Technical Memorandum

Prepared for: Lower South Platte Water Conservancy District

Project Title: South Platte Regional Water Development Concept Feasibility Study

Subject: SPROWG Concept Refinement and Alternatives Modeling

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Executive Summary

The South Platte Regional Opportunities Water Group (SPROWG) Concept is a collaborative effort to study the potential for a future, multi-purpose in-basin storage project that will utilize unappropriated South Platte water, reusable supplies, and transferrable consumptive use from Alternative Transfer Methods (ATMs) to meet South Platte basin municipal and industrial (M&I) and agricultural demands. Two objectives of the current SPROWG Feasibility Study (Study) were to refine the SPROWG Concept based on stakeholder feedback and to evaluate up to four alternative configurations of the SPROWG Concept. The refinements and alternative configurations built on modeling and analysis work conducted during the preliminary discussions of the SPROWG Concept.

Initial Concept Modeling

Early SPROWG Concept collaboration was assisted by Grand River Consulting and Wilson Water Group for technical analyses. The early technical analyses used a tailored version of the South Platte Point Flow Tool to identify potential infrastructure that could meet preliminary yield and performance goals and to characterize a project concept to carry forward into further feasibility analysis. Several concepts were analyzed, and a preliminary concept was developed that met the initial demand goals. The resulting concept was known as "Initial Concept C", and it included storage facilities in the vicinity of Henderson, Kersey, and downstream of Fort Morgan near Balzac. Initial Concept C sought to conjunctively utilize unappropriated water when available, reusable supplies, ATMs, and excess recharge credits to maximize the benefits of supplies, and it relied on exchanges to "move" water upstream to meet municipal demands in the South Platte Basin along the Front Range. Initial Concept C was the SPROWG Concept configuration that existed at the initiation of the Study.

Concept Alternatives and Modeling

The scope of work for the Study specified that up to four SPROWG Concept alternatives would be evaluated. The alternatives were developed first using Initial Concept C as a "baseline" and then refining/adding demands based on the feedback from outreach activities with stakeholders, guidance from the Advisory Committee, input from the Task Force, and consideration of other studies such as the Technical Update to Colorado's Water Plan. The alternatives do not each have the same delivery goals. Rather, each successive alternative, in general, builds upon and adds to the delivery goals and infrastructure included in the prior alternative. Table ES-1 provides a list of the alternatives and a general description of how they build upon one another.

Table ES-1. Overview of Alternatives 1, 2, 3, and 4

Initial Concept C Initial Concept	Alternative 1 Refine the Initial Concept	Alternative 2 Balzac First	Alternative 3 Add Julesburg Storage	Alternative 4 Additional Delivery
Initial Concept C is a "baseline". Alternatives 1, 2, 3, and 4 add infrastructure and refine/add demands based on the feedback from outreach activities.	Alternative 1 has similar overall delivery goals and infrastructure as Initial Concept C, but refinements based on feedback from outreach was incorporated.	Alternative 2 examines a scenario in which a storage facility downstream of Fort Morgan (near Balzac) is the primary facility from which deliveries are made. This alternative sets higher delivery goals for small municipalities downstream of Kersey. Denver Metro and NoCo demands are the same as Alternative 1.	Alternative 3 builds on Alternative 2 by adding another storage facility near the Colorado-Nebraska state line and increasing delivery goals for agriculture and small municipalities downstream of Kersey. Denver Metro and NoCo demands are the same as Alternative 1.	Alternative 4 builds on Alternative 3 by increasing delivery goals by 25 percent throughout the South Platte Basin and increasing storage facilities to meet the demands.

The Point Flow Model was used to evaluate the infrastructure and delivery goals for each alternative. Table ES-2 shows the size of infrastructure the modeling showed was necessary to meet the delivery goals developed for each alternative.

Table ES-2. Infrastructure Necessary to Meet Delivery Goals for Each SPROWG Concept Alternative

		Alternative 1 Refine the Initial Concept	Alternative 2 Balzac First	Alternative 3 Add Julesburg Storage	Alternative 4 Additional Delivery
Size of Infrastructure					
Henderson Storage (AF)*		45,000	40,000	40,000	85,000
Kersey Storage (AF)		150,000	100,000	100,000	200,000
Balzac Storage (AF)		25,000	75,000	75,000	95,000
Julesburg Storage (AF)		-	-	8,000	29,000
Total Storage		220,000	215,000	223,000	409,000
Balzac to Denver Pipeline Capacity (cfs)		0	30	30	30
Delivery Goals (wet and average years / dry years) – data in AF per year					
Municipal	Denver Metro Demand Gateway	20,000/60,000	20,000/60,000	20,000/60,000	25,000/75,000
Municipal	NoCo Demand Gateway	20,000/20,000	20,000/20,000	20,000/20,000	25,000/25,000
Municipal	Eastern Plains	2,000/2,000	5,000/5,000	10,000/10,000	15,000/15,000
	Total Municipal Delivery	**42,000/82,000**	**45,000/85,000**	**50,000/90,000**	**65,000/115,000**
Agricultural	Water District 2	750/2,500	750/2,500	1,500/5,000	2,250/7,500
Agricultural	Water District 1	2,250/7,500	2250/7,500	4,500/15,000	6,750/22,500
Agricultural	Water District 64	-	-	2,000/2,000	5,000/5,000
	Total Ag Delivery	**3,000/10,000**	**3,000/10,000**	**8,000/22,000**	**14,000/35,000**

**Storage at Henderson was contemplated to be 30,000 AF of gravel pit storage with the rest being aquifer storage and recovery in the Lost Creek basin*

Observations and Conclusions

Alternatives 1, 2, 3, and 4 are all viable options, and each Alternative provides an opportunity for the SPROWG Concept project to be successful. Table ES-3 describes key observations and conclusions from the modeling of each alternative.

	Table ES-3. Observations and Conclusions from Modeling			
	Alternative 1 Refine the Initial Concept	Alternative 2 Balzac First	Alternative 3 Add Julesburg Storage	Alternative 4 Additional Delivery
Municipal	• Projected future municipal demands were fully met in most years of the simulation. Municipal demands were not fully met in only 5 of the 69 years of simulation, and in those years, at least 90% of the municipal demand was met.	• Projected future municipal demands were fully met in most years of the simulation. Municipal demands were not fully met in only 3 of the 69 years of simulation, and in those years, at least 90% of the municipal demand was met.	• Projected future municipal demands were fully met in most years of the simulation. Municipal demands were not fully met in only 5 of the 69 years of simulation, and in those years, at least 90% of the municipal demand was met.	• Projected future municipal demands were higher in Alternative 4 and were fully met in most years of the simulation. Demands were not fully met in only 8 of the 69 years of simulation. In one of those years, 85% of municipal demand was met, and at least 90% was met in the rest of the years.
Agricultural	• Agricultural demands in Water District 1 were simulated to be met nearly all of the time • Agricultural demands in Water District 2 were met only 9% of the time because of limitations on exchange capacity. Other alternatives performed significantly better	• Agricultural demands were met nearly all of the time in Districts 1 and 2. District 2 improvements over Alternative 1 were due to releases from Henderson storage to meet agricultural demands in District 2	• Agricultural demands were met nearly all of the time in Districts 1 and 2. • The modeling suggested that at least 2,000 AF/year of agricultural demand could be met on a firm basis in District 64. • A variation on Alternative 3 was modeled that had higher delivery goals in wet/average years and lower goals in dry years and assumed water would be delivered to recharge basins. More agricultural demand was met using this strategy.	• Agricultural demands were met nearly all of the time in Alternative 4, even with 50 percent higher delivery goals than Alternative 3. • The modeling suggested that at least 5,000 AF/year of agricultural demand could be met on a firm basis in District 64.
Infrastructure and Operations	• Storage volumes at Henderson and Balzac were similar to Initial Concept C but larger at Kersey, because future exchange capacity limitations in Alternative 1 were greater than was assumed in Initial Concept C. • A modeled variation of Alternative 1 assumed a pumping station and pipeline would be constructed between Kersey and Henderson to eliminate reliance on exchange between these two facilities, and it resulted in lower storage needs at Henderson. Conveyance infrastructure like this could be considered in the future if adequate gravel pit storage at Henderson is unavailable, ASR in the Lost Creek basin becomes cost prohibitive or otherwise infeasible, or exchange capacity is severely limited.	• Exchange capacity limitations associated with Alternative 1 were somewhat relieved in Alternative 2, because municipal supplies can be directly delivered to Denver Metro water providers from storage at Balzac via the pipeline. • Various Denver Metro pipeline capacities were simulated, and 30 cfs seemed to provide the best operational performance. • Alternative 2 has less total storage than Alternative 1, but 50,000 AF of storage was shifted from Kersey to Balzac	• The Julesburg-area reservoir remained full most of the simulation, because water is readily available due to the presence of return flows and lack of downstream calls. • The Julesburg-area reservoir was primarily used to meet local (Water District 64) demands. The pipeline from the reservoir to above the Harmony Ditch played a key role in overcoming exchange capacity issues and delivering water to users. • Balzac-area storage can meet more Water District 1 demands when downstream demands in District 64 are met with Julesburg-area storage.	• The Julesburg-area reservoir remained full most of the simulation, because water is readily available due to the presence of return flows and lack of downstream calls. • Storage facilities at Henderson, Kersey, and Balzac were greatly drawn down in the modeling simulation during the droughts of the 1950s and 2000s.

Section 1: Introduction

1.1 Purpose of Technical Memorandum

This Technical Memorandum describes the work performed by Brown and Caldwell (BC) to model various South Platte Regional Opportunities Water Group (SPROWG) Concept alternatives to assess their ability to meet future demands. BC relied on the South Platte Point Flow Tool (Point Flow Tool), as previously modified by Wilson Water Group, to conduct the modeling analyses. The Point Flow Tool was further modified by BC for the purposes of this study to analyze four alternative SPROWG Concept configurations that are refinements to a preliminary SPROWG configuration known as “Initial Concept C”, which is further described later in the Technical Memorandum. BC’s work investigated the required infrastructure for the four alternatives to first meet the targeted municipal and industrial (M&I) demand targets in the South Platte Basin and then to meet additional agricultural needs. In addition, strategies were explored that would benefit environmental and recreation (E&R) needs.

1.2 SPROWG Concept Background

The South Platte Regional Opportunities Water Group (SPROWG) Concept is the result of multiple planning efforts and concepts that have been proposed and investigated in recent years. The Concept originated in the South Platte Basin Implementation Plan (SPBIP) as a “Conceptual Future In-Basin Multipurpose Project.” It contemplated points of diversion on the South Platte downstream of the St. Vrain and Cache la Poudre Rivers and Fort Morgan with pump stations and pipelines to convey supplies back upstream to meet municipal and industrial water needs. Proposed supplies for the project included unappropriated South Platte water, reusable supplies, and transferrable consumptive use from Alternative Transfer Methods (ATMs).

Pursuant to the SPBIP, a group of water managers and providers began discussing how to meet future water needs and further the SPBIP project described above. The group called themselves the South Platte Regional Opportunities Working Group (SPROWG). SPROWG members collaborated closely and brainstormed potential water supply solutions that would benefit the overall South Platte Basin. SPROWG also supported two phases of technical evaluations performed by consultants in 2016 and 2017. Through those discussions and technical evaluations, the SPROWG Concept was created.

