Selenium	TVS TVS
					Silver	TVS TVS
					Uranium	--- ---
					Zinc	TVS TVS

All metals are dissolved unless otherwise noted.
T = total recoverable
t = total
tr = trout

D.O. = dissolved oxygen
DM = daily maximum
MWAT = maximum weekly average temperature
See 38.6 for details on TVS, TVS(tr), WS, temperature standards.

REGULATION #38 STREAM CLASSIFICATIONS and WATER QUALITY STANDARDS

Lower South Platte River Basin

1. Mainstem of the South Platte River from the Weld/Morgan County line to the Colorado/Nebraska border.						
COSPLS01	Classifications	Physical and Biological			Metals (ug/L)	
Designation	Agriculture	DM	MWAT	acute chronic		
Reviewable	Aq Life Warm 2	Temperature °C	WS-II	WS-II	Aluminum	--- ---
	Recreation E		acute	chronic	Arsenic	340 0.02(T)
	Water Supply	D.O. (mg/L)	---	5.0	Beryllium	--- ---
Qualifiers:		pH	6.5 - 9.0	---	Cadmium	TVS TVS
Water + Fish Standards		chlorophyll a (mg/m ²)	---	---	Cadmium	5.0(T) ---
Other:		E. Coli (per 100 mL)	---	126	Chromium III	50(T) TVS
Temporary Modification(s):		Inorganic (mg/L)			Chromium VI	TVS TVS
Arsenic(chronic) = hybrid			acute	chronic	Copper	TVS TVS
Expiration Date of 12/31/2021		Ammonia	TVS	TVS	Iron	--- WS
		Boron	---	0.75	Iron	--- 1000(T)
		Chloride	---	250	Lead	TVS TVS
		Chlorine	0.019	0.011	Lead	50(T) ---
		Cyanide	0.005	---	Manganese	TVS TVS
		Nitrate	10	---	Manganese	--- WS
		Nitrite	---	0.5	Mercury	--- 0.01(t)
		Phosphorus	---	---	Molybdenum	--- 150(T)
		Sulfate	---	WS	Nickel	TVS TVS
		Sulfide	---	0.002	Nickel	--- 100(T)
					Selenium	TVS TVS
					Silver	TVS TVS
					Uranium	--- ---
					Zinc	TVS TVS

2a. All tributaries to the South Platte River, including all wetlands, from the Weld/Morgan County line to the Colorado/Nebraska border, except for the specific listings in Segment 2b.						
COSPLS02A	Classifications	Physical and Biological			Metals (ug/L)	
Designation	Agriculture	DM	MWAT	acute chronic		
UP	Aq Life Warm 2	Temperature °C	WS-II	WS-II	Aluminum	--- ---
	Recreation P		acute	chronic	Arsenic	340 0.02-10(T) ^A
	Water Supply	D.O. (mg/L)	---	5.0	Beryllium	--- 4.0(T)
Qualifiers:		pH	6.5 - 9.0	---	Cadmium	5.0(T) 10(T)
Other:		chlorophyll a (mg/m ²)	---	150*	Chromium III	50(T) 100(T)
*chlorophyll a (mg/m ²)(chronic) = applies only above the facilities listed at 38.5(4).		E. Coli (per 100 mL)	---	205	Chromium VI	50(T) 100(T)
*Phosphorus(chronic) = applies only above the facilities listed at 38.5(4).		Inorganic (mg/L)			Copper	--- 200(T)
			acute	chronic	Iron	--- WS
		Ammonia	---	---	Lead	50(T) 100(T)
		Boron	---	0.75	Manganese	--- WS
		Chloride	---	250	Mercury	--- ---
		Chlorine	---	---	Molybdenum	--- 150(T)
		Cyanide	0.2	---	Nickel	--- 100(T)
		Nitrate	10	---	Selenium	--- 20(T)
		Nitrite	---	1.0	Silver	100(T) ---
		Phosphorus	---	0.17*	Uranium	--- ---
		Sulfate	---	WS	Zinc	--- 2000(T)
		Sulfide	---	0.05		

All metals are dissolved unless otherwise noted.
T = total recoverable
t = total
tr = trout

D.O. = dissolved oxygen
DM = daily maximum
MWAT = maximum weekly average temperature
See 38.6 for details on TVS, TVS(tr), WS, temperature standards.

REGULATION #38 STREAM CLASSIFICATIONS and WATER QUALITY STANDARDS

Lower South Platte River Basin

2b. All tributaries to the South Platte River, including all wetlands, north of the South Platte River and below 4,500 feet in elevation in Morgan County, north of the South Platte River in Washington County, north of the South Platte River and below 4,200 feet in elevation in Logan County, north of the South Platte River and below 3,700 feet in elevation in Sedgwick County, and the mainstems of Beaver Creek, Bijou Creek and Kiowa Creek from their sources to the confluence with the South Platte River, except for the portion of Beaver Creek from its source to the Fort Morgan Canal.

COSPLS02B	Classifications	Physical and Biological			Metals (ug/L)		
Designation	Agriculture		DM	MWAT		acute	chronic
UP	Aq Life Warm 2	Temperature °C	WS-II	WS-II	Aluminum	---	---
	Recreation E		acute	chronic	Arsenic	340	100(T)
Qualifiers:		D.O. (mg/L)	---	5.0	Beryllium	---	---
Other:		pH	6.5 - 9.0	---	Cadmium	TVS	TVS
chlorophyll a (mg/m ³)(chronic) = applies only above the facilities listed at 38.5(4).		chlorophyll a (mg/m ²)	---	150	Chromium III	TVS	TVS
*Phosphorus(chronic) = applies only above the facilities listed at 38.5(4).		E. Coli (per 100 mL)	---	126	Chromium III	---	100(T)
		Inorganic (mg/L)			Chromium VI	TVS	TVS
		acute	chronic		Copper	TVS	TVS
		Ammonia	TVS	TVS	Iron	---	1000(T)
		Boron	---	0.75	Lead	TVS	TVS
		Chloride	---	---	Manganese	TVS	TVS
		Chlorine	0.019	0.011	Mercury	---	0.01(t)
		Cyanide	0.005	---	Molybdenum	---	150(T)
		Nitrate	100	---	Nickel	TVS	TVS
		Nitrite	---	0.5	Selenium	TVS	TVS
		Phosphorus	---	0.17*	Silver	TVS	TVS
		Sulfate	---	---	Uranium	---	---
		Sulfide	---	0.002	Zinc	TVS	TVS

3. Jackson Reservoir, Prewitt Reservoir, North Sterling Reservoir, Jumbo (Julesburg), Riverside Reservoir, Empire Reservoir, and Vancil Reservoir.

COSPLS03	Classifications	Physical and Biological			Metals (ug/L)			
Designation	Agriculture		DM	MWAT		acute	chronic	
UP	Aq Life Warm 1	Temperature °C	WL	WL	Aluminum	---	---	
	Recreation E	Temperature °C	4/1 - 12/31	WL*	26.1*	Arsenic	340	0.02(T)
	Water Supply	Temperature °C	4/1 - 12/31	WL*	27*	Beryllium	---	---
Qualifiers:		Temperature °C	4/1 - 12/31	WL*	28.1*	Cadmium	TVS	TVS
Other:			acute	chronic	Cadmium	5.0(T)	---	
*chlorophyll a (ug/L)(chronic) = applies only above the facilities listed at 38.5(4), applies only to lakes and reservoirs larger than 25 acres surface area.		D.O. (mg/L)	---	5.0	Chromium III	50(T)	TVS	
*Phosphorus(chronic) = applies only above the facilities listed at 38.5(4), applies only to lakes and reservoirs larger than 25 acres surface area.		pH	6.5 - 9.0	---	Chromium VI	TVS	TVS	
Temperature(4/1 - 12/31) = North Sterling Res. (MWAT=26.1)		chlorophyll a (ug/L)	---	20	Copper	TVS	TVS	
*Temperature(4/1 - 12/31) = Jumbo Reservoir (MWAT=27)		E. Coli (per 100 mL)	---	126	Iron	---	WS	
*Temperature(4/1 - 12/31) = Jackson Reservoir (MWAT=28.1)		Inorganic (mg/L)			Iron	---	1000(T)	
		acute	chronic		Lead	TVS	TVS	
		Ammonia	TVS	TVS	Lead	50(T)	---	
		Boron	---	0.75	Manganese	TVS	TVS	
		Chloride	---	250	Manganese	---	WS	
		Chlorine	0.019	0.011	Mercury	---	0.01(t)	
		Cyanide	0.005	---	Molybdenum	---	150(T)	
		Nitrate	10	---	Nickel	TVS	TVS	
		Nitrite	---	0.5	Nickel	---	100(T)	
		Phosphorus	---	0.083*	Selenium	TVS	TVS	
		Sulfate	---	WS	Silver	TVS	TVS	
		Sulfide	---	0.002	Uranium	---	---	
					Zinc	TVS	TVS	

All metals are dissolved unless otherwise noted.
T = total recoverable
t = total
tr = trout

D.O. = dissolved oxygen
DM = daily maximum
MWAT = maximum weekly average temperature
See 38.6 for details on TVS, TVS(tr), WS, temperature standards.

REGULATION #38 STREAM CLASSIFICATIONS and WATER QUALITY STANDARDS

Lower South Platte River Basin

4. All lakes and reservoirs tributary to the South Platte River from the Weld/Morgan County line to the Colorado/Nebraska border, except for specific listings in Segments 3 and 5.							
COSPLS04	Classifications	Physical and Biological			Metals (ug/L)		
Designation	Agriculture		DM	MWAT		acute	chronic
Reviewable	Aq Life Warm 2 Recreation P Water Supply	Temperature °C	WL	WL	Aluminum	---	---
Qualifiers:			acute	chronic	Arsenic	340	0.02-10(T) ^A
Other:	*chlorophyll a (ug/L)(chronic) = applies only above the facilities listed at 38.5(4), applies only to lakes and reservoirs larger than 25 acres surface area. *Phosphorus(chronic) = applies only above the facilities listed at 38.5(4), applies only to lakes and reservoirs larger than 25 acres surface area.	D.O. (mg/L)	---	5.0	Beryllium	---	4.0(T)
		pH	6.5 - 9.0	---	Cadmium	5.0(T)	10(T)
		chlorophyll a (ug/L)	---	20*	Chromium III	50(T)	100(T)
		E. Coli (per 100 mL)	---	205	Chromium VI	50(T)	100(T)
		Inorganic (mg/L)			Copper	---	200(T)
			acute	chronic	Iron	---	WS
		Ammonia	---	---	Iron	---	1000(T)
		Boron	---	0.75	Lead	50(T)	100(T)
		Chloride	---	250	Manganese	TVS	TVS
		Chlorine	---	---	Manganese	---	WS
		Cyanide	0.2	---	Mercury	---	0.01(t)
		Nitrate	10	---	Molybdenum	---	150(T)
		Nitrite	---	0.5	Nickel	---	100(T)
		Phosphorus	---	0.083*	Selenium	---	20(T)
		Sulfate	---	WS	Silver	100(T)	---
	Sulfide	---	0.002	Uranium	---	---	
				Zinc	---	2000(T)	
5. All lakes and reservoirs tributary to the South Platte River north of the South Platte River and below 4,500 feet in elevation in Morgan County, north of the South Platte River in Washington County, north of the South Platte River and below 4,200 feet in elevation in Logan County, north of the South Platte River and below 3,700 feet in elevation in Sedgwick County, and the mainstems of Beaver Creek, Bijou Creek and Kiowa Creek from their sources to the confluence with the South Platte River, except for those specific listings in Segment 3.							
COSPLS05	Classifications	Physical and Biological			Metals (ug/L)		
Designation	Agriculture		DM	MWAT		acute	chronic
Reviewable	Aq Life Warm 2 Recreation E Water Supply	Temperature °C	WL	WL	Aluminum	---	---
Qualifiers:			acute	chronic	Arsenic	340	0.02-10(T) ^A
Other:	*chlorophyll a (ug/L)(chronic) = applies only above the facilities listed at 38.5(4), applies only to lakes and reservoirs larger than 25 acres surface area. *Phosphorus(chronic) = applies only above the facilities listed at 38.5(4), applies only to lakes and reservoirs larger than 25 acres surface area.	D.O. (mg/L)	---	5.0	Beryllium	---	---
		pH	6.5 - 9.0	---	Cadmium	TVS	TVS
		chlorophyll a (ug/L)	---	20*	Cadmium	5.0(T)	---
		E. Coli (per 100 mL)	---	126	Chromium III	50(T)	TVS
		Inorganic (mg/L)			Chromium VI	TVS	TVS
			acute	chronic	Copper	TVS	TVS
		Ammonia	TVS	TVS	Iron	---	WS
		Boron	---	0.75	Iron	---	1000(T)
		Chloride	---	250	Lead	TVS	TVS
		Chlorine	0.019	0.011	Lead	50(T)	---
		Cyanide	0.005	---	Manganese	TVS	TVS
		Nitrate	10	---	Manganese	---	WS
		Nitrite	---	0.5	Mercury	---	0.01(t)
		Phosphorus	---	0.083*	Molybdenum	---	150(T)
		Sulfate	---	WS	Nickel	TVS	TVS
	Sulfide	---	0.002	Nickel	---	100(T)	
				Selenium	TVS	TVS	
				Silver	TVS	TVS	
				Uranium	---	---	
				Zinc	TVS	TVS	

All metals are dissolved unless otherwise noted.
 T = total recoverable
 t = total
 tr = trout

D.O. = dissolved oxygen
 DM = daily maximum
 MWAT = maximum weekly average temperature
 See 38.6 for details on TVS, TVS(tr), WS, temperature standards.

**SPSS Subtask 2.2 -
Water Quality Analysis**

**Appendix C
Regulation 93
Standards Attainment Assessment
Summaries**

Exhibit 1-38

South Platte River Basin

Rationales for Segments and Parameters Proposed
For Inclusion in
Regulation No. 93

Water-Quality-Limited Segments Requiring
Total Maximum Daily Loads
(2016 303(d) List)

October 6, 2015

Standards Attainment Assessment Summary

Segment Waterbody ID: COSPMS01b

Hydrologic Unit Code (HUC): 10190003

Segment Number & Description: 1b: Mainstem of the South Platte River from a point immediately below the confluence with St. Vrain Creek to the Weld/Morgan County Line.

Use Classifications: Aquatic Life Warm 2
Water Supply
Recreation E
Agriculture

Assessed portion	Listed portion	M&E parameters	303(d) parameters	Delisted parameters
ALL	ALL	None	<i>E. coli</i> Manganese Arsenic	Selenium

Attainment Summary:

The segment was listed on the 2012 303(d) List for selenium. Recent data for the segment shows that the segment is currently in attainment of the aquatic life use standard for selenium. The assessment included data from 14 stations (see Table 2 below) with a total of 46 data points. The previous listing for selenium was based on 78 data point from a period of record from 2003 through 2009. After further analysis of data from the previous listing cycle, it appears that there must have been an event in July 2005 that resulted in a spike of selenium levels at site 22. The elevated levels gradually decreased by 2007 and remained below the standard since March 2007. The current period of record (2008-2014) shows no individual exceedances in the standard in any of the data points at all stations. Thus the division proposes that this segment is delisted for selenium.

The 85th percentile of the ambient dissolved manganese concentrations for this segment is 108.64 ug/L. For the assessment of the water supply standard for manganese, the least stringent value of either the table value standard of 50 ug/L or existing quality as of the year 2000 is used to assess attainment. For this segment, the existing quality from 2000 is 35.85 ug/L, so the table value standard of 50 ug/L is less stringent. Current ambient conditions exceed this table value standard and the division is proposing this segment for the 303(d) List for manganese.

The 50th percentile of the ambient sulfate data for this segment is 320 ug/L. For the assessment of the water supply standard for sulfate, the least stringent value of either the table value standard of 250 ug/L or existing quality from 2000 is used to assess attainment. For this segment, the existing

quality of sulfate concentrations from 2000 is 329.5 ug/L; the table value standard of 250 ug/L is more stringent. Current conditions do not exceed existing quality from the year 2000 so the division is not proposing this segment for the 303(d) List for sulfate.

Data for arsenic was collected from all thirteen stations in this period of record with a total of 53 data points. However, detection limits for arsenic data collected and analyzed by River Watch are not sufficiently low enough to allow for a comparison of this data to the current standard. As such, this data was removed from this assessment, per Section III.D.5.a of the 2016 Section 303(d) Listing Methodology. After removing the River Watch arsenic data from this assessment 24 valid data points remained. The 50th percentile of the remaining arsenic data for this segment is 1.1 ug/L, which is greater than the water supply standard of 0.02. As such, the Division proposes to place this segment on the 303(d) List for arsenic.

For *E. coli* data assessment there are not enough data points for to make an attainment decision for two-month intervals. Thus the assessment is done on the seasonal basis, looking at the data from May through October. For the months of May through October for the period of record, the *E. coli* geometric mean value of 256.2 cfu/100 mL exceeded the recreation use-based standard of 126 cfu/100 mL with the sample size of eleven. Therefore, the division recommends this segment be added to the 303(d) List for *E. coli*.

Table 2. Water Quality Station Information

Site ID	Site Description	Org	Latitude	Longitude
SP85	South Platte at US Hwy 85 in Greeley	EPA	40.365810	-104.696620
5165	At Eagle Nest	River Watch	40.312327	-104.351652
5115	Below 37th St Br	River Watch	40.379285	-104.672418
5113	Below Conf Poudre	River Watch	40.421177	-104.600722
5195	Centennial SWA	River Watch	40.374500	-104.445600
5157	Downstream CR 61 Bridge	River Watch	40.378719	-104.467041
5140	Klein Property	River Watch	40.421179	-104.601111
5187	Mitani SWA	River Watch	40.421100	-104.600600
Kersey	South Platte at Hwy 37 at Kersey	MWRD	40.412000	-104.563000
Miliken	South Platte at Hwy 60 near Miliken	MWRD	40.320020	-104.811000
117	Twin Bridge	River Watch	40.320300	-104.812100
22	South Platte River near Kersey, CO	WQCD	40.412222	-104.562778
06754000	South Platte River near Kersey, CO	USGS	40.411925	-104.562737
SP-KER	South Platte River at Kersey, below confluence with the Poudre River	Northern	40.4125	-104.5632

Parameter	# of samples	Aquatic Life	Water Supply	Agriculture	# of Exceedances
Aluminum, ug/L	7	-	-	-	None
Ammonia, mg/L as N	53	8.82	-	-	None
Arsenic, ug/L	26	340	-	-	None
Nitrate + Nitrite, mg/L as N	47	-	-	-	None
Cadmium, ug/L	33	8.74	-	-	None
Copper, ug/L	32	47.24	-	-	None
Lead, ug/L	30	266.23	-	-	None
Manganese, ug/L	39	4656.53	-	-	None
Nickel, ug/L	9	1447.74	-	-	None
Selenium, ug/L	46	18.4	-	-	None
Silver, ug/L	13	20.14	-	-	None
Uranium, ug/L	12	-	-	-	None
Zinc, ug/L	37	538.39	-	-	None

Parameter	# of samples	Aquatic Life	Water Supply	Recreation	Agriculture	Ambient ¹	Exceeding Standard?
pH s.u.	62	6.5-9	6.5-9	6.5-9	-	7.8 - 8.3	No
D.O. mg/L ²	63	-	3	3	3	7.7	No
Hardness, mg/L	52	-	-	-	-	379.72	No
Aluminum, ug/L	7	-	-	-	-	46.4	No
Arsenic, ug/L	26	150	0.02	-	100	1.1	Yes
Cadmium, ug/L	33	1.16	5	-	10	0.45	No
Copper, ug/L	32	28.01	1000	-	200	4.59	No
Iron (Trec), ug/L	30	1000	-	-	-	544.5	No
Iron (dis), ug/L	49	-	300	-	-	38.48	No
Lead, ug/L	30	10.37	-	50	100	0.40	No

Table 4. Assessment of Attainment of Chronic or 30-day Standards

Parameter	# of samples	Aquatic Life	Water Supply	Recreation	Agriculture	Ambient ¹	Exceeding Standard?
Molybdenum, ug/L	-	-	-	-	-	-	No
Manganese, ug/L	39	2572.74	50	-	200	108.64	Yes
Nickel, ug/L	9	160.8	100	-	200	1.98	No
Selenium, ug/L	46	4.6	50	-	20	2.5	No
Silver, ug/L	13	3.18	100	-	-	0.09	No
Sulfate, mg/L	37	-	329.5 ³	-	-	320	No
Uranium, ug/L	12	-	16.8	-	-	26.7	No
Zinc, ug/L	37	407.78	5000	-	2000	32.6	No
Ammonia (mg/l as N)	53	2.57	-	-	-	0.475	No

1 - Ambient (statistic) = (e.g., 15th, 50th, 85th percentile or geometric mean)

2 - Class 1/Cold Water Biota D.O. during spawning 7.0 mg/l

3 - Standard represents existing quality from 2000 for SO4 from 1995 to 1999 with a sample size of 70.

Table 5. *E.coli* Assessment Segment Std: 126 cfu/100 mL

Months	2009	2010	2011	2012	2013	2014	5 year
Jan-Feb	0\ 0	1\ 101.2	0\ 0	0\ 0	0\ 0	0\ 0	1\ 101.2
Mar-Apr	0\ 0	1\ 45.9	0\ 0	0\ 0	1\ 44.8	2\ 18.8	4\ 29.2
May-Jun	0\ 0	1\ 204.6	0\ 0	0\ 0	1\ 102	2\ 688.8	4\ 315.5
July-Aug	0\ 0	0\ 0	0\ 0	0\ 0	2\ 595.8	2\ 414.2	4\ 496.7
Sep-Oct	0\ 0	0\ 0	0\ 0	0\ 0	1\ 70	2\ 86	3\ 80.3
Nov-Dec	0\ 0	0\ 0	0\ 0	0\ 0	1\ 45.7	0\ 0	1\ 45.7
POR Seasonal (May-Oct)	11\ 256.2						
POR Geomean	17\ 131.5						
	Sample size\Geomean (cfu/100 mL)						

Standards Attainment Assessment Summary

Segment Waterbody ID: COSPLS01

HUC Code (HUC): 10190003, 10190012, 10190018

Segment Number & Description: 1. Mainstem of the South Platte River from the Weld/Morgan County line to the Colorado/Nebraska border.

Use Classifications: Aquatic Life Warm 2
Water Supply
Recreation E
Agriculture

Table 1. Summary of Proposed Action

Assessed portion	Listed portion	M&E parameters	303(d) parameters	Delisted parameters
ALL	ALL	None	Mn ¹ , U, SO ₄	Se, Aquatic Life

¹This parameter was originally proposed for the 303(d) List in a previous cycle and the division is proposing to retain the listing.

Attainment Summary: The segment is currently on the M&E list for not meeting the aquatic life use and on the 303(d) list as being impaired for selenium (Se) and manganese (Mn).

Assessment during this period of record shows the segment is not in attainment of the water supply use-based standards for sulfate, manganese and uranium. Using information from historical records from the 2009 South Platte River RMH it was determined that the sulfate existing quality as of January 1, 2000 is equal to 411 mg/l. This was calculated from the 50th percentile during the period January 1, 1998 to December 31, 2002 of which there were 92 values. Current water quality for sulfate is equal to 744 ug/L and exceeds the standard. The division is proposing to add sulfate to the 303(d) list.

The 85th percentile of the manganese data for this segment is 69 ug/L, from 62 samples, which is greater than the chronic standard of 50 ug/L. The year 2000 ambient concentration for manganese was 25 ug/L based on 48 samples from 1995 to 1999. This is less than the manganese TVS. The division is proposing to add manganese to the 303(d) list.

The 85th percentile of the uranium data for this segment is 43.35 ug/L, from 12 samples, which is greater than the chronic standard of 30 ug/L. The division is proposing to add uranium to the 303(d) list.

Current data indicates the segment is attaining the selenium standard and should be delisted. The 85th percentile of the selenium data for this segment is 4.09 ug/L which is less than the chronic standard of 4.6 ug/L. The division is proposing to delist selenium from the 303(d) list. This change was not considered in the initial proposal.

Table 2. Water Quality Station Information

Site ID	Site Description	Org	Latitude	Longitude
187	South Platte River at Ft Morgan Riverside Pk	River Watch	40.26852648	-103.8012175

Table 2. Water Quality Station Information				
Site ID	Site Description	Org	Latitude	Longitude
188	South Platte River at Narrows	River Watch	40.32205065	-103.9222225
223	South Platte River at Proctor	River Watch	40.79279928	-102.9460105
5119	South Platter River nr Snyder Brush SWA	River Watch	40.3123	-103.6206
5121	South Platte River nr Red Lion	River Watch	40.87028719	-102.6874677
5122	South Platte River at Crook Hwy 55 Br	River Watch	40.84339487	-102.8051749
5123	South Platte River nr Atwood Hwy 63 Br	River Watch	40.53798712	-103.265293
5124	South Platte River at Atwood SWA #608	River Watch	40.51178162	-103.2985919
5134	South Platte River nr Merino Smith Ranch	River Watch	40.47078217	-103.3518942
5141	South Platte River abv Julesburg Pony Express SWA	River Watch	40.95179263	-102.3005643
5159	South Platte River Abv Hwy 52 Br at Reid nr Log Lane Village	River Watch	40.27926938	-103.8423151
5160	South Platte River at Wachorne Property blw Juleburg	River Watch	40.99559583	-102.2260006
5162	South Platte River at Crook Abv Hwy 55 Br	River Watch	40.84174901	-102.8034145
5163	South Platte River at Tamarack SWA Spot #22 nr Proctor	River Watch	40.80872191	-102.919711
5186	South Platte River nr Ovid Julesburg SWA	River Watch	40.95506	-102.38744
5190	South Platte River nr Sedgwick Hwy 59 Br	River Watch	40.9266	-102.5195
5193	South Platte River nr Sterling Bravo SWA	River Watch	40.6776	-103.1337
5194	South Platte River at Red Lion SWA	River Watch	40.8836	-102.6522
5196	South Platte River at Log Lane Village Boyd Ponds SWA	River Watch	40.2739	-103.829
Julesburg	South Platte at Hwy 385 at Julesburg	MWRD	40.973	-102.251
Hillrose	South Platte River at County Road 33 at Hillrose	MWRD	40.3584	-103.503
Iliff	South Platte River at County Road 55 at Iliff	MWRD	40.7475	-103.056
FtMorgan	South Platte River at Ft Morgan	MWRD	40.2683	-103.8015
Goodrich	South Platte River at Goodrich	MWRD	40.3418	-104.06
Crook	South Platte River at Highway 55 at Crook	MWRD	40.8416	-102.8052
6758500	SOUTH PLATTE RIVER NEAR WELDONA, CO	USGS	40.2684028	-103.8011917
403709103111900	SOUTH PLATTE RIVER AT HWY 6 AT STERLING, CO	USGS	40.6191529	-103.1890977
21	SOUTH PLATTE RIVER AT BALZAC	WQCD	40.40667	-103.466

Table 2. Water Quality Station Information

Site ID	Site Description	Org	Latitude	Longitude
128	SOUTH PLATTE R BELOW STERLING	WQCD	40.74737	-103.05598
5005	SOUTH PLATTE RIVER AT OVID	WQCD	40.95428333	-102.3873833
5006	SOUTH PLATTE RIVER AT TAMARACK SWA	WQCD	40.8416	-102.805
5015	SOUTH PLATTE AT COOPER	WQCD	40.3575	-103.5286111
5020	SOUTH PLATTE RIVER AT MASTERS	WQCD	40.32235	-103.5936017
5030	SOUTH PLATTE RIVER AT MESSEX SWA	WQCD	40.42131667	-103.42015
5040	SOUTH PLATTE RIVER AT BRUSH SWA	WQCD	40.30933333	-103.6265167
5049	S PLATTE R AT US HWY 395 NR JULESBURG	WQCD	40.97335	-102.25115

Table 3. Assessment of Attainment of Acute or One-day Standards (COSPLS01)

Parameter	# of samples	Aquatic Life	Water Supply	Agriculture	# of Exceedances
Aluminum, µg/L	12	NS	-	-	0
Ammonia, mg/L as N)	50	TVS	-	-	0
Arsenic, µg/L	59	340	-	-	0
Nitrate + Nitrite (mg/L)	54	-	10	100	0
Cadmium (dis), µg/L	62	9.15	10	-	0
Copper (dis), µg/L	62	49.62	-	-	0
Chromium-III, µg/L	0	NS	-	-	0
Chromium-IV, µg/L	0	16	-	-	0
Lead (dis), µg/L	62	280.85	50	-	0
Manganese (dis), µg/L	62	4737.94	-	-	0
Nickel, µg/L	12	1512.89	-	-	0
Selenium (dis), µg/L	62	18.4	-	-	0
Silver, µg/L	24	22.02	-	-	0
Uranium, µg/L	12	NS	-	-	0
Zinc (dis), µg/L	62	564.47	-	-	0

Table 4. Assessment of Attainment of Chronic or 30-day Standards (All)

Parameter	# of samples	Aquatic Life	Water Supply	Recreation	Agriculture	Ambient*	Exceeding Standard?
pH, s.u.	71	6.5 - 9	5 - 9	6.5-9.0	-	8.03	Attainment
D.O., mg/L	71	5	3	3	3	7.81	Attainment
Hardness, mg/L	61	-	-	-	-	-	N/A
Sulfate, mg/l	40	-	411**	-	-	744	Yes
Aluminum, µg/L	12	NS	-	-	-	0	No
Arsenic, µg/L	59	150	10	-	100	0	No
Cadmium (dis), µg/L	62	1.2	-	-	10	0.50	No
Copper (dis), µg/L	62	29.28	1000	-	200	6.96	No
Chromium-III, µg/L	0	230.67	50	-	100	N/A	-
Chromium-IV, µg/L	0	11	50	-	100	N/A	-
Iron (Trec), µg/L	58	1000	-	-	-	412.5	No

Table 4. Assessment of Attainment of Chronic or 30-day Standards (All)

Parameter	# of samples	Aquatic Life	Water Supply	Recreation	Agriculture	Ambient*	Exceeding Standard?
Iron (dis), µg/L	62	-	300	-	-	21.43	No
Lead (dis), µg/L	62	10.94	-	-	100	1.55	No
Molybdenum, µg/L	0	NS	210	-	300	N/A	No
Manganese (dis), µg/L	62	2617.71	50	-	200	69.12	Yes
Nickel, µg/L	12	168.04	100	-	200	2.35	No
Selenium (dis), µg/L	62	4.6	50	-	20	4.09	No
Silver, µg/L	24	3.47	100	-	-	0	No
Uranium, µg/L	12	NS	30	-	-	43.35	Yes
Zinc (dis), µg/L	62	427.54	5000	-	2000	31.9	No
Ammonia (mg/l as N)	50	TVS	-	-	-	0 Chronic Exceedances	

* Ambient (statistic) = (e.g., 15th, 50th, 85th percentile or geometric mean)

** 2009 South Platte River RMH it was determined that the sulfate existing quality as of January 1, 2000 is equal to 411 mg/l.

Table 5. *E. coli* Assessment (COSPLS01) Segment Std: 126 cfu/100 mL

Months	2008	2009	2010	2011	2012	2013	5 year
Jan-Feb	0\ 0	1\ 8.7	1\ 5.3	0\ 0	0\ 0	0\ 0	2\ 6.8
Mar-Apr	0\ 0	1\ 21.8	0\ 0	0\ 0	0\ 0	0\ 0	1\ 21.8
May-Jun	0\ 0	1\ 102.2	1\ 175.2	0\ 0	0\ 0	0\ 0	2\ 133.8
July-Aug	0\ 0	0\ 0	0\ 0	0\ 0	0\ 0	0\ 0	0\ 0
Sep-Oct	1\ 57.2	0\ 0	0\ 0	0\ 0	0\ 0	0\ 0	1\ 57.2
Nov-Dec	1\ 23.8	1\ 22.8	0\ 0	0\ 0	0\ 0	0\ 0	2\ 23.3
POR Seasonal (May-Oct)	-	-	-	-	-	-	3\ 100.8
POR Geomean	-	-	-	-	-	-	8\ 29.4
Sample size\Geomean (cfu/100 mL)							

Standards Attainment Assessment Summary

Segment Waterbody ID: COSPLS01

Hydrologic Unit Code: 10190012

Segment Number & Description: 1. Mainstem of the South Platte River from the Weld/Morgan County line to the Colorado/Nebraska border.

Use Classifications: Aquatic Life Warm 2
Recreation E
Water Supply
Agriculture

Table 1. Summary of Proposed Action

Assessed portion	Listed portion	303(d) parameters	M&E parameters	Delisted parameters
All	All	None	None	Aquatic Life

Attainment Summary:

The Multimetric Index (MMI) scores were calculated for the 2016 303(d) List based on the Water Quality Control Commission Policy 10-1, Aquatic Life Use Attainment. There are four stations within the segment with data in the current period of record. All the stations are located in Biotype 3 and have an attainment threshold of 37 and an impairment threshold of 22 (Table 4). The MMI scores for stations 5005, 5030 and 5040 are above the attainment threshold for Biotype 3 (Table 4). Station 5006 has an MMI score of 34.5, which falls between the attainment and impairment threshold for Biotype 3. Since this segment is a Class 2 waterbody, the “gray zone” does not apply and the MMI score is considered attaining. Since the most recent data from all four stations are attaining, the Division is proposes to remove this segment from the Monitoring and Evaluation list for aquatic life use.

Existing Water Quality Data:

Please refer to the previous pages of the rationale package to see a detailed description of the water quality impairments for this segment.

Table 2. Water Quality Macroinvertebrate Station Information

Station ID	Site Description	Organization	Latitude	Longitude	Biotype
5005	South Platte River at Ovid	WQCD	40.9543	-102.3874	3
5006	South Platte River at Tamarack SWA	WQCD	40.8416	-102.805	3
5030	South Platte River at Messex SWA	WQCD	40.4213	-103.42015	3
5040	South Platte River at Brush SWA	WQCD	40.309	-103.626	3
Waterbody Class: 2					

Table 3. Multimetric Index Score (MMI)				
Station ID	Collection Date	MMI score	Hilsenhoff Biotic Index (HBI)	Shannon Diversity Index
5005	9/21/2010	48.1	N/A	N/A
5006	9/21/2010	34.5	N/A	N/A
5030	9/21/2010	41.9	N/A	N/A
5040	9/21/2010	38.6	N/A	N/A
Rows in bold indicate impairment either due to failing MMI scores or failing HBI or SDI scores. Rows that include HBI and SDI scores are in the "Gray Zone" and those metrics have been reviewed.				

Comparison with Aquatic Life Thresholds: Thresholds are established based on analysis of the biological condition at reference sites in each of three biotypes.

Table 4. Aquatic Life Use Thresholds			
Biotype		Attainment Threshold	Impairment Threshold
1	Transition	52	42
2	Mountains	50	42
3	Plains & Xeric	37	22

- Class 2 water bodies: When the MMI score falls within the gray zone (between the attainment and impairment thresholds discussed above) and the site is from a Class 2 stream, the stream is considered to be in support of the use.

Standards Attainment Assessment Summary

Segment Waterbody ID: COSPLS03

Hydrologic Unit Code (HUC): 10190003, 10190012

Segment Number & Description: 3. Jackson Reservoir, Prewitt Reservoir, North Sterling Reservoir, Jumbo (Julesburg), Riverside Reservoir, Empire Reservoir, and Vancil Reservoir.

Use Classifications: Aquatic Life Warm 1
Recreation E
Water Supply
Agriculture

Assessed portion	Listed portion	M&E parameters	303(d) parameters	Delisted parameters
ALL	Jackson Reservoir	None	pH ¹	M&E -Se
ALL	North Sterling Reservoir	None	DO, Se	None
ALL	Jumbo Reservoir	Se ¹	None	None

¹This parameter was included on the 303(d) list or M&E list in a previous cycle and the division is proposing to retain the listing.

