Analysis and Technical Update to the Colorado Water Plan

Technical Memorandum

Prepared for:

Colorado Water Conservation Board

Subject:

Opportunities for Increasing Storage

Date: May 10, 2019

Prepared by: Jacobs

Reviewed by: Brown and Caldwell

Table of Contents

List of Figures

List of Tables

Section 1: Introduction & Purpose of Water Storage

This technical memorandum (TM) investigates concepts related to increasing water storage to assist in meeting current and future water supply challenges throughout Colorado. Section 6.5.3 of the 2015 Colorado's Water Plan (CWP) sets a measurable objective of attaining 400,000 acre-feet (AF) of innovative water storage by 2050.

The introduction to the CWP states that Colorado must develop additional storage to manage and share conserved water and manage the challenges of a changing future climate. The CWP further states that tomorrow's storage projects should work to increase the capacity of existing reservoirs, address a diverse set of needs[1], and involve more partners. New storage projects will be increasingly innovative and will rely on technologies such as aquifer storage and recovery. Additionally, water managers will need to be more agile in responding to changing future conditions so that storage can be more rapidly added to Colorado's water portfolio while maintaining strong environmental health. To accomplish these goals, a permitting system that currently can produce uncertainty, significant delays, and foster mistrust among project stakeholders must be addressed.

To provide further context to these future storage goals, this case study provides a summary of existing surface water storage across the state and describes opportunities for increasing surface water storage in existing facilities, constructing new surface water storage facilities, and utilizing groundwater aquifers as storage facilities.

This TM also includes brief permitting considerations for each of these types of potential new storage opportunities. However, this TM does not include a comprehensive discussion on detailed permitting processes or attempt to predict the likelihood of success of the permit process for a specific storage project or any of the storage concepts presented herein.

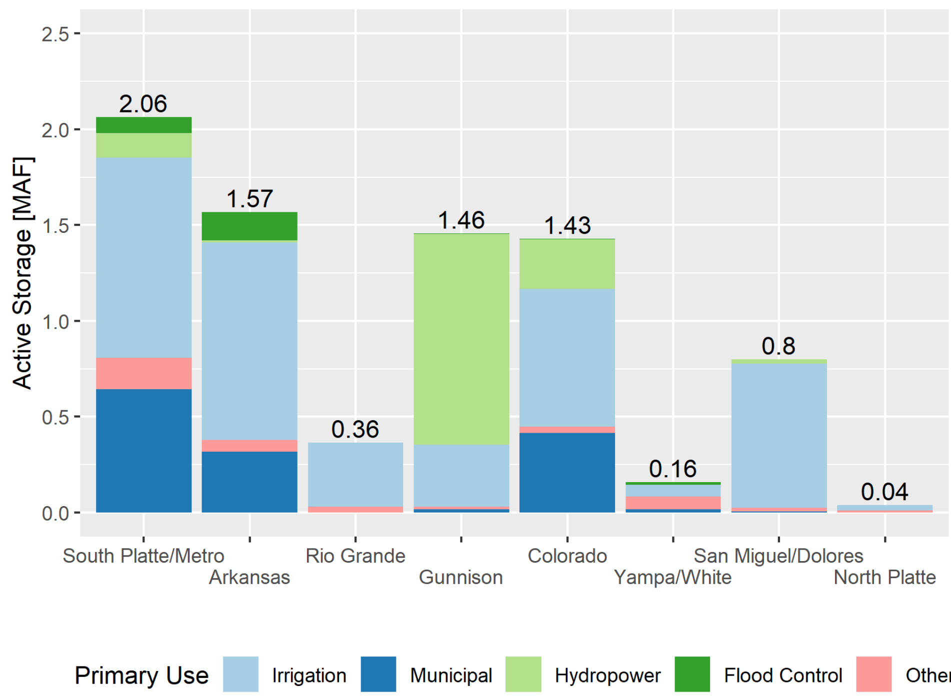
Section 2: Summary of Existing Surface Water Storage

Section 4 of the CWP provides an overview of surface water storage development in Colorado between the 1860s and 2010s. Figure 1 shows that there is currently about 7.5 million-acre-feet (MAF) of surface water storage in Colorado. Each reservoir in Colorado has a primary and often numerous secondary designated uses. Figure 1 shows how existing surface water storage is distributed across the state and how the designated primary uses vary significantly by basin.