In parallel with this initial conceptual planning, the South Platte Storage Study (Stantec, et al, 2017) was initiated through legislation from Colorado’s General Assembly. The South Platte Storage Study (SPSS) evaluated available, unappropriated water supplies in the South Platte Basin and identified potential locations along the South Platte River where storage facilities could be constructed to capture and use available supplies. In addition, the SPSS evaluated potential costs of projects and contemplated “project concepts” that incorporated diversion facilities as well as locations where water could be conveyed to meet demands.

The SPROWG Concept was rolled out to the Metro and South Platte basin roundtables on the heels of the SPSS study. The two studies complemented one another, and the roundtables expressed enthusiasm for furthering the multipurpose, regional storage concept embodied in the SPROWG Concept.

The overall purposes of this Feasibility Study (Study) are to broaden the pool of potential participants, identify feasible organizational structures, refine the Concept and demands based on participant needs, evaluate water treatment options, update cost estimates, and develop an outreach and education plan to further the development of the SPROWG Concept.

1.3 Initial Modeling and Development of Concept C

Early SPROWG collaboration was assisted by Grand River Consulting and Wilson Water Group for technical analyses. The early technical analyses used a customized version of the Point Flow Tool to identify potential infrastructure that could meet preliminary yield and performance goals and to characterize a project concept to carry forward into further feasibility analysis. The tailored version of the Point Flow Tool included an expanded time period, delivery demands at various locations, reservoir and pipeline operations, and consideration of multiple sources of supply. The initial yield and performance goals for the SPROWG Concept that were analyzed with the Point Flow Tool were as follows:

- Provide 50,000 AF/yr of firm yield for future M&I demands in the South Platte Basin along the Front Range
- Provide up to 10,000 AF/yr of yield for agricultural water users when supplies are available
- Utilize exchanges to the extent possible to “move” water upstream as opposed to pumping plants and pipelines

The initial analyses considered several concepts with each concept progressively incorporating more infrastructure until yield goals could be met. Initial concepts that were explored included the following:

- Concept A: Storage near Kersey
- Concept B: Storage near Kersey and Henderson
- Concept C: Storage near Kersey, Henderson, and Fort Morgan
- Concept D: Storage near Kersey, Henderson, Fort Morgan, and Julesburg

The preliminary concept that met initial demand goals was Concept C described above (hereinafter, “Initial Concept C”). The concept included storage facilities in the vicinity of Henderson, Kersey, and Fort Morgan to utilize free river supplies when available and relied on exchanges to “move” water upstream to meet municipal demands in the South Platte Basin along the Front Range. The type and number of storage facilities at each location were not specifically considered. In other words, the concept and analyses identified a need for storage of a particular volume in the general vicinity of Henderson, Kersey, and Fort Morgan. Storage at these locations could consist of several small facilities or one large facility. Initial Concept C considered Kersey storage as the “hub” of operations and the primary location from which demands would be met. Supplies from storage at Henderson and Fort Morgan were released to meet demands that could not be met by storage at Kersey or were released for subsequent storage at Kersey.

The initial modeling included numerous computational revisions to the Point Flow Tool to extend the analysis time period, consider multiple sources of supply, incorporate storage and exchanges, and reduce available flow to account for potential depletions from future projects. Most of the initial Point Flow Tool revisions and modeling assumptions were adopted for this Study. Section 2 describes the Point Flow Tool, the modeling assumptions, and the revisions to the Point Flow Tool and assumptions that were made to reflect the collaboration conducted during the Study.

Section 2: Description of the Point Flow Tool

The Point Flow Tool was initially developed by Kenny Fritzler and BC to support evaluations of exchange capacity in 2011 (Colorado Corn Growers Association, et al., 2011). The Point Flow Tool evaluated exchange capacity through each surface water diversion point on the South Platte River from the Burlington Ditch headgate to the Colorado-Nebraska state line. The tool used a daily point flow analysis and call information to determine when and where exchanges could have been run and how much water could have been exchanged through various points on the river during the historical study period which, at that time, ran from October 1999 through September 2008.

The Point Flow Tool is spreadsheet-based and is relatively straightforward to use, update, and adapt for a variety of analyses. Since its creation, the tool has been modified and used to quantify historical unappropriated supplies and exchange capacity for several efforts including the SPBIP and the SPSS.

The characteristics of and the modifications made to the Point Flow Tool for the purposes of the Study are described below.

2.1 Hydrology

A foundational data set in the Point Flow Tool is estimated, historical daily streamflow data for gaging stations and diversion points along the South Platte mainstem and the daily call chronology for the 1996 to 2015 period. Unmeasured gains and losses are calculated and apportioned to river flows based on distance between points of diversion. The tool includes diversions points and river gages along the mainstem of the South Platte River starting at the Denver gage and extending downstream to the Julesburg gage at the state line.

Annual estimates of natural flow at Kersey were used to “index” 1996 to 2015 flow data and create a longer modeling period that extends from 1947 to 1995. The total modeling time period in the current version of the Point Flow Tool is October 1, 1947 through September 30, 2015. While no guarantee of the future, the length of the hydrologic study period provides a wide range of flow and administrative conditions to consider in modeling potential SPROWG operations.

2.2 Reductions to Free River and Exchange Potential

Potential depletions from future water projects

The historical streamflow data described above were adjusted to reflect several future potential projects that would use unappropriated supplies. These adjustments were applied during the preliminary analyses of the SPROWG Concept and were not adjusted for the purposes of the Study:

- Chatfield Re-allocation Project: A monthly depletion schedule associated with operations of the Chatfield re-allocation project was obtained and applied.
- Conditional gravel pit storage: Depletions associated with 90,000 acre-feet of conditional gravel pit storage were reflected with 25 percent of total storage estimated to be filled with available unappropriated supplies occurring during free river conditions in April, May, and June to reflect storage under junior rights. The conditional gravel pit storage volume was obtained from South Platte Basin Implementation Plan.
- Northern Integrated Supply Project: Depletions associated with the Northern Integrated Supply Project were included plus an additional ten percent depletion “contingency”. A monthly depletion schedule was obtained from Northern Colorado Water Conservancy District.

South Platte Compact obligations

The State of Colorado’s obligations pursuant to the South Platte River Compact are incorporated into the model. The model does not allow diversions of unappropriated supplies into SPROWG Concept facilities that would cause South Platte River streamflow at the Colorado-Nebraska state line to fall below 120 cfs during the operative Compact administration dates (April 1 to October 15).

Conditional exchanges

The SPROWG Concept seeks to move water between storage facilities and to demands via exchange. However, numerous conditional exchange rights exist that, to the extent they are exercised in the future, would diminish the availability of exchange capacity. Preliminary modeling of the SPROWG Concept reduced exchange capacity by 150 cfs to accommodate conditional exchanges that may be perfected in the future. However, this estimate was altered for the Study.

During the SPSS, existing conditional exchanges and their associated flow rates in various reaches of the South Platte River were identified, compiled, and aggregated using queries of HydroBase. The results of this analysis are shown in the table below:

Table 1. Compilation of Existing Conditional Exchanges from the SPSS			
Reach	Aggregated Sum of Flow Rates Associated with Conditional Exchanges (cfs)	Conditional Exchange Flow Rates Assuming 25% are Implemented (cfs)	Conditional Exchange Flow Rates Assuming 33% are Implemented (cfs)
Above Denver	1,900	475	627
Denver to Kersey	7,600	1,900	2,508
Kersey to Balzac	1,100	275	363
Balzac to Stateline	1,200	300	396

The data in Table 1 should not be interpreted as a reflection of the exchange capacity that will be consistently used in the future. Conditional exchanges may not be completely perfected. Existing exchange rights owned by various water users will likely not be implemented concurrently. It is currently unknown how much of the future exchange capacity on the South Platte River will be used by the exchanges reflected in Table 1. However, after reviewing the magnitude of the existing conditional exchanges and associated flow rates developed in the SPSS, the Study team increased the allowance for conditional exchanges from 150 cfs to 300 cfs in all reaches in the South Platte River. If, for example, the Point Flow Tool estimated that 350 cfs of exchange capacity existed in a particular reach on a particular day, the future available exchange capacity for the SPROWG Concept would have been reduced from 350 cfs to 50 cfs to allow for potential senior exchanges to take place.

2.3 Water Sources

The SPROWG Concept seeks to conjunctively use several different sources of water supply, and this strategy is reflected in the modeling. The following are the sources of supply that are considered in the Study:

- Unappropriated supplies: Unappropriated native South Platte River flows currently available under historical free river conditions to be diverted under new junior water rights
- Existing unused, reusable return flows: 12,000 AF of legally reusable return flows owned by Denver Water and Aurora Water for which these utilities may not have a use or the capacity to use in the next several decades
- Reuse of SPROWG Concept return flows: Reuse of up to 40 percent of SPROWG project supplies delivered for indoor use (this supply essentially reduces next-day M&I demands)
- Excess recharge credits: Up to 40,000 AF of excess recharge credits[1] primarily originating from recharge operations downstream of the Kersey gage. In average years, only 15,000 AF of excess recharge credits are assumed to be available, and 40,000 AF are assumed to be available in wet years. No excess recharge credits are assumed to be available in dry years.

[1] Recent analyses completed for the Northeast Colorado Water Cooperative indicated that 10,000 af to 20,000 af and 20,000 af to 60,000 af of excess recharge credits may be available in Water District 64 and 1, respectively. These credits are generally available in average and wet years, and approximately 25 percent of the credits may be accruing to the river during free river conditions. The analysis made 50 percent of the excess recharge credits available to the SPROWG Concept. This reduction reflects the portion of the credits that are already a component of the free river in the system, and recognizes that a portion of the credits may be used for agricultural purposes or in other planned projects. This analysis acknowledges that there may be limitations to the use of the excess recharge credits outlined in the augmentation plan decrees, however does not reflect those limitations herein.

- **Alternative Transfer Methods**: Up to 30,000 AF of water derived via ATMs from irrigated land downstream of the Kersey gage. These supplies are assumed to be available only in the driest 30% of the years based on end-of-year total reservoir storage.
- **Denver Basin supplies**: Up to 5,000 AF of non-tributary Denver Basin supplies that can be used if no other supplies are available.

2.4 Water Demands

Locations of Demand

For the purposes of modeling, demands were assumed to occur at a limited number of locations that were conceptualized as "demand gateways". The demand associated with each gateway was considered to be an aggregation of demand from a variety of water providers/users, and it was assumed that if the SPROWG Concept could deliver water to the general locations represented by these gateways, individual water providers could then convey the water from the gateway to their respective water users. The various demand gateways for municipal and agricultural water users are described below. Note that figures depicting the layout of various SPROWG Concept alternatives also show the general locations and amounts of demand that the alternative seeks to meet.

Municipal/Industrial

- **Denver Metro Demand Gateway**: The Denver Metro Demand Gateway was considered to be at the location of the Prairie Waters Project North Campus (PWP). The modeling assumes that, if supply could be delivered to or stored in this general location, it could be conveyed to water users such as Denver, Aurora, South Metro Water Supply Authority members, or Brighton via an expansion in the PWP or through a parallel pumping/conveyance/treatment project. Delivery goals assumed that Denver Metro water providers served through this gateway have relatively mature water portfolios and have relatively low firm yield needs and higher needs during drought conditions when their other supplies are not as plentiful. The modeling also assumes that smaller but rapidly growing communities just north of the Denver Metro area (NoCo-S) could be served at this location and that these communities would have firm yield needs.
- **Northern Colorado Gateway**: The Northern Colorado (NoCo-N) Gateway was considered to be on the South Platte River just downstream of its confluence with the Cache la Poudre River. The NoCo-N Gateway could potentially serve water providers in the Loveland-Greeley area located roughly between US 285 and US 85 along the I-25 corridor. Delivery goals for this gateway assume that firm supplies will be required to support the needs of smaller but rapidly growing municipalities.
- **Eastern Plains**: The modeling assumed that communities along the South Platte River downstream of Kersey would use water supplies for augmentation purposes. As a result, no specific delivery location or gateway was considered for these communities.