Attainment Summary: North Sterling Reservoir was previously on the M&E list as potentially impaired by selenium. Sampling results during this assessment period (data period of record=2009-2012) from the top two meters indicate that North Sterling Reservoir is exceeding the selenium standard with a sample size of six (Table 4). Additionally, based on the profile measurements from 9/5/2012, the reservoir does not attain the dissolved oxygen (DO) standard of 5.0 mg/L. The DO profile measurements from 0.5 to 1.5 meters on this date were all below 5.0 mg/L (Table 3). The division proposes adding North Sterling Reservoir to the 303(d) list for selenium and DO.

Jackson Reservoir data confirms the reservoir continues to be impaired because it exceeds the pH standard. The ambient pH for the upper layer of Jackson Reservoir exceeds the pH standard of 9.0 s.u. The 85th percentile of the daily average samples in the top two meters is 9.03 s.u. based on five sampling days (Table 5). From these five sampling events during the current period of record (data period of record=2009-2012), the division concludes that Jackson Reservoir continues to be impaired by high pH and proposes retaining it on the 303(d) List.

Jackson Reservoir is in attainment of the aquatic life selenium standard. The 85th percentile of the selenium data is 4.4 µg/L, (n=5), a value less than the chronic standard of 4.6 µg/L. The previous assessment included four samples that indicated non attainment of the standard. The division proposes removing the selenium listing for Jackson Reservoir from the M&E list.

*Jackson Reservoir 2016 303(d)-pH, M&E-de-list Se
North Sterling Reservoir 2016 303(d)-D.O. and Se
Jumbo Reservoir M & E -Se*

Jumbo Reservoir is currently on the M&E list for selenium because, in the previous assessment, the 85th percentile was 6.27 µg/L (n=4), which exceeded the chronic standard of 4.6 µg/L. For the current assessment, two additional data points were collected that indicate attainment of the selenium standards for Jumbo Reservoir (Table 6). However, additional data collection is needed to remove it from the M&E list. Therefore the division proposes to retain the selenium listing on the M&E list.

Site ID	Site Description	Org	Latitude	Longitude	Datum	POR
5040A	North Sterling Reservoir	WQCD	40.8333333	-103.25	--	7/6/2009 - 9/05/2012
5050A	Jackson Reservoir	WQCD	40.39167	-104.07289	--	7/6/2009 - 7/16/2012
5030A	Jumbo Reservoir	WQCD	40.912801	-102.667117	--	8/16/2010 - 7/17/2012

Data Tables for North Sterling Reservoir:

LAKE	DATE	DEPTH (M)	TEMP C	DO mg/L	pH
NORTH STERLING	7/6/2009	1	22.72	11.88	8.53
NORTH STERLING		2	22.4	10.32	8.44
NORTH STERLING	8/17/2009	1	22.87	9.36	8.53
NORTH STERLING		2	22.68	8.4	8.51
NORTH STERLING	9/28/2009	0.5	15.78	9.13	8.54
NORTH STERLING		1	15.54	9.29	8.52
NORTH STERLING		1.5	15.03	8.71	8.5
NORTH STERLING		2	15.08	8.77	8.5
NORTH STERLING	7/29/2010	0.5	24.44	6.35	8.61
NORTH STERLING		1	24.32	6.24	8.63
NORTH STERLING		1.5	24.25	6.03	8.57
NORTH STERLING		2	24.14	5.56	8.54
NORTH STERLING	7/16/2012	0.5	26.39	10.01	8.85
NORTH STERLING		1	25.93	9.84	8.77
NORTH STERLING		1.5	25.18	5.19	8.31
NORTH STERLING		2	25.04	4.64	8.14
NORTH STERLING	8/7/2012	0.5	25.94	12.22	8.95
NORTH STERLING		1	24.88	6.41	8.51
NORTH STERLING		1.5	24.68	4.77	8.24

*Jackson Reservoir 2016 303(d)-pH, M&E-de-list Se
North Sterling Reservoir 2016 303(d)-D.O. and Se
Jumbo Reservoir M & E -Se*

Table. 3 Surface Probe Data for North Sterling Reservoir					
LAKE	DATE	DEPTH (M)	TEMP C	DO mg/L	pH
NORTH STERLING	9/5/2012	0.5	22.35	3.61	7.77
NORTH STERLING		1	22.09	1.34	7.61
NORTH STERLING		1.5	21.97	1.08	7.58

Table 4. Assessment of Attainment of Chronic or 30-day Standards for North Sterling Reservoir-Upper							
Parameter	# of samples	Aquatic Life	Water Supply	Recreation	Agriculture	Ambient*	Exceeding Standard?
Selenium (ug/L)	6	4.6	50		20	5.725	Yes
* Ambient (statistic) = the 85 th percentile							

Data Table for Jackson Reservoir:

Table. 5 Surface Probe Data for Jackson Reservoir					
LAKE	DATE	Depth (m)	Temp C	pH	DO mg/L
JACKSON	7/6/2009	1	24.66	8.39	9.03
JACKSON		2	23.82	8.32	7.52
JACKSON	8/17/2009	1	22.68	8.9	9.14
JACKSON		2	21.5	8.8	6.13
JACKSON	9/28/2009	0.5	14.85	8.56	8.69
JACKSON		1	14.79	8.55	8.65
JACKSON		1.5	14.72	8.55	8.68
JACKSON		2	14.66	8.54	8.51
JACKSON	7/29/2010	0.5	27.34	9.34	11.94
JACKSON		1	25.34	9.32	10.83
JACKSON		1.5	25.16	9.32	10.44
JACKSON		2	24.7	9.22	8.44
JACKSON	7/16/2012	0.5	26.34	8.86	7.31
JACKSON		1	25.63	8.84	7.32
JACKSON		1.5	25.21	8.79	7.05
JACKSON		2	24.76	8.68	6.54

*Jackson Reservoir 2016 303(d)-pH, M&E-de-list Se
North Sterling Reservoir 2016 303(d)-D.O. and Se
Jumbo Reservoir M & E -Se*

Data Table for Jumbo Reservoir:

Table 6. Assessment of Attainment of Chronic or 30-day Standards for Jumbo Upper							
Parameter	# of samples	Aquatic Life	Water Supply	Recreation	Agriculture	Ambient*	Exceeding Standard?
Selenium (ug/L)	2	4.6	50		20	2.04	No
* Ambient (statistic) = the 85 th percentile							

**SPSS Subtask 2.2 -
Water Quality Analysis**

**Appendix D
Detailed Compilation of Water Quality
Review Data**

APPENDIX D – Detailed Compilation of Water Quality Review

Parameter ¹	Water Quality Standard (WQS) ³	Designated Uses ²	Water Quality Criteria ² Associated with Use	Ambient Water Quality ^{4,5}	Meets WQS (Y/N)	Meets Criteria (Y/N)
Segment COSPM501b - Mainstem of South Platte River from a point immediately below the confluence with St. Vrain Creek to the Weld/Morgan county line						
Arsenic*	340 µg/L (acute, dissolved) 0.02 µg/L (chronic, tot. rec. †)	Agriculture	100 µg/L (30-day avg., tot. rec.)	50 th -ile of arsenic data = 1.1 ug/L (based on 24 samples)	NO – Water Supply chronic	Y
		Aquatic Life Warm 2	340 µg/L (acute, dissolved) 150 µg/L (chronic, dissolved)			Y
		Water Supply	0.02 – 10 µg/L (30-day avg., tot. rec.)††			NO
		Recreation	100 µg/L (chronic, tot. rec.)			Y
E. Coli*	126 cfu/100 mL (2-month geometric mean)	Agriculture	(no criteria)	Seasonal geometric mean = 256.2 cfu/100 ml	NO - Recreation	(none)
		Aquatic Life Warm 2	(no criteria)			(none)
		Water Supply	630 E. coli/100 mL			Y
		Recreation	126 E. coli/100 mL			NO
Manganese*	Table Value Equations = @ hardness ≥ 400 mg/L 4,738 µg/L (acute, dissolved) 2,618 µg/L (chronic, dissolved) 50 µg/L (30-day avg., tot. rec.) OR existing quality as of 1/1/2000, whichever is less restrictive	Agriculture	200 µg/L (30-day avg., tot. rec.)	85 th -ile of dissolved manganese data = 108.64 ug/L (based on 39 samples) (existing quality in 2000 = 35.85 ug/L; therefore WQS = 50 ug/L applies)	NO – Water Supply chronic	Y
		Aquatic Life Warm 2	Table Value Standards = 4,738 µg/L (acute, dissolved) 2,618 µg/L (chronic, dissolved) @ hardness ≥ 400 mg/L			Y
		Water Supply	50 µg/L (30-day avg., dissolved)			NO
		Recreation	(no criteria)			(none)
Sulfate***	250 µg/L (30-day avg., tot. rec.) OR existing quality as of 1/1/2000, whichever is less restrictive	Water Supply	250 µg/L (30-day avg., tot. rec.)	50 th percentile = 320 µg/L for segment (existing quality in 2000 = 329.5 µg/L; therefore WQS = 329.5 µg/L)	Yes, but barely	Y (barely)
Segment COSPL501 - Mainstem of South Platte River from the Weld/Morgan county line to the Colorado/Nebraska border						
Manganese*	Table Value Equations @ hardness ≥ 400 mg/L = 4,738 µg/L (acute, dissolved) 2,618 µg/L (chronic, dissolved) 50 µg/L (30-day avg., tot. rec.) OR existing quality as of 1/1/2000, whichever is less restrictive	Agriculture	200 µg/L (30-day avg., tot. rec.)	85 th -ile of manganese data = 69 ug/L (based on 39 samples) (existing quality in 2000 = 25 ug/L; therefore WQS = 50 ug/L applies)	NO – Water Supply chronic	Y
		Aquatic Life Warm 2	Table Value Standards = @ hardness ≥ 400 mg/L 4,738 µg/L (acute, dissolved) 2,618 µg/L (chronic, dissolved) @ hardness ≥ 400 mg/L			Y
		Water Supply	50 µg/L (30-day avg., dissolved)			NO
		Recreation	(no criteria)			(none)
Selenium*	18.4 µg/L (acute, dissolved) 4.6 µg/L (chronic, dissolved)	Agriculture	20 µg/L (30-day avg., tot. rec.)	85 th -ile of selenium data = 4.09 ug/L	Yes, but barely	Y
		Aquatic Life Warm 2	18.4 µg/L (acute, dissolved) 4.6 µg/L (chronic, dissolved)			Y (barely)
		Water Supply	50 µg/L (30-day avg., tot. rec.)			Y
		Recreation	(no criteria)			(none)
Uranium*	(no water quality standard assigned in Regulation 38; Water Quality Control Division used water quality criteria from Regulation 31 for 303(d) assessment))	Agriculture	(no criteria)	85 th -ile of uranium data = 43.35 ug/L (based on 12 samples)	(none)	(none)
		Aquatic Life Warm 2	Table Value Standards = 11,070 µg/L (acute, dissolved) 6,915 µg/L (chronic, dissolved)			Y
		Water Supply	16.8 – 30 µg/L (30-day avg., tot. rec.)††			NO
		Recreation	(no criteria)			(none)
Sulfate**	250 µg/L (30-day avg., tot. rec.) OR existing quality as of 1/1/2000, whichever is less restrictive	Agriculture	(no criteria)	50 th percentile = 744 µg/L for segment (existing quality in 2000 = 411 µg/L; therefore WQS = 411 µg/L)	NO – Water Supply chronic	(none)
		Aquatic Life Warm 2	(no criteria)			(none)
		Water Supply	250 µg/L (30-day avg., tot. rec.)			NO
		Recreation	(no criteria)			(none)
Segment COSPL503 - Jackson Reservoir portion only						
pH*	6.5 – 9.0 s.u. (instantaneous minimum and maximum, respectively)	Agriculture	(no criteria)	85 th percentile = 9.03 s.u. (based on 5 sampling days)	NO- Aquatic Life & Water Supply	(none)
		Aquatic Life Warm 1	6.5 – 9.0 (instantaneous, min – max)			NO
		Water Supply	5.0 – 9.0 (instantaneous, min – max)			NO
		Recreation E	(no criteria)			(none)
Segment COSPL503 – North Sterling Reservoir only						
Dissolved Oxygen*	5.0 mg/L (minimum) (see Reg. 31, Table I, Footnote 9 for exclusions)	Agriculture	3.0 mg/L	Dissolved oxygen measurements ranged from 1.08 mg/L to 12.22 mg/L	NO- All uses	NO
		Aquatic Life Warm 1	5.0 mg/L (minimum)			NO
		Water Supply	3.0 mg/L			NO
		Recreation E	3.0 mg/L			NO
Selenium*	18.4 µg/L (acute, dissolved) 4.6 µg/L (chronic, dissolved)	Agriculture	20 µg/L (30-day avg., tot. rec.)	85 th -ile of selenium data = 5.725 ug/L (based on 6 samples, 2009-2012)	NO – Chronic Aquatic Life	Y
		Aquatic Life Warm 1	18.4 µg/L (acute, dissolved) 4.6 µg/L (chronic, dissolved)			NO
		Water Supply	50 µg/L (30-day avg., tot. rec.)			Y
		Recreation E	(no criteria)			(none)

APPENDIX D – Detailed Compilation of Water Quality Review

Footnotes:

¹ Identified as a key parameter, based on inclusion on: Water Quality Control Commission, 2016 Colorado Section 303(d) List of Impaired Waters and Monitoring and Evaluation List (amended 10/11/16, effective 11/20/16), Regulation #93, 5 CCR 1002-93.

² Water Quality Control Commission, Basic Standards and Methodologies for Surface Water, (amended 1/9/17, effective 3/1/17), Regulation #31, 5 CCR 1002-31. **(Note: WQS are generally chosen as the most stringent of these values. Criteria may be used for water quality comparisons for a specific use.)**

³ Water Quality Control Commission, Classifications and Numeric Standards for South Platte River Basin, Laramie River Basin, Republican River Basin, Smoky Hill River Basin (amended 1/9/17 and 4/10/17, effective 6/30/17), Appendix 38-1 Stream Classifications and Water Quality Standards Tables, Regulation #31, 5 CCR 1002-31

⁴ Water Quality Control Division Proponent's Prehearing Statement for 2015 Regulation 93 Rulemaking Hearing, Exhibit 1-38, South Platte River Basin, Rationales for Segments and Parameters Proposed for Inclusion in Regulation No. 93 Water Quality-Limited Segments Requiring Total Maximum Daily Loads (2016 303(d) List), October 6, 2015.

⁵ The Water Quality Control Division uses the 50th percentile of ambient data to determine compliance with dissolved standards, and the 85th percentile to determine compliance with total recoverable standards. For assessment of *E.coli*, the Division uses a geometric mean.

Symbols:

* The Water Quality Control Commission has determined these parameters are not meeting the water quality standards.

** The Water Quality Control Commission has determined that there is reason to suspect water quality problems for these parameters.

*** Although the Water Quality Control Commission determined that this parameter was in compliance with the water quality standards, the parameter is included for analysis, as it may impact treatment costs.

† tot. rec. = total recoverable

†† The first number in the range is a strictly health-based value. The second number in the range is a maximum contaminant level, established under the federal Safe Drinking Water Act that has been determined to be an acceptable level of this chemical in public water supplies, taking treatability and laboratory detection limits into account. Control requirements, such as discharge permit effluent limitations, shall be established using the first number in the range as the ambient water quality target, provided that no effluent limitation shall require an "end-of-pipe" discharge level more restrictive than the second number in the range.

Other relevant water quality data conclusions from reference (4) above:

COSPMS01b:

- Sulfate 50th percentile = 320 µg/L for segment. Ambient quality in 2000 was 329.5 µg/L. The sulfate water quality standard is 250 µg/L OR existing quality as of 1/1/2000, whichever is less restrictive. Therefore, the Division determined this segment was in attainment of the less restrictive standard (though just barely). **This is a parameter that should be also considered for Segment COSPLSMS01b, as it may impact treatment costs, and is included in the table above.**
- The Division found the segment was in attainment of acute water quality standards for aquatic life, water supply, and agriculture for aluminum, ammonia, arsenic, nitrate + nitrite, cadmium, copper, lead, manganese, nickel, selenium, silver, uranium, and zinc.
- The Division found the segment was in attainment of chronic water quality standards for aquatic life, water supply, recreation, and agriculture for pH, dissolved oxygen, aluminum, cadmium, copper, iron, lead, molybdenum, nickel, selenium, silver, sulfate, uranium, zinc, and ammonia.

COSPLS01:

- The Division found the segment was in attainment of acute water quality standards for aquatic life, water supply, and agriculture for aluminum, ammonia, arsenic, nitrate + nitrite, cadmium, copper, lead, manganese, nickel, selenium, silver, uranium, and zinc. **However, the segment was retained on the 303(d) list in 2016 for selenium by the Water Quality Control Commission.**
- The Division found the segment was in attainment of chronic water quality standards for aquatic life, water supply, recreation, and agriculture for pH, dissolved oxygen, aluminum, arsenic, cadmium, copper, iron, lead, manganese, nickel, selenium, silver, zinc, and ammonia.

APPENDIX H – STORAGE ALTERNATIVE FORMULATION AND EVALUATION TM

NOTE: SOME OF THE INFORMATION IN THIS TM WAS CHANGED DURING
PREPARATION OF THE FINAL REPORT

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To: Joe Frank, Andy Moore
Lower South Platte Water Conservancy
District, Colorado Water Conservation
Board

From: Chip Paulson, Samantha Mauzy, Mary
Presecan
Stantec and LRE

Subject: **Storage Alternative Formulation and
Evaluation**

Date: October 24, 2017

INTRODUCTION

This Technical Memorandum presents the methods and results of the South Platte Storage Study (SPSS) storage alternative formulation and evaluation. It describes:

- the screening of storage options from the full inventory of options;
- the process of constructing surface storage and groundwater storage conceptual alternatives;
- the components comprising those conceptual alternatives;
- specific storage options linked to the conceptual alternatives;
- the modeling analysis used to estimate water supply available from each alternative; and
- the evaluation and comparison of alternatives based on cost, technical, environmental, and social factors.

SCREENING OF STORAGE OPTIONS

This section describes the process used to screen storage options and eliminate those options with fatal flaws or that did not meet minimum criteria related to SPSS project goals. The objective of this process was not to identify the best storage options, but to eliminate clearly inferior options that would not meet SPSS objectives.

The storage option screening process was conducted collaboratively in a workshop attended by members of the South Platte and Metro Basin Roundtables and the Stantec consultant team. Subsequent refinements were made by the consultant team with concurrence of the SPSS Review Committee.

Screening of Surface Reservoir Options

The following process was used to filter and screen options for traditional surface reservoir storage.

Step 1: Full Inventory of Potential Storage Options. The starting point for the screening analysis was the full inventory of surface and groundwater storage options listed in the TM “South Platte Storage Opportunities Literature Review.” This inventory was “scrubbed” to remove options that were duplicated, out of the study area, too far from the South Platte River to be practical, and for which no information was available. This resulted in a total of 73 potential storage options in the SPSS study area.

Step 2: Initial Screening – Phase 1. The 73 potential storage options were screened based on the following criteria:

- Sites that could not be filled practically from the mainstem of the South Platte River below Greeley were determined to not meet the SPSS objectives and were screened out. The SPSS hydrologic analysis and Point Flow Model did not extend upstream of Greeley so information on available flow at potential diversion points upstream of Greeley was not developed for this analysis.
- Sites with a storage capacity of less than 500 ac-ft were determined to be too small to meet the SPSS goals and were screened out.
- Sites that were clearly not the best fit solution among sites in very similar locations that would provide the same function were screened out.

This step in the screening process reduced the list of potential storage sites from 73 to 43.

Step 3: Initial Screening – Phase 2. In the screening workshop with Basin Roundtable members and the study team, refinements to the screening process were discussed and applied. These consisted of the following additional criteria:

- The minimum storage capacity assumed to be feasible for the SPSS study was set at 5,000 ac-ft for new reservoirs; smaller reservoir enlargements or rehabilitations were retained. This screened out 16 sites, and left 27 remaining.
- Each remaining site was discussed, and knowledge of the workshop attendees was used to eliminate sites that were known to be infeasible, clearly inferior to other similar options, or not available for use in a future SPSS project because they are owned by specific organizations that intend to develop them for their own purposes.

At the completion of this screening step, 22 traditional surface reservoir sites remained to be considered for incorporation into SPSS storage alternatives. These are shown in Figure 1.

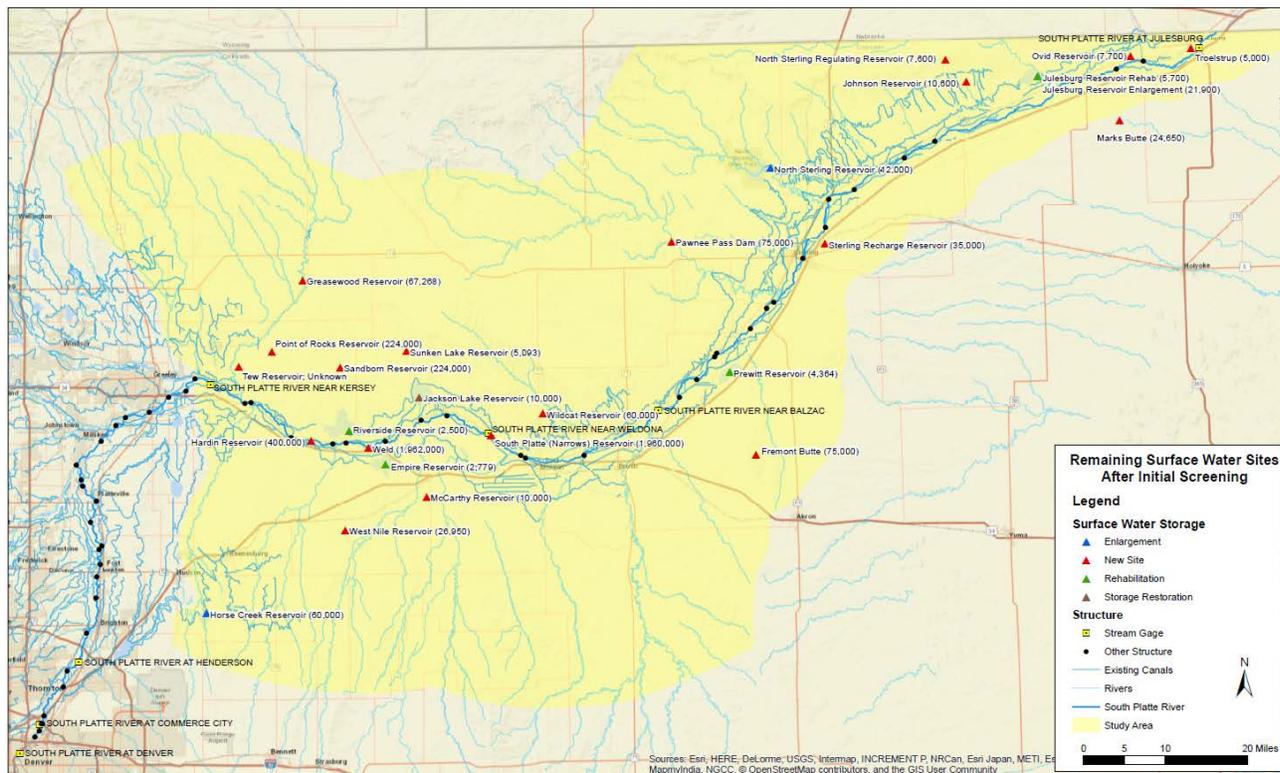


Figure 1. Surface Water Storage Sites Remaining After Screening

Screening of Aquifer Storage Options

Step 1: Full Inventory of Potential Storage Options. Twenty-two aquifer storage sites were identified in the SPSS study area in the Literature Review TM. The study team recommended screening out ASR sites in the Denver Metro area south of the SPSS study area boundary; this reduced the list to 12 aquifer storage sites.

Step 2: Initial Screening. Based on input from the study team and the Review Committee, storage options relying on shallow alluvial aquifers and aquifers used in augmentation programs were screened out. Storage in the shallow alluvial aquifer along the South Platte River or major tributaries was eliminated due to challenges with maintaining dominion and control of recharged water and current problems with high groundwater levels in some areas. The SPSS project was assumed to require capability for long-term carry-over storage and these aquifer types would be less suitable for that type of operation than others. Aquifer storage and recovery in the Denver Basin was also screened out due to assumed high cost of treating, injecting and extracting large volumes of water over short periods of time.

As a result of this screening process, 7 designated groundwater basins south of the South Platte River remained. These are shown in Figure 2.

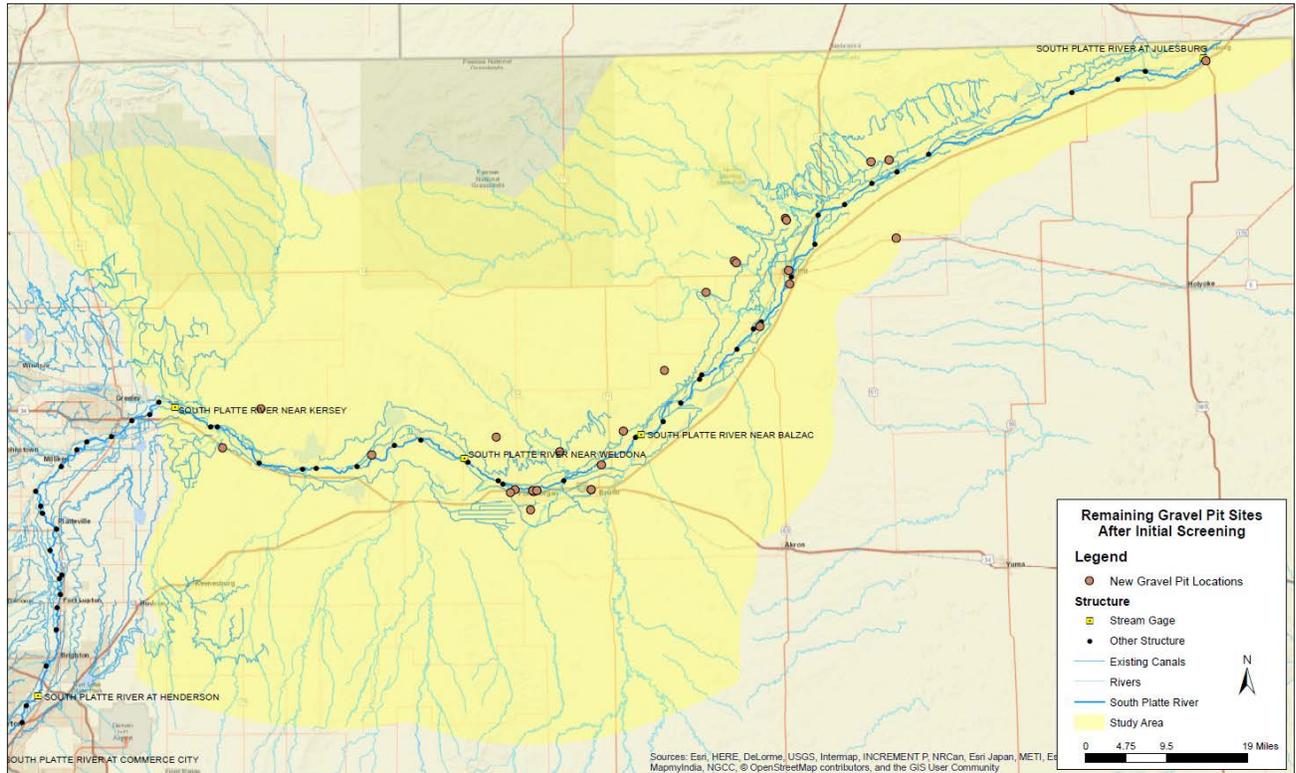


Figure 3. Gravel Pit Sites Remaining After Screening

STORAGE SOLUTION CONCEPTS

Selection of Storage Concepts

Conceptual storage solutions are generalized approaches to developing additional storage of South Platte River water in the SPSS study area below Greeley. Storage concepts were organized based on the reach of the lower South Platte River in which a storage project would be located, the reach from which water would be diverted, and whether storage would be achieved in a surface reservoir or groundwater basin. Each concept was required to have at least one actual storage site identified in the inventory of storage options described in the “South Platte Storage Opportunities Literature Review” TM.

The following storage concepts were developed for the SPSS.

1. Mainstem Storage – surface reservoir on the mainstem of the South Platte River
2. Upper Basin Storage – surface storage with a reservoir and river diversion between Greeley and the South Platte River near Weldona streamgauge

3. Mid Basin Storage North – surface storage with a reservoir and river diversion on the north side of the river between the South Platte River near Weldona streamgage and the South Platte River near Balzac streamgage
4. Mid Basin Storage South – surface storage with a reservoir and river diversion on the south side of the river between the South Platte River near Weldona streamgage and the South Platte River near Balzac streamgage
5. Lower Basin Storage – surface storage with a reservoir and river diversion downstream of the South Platte River near Balzac streamgage
6. Existing Reservoir Improvements – enlargements or rehabilitations of existing reservoirs anywhere in the study area
7. Designated Groundwater Storage Basin West – groundwater aquifer storage and recovery in a designated groundwater basin in the western portion of the study area
8. Designated Groundwater Storage Basin East – groundwater aquifer storage and recovery in a designated groundwater basin in the eastern portion of the study area

Definition of Components Associated with Storage Concepts

In order to analyze the relative benefits of the identified storage concepts, the common components necessary to implement the concepts were defined at a conceptual level. These components are described below.

Storage Components

The storage component for each concept consists of the “bucket” in which water would be stored. Table 1 lists the specific surface and groundwater storage options (“buckets”) remaining after the previously described screening process that could be associated with each storage concept.

Table 1. Specific Storage Options Linked to Generalized Storage Solution Concepts

Storage Solution Concepts	Potential Storage Sites and Maximum Capacities
Mainstem Storage	South Platte (Narrows) Reservoir Site (973,000 ac-ft) Hardin Reservoir Site (400,000 ac-ft)
Upper Basin Storage	Sandborn Reservoir Site (224,000 ac-ft) Point of Rocks Reservoir Site (224,000 ac-ft) Sunken Lake Reservoir Site (5,093 ac-ft) Greasewood Reservoir Site (67,268 ac-ft) Jackson Lake Reservoir Rehabilitation (10,000 ac-ft)
Mid Basin Storage North	Wildcat Reservoir Site (60,000 ac-ft) Pawnee Pass Reservoir Site (75,000 ac-ft)

Storage Solution Concepts	Potential Storage Sites and Maximum Capacities
Mid Basin Storage South	Beaver Creek Reservoir Site (95,000 ac-ft) Fremont Butte Reservoir Site (75,000 ac-ft) West Nile Reservoir Site (26,950 ac-ft) McCarthy Reservoir Site (10,000 ac-ft)
Lower Basin Storage	Julesburg Reservoir Enlargement/Rehabilitation (27,600 ac-ft) Ovid Reservoir Site (7,700 ac-ft) Troelstrup Reservoir Site (5,000 ac-ft) North Sterling Reservoir Enlargement (12,000 ac-ft) North Sterling Regulation Reservoir (7,600 ac-ft) Johnson Reservoir (10,600 ac-ft)
Existing Reservoir Improvements	Julesburg Reservoir Enlargement/Rehabilitation (27,600 ac-ft) North Sterling Reservoir Enlargement (12,000 ac-ft) Prewitt Reservoir Rehabilitation (4,364 ac-ft) Riverside Reservoir Rehabilitation (2,500 ac-ft) Jackson Lake Reservoir Rehabilitation (10,000 ac-ft)
Designated Groundwater Basin Storage West	Upper Lost Creek Aquifer (1,260,000 ac-ft) Lower Lost Creek Aquifer (157,000 ac-ft) Upper Kiowa Creek Aquifer (234,000 ac-ft) Lower Kiowa Creek Aquifer (806,000 ac-ft) Upper Bijou Creek Aquifer (466,000 ac-ft) Lower Bijou Creek Aquifer (1,067,000 ac-ft)
Designated Groundwater Basin Storage East	Beaver/Badger Aquifer (311,000 ac-ft)

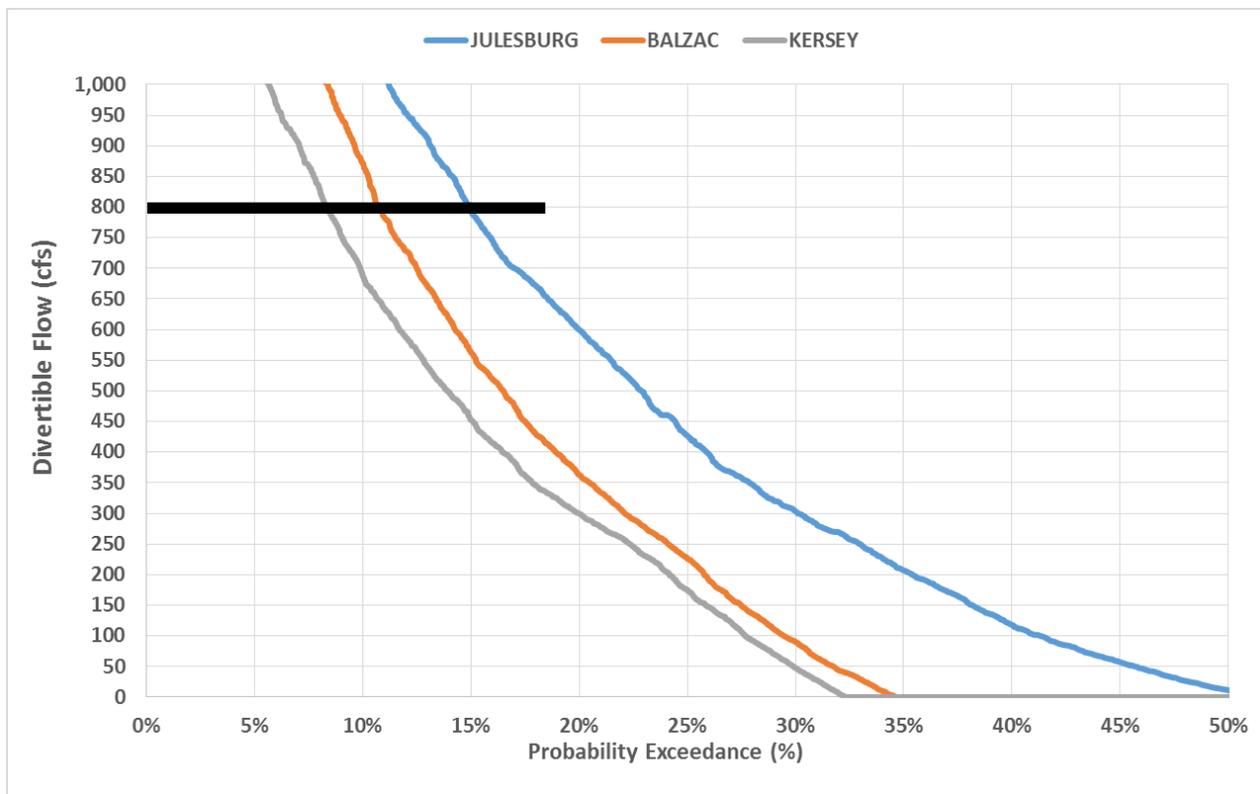
River Diversion and Intake Components

With the exception of the Mainstem Storage concept, all concepts require diversion of water from the South Platte River and conveyance to an off-channel storage facility. For any off-channel storage option, the water supply yield would be constrained by the capacity of the diversion and conveyance facilities used to fill the reservoir. An estimate of a reasonable assumption for filling capacity was developed in two steps.

