CITY OF ASPEN

INTEGRATED WATER RESOURCE PLAN

FINAL | November 2021

Prepared by

carollo® in association with ELEMENT Water Consulting ross STRATEGIC

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Abbreviations

AACP	Aspen Area Community Plan
ACRA	Aspen Chamber Resort Association
ACSD	Aspen Consolidated Sanitation District
AF	acre-feet
AFY	acre-feet per year
AMI	Advanced Metering Infrastructure
Aspen Ski Co.	Aspen Skiing Company
Carollo	Carollo Engineers
CDP	Criterium DecisionPlus
CDPHE	Colorado Department of Public Health and Environment
cfs	cubic feet per second
CIP	capital implementation plan
City	City of Aspen
CMIP3	Coupled Model Intercomparison Project 3
CWCB	Colorado Water Conservation Board
FT	full-time
gpm	gallons per minute
hp	horsepower
IRP	Integrated Water Resource Plan
ISF	instream flows
kWh	kilowatt-hour
kWh/AF	kilowatt-hour per acre-foot
µg/L	micrograms per liter
MCHPP	Maroon Creek Hydroelectric Power Plant
MCL	maximum contaminant level
MG	million gallons
mgd	million gallons per day
mg/L	milligrams per liter
NFT	non-full-time
NPV	net present value
pCi/L	picocuries per liter
SDO	State Demography Office
UGB	Urban Growth Boundary
WEP	Water Efficiency Plan
WTF	water treatment facility

INTEGRATED WATER RESOURCE PLAN

Executive Summary

ES.1 Overview

The City of Aspen (City) provides water to a population of about 11,300 permanent residents, a seasonal non-resident population ranging as high as approximately 16,500, and a wide range of commercial businesses. The significant range in customers served seasonally creates challenges for the City's water supply, and specifically its raw (untreated) water storage needs. The City operates an integrated water supply system, which currently includes water rights for surface water from streams and ditches, groundwater, and mine water.

The City has minimal raw water storage available upstream of its water treatment facility (WTF), equivalent to less than one day of peak demands. This results in operational constraints and potential challenges with water supply reliability. In 2018, the City formally committed to relocating its existing conditional storage rights for Castle Creek and Maroon Creek to a more environmentally compatible site. The IRP recommends an amount of storage that should be used to address operational needs and to mitigate vulnerabilities to water supply threats, in parallel with the City's ongoing investigation of several potential storage sites.

Variability in water supply availability is common across most of the western United States. In Aspen, conditions in recent years demonstrate how the availability of surface water resources can vary significantly from one year to the next. Exceptional drought conditions were prevalent in 2020 in Aspen and much of Colorado, when the state experienced one of the most severe wildfire seasons in recorded history. It is anticipated that climate change will further affect the yield and variability of the City's water resources portfolio.

This Integrated Water Resource Plan (IRP) evaluates the City's water supply portfolio and provides a robust plan to provide a safe, resilient, and reliable water supply to its customers through the coming decades, while respecting the City's commitment to environmental stewardship.

ES.2 Planning Basis

The City provides water service within the city limits and to portions of unincorporated Pitkin County for a total service area of approximately 8.5 square miles. The IRP is based on supplying water to the City's existing service area, plus the potential that City water service could be extended someday to the extents of the entire urban growth boundary (UGB).

The IRP includes water demand and supply forecasts and analyzes existing and potential new water supply sources for the City's service area through year 2070. Planning, permitting, and implementing water projects in Colorado can take years – sometimes decades – thus driving the need for a long-range outlook with a phased implementation schedule to meet the community's needs over time. The City deliberately chose a planning period of approximately 50 years to reflect the long-lasting implications of water resources decisions, such as siting storage for the Castle Creek and Maroon Creek conditional storage water rights, and the time it can take to plan, permit, construct, and implement water projects.

The IRP uses a conservative basis for planning coupled with an adaptive implementation approach, so the City is prepared for any reasonably foreseeable future condition, but only recommends system improvements when they become necessary. Planning uncertainties are greater in more distant years due to limitations in abilities to accurately forecast future conditions; this does not alleviate the need to plan water supplies far in advance. These uncertainties can be addressed in part by implementing IRP recommendations that are "trigger-based" – such as a certain demand level or frequency of shortages – rather than strictly on a planning year basis.

It is recommended that the IRP be updated regularly, such as every 10 years, to adjust for changes in "existing" conditions, incorporate new data and science, address evolving regulations, and extend the planning horizon.

ES.3 Stakeholder Engagement

The City made extensive efforts to engage stakeholders and the public in developing a plan that reflects a breadth of local technical expertise and the community's values and priorities through a multi-phase stakeholder engagement process. Primary elements of stakeholder engagement in support of IRP analyses included:

- Community interviews,
- Technical Work Group meetings,
- Community meetings, and
- Aspen Community Voice online engagement portal.

A series of 14 one-on-one interviews was conducted with community members to gain insights from a range of perspectives on Aspen's water supplies and water system. Three rounds of engagement were conducted in November 2020, January 2021, and March 2021, with each round including a community meeting and a Technical Work Group meeting. Each facilitated meeting featured a presentation on key aspects of the IRP development and included opportunities for participants to ask questions, discuss content, and advise the planning team. All meetings were held virtually due to restrictions associated with the COVID-19 pandemic that coincided with the development of the IRP.

The City's online public information and engagement platform, Aspen Community Voice, was used throughout the development of the IRP to inform the community and solicit input. In addition to providing background information on the City's water supply resources and options, the Aspen Community Voice site provided an opportunity for community members to ask the project team questions and provide additional input on key topics as the IRP development moved through its various phases of development. The City made deliberate outreach to the community to increase awareness of the site and participation in the online forum. This included outreach through local media, paid advertisements, City newsletters, Aspen Chamber Resort Association (ACRA) newsletters, water bill inserts, and Aspen Community Voice newsletters.

ES.4 Water Demand Forecasts

To provide a foundation for water supply planning, water demands were forecasted through the 50-year planning period to 2070. The City provides potable water (treated to drinking water standards) and untreated water (for irrigation and other non-potable uses) to its customers.

Water demands are higher during the summer months due primarily to outdoor water use. An analysis of water use records estimates that approximately 45 percent of potable water use was associated with outdoor water use from 2012 through 2019. Peak water production has typically occurred in June, July, or August each year.

Non-potable water deliveries serve primarily irrigation and snowmaking uses. The City serves approximately 60 irrigation customers through the non-pressurized open-channel ditch system and 11 irrigation customers through the pressurized non-potable water system via releases from Leonard Thomas Reservoir. The irrigation supply is typically available from mid-May through mid-October, with uses peaking in June, July, and August.

The City has a raw water agreement with the Aspen Skiing Company (Aspen Ski Co.) to provide a non-potable water supply for snowmaking for the Aspen Highlands Ski Area and an agreement to provide treated water for snowmaking on Aspen Mountain[1]. It also owns an absolute water right decreed for recreational boating use that supplies the Aspen Whitewater Park, located adjacent to the Roaring Fork River. The City's Maroon Creek Hydroelectric Power Plant (MCHPP) is a 400-kilowatt hydroelectric generation facility; 46 percent of the energy use in Aspen is served through hydroelectric power. The City also operates its senior water rights in a way that will maintain decreed instream flows while striving to meet voluntary instream flow targets, including flows in Castle Creek, Maroon Creek, Hunter Creek, and the Roaring Fork River.

As part of this analysis, a baseline demand projection and a range of potential future demand scenarios were developed to provide an envelope of potential potable water demands through 2070. For each projection scenario, four separate demand drivers were used to adjust demands under future conditions:

1. Population Growth and Visitor Occupancy.
2. Climate Change.
3. Water Use Efficiency and Conservation.
4. Non-Revenue Water.

The resulting total projected 2070 annual demands range from 4,878 to 9,281 acre-feet per year (AFY), as shown in Figure ES.1.

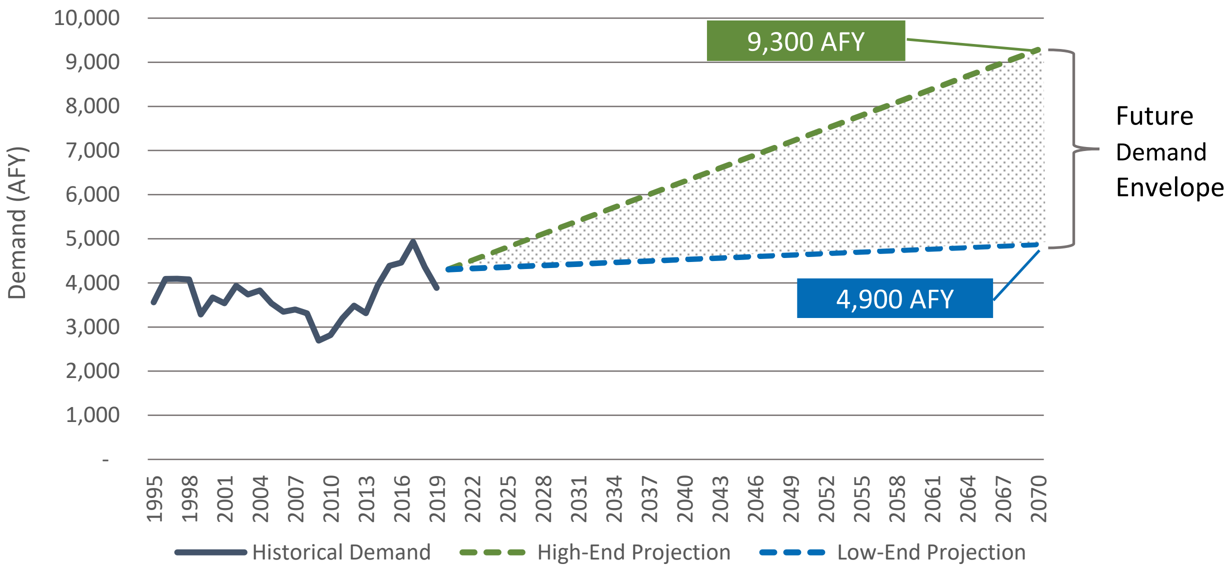


Figure ES.1 Historical and Projected Potable Water Demand Range through 2070

The methods used to project future potable water demands are not directly transferable to non-potable water demands due to limited data availability and because many of the non-potable water demands are constrained by legal agreements and water court decrees. In addition, some non-potable demands are limited to the supply available via raw water license agreements.

[1] "Treated water" and "potable water" are generally used interchangeably throughout this IRP to refer to water that has been treated at the City's WTF. However, water provided for snowmaking on Aspen Mountain is treated but may not meet potable standards at the point of use.

ES.5 Water Supplies

The majority of water served to the City's customers is supplied by diversions from Castle Creek and Maroon Creek. The City's primary potable water supply intake is located on Castle Creek; Maroon Creek is generally used as a supplemental supply when flows in Castle Creek are insufficient to meet demands or when Castle Creek exhibits lower water quality. Raw water is delivered from the Castle Creek pipeline and Maroon Creek pipeline to the City's WTF via Leonard Thomas Reservoir.

Water treated to drinking water standards is delivered to the community through approximately 73 miles of water mainlines that range in size from 4 to 24 inches in diameter. Untreated ("raw") water from a variety of sources is delivered to portions of the community through a network of piping and ditches. The City also utilizes its water rights and supplies in a way that supports maintenance of decreed instream flows, while also striving to meet voluntary flow goals.

The City does not currently have any meaningful raw water carryover storage capacity that would allow it to retime water supplies to match water deliveries with demands, or to provide a water supply if drought or emergency conditions prevent or reduce diversions from Castle Creek or Maroon Creek. Rather, the City is dependent upon direct use of available streamflow, which is susceptible to annual variability and changing conditions, as well as seasonal and daily variability. If the climate in the Castle Creek and Maroon Creek watersheds becomes drier in the future due to climate change, the City may face additional challenges in meeting demand from streamflow diversions alone while maintaining instream flow goals. For Aspen, the existing water supply is most vulnerable in late summer into early fall, after snowmelt runoff has tapered off, and while landscape irrigation demands are still high.

Lack of raw water storage also makes the City's water system vulnerable to threats that could prevent or constrain the City from diverting water through either or both of its diversions on Castle Creek and Maroon Creek and/or treating it to potable standards. Vulnerabilities assessed for each existing or potential future water supply source include:

- Persistent drought,
- Wildfire,
- Infrastructure failure,
- Power outage,
- Supply chain disruption,
- Malevolent acts or cybersecurity,
- Flooding,
- Treatment process outage,
- Avalanches,
- Source water contamination, and
- Staff turnover/loss of institutional knowledge.

The adjacent siting of the Castle Creek and Maroon Creek watersheds increases the potential that both could be impacted by the same event. The City does not have practical opportunities for interconnections with other municipal systems to provide water supply system redundancy.