Agricultural

- **Agriculture**: Like the Eastern Plains municipal demands, the modeling assumes that agricultural water users would utilize supplies from the SPROWG Concept for agricultural purposes. Consequently, no demand gateway was considered for agricultural water users. However, specific demands were identified in Districts 2, 1, and 64, and the model sought to deliver agricultural supplies to meet the specific needs in those districts using supplies available in various storage vessels.

Amount of Demand – Preliminary Analyses

The preliminary analyses of the SPROWG Concept set a target of providing 50,000 AF/year of consistent yield on average to meet future municipal and industrial demands from communities along the Front Range in the South Platte Basin. It was assumed that communities making up the greater Denver Metropolitan area have relatively mature water portfolios but will still need 10,000 AF of firm yield from a new project and an additional 40,000 AF (for a total of 50,000 AF) in dry years by 2060. The modeling assumed that the additional dry-year water would be provided in the years representing the 25 percent driest during the modeling period of record. SPROWG Concept supplies for the Denver Metro area would be in addition to water supplies from projects and strategies that are currently being pursued. In NoCo, the preliminary analyses recognized that there are several fast-growing communities along the I-25/US-285/US-85 corridor, and these communities will likely need more firm supplies. As a result, the preliminary modeling sought to provide 30,000 AF of firm annual water supply to these communities. Again, the demands in NoCo were considered to be those that will remain after communities implement water projects and supply strategies that they are currently pursuing. In the aggregate, to meet the 50,000 AF/year average consistent yield goal, the model sought to provide 40,000 AF/year of firm yield (10,000 AF/year to the Denver Metro area and 30,000 AF/year to NoCo) and an additional 40,000 AF of dry-year yield in one out of every four years to the Denver Metro area.

The preliminary modeling of the SPROWG Concept also considered agricultural demands. The modeling sought to meet agricultural demands with remaining yield (after meeting municipal and industrial demands) in average and dry years in Water Districts 2 and 1. While not fully met, an annual agricultural demand target of 10,000 AF, depending on year type, was distributed between Water Districts 1 and 2 and disaggregated across the irrigation season based on estimated crop shortages derived from the SPDSS StateCU analysis. Inclusion of the agricultural demands in the preliminary modeling reflected the future potential involvement of agricultural users in the SPROWG Concept. However, modeled demands of 10,000 AF/year in Water Districts 1 and 2 represent only a fraction of the agricultural shortages experienced by users in the South Platte Basin.

Amount of Demand – Current Analyses

The amount of demand for both municipal/industrial and agricultural water users varied in each of the SPROWG Concept alternatives evaluated in the Study. The demands, or delivery goals, for each alternative are described in Section 3. Below, however, are some overarching considerations that were used in developing the demands and delivery goals for each alternative:

- The 50,000 AF/year consistent delivery goal for Front Range communities in the South Platte Basin was adopted for most alternatives. The results of the survey that was distributed to municipal and industrial water providers tended to verify that this delivery goal is still valid.
- The survey suggested that 10,000 AF/year of the 30,000 AF/year initially identified for NoCo communities could potentially be provided from a location near the Denver Metro Demand Gateway. As a result, NoCo demands were split in the modeling with 20,000 AF/year being delivered to the NoCo-N Demand Gateway and 10,000 AF/year being delivered to the Denver Metro Demand Gateway.
- The survey identified approximately 2,000 AF of firm annual demand from smaller communities along the South Platte River downstream of Greeley. These demands were considered to be a minimum. Additional municipal demands from smaller communities were considered in several alternatives (see descriptions of alternatives in Section 3 for specific information on delivery goals). The additional municipal delivery goals were developed based on the results of the recently-completed Technical Update to Colorado's Water Plan and the amount of supply that the infrastructure in each alternative could reliably provide.
- Agricultural delivery goals were, at a minimum, consistent with the goals in the preliminary analyses of the SPROWG Concept (i.e. up to 10,000 AF/year when supplies are available). The monthly distribution

of agricultural demands was altered during the Study to be consistent with augmentation demands, which reflected the results of the survey and discussions with agricultural water users. Additional agricultural demands and delivery goals were considered in several alternatives. The additional delivery goals were based on the agricultural water supplies that could be reliably provided by the infrastructure considered in each alternative.

2.5 Other Modeling Assumptions and Operations

The modeling conducted for the Study incorporated a wide variety of assumptions regarding SPROWG Concept operations. Future analyses of the SPROWG Concept should review these assumptions to verify that they are still pertinent and consistent with how participants would construct and operate the eventual project.

Municipal Demands and Supplies

- The analysis assumes that municipal water providers would implement water conservation strategies (such as watering restrictions) to reduce demands during drought conditions. As a result, municipal/industrial delivery goals were considered to be met if supplies were adequate to meet at least 90% of the demand in each year of the analysis.
- Reusable municipal return flows from Denver Water and Aurora Water, SPROWG Concept reusable supplies, and storage are allocated pro-rata to municipal demands, which reflects a sharing of project supplies and shortages across both demand gateways.
  - Only half of Denver Metro demand can be met with unappropriated supply, which in many cases allows unappropriated supplies to run down the river to meet NoCo-N demands or to be stored in downstream storage facilities. While this operational protocol could result in some inefficiencies (e.g. increased transit losses), it reflects an allowance that downstream uses and storage facilities may have a more senior priority than upstream water uses, and it also reflects cooperative use of facilities.
  - Exchanges to the Denver Metro Demand Gateway are given priority in the model over exchanges to the NoCo-N Demand Gateway.
- Reuse of return flows generated from future NISP deliveries were not accounted for in the model.
- Non-tributary Denver Basin supplies were modeled as the last supply to be accessed and are allocated only to meet Denver Metro demand.

Agricultural Demands and Supplies

- Agricultural demands were met only from proposed storage near Kersey in Alternative 1 (see Section 3 for more information). This restriction was imposed to lessen the draw on storage facilities near Henderson, assuming that storage in this area will potentially be relatively expensive to site and construct. In Alternatives 2, 3, and 4, agricultural demands were met from any of the storage facilities included in the alternative.
- Consistent with Initial Concept C, agricultural demands were met with available supplies after municipal demands were met. In addition, the size of storage facilities in the model considered agricultural water needs, but the storage facilities were not increased to a size that would provide yields to consistently meet agricultural delivery goals. In other words, the modeling sought to supply firm yield to municipal water users and as much water to agricultural water users as could be provided with reasonably-sized infrastructure.
- ATM and excess recharge credit supplies are stored only in proposed storage near Kersey, Fort Morgan and Julesburg. They are not modeled as a direct supply to either meet demands or stored in proposed storage near Henderson.

Infrastructure and Conveyance

- All storage facilities are assumed to be off-channel. Contemplated storage facilities near Henderson are assumed to be filled through gravity-fed canals, whereas storage near Kersey and Fort Morgan is assumed to be filled through a pump from the South Platte River[2].
- Storage in proposed storage facilities was reduced for evaporative losses (approximately 33 in/yr). These evaporative losses would be conservative (and potentially overstated) if aquifer storage and recovery (ASR) strategies were incorporated as a component of the storage facilities at various locations.
- Transit losses of SPROWG Concept deliveries, conveyance losses to storage, or seepage from proposed reservoirs were not incorporated into the modeling.
- The modeling assumes that exchange bypasses will be constructed at the Jay Thomas/Hewes Cook and North Sterling diversion locations. These two diversions have frequently dried-up the South Platte River and would be a significant deterrent to running exchanges. The model does not limit the size of the exchange bypasses. They would eventually need to be sized based on the flow rate of water to be exchanged through them.

Section 3: Concept Alternatives and Modeling Results

The modeling objectives of the Study are to refine delivery goals, the configuration of the infrastructure components, and operational strategies to explore a range of potential needs that the SPROWG Concept could meet both from water supply and environmental/recreation perspectives. Section 3 of this technical memorandum describes SPROWG Concept alternatives and refinements and provides a summary of the modeling results and conclusions for each alternative.

The scope of work for the Study specified that up to four SPROWG Concept alternatives would be evaluated. The alternatives were developed first using Initial Concept C as a “baseline” and then refining/adding demands based on the feedback from outreach activities with stakeholders, guidance from the Advisory Committee, input from the Task Force, and consideration of other studies such as the Technical Update to Colorado’s Water Plan. The alternatives do not each have the same delivery goals. Rather, each successive alternative, in general, builds upon and adds to the delivery goals and infrastructure included in the prior alternative. The following is a list of the alternatives and a general description of how they build upon one another (more detail on each alternative is subsequently included in Section 3).

- Alternative 1: Refine the Initial Concept – Alternative 1 has generally the same overall delivery goals and infrastructure as Initial Concept C, but refinements based on outreach feedback were incorporated.
- Alternative 2: Balzac First – Alternative 2 examines a scenario in which a storage facility downstream of Fort Morgan (near Balzac) is the primary facility from which deliveries are made. In addition, this alternative sets higher delivery goals for small municipalities downstream of Kersey. Denver Metro and NoCo-N demands are the same as Alternative 1.
- Alternative 3: Add Julesburg Storage - Alternative 3 builds on Alternative 2 by adding another storage facility near the Colorado-Nebraska state line and increasing delivery goals for agriculture and small municipalities downstream of Kersey. Denver Metro and NoCo-N demands are the same as Alternative 1.
- Alternative 4: Additional Delivery – Alternative 4 builds on Alternative 3 by increasing delivery goals by 25 percent throughout the South Platte Basin and increasing storage facilities to meet the demands.

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[2] As an alternative, a storage facility near Fort Morgan could be filled by means of installing a pumping plant at Prewitt Reservoir and constructing a pipeline to the storage facility, thereby taking advantage of Prewitt’s high-capacity inlet (over 600 cfs).

Each alternative represents one particular set of delivery goals and infrastructure, but it is likely that the alternatives could be further refined in the future as water needs and potential participants evolve in the future.

3.1 Alternative 1: Refine the Initial Concept

Alternative 1 was entitled "Refine the Initial Concept" and is meant to build on previous SPROWG Concept analyses by incorporating refinements to Initial Concept C derived from Study outreach and collaboration. Similar to Initial Concept C, the intent of Alternative 1 was to utilize direct releases to the river and exchange capacity to delivery SPROWG water to various demand gateways via direct delivery or exchange without the need for pumping stations and pipelines.

Alternative 1 delivery goals and infrastructure are shown in Figure 1. Additional detail on demands, infrastructure and operations provided after the figure.