1. Historical records were reviewed for the largest existing diversions on the South Platte below Denver to get an indication of the effective capacity of current facilities. The maximum recorded diversion to Burlington Ditch was 635 cfs and the maximum recorded diversion to the North Sterling Canal was 764 cfs. Based on this, a tentative inlet capacity of 800 cfs was selected.
2. The 800 cfs capacity value was compared to the flow frequency data generated for future available flow in the hydrologic analysis described in the TM "South Platte River Hydrologic Analysis." Figure 4 plots the probability that a given diversion capacity would be equaled or exceeded by the storable flow in the South Platte at three of the streamgauge locations. This plot shows that with a diversion and conveyance capacity of 800 cfs, available storable flow would be exceeded on only 8 percent of the days in the 20-year Point Flow Model simulation

period at the Kersey streamgage, and on 15 percent of the days at the Julesburg stream gage. A diversion of this size would capture all the available water on most days and would only bypass storable flow on the days of highest runoff in a year. It was assumed to be a reasonable compromise between cost and capacity for this analysis.

Figure 4. Exceedance Probability of Future South Platte Storable Flow



Two “bookend” alternatives were considered for SPSS concepts:

- (1) Shared Infrastructure: use existing diversion structures and irrigation canals to the maximum extent possible.
- (2) Independent Infrastructure: construct new dedicated diversion structure, pump station and pipeline to convey water to the reservoir.

A cursory evaluation was performed of the potential to use existing irrigation structures to convey SPSS water to new or enlarged existing storage facilities. Information was collected for selected irrigation ditches from the Colorado Decision Support System HydroBase dataset, South Platte Decision Support System Task 5 Memoranda, and historical diversion data.

To assess the Shared Infrastructure alternative, the potential for using excess capacity in existing irrigation canals was investigated. Data for the capacity of existing canals was tabulated for selected conveyance structures that could be paired with SPSS storage options. Table 2 summarizes the pertinent data for this analysis, and shows that for all but one canal the estimated physical capacity is less than 800 cfs. The decreed capacity of the selected ditches is generally

much larger than the physical capacity. The SPSS Review Committee noted that the irrigation canals would generally be running close to full when the maximum SPSS deliveries would be available from the river, so little or no excess capacity would be available for SPSS project water. For these reasons, the Shared Infrastructure option was not analyzed for specific storage concepts. Nonetheless, if specific storage options are being formulated in the future, use of existing conveyance infrastructure should be reviewed as a potential way to minimize costs and maximize use of existing resources.

Table 2. Capacities of Existing Irrigation Canals That Could Fill SPSS Storage Options

Reservoir	Existing Irrigation System for Filling from South Platte River	Estimated Physical Capacity (cfs)
Sandborn	Greeley No. 2 Canal aka New Cache la Poudre Company Ditch	650
Riverside	Riverside Intake Canal	1,000
Wildcat	Riverside Canal	370
Beaver Creek	None	-
Morgan Beaver	None	-
Julesburg	Harmony Ditch No. 1	450
Ovid	Peterson Ditch	150
Troelstrup	Peterson Ditch	150
Jackson Lake	Riverside Canal	370
	Jackson Lake inlet	400
Prewitt	Lower Platte and Beaver Ditch	228
	Prewitt Intake Canal	695
North Sterling	North Sterling Canal	600

As a result, for the SPSS analysis inlet structure components were assumed to consist of:

- A new 800 cfs diversion structure on the South Platte River at a location close to the storage option
- Two new 96-inch pipelines from the diversion structure to the reservoir or aquifer recharge area

- A new pump station at the diversion structure sized to lift 400 cfs to the reservoir or aquifer recharge area. Gravel pit storage could be used to effectively reduce the size of conveyance facilities needed to fill reservoirs or aquifer storage. This strategy could affect all concepts similarly; for this preliminary analysis it was assumed that a 10,000 ac-ft gravel pit complex at the diversion point could allow the capacity of the intake conveyance facilities to be sized at 50 percent of the river diversion capacity.

Outlet Components

As described in the SPSS Water Demands TM, for purposes of the SPSS analysis, it was assumed that any storage project could be operated to meet demands in three ways: (1) make releases to the South Platte and exchange up to Kersey to meet demands in the Northern Front Range area; (2) make releases to the South Platte to meet demands downstream of the discharge point; and (3) make releases to a new pipeline to Brighton to meet demands in the Denver Metro/Northern Front Range area. To make these releases each storage concept included:

- Release of water back to the South Platte in the same pipeline used to fill the reservoir (bi-directional pipeline), with an unconstrained capacity.
- 100 mgd pipeline to Brighton. A capacity of 100 mgd was selected because it is similar to the ultimate capacity of the Prairie Waters pipeline that delivers water from the Brighton area to Aurora, some of which is ultimately used in the South Denver Metro region.
- A 20,000 ac-ft gravel pit complex near Kersey to serve as the exchange-to point for the exchange alternative.

STORAGE CONCEPT WATER SUPPLY ANALYSIS METHODS

In order to simulate operation of each storage concept to estimate the water supply yield it could produce, a MODSIM operations model was constructed for the Lower South Platte River. This section describes the methods used to create the MODSIM model and perform that analysis.

Hydrology

The MODSIM operations model used the daily estimate of available water under future river conditions for the period 1996-2015 from the Point Flow Model (see SPSS Hydrologic Analysis TM). The estimates of future available water account for effects of Identified Projects and Processes from the Colorado Water Plan and decreed but unexercised exchanges that would not have been reflected in the historical data in the Point Flow Model.

Demands

Demands were applied to each storage concept to evaluate its performance. The same demands were applied to each concept, regardless of where it was located in the SPSS study area. This provided a standard basis of comparison for all the storage concepts.

Development of demands for the SPSS project was described in the SPSS Water Demands TM. Demands were a combination of agricultural and municipal demands based on the SWSI 2010

water supply gap analysis for the lower South Platte Basin in 2050, assuming 60 percent implementation of IPPs. For purposes of the modeling analysis, demands were aggregated at the four primary streamgages in the SPSS study area. These are summarized in Table 3 and Figure 6. Weekly (or quarter-monthly) demand patterns were derived from typical municipal and agricultural water use records. The weekly demand pattern used in the storage concept modeling is shown in Figure 5.



Figure 5. Weekly Demand Pattern

Table 3. Summary of SPSS Water Demands

Reach	Agricultural Demand Based on Future Shortage (ac-ft/yr)	M&I Demand Based on Future Shortage (ac-ft/yr)	Total Demand (ac-ft/yr)
Upstream of Denver Gage	1,400	105,400	106,800
Denver Gage to Kersey Gage	210,200	111,300	321,500
Kersey Gage to Balzac Gage	46,600	9,500	56,100
Balzac Gage to Julesburg Gage	11,400	7,100	18,500
Basin Total	269,600	233,300	502,900

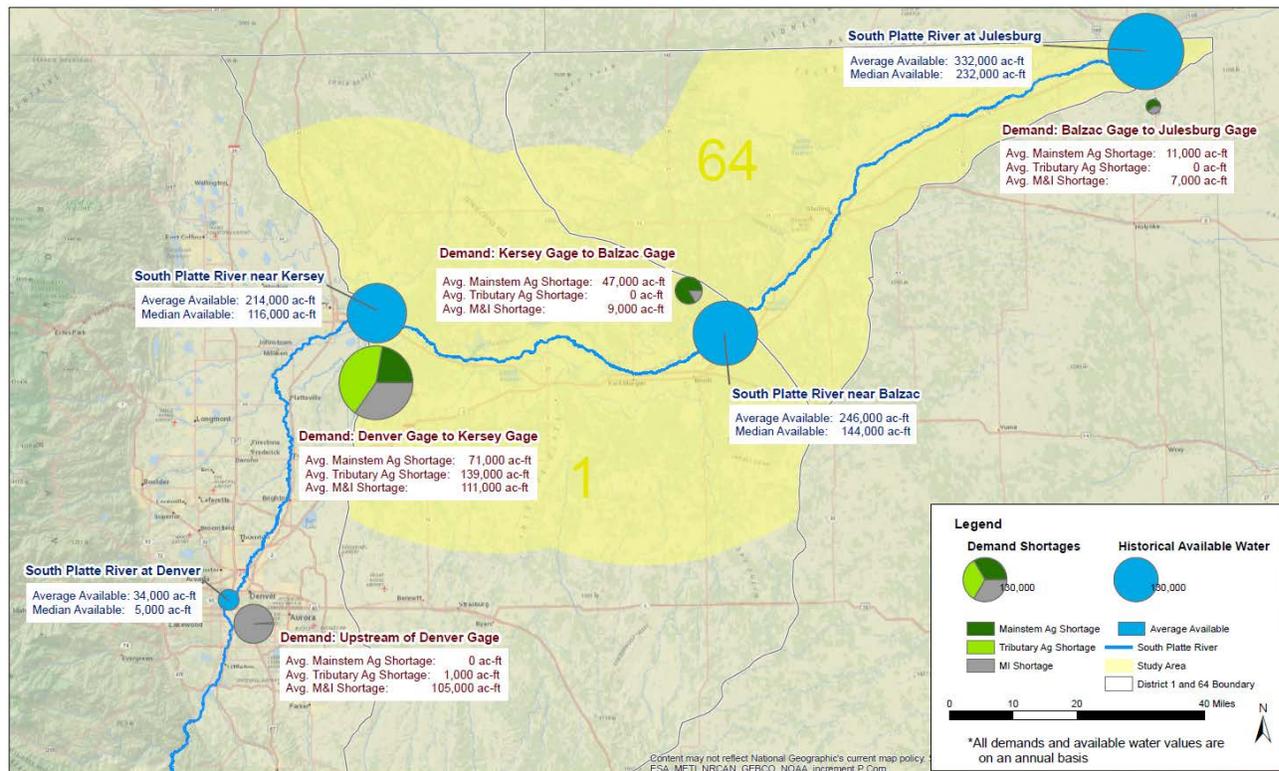


Figure 6. Summary of Available Water and Demands at Key Locations in SPSS Study Area

All storage concepts were simulated to concurrently meet the three demand scenarios according to the following logic.

1. Priority 1: Exchange to Kersey. Water was exchanged to Kersey to meet the M&I and agricultural demands aggregated at the Kersey gage. Demands at the Kersey gage represent M&I and agricultural shortages for areas primarily east and north of this point. It is recognized that infrastructure would be required to deliver water from Kersey to M&I or agricultural customers upstream of this point. That infrastructure has not been conceptualized and has not been included in the SPSS costs described in this report. This demand was given the highest priority in the modeling because it makes use of available exchange potential to move as much water as possible upstream to the largest number of potential users with a minimum of new infrastructure.
2. Priority 2: Release to River. Water was released back to the South Platte River to meet downstream agricultural and municipal demands. This would include use of the SPSS water to meet augmentation commitments.
3. Priority 3: Pipe to Brighton. Water delivered by pipeline to the Brighton area could meet demands for municipal customers upstream of the Denver gage and municipal and agricultural customers upstream of the Kersey gage. The pipeline would overcome the constraints of exchange potential and maximize the use of the SPSS water in the basin. This was given the lowest priority among the demand scenarios because it would have the highest capital and operating costs. The Pipe to Brighton option was not applied to the

Lower Basin Storage Concept because it was considered to be unrealistic to construct a pipeline from near Julesburg to the Denver Metro area.

In summary, it was assumed that the Kersey demand could be met through a combination of exchange and pipeline deliveries, the Denver demand could be met through pipeline deliveries alone, and the Balzac and Julesburg demands could be met by direct releases to the South Platte.

Storage Options

Representative storage options were selected for use in each of the storage concepts. This allowed realistic elevation-area-capacity data and evaporation data to be used in the simulations. The study team performed a best-fit evaluation to select a representative storage option for each storage concept. The best-fit option was selected based on data in the Site Evaluation Framework (described in a later section of this TM) including physical, environmental and social attributes of the candidate reservoir and groundwater sites in each region of the SPSS study area. Table 4 lists the representative storage options selected for simulating each storage concept, and the rationale used in the selection process. The locations of these representative storage options are shown in Figure 7. Appendix A contains maps of the representative storage options used for each storage concept, and the location of conceptual inlet-outlet facilities (intake pipelines, use of existing irrigation canals, or both).

Table 4. Representative Storage Sites Used for Simulation of Storage Concepts

Storage Solution Concepts	Representative Storage Sites	Rationale for Selection of Representative Storage Site
Mainstem Storage	South Platte (Narrows) Reservoir	Narrows has more capacity than Hardin. Hardin has more surface area, and therefore more evaporation. Hardin has more bald eagle habitat. Narrows was already selected as a preferred site because it went through a federal (USBR) environmental review process in the 1980s.
Upper Basin Storage	Sandborn Reservoir	Eliminated Greasewood because it is much further from the mainstem and would be hard to fill with diversion from the SPSS study area. Point of Rocks and Sandborn could be filled from an extension of Greeley No. 2 Canal. Remaining sites are similar in all but two categories – Sandborn has more State land in the reservoir area, and Point of Rocks has more oil and gas wells.
Mid Basin Storage North	Wildcat Reservoir	Wildcat is the largest of the potential sites.
Mid Basin Storage South	Beaver Creek Reservoir	Beaver Creek is closer to the mainstem than Fremont Butte.
Lower Basin Storage	Julesburg Enlargement/Rehabilitation, Ovid Reservoir, Troelstrup Reservoir	Logical combination of small reservoirs as close to the state line as possible.

Storage Solution Concepts	Representative Storage Sites	Rationale for Selection of Representative Storage Site
Existing Reservoir Improvements	Julesburg, North Sterling, Prewitt, Jackson Lake, Riverside	Use all existing reservoirs with potential for enlargement or rehabilitation.
Designated Groundwater Basin Storage West	Lower Lost Creek Aquifer	Rely on Colorado Geological Survey (CGS) ranking of aquifer storage sites from a previously published report. Upper Lost Creek is best from the standpoint of avoiding conflicts with other infrastructure and for recovery of stored water, but it is further from the mainstem in the study area so would be more difficult to fill. Lost Creek basins are farthest west of the designated basins.
Designated Groundwater Basin Storage East	Beaver/Badger Aquifer	Badger/Beaver Basin is farthest east and scored high in the CGS evaluation.

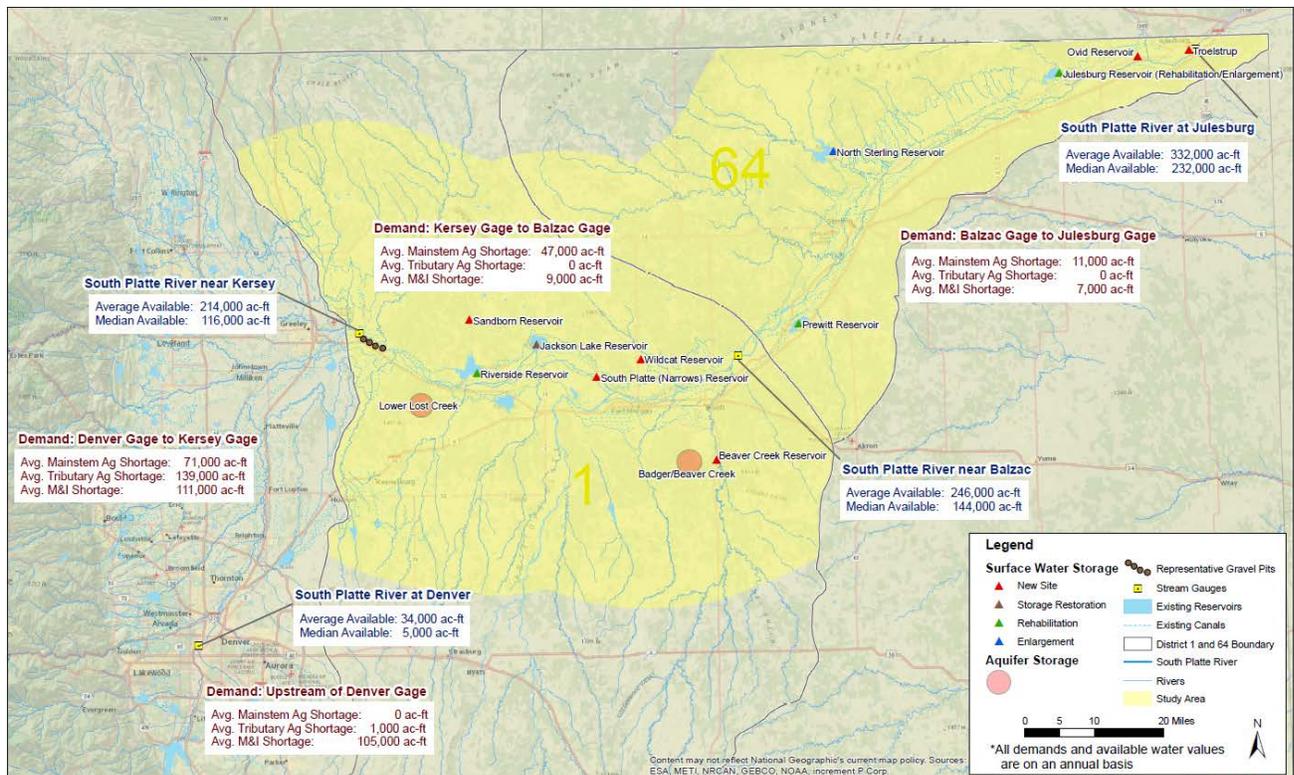


Figure 7. Representative Storage Options Used to Model Storage Concepts

System Losses

Losses in pipelines and pump stations were set at 5 percent of the flow conveyed.

Net evaporation at all the reservoir sites was set at 34 inches/year, based on a typical value for the lower South Platte Basin.

Groundwater Storage Options

To simplify the initial comparison of options, all groundwater storage options were assumed to be operated in an aquifer storage and recovery mode in which recharge would occur in surface infiltration basins and recovery would occur through a gallery of extraction wells. A more detailed description of the aquifer storage options and assumptions for analysis and cost estimating is presented in a separate technical memorandum.

The primary assumptions used to simulate groundwater storage options were developed based on review of available documentation for hydrogeologic characteristics of the designated basins and professional judgment, and are listed in Table 5. Year-to-year carryover storage was allowed as it would be in a surface reservoir. Deliveries from the river were assumed to occur from new river diversions and dedicated pipelines without any regulating storage (e.g., gravel lakes), similar to operation of the surface storage options. The river diversion rates are much higher than aquifer infiltration rates could reasonably allow, and so some intermediate storage is assumed to be included in the aquifer storage concepts near the point of river diversion.

Table 5. Aquifer Storage Modeling Assumptions

Characteristic	Lower Lost Creek Basin	Badger/Beaver Basin
Storage Capacity (ac-ft)	157,000	311,000
Storage per Acre (ac-ft/ac)	5.7	4.4
Maximum Inflow (ac-ft/month)	24,000	24,000
Maximum Outflow (ac-ft/month)	12,000	12,000
Dominion and Control / Residence Time	Challenging	Challenging
Multi-year Storage	Challenging	Challenging
Infiltration Rate (ft/day)	1.0	1.0
Extraction Well Capacity (gpm)	500	500
Approximate Well Count	190	190
Losses in Aquifer (% of inflow)	10	10

Reservoir Operations

Reservoir storage could be operated in many different ways depending on the needs of the owners. Conceptually, water from storage could be:

- used as a base supply with a constant amount taken every year;
- used as a supplemental dry year supply with water withdrawn only in drought periods;
- used as a primary supply with water taken whenever it is available; or
- used as a mitigation supply to augment diversions from other sources.

Because SPSS reservoir ownership is unknown and the demands the reservoir could be operated to meet are unknown, a standard operating approach was adopted for each storage concept such that the performance of the concepts could be compared against the same set of conditions. Two operating approaches were considered.

1. **Firm Yield Analysis.** Firm yield is the maximum yield that can be delivered in every year, for all years of the simulation. In this approach the firm yield for each concept was determined by varying the total demand on a trial-and-error basis until the maximum demand that could be met in every year was determined. Total system demands in Table 3 were scaled up or down keeping the same geographic and temporal distribution.
2. **As-Available Analysis.** This approach estimated the yield that can be delivered if the water is taken from the river into storage whenever it is available and delivered from storage to a demand center whenever there is demand. It assumes SPSS water is the primary supply for the user and would be taken whenever it is available.

Results from simulations of storage concepts using both approaches to reservoir operations were investigated to assure that the selection of a particular operating assumption would not bias the study recommendations.

STORAGE CONCEPT WATER SUPPLY ANALYSIS RESULTS

Basic Firm Yield Analysis

The firm yield for each of the storage concepts was estimated for the maximum capacity of the representative storage options. Results are shown in Table 6. As an example of the firm yield simulations, Figure 8 shows a plot of daily model results for the Upper Basin – Sandborn Reservoir simulation. The figure shows the demand met on a daily basis by a 224,000 ac-ft reservoir diverting from the Upper Basin. The firm yield is met on almost every day of the simulation; the shortages are due to the tolerance in the iterative routine used to estimate firm yield in the MODSIM model. The plot shows the reservoir emptying during the critical drought in the model period. Similar plots for the other storage concepts are included in Appendix B.

Table 6. Storage Concept Firm Yield for Maximum Capacity of Representative Storage Sites

Storage Concept	Representative Storage Site(s)	Reservoir Capacity (ac-ft)	Firm Yield (ac-ft/yr)
Mainstem Storage	South Platte (Narrows)	973,000	62,000
Upper Basin Storage	Sandborn	224,000	22,000
Mid Basin Storage North	Wildcat	60,000	9,000
Mid Basin Storage South	Beaver Creek	95,000	11,000
Lower Basin Storage	Julesburg, Ovid, Troelstrup	40,300	24,000
Existing Reservoir Improvements	Riverside, Jackson, Prewitt, Julesburg, North Sterling	56,464	17,000
Designated Groundwater Basin Storage West	Lower Lost Creek Aquifer	157,000	20,000
Designated Groundwater Basin Storage East	Beaver/Badger Aquifer	311,000	36,000

The firm yield analysis supports the following findings.

- In general, concepts located further downstream in the basin have greater yield for similar storage capacities. This is due to the increase in available water in the downstream direction on the South Platte River.
- Average annual available water under future conditions varies from about 160,000 ac-ft/yr at Greeley to about 290,000 ac-ft/yr at Julesburg. Firm yields are much less than these values even for the large storage options due to the significant year-to-year variability in streamflow. Substantially more storage would be required to significantly increase firm yields from the alternatives.
- Storage concepts that incorporate more than one reservoir option tend to provide greater firm yield than single reservoir options. This is due to the ability of multiple diversion and inlet structures to capture more available water than a single inlet structure. While specific alternatives would have to be studied, in general this highlights the benefits of developing multiple off-channel storage projects as part of an overall SPSS strategy.

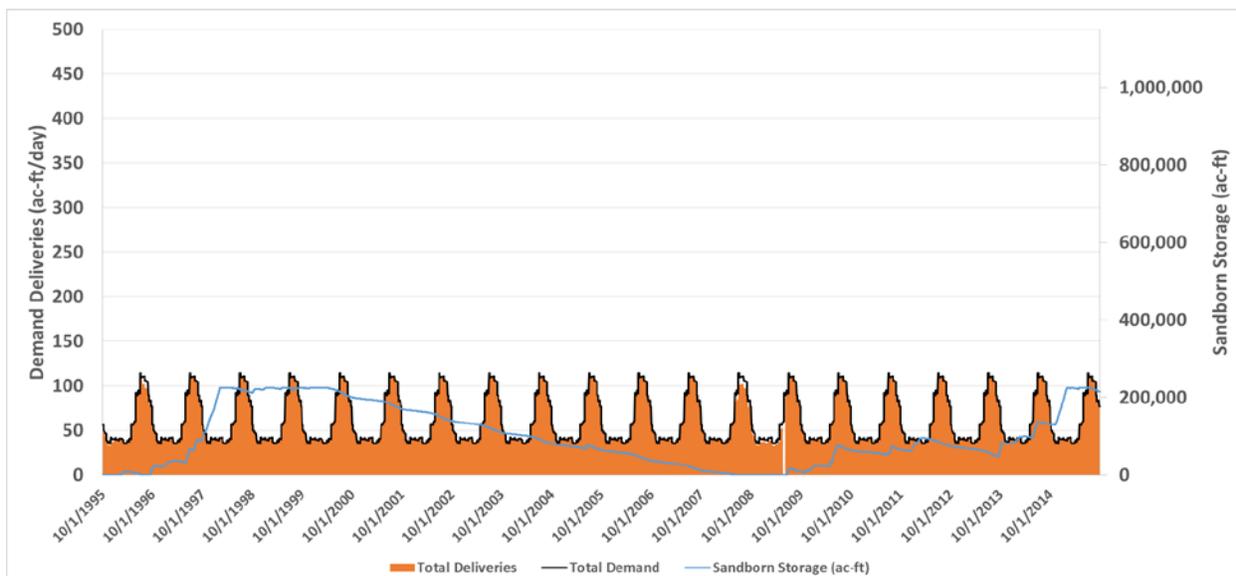


Figure 8. Demand Met and Storage Contents for Sandborn Reservoir Firm Yield Analysis

Figure 9 plots the demand locations receiving deliveries of firm yield for each of the storage concepts. Recall that the Kersey demand is met through a combination of exchange and pipeline deliveries, the Denver demand is met through pipeline deliveries alone, and the Balzac and Julesburg demands are met by direct releases to the South Platte. Kersey demands receive the majority of the firm yield for most concepts. Exchanges have the highest priority in the model when attempting to satisfy demands, so those are exercised first and remaining water is released to the river or piped to Brighton. For concepts with some or all of the storage in the lower basin (Lower Basin Storage, Existing Reservoir Improvements), direct releases are the primary mechanism for meeting demands because of the constraints of limited exchange potential and the assumption that

a pipeline to Brighton was not feasible for storage options near Julesburg. Different reservoir operation assumptions would give different results for distribution of demands being met; for this analysis, the total firm yield is the most important parameter for comparing storage concepts.

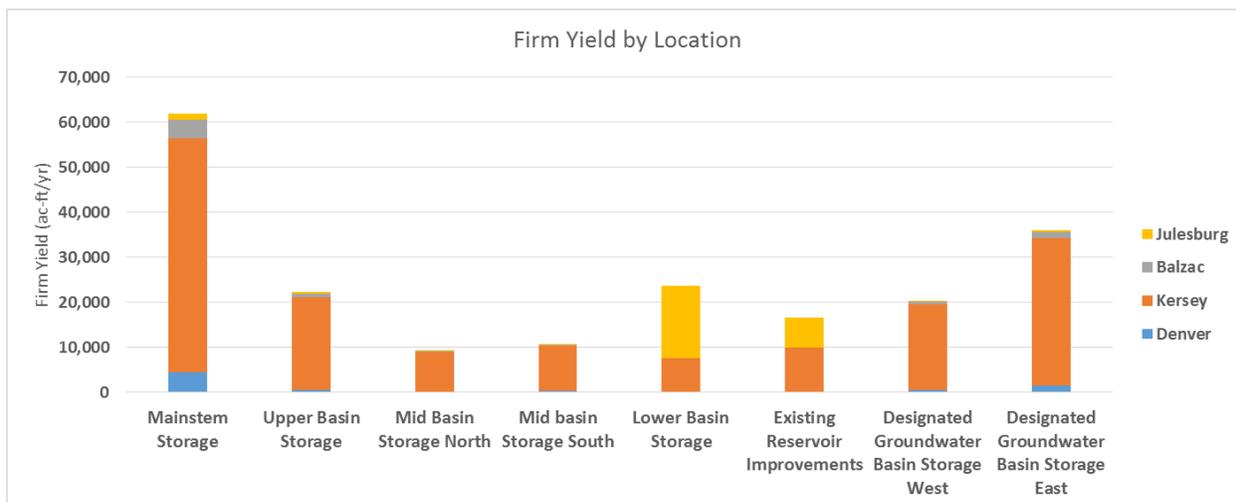


Figure 9. Distribution of Firm Yield to Demand Points for Storage Concepts with Maximum Capacity of Representative Storage Site

Firm Yield Sensitivity Analyses

In the firm yield sensitivity analysis, selected alternative sizes of storage capacity for certain storage concepts were investigated to assess the effect of capacity on firm yield.

Mainstem Storage Concept. Table 7 and Figure 10 compare firm yield at the South Platte (Narrows) Dam site for reservoir capacities of 973,000 ac-ft (the maximum capacity), 500,000 ac-ft and 250,000 ac-ft. Results show firm yield is strongly correlated to reservoir capacity. Although the storage efficiency (storage-to-yield ratio) is better for the smaller reservoir, in general bigger is better for the mainstem dam sizes investigated.

Table 7. Mainstem Storage Concept Sensitivity Analysis Results

Reservoir Capacity (ac-ft)	Firm Yield (ac-ft/yr)	Storage:Yield Ratio
973,000	61,700	16:1
500,000	38,000	13:1
250,000	20,300	12:1

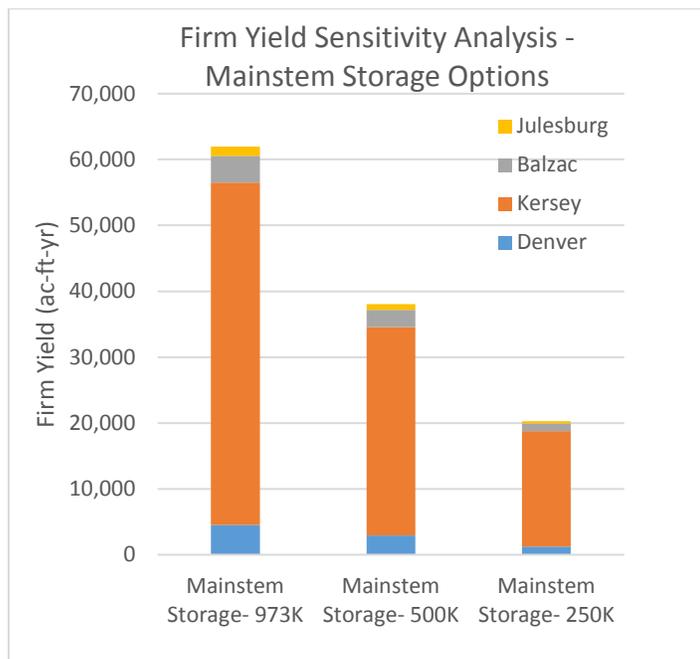


Figure 10. Mainstem Storage Concept Sensitivity Analysis Results

Mid Basin Storage Concept. A larger storage capacity than the two identified Mid Basin sites was simulated to estimate potential benefits from additional storage in this region. A 150,000 ac-ft capacity was simulated at the Wildcat Reservoir location. Results are shown in Table 8. A larger storage capacity provides a significant increase in firm yield in this region because firm yield is not supply limited even with off-channel storage options. Because of the high variability in annual flow the storage:yield ratio is better for smaller reservoir sizes.

Table 8. Mid Basin Concept Sensitivity Analysis

Storage Site	Capacity (ac-ft)	Firm Yield (ac-ft/yr)	Storage:Yield Ratio
Wildcat	60,000	9,300	6:1
Beaver Creek	95,000	10,700	9:1
Wildcat	150,000	17,200	9:1

Aquifer Storage vs Surface Storage. To compare relative benefits of surface storage and aquifer storage, the Upper Basin Storage Concept using Sandborn Reservoir was simulated with a capacity of 150,000 ac-ft, which is similar to the Lost Basin ASR capacity of 157,000 ac-ft. Results are shown in Table 9. The ASR concept gives a higher firm yield and better storage:yield ratio for essentially the same storage capacity. This is likely due primarily to the elimination of evaporation losses in the aquifer storage concept (although the simulation does include some groundwater losses).

Table 9. Surface Storage vs Aquifer Storage Comparison in Upper Basin

Storage Option	Capacity (ac-ft)	Firm Yield (ac-ft/yr)	Storage:Yield Ratio
Upper Basin Surface Storage	224,000	22,200	10:1
Upper Basin Surface Storage	150,000	16,200	9:1
Upper Basin Aquifer Storage	157,000	20,100	8:1

Combination of Upper Basin + Lower Basin Concepts. Benefits of combining an Upper Basin project with a Lower Basin project were investigated by simulating a combination of Lost Creek ASR in the Upper Basin with the three surface reservoirs in the Lower Basin Storage concept. Results are shown in Table 10 and Figure 11. The benefits are significant; firm yield of this combination is exceeded only by the large Mainstem Dam concept. While the firm yield of the combined concepts is less than the sum of the individual concepts operating alone (because they both attempt to store some of the same water), the combined firm yield is significantly greater than the firm yield of either one of the individual concepts. This shows the benefits of storage distributed in multiple sites throughout the basin.

Table 10. Firm Yield for Combined Upper and Lower Basin Storage Concepts

Storage Concept	Storage Options Simulated	Total Capacity (ac-ft)	Firm Yield (ac-ft/yr)	Storage:Yield Ratio
Lower Basin Storage Alone	Julesburg Enlargement/ Rehabilitation, Ovid, Troelstrup	40,300	23,500	2:1
Upper Basin Storage Alone	Lower Lost Creek ASR	157,000	20,100	8:1
Combined Upper and Lower Basin Storage	All of above	197,300	39,200	5:1

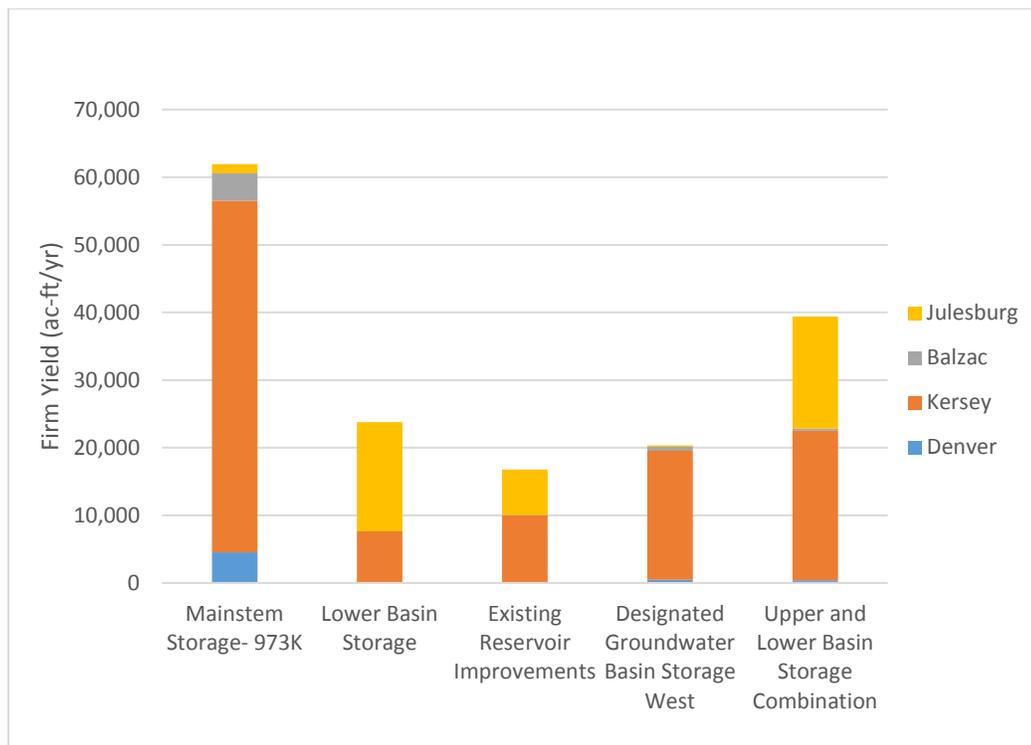


Figure 11. Comparison of Firm Yield for Combined Upper and Lower Basin Storage Concept with Other Concepts

As-Available Analysis of Storage Concepts

As noted previously, actual operations of any of the SPSS storage concepts are unknown because the ownership is unknown. Reservoir owners could choose to operate their storage in something other than a firm yield approach. To test the sensitivity of the comparison of storage concepts to operating assumptions, two other operational scenarios were simulated that assumed the storage would be operated to meet as much demand as possible whenever that demand occurred. These scenarios varied only in the amount of demand applied to the storage reservoirs.