Figure 1 is presented here to provide the reader with a frame of reference of what it may mean to contemplate varying volumes of future storage projects as outlined in the following sections of this TM.

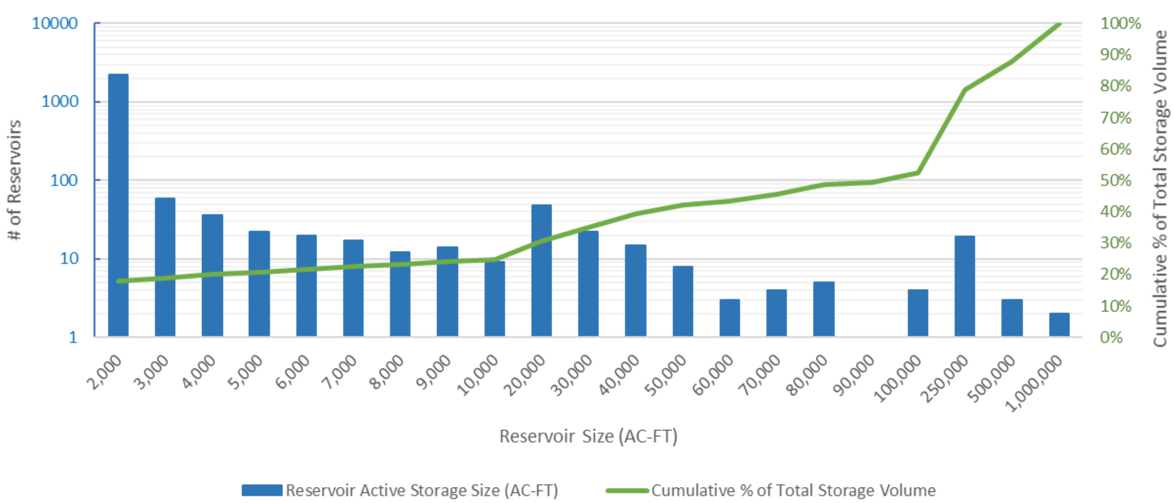
[1] Note that this TM only briefly considers multi-purpose storage and does not intend to identify or predict the likelihood for any specific project.

Figure 1: Existing Surface Water Storage in Colorado in 2018, by Basin



For some perspective on the number of existing reservoirs and their size, the vast majority (92%) of jurisdictional reservoirs in Colorado are less than 5,000 acre-feet (shown in Figure 2). Large reservoirs make up a small fraction of the total number of reservoirs in the state, with only 41 reservoirs being larger than 50,000 acre-feet. However, these reservoirs account for more than 50% of total storage volume. To accomplish the CWP's goal of 400,000 acre-feet of new storage, at least some new large reservoirs are needed.

Figure 2: DWR Jurisdictional Dam Active Storage Overview



Section 3: Opportunities to Increase Operational Storage of Existing Reservoirs

There are numerous opportunities to increase operational storage in existing reservoirs that (if made available) could increase both reliable water deliveries to municipal and agricultural water users and environmental and recreation flows during critical drought periods. Key opportunities are summarized below:

Reallocate Some Flood Storage to Active Storage: The Colorado Department of Water Resources (DWR) requires that reservoirs be designed to safely pass a designated Inflow Design Flood (IDF) which is based on the hazard classification of each dam. Current dam safety regulations dictate a range of frequency rainfall events from as low as a 1/25 percent per year event up to and including the Probable Maximum Precipitation (PMP) be utilized when determining the IDF. To provide this capability, many reservoirs throughout Colorado are designed and operated with a flood pool that is not used for storage operations. Instead, this volume is held in reserve and only used to safely capture and then immediately release flood waters in a controlled fashion. The required volume of unused storage dedicated to passing the IDF event is sometimes based on dated meteorology, hydrology, and dam engineering practices and data. In some cases, assessing the required flood storage against newer meteorological and hydrological design methodologies could allow a portion of the currently dedicated IDF volume in many reservoirs to be reallocated to active operational storage. This volume reallocation concept is referred to as the "storage delta concept" in Section 4 of the CWP.

To accurately define the potential to reallocate flood storage to active operational storage, detailed hydrological assessments would need to be performed at each individual reservoir being considered for reallocated storage. A comprehensive effort to perform these analyses in Colorado has not yet occurred; however, however many dams do have some amount of dedicated flood control volume. Even if a small amount of capacity in a select few of these reservoirs could be reallocated to active operational storage, the "storage delta concept" could provide meaningful contributions towards the CWP's goal of achieving additional storage in existing reservoirs.