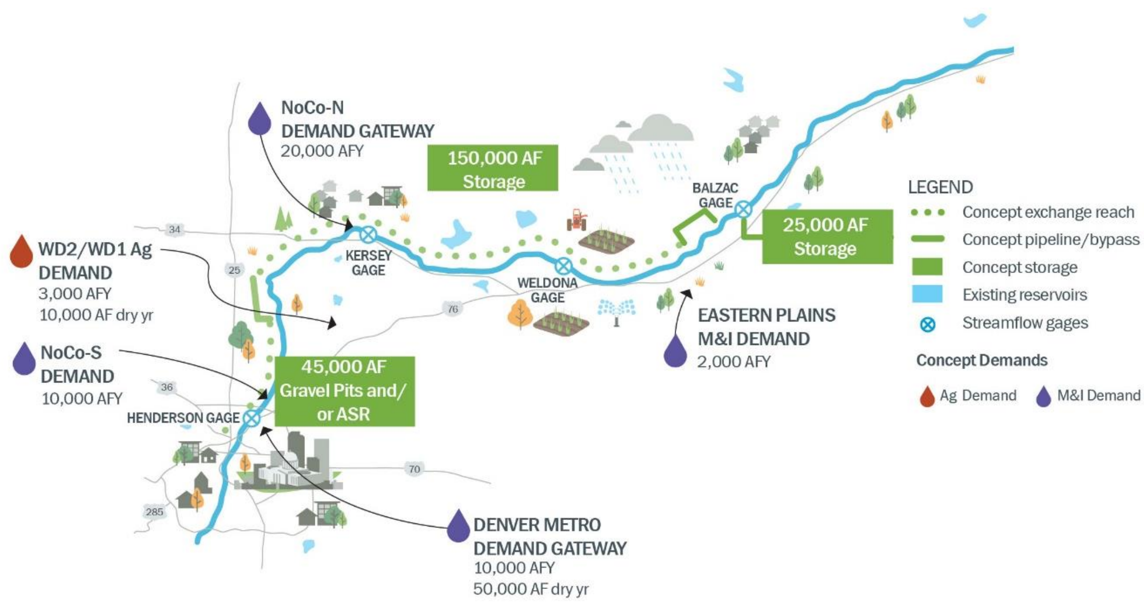


Figure 1. Schematic of Alternative 1 Delivery Goals and Infrastructure

Delivery Goals

Alternative 1 delivery goals were based in part on SPROWG Concept goals associated with Initial Concept C, and in part on feedback during outreach activities during the current Study. Similar to Initial Concept C, Denver Metro area water providers were assumed to have a more mature water supply portfolio, and so will need less water on a constant basis but have a large demand in dry years when other rights experience low yields. The developing communities north of the Denver Metro area need more firm yield supply in all hydrologic conditions. The demands for the Denver Metro and NoCo regions were consistent with those described in Section 2.4 and total 50,000 AF/year on average (with variations in demand during dry vs normal and wet years).

Initial Concept C sought to provide 30,000 AF/year of firm yield to growing communities in NoCo at the NoCo-N Demand Gateway. However, the M&I outreach effort suggested that M&I demand north of the Denver Metro area could be split between two general regions: municipalities just north of the Denver Metro area, and municipalities further north in the Greeley/Loveland/Ft. Collins area. To understand the sensitivity of the model to demands at the two municipal demand gateways, a variation on Alternative 1 was developed that split the NoCo demands and sought to deliver one-third of the NoCo demand to the Denver Metro

Demand Gateway and two-thirds of the NoCo demand to the NoCo-N Demand Gateway. The modeling results for the variation of Alternative 1 did not indicate that splitting the NoCo demands would impact reliability or the size of needed infrastructure. The Study team and Advisory Committee felt that it is more likely that the NoCo demands would be supplied from two locations rather than one. As a result, the delivery locations for NoCo firm yield demands were modeled at the NoCo-N Demand Gateway (20,000 AF/year) and at the Denver Metro Demand Gateway (10,000 AF/year).

In addition to Front Range water demands, an additional municipal water demand was added for communities on the Eastern Plains of 2,000 AF/year based on the results of stakeholder outreach. The demand was assumed to be for augmentation of additional well pumping, rather than for direct diversion to municipal supply.

Also similar to Initial Concept C, agricultural demands were included in Alternative 1 and were met after deliveries were made to M&I water providers. Consistent with Initial Concept C, agricultural demands totaled 3,000 AF in all years with an additional 7,000 AF in dry years (for a total dry-year demand of 10,000 AF). Agricultural demands were split between Districts 2 and 1 using a 3:1 ratio based on information gathered during the agricultural outreach, which indicated much higher demand in WD 1 than WD2.

The delivery goals for this alternative are summarized in Table 2.

Table 2. Alternative 1 Delivery Goals

M&I Demands (AF)			Agricultural Demands (AF)	
Denver Metro (avg/dry)	Northern Colorado (avg/dry)	Eastern Plains (avg/dry)	Water District 2 (avg/dry)	Water District 1 (avg/dry)
20,000/60,000	20,000/20,000	2,000/2,000	750/2,500	2,250/7,500

Infrastructure and Operations

The infrastructure for Alternative 1 is based on Initial Concept C, with storage at Henderson, Kersey and downstream of Fort Morgan near Balzac. No pumping stations or pipelines were included in Alternative 1 modeling, which is also consistent with Initial Concept C.

The storage facility at Kersey was simulated as a “hub” of operations in the following ways:

- All agricultural demands were met from storage at Kersey.
- When space was available and exchange capacity existed, water stored downstream of Fort Morgan near Balzac was exchanged up to Kersey.
- NoCo-N Demand Gateway demands not met by unappropriated or reusable supplies were primarily met from Kersey.
- If adequate exchange capacity existed between Kersey and the Denver Metro Demand Gateway, Denver Metro demands were met from storage at Kersey and then available storage at Henderson (after unappropriated and reusable supplies were used).

While siting or designing specific storage facilities was beyond the scope of the Study, the potential storage sites investigated as part of the SPSS informed the feasibility of storage options, potential storage volumes at each site, operations, and potential costs (note that potential costs are described in a different Technical Memorandum). The modeled storage capacities and contemplated types of storage at each location are shown in Table 3. As noted earlier, storage volumes shown in Table 3 were informed by the SPSS, but they were primarily derived based on modeling results and the amount of storage needed to meet demands.

Table 3. Alternative 1 Infrastructure		
Henderson Storage	30,000 AF (gravel pit storage)	15,000 AF (Lost Creek ASR)
Kersey Storage	150,000 AF (Sanborne Reservoir Site)	
Balzac Storage	25,000 AF (Fremont Butte Reservoir Site)	

As shown in Table 3, storage at Henderson was divided between gravel pit storage and ASR in the Lost Creek designated basin. Several stakeholders have expressed concern about the lack of available sites on which to build gravel pit storage facilities along the South Platte River in the vicinity of Henderson. The Study team conducted outreach to gravel companies and large municipal water providers who own existing gravel pits to investigate their general sense of how much gravel pit storage could be developed as a part of the SPROWG Concept. After considering the feedback from the outreach and discussing it with the Advisory Committee, the Study team concluded that 30,000 AF of additional gravel pit storage would be assumed for costing purposes. The Study team assumed that additional storage in the Henderson area beyond 30,000 AF could come from ASR in the Lost Creek basin (which was a strategy investigated in the SPSS).

Summary of Modeling Results

The Point Flow Tool was used to simulate SPROWG Concept operations based on the demands and infrastructure described above. The infrastructure was sized to meet municipal and agricultural demands per the criteria described previously. Table 4 summarizes the results of the modeling and the performance of Alternative 1.

Table 4. Summary of Alternative 1 Modeling Results		
Municipal	Number of years M&I demands fully met	64
	Number of years M&I demands not fully met	5
	Average M&I demand not met (when this occurs)	1,600 AF
	Max M&I demand not met (in AF and percent of total demand)	4,300 AF (5% of dry-year demand)
	Average Denver Basin supply in dry years	3,000 AF
Agricultural	Water District 2 demand met	9%
	Water District 1 demand met	97%
Infrastructure	Number of years Henderson storage fully depleted	2
	Number of years Kersey storage fully depleted	5
	Number of years Fort Morgan storage fully depleted	0

Figure 2 shows the modeled end-of-day content for the storage facilities at Kersey, Henderson, and downstream of Fort Morgan near Balzac.

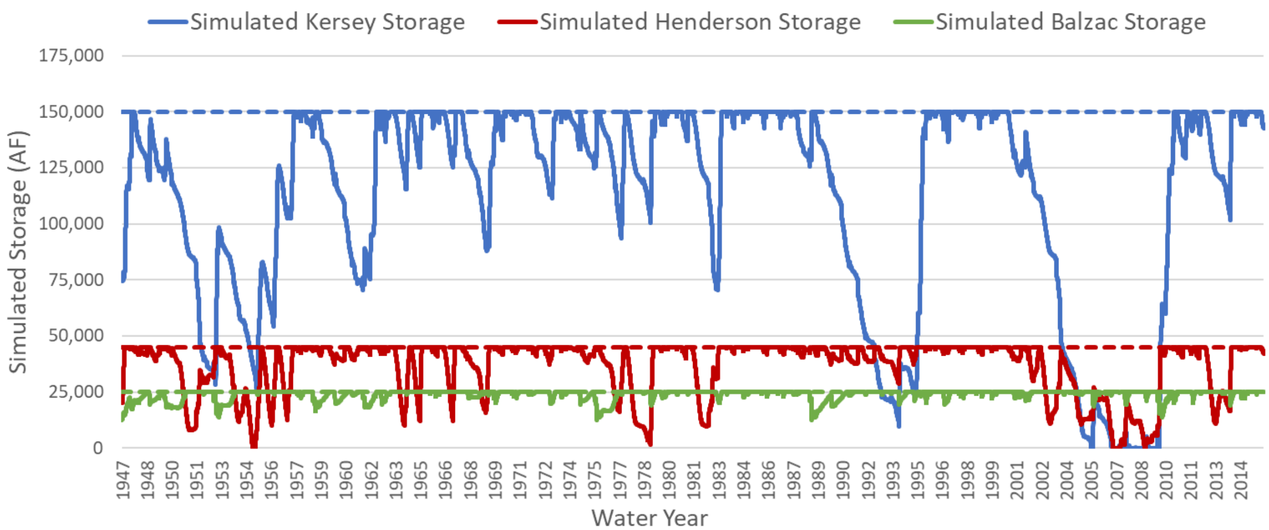


Figure 2. Modeled End-of-Day Storage for Facilities Included in Alternative 1

Observations and Conclusions

Below are several observations and conclusions regarding the modeling results for Alternative 1:

Municipal/Industrial

- Alternative 1 was simulated to meet 90% or more of the municipal demand in every year.
- Municipal demands were not fully met in only 5 of the 69 years of simulation. The maximum amount of demand that was not met was 4,300 AF, and this was simulated to occur in 2006 during the severe drought of the early 2000s. The amount of demand not met in that year was 5% of the dry-year municipal delivery goal.

Agricultural

- Agricultural demands in Water District 1 were simulated to be met nearly all of the time.
- Agricultural demands in Water District 2 were met only 9% of the time during the modeling period. The difficulty in meeting Water District 2 agricultural demands was due to limitations on exchange capacity because of the allowance for existing conditional exchanges and the criteria for releasing water from storage at Henderson to only meet municipal demands. A variation of Alternative 1 was developed to allow releases from Henderson storage to meet agricultural demands in District 2, but the size and likely cost of infrastructure necessary to meet those needs were very large. While Alternative 1 modeling did not meet much agricultural demand in Water District 2, other alternatives performed significantly better.

Infrastructure and Conveyance

- Necessary storage volumes at Henderson and downstream of Fort Morgan were similar in Alternative 1 to Initial Concept C. However, the storage volume at Kersey was 150,000 AF compared to 100,000 AF in Initial Concept C. The additional storage volume at Kersey was needed primarily due to the additional allowance the Study considered for existing conditional exchanges. Initial Concept C reduced exchange capacity by 150 cfs to allow for conditional exchanges that may be implemented in the future, whereas this Study reduced exchange capacity by 300 cfs. The increased allowance for existing conditional exchanges restricted the ability to move unappropriated supplies upstream to meet demands or move water upstream between storage facilities. Additional storage was needed at Kersey to stage supplies and exchange them to demands or upstream storage when adequate exchange capacity was available.