- Scenario 1 – Demand on the reservoir was set to the total demand estimated for the future South Platte Basin gap at the four demand centers as described in the previous “Demands” section (annual demand = 502,882 AFY).
- Scenario 2 – Scaled-back demand to force reservoirs to hold more water in storage during wet periods (annual demand = 97,000 AFY).

Modeling results are summarized in Table 11 for the maximum potential capacities at each of the representative storage sites for the SPSS storage concepts. The average annual deliveries under this kind of operating assumption are much higher than the firm yields shown in Table 6. However, when full gap demands were simulated, the applied demand was very large relative to the supply

and the storage capacity so on most days the model moved all the available water from the river to storage and then immediately out of storage to meet the demand. This is shown for one of the storage concepts (Upper Basin Storage) in Figure 12 as an example. Essentially the demand being met was supply limited, as water was diverted from the river whenever it was available, leaving limited water to store in the reservoirs. Very high demands are met on a few days but during large parts of the simulation no deliveries are made; that is, reliability is very low. For the Upper Basin Storage simulation in Figure 12, the reliability (percentage of days the full applied demand is completely satisfied) is only 1 percent. For the Mainstem Storage concept the reliability is higher – 9 percent – because the storage volume is larger and there are no constraints in diversion and intake capacities. Figure 12 also shows that the storage is rarely used because demands are so high water is moved directly from the river to the demand centers. The simulation of this type of operation does not highlight the value of storage, but does demonstrate that there is a large amount of available water in the river to meet high demands on a very infrequent basis.

Table 11. Yield of Storage Concepts Based on As-Available Operations

Solution Name	Representative Storage Site(s)	Reservoir Capacity (AF)	Full Gap Demand (502,882 AFY) - Average Annual Delivery (AF/Y)	Scaled Demand (97,000 AFY) - Average Annual Delivery (AF/Y)
Mainstem Storage	Narrows	973,000	118,000	81,000
Upper Basin Storage	Sandborn	224,000	74,000	48,000
Mid Basin Storage North	Wildcat	60,000	82,000	43,000
Mid basin Storage South	Beaver Creek	95,000	85,000	46,000
Lower Basin Storage	Julesburg, Ovid, Troelstrup	40,300	129,000	48,000
Existing Reservoir Improvements	Riverside, Jackson, Prewitt, Julesburg, North Sterling	56,464	143,000	59,000
Designated Groundwater Basin Storage West	Lost Creek Aquifer	157,000	70,000	43,000
Designated Groundwater Basin Storage East	Beaver/Badger Aquifer	311,000	80,000	51,000

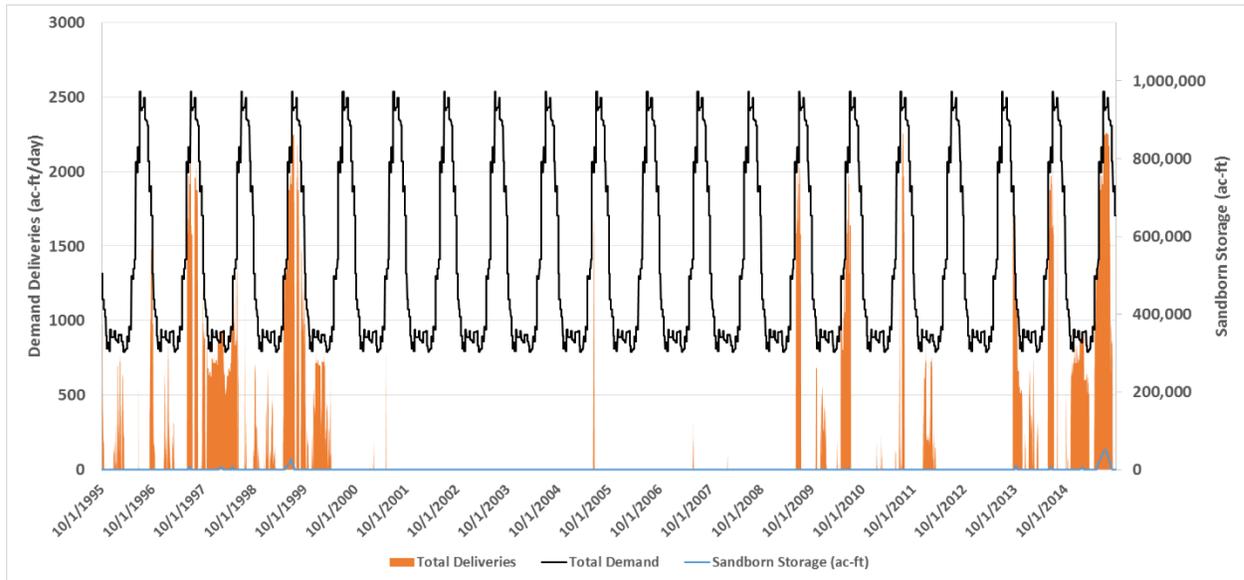


Figure 12. Simulation of Sandborn Reservoir with Full Gap Demand Applied in As-Available Operation Mode

Simulation of the scaled-back demands is summarized for each concept in Table 11, and is displayed for the Upper Basin (Sandborn) concept in Figure 13. The scaled-back demands are 97,000 ac-ft/yr compared to over 502,000 ac-ft/yr for the full gap demands. Average annual deliveries are less than for the full gap scenario (because less water is demanded) and the benefits of storage are more evident. In addition, Figure 13 shows that the reliability for this condition is approaching 50 percent, which is much better than when the full gap demands are applied.

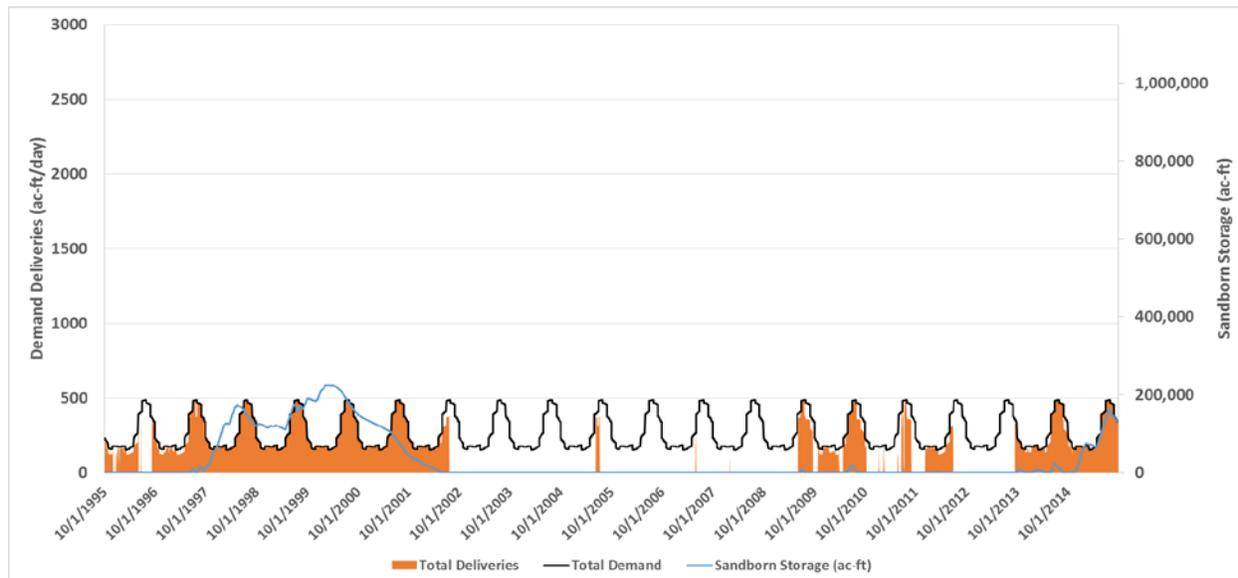


Figure 13. Simulation of Sandborn Reservoir with Scaled-Back Demand Applied in As-Available Operation Mode

A preliminary version of the SPSS MODSIM model was used to run a sensitivity analysis of different reservoir sizes for each of the concepts with the Full Gap Demands applied. Results showed very little difference in the average yield that could be provided even with very different storage capacities, because under this condition with very large demands the system is supply limited, not storage limited.

Summary of Storage Concept Simulations

The key findings of the storage concept analysis are as follows.

- The Firm Yield results are the most useful for this analysis and have an easier message to convey. Thus the firm yield results will be used to draw conclusions. The results of the As-Available analysis generally point to the same findings.
- Not surprisingly, the large mainstem reservoir has the best performance. Smaller mainstem reservoirs have significantly less firm yield and are comparable to other off-channel options.
- Aquifer storage projects perform better than surface storage projects of the same size diverting from the same reach of the South Platte. Lower evaporation losses offset assumed losses to the groundwater basin from ASR.
- Storage options lower in the basin tend to be more efficient (better storage:yield ratio) because there is more water available. This is biased by the fact that the lower basin concepts simulated in this study have multiple storage buckets and hence multiple inlets, so there is more diversion capacity, but the additional water is still an important factor in performance of storage options.
- A combination of upper basin and lower basin storage concepts rivals the large mainstem dam for firm yield benefits.

- Combinations of storage options can provide significantly more benefit than individual options, but the increase is not linear – i.e., the total yield from two storage options is less than the sum of the yield from the options operating alone.
- No feasible storage concepts or reasonable combinations of concepts are capable of putting all the available flow in the lower South Platte River to beneficial use. Therefore as a general principle, more storage will always be “better” in this region in terms of maximizing available supply for basin water users.
- Because nearly all concepts require off-channel storage and diversion from the South Platte River, intake capacity constraints can be important and there are benefits to having multiple off-channel storage projects to minimize these effects.

CHARACTERIZATION OF STORAGE OPTIONS – SITE EVALUATION FRAMEWORK

The previous section discussed the ability of storage concepts to provide water supply benefits in the South Platte Basin. Individual SPSS storage options were then evaluated and compared based on technical, cost, and environmental and permitting factors. This section describes the data compiled for each storage option.

The surface and groundwater storage options in the SPSS study area were characterized based on a variety of technical and environmental and permitting parameters. Data for all storage options remaining after the initial screening process were collected. The sources available for candidate reservoir sites were described in the South Platte Storage Opportunities Literature Review TM.

Data were compiled in a Site Evaluation Framework (SEF) database. Database attributes (parameters, data types) and qualifiers (values, ratings) for the SEF are defined in Appendix C.

Where possible, data were collected from previous studies and reports. The SPSS study team used the best available maps, aerial photography and other resources to fill in the database attributes for each storage option. Professional judgment was used where necessary. For each storage option the descriptive data were based on the maximum storage capacity reported for that site.

Database entries for each storage option are shown in Appendix D.

The information in the SEF was used to select the representative storage sites for modeling each storage concept as described previously. Representative sites were the sites that provided the best balance of technical feasibility and size while avoiding difficult environmental and social impacts to the extent possible. While the representative sites were selected as the “best fit” among the potential sites in each portion of the SPSS study area (see Table 4), further study could determine that other sites are as good or better. The data in the SEF can provide the starting point for future studies if desired.

COST ESTIMATES

A summary of cost estimates for components included in the SPSS storage scenarios is provided in this section. A separate technical memorandum provides details on the derivation of the cost estimates.

Surface Storage Costs

Surface reservoir construction costs are summarized in Table 12. These cost estimates include capital construction, land acquisition, permitting, and design. The reservoirs with the lowest unit cost are the most cost-effective in terms of storage provided per dollar spent. For new surface reservoirs, unit cost is generally inversely correlated with capacity such that the largest reservoirs have the lowest unit cost. This is shown in Figure 14. Enlarged or rehabilitated existing reservoirs have more variable unit costs because the type of work required to achieve the additional storage varies considerably from site to site.

Table 12. Summary of Surface Reservoir Costs

Dam Type/Name	Storage Capacity (ac-ft)	Estimated 2017 Cost (\$ million)	Unit Cost (\$/ac-ft)
New Site			
Sandborn Reservoir	224,000	\$128	\$570
West Nile Reservoir	26,950	57	\$2,100
McCarthy Reservoir	10,000	25	\$2,500
South Platte (Narrows) Reservoir	1,960,000	\$125	\$64
Wildcat Reservoir	60,000	\$74	\$1,200
Pawnee Pass Dam	75,000	\$249	\$3,300
Fremont Butte	76,000	\$71	\$940
North Sterling Regulating Reservoir	7,600	\$35	\$4,600
Johnson Reservoir	10,600	\$21	\$2,000
Ovid Reservoir	7,700	\$21	\$2,700
Troelstrup	5,000	\$16	\$3,100
Beaver Creek	95,000	\$61	\$640
Enlargement			
North Sterling Reservoir Enlargement	12,000	\$22	\$1,800
Julesburg Reservoir Enlargement	21,900	\$44	\$2,000
Rehabilitation			
Empire Reservoir Rehab	2,779	\$14	\$5,000
Prewitt Reservoir Rehab	4,364	\$5.5	\$1,300
Julesburg Reservoir Rehab	5,700	\$31	\$5,400
Jackson Lake Reservoir Rehab	10,000	\$1.8	\$190
Riverside Reservoir Rehab	2,500	\$13	\$5,000

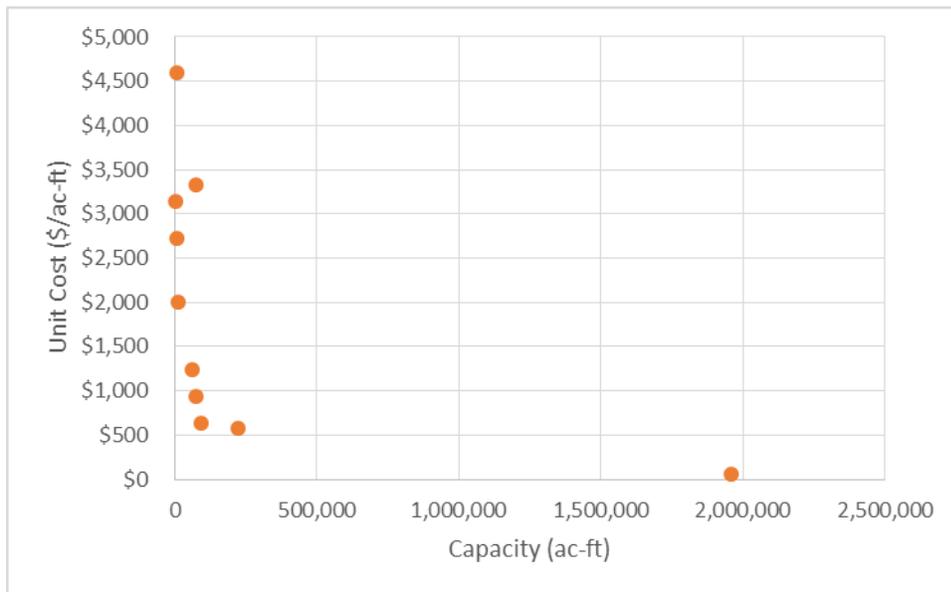


Figure 14. Unit Cost of Surface Storage vs Capacity for New Reservoirs

Aquifer Storage Costs

Aquifer storage costs were based on conceptual designs for infiltration basin recharge and recovery within an alluvial aquifer. Conceptual designs include components required to recharge and recovery of water at a site, but not the conveyance to and from the site.

Aquifer storage and recovery concept costs are more correlated to recharge and recovery rates than total storage volumes. Because of this, Table 13 presents the same total cost estimate for Lower Lost Creek Basin and Badger/Beaver Basin. These costs were developed on a unit basis so future cost estimates can be scaled to different recharge and recovery scenarios.

Table 13. Aquifer Storage and Recovery Costs

Storage Concept	Storage Capacity (ac-ft)	Recharge Rate (ac-ft per month)	Recovery Rate (ac-ft per month)	Estimated 2017 Cost (\$ million)	Unit Cost (\$/ac-ft)
Lower Lost Creek Aquifer	157,000	24,000	12,000	\$163	\$1,038
Beaver/Badger Aquifer	311,00	24,000	12,000	\$163	\$524

The aquifer storage cost estimates were based on SPSS delivery and demand scenarios with 10,000 ac-ft of gravel pit regulating storage near the river diversion. Aquifer storage concepts were modeled with a capacity of 24,000 ac-ft per month of inflow/recharge and 12,000 ac-ft per month of outflow/recovery. It is possible that these scenarios would not represent reasonable rates of alluvial aquifer recharge and recovery for all alluvial ASR sites, but these rates were used to provide a similar

cost comparison to surface water storage options. It was also assumed that land availability and hydrogeologic conditions would not constrain site construction or operations for recharge or recovery.

Conveyance Costs

As described previously, storage concepts require combinations of river diversions, facilities to convey water from the river to the reservoir, and facilities to convey water from the reservoir to demand centers. Derivation of these costs is described in the Cost Estimating TM. For purposes of the SPSS conceptual costs it was assumed that new diversion and conveyance facilities would be required for SPSS projects; use of existing diversion structures or irrigation canals to fill reservoirs could reduce actual costs upon further analysis. Summaries of SPSS cost estimating assumptions and data are provided below.

At the conceptual level, all diversion structures were assumed to be sized for 800 cfs at a cost of \$3.6 million regardless of their location.

For purposes of conceptual cost estimating it was assumed that a maximum flow rate of 400 cfs would be pumped and piped from the diversion structure to the storage reservoir in a bi-directional pipeline, which would then be used to release water back to the river when the reservoir is operated to meet downstream demands. This assumes a 10,000 ac-ft gravel pit storage complex at the diversion structure to balance peak flows.

Table 14 summarizes key parameters and costs for conceptual intake conveyance systems for each storage concept. Conveyance facility and cost requirements should be considered conservative, but allow for equal comparison of concepts. These costs represent construction cost only, and do not include costs for permitting, design, land acquisition, easement and right-of-way acquisition, or environmental impact mitigation.

Table 14. Cost Estimates for Intake Conveyance Systems for Storage Concepts

Alternative	Pipeline Cost	Pump Station Cost	Dam and Diversion Structure Cost	Gravel Pit Storage Cost	Contingency	Total Conveyance Cost
Upper Basin Storage-Sandborn Reservoir	\$43,750,000	\$50,360,000	\$3,600,000	\$15,000,000	\$56,355,000	\$169,065,000
Mid Basin Storage North- Wildcat Reservoir	\$26,110,000	\$49,950,000	\$3,600,000	\$15,000,000	\$47,330,000	\$141,990,000
Mid Basin Storage South- Beaver Creek Reservoir	\$140,690,000	\$113,010,000	\$3,600,000	\$15,000,000	\$136,150,000	\$408,450,000
Lower Basin Storage-Trilakes Northeast (Julesburg, Ovid, and Troelstrup)	\$9,010,000	\$16,750,000	\$5,600,000	\$30,000,000	\$30,680,000	\$92,040,000
Existing Reservoir Improvements (Julesburg, North Sterling, Prewitt, Jackson, and Riverside)	\$34,970,000	\$59,270,000	\$8,400,000	\$45,000,000	\$73,820,000	\$221,460,000
Groundwater Basin Storage West- Lost Creek Aquifer	\$62,550,000	\$78,210,000	\$3,600,000	\$15,000,000	\$79,680,000	\$239,040,000
Groundwater Basin Storage East- Beaver Badger Aquifer	\$70,790,000	\$138,150,000	\$3,600,000	\$15,000,000	\$113,770,000	\$341,310,000

Deliveries to demand centers would require infrastructure as follows.

- Exchange to Kersey: A 20,000 ac-ft gravel pit reservoir was included with all concepts so facilitate exchanges and improve efficiencies of deliveries to customers in the northern Front Range area. The cost of the gravel pit and ancillary facilities was estimated to be \$30 million.
- Release to River: No separate facilities are needed. For this evaluation it was assumed the intake pipeline would be a bi-direction pipeline that could be used to both fill the reservoir from the South Platte River and also release water to the South Platte River to meet downstream demands.
- Pipe to Brighton: The 100 mgd pipeline to Brighton was assumed to be a 60-inch pipeline for all alternatives. Pipeline length and pumping station cost varied for each alternative.

Table 15 summarizes the capital cost estimates for these conveyance requirements. These values do not include costs for permitting, design, land acquisition, easement and right-of-way acquisition, or environmental impact mitigation.

Table 15. Conveyance Costs for Pipeline to Brighton Component of Storage Concepts

Alternative	Length (mi)	Pipeline Cost	Pump Station Cost	Contingency	Total Cost
Mainstem Storage – Pipe from South Platte (Narrows) Reservoir	62	\$138,170,000	\$85,130,000	\$111,650,000	\$334,950,000
Upper Basin Storage – Pipe from Sandborn Reservoir	52	\$114,640,000	\$69,850,000	\$92,245,000	\$276,735,000
Mid Basin Storage North – Pipe from Wildcat Reservoir	71	\$157,560,000	\$100,780,000	\$129,170,000	\$387,510,000
Mid Basin Storage South – Pipe from Beaver Creek Reservoir	72	\$158,920,000	\$102,530,000	\$130,725,000	\$392,175,000
Lower Basin Storage- Trilakes Northeast – Pipe from Julesburg Reservoir	164	\$364,640,000	\$209,100,000	\$286,870,000	\$860,610,000
Existing Reservoir Improvements – Pipe from Riverside Reservoir	52	\$114,640,000	\$69,850,000	\$92,245,000	\$276,735,000
Groundwater Basin Storage West – Pipe from Lost Creek Aquifer	32	\$69,860,000	\$47,950,000	\$58,905,000	\$176,715,000
Groundwater Basin Storage East – Pipe from Badger / Beaver Aquifer	64	\$141,400,000	\$91,250,000	\$116,325,000	\$348,975,000

Summary of Costs by Storage Concept

Table 16 summarizes capital costs for SPSS storage concepts. These costs are based on the largest feasible storage capacity for the surface reservoir or ASR project. No cost optimization was performed for this analysis.

Table 16. Summary of Storage Concept Costs for Maximum Representative Storage Site

Storage Concept (Representative Site)	Storage Capacity (ac-ft)	Storage Cost (\$M)	Intake System Cost (\$M) (Diversion, Gravel Pits, Pipes, Pump)	Delivery System Cost (\$M) (Pipe to Brighton, Kersey Gravel Pits)	Total Storage Concept Cost (\$M)	Firm Yield (AFY)	Total Unit Cost (\$/AFY)
Mainstem Dam (Narrows)	973,000	\$125	-	\$335	\$460	62,000	\$7,400
Upper Basin Storage (Sandborn)	224,000	\$128	\$168	\$277	\$573	22,000	\$26,000
Mid Basin Storage North (Wildcat)	60,000	\$74	\$141	\$388	\$602	9,000	\$66,900
Mid Basin Storage South (Beaver)	95,000	\$61	\$407	\$392	\$860	11,000	\$78,200
Existing Reservoirs	40,300	\$121	\$221	\$277	\$619	17,000	\$36,400
Lower Basin Storage	56,464	\$58	\$92	\$781	\$932	24,000	\$38,800
Groundwater Storage West (Lost Creek)	157,000	\$163	\$354	\$177	\$693	20,000	\$34,700
Groundwater Storage East (Badger/Beaver)	311,000	\$163	\$336	\$349	\$848	36,000	\$23,600

COMPARISON OF STORAGE SITES

Criteria and data from the SEF were used to compare storage sites using a simple scoring system. The purpose of the scoring system was to provide a means of identifying the more feasible storage options. At this level the comparison of sites is not a precise assessment, and results should be used only to identify overall trends or large differences between options.

Appendix C lists numerical values assigned to each of the qualifiers for the attributes. Assigning values to the qualifiers allowed for calculation of a triple bottom line evaluation score for each option. Due to the limited level of analysis conducted at this stage, most attributes were quantified using values 1 for good performance and 0 for poor performance. In some cases intermediate values of 0.5 were assigned. For attributes with a negative impact, negative values were used.

Evaluation of alternatives using a triple bottom line scoring system with multiple criteria requires assumptions for the weight of the criteria. For this analysis three weighting scenarios were tested:

- Equal Weights; all criteria received an equal weight of 1.
- Technical Weights; all criteria related to technical feasibility of the storage option (e.g., scalability, constructability, ability to use existing infrastructure) were given a weight of 3 and all other criteria were given a weight of 1.

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- Environmental Weights; all criteria related to environmental parameters (e.g., wetlands, habitat impacts, permissibility) were given a weight of 3 and all other criteria were given a weight of 1.

Table 17 summarizes the results of the triple bottom line site evaluation process for the three criteria weighting scenarios. The table shows the numerical score for the storage options. In addition, the average of the scores was computed across the 3 weighting scenarios for each storage option to assess how the sites performed across all weightings. This is shown in Table 18. Figure 15 shows the range of scores for each of the weighting scenarios as well as the maximum possible score for each scenario.

Result of the multi-criteria comparison of sites can be summarized as follows:

- Sites that tend to rise to the top of the scoring process tend to do so regardless of the weights assigned to the criteria. Similarly, sites that tend to fall to the bottom of the scoring process tend to do so regardless of the weights assigned to the criteria. This is helpful in that the relative scoring of most sites is fairly independent of the weight assigned to the criteria in the SEF.
- As expected, aquifer storage options and enlargements and rehabilitations of existing reservoirs tend to score higher than new reservoirs.
- Also as expected, the on-channel storage options (Narrows Reservoir and Hardin Reservoir) score poorly relative to most other options.
- Of the new off-channel reservoir options, the sites with the most promise appear to be Wildcat, Point of Rocks, Beaver Creek, Johnson, North Sterling Regulating, and Sandborn.
- Scores are clustered over a relatively narrow range compared to the maximum possible score for each weighting scenario, and no storage options had a score close to the maximum possible score. Differences among storage options are small, and at this level of analysis the triple bottom line scoring process should not be used to eliminate options.

At this level of analysis, the storage option scoring process is very approximate and is based on conceptual information and considerable professional judgment. Significant information about individual sites was unknown at this stage. Refinement of site specific data could change scores of options significantly. In addition, sites were scored without regard for how they could be used in a specific solution that could be formulated by a specific water user. When considering how storage sites would be incorporated into a particular alternative and integrated into the operations of a particular water user, results for the scoring process could vary considerably from this generic approach.

Table 17. Summary of Storage Site Evaluation Scores for Different Criteria Weighting Scenarios

Name	Category	Site Score-Equal Weighting	Site Score-Feasibility Weighting	Site Score-Environmental Weighting
Range of Possible Scores (Min / Max)		0 / 20.5	0 / 43.5	0 / 37.5
Badger/Beaver Creek	Aquifer	9.5	24.5	13.5
Beaver Creek Reservoir	New Site	8.5	18.5	12.5
Fremont Butte	New Site	7.5	18.5	7.5
Greasewood Reservoir	New Site	6.5	16.5	6.5
Hardin Reservoir	New Site	6	20	0
Jackson Lake Reservoir	Rehabilitation	9.5	25.5	10.5
Johnson Reservoir	New Site	7	21	7
Julesburg Reservoir (Enlrg)	Enlargement	8	25	8
Julesburg Reservoir (Rehab)	Rehabilitation	10.5	27.5	15.5
Lower Bijou Creek	Aquifer	10.5	28.5	13.5
Lower Kiowa Creek	Aquifer	10	26	12
Lower Lost Creek	Aquifer	11.5	28.5	17.5
McCarthy Reservoir	New Site	6	16	6
North Sterling Reg Res	New Site	7	21	7
North Sterling Reservoir	Enlargement	7	22	6
Ovid Reservoir	New Site	6.5	21.5	4.5
Pawnee Pass Dam	New Site	7	19	6
Point of Rocks Reservoir	New Site	8.5	21.5	10.5
Prewitt Reservoir	Rehabilitation	9	26	8
Riverside Reservoir	Rehabilitation	10	25	13
Sandborn Reservoir	New Site	7	19	7
South Platte (Narrows) Res	New Site	7.5	22.5	3.5
Sunken Lake Reservoirs	New Site	6.5	18.5	5.5
Troelstrup	New Site	6.5	21.5	4.5
Upper Bijou Creek	Aquifer	8.5	20.5	11.5
Upper Kiowa Creek	Aquifer	8.5	20.5	11.5
Upper Lost Creek	Aquifer	10	26	14
West Nile Reservoir	New Site	5.5	14.5	5.5
Wildcat Reservoir	New Site	9	26	8

Note: Green shading indicates approximately top 20% of scores; red shading indicates approximately bottom 20% of scores.

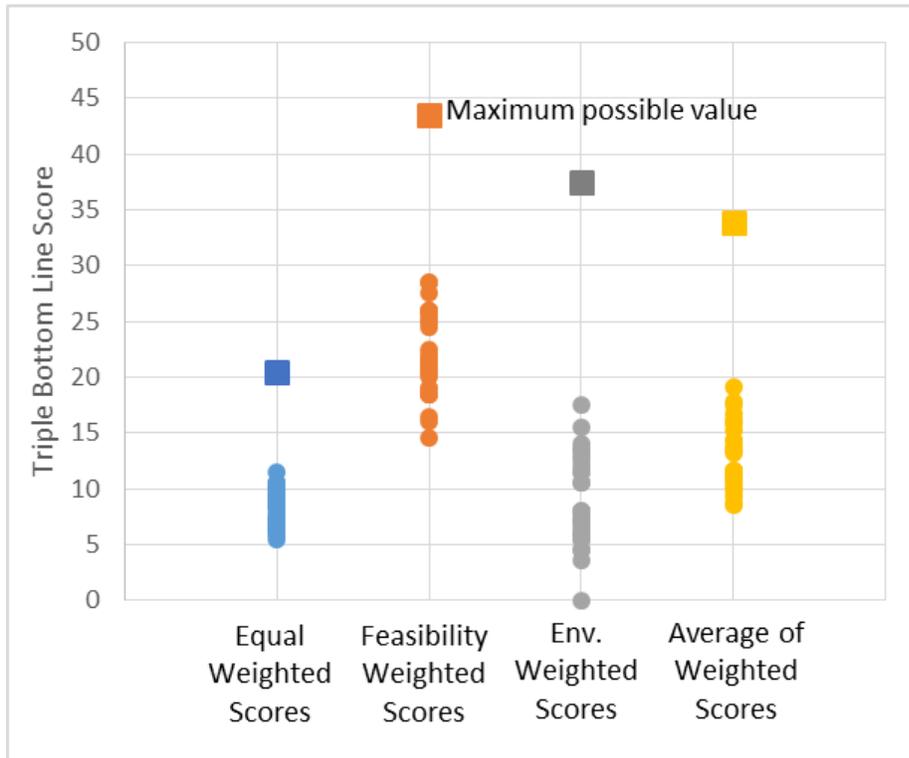


Figure 15. Range of Storage Site Scores for Different Weighting Scenarios

Table 18. Average of Scores Across Three Weighting Scenarios for Reservoir Storage Options

Storage Options Sorted by Average Score	Average of Scores for 3 Weighting Scenarios
Lower Lost Creek	19.2
Julesburg Reservoir (Rehabilitation)	17.8
Lower Bijou Creek	17.5
Upper Lost Creek	16.7
Lower Kiowa Creek	16.0
Riverside Reservoir	16.0
Badger/Beaver Creek	15.8
Jackson Lake Reservoir	15.2
Prewitt Reservoir	14.3
Wildcat Reservoir	14.3
Julesburg Reservoir (Enlargement)	13.7
Point of Rocks Reservoir	13.5
Upper Bijou Creek	13.5
Upper Kiowa Creek	13.5

Storage Options Sorted by Average Score	Average of Scores for 3 Weighting Scenarios
Beaver Creek Reservoir	13.2
Johnson Reservoir	11.7
North Sterling Regulating Reservoir	11.7
North Sterling Reservoir	11.7
Fremont Butte	11.2
South Platte (Narrows) Reservoir	11.2
Sandborn Reservoir	11.0
Ovid Reservoir	10.8
Troelstrup	10.8
Pawnee Pass Dam	10.7
Sunken Lake Reservoir	10.2
Greasewood Reservoir	9.8
McCarthy Reservoir	9.3
Hardin Reservoir	8.7
West Nile Reservoir	8.5

Note: Orange indicates aquifer storage, green indicates existing reservoir modification, blue indicates off-channel surface reservoir, and white indicates on-channel surface reservoir.

When comparing storage sites, attributes of size, cost and triple bottom line scoring are all important. Table 19 compares these features for each of the storage sites. In this table the storage cost includes the cost of conveying water from the South Platte River to the storage site. The inlet cost includes a new diversion structure and a new, dedicated pipeline and pump station system from the river to the storage site. In some cases existing irrigation canals could be used to convey a portion of the project water to a location fairly near the site, potentially reducing the storage+inlet cost.

Table 19. Comparison of Storage Site Capacity, Cost and Triple Bottom Line Score

Dam Type/Name	Storage Capacity (ac-ft)	Storage + Inlet System			Triple Bottom Line Score
		Dam or ASR Cost (\$ million)	Inlet Cost ⁽¹⁾ (\$ million)	Total Unit Cost ⁽²⁾ (\$/ac-ft)	
New Surface Storage					
Sandborn Reservoir	224,000	\$128	\$168	\$296	11.0
West Nile Reservoir	26,950	57	\$168	\$225	8.5
McCarthy Reservoir	10,000	25	\$150	\$175	9.3
South Platte (Narrows) Reservoir	1,960,000	\$125	\$0	\$125	11.2
Wildcat Reservoir	60,000	\$74	\$141	\$215	14.3
Pawnee Pass Dam	75,000	\$249	\$200	\$449	10.7
Fremont Butte	76,000	\$71	\$273	\$344	11.2
North Sterling Regulating Reservoir	7,600	\$35	\$168	\$203	11.7

Dam Type/Name	Storage Capacity (ac-ft)	Storage + Inlet System			Triple Bottom Line Score
		Dam or ASR Cost (\$ million)	Inlet Cost ⁽¹⁾ (\$ million)	Total Unit Cost ⁽²⁾ (\$/ac-ft)	
Johnson Reservoir	10,600	\$21	\$89	\$110	11.7
Ovid Reservoir	7,700	\$21	\$35	\$56	10.8
Troelstrup	5,000	\$16	\$35	\$51	10.8
Beaver Creek	95,000	\$61	\$200	\$261	13.2
Enlargement of Surface Storage					
North Sterling Reservoir Enlargement	12,000	\$22	60	\$82	11.7
Julesburg Reservoir Enlargement	21,900	\$44	\$40	\$84	13.7
Rehabilitation of Surface Storage					
Empire Reservoir Rehab	2,779	14	40	\$54	NA
Prewitt Reservoir Rehab	4,364	5.5	40	\$46	14.3
Julesburg Reservoir Rehab	5,700	\$31	\$40	\$71	17.8
Jackson Lake Reservoir Rehab	10,000	\$2	\$40	\$42	15.2
Riverside Reservoir Rehab	2,500	12.5	35	\$48	16.0
Aquifer Storage					
Lower Lost Creek Basin	157,000	163	354	\$517	19.2
Badger/Beaver Basin	311,000	163	336	\$499	15.8

Notes:

- (1) Inlet cost assumes new diversion, pipeline and pump station(s) from South Platte River to storage site.
- (2) Storage sites that could be filled in part using existing irrigation canals, thus reducing cost, are shown in bold.