Removal of Sediment: Sediment transport is a natural process that takes place in watersheds upstream of reservoirs, and it can be accelerated due to landscape changes that increase erosion potential. For example, large sediment transport events can occur over a relatively short period in watersheds that have experienced large-scale wildfires or other events that disrupt the watershed. In many cases, these sediments are transported into on-channel and off-channel reservoirs. Over time, the accumulation of sediment can displace a significant amount of the original operational storage volume of the reservoir. Reservoir sediment removal projects require significant planning to identify technically feasible methods for removing the sediments and identifying economically viable options for transporting and disposing of the removed sediments. Reservoirs that have been in operation for many decades or are downstream of wildfire areas could be good candidates for sediment removal as a means to increase operational storage volume.

It is important to note that sediment removal can be attractive because it recovers active storage in an existing structure and does not require a new reservoir permit. However, key technical considerations that may impact feasibility and cost can include removal of sediment using dredging versus pumping, identifying suitable locations for ultimate disposal of removed sediments, and the associated haul distance. Depending upon these characteristics, physically removing sediment can be technically difficult and can potentially cost more than new reservoir construction.

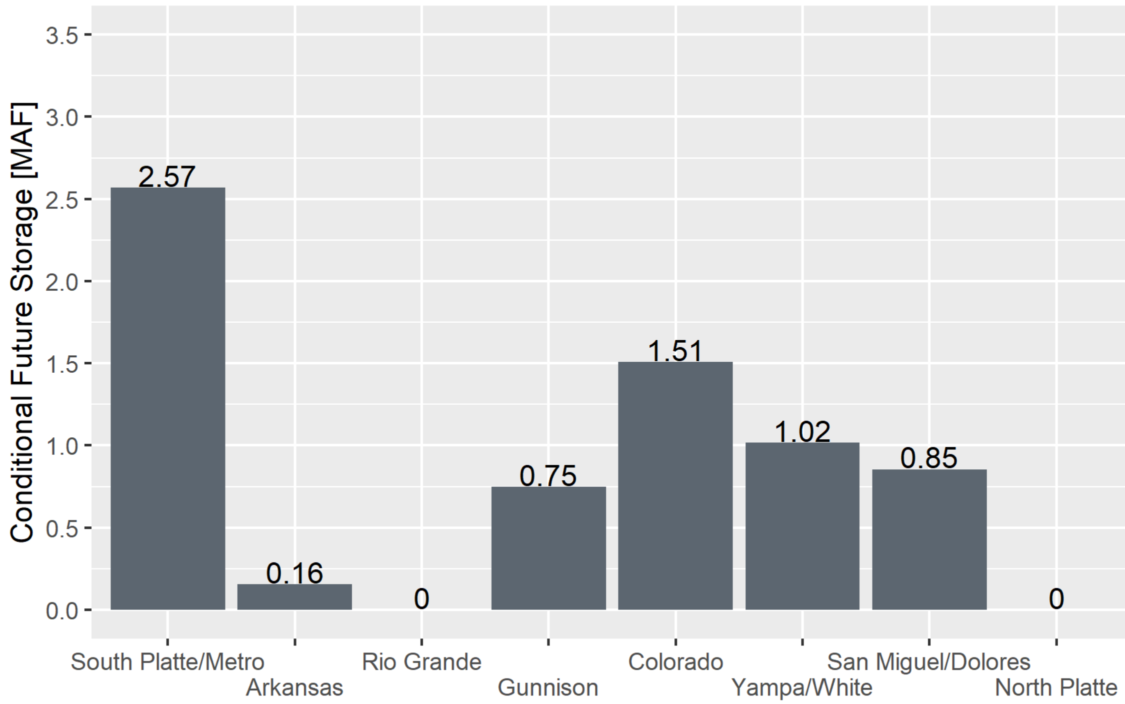
Rehabilitate Dams Currently Under Storage Restrictions: State statutes require that the State Engineer (DWR Dam Safety) inspect and evaluate regulated dams for signs of instability and set the safe storage level at those dams based on the conditions. When unsafe conditions are observed that risk is mitigated through storage restrictions that reduce the safe storage level to something less than full storage. Due to aging dams, a number of storage restrictions are ordered annually. Similarly, due to dam owner desire and based on the value of the lost storage, dams are rehabilitated and returned to full storage annually. In an average year there are about 130 dams with storage restrictions in Colorado. Some of the dams on the restricted list have issues that have not been addressed for numbers of years or even decades, and those dams remain to be utilized at less than full storage capacities. Rehabilitation of dams with long-standing storage restrictions could restore some or all of the original operational storage volume and, in some cases, rehabilitation would also safely allow enlargement of capacity at those facilities. DWR maintains an up-to-date database of all dams with reservoirs currently under storage restrictions. The database documents the deficiency that causes the restriction as well as the volume of lost storage compared to original design storage volume. It is also worth noting that many of the reservoirs under long-standing storage restrictions are owned by agricultural interests that may not have the funds to perform the rehabilitation that would return the reservoir to normal operations. However, some of the largest reservoirs that are under fill restrictions may be good candidates for a collaborative municipal and agricultural project where municipal water providers assist in funding the rehabilitation in exchange for use of a portion of the recovered storage volume.