ES.6 Water Supply Portfolios

To mitigate the supply vulnerabilities discussed above and to avoid the potential for a water supply shortfall (demands exceeding supply), the following potential supply options were packaged into alternative water supply portfolios:

- Enhanced Water Conservation: In addition to the community's existing conservation practices and increased levels of efficiency built into the demand projections, enhanced conservation could further reduce per-capita water use.

- Groundwater Wells: The City owns three alluvial wells located in the downtown area currently not connected to the potable water distribution system because of concerns with their ability to meet drinking water standards. A new blending structure and associated infrastructure would allow reinstatement of these wells, delivering a total of 3.2 million gallons per day (mgd) of potable water. The potential for stream depletions associated with use of these wells was evaluated as part of IRP analyses.
- Hunter Creek: The City owns water rights on Hunter Creek that could be used to meet potable water needs. Hunter Creek was at one time diverted and treated by the City, but the treatment facility was subsequently decommissioned and would need to be rebuilt.
- Water Reuse: A system to deliver reclaimed water from the Aspen Consolidated Sanitation District (ACSD) water reclamation facility could be used to support non-potable irrigation and snowmaking needs. The City has already constructed a pipeline from near the ACSD facility to the Aspen Municipal Golf Course with the intent of supplying irrigation water to the golf course. Completion of this system would require construction of a new pump station and a supplemental disinfection system.
- New Raw Water Storage ("Operational Storage"): The City is evaluating several sites outside the Castle Creek and Maroon Creek watersheds for potential storage of Castle Creek and Maroon Creek flows. Stored water would be pumped to the WTF to augment or replace direct diversions from Castle Creek and Maroon Creek when necessary due to low creek flows, water quality reasons, or emergency conditions.
- Drought Management: The IRP assumes that the City will continue to deploy its existing four-stage system to temporarily reduce demands when necessary, under drought or other emergency conditions.

Each of these supply options is locally available and could help meet the City's future needs, avoiding some of the significant costs and socioeconomic concerns that can be associated with non-local or inter-basin supply transfers. Given the availability of local supply options, non-local supply options were not considered in this IRP.

It was assumed that the City will continue to use Castle Creek and Maroon Creek as primary supplies and will utilize its existing drought restriction system as needed. Portfolios were constructed assuming that the City could implement up to "Extreme – Stage 3" drought restrictions to reduce systemwide water use by up to 25 percent when needed. The "Exceptional – Emergency Response" restrictions are assumed to be kept in reserve for emergencies outside of normal operational considerations.

Modeling of the City's existing supplies using 25 years of historical hydrology modified to reflect 2070 climate change impacts with 2070 demands indicated that the largest supply shortfall would occur in two consecutive dry years (i.e., the hydrologic conditions of 1977 and 1978, modified to include hotter and drier conditions due to climate change). At the conservative (high-end) demand projection, these conditions would produce a total supply shortage ("gap") of approximately 2,300 acre-feet (AF) over the course of both years. Combinations of supply options ("portfolios") were modeled to confirm that they could resolve this supply gap, such that no shortages would be expected under 2070 demand and climate conditions.

Six water supply portfolios were compiled from the potential supply options based on meeting the minimum threshold of being able to fully meet maximum 2070 demand (9,281 AFY) under the worst-case future climate condition considered in this IRP. This conservative approach for projecting water supply shortages also drives a conservative level of potential water supply investments that will be needed to meet 2070 demands. However, this IRP recommends that the City adopt an adaptive approach to implementing its water supply recommendations, using supply/demand triggers to implement additional supplies and demand management options over time in response to observed conditions. As such, the City will have a plan in place for how it will meet demands if these conservatively assumed conditions materialize over the next 50 years, but it will only implement the components that are needed, when they are needed. If conditions do not require this pace of implementation, new supply strategies can be deferred.

The supply portfolios analyzed are summarized in Table ES.1. Operational raw water storage is included in all supply portfolios (other than Portfolio 1, No Action) because no single supply option or combination of supply options can completely mitigate shortages in the driest 2-year period of the 25 years of hydrology analyzed (including projected climate change impacts) without the use of at least some operational storage. However, the amount of operational storage included in each portfolio varies based on the extent to which the other supply options included in each portfolio can mitigate the supply and demand gap during the driest 2-year period analyzed. The composition of how each supply portfolio mitigates the supply-demand gap during the driest 2-year period is also graphically shown in Figure ES.2.

Table ES.1 Supply Portfolio Summary

Portfolio	Operational Storage (AF)(1)	Hunter Creek	Groundwater	Enhanced Conservation	Non-Potable Reuse
1. No Action	0	-	-	-	-
2. Storage Only	2,200	-	-	-	-
3. Hunter Creek + Storage	2,000	●	-	-	-
4. Groundwater + Storage	800	-	●	-	-
5. Enhanced Conservation + Storage	1,600	-	-	●	-
6. Groundwater + Storage + Enhanced Conservation + Reuse	400	-	●	●	●

Notes:
(1) The raw water storage amount does not include emergency storage or an allocation for storage inefficiencies, which add to the amount of storage recommended.

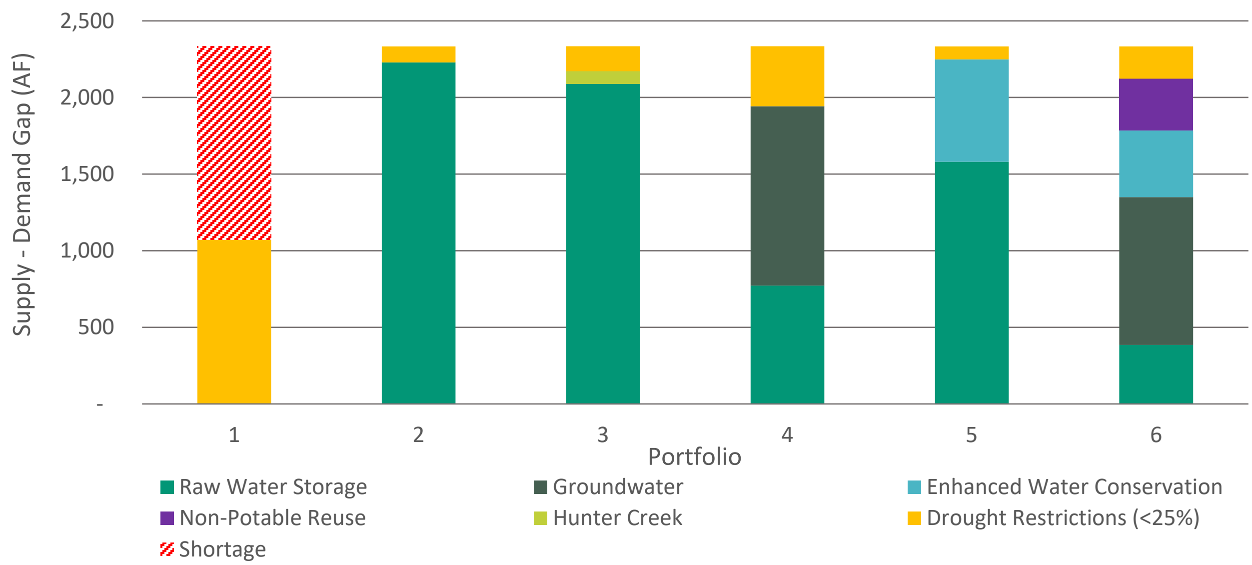


Figure ES.2 Supply Portfolio Composition to Mitigate the Two-Year Supply-Demand Gap

ES.7 Portfolio Evaluation

The six portfolios were evaluated and compared using a suite of economic and non-economic criteria. Selection of the criteria and the importance of each in choosing a supply portfolio were guided by public input to reflect the needs and priorities of the community. The criteria included the following major objectives:

- Supply availability,
- Supply resilience,
- Community and environmental benefits,
- Affordability,
- Ease of implementation, and
- Ease of operations.

To facilitate the evaluation, a decision model was used to normalize the criteria scores and apply the criteria weights to compare portfolios. Portfolios that score well against the most important criteria receive a higher decision score, which indicates a preferable portfolio. The normalized total decision score for each portfolio ranges from 0 to 1, with 1 being a perfect score across all criteria. The results of the analysis are shown in Figure ES.3. Portfolio 6 best met the range of criteria, followed by Portfolios 5 and 4. Portfolio 1 scored the worst, clearly confirming that "no action" is not a viable approach.

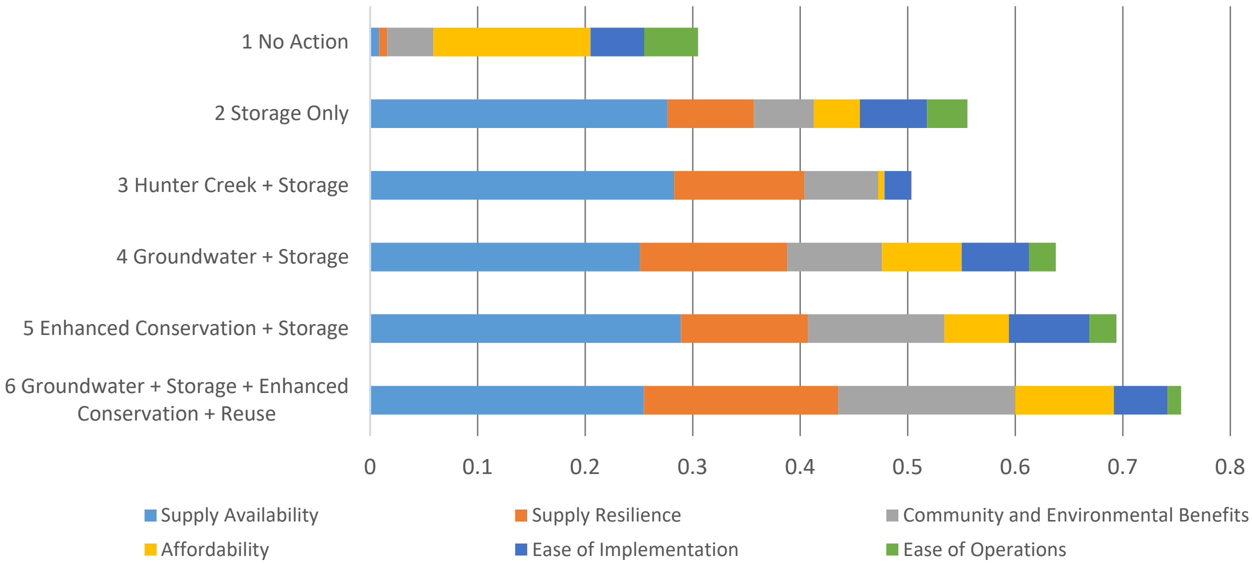


Figure ES.3 Portfolio Evaluation Results

ES.8 Emergency Raw Water Storage

The operational raw water storage needs described above are intended to be used in conjunction with other supply options to eliminate the potential seasonal gap between supply and demand in particularly dry years. Operational raw water storage helps buffer natural seasonal and annual fluctuations in available supply from Castle Creek and Maroon Creek to allow the City to continue to serve customers if creek supplies fall below demand.

In contrast, emergency raw water storage is intended to be used when the capacity of the City's water supply sources cannot meet demand due to a temporary emergency situation. This may occur due to a supply vulnerability event, such as wildfire or critical infrastructure failure. Emergency storage needs increase total storage needs above and beyond operational raw water storage. In order for emergency storage to be effective, it must be "full" and ready for use when the need arises; its quantity should be considered to be separate and distinct from (not "shared" with) operational storage, which could result in less water available in storage than needed when an emergency event occurs. However, to take advantage of economies of scale and ease of operations, operational storage and emergency storage could be co-located within a single storage facility, with separate "paper" tracking of stored volumes.

The recommended amount of emergency storage was determined by assessing the amount of additional supply needed if the City's largest supply source for the top-ranked portfolio is unavailable due to the worst-case threat scenario for a period of 1 to 12 months. Under Portfolio 6, the largest supply source will continue to be direct diversions from Castle Creek and Maroon Creek, even after diversification of supplies. Reinstating the City's three groundwater wells in central Aspen will reduce the need for emergency storage, because they will be able to meet a portion of the community's demands. However, blending will be used to meet water quality requirements – meaning groundwater cannot operate as the sole source of potable water for the community at any point, and some amount of treated water sourced from Castle Creek, Maroon Creek, or storage will be required at all times.

Emergency raw water storage sizing is summarized in Figure ES.4 for the upper end of projected 2040 and 2070 demand levels as a function of the duration of Castle Creek and Maroon Creek diversion interruptions. If demands increase at a slower rate, emergency storage needs would be lower, and expansions could be deferred. Faster growth (or failure to implement other components of Portfolio 6, such as reinstating the groundwater wells) would accelerate the need for emergency storage expansions. Note that the need for emergency storage is not delayed until 2040; 2040 was selected as an interim year for illustrating the increasing need for and importance of storage in protecting against emergency conditions.