COMPARISON OF STORAGE CONCEPTS

In addition to data for individual storage sites, the SEF for the SPSS contains many attributes that apply to the overall solutions and storage concepts. These attributes are listed and described in Appendix C. Many of the storage concept attributes are based on the specific criteria listed in HB-1256 for evaluating SPSS alternatives. Others were developed by the study team to assist in comparing the storage concepts on a relative basis.

Table 20 shows the attribute values for the eight SPSS storage concepts considered in this study. It also lists the cumulative scores for each storage concept when numerical values are assigned to the attribute qualifiers (e.g., 1.0, 0.5, 0) as shown in Appendix C. For many of the attributes, particularly those associated with the HB-1256 criteria, the storage concepts have very similar performance. They were formulated to meet demands in a variety of locations in the basin and thus have similar capabilities of providing water supply benefits listed in HB-1256. The storage concepts relying on reservoirs lower in the South Platte basin (e.g., Lower Basin Storage, Existing Storage) have lower scores due to the relatively greater difficulty in providing water supply and flood management benefits for large portions of the basin when storage is located downstream.

It is noted that this comparison is based on the storage concepts and representative storage sites simulated in the MODSIM model. For the SPSS analysis it was necessary to select a limited number of concepts for analysis. Many variations of these concepts would be feasible, including

use of different storage options, increased storage, and different operating assumptions. Variations in these storage concept definitions could result in substantial differences in scores exceeding the variability in the scores in Table 20. Furthermore, none of the concepts or individual site designs were optimized at this level because ownership of storage projects is not known. Results in this table should be used only for a high-level comparison of storage concepts. The fact that the comparison yields fairly similar scores for all of the storage concepts suggests that any of them could be candidates for further study in the future under the right circumstances. However, concepts with more storage higher in the basin offer a greater potential for benefits and could be more attractive to a broader variety of potential participants.

Table 20. Site Evaluation Framework Attribute Values for Storage Concepts

Attribute	Description	Mainstem Dam	Upper Basin Storage	Mid Basin Storage - North	Mid Basin Storage - South	Lower Basin Storage	Existing Storage	Aquifer Storage West	Aquifer Storage East	Comments
Water Supply Gap Solution	The storage solution could capture water to meet demands in the basin.	High	Medium	Low	Medium	Medium	Medium	Medium	Medium	Based on firm yield
Reduce TransBasin Diversions	The storage solution could yield additional supplies from in-basin sources, reducing the need for future transbasin diversions.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Any in-basin yield substitutes for transbasin diversions
Multiple Users Supply	The storage solution could supply water to various municipal, industrial, environmental, and agricultural water users in the basin.	High	High	High	High	Low	Medium	High	Medium	Upstream is good. Far downstream with no pipeline is bad.
Augmentation Plan Operation Enhancement	The storage solution could be used to optimize the operation of existing or future augmentation plans.	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Any storage concept can release to river so all those above Lower Basin could be operated for augmentation
Aquifer Recharge Operations	The storage solution is an aquifer recharge facility, directly delivers water to aquifer recharge facilities, or facilitates conjunctive use.	Medium	Medium	Medium	Medium	Low	Medium	High	High	Lower Basin would be below aquifer recharge facilities

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Attribute	Description	Mainstem Dam	Upper Basin Storage	Mid Basin Storage - North	Mid Basin Storage - South	Lower Basin Storage	Existing Storage	Aquifer Storage West	Aquifer Storage East	Comments
ATM Partnership	A storage solution would have available storage for temporary leased water to be stored to help the ATM operations and partnerships.	High	High	High	High	High	High	High	High	All could do this
Exchange Potential Enhancement	The storage solution adds storage capacity for interim storage or "leap-frogging" exchanges, or could add streamflows that would increase exchange potential in the river.	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes for all except Lower Basin
Recreation Benefit	The storage solution would increase recreational opportunities.	Positive	Positive	Positive	Positive	Positive	Neutral	Neutral	Neutral	Positive for new surface sites; neutral for GW and existing storage sites
Enhance Streamflow	The storage solution could deliver water to downstream users via natural channels, enhancing stream flow.	Medium	High	High	High	Medium	Medium	High	High	All could release to South Platte; some could release to tribs
Compact Compliance	The storage solution could increase low flows at the state line and reduce frequency of compact calls.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	All would do this
Increase Ag Production	The storage solution could help meet the agricultural demand gap in the basin.	Low	Low	Low	Low	High	Low	Low	Low	

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Attribute	Description	Mainstem Dam	Upper Basin Storage	Mid Basin Storage - North	Mid Basin Storage - South	Lower Basin Storage	Existing Storage	Aquifer Storage West	Aquifer Storage East	Comments
Reduce Buy&Dry	The storage solution could yield additional M&I supplies from in-basin sources, reducing the pressure to buy Ag water rights.	High	Medium	Low	Medium	Medium	Medium	Medium	Medium	Based on firm yield
Delivery Water Quality	The storage solution would deliver raw water requiring advance treatment to achieve primary and/or secondary drinking water standards.	Low	Low	Low	Low	Low	Low	Low	Low	All water in SPSS study area would need advanced treatment for potable use
Permitting Feasibility	The potential permitting feasibility of site and solution.	Low	Medium	Medium	Medium	Medium	High	High	High	On channel is worst; existing dams and GW are best
Water Rights	Measure of the perceived ease in obtaining the water rights/decrees required to operate the solution.	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Set all to medium. All will have some issues.
Combined Permitting	Captures the potential increase in permitting complexity for the solutions compared to storage sites alone.	Same	Same	Same	More	More	More	Same	More	Used "More" for concepts requiring longer pipelines to Brighton
Estimated Permit Timeline	The probability that permits would be secured quickly.	Low	Medium	Medium	Medium	Medium	High	Medium	Medium	Mainstem dam is longest. Modifications to existing reservoirs is shortest.

Attribute	Description	Mainstem Dam	Upper Basin Storage	Mid Basin Storage - North	Mid Basin Storage - South	Lower Basin Storage	Existing Storage	Aquifer Storage West	Aquifer Storage East	Comments
Combined Impact	Captures the potential increase in environmental impacts for the solutions compared to individual sites alone.	More	More	More	More	More	More	More	More	All require facilities outside the storage footprint
River Reach	River reach where the solution is predominantly located.	Kersey-Balzac	Kersey-Balzac	Kersey-Balzac	Kersey-Balzac	Balzac-Julesburg	Balzac-Julesburg	Kersey-Balzac	Balzac-Julesburg	
Meet Demands	Ability of a solution to meet demands, either upstream or downstream	US and DS	US and DS	US and DS	US and DS	US and DS	US and DS	US and DS	US and DS	All concepts were formulated to meet demands throughout Basin
Total Score (Unweighted)		11.5	12	11	11	8	10	12	10.5	

The ability of the simulated storage concepts to put Colorado’s South Platte River water to beneficial use is summarized in Table 21. This analysis used future hydrology, and shows that while a significant amount of water that would otherwise leave the State could contribute to in-state beneficial uses, considerably more storage would be required to use all the State’s available South Platte water resources.

Table 21. Water Leaving the State Under Future Hydrology for Simulated Storage Concepts

Storage Concept	Average Annual Water Leaving State (ac-ft)	Percentage of Available Water Contributing to Beneficial Use (1)
No Storage	343,000	-
Mainstem Storage	169,000	51%
Upper Basin Storage	279,000	19%
Mid Basin Storage North	272,000	21%
Mid Basin Storage South	269,000	22%
Lower Basin Storage	193,000	44%
Existing Reservoir Improvements	173,000	50%
Designated Groundwater Basin Storage West	280,000	18%
Designated Groundwater Basin Storage East	271,000	21%

Notes:

(1) Includes evaporation losses and other losses which would not be beneficial uses

SUMMARY OF FINDINGS AND CONCLUSIONS

A preliminary summary of high-level findings and conclusions is presented here. These will be refined and finalized after discussion with the SPSS Review Committee and other stakeholders.

- Not surprisingly, a large mainstem reservoir has the best performance in terms of putting the state’s water to beneficial use. However, permitting obstacles may be insurmountable.
- Many off-channel storage options are feasible and can be combined in a wide variety of water supply concepts.
- Aquifer storage projects perform better than surface storage projects of the same size diverting from the same reach of the South Platte. Lower evaporation losses offset assumed losses to the groundwater basin from ASR.

- Storage options lower in the basin tend to be more efficient (better storage:yield ratio) because there is more water available. However they are further from the main demand centers.
- Combinations of storage options can provide significantly more benefit than individual options. A combination of upper basin and lower basin storage concepts rivals the large mainstem dam option for firm yield benefits.
- No feasible storage concepts or reasonable combinations of concepts are capable of putting all the available flow in the lower South Platte River to beneficial use. Therefore as a general principle, more storage will always be “better” in this region in terms of maximizing available supply for basin water users.
- Because nearly all concepts require off-channel storage and diversion from the South Platte River, intake capacity constraints can be important and there are benefits to having multiple off-channel storage projects to minimize the effects of these constraints.
- Aquifer storage options and enlargements and rehabilitations of existing reservoirs tend to score higher than new reservoirs in the multi-criteria ranking process.
- Triple bottom line scores for the storage sites analyzed in this study were fairly similar at this level of analysis without specific information on how the sites would be used in a water supply strategy; thus the triple bottom line scoring process should not be used to eliminate options at this time.
- Any of the storage concepts could be candidates for further study in the future under the right circumstances. However, concepts with more storage higher in the basin generally offer a greater potential for benefits and could be more attractive to a broader variety of potential participants.

APPENDIX A

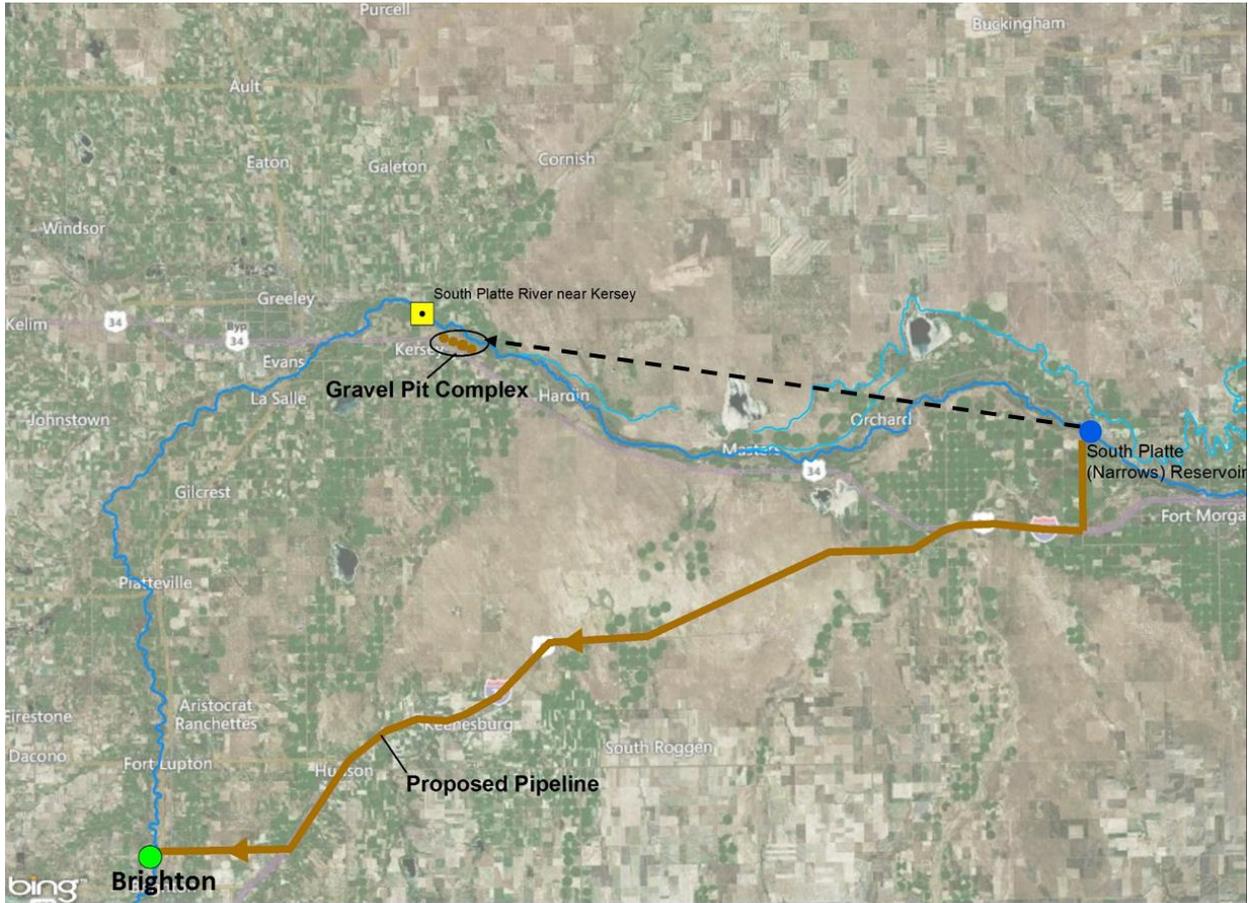
MAPS OF REPRESENTATIVE STORAGE OPTIONS FOR STORAGE CONCEPTS

APPENDIX A – MAPS OF REPRESENTATIVE STORAGE OPTIONS FOR STORAGE CONCEPTS

Upper Basin Storage – Sandborn Reservoir



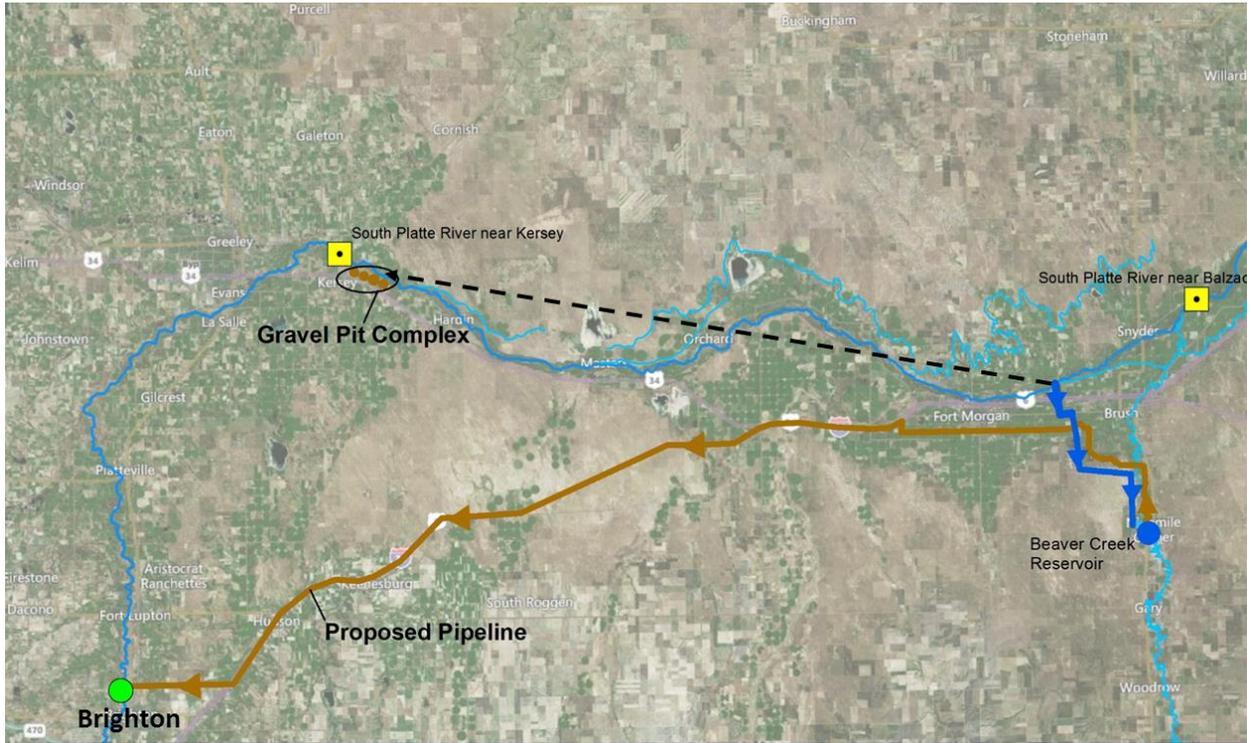
Mainstem Storage – South Platte (Narrows) Reservoir



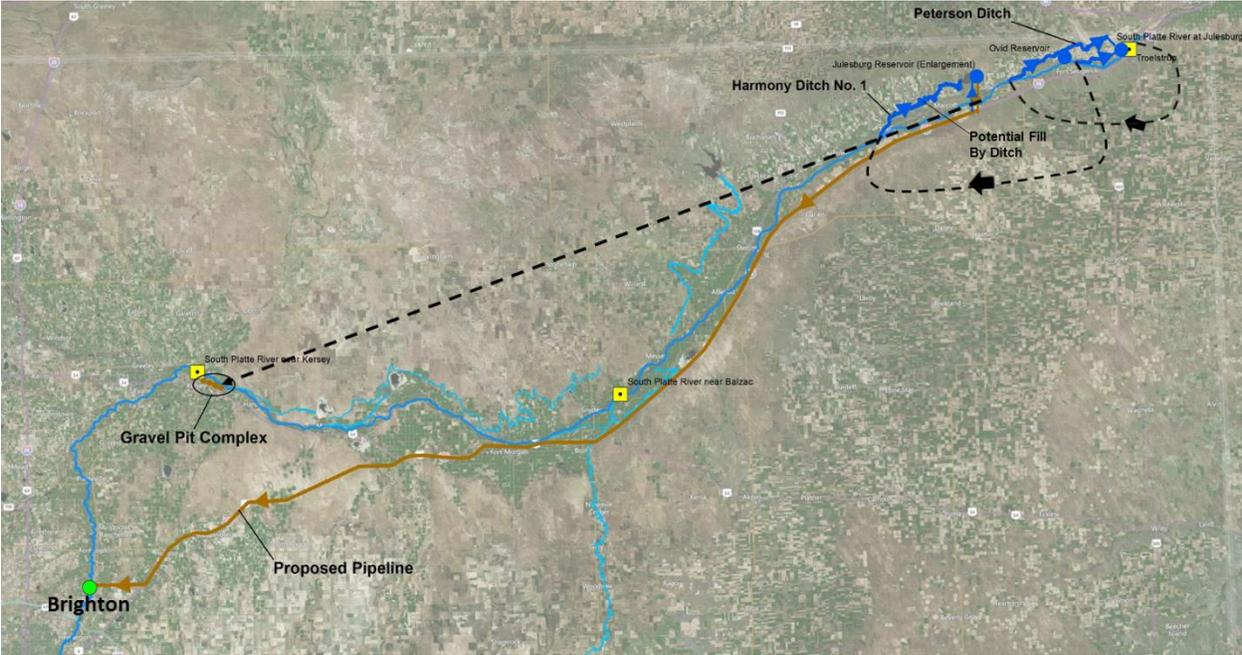
Mid Basin Storage North – Wildcat Reservoir



Mid Basin Storage South – Beaver Creek Reservoir



Lower Basin Storage – Julesburg, Ovid, Troelstrup



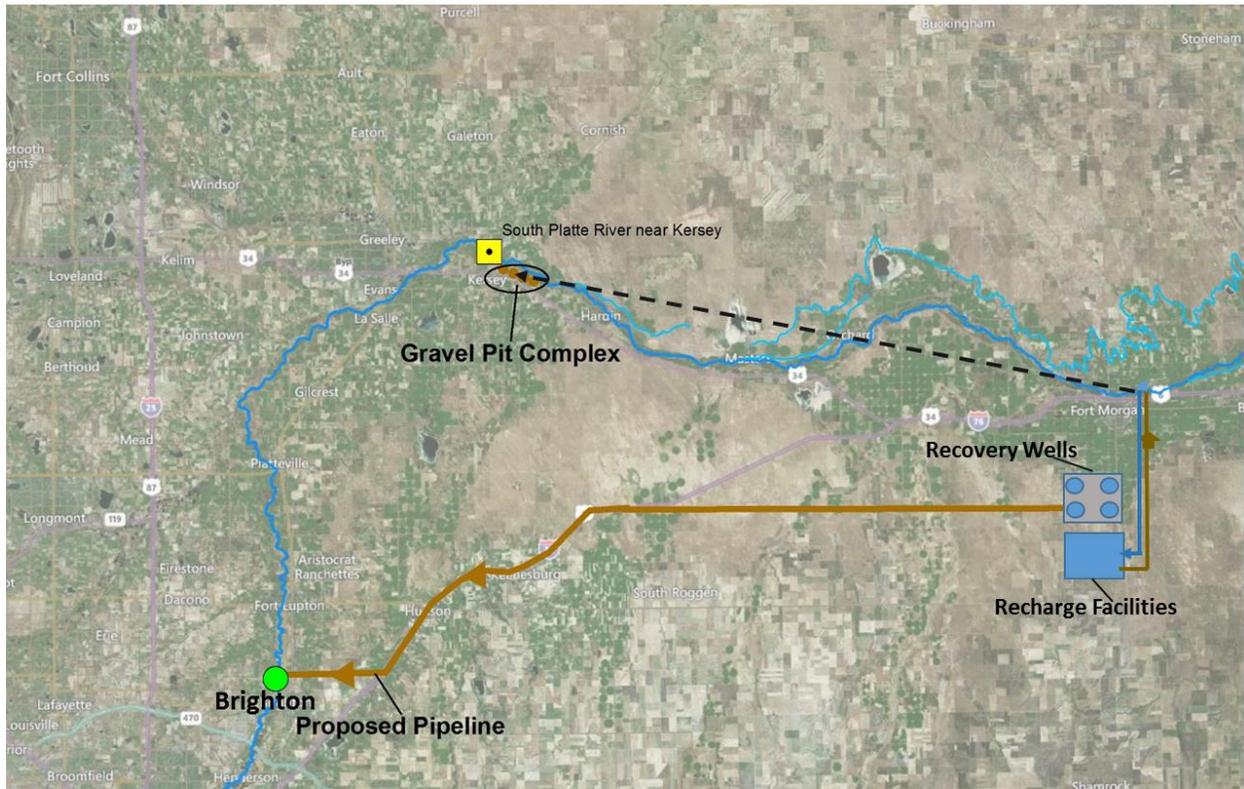
Existing Reservoir Improvements – Julesburg, North Sterling, Prewitt, Jackson Lake, Riverside



Designated Groundwater Storage Basin West - Lost Creek Basin



Designated Basin Groundwater Storage East – Badger/Beaver Basin

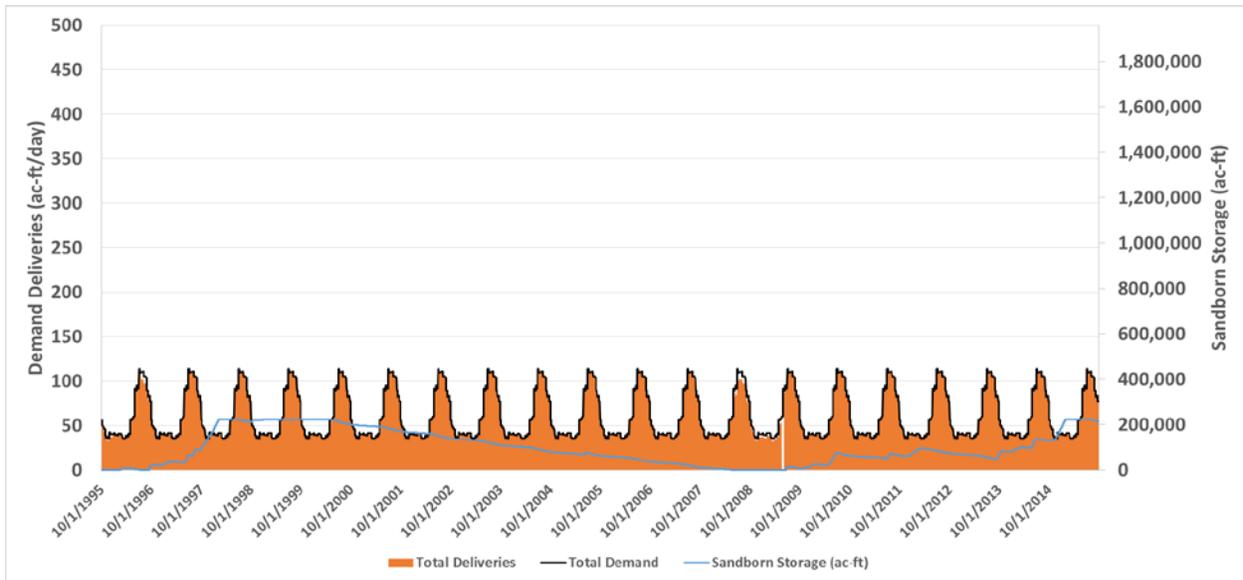


APPENDIX B

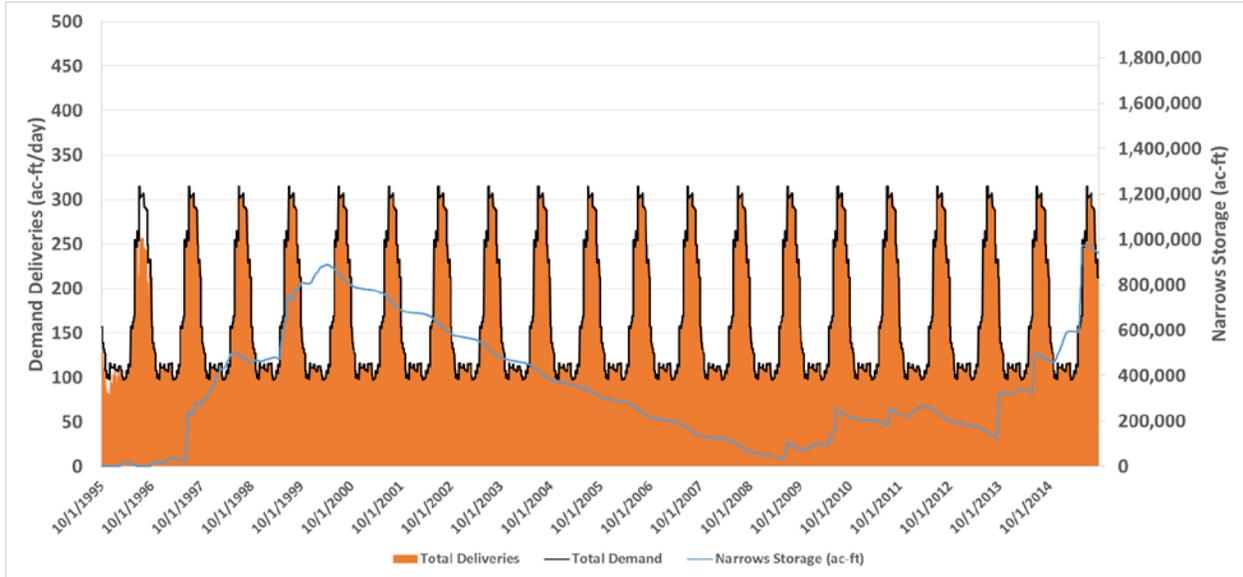
DEMAND MET AND STORAGE CONTENTS PLOTS FOR STORAGE CONCEPTS

APPENDIX B – DEMAND MET AND STORAGE CONTENTS PLOTS FOR STORAGE CONCEPTS

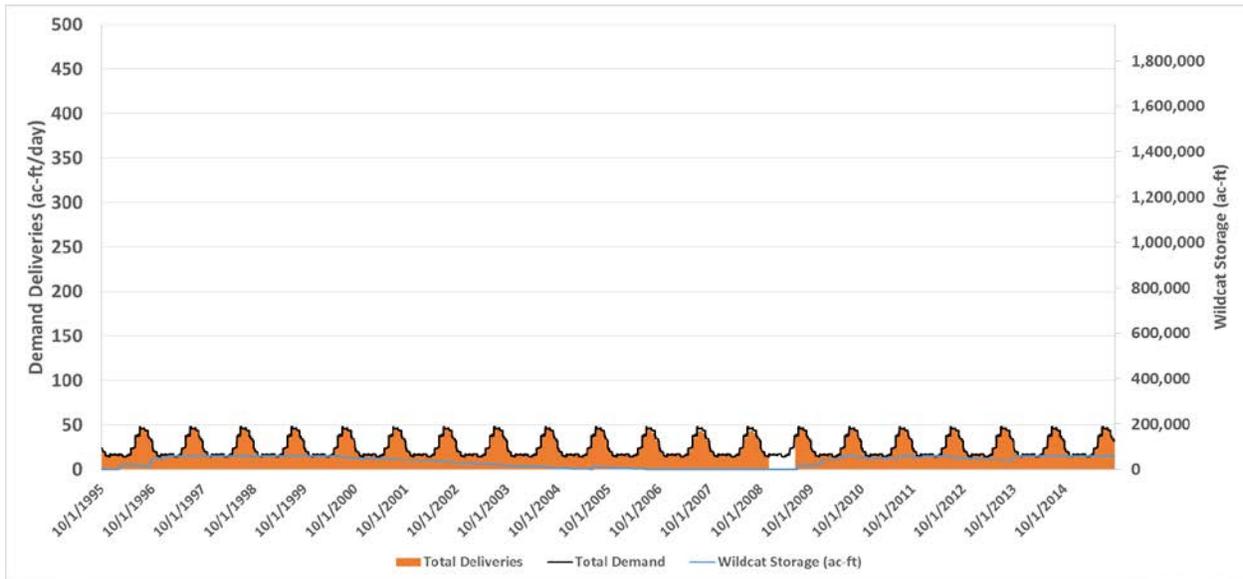
Upper Basin Storage – With Sandborn Reservoir as representative storage site



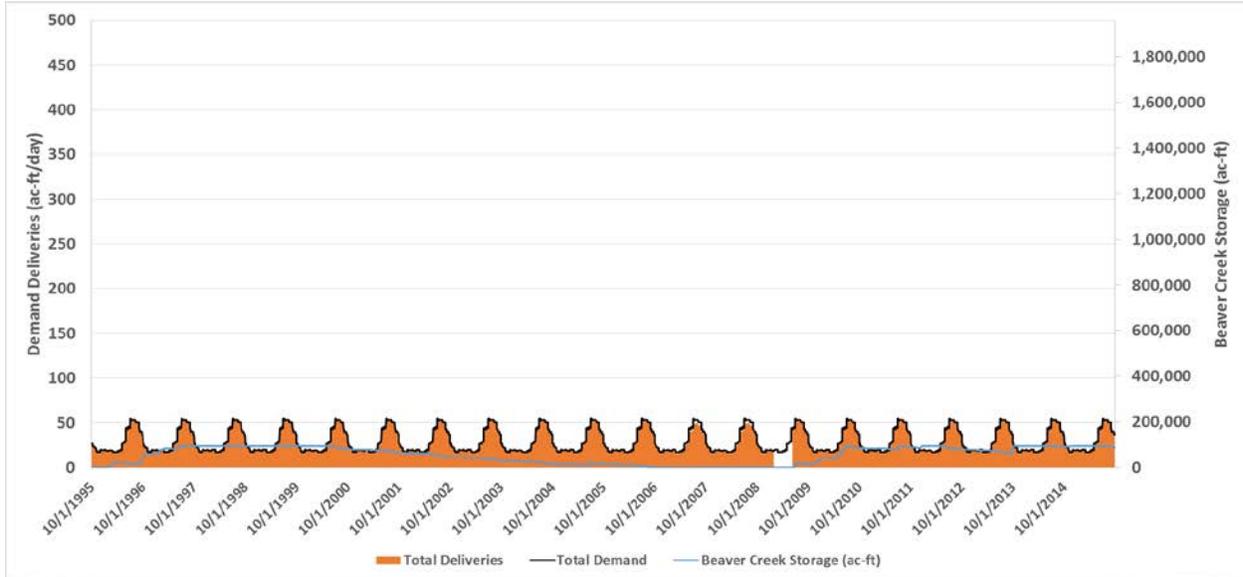
Mainstem Storage – With South Platte (Narrows) Reservoir as representative storage site



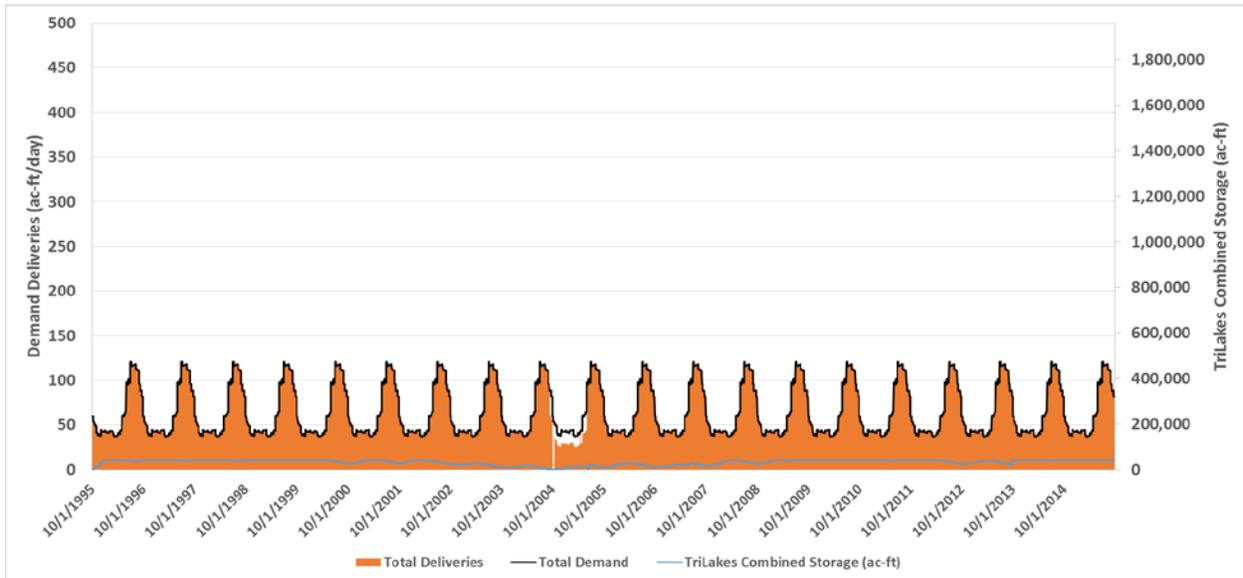
Mid Basin Storage North – With Wildcat Reservoir as representative storage site



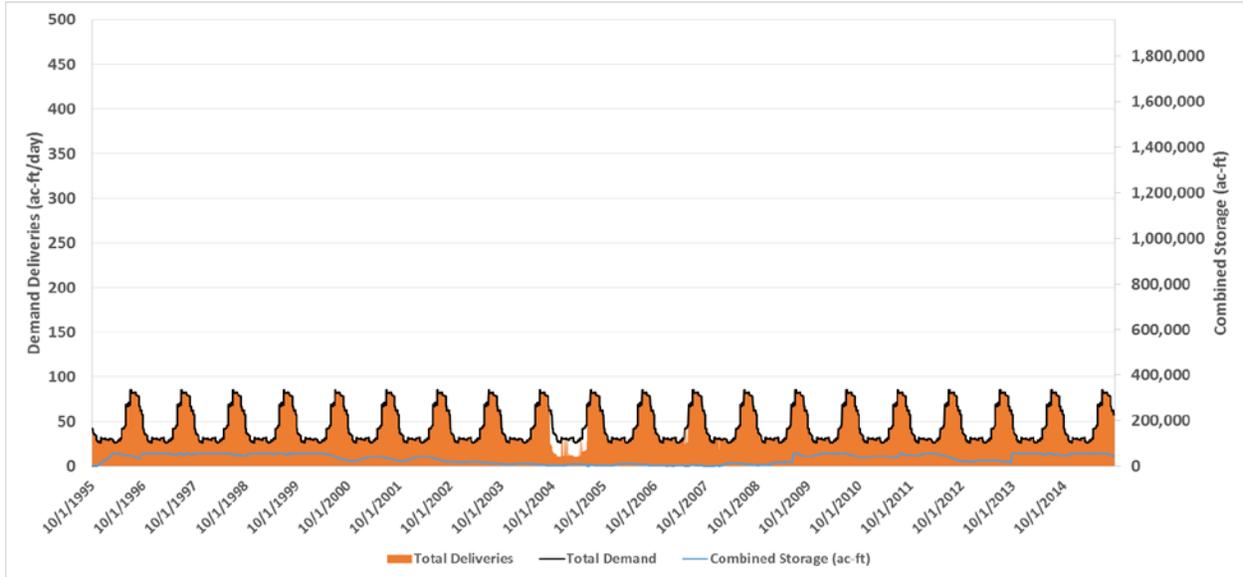
Mid Basin Storage South – With Beaver Creek Reservoir as representative storage site