Dam Enlargements: Increasing the height of existing dams is one option for providing additional future water storage. When compared to constructing entirely new dams, enlarging existing dams could have lower environmental impacts because changes to the natural landscape have already occurred at the existing dam location. However, detailed environmental assessments and permitting are typically still required, and the dam enlargement must be shown to be the least environmentally damaging alternative for meeting the documented storage need. In addition to permitting considerations, the existing dam must be in a location where the increased storage strategically fits into the overall operation of the regional water infrastructure and where excess water is physically and legally available for storage. Therefore, the number of dams that could be feasibly enlarged depends on many factors that require further detailed technical analyses.

Section 4: New Surface Water Storage Opportunities

In Colorado, water right holders can file for conditional water rights and conditional storage rights when there is an expected future water need or a current need with yet to be secured funding or permits. To gain one perspective of the opportunity for potential new surface water storage sites, the State's current water right database was queried for potential reservoir sites with conditional storage rights that are greater than 5,000 acre-feet. Sites smaller than 5,000 acre-feet were also queried. However, for this analysis it was assumed that the intended purpose of the smaller sites was for daily or seasonal operational storage. A cursory analysis showed that a larger number of smaller reservoirs do not accomplish the same operational objectives as a mix of larger reservoirs due to significant increases in evaporation losses and the loss of the benefits of economies of scale, which are significant for dams. The findings of the database query are shown in Figure 3.

Figure 3: Summary of Conditional Surface Water Storage Rights (Greater Than 5,000 AF), by Basin



As shown in Figure 3, there are over 6.5 million-acre-feet (MAF) of conditional storage rights that are greater than 5,000 AF on file with the State of Colorado. To gain a further understanding of the types of proposed facilities that make up the values shown in Figure 2, the top five conditional storage sites (greater than 5,000 AF) statewide and for each basin are listed in Table 1.

Table 1: Largest Conditional Storage Sites by Basin (Greater Than 5,000 AF)