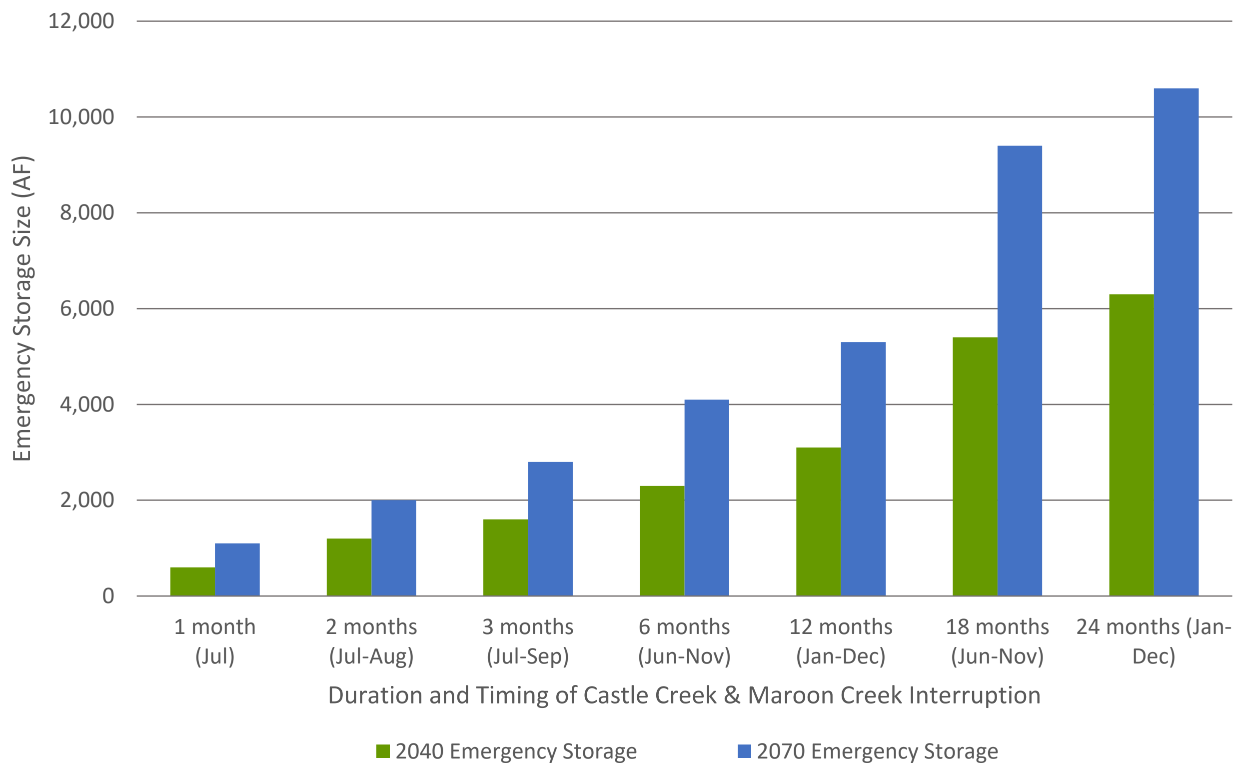


Figure ES.4 Emergency Storage Sizing as a Function of Castle Creek and Maroon Creek Diversion Interruption

Total raw water storage needs for 2070 conditions include a minimum of 520 AF for operational storage (400 AF plus a 30 percent allocation for storage inefficiencies) plus 5,300 AF to provide up to 12 months of emergency storage (including storage inefficiencies). While 12 months of emergency storage is recommended in this IRP as a balance between extreme-scenario resilience and capital costs, some Colorado utilities have constructed raw water storage for as much as 3 years of demand.

Together, this 5,820 AF of raw water storage will provide coverage for seasonal and annual fluctuations in Castle Creek and Maroon Creek flows and 12 months of emergency interruptions in Castle Creek and Maroon Creek diversions. An accelerated rate of increasing demand (or incomplete achievement of other Portfolio 6 supply options) would increase and accelerate the need for storage, and vice versa. It should be recognized that there is significant uncertainty in future demand projections and supply conditions (particularly regarding climate change), and that the IRP projects needs only through 2070. Application of a safety factor and planning for conditions beyond 2070 could significantly increase the storage need beyond the 5,820 AF value identified here.

It is estimated that construction of 5,820 AF of storage and its associated conveyance infrastructure would cost over $400 million in 2021 dollars as it is implemented over the coming decades. Emergency storage capital costs directly correlate to the associated level of water supply reliability. Greater amounts of storage would increase the costs and the amount of reliability provided, whereas smaller investments associated with less storage would reduce the supply reliability benefit. Phased design and construction of storage provides the City the flexibility to further assess these tradeoffs, monitor demand growth, and conduct financial planning in the coming years.

The majority of storage sites considered in the City's ongoing siting investigations would be constructed as *in situ* (subsurface) storage. Two of the sites considered, Woody Creek and Vagneur Gravel Pit, could be developed as open (surface) storage.

ES.9 Implementation Plan

Water supply system enhancements should be implemented in a prioritized, phased manner to continue to reliably meet water demands, reduce system vulnerabilities, while being mindful of surges in capital expenditures. The implementation plan includes a near-term (10-year) capital implementation plan (CIP) and an approach for later phases of system improvements beyond 2030 to maintain a reliable water supply system through 2070. The IRP uses adaptive planning to define the system improvements needed to reliably meet demands in 2070, coupled with a trigger-based approach that provides for phased implementation of those improvements when conditions develop to the point that the improvements become necessary. The implementation plan is summarized in Figure ES.5.

Implementation of the projects shown in Figure ES.6 will address near-term priority water supply needs in the City's water supply system and longer-term investments to reflect conditions over time as water demands increase and climate change impacts intensify. It is important to recognize that the timing of each of these improvements – particularly after the near-term CIP period (2022 through 2030) – will be affected by factors such as water use patterns and amounts, and by water supply and snowmelt runoff patterns. The result could be a need to accelerate or an opportunity to delay implementation of each project.

In support of the capital projects described and as part of continued stewardship of the City's water supplies and infrastructure, the following additional projects are recommended:

- WTF condition assessment and master plan in 2023, including recommendations for Project WT1 to modify treatment processes to better accommodate water quality constraints following wildfires in the Castle Creek and Maroon Creek watersheds.
- Groundwater level monitoring and water quality monitoring upon reactivation of the groundwater wells.
- Water Efficiency Plan Updates in 2022 and every 7 years thereafter.
- Water Transmission and Distribution Master Plan building on the 2018 hydraulic modeling project (Bohannon Huston, 2019), including demand updates and a condition assessment to support asset management on the City's linear water assets and storage facilities, in 2025 and updated at least every 10 years.
- IRP updates every 10 years, including climate change supply availability analysis updates.
- Updated Rate Study following completion of master plans for the WTF and Transmission and Distribution systems.

	Est. Capital Cost 2022-2030 (in 2021 $M)	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031-2050	2051-2070
Capital Projects												
WR1: Water Reuse at Aspen Municipal Golf Course	$4.0											
WR2: Water Reuse Expansion	$0.2											
GW1: Groundwater Blending Facility	$8.1											
EC1: Enhanced Conservation Phase 1	$4.0											
EC2: Enhanced Conservation Phase 2	$0											
EC3: Enhanced Conservation Phase 3	$0											
WT1: Water Treatment Facility Resilience Improvements	$5.0											
ES1: Emergency Storage Phase 1	$10.9	Planning/Siting		Preliminary Design	Permitting/Financing					Final Design		
ES2: Emergency Storage Phase 2	$0											
ES3: Emergency Storage Phase 3	$0											
OS1: Operational Storage Phase 1	$0											
OS2: Operational Storage Phase 2	$0											
Master Planning												
Water Efficiency Plan Update	$0.05 per update											
Transmission/Distribution Master Plan	$0.1											
Water Treatment Plant Master Plan	$0.1											

Phase Key:

Study/Planning
Design/Bidding
Construction/Implementation

Figure ES.5 Implementation Plan Summary

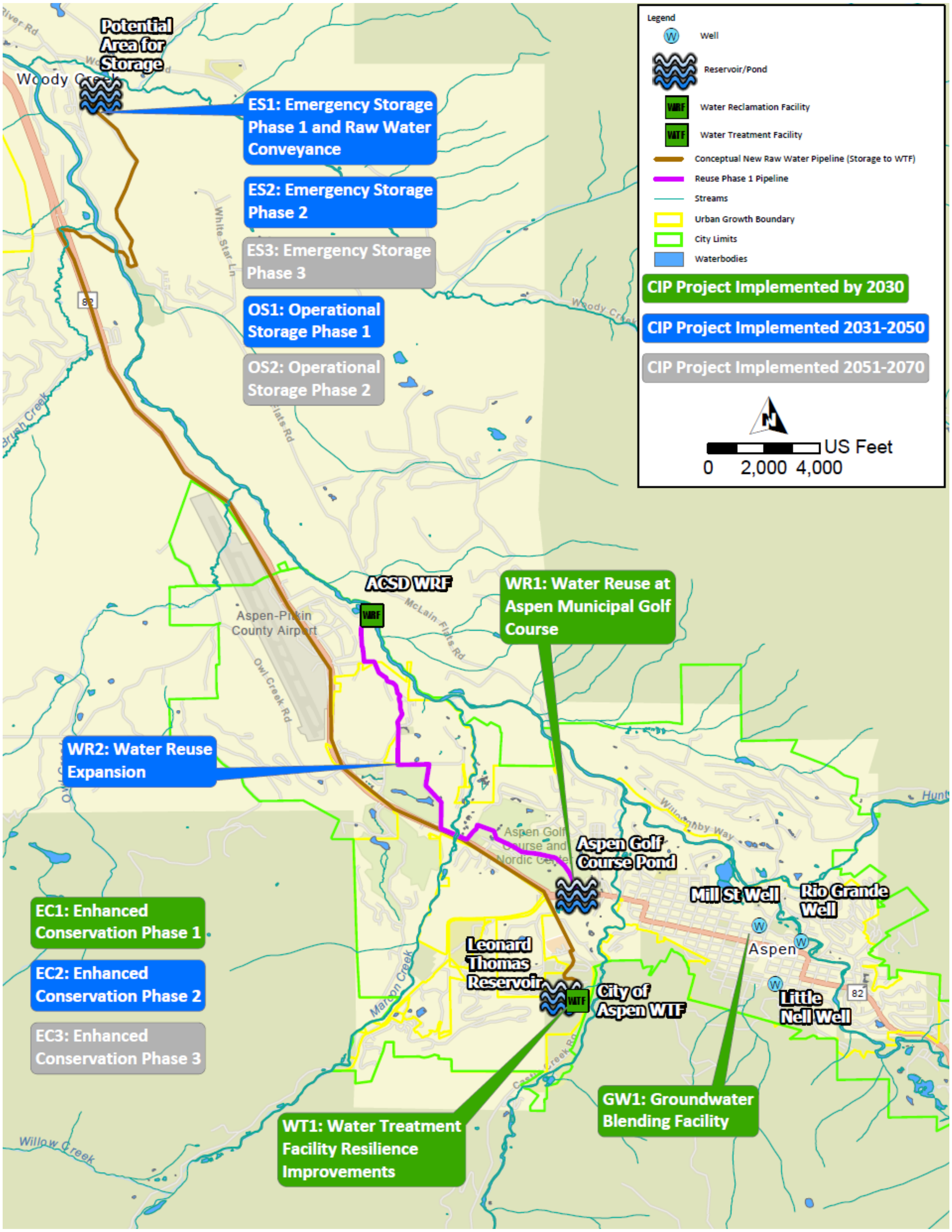


Figure ES.6 Overview of IRP Water Supply Projects

ES.10 Capital Improvement Plan Summary

A summary of capital project expenditures through 2030 is provided in Table ES.2. Near-term investments in water reuse and groundwater blending will enhance the City's water use efficiency and reduce existing vulnerabilities in the Castle Creek and Maroon Creek sources.

Altogether, the near- and long-term investments identified in this IRP will result in a resilient, reliable water supply for the Aspen community for the next 50 years.