- A variation of Alternative 1 was developed that assumed a pumping station and pipeline would be constructed between Kersey and Henderson to eliminate reliance on exchange between these two facilities. The pipeline would allow water to freely move from Kersey to Henderson and would reduce the amount of storage required at Henderson. Conveyance infrastructure like this could be considered in the future if adequate gravel pit storage at Henderson is unavailable, ASR in the Lost Creek basin becomes cost prohibitive or otherwise infeasible, or the allowance of 300 cfs to accommodate existing conditional exchanges is not sufficient.
- Drought conditions and resulting lack of unappropriated supplies coupled with higher dry-year demands depleted storage in Kersey and Henderson during the drought of the early 2000s. The amount of storage needed to meet demands was heavily influenced by the conditions simulated during this drought.

3.2 Alternative 2: Balzac First

Alternative 2 was named "Balzac First" because it assumes that the storage facility downstream of Fort Morgan near Balzac will be the hub of operations as opposed to the storage facility near Kersey. Alternative 2 builds upon Alternative 1, but with two key differences:

- It increases contemplated storage at Balzac (and decreases storage at Kersey)
- It adds the Denver Metro pipeline from Balzac storage back to Henderson.

These refinements served to make Balzac the "hub" of operations because of its ability to benefit from additional free river supplies resulting from agricultural return flows, its central location relative to agricultural water users that could potentially participate in ATMs, and the ability to use the Denver Metro pipeline to circumvent limited exchange capacity and convey water upstream to the top of the system for release to the demand gateways.

Alternative 2 delivery goals and infrastructure are shown in Figure 3. Additional detail on demands, infrastructure and operations are provided after the figure.

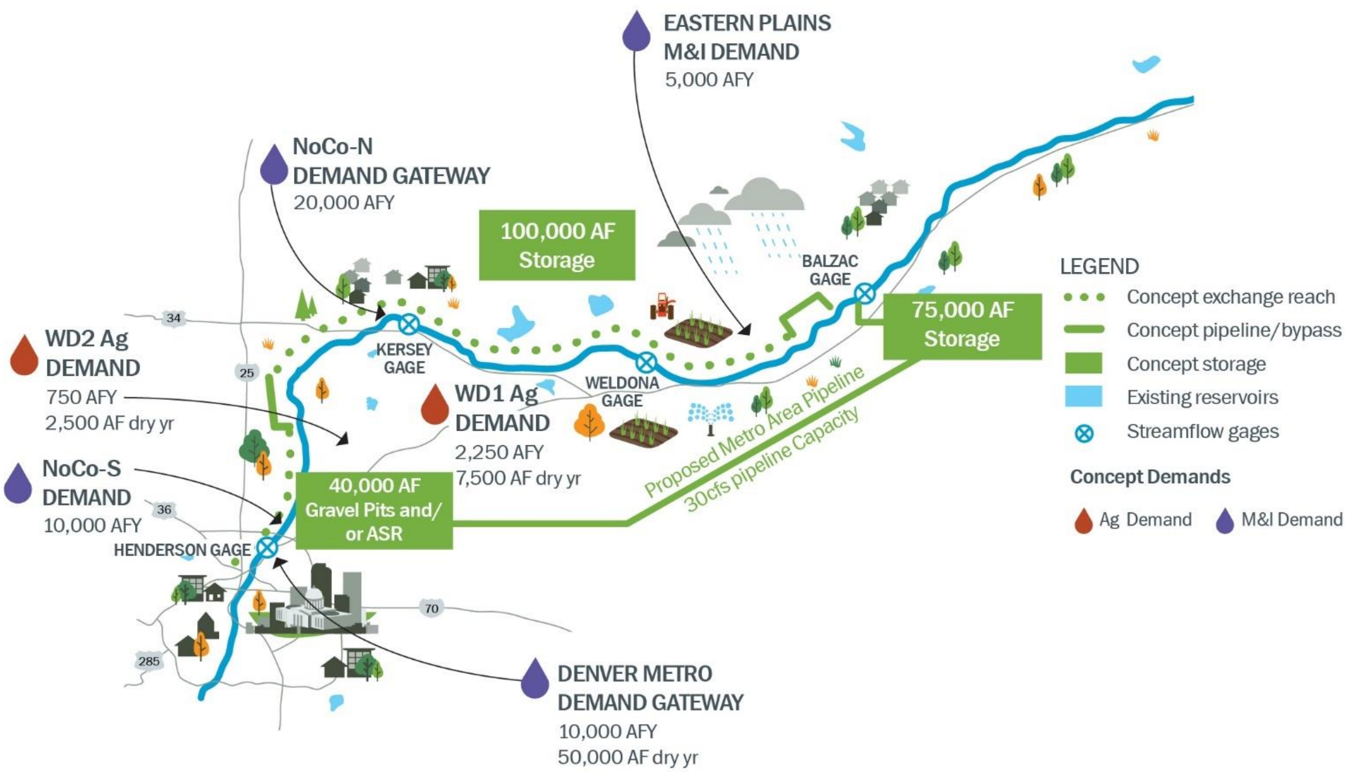


Figure 3. Schematic of Alternative 2 Delivery Goals and Infrastructure

Delivery Goals

Delivery Goals for Alternative 2 were the same as Alternative 1 for South Platte Basin municipalities along Front Range. However, Alternative 2 sought to provide additional M&I deliveries to Eastern Plains municipalities (see Table 5) given the increased use and storage capacity at Balzac.

Initial modeling of Alternative 2 included higher agricultural delivery goals in Water Districts 2 and 1 than Alternative 1, but the higher goals could not be met with the size of infrastructure contemplated in Alternative 2. As a result, the agricultural delivery goals in Alternative 2 for Water Districts 2 and 1 were the same as in Alternative 1.

Table 5. Alternative 2 Delivery Goals

M&I Demands			Agricultural Demands	
Denver Metro (avg/dry)	Northern Colorado (avg/dry)	Eastern Plains (avg/dry)	Water District 2 (avg/dry)	Water District 1 (avg/dry)
20,000/60,000	20,000/20,000	5,000/5,000	750/2,500	2,250/7,500

Infrastructure and Operations

As described previously, the infrastructure associated with Alternative 2 is similarly located with respect to Alternative 1, but storage volumes are different, and Alternative 2 includes a pipeline from the Balzac storage area back to the Henderson storage area.

The Denver Metro pipeline included in Alternative 2 offers the advantage of circumventing the exchange capacity issues described in Alternative 1 and allows deliveries to be made from the Balzac area directly to Denver Metro water providers. It also allows supplies from downstream to be conveyed to an upstream location for release to NoCo-N demands.

Storage at Kersey is lower in Alternative 2 than in Alternative 1, because storage at Balzac was increased and the Denver Metro pipeline can be used to meet demands in Alternative 2 that were previously being met by storage at Kersey in Alternative 1.

The modeled storage capacities and contemplated types of storage at each location are shown in Table 6. As noted earlier, storage volumes shown in Table 6 were informed by the SPSS, but they were primarily derived based on modeling results and the amount of storage needed to meet demands. As with Alternative 1, Lost Creek ASR was assumed to provide storage at Henderson that exceeds the 30,000 AF from gravel pits.

Table 6. Alternative 2 Infrastructure		
Henderson Storage	30,000 AF (gravel pit storage)	10,000 AF (Lost Creek ASR)
Kersey Storage	100,000 AF (Sanborne Reservoir Site)	
Balzac Storage	75,000 AF (Fremont Butte Reservoir Site)	
Denver Metro Pipeline	30 cfs pipeline from Balzac to Henderson	

Summary of Modeling Results

The Point Flow Tool was used to simulate SPROWG Concept operations based on the demands and infrastructure described above. The infrastructure was sized to meet municipal and agricultural demands per the criteria described previously. Table 7 summarizes the results of the modeling and the performance of Alternative 2.

Table 7. Summary of Alternative 2 Modeling Results		
Municipal	Number of years M&I demands fully met	66
	Number of years M&I demands not fully met	3
	Average M&I demand not met (when this occurs)	90 AF
	Max M&I demand not met (in AF and percent of total demand)	130 AF (<1% of dry-year demand)
	Average Denver Basin supply in dry years	0 AF
Agricultural	Water District 2 demand met	100%
	Water District 1 demand met	98%
Infrastructure	Number of years Henderson storage fully depleted	0
	Number of years Kersey storage fully depleted	4
	Number of years Fort Morgan storage fully depleted	3

Figure 4 shows the modeled end-of-day content for the storage facilities at Kersey, Henderson, and downstream of Fort Morgan near Balzac.

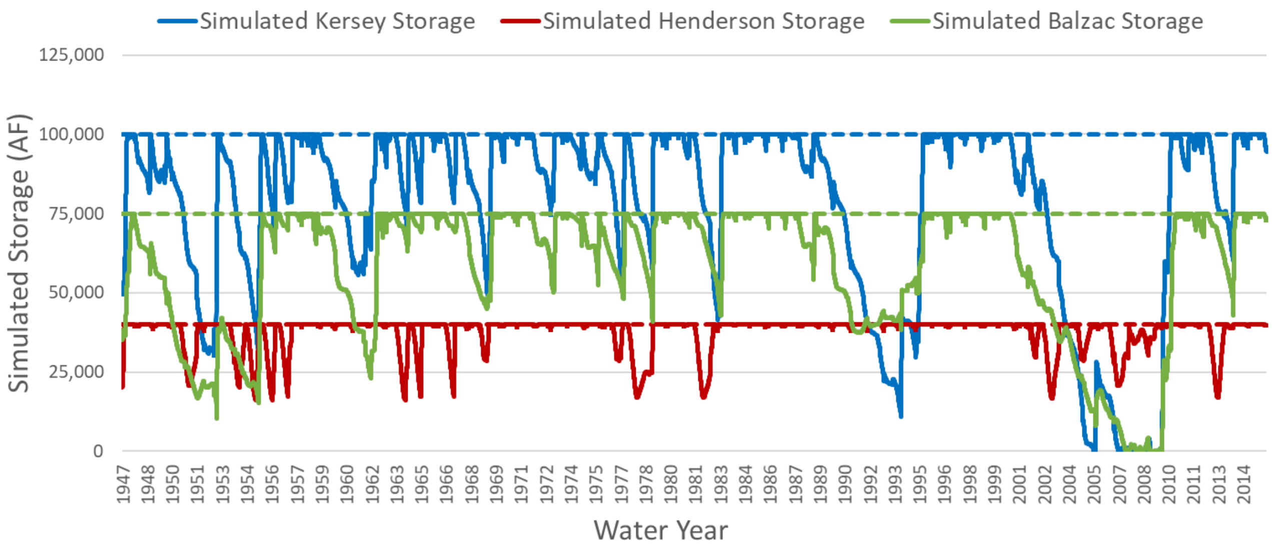


Figure 4. Modeled End-of-Day Storage for Facilities Included in Alternative 2

Observations and Conclusions

Below are several observations and conclusions regarding the modeling results for Alternative 2:

Municipal/Industrial

- Nearly all municipal demand was simulated to be met all the time.
- Initial modeling of Alternative 2 included higher municipal delivery goals for municipalities on the Eastern Plains. However, the size of contemplated infrastructure was inadequate to meet the increased need, and the delivery goals were reduced. Even with the reduction, however, Eastern Plains municipal delivery goals and met demands are greater than Alternative 1.