Statewide		
Conditional Storage Name	Filed Conditional Storage Volume [AF]	Notes
Two Forks Reservoir	672,737	Denver Water, in conjunction with other Front Range utilities, pursued permitting of Two Forks Reservoir near Deckers. The project was vetoed by the EPA in 1990, although an alternate configuration, size, and precise location could be considered in the future, and therefore the project's conditional water rights are still active.
Animas-LaPlata Project	618,000	Conditional storage rights for unconstructed reservoirs as part of part of the Project are still active. Numerous configurations of this project have been proposed. A smaller scale configuration was completed in 2009 when Lake Nighthorse began to fill.
Weld Co. Reservoir	350,570	Proposed South Platte River reservoir near existing Riverside Reservoir.
Eagle-Colorado Reservoir	350,000	Denver Water maintains conditional storage rights for a new reservoir near Wolcott that could store water from the Eagle or Colorado Rivers.
Union Park Reservoir	320,550	Proposed reservoir near Taylor Park Reservoir. Project was canceled in mid-2000s, although conditional storage rights remain active.
South Platte/Metro Basin		
Conditional Storage Name	Filed Conditional Storage Volume [AF]	Notes
Two Forks Reservoir	672,737	Denver Water, in conjunction with other Front Range utilities, pursued permitting of Two Forks Reservoir near Deckers. The project was vetoed by the EPA in 1990, although an alternate configuration, size, and precise location could be considered and therefore the project's conditional water rights are still active.
Weld Co. Reservoir	350,570	Proposed South Platte River reservoir near existing Riverside Reservoir.
Grey Mtn. Dam (Glade)	220,000	Part of proposed Northern Integrated Supply Project.
Dowe Flats Reservoir	119,000	Proposed by St. Vrain & Left Hand Water Conservancy District, north of Hygiene.
Coffintop Reservoir	115,902	Proposed by St. Vrain & Left Hand Water Conservancy, south of Lyons.
Arkansas Basin		
Conditional Storage Name	Filed Conditional Storage Volume [AF]	Notes
Tri-State Reservoir	85,000	Proposed reservoir as part of Tri-State power generation project.
Williams Creek Reservoir	35,000	Proposed reservoir as part of Colorado Springs Utilities' Southern Delivery System.
Southeast Plant Reservoir	20,000	Proposed Arkansas River irrigation and industrial reservoir near Los Animas.
Phantom Canyon Reservoir	8,400	Proposed power generation reservoir outside Canon City.
White Creek Reservoir	7,000	Proposed M&I and irrigation reservoir outside Walsenburg.
Gunnison Basin[1]		
Conditional Storage Name	Filed Conditional Storage Volume [AF]	Notes
Union Park Reservoir	320,550	Proposed reservoir near Taylor Park Reservoir. Project was canceled in mid-2000s, although conditional storage rights remain active.
Snowshoe Dam & Reservoir	74,955	Proposed industrial (coal mining) reservoir outside Paonia, conditional storage rights remain active.
Saltado Reservoir	72,600	Proposed irrigation reservoir west of Telluride as part of San Miguel Project.
Radium Reservoir	49,600	Proposed irrigation reservoir near Nucla as part of San Miguel Project.
Gorsuch Reservoir	28,754	Proposed reservoir as part of the Grand Mesa Project located on Currant Creek, tributary to the Gunnison River.

Conditional Storage Name	Filed Conditional Storage Volume [AF]	Notes
Colorado Basin		
Eagle-Colorado Reservoir	350,000	Denver Water maintains conditional storage rights for a new reservoir near Wolcott that could store water from the Eagle or Colorado Rivers.
Azure Reservoir	178,794	Proposed irrigation and M&I reservoir west of Kremmling.
Una Reservoir	173,477	Proposed irrigation, M&I, and power generation reservoir west of Parachute.
Red Cliff Proj. Iron Mt	98,042	Proposed irrigation, M&I, and power generation reservoir on Homestake Creek near Red Cliff.
Roan Creek Reservoir	71,300	Proposed irrigation, M&I, and power generation reservoir west of Parachute.
Yampa/White Basin		
Rio Blanco Reservoir	131,034	Proposed M&I reservoir north of Glenwood Springs.
Wolf Creek Reservoir	90,000	Recently filed with DWR by Rio Blanco Water Conservancy District Project (RBWCD)-conditional storage volume estimated.
Fourteen Mile Reservoir	85,988	Proposed irrigation and M&I reservoir north of Rifle.
South Fork Reservoir	85,342	Conditional rights transferred to RBWCD for proposed Wolf Creek Reservoir, located on South Fork of the White River.
Strawberry Creek Reservoir	75,957	Proposed outside Meeker.
San Miguel/Dolores Basin		
Animas-LaPlata Project	618,000	Conditional storage rights for unconstructed reservoirs as part of part of the Project are still active. Numerous configurations of this project have been proposed. A smaller scale configuration was completed in 2009 when Lake Nighthorse began to fill.
Plateau Creek Afterbay	44,900	Proposed by Dolores WCD, irrigation and M&I storage north of Cortez.
Oneal Park Reservoir	40,700	Proposed irrigation reservoir by Southwestern Water Conservation District.
Dawson Creek Reservoir	35,635	Located on Dawson Creek in Gunnison County.
Campbell Forebay	22,800	Proposed as part of Plateau Creek Afterbay.
Rio Grande Basin		
None Identified		
North Platte Basin		
None Identified		

1. Radium Evap. Pond (86,800 conditional AF) was not included in this list. This reservoir's proposed use is for brine storage as part of the Paradox Valley Unit Salinity Control Program, and is therefore assumed to be not applicable to water supply storage.