Table ES.2 Near-Term CIP Summary

Project	Expenditure (2021 $M unless noted otherwise)								
	2022	2023	2024	2025	2026	2027	2028	2029	2030
Capital Projects[1]	**$0.3**	**$1.8**	**$4.2**	**$8.1**	**$5.0**	**$0.5**	**$0.5**	**$0.6**	**$11.1**
WR1: Reuse at Aspen Municipal Golf Course	$0.1	$1.2	$2.6						
WR2: Reuse Expansion								$0.03	$0.2
GW1: Groundwater Blending Facility	$0.1	$0.1	$0.8	$7.1					
EC1: Enhanced Conservation Phase 1		$0.5	$0.5	$0.5	$0.5	$0.5	$0.5	$0.5	$0.5
WT1: Water Treatment Facility Resilience Improvements				$0.5	$4.5				
ES1: Emergency Storage Phase 1 and Raw Water Conveyance	$0.04	$0.04	$0.25	$0.04	$0.04	$0.04	$0.04	$0.04	$10.4
Master Planning	**$0.1**	**$0.1**	**$0.0**	**$0.1**	**$0.0**	**$0.0**	**$0.0**	**$0.1**	**$0.0**
WTF Master Plan		$0.1							
Water Efficiency Plan Update	$0.05							$0.05	
Transmission/Distribution Master Plan				$0.1					
Total Expenditures (2021 $M)	**$0.3**	**$1.9**	**$4.2**	**$8.2**	**$5.0**	**$0.5**	**$0.5**	**$0.6**	**$11.1**
Total Expenditures (Escalated $M)[2]	**$0.3**	**$2.0**	**$4.6**	**$9.3**	**$5.8**	**$0.6**	**$0.7**	**$0.8**	**$14.5**

Notes:
(1) Projects initiated in 2031 and beyond are not detailed in this table; see Figure ES.5 for schedule and Section 5.3 for narrative descriptions.
(2) Escalation to future years at assumed 3% annual rate.

Chapter 1

INTRODUCTION

1.1 Overview

The City provides water to a service area population of about 11,300 permanent residents, a seasonal non-resident population ranging as high as approximately 16,500, and a wide range of commercial businesses. The significant range in customers served seasonally creates challenges for the City's water supply, and specifically its raw (untreated) water storage needs. The City initiated development of this IRP for water to analyze its water supply portfolio and develop a robust plan to provide a safe, resilient, and reliable water supply to its customers through the coming decades, while respecting the City's commitment to environmental stewardship.

The City operates an integrated water supply system, which currently includes water rights for surface water from streams and ditches, groundwater, and mine water. The City has minimal raw water storage available upstream of its WTF, equivalent to less than one day of peak demands. This results in operational constraints and potential challenges with water supply reliability. In 2019, the City formally committed to relocating its existing conditional storage rights for Castle Creek and Maroon Creek to one or more environmentally compatible sites at specified locations. Significant planning work has been completed by the City in recent years to explore the feasibility and cost of storage at these sites, and this work is ongoing.

Variability in water supply availability is common across most of the western United States. In Aspen, conditions in recent years demonstrate how the availability of surface water resources can vary significantly from one year to the next. The drought that impacted southern and western Colorado in 2018 illustrates how near-record low snowpack can impact Aspen's water supply, and dry conditions persisted through summer 2018. Then in 2019, Aspen and other communities across Colorado benefited from abundant snowfall and ongoing wet conditions. The threat of watershed wildfires in mid-2018 was supplanted by the impact of a major avalanche on Aspen's watershed in early 2019. Exceptional drought conditions returned in 2020 to Aspen and much of Colorado, and the state experienced one of the most severe wildfire seasons in recorded history. It is anticipated that climate change will further affect the yield and variability of the City's water resources portfolio.

Water supply planning and management is more dynamic in Aspen than many communities because water demands are extremely variable, driven by factors such as tourism and partial-year occupancy of many local residences. The community strongly values local and regional environmental and recreational amenities, which is a factor in how the City manages its water resources portfolio. Water planning efforts in recent years have focused largely on water efficiency strategies and drought response planning.

This IRP includes water demand and supply forecasts and analyzes existing and potential new water supply sources for the City's service area through a 50-year planning period. Planning, permitting, and implementing water projects in Colorado takes years – sometimes decades – thus driving the need for a long-range outlook with a phased implementation schedule to meet the community's needs over time. This IRP provides a roadmap for the City's long-term water strategy through year 2070.

1.2 Planning Drivers and Objectives

The City has many drivers for developing this IRP. The City's drivers, vision, and goals for the IRP were developed based on input provided by City staff from different departments, local and regional stakeholders, and community members in late 2019 and 2020. The key drivers that were identified through the first phase of this IRP include the City's need for:

- Clear and timely direction on raw water storage (size, siting, and implementation) for Castle Creek and Maroon Creek conditional storage rights.
- Enhanced plans for optimized use of the City's various water rights.
- Increased community awareness regarding water reliability and scarcity.
- Securing a sustainable, reliable water supply for decades to come, in the face of threats such as extended drought and climate change.
- Leveraging relevant elements of previous studies regarding water supply challenges and opportunities.

The City's vision and goals for the IRP include the following:

- Provide a comprehensive assessment of future demands, existing supply capabilities, and future supply opportunities, including consideration of reliability, water quality, cost-effectiveness, and treatability.
- Identification of water supply vulnerabilities for a resilient, reliable supply system.
- Assessment of future raw water storage siting and assessment of the infrastructure and operational implications of storing water lower in the system.
- Use of a transparent, inclusive process and clear documentation of the analyses, rationale for decision-making, and results.
- Engagement of key stakeholders and community members, including a "consultative" approach to interacting with key stakeholders.
- Integration of water planning via the IRP with other key City planning efforts, such as conservation and efficient landscaping programs, Parks initiatives, Community Development planning processes, the Climate Action Plan, and the River Management Plan.

Three key products of the IRP are:

1. Roadmap for the City's water strategy to provide long-term water supply resilience, reliability, and security;
2. Path forward for development and use of the City's conditional storage rights; and
3. Long-term water supply capital program.

1.3 Planning Basis

1.3.1 Study Area

Aspen is located in Pitkin County along Colorado State Highway 82, about 105 miles southwest of Denver and 95 miles east of Grand Junction. Aspen is in the upper reaches of the Roaring Fork Valley at an elevation of approximately 7,900 feet. The incorporated area within the municipal boundary is approximately 3.8 square miles, but the City serves a larger area outside of the municipal boundary in unincorporated Pitkin County for a total service area of approximately 8.5 square miles (Element Water Consulting, 2015), as depicted in Figure 1.1.

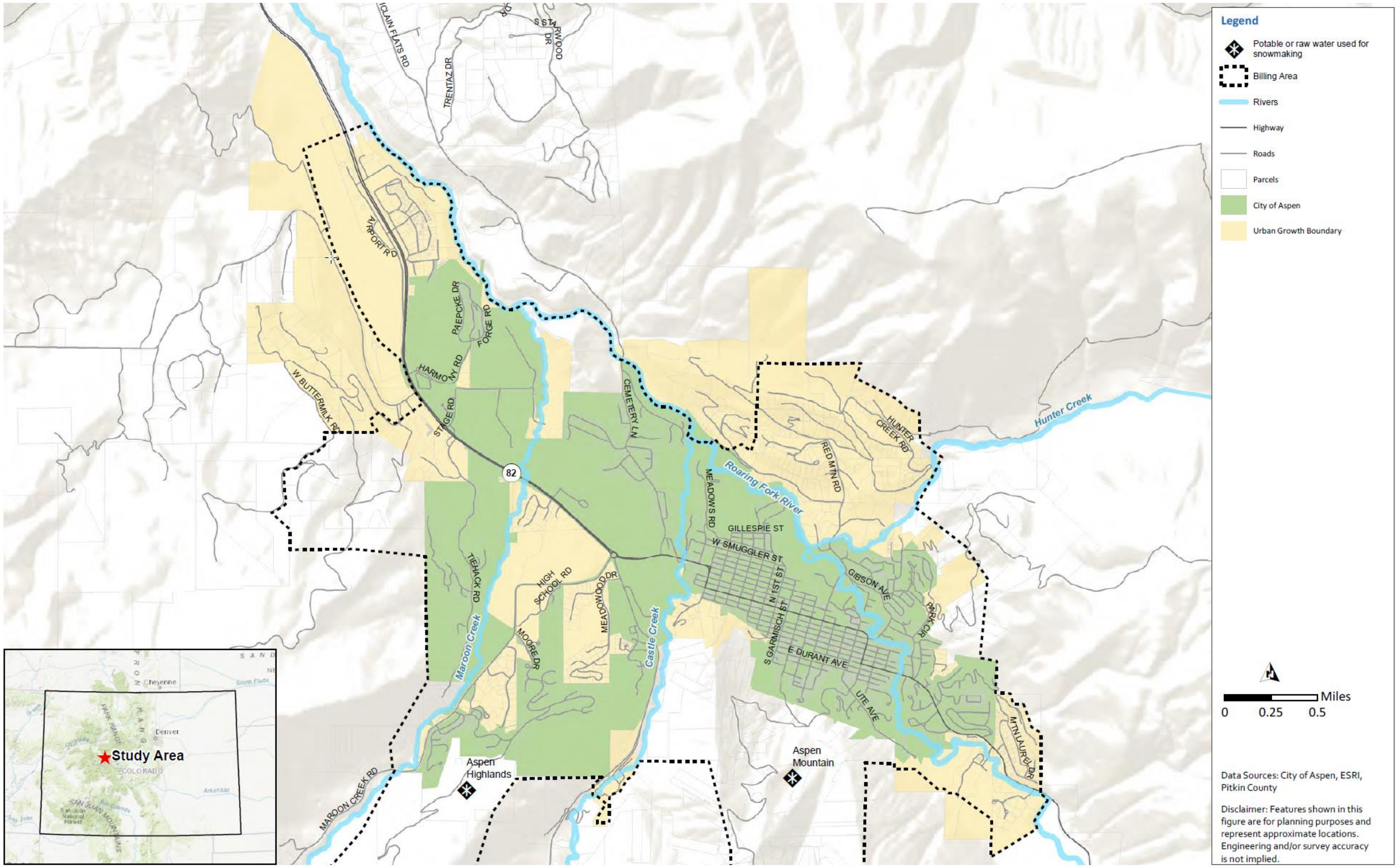


Figure 1.1 Study Area

All land within the city limits is within the City's existing water service area (also referred to as the billing area). In addition, the City also provides potable water and raw (untreated) water for snowmaking at Aspen Mountain and Aspen Highlands, respectively.

The City has established an Urban Growth Boundary (UGB) to focus development inside of the boundary, while discouraging urban levels of development outside of the boundary. The UGB extends beyond the city limits. Portions of the UGB are within the existing water service area, while other portions are outside the existing water service area.

The study area for this IRP consists of the City's current service area and the UGB, which are shown on Figure 1.1.

1.3.2 IRP Planning Period

This IRP serves as a guiding document for the planning and implementation of water supply improvements to accommodate future water supply needs through year 2070. The City deliberately chose a planning period of approximately 50 years to reflect the long-lasting implications of water resources decisions, such as siting storage for the Castle Creek and Maroon Creek water rights, and the time it can take to plan, permit, construct, and implement water projects. Interim planning years include the following:

- 2030 to provide guidance for supply projects that should be initiated and budgeted for in the near-term;
- 2050 to provide strategies for longer-term supply needs; and
- 2070 to develop a roadmap for long-range needs and set a course toward implementing any complex solutions.

The IRP's 2070 planning horizon extends 20 years beyond that studied in Colorado's Water Plan (Colorado Water Conservation Board [CWCB], 2015) and the population and housing projections available from the Colorado State Demography Office. Accordingly, strategies are employed in this IRP to use those information sources as a baseline and project forward from there.

Planning uncertainties are greater in more distant years due to limitations in abilities to accurately forecast future conditions; this does not alleviate the need to plan water supplies far in advance. These uncertainties can be addressed in part by implementing IRP recommendations that are "trigger-based" – such as a certain demand level or frequency of shortages – rather than strictly on a planning year basis. Additionally, it is recommended that the IRP be updated regularly, such as every 10 years, to adjust for changes in "existing" conditions, incorporate new data and science, address evolving regulations, and extend the planning horizon.

1.3.3 Water Supply Goals

The City's treated water supply is designed and operated to divert water from its sources, then treat, store, convey, and distribute it to customers throughout the service area while meeting system pressure and water quality standards. In addition, a portion of the community's outdoor water use is supplied by diverting water from surface water resources without treatment, delivered to points of use through a network of raw (untreated) water pipelines and ditches. Water supply reliability is affected by the combined availability of water at the City's water sources, water quality, the performance of water system facilities, and the variability of demands.

As part of the IRP, projections of future demands include an assessment of the magnitude, timing, and variability in those demands, considered relative to the City's available water supplies and the magnitude and variability they exhibit. To the degree the IRP identifies the potential that the City's existing supplies will be unable to meet the full range of demands through the planning period, strategies were developed to mitigate the projected shortages.

Meeting demands also requires operational strategies, particularly in times of periodic drought or other constraints on supply capacity (such as an emergency condition at the water treatment facility or major disruption in water conveyance). The City's *Drought Mitigation and Response Plan* (Element Water Consulting, 2020) identifies a working list of priority uses, in decreasing order of priority, listed in Table 1.1. For purposes of identifying and sizing additional supplies, the IRP assumes that the City's existing system for reducing demand with drought response measures can and will be used when needed, up to Stage 3 ("Extreme") drought response measures.