Agricultural

- Agricultural demands were met nearly all of the time in Alternative 2.
- Initial modeling of Alternative 2 included higher agricultural delivery goals in Districts 2 and 1. However, the size of contemplated infrastructure was inadequate to meet the increased need, and the delivery goals were reduced to the same levels as Alternative 1.
- Initial modeling of Alternative 2 did not allow releases from Henderson to meet agricultural demands in District 2. The model was revised to provide agricultural water supplies from Henderson, and the performance in meeting these demands improved greatly, because they could be met via releases from storage rather than by exchange from downstream sources. This model revision was also adopted in Alternatives 3 and 4.

Infrastructure and Conveyance

- Exchange capacity issues associated with Alternative 1 were somewhat relieved in Alternative 2, because municipal supplies can be directly delivered to Denver Metro water providers without the exchange capacity restrictions between Kersey and Henderson. Exchange capacity is still a limitation, however, in moving water upstream from Balzac to Kersey storage and in exchanging water from Kersey upstream to Henderson (which has diminished importance with the pipeline).
- Various Denver Metro pipeline capacities were simulated, and 30 cfs seemed to provide the best operational performance of capacities simulated. At a lower capacity the Denver Metro demands were not

adequately met. At a higher capacity, too much water was removed from Balzac storage, and Eastern Plains demands could not be sufficiently met.

- Storage levels at Balzac fluctuate more than in Alternative 1 due to the greater reliance on Balzac storage to directly meet demand. Simulated storage at Balzac was greatly drawn-down during the drought of the 2000s.
- Alternative 2 has less total storage than Alternative 1, but 50,000 AF of storage was shifted from Kersey to Balzac.

3.3 Alternative 3: Add Julesburg Storage

Alternative 3, “Add Julesburg Storage,” builds on Alternative 2 with the addition of a storage facility near Julesburg and the Colorado-Nebraska state line. Other storage and conveyance infrastructure included in Alternative 3 were the same size as in Alternative 2. Many delivery goals were the same as in Alternative 2, but some increased due to the additional storage.

While not explicitly modeled as a part of Initial Concept C, the consideration of new storage near Julesburg has been both explored in other studies and was contemplated during the preliminary discussions of the SPROWG Concept. Alternative 3 was developed to evaluate the benefit of this additional storage facility.

Alternative 3 delivery goals and infrastructure are shown in Figure 5. Additional detail on demands, infrastructure and operations are provided after the figure.

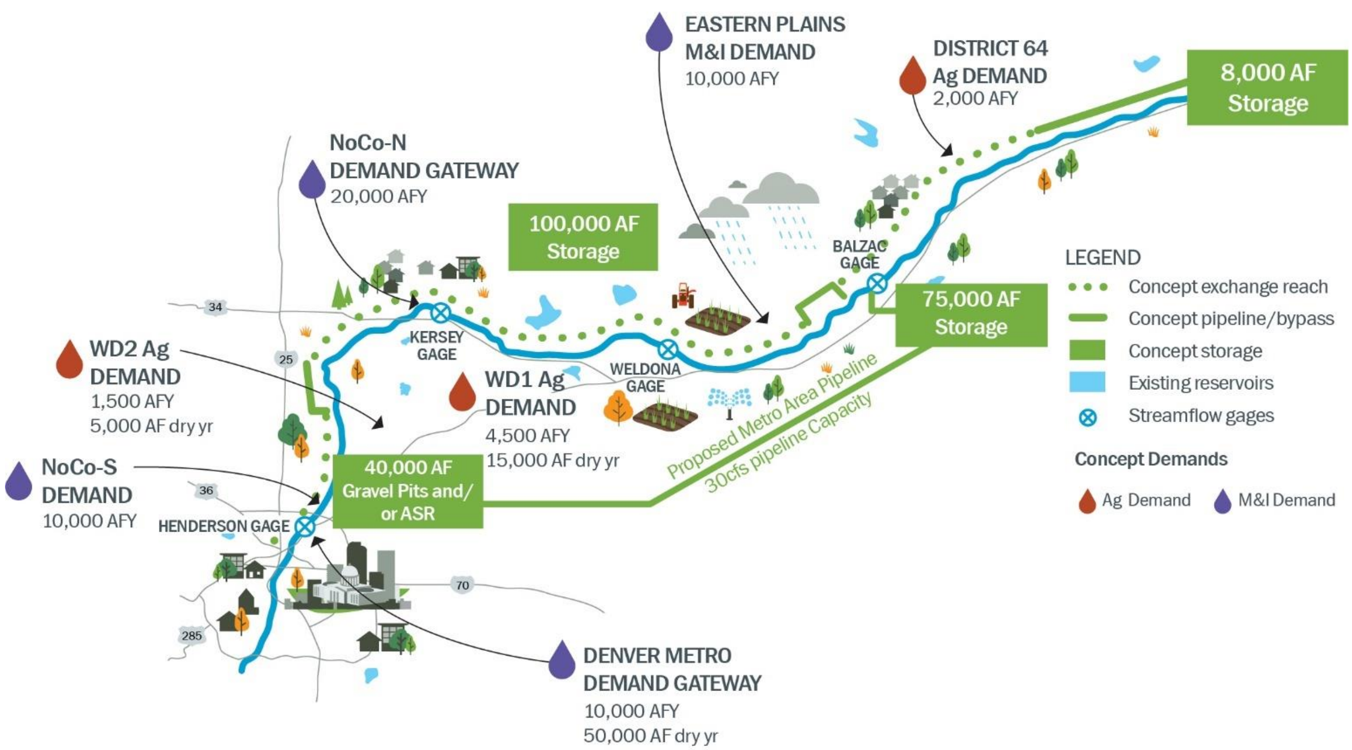


Figure 5. Schematic of Alternative 3 Delivery Goals and Infrastructure

Delivery Goals

Front Range municipal delivery goals were the same as in Alternative 2, but Eastern Plains municipal and agricultural delivery goals were increased due to the additional downstream storage at Julesburg. The delivery goals are shown in Table 8.

As with Alternative 2, the Eastern Plains municipal and agricultural delivery goals were initially higher than the values shown in Table 8. The delivery goals were reduced to levels that could be supported by the Alternative 3 infrastructure depicted in Figure 5. Even with the downward adjustments, however, the delivery goals in Alternative 3 for Eastern Plains municipal and agricultural users are twice that of Alternative 2.

Table 8. Alternative 3 Delivery Goals

M&I Demands			Agricultural Demands		
Denver Metro (avg/dry)	Northern Colorado (avg/dry)	Eastern Plains (avg/dry)	Water District 2 (avg/dry)	Water District 1 (avg/dry)	Water District 64 (avg/dry)
20,000/60,000	20,000/20,000	10,000/10,000	1,500/5,000	4,500/15,000	2,000/2,000

Infrastructure and Operations

The only infrastructure change in Alternative 3 compared to Alternative 2 is the new storage in the Julesburg area. Exchange capacity is limited from Julesburg upstream to other water users or storage facilities because of diversions such as the Harmony Ditch, which frequently creates a dry-up point in the river (resulting from the legal operation of their water rights). The modeling assumed that a pipeline could be used to convey releases from the Julesburg storage site to just upstream of the Harmony Ditch, thereby avoiding the exchange limitation and providing a greater ability to meet demands in Water District 64. See Table 9 for a summary of Alternative 3 infrastructure.

Table 9. Alternative 3 Infrastructure

Henderson Storage	30,000 AF (gravel pit storage)	10,000 AF (Lost Creek ASR)
Kersey Storage	100,000 AF (Sanborne Reservoir Site)	
Balzac Storage	75,000 AF (Fremont Butte Reservoir Site)	
Julesburg Storage	8,000 AF (Ovid Reservoir Site) with pipeline to release above Harmony Ditch	
Denver Metropolitan Pipeline	30 cfs pipeline from Balzac to Henderson	

Summary of Modeling Results

The Point Flow Tool was used to simulate SPROWG Concept operations based on the demands and infrastructure described above. The infrastructure was sized to meet municipal and agricultural demands per the criteria described previously. Table 10 summarizes the results of the modeling and the performance of Alternative 3.

Table 10. Summary of Alternative 3 Modeling Results		
Municipal	Number of years M&I demands fully met	64
	Number of years M&I demands not fully met	5
	Average M&I demand not met (when this occurs)	120 AF
	Max M&I demand not met (in AF and percent of total demand)	380 AF (<1% of dry-year demand)
	Average Denver Basin supply in dry years	0 AF
Agricultural	Water District 2 demand met	100%
	Water District 1 demand met	95%
	Water District 64 demand met	100%
Infrastructure	Number of years Henderson storage fully depleted	0
	Number of years Kersey storage fully depleted	6
	Number of years Fort Morgan storage fully depleted	5
	Number of years Julesburg storage fully depleted	0

Figure 6 shows the modeled end-of-day content for the storage facilities at Kersey, Henderson, downstream of Fort Morgan near Balzac, and Julesburg.

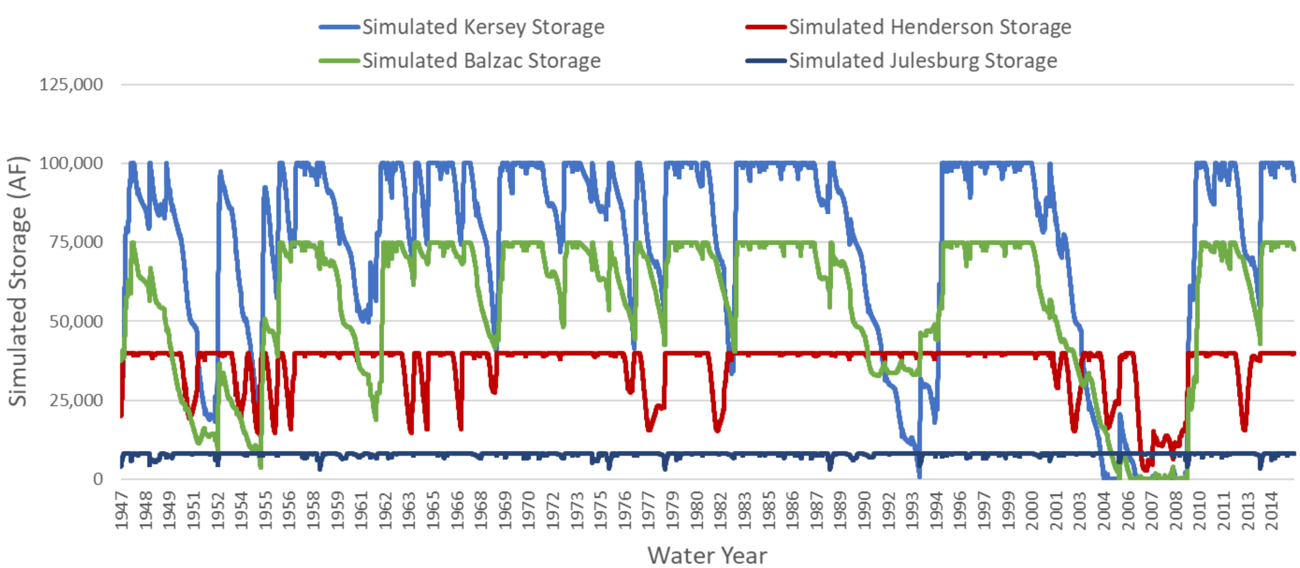


Figure 6. Modeled End-of-Day Storage for Facilities Included in Alternative 3

Observations and Conclusions

Below are several observations and conclusions regarding the modeling results for Alternative 3:

Municipal/Industrial

- Nearly all municipal demand was simulated to be met all the time.
- As stated previously, initial modeling of Alternative 3 included higher municipal delivery goals for municipalities on the Eastern Plains. However, the size of contemplated infrastructure was inadequate to meet

the increased need, and the delivery goals were reduced. Even with the reduction, however, Eastern Plains municipal delivery goals and met demands were twice that of Alternative 2.