It is worth noting that some of the storage sites shown in Table 1 have previously undergone some amount of permitting efforts and, on occasion, some of the previous permitting efforts were either abandoned or the lead permitting agency declined to issue the required permits to construct the dam. However, conditional storage rights for the sites remain active since alternate sizes and configurations to those originally proposed remain a consideration.

Additionally, 6.5 million acre-feet (MAF) of conditional storage rights (if constructed) would nearly double the existing surface water storage in Colorado and is more than fifteen times the CWP's measurable objective of 400,000 AF of additional storage by 2050. Although the 6.5 MAF of new surface water storage is not likely to occur by 2050, if only a portion of the conditional storage sites are ultimately determined to be technically and environmentally feasible, those new surface water storage facilities could become a critical component to a balanced approach to meeting the projected water resources gaps throughout Colorado.

Section 5: Aquifer Storage and Recovery Opportunities

Groundwater aquifer storage and recovery (ASR) is another method for storing water for later use[2]. Generally, there are two types of aquifer storage projects: 1) water stored in an unconfined aquifer and 2) water stored in a confined aquifer. Both types of ASR can be implemented to contribute to the Colorado's Water Plan 400,000 AF storage goal.

Unconfined ASR: Unconfined ASR projects often include diverting surface water during times when recharge water rights (generally, these water rights are relatively junior) are in priority and conveying that water to recharge pits that allow the water to naturally percolate into the alluvial aquifer system. Depending on the characteristics of the unconfined aquifer system, the recharge water can be used as credit for depletions associated with alluvial groundwater pumping. Because the entity implementing unconfined ASR does not have complete control over how the recharged water migrates through the alluvial system, it is possible that the water stored in the unconfined alluvial system can flow back into the surface water system during a time when the water is not needed, and the storage objective is therefore not always achieved. This type of ASR project may be most applicable for near-term or seasonal retiming of water availability and less applicable for equalizing water availability over a series of dry and wet years. Additionally, there has been more recent interest in developing long term recharge credits that would help provide augmentation supply during dry times, although a challenge with this method is ensuring that the timing of recharge credits aligns with the need for dry-year supplies.

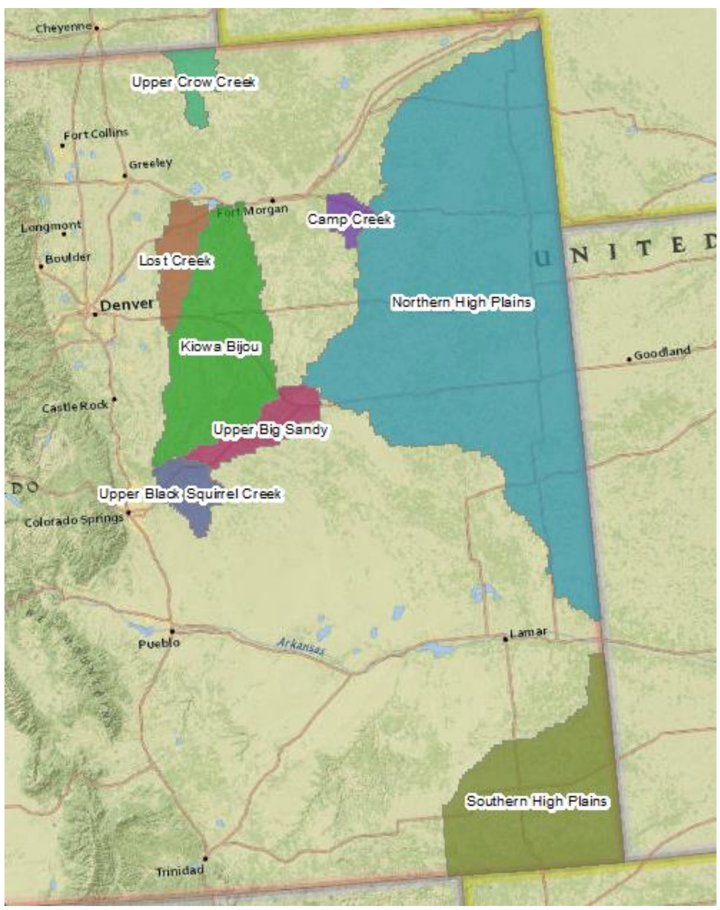
Confined ASR: Confined ASR projects often include diverting surface water during times when the surface water is not immediately needed for other uses, treating the water to drinking water standards and EPA Class V injection well standards and then injecting the water into a deep/confined aquifer system. Because the water is put into a confined system, it generally remains available for subsequent withdrawal even several years after injection occurs. However, a major disadvantage is that deep aquifer characteristics in Colorado are such that it can be difficult to achieve sustainable injection rates of over 250 gallons per minute per well. This means that if an entity desired to store 10,000 acre-feet of wet-year