Table 1.1 General Water Use Priorities during Water Shortage Conditions

Priority	Representative End Uses	Description
1	Health and Safety	Indoor sanitary uses for residential, commercial, schools, health services, etc., firefighting, and hydrant flushing.
2	Protection of Natural Environment	Protection and maintenance of decreed instream flows.
3	Discretional Commercial and Industrial Use	Non-sanitary indoor uses; outdoor commercial uses to support stability.
4	Public Parks and Recreation	Outdoor potable or raw water irrigation of public areas, including lawn grass in active recreation areas.
5	Residential Landscaping Features	Outdoor potable or raw water irrigation of trees and shrubs in residential areas.
6	Lawn Grass Irrigation	Outdoor potable or raw water irrigation of residential lawn grass and public areas with low foot-traffic throughout the City.
7	Hydroelectric Power Generation	Generation of hydroelectric power from Maroon Creek diversions.

The City set out to develop this IRP as a roadmap for reliably meeting future demands and addressing vulnerabilities that could impact water system reliability, while reflecting community values and addressing trade-offs between alternative strategies. This integrated water resource plan provides a roadmap for the City to provide a legal, reliable water supply for the next 50 years. Although hydroelectric production at current levels is included, this IRP does not address increased hydroelectric production using the City's existing water rights decreed for this use. The City will continue to evaluate future hydroelectric opportunities.

The goals outlined in Table 1.2 were established for evaluating alternative approaches for meeting the community's future water needs. The City is committed to sustainable solutions for water and energy, and strives to produce hydropower when water supply availability conditions allow. The relative importance of each of these goals, and the use of these goals in evaluating alternative supply approaches, is described in Chapter 4.

Table 1.2 Water Supply Goals

Goal	Component
Affordability	• Capital cost • Life cycle cost
Supply Availability	• Magnitude of use of drought response measures • Frequency of use of drought response measures
Supply Resilience	• Diversity of supply sources • Vulnerability risks
Ease of Operations	• Degree of operational simplicity
Community and Environmental Benefits	• Protect instream flows • Efficient water use • Energy footprint
Ease of Implementation	• Construction and permitting complexity • Ability to phase capacity

1.4 Stakeholder Engagement

The IRP was developed to meet the near- and long-term needs of the Aspen community. The City made extensive efforts to engage stakeholders and the public in developing a plan that reflects a breadth of local technical expertise and the community's values and priorities through a multi-phase stakeholder engagement process.

Primary elements of stakeholder engagement in support of IRP analyses included:

- Community interviews,
- Technical Work Group meetings (three meetings over the course of IRP development),
- Community meetings (three meetings over the course of IRP development), and
- Aspen Community Voice online engagement portal.

1.4.1 Community Interviews

A series of 14 one-on-one interviews was conducted early in the IRP development process to establish a foundational understanding of community water-related interests, needs, and priorities. Stakeholder engagement activities included discussions in fall 2020 with community members and organizations representing a range of business, citizen, and environmental perspectives.

Interview participants were asked to share both their sense of priorities for Aspen's long-term water future, as well as those they believed, are prevalent within the Aspen community. Substantial overlap exists among the perspective provided with six areas emerging as prominent for water plan consideration:

- Water for Human Consumption and Equity of Access: Maintaining a reliable and resilient supply of water for human consumption was a consistent top priority/value among interviewees.
- Ecosystem Health: The role of water in ecosystem health emerged across the interviews as an important priority.
- Recreation: Supporting and maintaining recreational uses was consistently identified as a priority.
- Water System Resilience: Interviewees linked redundancy to the foundation of a reliable water supply. Redundancy must be built into the system.

- Clarity and Transparency in the Planning Process: Conducting a robust and detailed process that clearly identifies needs (future demand) and resources available (water supply) was a commonly shared value among interview participants.
- Business and Development: With demand increasing as supply continues to decrease, new development pressures on water were highlighted by some interview participants as a focal point for the planning process, specifically regarding land use planning, associated patterns of development, and resulting future water demand.

Participants also expressed perspectives on challenges and concerns related to the City's water system and planning process. Interview participants consistently indicated that they do not have concerns about current quality in the Aspen drinking water system and that they believed the system is well maintained. But even as there was comfort with current water systems operations, interview participants identified a series of challenges/concerns for attention during the planning process. These include:

- Water Security: Interviewees highlighted a concern related to water security and reliability, with a short safety window (i.e., limited storage in the system) and a lack of focus on water reuse raising concerns among some interviewees.
- Climate Change Impacts: Interview participants consistently identified the effects a changing climate will have on the community's water supply.
- Awareness of and Incentives for Water Conservation: Improving demand management was consistently identified as an important aspect of an overall water plan. The types of concerns and opportunities expressed by participants included water pricing strategies, a "water scarcity" ethic held by residents, potential disincentives to conservation, basic water literacy, non-resident workers, and water reuse opportunities.

During the interviews, participants were asked to identify differences of opinions that are likely to exist within the Aspen community relevant to the City's water future. In response, interview participants identified four areas: growth (water as an enabler of further growth); aesthetic uses (lush, non-native plantings or natural landscaping); storage (how much, where, and to what purpose); and balancing priorities (sorting what uses will receive how much support), specifically:

- Growth: Participants shared a continuum of perspectives regarding further growth and development in Aspen and the role water availability plays in enabling growth and the influence on water scarcity.
- Aesthetics: Interview participants indicated that a continuum also exists across the Aspen community relative to the use of water for aesthetic purposes, including fountains and other water features, landscaping, etc.
- Water Storage: Interview participants indicated a belief that there is general recognition across the Aspen community of the need for more water storage, while differing opinions exist across the community regarding the amount of storage needed, appropriate location(s) for storage, and the existence of more storage enabling growth.
- Balancing Priorities: As the Community Priorities section indicated, interview participants identified a range of potentially competing uses for water, creating a need for an explicit prioritization (or balancing) of water uses in the context of the Aspen water plan.

Additional findings from these interviews are documented in Appendix B. Perspectives from these interviews were used to guide development of subsequent stakeholder engagement activities and shape the factors used to evaluate water supply alternatives.

1.4.2 Community Meetings and Technical Work Group Meetings

The City proactively communicated with the public and technical experts through a series of press releases and meetings throughout the course of developing the IRP. Local media representatives participated in the community meetings and periodically published articles about the IRP, further extending outreach to the community. In tandem with each public meeting, the City facilitated a meeting of the IRP Technical Work Group to discuss detailed analyses and obtain feedback and advice. Input from the community and the Technical Work Group was obtained as the IRP development progressed through key phases of analysis and decision-making.

Three rounds of engagement were conducted, on November 18, 2020, January 14, 2021, and March 3, 2021, each of which included a community meeting and a Technical Work Group meeting. Each facilitated meeting featured a presentation on key aspects of the IRP development and included opportunities for participants to ask questions, discuss content, and advise the planning team. All meetings were held virtually due to restrictions associated with the COVID-19 pandemic that coincided with the timing of development of the IRP. Information about each round of engagement is included in Appendix B.

1.4.3 Aspen Community Voice Online Engagement and Local Television Coverage

The City's online public information and engagement platform, Aspen Community Voice, was used throughout the development of the IRP to inform the community and solicit input. In addition to providing background information on the City's water supply resources and options, the Aspen Community Voice site provided an opportunity for community members to ask the project team questions and provide additional input on key topics as the IRP development moved through its various phases of development.

Presentation materials and recordings of online meetings were posted to the site, allowing members of the community to stay up to date and participate in IRP development, even if they were unable to attend project meetings. Key interim documents from the IRP were also posted to the site. Specific discussion sections were established on the site to facilitate public input on community values, key water supply issues and concerns, water supply considerations for evaluating supply strategies, and water supply portfolios.

The City made deliberate outreach to the community to increase awareness of the site and participation in the online forum. This included outreach through local media, paid advertisements, City newsletters, ACRA newsletters, water bill inserts, and Aspen Community Voice newsletter. Altogether:

- Over 2,200 invitations were sent to participate and learn about the project via Aspen Community Voice newsletter,
- 400 individuals visited the IRP page on Aspen Community Voice,
- 4,127 individuals were reached with a Facebook post about the project in January 2021
- 2,556 individuals were reached with a Facebook post about the project in February 2021
- 10-30 people attended each of the 1.5-hour virtual community meetings that took place in November 2020, January 2021, and March 2021, and
- 10-12 people attended each of the 2-hour virtual technical work group meetings that took place in November 2020, January 2021, and March 2021.

Visitors to the Aspen Community Voice IRP page participated in a wide range of activities, such as viewing photos, downloading documents, confirming schedule and meeting details, contributing on forums, and participating in polls.

The City also recorded a television interview segment with the planning team near the project outset to increase community awareness and participation in the development of the IRP. The segment was moderated by Mitzi Rapkin, the City's Communications Manager, and aired on Grassroots Community Television in late 2019.

1.5 Report Organization

This report documents the analyses and findings of the IRP. The report is organized into chapters that reflect key elements of the IRP process and its outcomes, including:

- Executive Summary,
- Chapter 1: Introduction,
- Chapter 2: Water Demands,
- Chapter 3: Existing and Future Water Supplies,
- Chapter 4: Future Supply Strategy, and
- Chapter 5: Implementation Plan.

1.6 Acknowledgements

The IRP was developed through the vision of the Aspen City Council, who authorized the development of this plan. Numerous individuals contributed to the IRP, ranging from data gathering and analysis to review and evaluation of the water supply options and management strategies. The primary planning team is recognized and appreciated for their many contributions toward this planning effort, including the individuals listed in Table 1.3.

Table 1.3 Primary Planning Team for the IRP

Organization	Individual	Role
City of Aspen	Tyler Christoff	Utilities Director
	Steve Hunter	Utilities Resource Manager; Project Manager
	Mitzi Rapkin	Community Relations Manager
	Raquel Flinker	Project Engineer
	Lee Ledesma	Utilities Finance and Administrative Manager
Carollo Engineers	John Rehring	Project Manager
	Inge Wiersema	Technical Lead
	Rachel Gross	Project Engineer
	Madison Rasmus	Staff Engineer
Element Water Consulting	Beorn Courtney	Water Demand and Supply Lead
	Logan Burba	Water Demand and Supply Specialist
Ross Strategic	Rob Greenwood	Engagement Lead
	Micaela Unda	Engagement Staff
	Sarah Shadid	Engagement Specialist

Members of the Technical Work Group are also recognized and thanked for their contributions to the project. Technical Work Group members are listed in Table 1.4.

Table 1.4 Technical Work Group Members

Individual	Title	Organization
David Graf	Community Science Manager	Colorado Department of Natural Resources
Lisa Tasker	Citizen Advisory Board Member	Pitkin County: Healthy Rivers Board
Laura Makar	Assistant Attorney	Pitkin County: Healthy Rivers Board
April Long	Executive Director	Ruedi Water and Power Authority
Elise Osenga	Research and Education Coordinator	Aspen Global Change Institute
Tim Miller	Hydrologist	Bureau of Reclamation
Laura Belanger	Senior Water Resources Engineer & Policy Advisor	Western Resource Advocates
Rob Viehl	Senior Water Resource Specialist	Colorado Water Conservation Board
Mickey O'Hara	Director of Programs	Colorado Water Trust
Julie Vano(1)	Research Director	Aspen Global Change Institute
Guy Wohl	Program Coordinator of Emerging Solutions	Rocky Mountain Institute
John Schroeder	Data Scientist	Rocky Mountain Institute
Tom Moore	President	Salvation Ditch Company
Kendall Bakich	Aquatic Biologist	Colorado Parks and Wildlife

Notes:
(1) Provided technical advisory guidance on climate change scenarios outside the Technical Work Group meeting process.


INTEGRATED WATER RESOURCE PLAN

Chapter 2

WATER DEMANDS

To provide a foundation for water supply planning, water demands were forecasted through the 50-year planning period to 2070. Additional detail regarding the demand forecast analyses is provided in the *City of Aspen Water Demand Projection Update* memorandum prepared by Element Water Consulting (2021) in support of developing this IRP. This memorandum is included in Appendix C.

2.1 Existing Demands

Recent years' water use was assessed to establish a baseline condition for demand forecasts. Data were analyzed through 2019, the most recent calendar year for which data were available at the time the analyses were conducted. Previous iterations of demand quantifications, performed in 2015, were updated to account for recent conservation efforts in the City's service area and to assess the impacts of a range of uncertainties associated with key demand drivers.

2.1.1 Potable Water Use

The City provides potable water service to approximately 3,960 customer connections within its water service area. The current service area includes the City of Aspen and some areas outside of the municipal boundary that are within the UGB, as shown in Figure 1.1 and described in Chapter 1. For purposes of the IRP, it is assumed that the full UGB represents the maximum potential future water service area for the City, and that City water service will not be extended beyond the UGB. Areas within the UGB that the City does not currently serve include portions of the Airport Business Area and Buttermilk Ski Area to the northwest of the current service area, and portions of Red Mountain to the north of the current service area.

2.1.1.1 Water Use Categories

The City uses the following customer category assignments for most of its potable water service accounts that are metered and billed (referred to herein as "Metered Customer Categories"):

- Single-family residential,
- Multi-family with two to four units,
- Multi-family with greater than five units,
- Commercial/industrial,
- City facilities, and
- Irrigation.