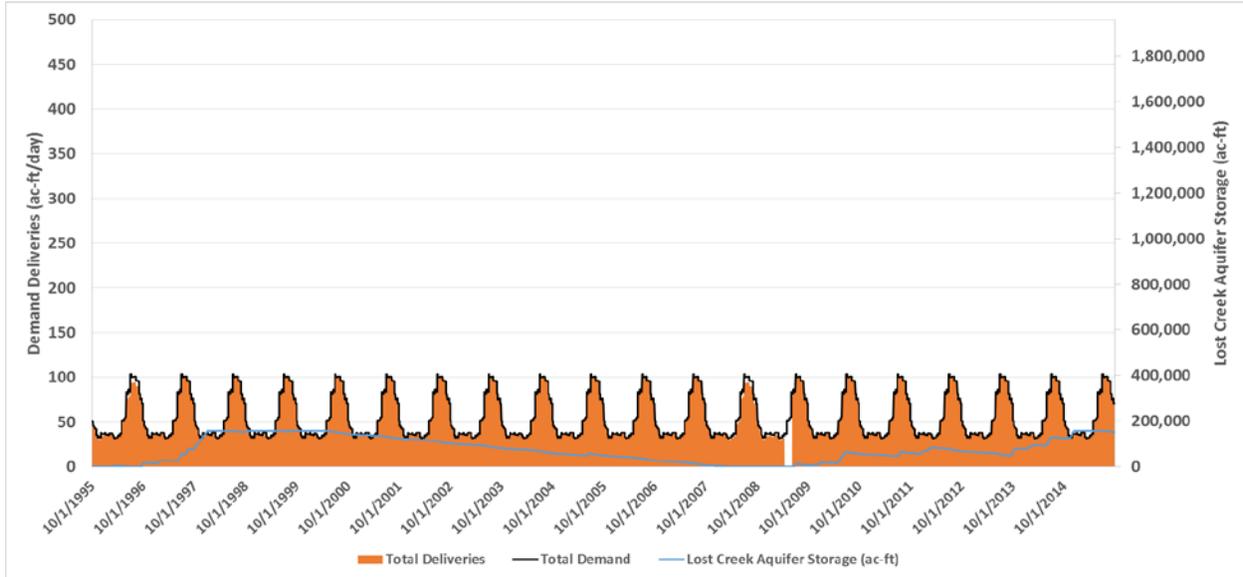
Lower Basin Storage – With TriLakes Northeast (Julesburg, Ovid, Toelstrup) as representative storage sites



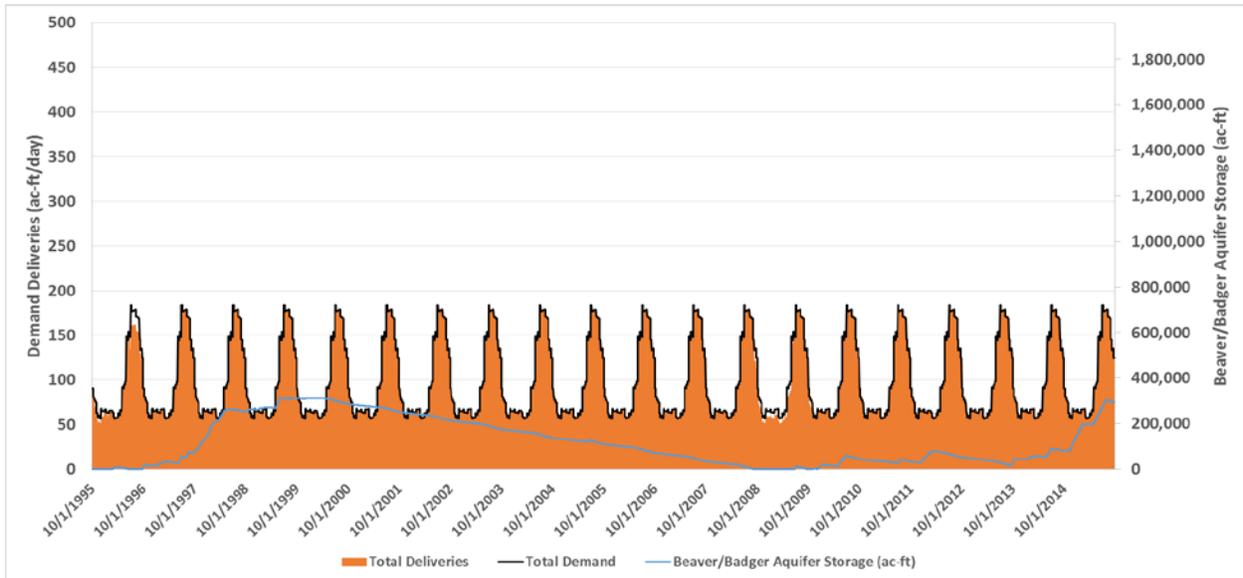
Existing Reservoir Improvements – With Julesburg, North Sterling, Prewitt, Jackson Lake, Riverside as representative storage sites



Designated Groundwater Storage Basin West – With Lost Creek Basin as representative storage site



Designated Basin Groundwater Storage East – With Badger/Beaver Basin as representative storage site



APPENDIX C

SITE EVALUATION FRAMEWORK ATTRIBUTES AND QUALIFIERS

APPENDIX C – SITE EVALUATION FRAMEWORK ATTRIBUTES AND QUALIFIERS

Attribute Name	HB 1256 Connection	Attribute Definition	Applies To	Evaluation Type	Qualifier	Qualifier Score	Qualifier Definition
MigratoryBirdHabitat	Enhancing migratory bird habitats	The storage site adds surface water areas that could be used for migratory birds.	Storage Site	Qualitative	Yes	1	Storage site has surface water area that improves habitat for migratory birds.
					No	0	Storage site does not improve habitat for migratory birds.
FloodControlRank	Flood control	The storage site could store flows that would otherwise cause flooding. The potential to reduce flood damages is based on project type, size, and area infrastructure.	Storage Site	Quantitative	High	1	On-stream reservoir on the mainstem greater than 50,000 ac-ft, and upstream of urban/municipal areas.
					Medium	0.5	On-stream reservoir on a tributary greater than 50,000 ac-ft, and upstream of urban/municipal areas.
					Low	0	Less than 50,000 ac-ft, or off-stream reservoir/aquifer recharge, or downstream of all urban/municipal areas.
WaterSupplyGapSoln	An increased ability to address Colorado’s predicted future water supply-demand gap	The storage solution could capture water to meet demands in the basin. It is estimated based on the average annual yield for the historical period.	Storage Solution	Quantitative	High	1	Solution's annual average yield is more than 50,000 acre-feet.
					Medium	0.5	Solution's annual average yield is between 10,000 and 50,000 acre-feet.
					Low	0	Solution's annual average yield is less than 10,000 acre-feet.
ReduceTransBasinDiversion	Reducing present and future needs to import water from one basin to another water basin through a transbasin diversion	The storage solution could yield additional supplies from in-basin sources, reducing the need for future transbasin diversions beyond those identified in regional or state plans.	Storage Solution	Qualitative	Yes	1	Storage solution would reduce the need for future transbasin diversions beyond those identified in regional or state plans.
					No	0	Storage solution would not reduce the need for transbasin diversions.
MultipleUsersSupply	Increased municipal, industrial, environmental, and agricultural water supply	The storage solution could supply water to various municipal, industrial, environmental, and agricultural water users in the basin.	Storage Solution	Qualitative	High	1	Storage solution easily supplies water to many municipal, industrial, environmental, and agricultural water users.
					Medium	0.5	Storage solution supplies water to a few municipal, industrial, environmental, and agricultural water users, or can supply many users with more difficulty.
					Low	0	Storage solution supplies water to only one water user.
AugPlanOperationEnhancement	not applicable	The storage solution could be used to optimize the operation of existing or future augmentation plans.	Storage Solution	Qualitative	Yes	1	Operation of this storage solution would enhance the operation of existing and future augmentation plans.
					Maybe	0.5	There is potential for this storage solution to enhance operation of existing and future augmentation plans.

Attribute Name	HB 1256 Connection	Attribute Definition	Applies To	Evaluation Type	Qualifier	Qualifier Score	Qualifier Definition
					No	0	There is limited to no opportunity for this storage solution to enhance operation of existing and future augmentation plans.
AquiferRechargeOperations	Providing storage water rights that allow for aquifer recharge	The storage solution is an aquifer recharge facility, directly delivers water to aquifer recharge facilities, or facilitates conjunctive use.	Storage Solution	Qualitative	High	1	Storage solution includes an aquifer recharge facility.
					Medium	0.5	Storage solution could deliver water to an aquifer recharge facility.
					Low	0	Storage solution would not benefit aquifer recharge.
ATMPartnership	Providing the ability to use alternative agricultural transfer methods in conjunction with water storage	A storage solution would have available storage for temporary leased water to be stored to help the ATM operations and partnerships. ATM partnership potential is based on average available storage.	Storage Solution	Quantitative	High	1	For a reservoir sized to capture the available flows, on average, site has 10,000 ac-ft of available storage.
					Low	0	For a reservoir sized to capture the available flows, on average, site has less than 10,000 ac-ft of available storage.
ExchPotentialEnhancement	Enhancing exchange potential	The storage solution adds storage capacity for interim storage or "leap-frogging" exchanges, or could add streamflows that would increase exchange potential in the river.	Storage Solution	Qualitative	Yes	1	The storage solution would add interim storage or add streamflows to facilitate or increase exchange potential.
					No	0	The storage solution would not add interim storage and would not add streamflows to facilitate or increase exchange potential.
RecreationBenefit	Recreational benefits	The storage solution would increase recreational opportunities.	Storage Solution	Qualitative	Positive	1	Construction of this storage solution would increase recreational opportunities compared to pre-construction condition.
					Neutral	0	Construction of this storage solution would not change recreational opportunities compared to pre-construction condition.
					Negative	-1	Construction of this storage solution would decrease recreational opportunities compared to pre-construction condition.
EnhanceStreamflow	Improving instream flow	The storage solution could deliver water to downstream users via natural channels during dry periods, enhancing stream flow.	Storage Solution	Qualitative	High	1	Solution could deliver water to downstream users via South Platte River and natural channels during dry periods, thereby enhancing streamflows.
					Medium	0.5	Solution could deliver water to downstream users via South Platte River, thereby enhancing streamflows
					Low	0	Solution could not deliver water to downstream users via natural channels during dry periods, little to no opportunity for streamflow enhancement

Attribute Name	HB 1256 Connection	Attribute Definition	Applies To	Evaluation Type	Qualifier	Qualifier Score	Qualifier Definition
CompactCompliance	Improving water compact compliance	The storage solution could increase low flows at the state line and reduce frequency of compact calls. Note that the storage solution would not be operated to meet compact requirements, but return flows from additional supplies could increase flows at the stateline.	Storage Solution	Qualitative	Yes	1	Would decrease frequency of compact calls.
					No	0	Would not decrease frequency of compact calls.
IncreaseAgProduction	Increased agricultural production	The storage solution could capture water to meet the agricultural demand gap in the basin. It is estimated based on the average annual yield for the historical period.	Storage Solution	Quantitative	High	1	Project would provide water greater than the agricultural demand (gap) in its demand reach, and could supply agricultural water to other demand reaches.
					Medium	0.5	Project would provide water equal to or greater than the agricultural demand (gap) in its demand reach.
					Low	0	Project would provide less water than the projected agricultural demand (gap) in its demand reach.
ReduceBuyDry	Reducing reliance on the practice of buying agricultural water and drying up the agricultural land served by the water	The storage solution could yield additional supplies from in-basin sources, reducing the pressure to buy water rights and dry the land. This attribute captures the ability of the site to provide additional water to M&I demands.	Storage Solution	Quantitative	High	1	Annual average delivery to M&I users would be more than 50,000 acre-feet.
					Medium	0.5	Annual average delivery to M&I users would be between 10,000 and 50,000 acre-feet.
					Low	0	Annual average delivery to M&I users would be less than 10,000 acre-feet.
WildlifeHabitatImpact	Improving wildlife habitats	The storage site could impact wildlife habitats. The potential degree of impact is based on aerial imagery review.	Storage Site	Qualitative	Positive	1	Construction will positively impact wildlife habitat compared to pre-construction condition.
					Neutral	0	Construction will not change the wildlife habitat conditions at the site compared to pre-construction conditions.
					Negative	-1	Construction will negatively impact wildlife habitat at the site compared to pre-construction conditions.
CriticalHabitat_ESA	Enhancing compliance with endangered species habitat regulations	A Designated Critical Habitat (DCH) of a species would be present at the storage site. DCH is an area of habitat believed to be essential to a federal species. The attribute is based on a comparison of site(s) to the DCH as mapped by US Fish & Wildlife.	Storage Site	Qualitative	Yes	-1	The site would be located within Designated Critical Habitat.
					No	0	The site would be not located within Designated Critical Habitat.
NWI	not applicable	Wetlands would be present at the site, and is based on the National Wetlands Inventory (NWI) data set.	Storage Site	Qualitative	High	-1	There would be more than 100 acres of wetlands at the site.
					Medium	-0.5	There would be more than 10 acre but less than 100 acres of wetlands at the site.

Attribute Name	HB 1256 Connection	Attribute Definition	Applies To	Evaluation Type	Qualifier	Qualifier Score	Qualifier Definition
					Low	0	There would be less than 10 acre wetlands present at the site.
WildlifeSpeciesImpact	Enhancing compliance with endangered species habitat regulations.	The storage site could impact wildlife. The potential degree of impact is based on aerial imagery review, CO county lists, and USFWS IPaC Planning System's list of T&E species.	Storage Site	Qualitative	Positive	1	Construction will positively impact wildlife species compared to pre-construction condition.
					Neutral	0	Construction will not impact wildlife species at the site compared to pre-construction conditions.
					Negative	-1	Construction will negatively impact wildlife species at the site compared to pre-construction conditions.
EvapPotential	not applicable	The storage site could lose water to evaporation. It is assumed that surface water storage sites will have similar evaporation rates while aquifer storage sites will have minimal evaporation loss.	Storage Site	Qualitative	High	0	Surface water storage would have high potential for evaporation loss.
					Low	1	Aquifer storage would have low potential to evaporation loss.
SourceWaterQual	not applicable	The existing or source water supply would have parameters on 303(d) or M&E list.	Storage Site	Qualitative	Yes	0	Existing or source water for the project site has parameters on the 303(d) list.
					No	1	The state has not determined that the existing or source water quality does not meet standards.
					Unknown	0.5	Existing or source water for the project site has parameters on the M&E list.
DeliveryWaterQual	not applicable	The storage solution would deliver raw water at various quality levels. Water quality is based on whether advance treatment (Ultrafiltration or reverse osmosis) is needed to achieve primary and/or secondary drinking water standards.	Storage Solution	Qualitative	High	1	No advanced treatment would be needed after water is withdrawn to meet primary and/or secondary drinking water standards.
					Low	0	Advanced treatment would be needed after water is withdrawn to achieve primary and/or secondary drinking water standards.
Scalability	not applicable	The storage solution could be enlarged by constructing it in phases, triggered by need thresholds or change in future conditions. In general, large Infrastructure projects like dams are less scalable than pump stations. Typical of aquifer storage with facilities that can be enlarged by adding pumps or parallel pipelines.	Storage Site	Qualitative	High	1	Infrastructure could be added to the project that would increase the storage capacity or yield.
					Medium	0.5	There are alternatives for enlargement and yield increase, with potential high cost (e.g., engineering and retrofitting).
					Low	0	Options to enlarge the storage and yield of the project have not been identified.
FederalNexus	not applicable	A federal nexus exists if a project requires a federal permit or federal funding would be used for the project.	Storage Site	Qualitative	Yes	0	Would have a federal nexus.
					No	1	Would not have a federal nexus.
					Maybe	0.5	There is potential for a federal nexus.
PermittingFeasibility	not applicable	The potential permitting feasibility of site and solution.	Storage Solution	Qualitative	High	1	High probability that the storage solution could be permitted.
					Medium	0.5	Some risk have been identified, however the storage solution could reasonable be permitted.

Attribute Name	HB 1256 Connection	Attribute Definition	Applies To	Evaluation Type	Qualifier	Qualifier Score	Qualifier Definition
					Low	0	It is unlikely that the storage solution could be permitted effectively.
WaterRights	not applicable	Measure of the perceived ease in obtaining the water rights/decrees required to operate the storage solution.	Storage Solution	Qualitative	High	1	The water rights necessary to operate the storage solution would be fairly straight forward.
					Medium	0.5	There would be some complexity and perceived opposition to the project, but it would be possible to obtain water rights.
					Low	0	There would be a high degree of complexity and perceived opposition to this project, and there may be challenges to obtaining the water rights.
CombinedPermitting	not applicable	Captures the potential increase in permitting complexity (i.e., cost and time) for the solutions in cases that the permitting of the combined solution result in additional efforts.	Storage Solution	Qualitative	Same	1	The permitting of the solution would not be more complex than permitting the individual elements of the solution.
					More	0	Permitting complexity would increase when permitting the storage solution.
LandOwner	not applicable	Type of land ownership for the storage site. This is important to determine feasibility and cost. [Private, Public, etc.]	Storage Site	Qualitative	Private	1	The storage site would be located only in private land.
					Public	0.5	The storage site would be fully or partially located in public land.
					Historical	0	The storage site would be fully or partially located in a historic denominated site.
Partnerships_Consumptive	not applicable	For sites previously identified, this field captures if current site idea owners have expressed willingness to consider partnerships that will result in additional storage for the basin. For new sites, without idea owner, the default will be YES to partnerships.	Storage Site	Qualitative	Yes	1	Idea owners have expressed interest to consider partnerships that would result in additional storage for the basin.
					No	0	Idea owners have expressed no interest in partnerships.
					Unknown	0.5	There is no current information whether or not partnership opportunities would be considered for this site.
Partnerships_NonConsumptive	not applicable	Capture idea-owners interest in exploring partnerships to provide non-consumptive benefits.	Storage Site	Qualitative	Yes	1	Idea owners have expressed interest to consider partnerships that would result in benefits to non-consumptive uses.
					No	0	Idea owners have expressed no interest in partnerships for non-consumptive uses.
					Unknown	0.5	There is no current information for this site whether or not partnership opportunities would be considered for this site.
EstPermitTimeline	not applicable	The probability that permits would be secured quickly.	Storage Solution	Qualitative	High	1	Permitting would be less than five years.
					Medium	0.5	Permitting could be 5 years to 15 years.
					Low	0	Permitting could be longer than 15 years.

Attribute Name	HB 1256 Connection	Attribute Definition	Applies To	Evaluation Type	Qualifier	Qualifier Score	Qualifier Definition
MigratoryBirdImpact	not applicable	The potential degree of impact to migratory bird habitat based on aerial imagery review.	Storage Site	Qualitative	Positive	1	Construction of this water project will positively impact migratory bird habitat compared to pre-construction condition.
					Neutral	0	Construction of this water project will not change the migratory bird habitat conditions at the site.
					Negative	-1	Construction of this water project will negatively impact migratory bird habitat.
SPWRAPPotential	not applicable	If a Federal Nexus exists, does the new water related activity meet all project requirements of the PRRIP and is there potential for the benefit of streamlined permitting by inclusion in SPWRAP?	Storage Site	Qualitative	Yes	1	All PRRIP project requirements would be met and there is potential for streamlined permitting by inclusion in SPWRAP.
					No	0	PRRIP project requirements would not be met and there is no potential for streamlined permitting by inclusion in SPWRAP.
BaldEagleNestsImpacts	not applicable	Bald Eagle nest sites (active and inactive) are recorded (in the CPW dataset) near the site.	Storage Site	Qualitative	High	0	Colorado Parks and Wildlife has identified active Bald Eagle nest site(s) near proposed project site.
					Medium	0.5	Colorado Parks and Wildlife has identified destroyed, inactive, or roost area for Bald Eagle near the proposed project site.
					Low	1	No Bald Eagle nest sites have been identified within or adjacent to the proposed project site. On-site investigation required to confirm.
ExistingWaterQuality	not applicable	An existing storage site proposed for enlargement, rehabilitation, or restoration that has parameters on 303(d) or M&E list	Storage Site	Qualitative	Yes	0	Existing water for the project site has parameters on the 303(d) list.
					No	0	The state has not determined that the existing water quality does not meet standards.
					Unknown	0.5	Existing water for the project site has parameters on the M&E list.
					Not Applicable	0	Not an existing site.
SolutionCompatibility	not applicable	A storage site typically is able to meet demands in its proximity (demand segment), but could meet additional demands farther from the site if incorporated into a conveyance or exchange water supply solution.	Storage Site	Qualitative	Yes	1	The site could be incorporated into one or more water supply solutions to meet additional demands outside the site's demand segment.
					No	0	The site could not be incorporated into a solution to meet additional demands outside the site's demand segment.
CombinedImpact	not applicable	Captures the potential increase in environmental impacts for the solutions in cases that require construction of pipelines and other infrastructure not within the site footprint.	Storage Solution	Qualitative	Same	1	The concepts involved in the solution do not add additional environmental impacts outside of individual site footprints.
					More	0	The concepts involved in the solution add additional environmental impacts outside of the footprints of the individual sites.

Attribute Name	HB 1256 Connection	Attribute Definition	Applies To	Evaluation Type	Qualifier	Qualifier Score	Qualifier Definition
SoilType	not applicable	Is the soil type within 1 mile of the site compatible with the desired use (i.e. Hydrologic Soil Group A for aquifer storage or Hydrologic Soil Group B, C, or D for surface water storage)	Storage Site	Qualitative	Yes	1	All soil within 1 mile of the site is classified as Hydrologic Soil Group A for Aquifer storage or B, C, or D for surface storage.
					No	0	Within 1 mile of the site, there is an occurrence of soil type that is not compatible with the desired use.
SiteFillMethod	not applicable	Can the storage site be filled by gravity or will pumping be required?	Storage Site	Qualitative	Pumping	0	It is not possible to fill this site by gravity using existing facilities. Pumping is required or construction of new facilities is required.
					Gravity Fill	1	It is possible to fill this site solely by the use of gravity through existing facilities. No pumping would be required.
Constructability	not applicable	Captures engineering feasibility/constructability.	Storage Site	Qualitative	High	1	No documented engineering constructability issues or complications.
					Low	0	Potential for engineering constructability issues or complications have been documented.
RegionalIntegration	not applicable	Opportunities may exist to operate the site cooperatively with nearby sites, either new or existing.	Storage Site	Qualitative	Yes	1	There is potential to operate this site in cooperation with nearby sites.
					No	0	There is no opportunity to coordinate with nearby sites or no other sites are near enough for cooperation.
RiverReach	not applicable	Which river reach is the solution predominantly in?	Storage Solution	Qualitative	Denver-Kersey	0	The solution is predominantly in the reach between South Platte at Denver and South Platte at Kersey gages.
					Kersey-Balzac	0	The solution is predominantly in the reach between South Platte at Kersey and South Platte near Balzac gages.
					Balzac-Julesburg	0	The solution is predominantly in the reach between South Platte near Balzac and South Platte at Julesburg gages.
MeetDemands	not applicable	Describes the ability of a solution to meet demands, either upstream or downstream	Storage Solution	Qualitative	Within	0	The solution is able to meet demands within its own reach.
					US or DS	0.5	The solution is able to meet demands in upstream reaches or downstream reaches.
					US and DS	1	The solution is able to meet demands in both upstream and downstream reaches.
					None	-1	The solution is not able to meet demands in any reach.
OilAndGasWells	not applicable		Storage Site	Qualitative	None	1	No oil and gas wells were identified at or near the site location

Attribute Name	HB 1256 Connection	Attribute Definition	Applies To	Evaluation Type	Qualifier	Qualifier Score	Qualifier Definition
		Indicates presence of oil and gas wells at or near the site location upon inspection of satellite imagery			Low	0.5	Few oil and gas wells were identified at or near the site location
					High	0	Many oil and gas wells were identified at or near the site location
UseExistInfrastructure	not applicable	Does infrastructure exist that can be used to fill the storage site?	Storage Site	Qualitative	Yes	1	Infrastructure exists that could be used to fill the storage site
					No	0	Infrastructure does not exist that could be used to fill the storage site
EaseToUseExisting	not applicable	If infrastructure exists, how easy will it be to utilize in order to fill the storage site?	Storage Site	Qualitative	Easy	1	Existing infrastructure could be used as-is or with minor modifications.
					Medium	0.5	Some modifications would be necessary in order to use the existing infrastructure
					Difficult	0	Major modifications would be necessary in order to use the existing infrastructure
					N/A	0	Infrastructure does not exist.

APPENDIX D

SITE EVALUATION FRAMEWORK ENTRIES



Sites Evaluation

Site ID:

Badger/Beaver Creek

Category:

IPP Gravel Lake

Site Score (Equal Weighting):

Site Screened Out

FEATURES

Existing Capacity: ac-ft

New Capacity ac-ft

Total Capacity ac-ft

Inundated Area: acres

Evaporation Potential:

Soil Type

Fill Method:

Land Owner

Reservoir Owner:

Consumptive Partnerships:

Non-Consumptive Partnerships:

Regional Integration:

Existing Water Quality:

Source Water Quality:

Constructability:

Scalability:

Use Existing Infrastructure:

Ease To Use Existing Infrastructure:

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank:

Migratory Bird Habitat

Solution Compatibility:

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes:

Site ID: 519

Beaver Creek Reservoir

Category: New Site

IPP Gravel Lake

Site Score (Equal Weighting):

8.5

Site Screened Out

FEATURES

Existing Capacity: 0 ac-ft

New Capacity: 95,000 ac-ft

Total Capacity: 95,000 ac-ft

Inundated Area: acres

Evaporation Potential: High

Soil Type: No

Fill Method: Pumping

Land Owner: Private

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: No

Ease To Use Existing Infrastructure: N/A

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$) 0

Cost Estimate Year 0

BENEFITS (Site- Level)

Flood Control Rank: Medium

Migratory Bird Habitat: Yes

Solution Compatibility: Yes

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes:

Site ID: 517

Fremont Butte

Category: New Site

IPP

Gravel Lake

Site Score (Equal Weighting):

6.5

Site Screened Out

FEATURES

Existing Capacity: 0 ac-ft

New Capacity: 76,000 ac-ft

Total Capacity: 76,000 ac-ft

Inundated Area: acres

Evaporation Potential: High

Soil Type: No

Fill Method: Pumping

Land Owner: Private

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: No

Ease To Use Existing Infrastructure: N/A

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank: Medium

Migratory Bird Habitat: Yes

Solution Compatibility: Yes

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes:

Site ID: 263

Greasewood Reservoir

Category: New Site

IPP

Gravel Lake

Site Score (Equal Weighting):

6.5

Site Screened Out Second Screening- Eliminated in favor of Point of Rocks/ Sandborn. Too far fro

FEATURES

Existing Capacity: 0 ac-ft

New Capacity: 67,268 ac-ft

Total Capacity: 67,268 ac-ft

Inundated Area: acres

Evaporation Potential: High

Soil Type: No

Fill Method: Pumping

Land Owner: Private

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: No

Ease To Use Existing Infrastructure: N/A

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank: Medium

Migratory Bird Habitat: Yes

Solution Compatibility: Yes

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes:

Site ID:

Hardin Reservoir

Category:

IPP Gravel Lake

Site Score (Equal Weighting):

Site Screened Out

FEATURES

Existing Capacity: ac-ft

New Capacity ac-ft

Total Capacity ac-ft

Inundated Area: acres

Evaporation Potential:

Soil Type

Fill Method:

Land Owner

Reservoir Owner:

Consumptive Partnerships:

Non-Consumptive Partnerships:

Regional Integration:

Existing Water Quality:

Source Water Quality:

Constructability:

Scalability:

Use Existing Infrastructure:

Ease To Use Existing Infrastructure:

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank:

Migratory Bird Habitat

Solution Compatibility:

ENVIRONMENTAL

National Wetlands Inventory: High

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Negative

Wildlife Habitat Impact: Negative

Migratory Bird Impact: Negative

Bald Eagle Nests Impact: High

Presence of Oil and Gas Wells: High

PERMITTING

Federal Nexus: Yes

SPWRAP Potential: No

Notes: See (Dames & Moore, 1982). Difference in capacity due to with and without a flood control pool of 200,000 ac-ft. Cost estimate based on smaller reservoir size. Larger size = \$298,000. For soils- 1.5 mile buffer used. NWI: 338 acres (PEM, PFO, and PSS).

Site ID:

Jackson Lake Reservoir

Category:

IPP Gravel Lake

Site Score (Equal Weighting):

Site Screened Out

FEATURES

Existing Capacity: ac-ft

New Capacity ac-ft

Total Capacity ac-ft

Inundated Area: acres

Evaporation Potential:

Soil Type

Fill Method:

Land Owner

Reservoir Owner:

Consumptive Partnerships:

Non-Consumptive Partnerships:

Regional Integration:

Existing Water Quality:

Source Water Quality:

Constructability:

Scalability:

Use Existing Infrastructure:

Ease To Use Existing Infrastructure:

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank:

Migratory Bird Habitat

Solution Compatibility:

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes:

Site ID: 188

Johnson Reservoir

Category: New Site

IPP

Gravel Lake

Site Score (Equal Weighting):

7

Site Screened Out

FEATURES

Existing Capacity: 0 ac-ft

New Capacity: 10,600 ac-ft

Total Capacity: 10,600 ac-ft

Inundated Area: acres

Evaporation Potential: High

Soil Type: No

Fill Method: Gravity Fill

Land Owner: Public

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: Yes

Ease To Use Existing Infrastructure: Medium

COST (Site- Level)

Storage Unit Cost (\$/ac-ft): 1,120

Total Storage Cost (\$) 11,820,000

Cost Estimate Year 2001

BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat: Yes

Solution Compatibility: No

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes:

Site ID:

Julesburg Reservoir (Enlargement)

Category:

IPP Gravel Lake

Site Score (Equal Weighting):

Site Screened Out

FEATURES

Existing Capacity: ac-ft

New Capacity ac-ft

Total Capacity ac-ft

Inundated Area: acres

Evaporation Potential:

Soil Type

Fill Method:

Land Owner

Reservoir Owner:

Consumptive Partnerships:

Non-Consumptive Partnerships:

Regional Integration:

Existing Water Quality:

Source Water Quality:

Constructability:

Scalability:

Use Existing Infrastructure:

Ease To Use Existing Infrastructure:

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank:

Migratory Bird Habitat

Solution Compatibility:

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes:

Site ID:

Julesburg Reservoir (Rehabilitation)

Category:

IPP Gravel Lake

Site Score (Equal Weighting):

Site Screened Out

FEATURES

Existing Capacity: ac-ft

New Capacity ac-ft

Total Capacity ac-ft

Inundated Area: acres

Evaporation Potential:

Soil Type

Fill Method:

Land Owner

Reservoir Owner:

Consumptive Partnerships:

Non-Consumptive Partnerships:

Regional Integration:

Existing Water Quality:

Source Water Quality:

Constructability:

Scalability:

Use Existing Infrastructure:

Ease To Use Existing Infrastructure:

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank:

Migratory Bird Habitat

Solution Compatibility:

ENVIRONMENTAL

National Wetlands Inventory: High

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Neutral

Wildlife Habitat Impact: Neutral

Migratory Bird Impact: Neutral

Bald Eagle Nests Impact: Low

Presence of Oil and Gas Wells: None

PERMITTING

Federal Nexus: Yes

SPWRAP Potential: Yes

Notes: For soils- 1.5 mile buffer used. 343 acres- nwi.

Site ID: 162

Lower Bijou Creek

Category: Aquifer Storage

IPP Gravel Lake

Site Score (Equal Weighting):

10.5

Site Screened Out Second Screening- Dropped in favor of Upper/Lower Lost Creek and Badger/Be

FEATURES

Existing Capacity: 0 ac-ft

New Capacity 1,067,000 ac-ft

Total Capacity 1,067,000 ac-ft

Inundated Area: 0 acres

Evaporation Potential: Low

Soil Type Yes

Fill Method: Gravity Fill

Land Owner Public

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Unknown

Source Water Quality: Unknown

Constructability: High

Scalability: Medium

Use Existing Infrastructure: No

Ease To Use Existing Infrastructure: N/A

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat No

Solution Compatibility: Yes

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes:

Site ID: 141

Lower Kiowa Creek

Category: Aquifer Storage

IPP

Gravel Lake

Site Score (Equal Weighting):

10

Site Screened Out Second Screening- Dropped in favor of Upper/Lower Lost Creek and Badger/Be

FEATURES

Existing Capacity: 0 ac-ft

New Capacity 806,000 ac-ft

Total Capacity 806,000 ac-ft

Inundated Area: 0 acres

Evaporation Potential: Low

Soil Type Yes

Fill Method: Gravity Fill

Land Owner Public

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Yes

Source Water Quality: Yes

Constructability: High

Scalability: Medium

Use Existing Infrastructure: No

Ease To Use Existing Infrastructure: N/A

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat No

Solution Compatibility: Yes

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes: New Capacity = Total volume 4,032,145 x Porosity 0.2. Unclear - site buffer crosses COSPLS02b which has parameters on 303(d) list. Need to confirm if water from this segment is being used as existing/source water. Federal nexus - depends on details.