Agricultural

- Agricultural demands were met nearly all of the time in Alternative 3.
- Initial modeling of Alternative 3 included higher agricultural delivery goals in Districts 2 and 1. However, the size of contemplated infrastructure was inadequate to meet the increased need, and the delivery goals were reduced to levels that could be reliably met. Even with the reduction, however, District 2 and 1 delivery goals and met demands were twice that of Alternative 2.
- The modeling suggested that at least 2,000 AF/year of agricultural demand could be met on a firm basis in WD 64. It is possible that more demand could be met in average and wet years if lower deliveries could be tolerated in drier years.

Infrastructure and Conveyance

- Water is readily available for the Julesburg-area reservoir due to the presence of return flows and lack of downstream calls. As a result, it remained full most of the time in the modeling simulation.
- The Julesburg-area reservoir was primarily used to meet local (Water District 64) demands. The pipeline from the reservoir to above the Harmony Ditch played a key role in overcoming exchange capacity issues and delivering water to users. Without the pipeline, exchange limitations could prevent delivery of water to District 64 users upstream of the reservoir or exchange water released from storage into Balzac Reservoir.
- Balzac-area storage can meet more Water District 1 demands when downstream demands in District 64 are met with Julesburg-area storage.

Alternative Delivery of Water for Agriculture

A variation of the Alternative 3 model was developed to explore the potential benefits of changing the pattern in which deliveries are made to agricultural water users. In all of the alternatives, more water is delivered to agricultural water users in dry years than in average and wet years. This delivery pattern is logical in that agricultural water demands are higher in dry years, and water supplies are lower. However, the outreach conducted with agricultural water users suggested that their demands are generally for well augmentation rather than direct diversion. Most augmentation plans rely partially or heavily on alluvial aquifer recharge as source of augmentation supply. Agricultural water users could benefit if SPROWG Concept supplies could be delivered to recharge basins during wet years and in locations that have lengthy lag times, resulting in recharge credits several years in the future when dry conditions may potentially exist.

To explore this, agricultural delivery goals in the Point Flow Tool were changed in Districts 2 and 1 to reflect greater demands in wet and average years (20,000 AF) and less during dry years (6,000 AF). Note that District 64 demands in Alternative 3 were the same under all hydrologic conditions. Providing water under this delivery protocol would require that recharge basins be constructed at strategic locations with lag times that would benefit augmentation plans. The construction of additional recharge basins was not included in the SPROWG Concept cost estimates and is not considered to be a part of Alternative 3.

Results under this alternative delivery for agricultural water show that increasing deliveries to ag in years when water is more plentiful greatly increases overall yield of ag water (by approximately 5,000 AF per year). Therefore, providing additional delivery to agriculture (and retiming that water through recharge) could be an important part of the SPROWG Concept.

3.4 Alternative 4: Additional Delivery

Alternative 4, "Additional Delivery" was developed to explore additional deliveries that could be met by the SPROWG Concept. This alternative uses the largest storage volumes contemplated in the SPSS at the four storage locations, as well as the Denver Metropolitan pipeline. Delivery goals were 25 to 50 percent higher than the previous alternatives.

Alternative 4 delivery goals and infrastructure are shown on Figure 7. Additional detail on demands, infrastructure and operations are provided after the figure.

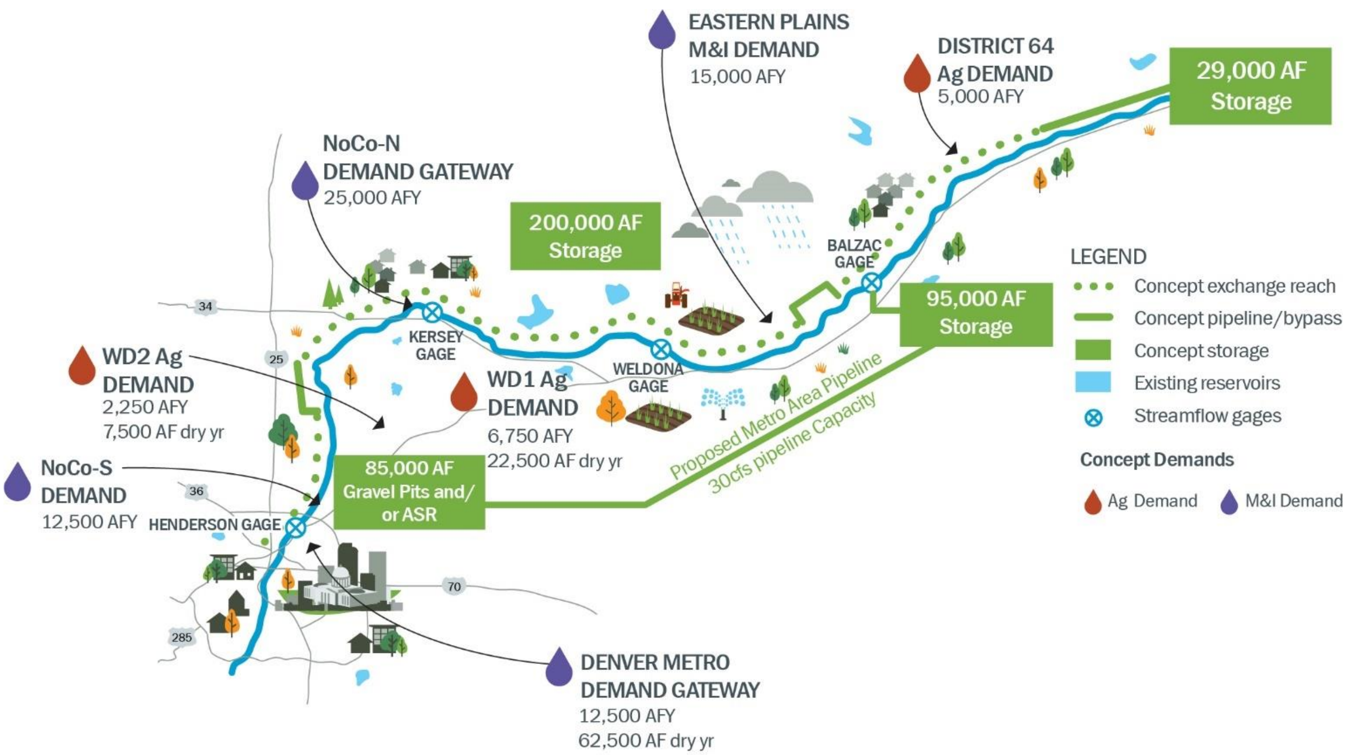


Figure 7. Schematic of Alternative 4 Delivery Goals and Infrastructure

Delivery Goals

To test how the largest storage projects could perform, delivery goals for both M&I and agricultural uses were increased significantly over the previous alternatives. M&I demands were increased by 25 percent, while agricultural demands were increased by 50 percent. These delivery goals are shown in Table 11.

Table 11. Alternative 4 Delivery Goals

M&I Demands			Agricultural Demands		
Denver Metro (avg/dry)	Northern Colorado (avg/dry)	Eastern Plains (avg/dry)	Water District 2 (avg/dry)	Water District 1 (avg/dry)	Water District 64 (avg/dry)
25,000/75,000	25,000/25,000	15,000/15,000	2,250/7,500	6,750/22,500	5,000/5,000

Infrastructure and Operations

The infrastructure for Alternative 4 is the same as Alternative 3, but at much larger capacities. The model used the maximum storage capacities for specific projects as detailed in the SPSS. Alternative 4 infrastructure is summarized in Table 12.

Table 12. Alternative 4 Infrastructure		
Henderson Storage	30,000 AF (gravel pit storage)	55,000 AF (Lost Creek ASR)
Kersey Storage	200,000 AF (Sanborne Reservoir Site)	
Balzac Storage	95,000 AF (Fremont Butte Reservoir Site)	
Julesburg Storage	29,000 AF (Ovid Reservoir Site and Julesberg Reservoir expansion) with pipeline to release above Harmony Ditch	
Denver Metropolitan Pipeline	30 cfs pipeline from Balzac to Henderson	

Summary of Modeling Results

The Point Flow Tool was used to simulate SPROWG Concept operations based on the demands and infrastructure described above. The infrastructure was sized to meet municipal and agricultural demands per the criteria described previously. Table 13 summarizes the results of the modeling and the performance of Alternative 4.

Table 13. Summary of Alternative 4 Modeling Results		
Municipal	Number of years M&I demands fully met	61
	Number of years M&I demands not fully met	8
	Average M&I demand not met (when this occurs)	2,100 AF
	Max M&I demand not met (in AF and percent of total demand)	7,000 AF (6% of dry-year demand)
	Average Denver Basin supply in dry years	2,600 AF
Agricultural	Water District 2 demand met	99%
	Water District 1 demand met	92%
	Water District 64 demand met	100%
Infrastructure	Number of years Henderson storage fully depleted	3
	Number of years Kersey storage fully depleted	8
	Number of years Fort Morgan storage fully depleted	8
	Number of years Julesburg storage fully depleted	0

Figure 8 shows the modeled end-of-day content for the storage facilities at Kersey, Henderson, downstream of Fort Morgan near Balzac, and Julesburg.

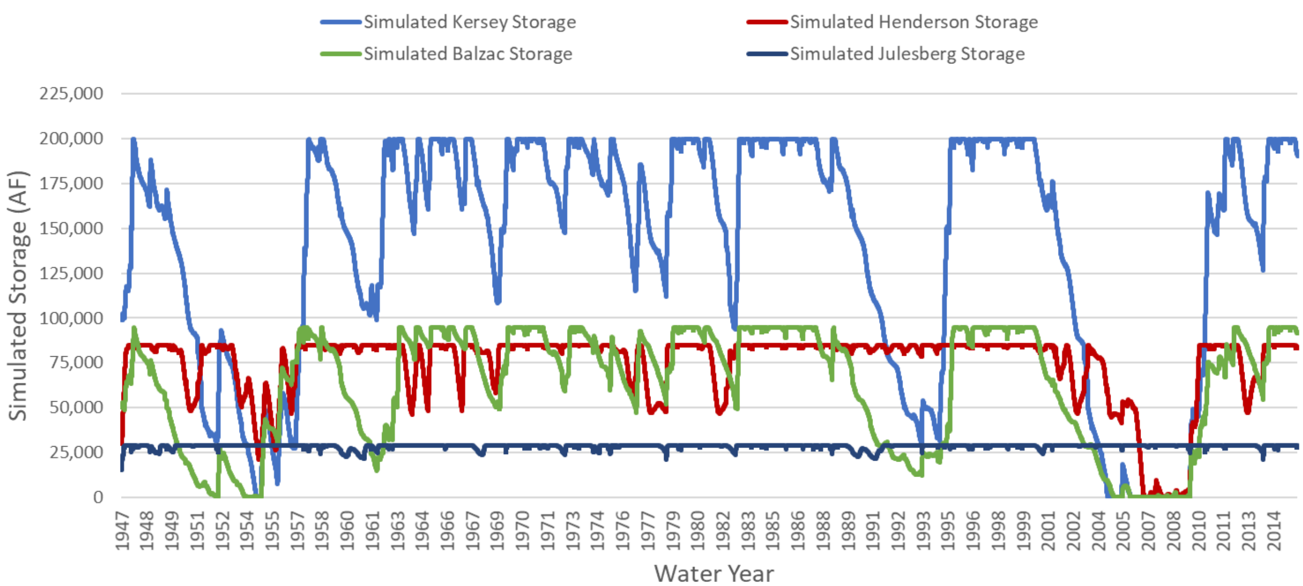


Figure 8. Modeled End-of-Day Storage for Facilities Included in Alternative 4

Observations and Conclusions

Below are several observations and conclusions regarding the modeling results for Alternative 4:

Municipal/Industrial

- Nearly all municipal demand was simulated to be met all the time. However, several years of very high dry-year demands in the 2000s resulted in only 85% of M&I demand being met in 2008.
- As stated previously, initial modeling of Alternative 4 included higher municipal delivery goals for municipalities on the Eastern Plains. However, the size of contemplated infrastructure was inadequate to meet the increased need, and the delivery goals were reduced. Even with the reduction, however, Eastern Plains municipal delivery goals and met demands were twice that of Alternative 3.