A small portion of the potable water that the City produced in 2019 was provided for "Other" purposes as described below:

- Snow Making: The City provides treated water to Aspen Ski Co. for snowmaking at Aspen Mountain[1].
- Buttermilk Metro District: The City provides potable water to the Buttermilk Metro District, which serves 77 homes in West Buttermilk for indoor and outdoor uses, which is metered in bulk by the City and provided to Buttermilk Metro District.
- Billed Unmetered: The City has unmetered customers who are billed at a flat, rather than tiered, rate. This usage typically involves service to construction projects before a permanent meter is installed. The amount of water is estimated by City staff based on the number of active construction permits.
- Unbilled Unmetered Authorized: The City has a small number of bulk water sales each year for filler hydrant draw permits, typically related to construction. Before 2017, the tracking of this water use category was based on staff estimates. For 2017 and 2018, this water use was based on customer log sheets. In 2019, a fill station was installed to replace filler hydrants and the use is now metered. Other unbilled unmetered authorized consumption includes commercial fire system testing, maintenance and construction/system flushing, water quality flushing, and fire hydrant usage by the Aspen Fire Department. This use is estimated to be less than 1 percent of these "Other" uses.

Total potable water demand for the City's system, including treated water supplies for the "Other" accounts, averaged approximately 3,027 acre-feet per year (AFY) from 2012 through 2019, as detailed in Table 2.1. It remained relatively constant over this 8-year period, even though there has been some growth in the service area through redevelopment and new development.

Residential demands (single family and multi-family units) accounted for approximately 59 percent of the 2019 potable water demand in the City's service area. Commercial accounts have the next highest annual demand, accounting for 23 percent of potable water use in 2019. A chart showing the distribution of 2019 water use by customer category is presented in Figure 2.1.

[1] The City also provides raw water to Aspen Ski Co. for snowmaking at Aspen Highlands Ski Area. "Treated water" and "potable water" are generally used interchangeably throughout this Plan to refer to water that has been treated at the City's WTF. However, water provided for snowmaking on Aspen Mountain is treated but may not meet potable standards at the point of use.

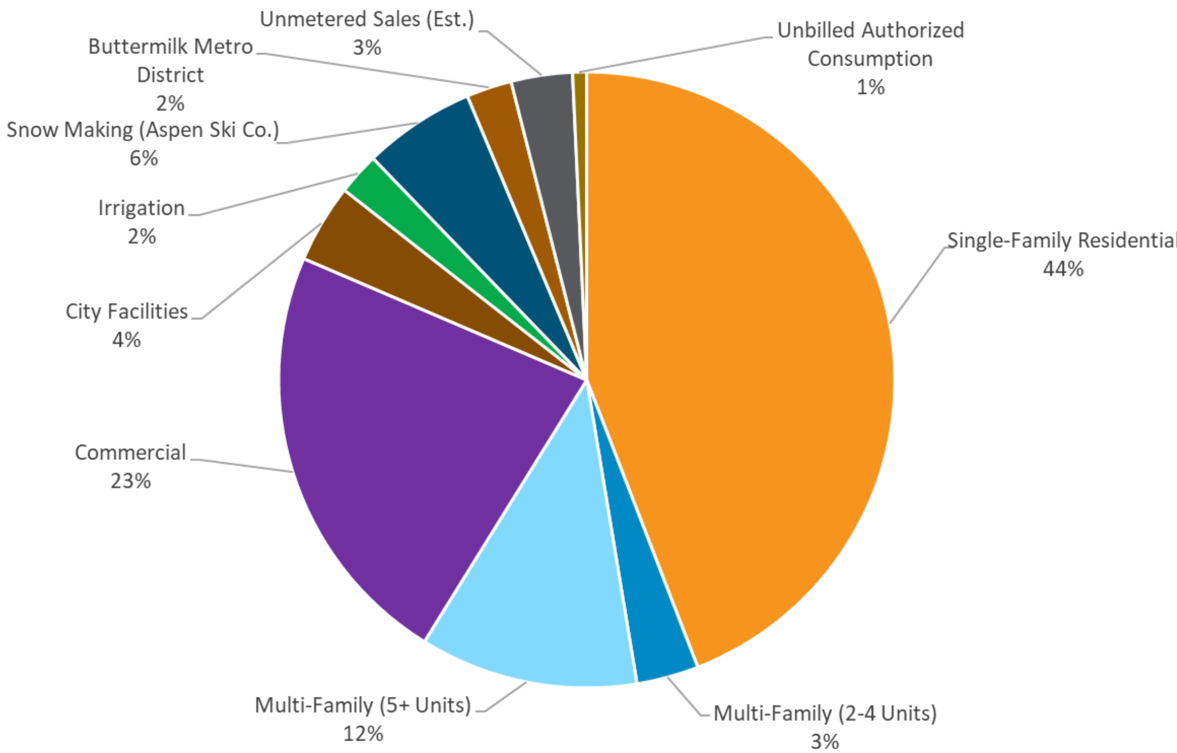


Figure 2.1 Potable Water Use Distribution in 2019

Table 2.1 Annual Potable Water Use by Customer Category from 2012 through 2019

Year	Metered Customer Accounts (AFY)							Other Potable Uses (AFY)				Total (AFY)
	Single-Family Residential	Multi-Family (2-4 Units)	Multi-Family (5+ Units)	Commercial	City Facilities	Irrigation Only	Total	Snow Making (Aspen Ski Co.)	Buttermilk Metro District	Unmetered Sales (Est.)	Unbilled Authorized Consump-tion(1)	
2012	1,391	101	387	650	124	85	2,739	113	79	208	47	3,185
2013	1,217	99	380	623	124	72	2,514	169	73	92	42	2,891
2014	1,267	98	365	646	99	80	2,555	200	68	92	50	2,966
2015	1,180	94	362	666	107	79	2,489	194	66	92	55	2,895
2016	1,257	97	352	639	112	84	2,541	227	70	92	62	2,993
2017	1,307	130	354	650	124	92	2,658	127	93	92	210	3,180
2018	1,397	98	341	664	113	84	2,697	247	75	92	117	3,228
2019	1,263	93	328	647	118	63	2,513	183	68	92	21	2,878
Average	**1,285**	**101**	**359**	**648**	**115**	**80**	**2,588**	**183**	**74**	**107**	**75**	**3,027**
Average (% of total of all uses)	42%	3%	12%	21%	4%	3%	85%	6%	2%	4%	2%	100%

Source: Element Water Consulting, 2021. *City of Aspen Water Demand Projection Update*

Notes:

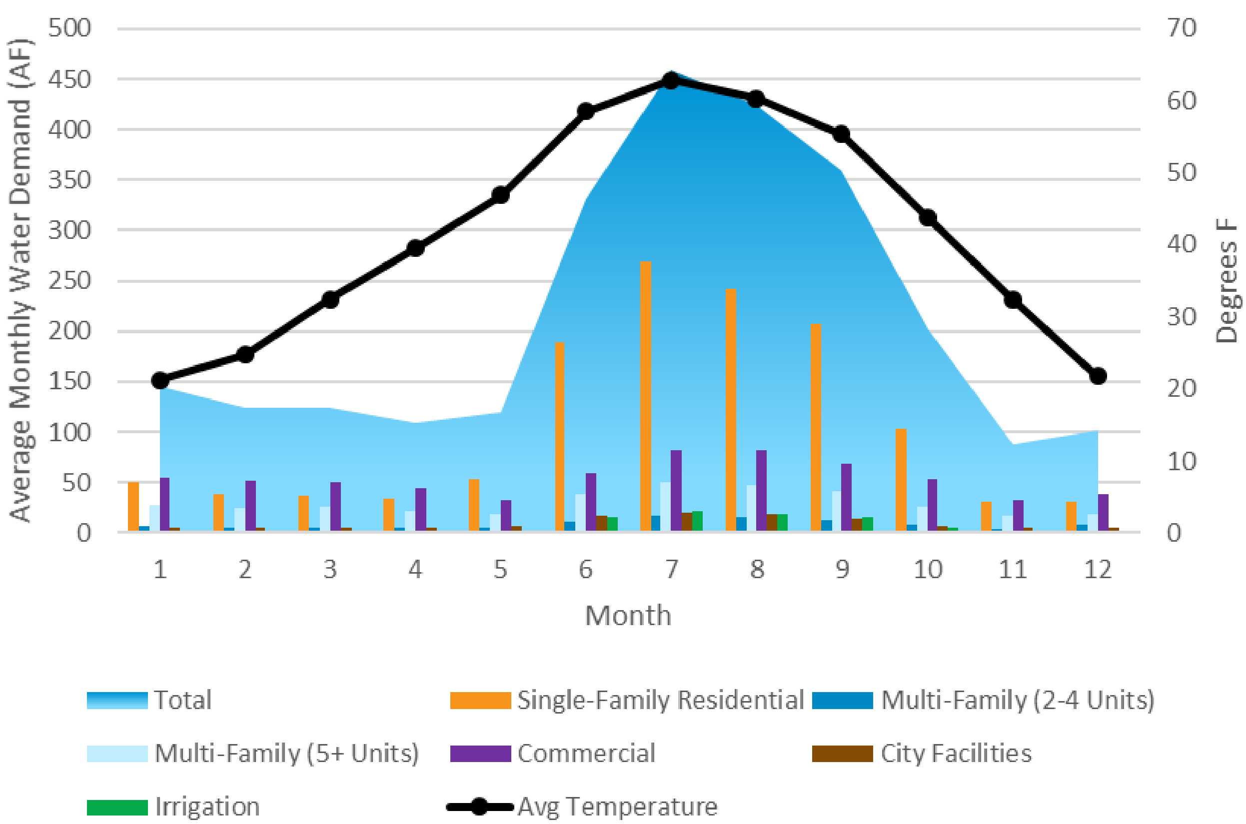
(1) Use under this category was unmetered through 2018. The filler hydrant was replaced and metered starting in 2019. All other unbilled authorized uses remain unmetered.

2.1.1.2 Seasonal Water Use Patterns and Peaking Factors

Potable water demands are higher during the summer months due primarily to outdoor water use. An analysis of water use records estimates that approximately 45 percent of potable water use in the Metered Customer Categories was associated with outdoor water use from 2012 through 2019, with only minor variations from year to year over this period.

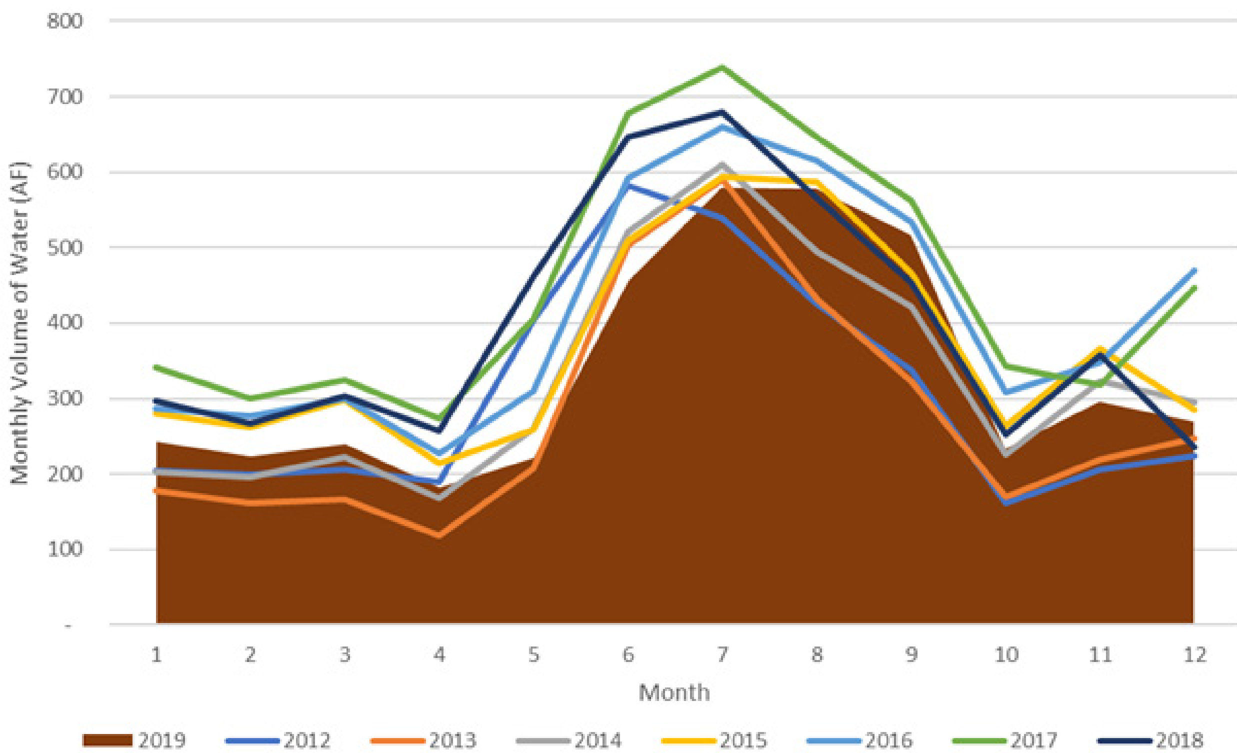
Peak water production has typically occurred in June, July, or August each year, and use patterns show higher demands continuing through September before notably decreasing in October. A small upswing can be observed late in the year, associated with snowmaking demands and the beginning of ski season tourism. Multi-family residential and commercial water usage increases during summer months to a lesser degree than use in the single-family residential and city facilities categories, reflecting the amount of outdoor water use associated with each of these customer categories.