Site ID: 139

Lower Lost Creek

Category:

IPP Gravel Lake

Site Score (Equal Weighting):

Site Screened Out

FEATURES

Existing Capacity: ac-ft

New Capacity ac-ft

Total Capacity ac-ft

Inundated Area: acres

Evaporation Potential:

Soil Type

Fill Method:

Land Owner

Reservoir Owner:

Consumptive Partnerships:

Non-Consumptive Partnerships:

Regional Integration:

Existing Water Quality:

Source Water Quality:

Constructability:

Scalability:

Use Existing Infrastructure:

Ease To Use Existing Infrastructure:

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank:

Migratory Bird Habitat

Solution Compatibility:

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes:

Site ID: 111

McCarthy Reservoir

Category: New Site

IPP

Gravel Lake

Site Score (Equal Weighting):

5.5

Site Screened Out

FEATURES

Existing Capacity: ac-ft

New Capacity: 10,000 ac-ft

Total Capacity: ac-ft

Inundated Area: acres

Evaporation Potential: High

Soil Type: No

Fill Method: Pumping

Land Owner: Public

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: No

Ease To Use Existing Infrastructure: N/A

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat: Yes

Solution Compatibility: Yes

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes:

Site ID: 193

North Sterling Regulating Reservoir

Category: New Site

IPP

Gravel Lake

Site Score (Equal Weighting):

7

Site Screened Out

FEATURES

Existing Capacity: 0 ac-ft

New Capacity: 7,600 ac-ft

Total Capacity: 7,600 ac-ft

Inundated Area: acres

Evaporation Potential: High

Soil Type: No

Fill Method: Gravity Fill

Land Owner: Private

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: Yes

Ease To Use Existing Infrastructure: Difficult

COST (Site- Level)

Storage Unit Cost (\$/ac-ft): 2,610

Total Storage Cost (\$) 19,800,000

Cost Estimate Year 2001

BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat: Yes

Solution Compatibility: No

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes:

Site ID:

North Sterling Reservoir

Category:

IPP Gravel Lake

Site Score (Equal Weighting):

Site Screened Out

FEATURES

Existing Capacity: ac-ft

New Capacity ac-ft

Total Capacity ac-ft

Inundated Area: acres

Evaporation Potential:

Soil Type

Fill Method:

Land Owner

Reservoir Owner:

Consumptive Partnerships:

Non-Consumptive Partnerships:

Regional Integration:

Existing Water Quality:

Source Water Quality:

Constructability:

Scalability:

Use Existing Infrastructure:

Ease To Use Existing Infrastructure:

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank:

Migratory Bird Habitat

Solution Compatibility:

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes: Based on raising dam 4ft (State sometimes refers to this site as Point of Rocks. Not the same as SiteID 17. Land owner from GIS shapefile. For soils- 1.5 mile buffer used. Fill method, existing capacity (estimated) from CPW flier. Existing surface area 2,880 acres from CPW flier

Site ID: 186

Ovid Reservoir

Category: New Site

IPP

Gravel Lake

Site Score (Equal Weighting):

6.5

Site Screened Out

FEATURES

Existing Capacity: 0 ac-ft

New Capacity: 7,700 ac-ft

Total Capacity: 7,700 ac-ft

Inundated Area: 286 acres

Evaporation Potential: High

Soil Type: No

Fill Method: Gravity Fill

Land Owner: Private

Reservoir Owner: District 64 Reservoir Company

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: Yes

Ease To Use Existing Infrastructure: Medium

COST (Site- Level)

Storage Unit Cost (\$/ac-ft): 1,640

Total Storage Cost (\$) 12,600,000

Cost Estimate Year 2003

BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat: Yes

Solution Compatibility: No

ENVIRONMENTAL

National Wetlands Inventory: High

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Negative

Wildlife Habitat Impact: Negative

Migratory Bird Impact: Negative

Bald Eagle Nests Impact: Low

Presence of Oil and Gas Wells: None

PERMITTING

Federal Nexus: Yes

SPWRAP Potential: Yes

Notes: NWI = 776 acres. COSPL201 crosses site and is on 303d list. Need to confirm existing/source water.

Site ID: 200

Pawnee Pass Dam

Category: New Site

IPP

Gravel Lake

Site Score (Equal Weighting):

7

Site Screened Out

FEATURES

Existing Capacity: 0 ac-ft

New Capacity: 65,000 ac-ft

Total Capacity: 65,000 ac-ft

Inundated Area: 8,100 acres

Evaporation Potential: High

Soil Type: No

Fill Method: Pumping

Land Owner: Private

Reservoir Owner: Logan County Water Conservancy District

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: Yes

Ease To Use Existing Infrastructure: Difficult

COST (Site- Level)

Storage Unit Cost (\$/ac-ft): 913

Total Storage Cost (\$) 91,366,000

Cost Estimate Year 2010

BENEFITS (Site- Level)

Flood Control Rank: Medium

Migratory Bird Habitat: Yes

Solution Compatibility: Yes

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes:

Site ID:

Point of Rocks Reservoir

Category:

IPP Gravel Lake

Site Score (Equal Weighting):

Site Screened Out

FEATURES

Existing Capacity: ac-ft

New Capacity ac-ft

Total Capacity ac-ft

Inundated Area: acres

Evaporation Potential:

Soil Type

Fill Method:

Land Owner

Reservoir Owner:

Consumptive Partnerships:

Non-Consumptive Partnerships:

Regional Integration:

Existing Water Quality:

Source Water Quality:

Constructability:

Scalability:

Use Existing Infrastructure:

Ease To Use Existing Infrastructure:

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank:

Migratory Bird Habitat

Solution Compatibility:

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes:

For soils- site location may not be exact, 1.5 mile buffer used. There still could be a federal trigger depending on project details. Could be filled with extention of Greeley No 2 Canal

Site ID:

Prewitt Reservoir

Category:

IPP Gravel Lake

Site Score (Equal Weighting):

Site Screened Out

FEATURES

Existing Capacity: ac-ft

New Capacity ac-ft

Total Capacity ac-ft

Inundated Area: acres

Evaporation Potential:

Soil Type

Fill Method:

Land Owner

Reservoir Owner:

Consumptive Partnerships:

Non-Consumptive Partnerships:

Regional Integration:

Existing Water Quality:

Source Water Quality:

Constructability:

Scalability:

Use Existing Infrastructure:

Ease To Use Existing Infrastructure:

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank:

Migratory Bird Habitat

Solution Compatibility:

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes:

Site ID:

Riverside Reservoir

Category:

IPP Gravel Lake

Site Score (Equal Weighting):

Site Screened Out

FEATURES

Existing Capacity: ac-ft

New Capacity ac-ft

Total Capacity ac-ft

Inundated Area: acres

Evaporation Potential:

Soil Type

Fill Method:

Land Owner

Reservoir Owner:

Consumptive Partnerships:

Non-Consumptive Partnerships:

Regional Integration:

Existing Water Quality:

Source Water Quality:

Constructability:

Scalability:

Use Existing Infrastructure:

Ease To Use Existing Infrastructure:

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank:

Migratory Bird Habitat

Solution Compatibility:

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes:

Site ID: 16

Sandborn Reservoir

Category: New Site

IPP

Gravel Lake

Site Score (Equal Weighting):

7

Site Screened Out

FEATURES

Existing Capacity: 0 ac-ft

New Capacity: 224,000 ac-ft

Total Capacity: 224,000 ac-ft

Inundated Area: acres

Evaporation Potential: High

Soil Type: No

Fill Method: Gravity Fill

Land Owner: Public

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: Yes

Ease To Use Existing Infrastructure: Difficult

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat: Yes

Solution Compatibility: Yes

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes: Land owner from GIS shapefile. For soils- site location may not be exact, 1.5 mile buffer used. Kept as "best fit" between Greasewood and Point of Rocks. Could be filled with extension of Greeley No 2 Canal

Site ID:

South Platte (Narrows) Reservoir

Category:

IPP

Gravel Lake

Site Score (Equal Weighting):

Site Screened Out

FEATURES

Existing Capacity: ac-ft

New Capacity ac-ft

Total Capacity ac-ft

Inundated Area: acres

Evaporation Potential:

Soil Type

Fill Method:

Land Owner

Reservoir Owner:

Consumptive Partnerships:

Non-Consumptive Partnerships:

Regional Integration:

Existing Water Quality:

Source Water Quality:

Constructability:

Scalability:

Use Existing Infrastructure:

Ease To Use Existing Infrastructure:

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank:

Migratory Bird Habitat

Solution Compatibility:

ENVIRONMENTAL

National Wetlands Inventory: High

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Negative

Wildlife Habitat Impact: Negative

Migratory Bird Impact: Negative

Bald Eagle Nests Impact: Low

Presence of Oil and Gas Wells: None

PERMITTING

Federal Nexus: Yes

SPWRAP Potential: No

Notes: Check on owner- may be USBR. Will provide recreatio benefit, instream flow benefit. Annual O&M and replacement cost = \$1.4M (1980 dollars). For soils- 1.5 mile buffer used. 285 acres= NWI. COSPLS01 is on 303d list - need to confirm existing/source water. Chosen as "best fit" for Hardin.

Site ID: 271

Sunken Lake Reservoir

Category: New Site

IPP

Gravel Lake

Site Score (Equal Weighting):

6.5

Site Screened Out Second Screening- Storage barely over 5,000 ac-ft cutoff

FEATURES

Existing Capacity: 0 ac-ft

New Capacity 5,093 ac-ft

Total Capacity 5,093 ac-ft

Inundated Area: acres

Evaporation Potential: High

Soil Type Yes

Fill Method: Pumping

Land Owner Private

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: No

Ease To Use Existing Infrastructure: N/A

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat Yes

Solution Compatibility: Yes

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes:

Site ID: 196

Troelstrup

Category: New Site

IPP

Gravel Lake

Site Score (Equal Weighting):

6.5

Site Screened Out

FEATURES

Existing Capacity: 0 ac-ft

New Capacity: 5,000 ac-ft

Total Capacity: 5,000 ac-ft

Inundated Area: acres

Evaporation Potential: High

Soil Type: No

Fill Method: Gravity Fill

Land Owner: Private

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: Yes

Ease To Use Existing Infrastructure: Medium

COST (Site- Level)

Storage Unit Cost (\$/ac-ft): 1,730

Total Storage Cost (\$) 8,640,000

Cost Estimate Year 2001

BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat: Yes

Solution Compatibility: No

ENVIRONMENTAL

National Wetlands Inventory: High

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Negative

Wildlife Habitat Impact: Negative

Migratory Bird Impact: Negative

Bald Eagle Nests Impact: Low

Presence of Oil and Gas Wells: None

PERMITTING

Federal Nexus: Yes

SPWRAP Potential: Yes

Notes:

For soils- site location may not be exact, 1.5 mile buffer used. NWI = 561 acres. COSPLS01 is crossed by site and is on 303d list - need to confirm existing/source water.

Site ID: 161

Upper Bijou Creek

Category:

IPP

Gravel Lake

Site Score (Equal Weighting):

Site Screened Out

FEATURES

Existing Capacity: ac-ft

New Capacity ac-ft

Total Capacity ac-ft

Inundated Area: acres

Evaporation Potential:

Soil Type

Fill Method:

Land Owner

Reservoir Owner:

Consumptive Partnerships:

Non-Consumptive Partnerships:

Regional Integration:

Existing Water Quality:

Source Water Quality:

Constructability:

Scalability:

Use Existing Infrastructure:

Ease To Use Existing Infrastructure:

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank:

Migratory Bird Habitat

Solution Compatibility:

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes:

Site ID: 160

Upper Kiowa Creek

Category:

IPP Gravel Lake

Site Score (Equal Weighting):

Site Screened Out

FEATURES

Existing Capacity: ac-ft

New Capacity ac-ft

Total Capacity ac-ft

Inundated Area: acres

Evaporation Potential:

Soil Type

Fill Method:

Land Owner

Reservoir Owner:

Consumptive Partnerships:

Non-Consumptive Partnerships:

Regional Integration:

Existing Water Quality:

Source Water Quality:

Constructability:

Scalability:

Use Existing Infrastructure:

Ease To Use Existing Infrastructure:

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank:

Migratory Bird Habitat

Solution Compatibility:

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes:

Site ID: 140

Upper Lost Creek

Category: Aquifer Storage

IPP

Gravel Lake

Site Score (Equal Weighting):

10

Site Screened Out

FEATURES

Existing Capacity: 0 ac-ft

New Capacity: 1,260,000 ac-ft

Total Capacity: 1,260,000 ac-ft

Inundated Area: 0 acres

Evaporation Potential: Low

Soil Type: Yes

Fill Method: Gravity Fill

Land Owner: Public

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: No

Existing Water Quality: Not Applicable

Source Water Quality: No

Constructability: High

Scalability: Medium

Use Existing Infrastructure: No

Ease To Use Existing Infrastructure: N/A

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat: No

Solution Compatibility: Yes

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes: New Capacity = Total volume 6,298,259 x Porosity 0.2. Federal nexus - depends on project details. Keep this site- ranked favorably on CGS evaluation. Avoids conflicts with other infrastructure and recovery of stored water.

Site ID: 272

West Nile Reservoir

Category: New Site

IPP Gravel Lake

Site Score (Equal Weighting):

5.5

Site Screened Out

FEATURES

Existing Capacity: 0 ac-ft

New Capacity: 26,950 ac-ft

Total Capacity: 26,950 ac-ft

Inundated Area: acres

Evaporation Potential: High

Soil Type: No

Fill Method: Pumping

Land Owner: Public

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: No

Ease To Use Existing Infrastructure: N/A

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat: Yes

Solution Compatibility: Yes

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes:

Site ID:

Wildcat Reservoir

Category:

IPP Gravel Lake

Site Score (Equal Weighting):

Site Screened Out

FEATURES

Existing Capacity: ac-ft

New Capacity ac-ft

Total Capacity ac-ft

Inundated Area: acres

Evaporation Potential:

Soil Type

Fill Method:

Land Owner

Reservoir Owner:

Consumptive Partnerships:

Non-Consumptive Partnerships:

Regional Integration:

Existing Water Quality:

Source Water Quality:

Constructability:

Scalability:

Use Existing Infrastructure:

Ease To Use Existing Infrastructure:

COST (Site- Level)

Storage Unit Cost (\$/ac-ft):

Total Storage Cost (\$)

Cost Estimate Year

BENEFITS (Site- Level)

Flood Control Rank:

Migratory Bird Habitat

Solution Compatibility:

ENVIRONMENTAL

National Wetlands Inventory:

Critical Habitat in Environmentally Sensitive Areas:

Wildlife Species Impact:

Wildlife Habitat Impact:

Migratory Bird Impact:

Bald Eagle Nests Impact:

Presence of Oil and Gas Wells:

PERMITTING

Federal Nexus:

SPWRAP Potential:

Notes:

APPENDIX E

AQUIFER STORAGE AND RECOVERY COST ESTIMATES

SPSS Draft Memorandum

To: Chip Paulson, Stantec
From: Leonard Rice Engineers, Inc.
Date: November 20, 2017
Project: South Platte Storage Study
Subject: **DRAFT Task 4.5: Aquifer Storage and Recovery Cost Estimates**

This memorandum presents the Aquifer Storage and Recovery (ASR) cost estimates developed for the South Platte Storage Study (SPSS). These are Class 5 capital cost estimates based on simplifying assumptions that allow them to be linearly scaled for desired rates of recharge or recovery. In order to provide representative cost comparisons, the recharge and recovery rates shown are defined by the water delivery and demand scenarios being considered for surface water sites. Realistically, these rates of recharge and recovery will be limited at specific ASR sites because of local hydrogeologic conditions. The general cost estimates presented can be adapted to ASR sites considered in the SPSS based on their site specific hydrogeologic characteristics.

ASR Site Conceptual Design

We developed a conceptual design for an infiltration basin ASR site in an alluvial aquifer setting. The conceptual alluvial ASR site has the following components:

- Recharge basins
- Recovery wells
- Well instrumentation and controls (I&C)
- Yard piping for distribution of water on site
- Piping and power connections
- Supervisory Control and Data Acquisition (SCADA) Systems
- Well house or vault structures

The conceptual alluvial ASR site does not include electrical grid upgrades, transmission piping or pumping facilities for transporting water to and from the site.

Recharge Basins

The conceptual recharge basins are designed to have a 20 acre bottom area for infiltration. We estimated excavation depth to be 10 feet deep to allow for the removal of any low permeability soil overburden. It is assumed that no clearing/grubbing, hauling, backfill or compaction will be necessary. The conceptual recharge basins have 3:1 side slopes, with 4:1 end slopes that can accommodate heavy equipment entering and exiting the basins for construction and maintenance. The 20 acre basin bottom areas are designed to be 2,000 feet long by 436 feet wide. The top area will be 2,080 feet long by 496 feet wide. Each basin will require the excavation of approximately 350,000 cubic yards of material. Recharge basins will receive water through inlet piping at various locations along the basin bottom.

The recharge basins are designed to have one to two feet of water depth. We selected a conceptual infiltration rate of one foot per day for recharge calculations, which results in a recharge rate of 20 acre feet (ac-ft) per day, per basin.

Figure 1 shows a plan and profile drawing of a conceptual alluvial ASR recharge basin.

Recovery Facilities

Once water is stored at an alluvial ASR site, it will be recovered through a well field located at the same site, or at some separate, downgradient recovery facility. The recovery facility location will be dependent on site specific hydrogeology.

For general costing purposes, the recovery wells are conceptually designed as 150 foot deep, 12-inch diameter wells capable of pumping 500 gallons per minute (GPM) against 200 feet of total dynamic head (TDH). The wells will include a variable frequency drive with water level, pressure, and pumping rate monitoring. The recovery wells will be operated through a SCADA system. Well controls, valving, and associated appurtenances will be protected in well vaults or buildings.

Cost Estimate Approach

Preliminary capital cost estimates are based on SPSS maximum delivery and demand scenarios. It is unlikely that these scenarios represent reasonable rates of alluvial aquifer recharge and recovery for one alluvial ASR site, but they are being used to provide a similar cost comparison to surface water storage options.

Maximum Delivery Scenario

We assumed that monthly inflow of water for storage at an ASR site would be 5,000 acre-feet (AFM). There are several construction and operational assumptions related to this maximum delivery amount:

- We are assuming that there is 10,000 ac-ft of “regulating storage” (e.g. gravel pits) that can temporarily store water and deliver it to an ASR storage site at a lower rate, and/or for a longer period of time.
- Recharging the maximum amount of 5,000 ac-ft for one month will define the infiltration area required. We are assuming that the maximum delivery amount will only occur for a portion of the year. This will allow for portions of the recharge facility to remain inactive the majority of the time. Frequent drying/maintenance of basins will be necessary to maintain infiltration capacity.
- We are assuming that land availability and hydrogeologic conditions will not constrain site construction or operations. This is unlikely and specific alluvial ASR recharge sites will require additional evaluation to refine the maximum inflow/recharge rate they can accept.

Given the alluvial ASR conceptual design characteristics detailed above, this maximum delivery rate will require 165 acres of recharge area and a total of 8 recharge basins.

Demand Scenario

The stored water demand is assumed to be 4,000 AFM. This will define the rate of water recovery/outflow and the scale of associated ASR components, mainly the number of wells.

As with recharge water delivery, the maximum demand scenario is based on simplifying assumptions that are unlikely to be applicable at all alluvial ASR sites being considered. The most important consideration is that we are assuming land availability and hydrogeologic conditions will not constrain the construction and operation of a recovery facility.

The conceptual alluvial ASR facilities described above would require 60 wells to recover water out of aquifer storage at the 4,000 AFM demand rate.

Cost Estimate Results

Capital costs were estimated for the components of a conceptual alluvial ASR site based on information from construction contractors, previous projects, and published data. The estimated costs are presented in **Table 1**. The costs presented are only for onsite equipment and construction. Costs are not considered for electrical grid upgrades or transmission of water to and from the site. There is no contingency included, but the unit prices are presented as ranges to reflect uncertainty in cost estimates. The median cost estimate was used for calculating the total price.

Costs for construction, engineering, and permitting were estimated as a percentage of other component costs.

Figure 2 shows the estimated costs for conceptual ASR site components as a percentage of the total price. The majority of costs come from recharge cell excavation, and there will be ways to minimize these costs. For example, excavated material can be placed next to the basins to act as a berm.

The conceptual alluvial ASR site cost estimates are based on the maximum delivery and demand scenarios discussed above. However they are configured to be linearly scalable based on the amount of water delivery or demand. This cost estimate configuration will enable scaling for specific alluvial ASR sites that may have different recharge and recovery capacities.

Limitations

These Class 5 capital cost estimates are intended for preliminary planning and have order of magnitude confidence intervals. The generalization for each of the conceptual ASR site components contributes to additional cost uncertainty when applied to specific sites. They should only be used for evaluation of alluvial ASR sites being considered in the SPSS.

Table 1 – Alluvial ASR Site Level 5 Cost Estimate

Item	Description	Unit	Unit price	Quantity	Total Price (Median Basis)	Notes
1	Recharge Cell Excavation	Cubic Yards	\$2 - \$15	2,909,091	\$24,727,273	Assumes 20 acre basins with approximately 352,000 cubic yards of excavation per cell. Assumes no material hauling, backfill/compaction, or clearing/grubbing necessary.
2	Recovery Wells	Well	\$60,000 - \$150,000	60	\$6,279,267	Includes 150 foot deep wells (12-inch diameter, stainless steel), pump/motor capable of 500 GPM @200 feet of TDH, discharge piping, downhole power.
3	Well I&C, yard piping, manifold & power connections, SCADA, well house	Well	\$60,000 - \$100,000	60	\$4,784,204	Assume VFD with level, pressure, and pumping rate monitoring, 200 feet of yard piping, connection to existing on site power.
4	Recharge Cell Infrastructure	Cell	\$20,000 - \$50,000	8	\$289,256	Slope stabilization, inflow distribution/piping
5	Construction	Lump Sum			\$1,014,692	%20 of subtotal from items 3-4
6	Engineering and Construction Support	Lump Sum			\$1,136,000	%10 of subtotal from items 2-4
7	Permitting	Lump Sum			\$1,136,000	%10 of subtotal from items 2-4
8	Land Acquisition	Acre	\$1,000 - \$1,500	248	\$309,917	Assuming recharge area plus 50% increase for facility size. Based on 2015 price of non-irrigated land (no water rights purchase).
Grand Total:					\$39,366,692	
Recharge Rate (AFM):					5,000	
Recovery Rate (AFM):					4,000	

Notes

No contingency included. AFM - acre feet per month
 GPM - gallons per minute VFD - variable frequency drive
 TDH - total dynamic head SCADA - supervisory control and data acquisition

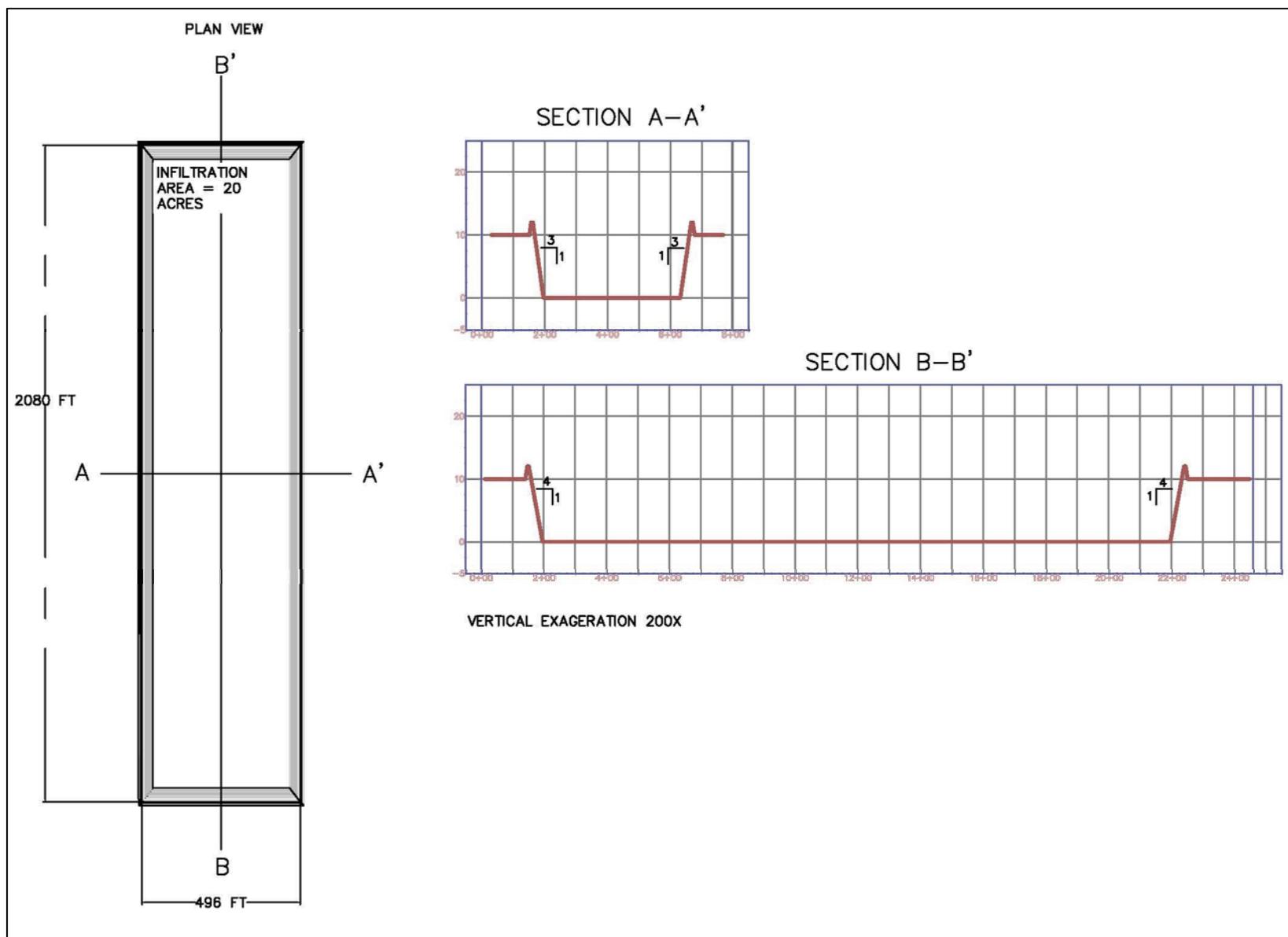


Figure 1 - Conceptual Alluvial ASR Recharge Basin Dimensions

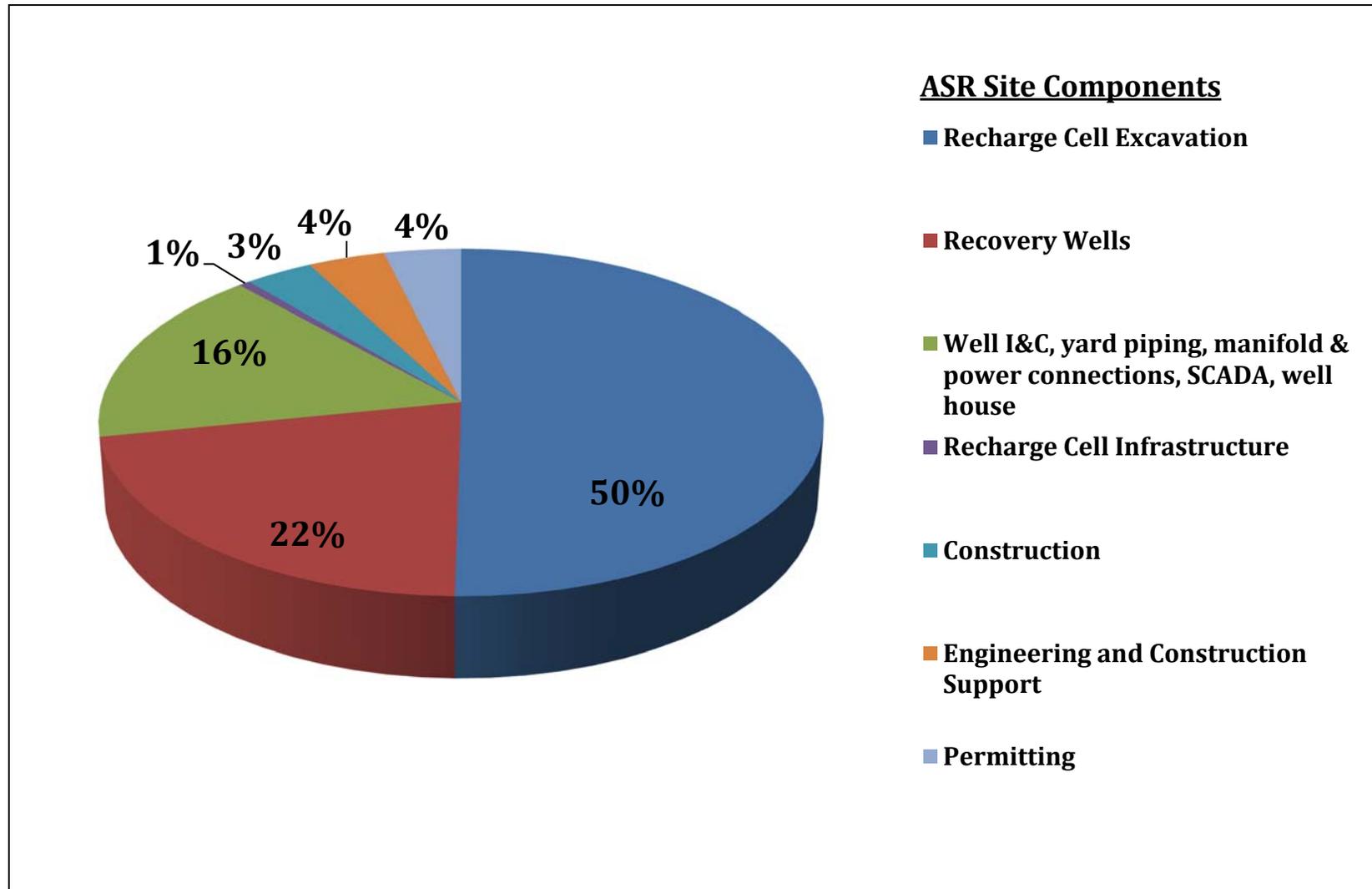


Figure 2 - Conceptual Alluvial ASR Site Component Estimated Costs as a Percentage of Total Cost

APPENDIX I – COST ESTIMATES TM

NOTE: SOME OF THE INFORMATION IN THIS TM WAS CHANGED DURING
PREPARATION OF THE FINAL REPORT

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TECHNICAL MEMORANDUM

To: Joe Frank, Andy Moore
Lower South Platte Water Conservancy
District, Colorado Water Conservation
Board

From: Chip Paulson, Pranay Sanadhya,
Wonnie Kim
MWH Now Part of Stantec

Subject: **Cost Estimation of Potential
Reservoir Alternatives in the South
Platte River Basin**

Date: November 28, 2017

INTRODUCTION

HB 16-1256, which authorized the South Platte Storage Study (SPSS), included a requirement to develop cost estimates for the storage alternatives that could be effective in storing surplus water in the South Platte River Basin. These alternatives include surface reservoirs and groundwater aquifer storage. This technical memorandum (TM) documents the methods used to prepare cost estimates for the SPSS.

Due to the conceptual nature of the storage projects and water supply concepts evaluated in the SPSS, cost estimates were prepared at a conceptual level only. Cost estimates are AACE International Class 5 cost estimates. Class 5 estimates are generally prepared based on limited site-specific information, and subsequently have wide accuracy ranges. Typically, engineering is from 2% to 10% complete. They are often prepared for strategic planning purposes, market studies, assessment of viability, project location studies, and long range capital planning. Most Class 5 estimates use stochastic estimating methods such as cost curves, capacity factors, and other parametric techniques. Expected accuracy ranges are from -20% to -50% on the low side and +30% to 100% on the high side, depending on technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination.

This TM describes the methods and data used to prepare cost estimates for new surface reservoirs, enlargements and rehabilitations, diversion structures, gravel pits, and pipelines and pump stations. Costs for aquifer storage options are documented in a separate TM. Because any storage project must be integrated into a broad water supply concept or strategy, costs for delivering water from South Platte River into storage and then from storage to assumed demand centers were included in the SPSS cost analysis.

Due to the conceptual nature of the SPSS analysis, past studies were relied on where possible and previous cost estimates were updated to current conditions. Cost estimates were developed in 2017 dollars.

The SPSS analysis included developing estimates of permitting, design, construction, and land acquisition costs. It is noted that many of the storage sites and storage concepts would involve

significant operation and maintenance (O&M) costs due to pumping requirements for filling and delivering water to demand centers. O&M cost estimates were not developed for this study.

COST ESTIMATES FOR SURFACE RESERVOIRS

Capital costs were estimated for surface storage sites that were short-listed during the SPSS study for incorporation into lower South Platte Basin storage concepts. The short-listed reservoir sites include the following:

- New Sites: Sandborn Reservoir, South Plate (Narrows) Reservoir, Wildcat Reservoir, Pawnee Pass Reservoir, Fremont Butte Reservoir, North Sterling Regulating Reservoir, Johnson Reservoir, Ovid Reservoir, Troelstrup Reservoir, Beaver Creek Reservoir
- Rehabilitation: Julesburg Reservoir
- Enlargement: Julesburg Reservoir
- Storage Restoration: Jackson Lake Reservoir

Costs for other surface storage options could be scaled off of cost estimates for these sites.

For the dams that had conceptual level design costs developed in a previous study, the costs from those previous studies were escalated using information from the United States Bureau of Reclamation (USBR) construction cost trends (USBR, 2017). An escalation factor was calculated from the published earth dam construction cost index between 2017 and the year in which the construction costs were estimated.

For the dams that had conceptual level designs but no costs, quantities were calculated from the conceptual design report and 2017 costs were estimated. In order to maintain as much consistency and comparability between the various cost estimates, the new cost estimates were calculated using the same unit costs as were used in the majority of the previous cost estimates, i.e., the unit costs in the GEI report on Lower South Platte Basin storage options (GEI, 2001). The costs calculated from the 2001 unit costs were also escalated to 2017 conditions in the same manner discussed above.

For the dams that had no previous conceptual level designs, a conceptual level design was prepared by Stantec. Conceptual designs consisted of an assumed dam alignment, an earthfill dam type, a typical overflow spillway, and an allowance for outlet works and other ancillary features. Quantities were estimated based on the conceptual design and 2017 costs were estimated. In order to maintain as much consistency and comparability between the various cost estimates, the new cost estimates were calculated using the same unit costs as were used in the majority of the previous cost estimates, i.e., the GEI, 2001 report. The costs calculated from the 2001 unit costs were also escalated to 2017 conditions in the same manner discussed above.

Construction cost categories included site clearing and excavation, foundation grouting, dam fill materials, outlet works, spillway, and instrumentation. Costs for other piping, diversions, or other appurtenant facilities were not included within the construction costs. The estimated construction costs include an allowance for "unlisted items" of 10% of listed items. Mobilization, bonds, and insurance was also included at 6% of base construction cost. A contingency of 25% (of the base

construction cost and mobilization, bonds, and insurance) was also included to get the direct construction subtotal (DCS) cost.

Other costs in addition to the construction costs were included in the capital cost estimate as a percentage of the DCS cost. These costs included design engineering (7.5 percent), permitting (3 percent base cost plus additional cost for complex permitting situations), legal and administration (2 percent), and construction administration and engineering costs (7.5 percent). Land costs were also included, based on an average land cost of \$1,000 per acre in Logan and Morgan Counties in 2017 plus \$300,000 in legal fees per site.

The estimated conceptual costs were based on Stantec's professional opinion of the cost to develop and construct the project. The estimated costs were based on the sources of information described above and our knowledge of current construction cost conditions in the Front Range region. Actual project construction and development costs are affected by a number of factors beyond our control such as supply and demand for the types of construction required at the time of bidding and in the project vicinity; changes in material supplier costs; changes in labor rates; the competitiveness of contractors and suppliers; changes in applicable regulatory requirements; changes in design contractors and suppliers; changes in design standards; and environmental mitigation requirements and other conditions of project permitting. Therefore, conditions and factors that arise as project development proceeds through planning, design and construction may result in project costs that differ from the estimates document in this report.

Capital cost estimates for surface storage reservoirs are summarized in Table 1.