[2] Note that Colorado Department of Public Health & Environment Water Quality Control Commission Regulation No. 41 establishes use classifications and water quality standards for groundwater supplies in Colorado.

spring river flows over a two-month period, approximately 150 injection wells may be needed. This is impractical from both a cost perspective and well-siting perspective. For these reasons, deep aquifer/confined ASR projects work best in conjunction with surface water storage projects, where surface water reservoirs capture peak available surface water flows and then slowly transfer that water to a deep well injection system. The water transferred to the deep aquifer can be stored for years and be available during the next major drought. As the water is transferred from the surface storage system, surface storage capacity is made available to capture the next round of high surface water flows. A well-known example in Colorado is the Centennial Water and Sanitation District capturing surface water under junior water rights, storing that water in South Platte Reservoir, and then treating and injecting that water into their Denver Basin wells at a controlled rate.

Designated Groundwater Basins: In Colorado, there is an additional type of recognized aquifer system. Called Designated Groundwater Basins, these eight basins (Figure 4) in Colorado's eastern plains are administered by the Colorado Groundwater Commission instead of through water court. Groundwater identified as being in a Designated Basin is mostly confined, although may also contain characteristics of both confined and unconfined aquifer systems, with some (but little) hydrologic connectivity to surface water systems. Careful analysis is required when contemplating use of a Designated Basin for ASR, and both advantages and disadvantages of ASR in unconfined and confined systems (described above) may be realized. Additionally, stored water in a Designated Basin may be vulnerable to other users' pumping.

Figure 4: Designated Groundwater Basins



`

Section 6: Storage Opportunities Summary and Conclusions

There are several different types of potential storage options that could assist efforts to meet Colorado's projected water supply/demand gaps. Table 2 summarizes the key considerations for each type of potential storage discussed in this TM.

Table 2: Overview of Different Water Storage Opportunities

Reallocation of Some Flood Storage to Active Storage
• The volume reallocation from flood control to reservoir operations (referred to as the "storage delta concept") could be a part of achieving additional storage in existing reservoirs. • Further meteorological and hydrologic analysis could be performed on key reservoirs that have dedicated flood storage to identify the most likely opportunities for implementing the "storage delta concept in the future.
Removal of Sediment
• Further analysis should be completed on key reservoirs (i.e. reservoirs that have been in operation for a long period of time or are downstream of wildfire areas) to clarify the degree to which sediment removal could achieve additional operational storage volume.
Rehabilitation of Fill Restricted Dams
• Further analysis should be completed on key reservoirs with fill restrictions to determine the degree to which dam rehabilitation and removal of fill restrictions could achieve additional operational storage volume. • Collaborative partnerships between municipal and agricultural water users should be explored as a way to share in the cost of reservoir rehabilitation in some cases.
Dam Enlargements
• In select cases where water is physically and legally available, and the reservoir fits into existing system operations, raising the height of a dam could be a feasible option for achieving additional storage in an existing reservoir. • In a dam enlargement situation, significant permitting efforts will be required.
New Dam Sites
• Approximately 6.5 million acre-feet of conditional storage water rights that are greater than 5,000 AF are on file with DWR. Many of the largest conditional storage rights in each basin are decreed for municipal, industrial, and irrigation uses. • When considering future storage options, a larger number of smaller reservoirs do not accomplish the same operational objectives as a mix of larger reservoirs due to significant increases in evaporation losses and the loss of the benefits of economies of scale.
Aquifer Storage and Recovery (ASR)
• Unconfined/Shallow ASR projects may be best for near-term or seasonal surface water availability retiming due to potential connections to surface water systems that may limit the duration water can feasibly be stored in the unconfined system. • Confined/Deep ASR projects may be most applicable for longer-term water storage and can be used in conjunction with a surface water storage system to better enable capture of surface water peak flows and optimize the sizing of the ASR system.