Figure 2.2 shows the monthly metered potable water demands 2019 for the City's Metered Customer Categories and Figure 2.3 shows historical monthly water production for 2012 through 2019. Note that the difference between monthly water production and monthly water demand can be attributed to non-revenue water as described in Section 2.1.1.3.



Data Source: City of Aspen Water Demand Projection Update (Element Water Consulting, 2021)

Figure 2.2 Average 2012 through 2019 Monthly Metered Potable Demands by Customer Category



Data Source: City of Aspen Water Demand Projection Update (Element Water Consulting, 2021)

Figure 2.3 Historical Monthly Water Production

As shown in Figure 2.3, unlike in most recent years, demands in 2012 peaked in June before a significant decline in demands through October. The City declared a Stage 1 Drought in June 2012, which called for voluntary water-use reductions from customers, placed water use restrictions on public facilities, and increased water rates for the City's highest billing tiers. The decline in water use starting in July 2012 may reflect a reduction in use influenced by the Stage 1 declaration, which continued through the summer of 2013, likely influencing demands through the conclusion of the declaration in September 2013. For all subsequent years, peak production has occurred in July.

Starting in 2014, production patterns show higher uses continuing through September before notably decreasing in October before a small upswing in November and December for snowmaking and the beginning of ski season tourism. The water use volumes indicate that the irrigation season has been extending further into September in more recent years. This could be an indication of climate change, with customers responding to warmer temperatures extending further into late summer and early fall.

Maximum day and average day production values were provided by the City and used to calculate seasonal peaking factors. A summary of the City's annual and daily peak water production values from 2012 through 2019 is presented in Table 2.2. The data indicate the average daily production from 2012 through 2019 was 3.84 million gallons per day (mgd), with an average maximum daily production of 8.09 mgd. The average and maximum day production increased through 2017 and then declined in 2018 and 2019. These data indicate that a maximum day demand peaking factor (measured as the peak day production divided by the annual average production within a given calendar year) of approximately 2.1 is typically representative of the City's water demand.

Table 2.2 Historical Variability in Potable Water Production from 2012 through 2019

Year	Annual Peaking Calculations						Winter (October through April) Peaking Calculations			
	Annual Production (AFY)	Annual Production (MG)	Average Daily Production (mgd)	Maximum Daily Production (mgd)	Annual Peaking Factor	Peak Demand Day	Average Daily Production (mgd)	Maximum Daily Production (mgd)	Winter Peaking Factor	Winter Peak Day
2012	3,681	1,200	3.29	7.6	2.3	6/21/2012	1.97	3.84	1.9	12/15/2012
2013	3,314	1,080	2.96	8.0	2.7	7/24/2013	1.81	4.19	2.3	12/4/2013
2014	3,942	1,284	3.52	7.0	2.0	7/20/2014	2.42	5.02	2.1	11/17/2014
2015	4,386	1,429	3.92	8.3	2.1	7/3/2015	2.99	5.04	1.7	12/1/2015
2016	4,928	1,606	4.40	8.1	1.8	7/29/2016	3.39	6.35	1.9	12/2/2016
2017	5,378	1,752	4.80	9.8	2.0	7/7/2017	3.60	6.39	1.8	12/7/2017
2018	4,780	1,558	4.27	8.7	2.0	6/23/2018	3.04	5.71	1.9	11/8/2018
2019	4,039	1,316	3.61	7.2	2.0	7/12/2019	2.60	5.22	2.0	11/30/2019
Average	4,306	1,403	3.84	8.09	2.1	-	2.73	5.22	1.9	-

Notes:
Source: Element Water Consulting, 2021. City of Aspen Water Demand Projection Update

Aspen experiences a "second peak" during the winter, influenced by snowmaking and increased visitor populations. Since 2012, this second production peak has occurred in November or December each year. Although the ratio of the maximum winter (October through April) daily production to the average winter daily production is 1.9, similar to the annual maximum day demand peaking factor of 2.1, the average daily winter demand is significantly lower than the annual average daily production.

2.1.1.3 Non-Revenue Water

Non-revenue water is defined as the difference between the amount of water that is treated ("produced") at the City's water treatment plants and the total billed authorized (metered and unmetered) water use. Non-revenue water peaked in 2017 'and has been declining as the result of industry best practices engaged by the City, including meter calibrations and validation, advanced leak detection, system testing, and repairs. Additional efforts are underway to verify the actual amounts of non-revenue water that are apparent from the data, and to reduce non-revenue water across the City's system.

2.1.2 Non-Potable Water Use

The City uses raw (non-potable) water to meet irrigation demands at the City golf course (the Aspen Golf Club) and certain municipal parks and for maintenance of aesthetic features such as fountains, the downtown mall, and many of the City's street trees located along the ditch system. The City also provides non-potable water to private landowners under raw water agreements and to Aspen Ski Co. for snowmaking at Aspen Highlands. The City uses additional non-potable water supplies to produce hydroelectric power and to maintain its recreational water right for a whitewater park.

The City holds raw water agreements with customers for irrigation and snowmaking uses. Customers are either served through the City's pressurized non-potable water system or a non-pressurized open ditch system. Water supplies delivered through these agreements may be owned by the City or in some cases by the customer, with the City delivering the customer's water. Customers served through the City's pressurized non-potable water system, which is supplied through Leonard Thomas Reservoir releases, are metered and billed based on measured water use. Customers served through the City's non-pressurized system have water delivered by open channel ditch systems and are billed based on estimated water usage, not measured deliveries. Non-pressurized raw water use is based on irrigated area and a formula of 15 gallons per square foot per irrigation season. The raw water agreements state that non-potable water service to customers is interruptible.

Because not all non-potable water use is metered, it is difficult to accurately estimate non-potable water use in Aspen. Additional information on non-potable demands is provided in the *City of Aspen Water Demand Projection Update* memo by Element Water Consulting (Appendix C).

2.1.2.1 Non-Potable Irrigation

The City serves approximately 60 irrigation customers through the non-pressurized open-channel ditch system and 11 irrigation customers through the pressurized non-potable water system via releases from Leonard Thomas Reservoir. The irrigation supply is typically available from mid-May through mid-October, with uses peaking in June, July, and August. Table 2.3 shows the water use attributed to irrigation accounts for the pressurized and non-pressurized systems in 2019.

Table 2.3 2019 Non-Potable Water Use for Billed Irrigation Customers

Non-Potable Water Usage Category	Non-Potable Water Usage (AFY)
Total Non-Pressurized via Open Ditch System	1,047
Total Pressurized via Leonard Thomas Reservoir	142

Non-pressurized system customers are billed based on an estimated seasonal irrigation demand calculated from an approximate irrigation area and an estimated unit irrigation demand as a function of irrigated area. The top users under the City's non-pressurized non-potable water system include private residences, golf course irrigation, multi-family residence irrigation, and City facilities.

2.1.2.2 Non-Potable Snowmaking

The City has a raw water agreement with the Aspen Ski Co. to provide a non-potable water supply for snowmaking for the Aspen Highlands Ski Area. This water is supplied through a pressurized and metered connection which is read annually near the end of the ski season. Water use for snowmaking predominantly occurs in November and December. For the 2019 season, approximately 90 (AF of non-potable water was used for this purpose. This amount is separate from the approximately 180 AF of treated water provided to Aspen Mountain that was previously described.

2.1.2.3 Whitewater Park

The City owns an absolute water right decreed for recreational boating use that supplies the Aspen Whitewater Park, located adjacent to the Roaring Fork River. The water right is limited to diversion to the Whitewater Park from June through August. The historical maximum recorded diversion was approximately 350 cubic feet per second (cfs) in July 2007.

2.1.2.4 Hydroelectric Power Generation

The City owns and operates the MCHPP, which is a 400-kilowatt hydroelectric generation facility; 46 percent of the energy use in Aspen is served through hydroelectric power. The annual hydropower diversions are typically approximately 20,000 AFY. This water is diverted and then returned to the creek, so it is considered a non-consumptive use. Water can be delivered to the MCHPP year-round, with demands peaking during summer months.

2.1.3 Instream Flow Requirements

In 1980, the City entered into an agreement with the CWCB to allow the City's 15 cfs Hunter Creek Flume and Pipeline senior water right to be used for instream flows on Hunter Creek, and the water court approved that use. Then in 1993, the City Council adopted water management policies intended to provide for current and future municipal water needs while at the same time maintaining streamflow in Castle Creek and Maroon Creek downstream of its diversion structures at flow rates that are at or above the CWCB's decreed instream flow rights for the protection of the fishery and the associated aquatic habitats in those streams. This is reflected in the objectives and operating principles described in the City's *Drought Mitigation and Response Plan* (Element Water Consulting, 2020).

The City has an intergovernmental agreement with the CWCB to protect the natural environment of Castle Creek by operating the City's water rights on Castle Creek in a manner that will allow the decreed minimum streamflow of 12 cfs to be maintained unless needed for municipal purposes under circumstances such as extraordinary drought or emergency conditions in its municipal water supply. An additional 1.3 cfs flow rate is maintained on Castle Creek below the Marolt Ditch headgate, which is not decreed but has been determined to be a more correct calculation of the instream flow required to protect the natural environment to a reasonable degree. As such, the City strives to maintain this additional 1.3 cfs. Although the City does not have a similar agreement regarding Maroon Creek, it also operates its senior Maroon Creek water rights in a way that strives to maintain the decreed instream flow at 14.0 cfs.

Even though the City does not divert water to these flows in the same manner that it diverts water to meet potable and non-potable water demands, the instream flows are a priority for the City and directly affect the City's water system operations. At times, the City limits its surface water diversions to prioritize the protection of decreed instream flows.

2.2 Potable Water Demand Projections

As part of this analysis, a baseline demand projection and six demand scenarios were developed to provide a demand envelope of potential potable water demands through 2070.

2.2.1 Demand Projection Drivers

For each of the six projection scenarios, four separate demand drivers were used to adjust the Metered Customer Category demands under future conditions:

1. Population Growth and Visitor Occupancy.
2. Climate Change.
3. Water Use Efficiency and Conservation.
4. Non-Revenue Water.

Additional adjustments for the "Other" demand categories include:

- Future snowmaking coverage, estimated at 360 AFY.
- Future water delivery to Buttermilk Metro District, estimated at 108 AFY.

2.2.1.1 Population Growth and Visitor Occupancy

The Colorado Department of Local Affairs State Demography Office (SDO) has historical full-time population data tabulated by county and by municipality from 1980 through 2018. According to the dataset, the City's full-time population averaged approximately 40 percent of the Pitkin County reported population from 2010 through 2018. Over this period, the Aspen and Pitkin County full-time populations grew similarly year-to-year except for 2015 and 2016, when the City had notably higher annual growth than Pitkin County. The City's full-time population annual growth rate has averaged 1.3 percent over these 9 years, which is very close to and supports the use of the City's long-term planning growth rate of 1.2 percent. The City's 2020 full-time water service area population, including areas within and outside the municipal boundary, was estimated to be 11,285 people.

The SDO population data for Aspen do not include the full-time population within the UGB that is outside of the municipal boundary. Demographer data and the 2012 Aspen Area Community Plan (AACP) (City of Aspen, 2012) indicate that the full-time population located within Aspen's UGB around the year 2010 was approximately 1.5 times the City's full-time municipal boundary population.

The full-time population has a year-round water demand. Water demands for the non-full-time population are less clear and depend upon influences of the duration and seasonality of occupancy. Utilizing available data on average visitor stay duration, visitor occupancy levels, and wastewater flows, recent peak season UGB population is reported to be approaching 40,000 people and, based on the references reviewed, averages over the year to an equivalent population of almost 27,800 people. For this analysis, the 2020 annual total population within the UGB is assumed to be approximately 2.5 times the full-time UGB population. Table 2.4 shows the range of populations in 2070 that could be projected by using 1.2 and 1.8 percent growth rates. Prior studies have utilized a 1.8 percent growth rate, in contrast to the 1.2 percent typically used by the City. Average annual total population projections for 2070 range from 37,000 to 67,900.