Table 1. Surface Storage Capital Cost Summary

Dam Type/Name	Storage (acre-ft)	Crest Height (ft)	Dam Length (ft)	Reservoir Area (ac)	Reference	Prelim Cost from Past Study Data	USBR Factor – Earth Dam	Land Cost (2017)	Additional Permitting Cost	Estimated Capital Cost (2017)	Unit Cost (\$/ac-ft)	Notes
New Site												
Sandborn Reservoir	224,000	132	18,654	8,844	MWH 2004	\$68,689,323	--	\$9,144,000	\$3,000,000	\$130,789,194	\$584	Quantities and costs estimated by Stantec based on conceptual layout in MWH, 2004
South Platte (Narrows) Reservoir	1,960,000	140	14,600	22,000	USBR, 1983	\$59,413,000	1.73	\$22,300,000	\$20,000,000	\$144,922,455	\$74	Cost based on quantities and costs from GEI 2001- converted to 2017 cost
Wildcat Reservoir	60,000	94	7,762	4,664	--	\$40,029,348	--	\$4,964,000	\$5,000,000	\$79,105,602	\$1,318	Conceptual layout, quantities and costs estimated by Stantec
Pawnee Pass Dam	75,000	100	5,280	9,900	Platte River Hydrologic Research Center (PRHRC) 2004	\$158,000,000	1.51	\$10,200,000	\$5,000,000	\$254,297,345	\$3,391	Cost based on quantities and costs from PRHRC 2004 - converted to 2017 cost
Fremont Butte	76,000	74	10,296	4,405	--	\$38,461,587	--	\$4,705,000	\$3,000,000	\$74,138,651	\$976	Conceptual layout, quantities and costs estimated by Stantec
North Sterling Regulating Reservoir	7,600	65	6,100	450	GEI 2001	\$19,800,000	1.73	\$750,000	\$3,000,000	\$37,950,000	\$4,993	Cost based on quantities and costs from GEI 2001- converted to 2017 cost
Johnson Reservoir	10,600	70	4,300	450	GEI 2001	\$11,820,000	1.73	\$750,000	\$3,000,000	\$24,166,364	\$2,280	Cost based on quantities and costs from GEI 2001- converted to 2017 cost
Ovid Reservoir	7,700	30	15,050	490	Applegate Group, Inc. 2003	\$12,600,000	1.60	\$790,000	\$3,000,000	\$23,926,449	\$3,107	Cost based on quantities and costs from Applegate Group, Inc. 2003- converted to 2017 cost
Troelstrup	5,000	30	17,650	500	GEI 2001	\$8,640,000	1.73	\$800,000	\$3,000,000	\$18,723,636	\$3,745	Cost based on quantities and costs from GEI 2001- converted to 2017 cost
Beaver Creek	95,000	80	34320	7,574	--	\$30,472,181	--	\$7,874,000	\$5,000,000	\$65,507,767	\$690	Conceptual layout, quantities and costs estimated by Stantec
Rehabilitation												
Julesburg Reservoir Rehab	5,700	--	--	0	GEI 2001	\$8,820,000	1.73	\$0	\$2,000,000	\$17,234,545	\$3,024	Cost based on quantities and costs from GEI 2001- converted to 2017 cost
Julesburg Reservoir Enlargement	21,900	--	--	400		\$25,100,000	1.73	\$700,000	\$2,000,000	\$46,054,545	\$2,103	Cost based on quantities and costs from GEI 2001- converted to 2017 cost
Restoration												
Jackson Lake Reservoir	10,000	25	10,560	0	Smith Geotechnical, 1993	\$896,050	2.06/3.14	0	\$2,000,000	\$3,846,079	\$385	Cost based on quantities and costs from Smith Geotechnical 1993- converted to 2017 cost

COST ESTIMATES FOR CONVEYANCE SYSTEMS

SPSS conveyance components include pipelines, pump stations, river diversions, and gravel pits for regulating storage.

Pipelines

Pipelines were required to fill reservoirs from the South Platte River and to deliver water from storage to a demand center. In all cases pipeline costs were based on a unit cost expressed as dollars per inch diameter per linear foot. Pipeline diameter was computed based on an assumed design flow and a criterion to maintain a flow velocity of 6-8 ft/sec. Pipeline alignments were extremely approximate; no effort was made to review property ownership or potential easements or obstructions. Pipeline unit cost was based on information collected by Stantec for previous conceptual infrastructure studies in the Front Range. A unit cost of \$7 per inch diameter per lineal foot was used to calculate costs for the large pipelines included in the SPSS alternatives.

Pump Stations

Pump stations were sized based on the horsepower requirement to lift the design flow rate over the assumed elevation difference between intake at the South Platte River and outlet at the proposed storage site. This included the static head associated with the elevation difference and dynamic head associated with energy losses in the pipeline. Unit pump station costs as a function of total horsepower were based on previous Front Range experience, and are summarized below.

Total Horsepower (HP)	Unit cost (\$/HP)
HP≤500	5,500
HP>500 and ≤1500	4,500
HP>1500 and ≤3000	3,500
HP>3000	2,500

South Platte River Diversion Structures

Any off-channel storage projects were assumed to require a new diversion from the South Platte River. To simplify the analysis, all new diversion structures were assumed to be similar to the Lower Platte Beaver diversion structure (Id: 518) shown below, consisting of a new concrete check dam and a diversion headgate. The following dimensions and unit costs were used to calculate an approximate cost of \$1,900,000 for the dam structure.



Concrete	
Length (ft)	220
Top Width (ft)	3
Bottom Width (ft)	5
Height (ft)	30
Unit Cost (\$/yard of concrete)	800

Grouted Riprap	
Width (ft)	50
Unit Cost (\$/sq-yd of grouted rip rap)	80

A cost of \$900,000 was used for gate structure to divert flows at a maximum rate of 800 cfs. The total diversion cost was estimated to be \$2.8 million.

Gravel Pit Storage

Gravel pit regulating storage was assumed to be part of any alternative involving a new diversion from the South Platte River. This regulating storage would reduce the size of the conveyance system needed to fill a proposed storage option by balancing diversion of high flows from the river. Based on Stantec research in the Arkansas Valley, a unit cost of \$1,500/ac-ft was adopted for gravel pit storage. To standardize storage concepts, each was assumed to include a 10,000 ac-ft gravel pit complex with a cost of \$15 million.

Contingency

A 50% contingency was applied when estimating the cost of conveyance facilities.

Conveyance Cost Summary

Table 2 shows the capital cost estimates for conveyance facilities needed to fill reservoirs from the South Platte River. Costs assume up to 800 cfs would be diverted from the river to a gravel pit complex, and up to 400 cfs would be conveyed to the storage option.

Table 3 shows the capital cost estimates for conveyance facilities needed to deliver a maximum of 150 cfs from storage to an assumed SPSS demand center in the Brighton area.

Table 2. Conveyance Capital Costs for Filling Storage Options in Selected Storage Concepts (400 cfs capacity)

Alternative	Description	Pipeline	Pump Stations	Dam and Diversion Structure	Gravel Pit Storage	Contingency	Total Cost
Upper Basin Storage-Sandborn Reservoir	Pipeline from SPR to Riverside Reservoir. Pipeline from Riverside Reservoir to Sandborn Reservoir	\$43,750,000	\$50,360,000	\$2,800,000	\$15,000,000	\$55,955,000	\$167,865,000
Mid Basin Storage North- Wildcat Reservoir	Pipeline from SPR to Wildcat Reservoir	\$26,110,000	\$49,950,000	\$2,800,000	\$15,000,000	\$46,930,000	\$140,790,000
Mid Basin Storage South- Beaver Creek Reservoir	Pipeline from SPR to Morgan Beaver Reservoir. Pipeline from Morgan Beaver Reservoir to Beaver Creek Reservoir.	\$140,690,000	\$113,010,000	\$2,800,000	\$15,000,000	\$135,750,000	\$407,250,000
Lower Basin Storage-Trilakes Northeast (Julesburg, Ovid, and Troelstrup)	Separate pipelines from 2 new diversions on SPR to Julesburg Reservoir, Ovid Reservoir and Troelstrup Reservoir	\$9,010,000	\$16,750,000	\$5,600,000	\$30,000,000	\$30,680,000	\$92,040,000
Existing Reservoir Improvements-Julesburg, North Sterling, Prewitt, Jackson, and Riverside	Separate pipelines from 3 new diversions on SPR to each reservoir	\$34,970,000	\$59,270,000	\$8,400,000	\$45,000,000	\$73,820,000	\$221,460,000
Groundwater Basin Storage West- Lost Creek Aquifer	Pipeline from SPR to feed recharge facilities for Lost Creek Aquifer	\$91,030,000	\$126,850,000	\$2,800,000	\$15,000,000	\$117,840,000	\$353,520,000
Groundwater Basin Storage East- Beaver Badger Aquifer	Pipeline from SPR to Morgan Beaver Reservoir. Pipeline from Morgan Beaver Reservoir to recharge facilities for Beaver Badger Aquifer.	\$70,790,000	\$135,390,000	\$2,800,000	\$15,000,000	\$111,990,000	\$335,970,000

Table 3. Capital Cost Estimates for Delivery Systems from Storage to Brighton Demand Center (150 cfs capacity)

Alternative	Description	Pipeline	Pump Stations	Contingency	Total Cost
Upper Basin Storage- Sandborn Reservoir	Pipeline from Sandborn Reservoir to Brighton	\$114,640,000	\$69,850,000	\$92,245,000	\$276,735,000
Mainstem Storage- South Platte (Narrows) Reservoir	Pipeline from Narrows Reservoir to Brighton	\$138,170,000	\$85,130,000	\$111,650,000	\$334,950,000
Mid Basin Storage North- Wildcat Reservoir	Pipeline from Wildcat Reservoir to Brighton	\$157,560,000	\$100,780,000	\$129,170,000	\$387,510,000
Mid Basin Storage South- Beaver Creek Reservoir	Pipeline from Beaver Creek Reservoir to Brighton	\$158,920,000	\$102,530,000	\$130,725,000	\$392,175,000
Lower Basin Storage- Trilakes Northeast (Julesburg, Ovid, and Troelstrup)	Pipeline from Julesburg Reservoir to Brighton	\$324,660,000	\$196,330,000	\$260,495,000	\$781,485,000
Existing Reservoir Improvements- Julesburg, North Sterling, Prewitt, Jackson, and Riverside	Pipeline from Riverside Reservoir to Brighton	\$114,640,000	\$69,850,000	\$92,245,000	\$276,735,000
Groundwater Basin Storage West- Lost Creek Aquifer	Pipeline from west of Wiggins to Brighton	\$69,860,000	\$47,950,000	\$58,905,000	\$176,715,000
Groundwater Basin Storage East- Beaver Badger Aquifer	Pipeline from south of Brush to Brighton	\$141,400,000	\$91,250,000	\$116,325,000	\$348,975,000

References

Applegate Group, Inc. 2003. Ovid Reservoir Comprehensive Feasibility Study SB05-179 Analysis. December.

GEI Consultants (GEI), 2001. Lower South Platte River Water Management and Storage Sites Reconnaissance Study. Prepared for Colorado Water Conservation Board. December.

MWH, 2004. Northern Integrated Supply Project Feasibility Study. Prepared for Northern Colorado Water Conservancy District.

Platte River Hydrologic Research Center (PRHRC), 2004. Preliminary Conceptual Plan for Proposed Pawnee Pass Dam and Reservoir in Logan County, Colorado. Prepared for Logan County Water Conservancy District, Sterling, Colorado. June

Smith Geotechnical, 1993. Feasibility Study for Jackson Lake Dam, Volume I&II (). Prepared for Jackson Lake Reservoir And Irrigation Company Fort Morgan, Colorado. November.

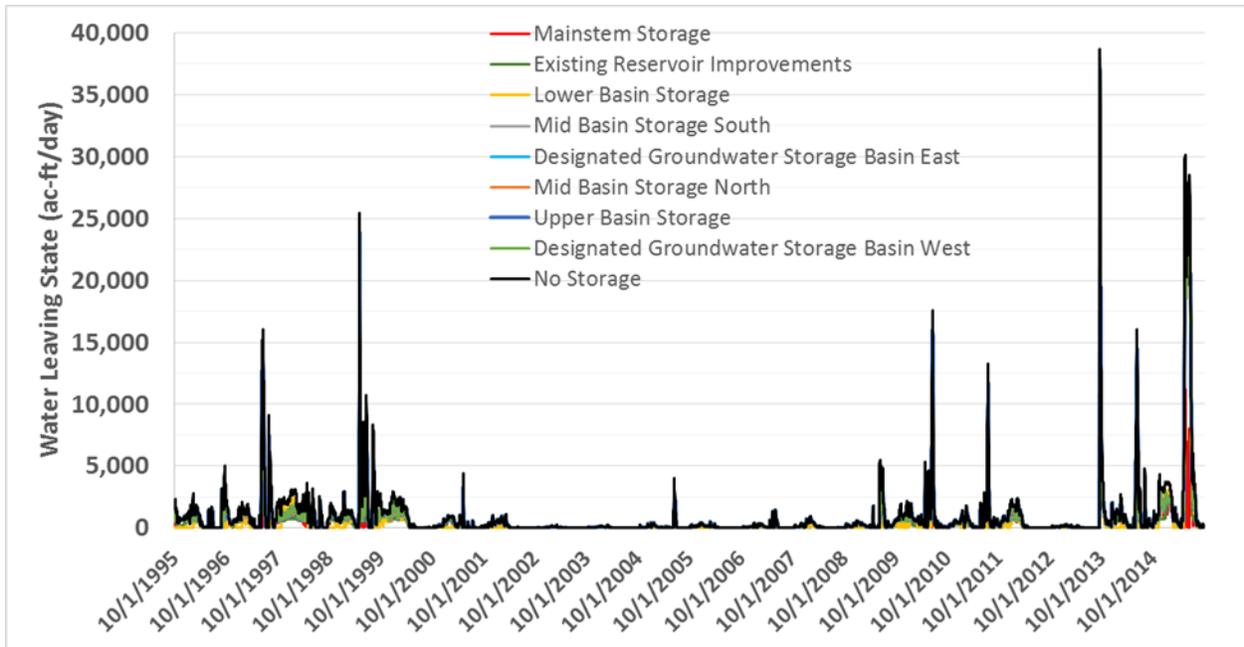
USBR, 1983. Narrows Unit Pick-Sloan Missouri Basin Program, Colorado. Addendum No. 2 to Definite Plan Report. June

**APPENDIX J – WATER LEAVING THE STATE
WITH OPERATION OF STORAGE
CONCEPTS**

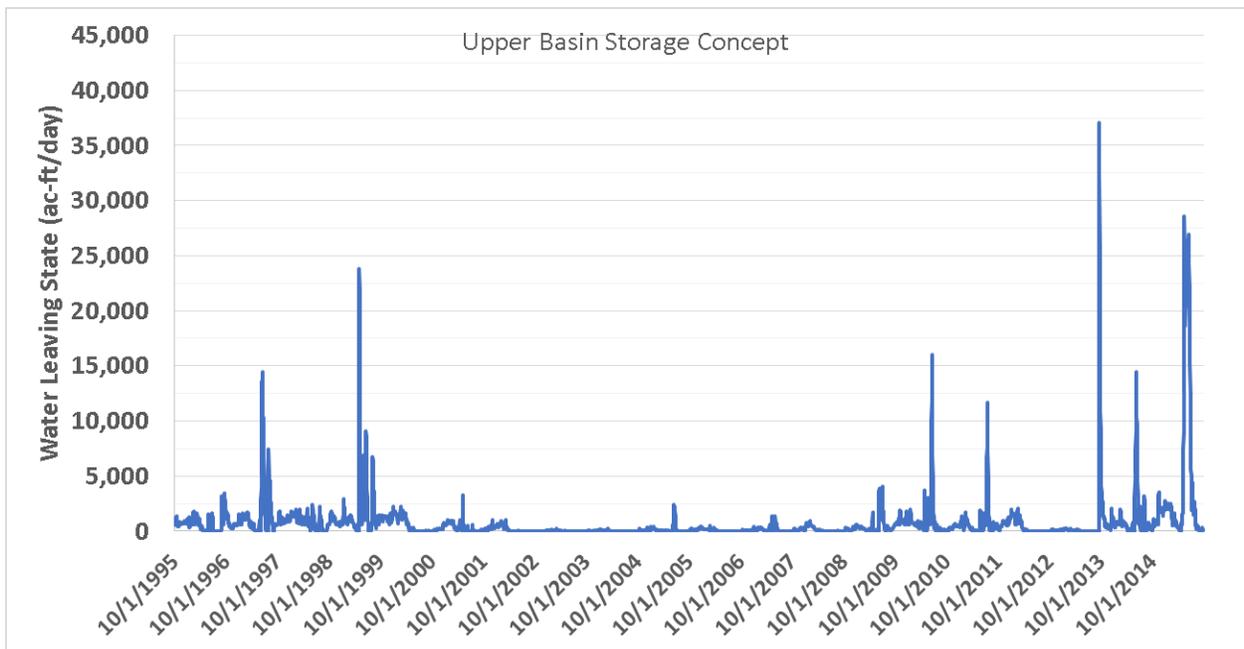
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Daily Plots of Water Leaving State for SPSS Storage Concepts

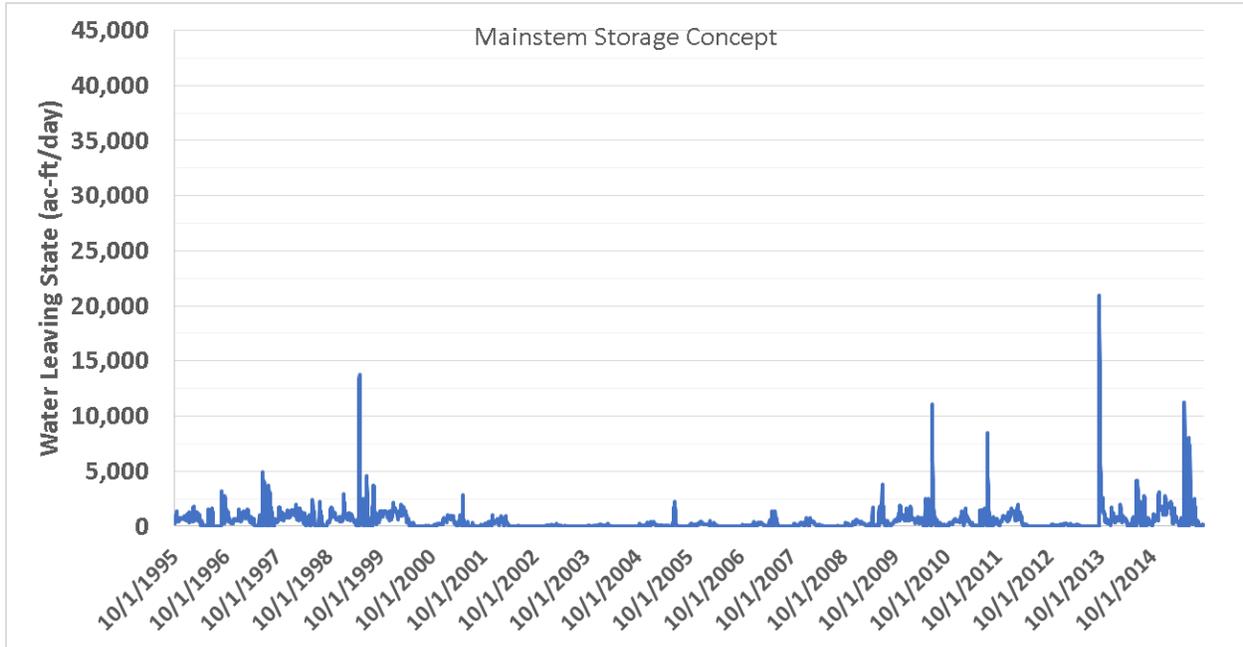
All Storage Concepts



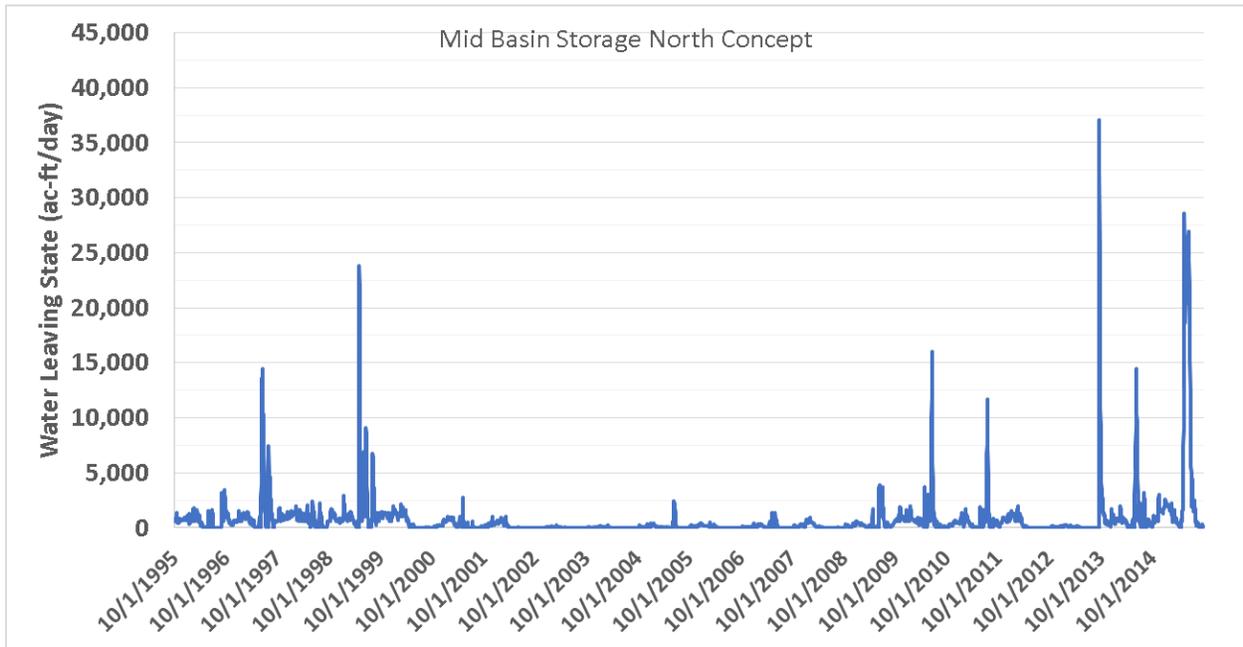
Upper Basin Storage – Sandborn Reservoir



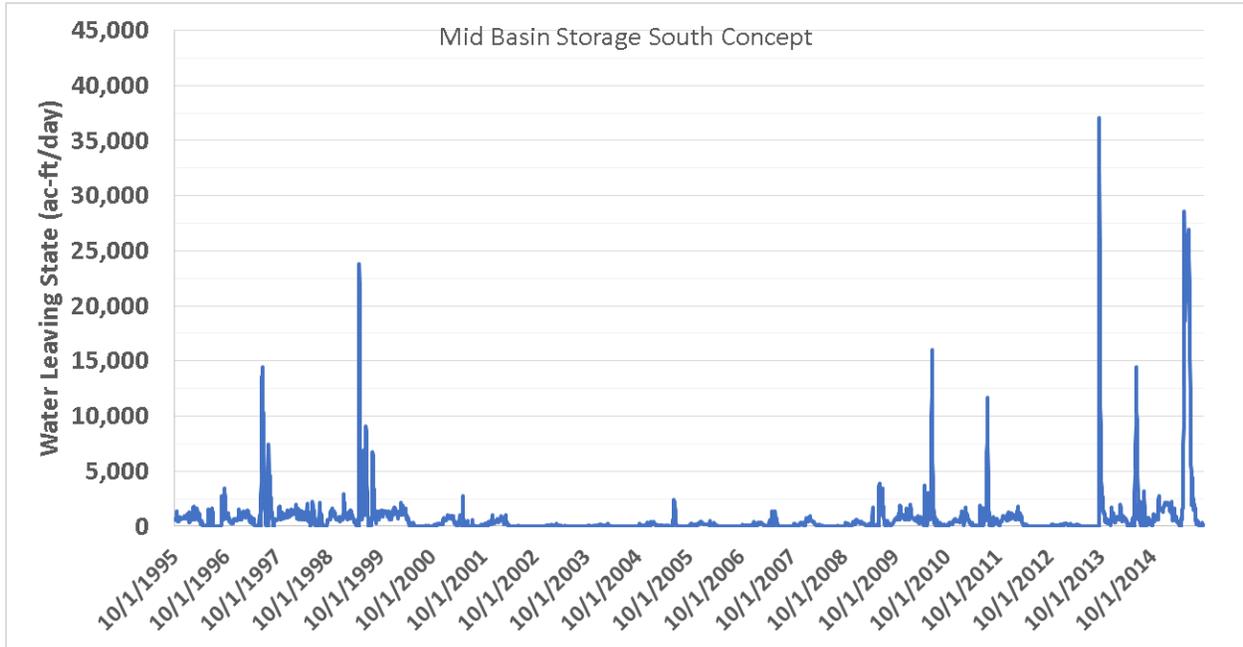
Mainstem Storage – South Platte (Narrows) Reservoir



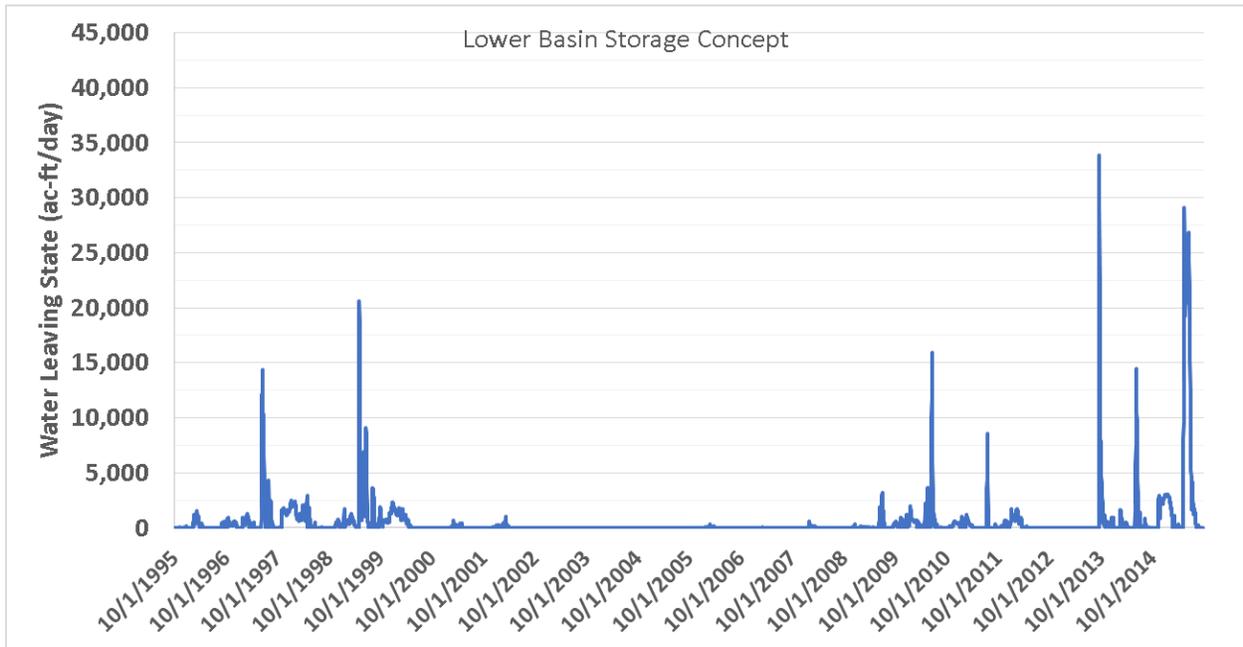
Mid Basin Storage North – Wildcat Reservoir



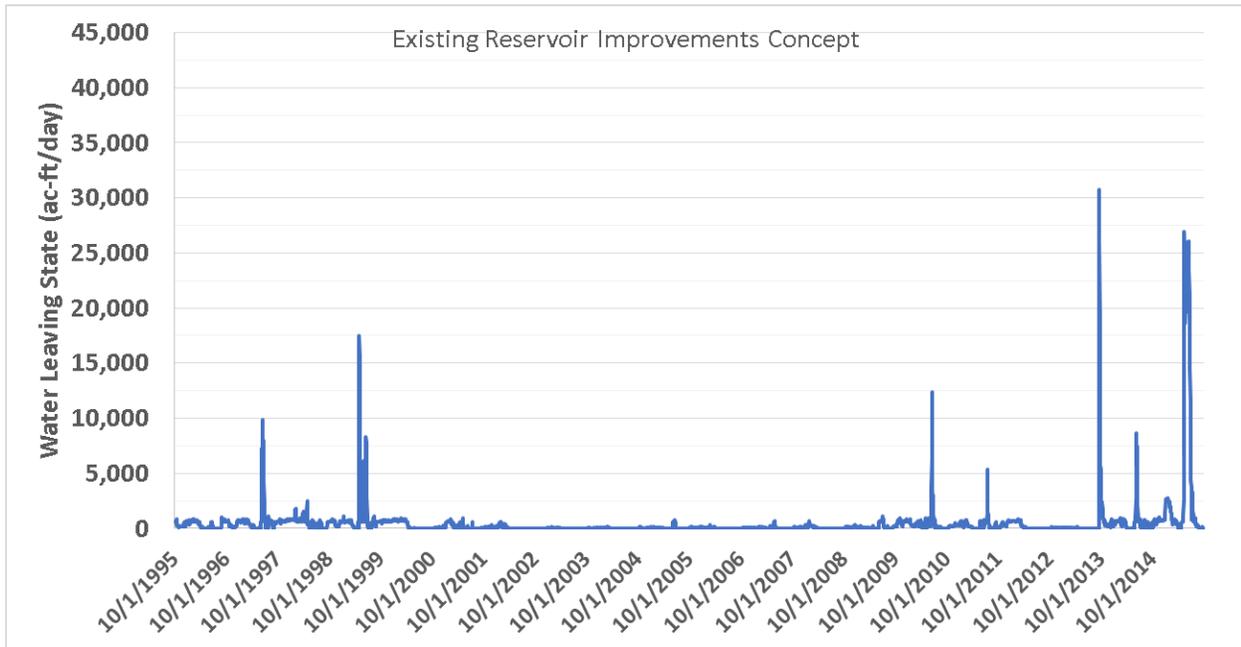
Mid Basin Storage South – Beaver Creek Reservoir



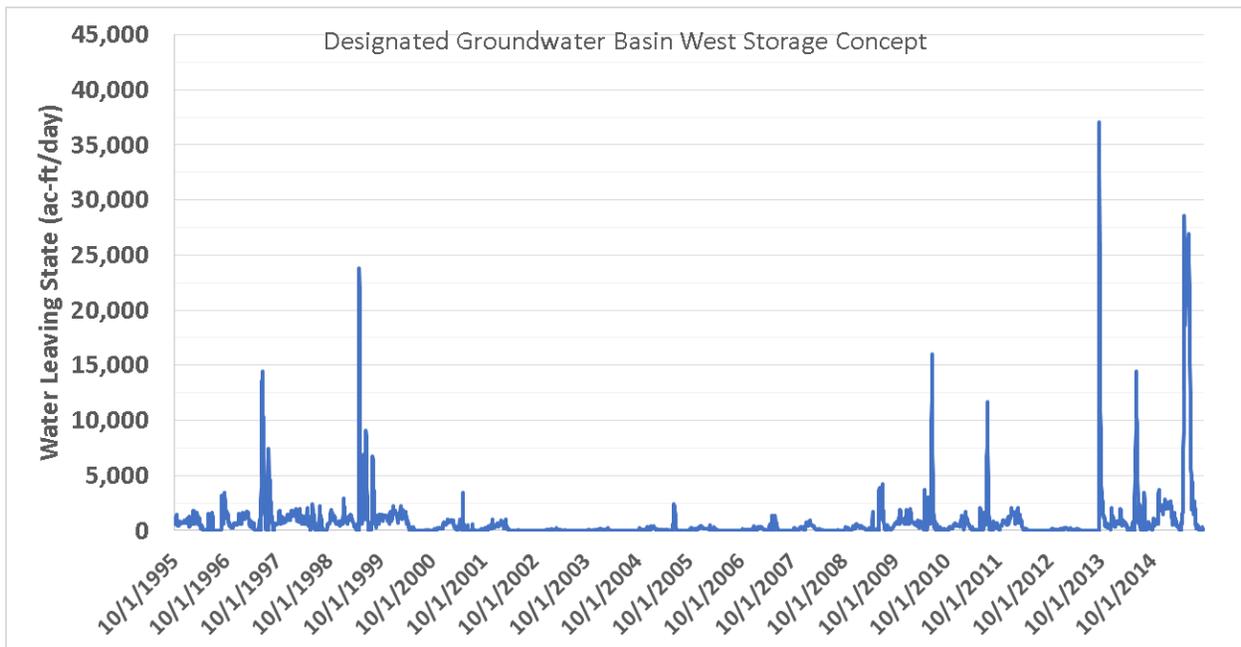
Lower Basin Storage – Julesburg, Ovid, Troelstrup



Existing Reservoir Improvements – Julesburg, North Sterling, Prewitt, Jackson Lake, Riverside

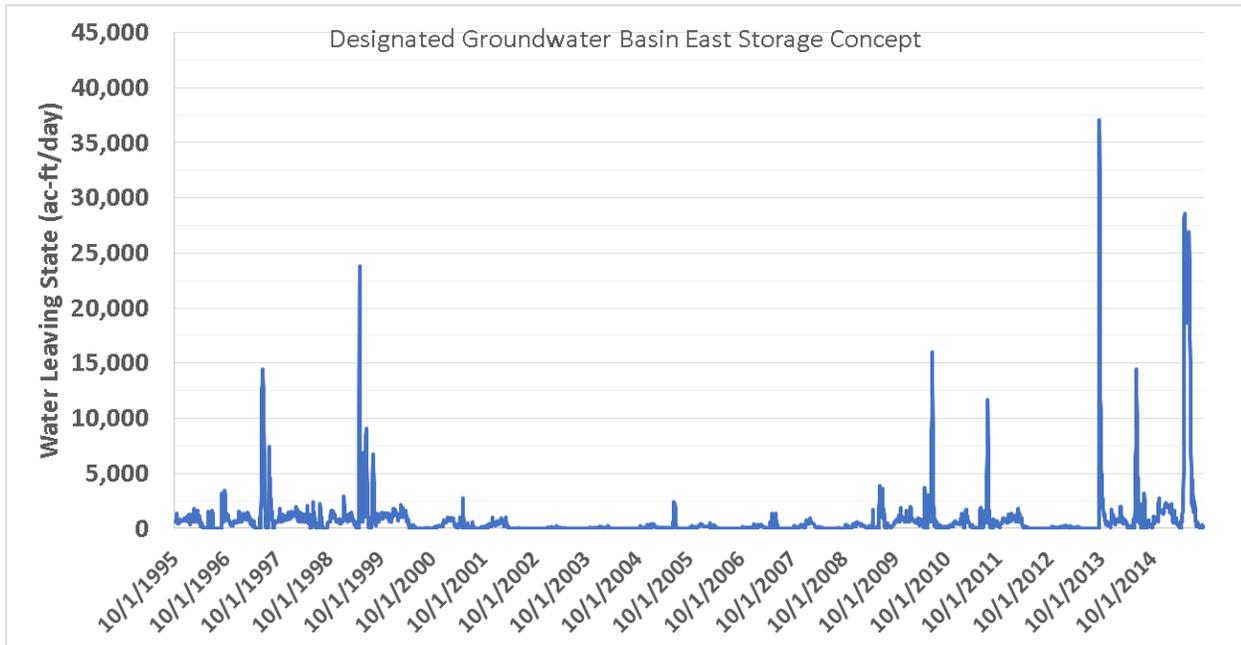


Designated Groundwater Storage Basin West - Lost Creek Basin – Sized with Large Inlet/Outlet Facilities to be Similar to Surface Storage Concepts



Water leaving the state for this groundwater option sized based on typical ASR facilities in Colorado would be much higher.

Designated Basin Groundwater Storage East – Badger/Beaver Basin – Sized with Large Inlet/Outlet Facilities to be Similar to Surface Storage Concepts



Water leaving the state for this groundwater option sized based on typical ASR facilities in Colorado would be much higher.

No Storage