Agricultural

- Agricultural demands were met nearly all of the time in Alternative 4, even with 50 percent higher delivery goals than Alternative 3.
- Initial modeling of Alternative 4 included higher agricultural delivery goals in Districts 2 and 1. However, the size of contemplated infrastructure was inadequate to meet the increased need, and the delivery goals were reduced to levels that could be reliably met. Even with the reduction, however, District 2 and 1 delivery goals and met demands were 50 percent higher than that of Alternative 3.
- The modeling suggests that at least 5,000 AF/year of agricultural demand could be met on a firm basis in District 64. It is possible that more demand could be met in average and wet years if lower deliveries could be tolerated in drier years.

Infrastructure and Conveyance

- Water is readily available for the Julesburg-area reservoir due to the presence of return flows and lack of downstream calls. As a result, it remained full most of the time in the modeling simulation.
- Storage facilities at Henderson, Kersey, and Balzac were greatly drawn down in the modeling simulation during the droughts of the 1950s and 2000s

Section 4: Environmental and Recreation Considerations

Future operation of any of the SPROWG Concepts will result in changes to flow in the South Platte River, both reductions in streamflow and increases in streamflow. Reductions in streamflow will occur as a result of the diversion of water from the South Platte River into storage or diversion of water out of the South Platte River to meet an M&I or agriculture demand. Increases in streamflow will occur as a result of releases of water from an upstream to downstream reservoir or to meet a downstream demand, to facilitate upstream exchange or the availability of supplies (such as excess recharge credits) that cannot be stored because of a lack of demand, storage space, or exchange capacity. In addition to flow changes, the development of new reservoirs, pumping, conveyance and treatment systems would all have impacts to environmental and recreational uses in the basin.

Opportunities and Needs for Future Consideration

Currently the modeled simulations of the SPROWG Concept do not explicitly include considerations for environmental and recreation needs and opportunities, but this is something that could be incorporated in the future. Below are several opportunities and needs identified by environmental and recreation stakeholders that could be addressed in future modeling and design of the SPROWG Concept.

- **Allocation of project reservoir storage for needs such as flood control, conservation/multi-use, or sediment accumulation.** Such pools of storage are often referred to as flood control pools, conservation pools (also known as multi-use pools or environmental pools), and inactive pools, respectively. The flood control pool is intended to be empty until needed to hold floodwaters. The conservation pool contains all the water that can be used for the specified purposes of the reservoir and may include water supply, environmental flows, irrigation, hydropower, navigation, or recreation. Often, when the reservoir level is within the conservation pool, releases or withdrawals from the reservoir are only allowed for users that have permits assigned to storage within the conservation pool. The inactive pool is intended to fill with sediment over the life of the project however water in the inactive pool could be used during extreme droughts or emergencies, but only after the conservation pool has been emptied. Some examples of reservoirs in Colorado having storage pools for specific uses include: the environmental pool that is currently being created as part of the Chatfield Reservoir reallocation project to allow for strategic releases to enhance stream flows and water quality in the South Platte River below the reservoir and ancillary recreational benefits; the environmental pool in Elkhead Reservoir that is managed to provide water for augmenting summer low flows in the lower Yampa River; and Pueblo Reservoir which operates a minimum pool for fish, wildlife, and recreation purposes.
- **Delivery of water into project reservoirs to support specific environmental needs.** Water delivered into project reservoirs and project recharge facilities could be used to satisfy demand associated with wetland vegetation within the reservoir, wetland vegetation along sloughs or waterways supported by accretions resulting from prior delivery to and recharge from project reservoirs; and development of habitat within reservoirs for waterfowl and shore birds. Future modeling should consider the optimal timing of delivery of water into a project reservoir, and the potential for such delivery to be available (either directly or after recharge) to satisfy other project demands including potential recapture and reuse of project water.
- **Delivery of water from a SPROWG reservoir back to the South Platte River for the purpose of meeting water needs for specific resource values.** The voluntary flow management program (VFMP) in the Arkansas River is an example of managing reservoir releases and streamflow for specific resource values. The specific environmental and recreation resource needs recognized in the VFMP include fisheries needs, boating needs, angling needs, wildlife and riparian needs, and other needs such as dilution to benefit water quality. Based on feedback received from environmental and recreation stakeholders, resource values to be considered in the South Platte River may include but are not limited to: maintenance of peak flows, scouring flows, and sediment transport flows; elimination of dry up points in the South

Platte River or the reestablishment of hydrology and habitat at existing dry up points; habitat, incubation flows and spawning flows for small body plains fish; and habitat, incubation flows, and spawning flows for warm water fish.

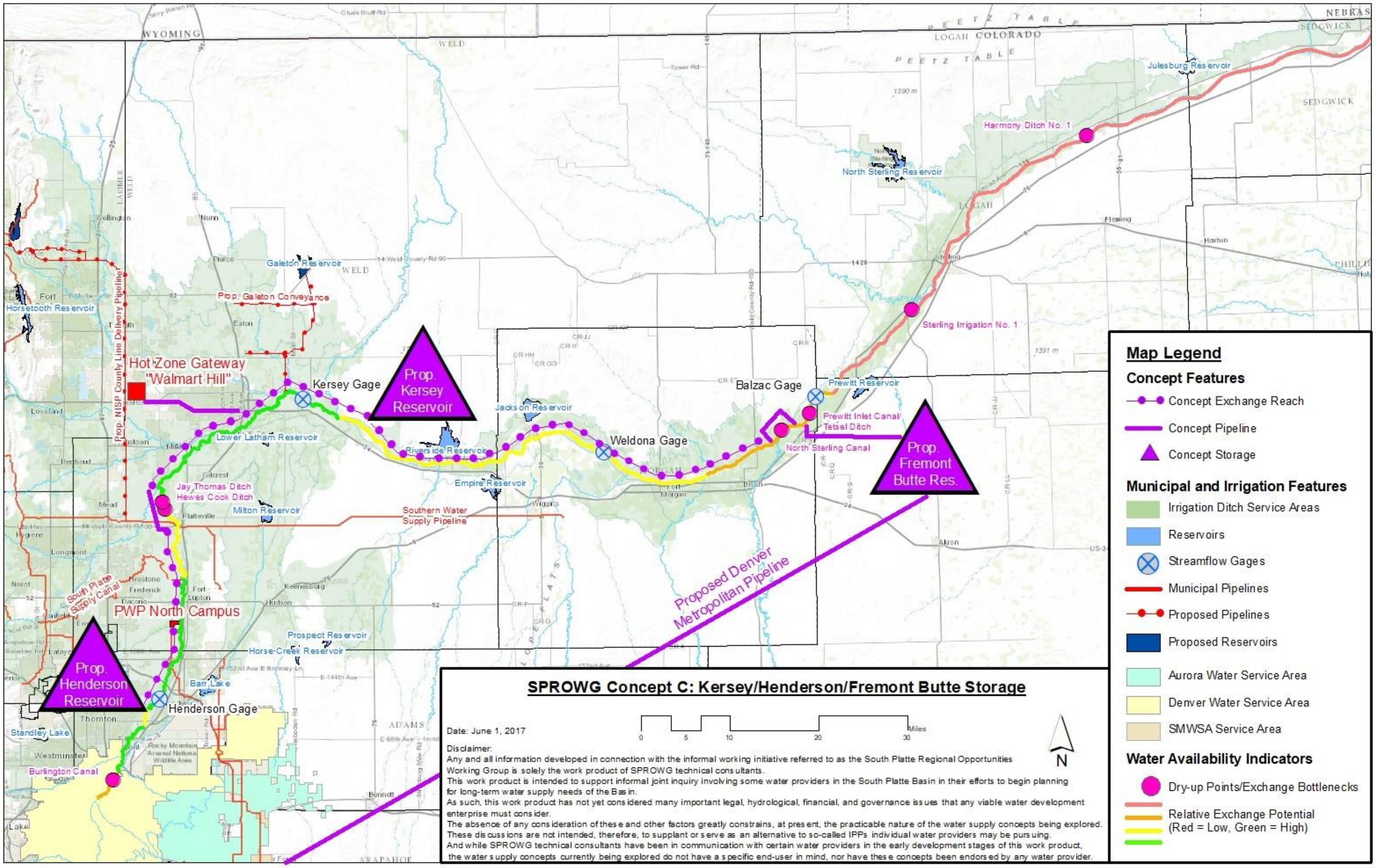
- **Impact of SPROWG Concept development and operation on environmental attributes and recreation.** Development and operation of the SPROWG Concept will change the flow of water in the South Platte River. Future phases of SPROWG should consider the impact of project development and operation and resultant flows on water quality, water temperature, environmental resources, and recreation, and mitigation strategies to address potential impacts.
- **Additional project definition is needed before the SPROWG Concept is ready for consideration from the permitting perspective**: The SPROWG Concept is not sufficiently defined in terms of participants, infrastructure or yields for permitting purposes. Given the conceptual nature of the SPROWG Concept, the impact of the project cannot be fully evaluated. Additional information needed prior to consideration from a permitting perspective includes but is not limited to: the amount of water involved; the location of project components; details regarding project operation; project participants; and the time, location, and amount of project demands. If the final project proponents are able to utilize a streamlined Section 7 Endangered Species Act consultation and the template Biological Opinion through its participation in South Platte Water Related Activities Program (SPWRAP) through the Platte River Recovery Implementation Program (PRRIP), the project participants will need to be SPWRAP members. In addition, the SPROWG Concept will comply with requirements of the South Platte River Compact of 1923. Additional information will also be needed on the extent to which SPROWG may or may not affect Colorado's responsibility for mitigating the impacts of new water-related activities in Colorado through the PRRIP.

References

Colorado Corn Growers Association, et al. *Completion Report: Development of Practical Alternative Agricultural Water Transfer Measures for Preservation of Colorado Irrigated Agriculture.* Colorado Water Conservation Board Competitive Grant Program, May, 2011.

Stantec, Leonard Rice Engineers, Inc., *HB16-1256 South Platte Storage Study, Final Report*. In coordination with the Colorado General Assembly, Colorado Water Conservation Board, Colorado Division of Water Resources, and the South Platte and Metro Basin Roundtables, December 15, 2017.

Attachment A: Initial Concept C Locations



Initial Concept C Locations (from Wilson Water Group)