Table 2.4 Population Scenarios for 2070 Demand Projections

UGB Population Category & Growth Rate	2020 Baseline	2070 @ 1.2% FT Growth, Current NFT	2070 @ 1.2% FT & NFT Growth	2070 @ 1.8% FT Growth, Current NFT	2070 @ 1.8% FT & NFT Growth
Full-Time (FT) Population	11,300	20,500	20,500	27,500	27,500
Non-Full-Time (NFT) Population(1)	16,500	16,500	30,000	16,500	40,400
Annual Average Total Population(1)	27,800	37,000	50,500	44,000	67,900
Total Growth Rate	NA	0.57%	1.2%	0.92%	1.8%

Notes:
Source: Colorado Department of Local Affairs State Demography Office
(1) The estimated breakdown between FT and NFT population is provided to demonstrate relative magnitudes. The growth rate factor, rather than the population breakdown, is applied in the demand projection.

2.2.1.2 Climate Change

Using the available projected climate change factors from Pitkin County and information from the Colorado River Water Availability Studies for the western Colorado region, a 25 percent increase in outdoor water demand by 2070 is anticipated in Aspen due to expected climate change impacts on landscaping demand due to higher temperatures and associated increases in evapotranspiration. The influence of a warmer and drier future climate is considered under future scenarios by applying this percent increase to the current outdoor water demands. This provides a demand scenario in which customers respond to a warmer and drier future climate by using more water to irrigate landscapes. The impacts of climate change in 2070 are uncertain and could be even greater. Landscaping transformations may also be made to incorporate lower water use landscaping that can survive under hotter and drier conditions, offsetting the need to apply as much water to landscapes. These possibilities were considered in selecting the 25 percent adjustment factor for this analysis.

2.2.1.3 Water Use Efficiency and Conservation

The City's water efficiency programs are designed to meet relatively near-term water use reduction goals. City staff and customers have historically demonstrated a high level of dedication to the efficient use of natural resources, including water, and it is anticipated this commitment will continue. For the 2070 demand projections, it is assumed that the City will continue to advance its conservation initiatives and efforts beyond the programs currently in place. Considering that the City's current indoor use is already relatively low, and that City staff report a significant amount of remodeling throughout the City that has resulted in updates to higher efficiency plumbing fixtures and appliances, a 2 percent modest level of additional indoor savings was included in each of the 2070 projection scenarios. A range of low (5 percent), medium (10 percent), and high (20 percent) levels of outdoor savings (beyond existing conservation savings) was evaluated for ongoing and future outdoor efficiency programs, consistent with the range used for the Colorado Water Plan Technical Update (CWCB, 2019).

2.2.1.4 Non-Revenue Water

As previously described, the City has experienced a recent peak and subsequent decline in its apparent non-revenue, or unaccounted for, water. For the 2070 demand projections, non-revenue water is represented as a percent of the future water production, which is different than the categories that apply a percentage increase or decrease to a future baseline demand. Future scenarios with the lowest non-revenue water percent reflect aggressive efforts to reduce the City's non-revenue water over time. The City has already engaged in annual water loss audits and advanced investigations, so it is reasonable to assume these efforts will continue and support a sustained 15 percent non-revenue water value. However, to bracket a range of potential future non-revenue water conditions, medium (20 percent) and higher (25 percent) percentages of non-revenue water were included in some of the scenarios.

2.2.2 Potable Water Demand Projections

The average annual potable use data over the period 2012 through 2019 were used to develop a 2020 baseline water demand. Six unique 2070 water demand projections were prepared using reasonable combinations of the critical demand drivers described above to support the City's water planning efforts. Considered together, these six scenarios form an "envelope" or range of potential future demand conditions. Note that while this envelope contains a wide range of demand projections, the uncertainties in future climate and other demand drivers mean that future demands could potentially fall outside of this envelope.

The demand projection scenarios and the respective demand drivers shown in Table 2.5 were applied to the 2020 baseline demands to create a future water demand envelope for planning year 2070. These drivers were applied to all Metered Customer Categories. The potable water demands categorized as "Other" uses were projected as described in Section 2.2.1. The resulting total projected 2070 annual demands range from 4,878 to 9,281 AFY, as shown in Table 2.5. The rounded demand forecasts of Scenarios A and F are shown as the low- and high-end demand projections in Figure 2.4.

Table 2.5 Metered Customer Category Drivers for 2070 Demand Projections

Drivers	Growth Rate	Climate Change Impact	Efficiency and Conservation		Non-Revenue	Total Demand (AFY)
Potential Level of Future Demand Relative to Baseline	% Increase in Metered Customer Demands	% Increase in Outdoor Demands	% Decrease in Indoor Demands	% Decrease in Outdoor Demands	% of Total Production	
Scenario A	0.57%	0%	2%	10%	20%	4,878
Scenario B	1.20%	25%	2%	5%	25%	7,589
Scenario C	1.20%	25%	2%	15%	25%	7,239
Scenario D	0.92%	25%	2%	5%	20%	6,310
Scenario E	0.92%	25%	2%	15%	15%	5,670
Scenario F	1.8%	25%	2%	5%	20%	9,281

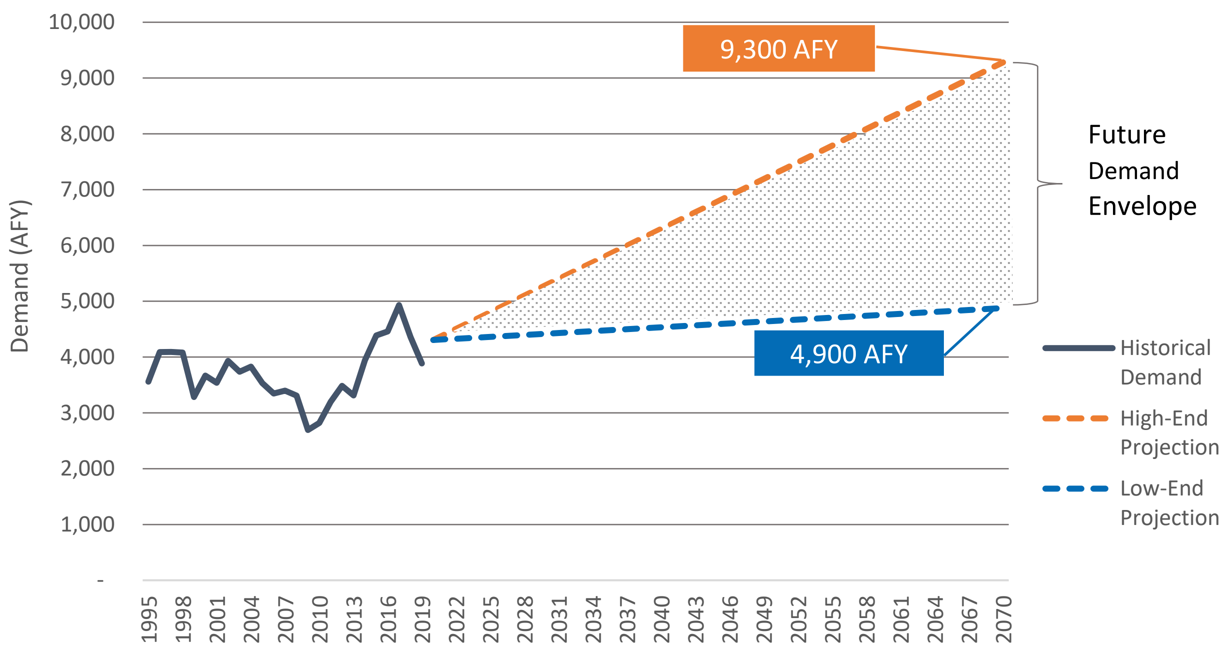


Figure 2.4 Historical and Projected Potable Water Demand Range through 2070

Interim-year demand projections between 2020 and 2070 were not developed for this study because of the lack of available detailed forecasts on growth rates, coupled with significant uncertainty regarding the pace at which climate change impacts will take hold between now and the projected 2070 condition. Instead, demands in interim years can be approximated by linear interpolation between 2020 and 2070, which can be verified by ongoing monitoring of demands and periodic updates to demand forecasts over time. The IRP uses an adaptive planning approach (Chapter 5) that defines the system improvements needed to reliably meet demands in 2070, coupled with a trigger-based approach that provides for phased implementation of those improvements when conditions develop to the point that they become necessary.

2.3 Non-Potable Water Demand Projections

The methods used to project future potable water demands are not directly transferable to non-potable water demands due to limited data availability and because many of the non-potable water demands are constrained by legal agreements and water court decrees. In addition, some non-potable demands are limited to the supply available via raw water license agreements. Those factors, coupled with a lack of detailed data for non-potable water use associated with unmetered use, preclude the development of accurate non-potable water demand projections. A rigorous analysis of existing non-potable water use at metered and unmetered customer sites, coupled with a detailed assessment of raw water supply availability to meet those demands, was not a component of IRP development. However, recommendations for potential approaches and limitations in developing a 2070 non-potable water demand projection for specific non-potable water use categories are provided in the *City of Aspen Water Demand Projection Update* memo by Element Water Consulting (Appendix C).

INTEGRATED WATER RESOURCE PLAN

Chapter 3

EXISTING AND FUTURE WATER SUPPLIES

Water supplies are characterized in the IRP to facilitate consideration of their potential use in meeting the City's near- and long-term water demands. Much of the information in this chapter is based on work completed by Element Water Consulting in support of IRP development. This chapter includes an overview of the City's existing water supplies and associated facilities, followed by a high-level summary of the City's water supply portfolio and concluding with an examination of potential additions to the City's water supply portfolio. These supplies were subsequently packaged into several alternative portfolios of future supply that were compared for potential implementation, as described in Chapter 4.

3.1 Existing Water System Overview

The City owns and operates its water supply system, providing treated (potable) water to customers throughout its service area and raw (non-potable) water for irrigation and snowmaking. The City also uses its water supplies to generate hydroelectric power at MCHPP when water availability conditions allow and to support recreation and decreed instream flows (ISF).

While the City maintains a robust water system today, the City reports that there are signs of aging infrastructure and many components are beyond their expected useful life. Without strategic asset renewal, many components of the system, such as source water diversion and conveyance, treatment, and distribution infrastructure, will be beyond their expected useful life by the end of the IRP planning period (2070).

An overview of the City's existing water supply sources and facilities is provided in the following subsections.

3.1.1 Aspen Water Treatment Facility and Leonard Thomas Reservoir

The majority of water served to the City's customers is supplied by diversions from Castle Creek and Maroon Creek. The City's primary potable water supply intake is located on Castle Creek; Maroon Creek is generally used as a supplemental supply when flows in Castle Creek are insufficient to meet demands or when Castle Creek is experiencing high levels of turbidity. Aside from the turbidity concern, both Castle Creek and Maroon Creek typically exhibit excellent raw water quality.

Raw water is delivered from the Castle Creek pipeline and Maroon Creek pipeline to the City's WTF via Leonard Thomas Reservoir, a terminal reservoir constructed in 1966 with a capacity of about 12 AF. When full, this storage equates to less than a full day of demand in the summer months. From Leonard Thomas Reservoir, raw water is delivered through a 24-inch diameter raw water intake line to the WTF or through a 12-inch diameter pressurized water line to serve non-potable water demands (as described in Chapter 2).

The City operates two adjacent treatment trains, referred to as the West and East Treatment Plants, or collectively as the WTF. The West Treatment Plant was constructed in 1965 and has a hydraulic capacity of 8 mgd; the East Treatment Plant was constructed in 1985 with a hydraulic capacity of 12 mgd. Recent years' demands have not approached the capacity of the WTF, and accordingly, there is some degree of uncertainty as to whether the WTF could reliably produce these peak flows. However, City staff indicate that both plants are in operable condition and have the capacity to supply the City with 100 percent of its current potable water demands.

Each treatment plant consists of the following unit processes: pretreatment, filtration, and disinfection. Pretreatment is accomplished through chemical addition to the raw water before it enters the sedimentation basin or clarification basins. The chemicals cause particles in the raw water to attach to one another, thus becoming larger and heavier and settling out by gravity before the water is filtered. Filter aid polymer is added to assist with filtration effectiveness. Fluoride and chlorine are added before the water is conveyed to the 2-million-gallon (MG) clear well. The clear well provides contact time for the chlorine disinfectant to react with the remaining pathogens before being distributed to customers. To meet Colorado Department of Public Health and Environment (CDPHE) disinfection requirements, a serpentine curtain was installed in the clear well and used since 1994 to increase chlorine contact effectiveness. From the clear well, potable water is delivered by gravity to the distribution system through two 24-inch diameter pipelines. Both water lines are metered.

Because the IRP focuses on enhancing the reliability of the City's raw water supply sources, it did not evaluate water treatment processes or capacities. It is recommended that the City conduct a thorough water treatment master planning effort every 5 to 10 years to develop a capital improvement plan to maintain asset renewal, provide for ongoing compliance with current and anticipated future regulations, and reliably meet the City's service area demands. This work should be conducted in conjunction with the phased implementation of the recommended water supply system improvements identified in this IRP.

3.1.2 Treated Water Distribution System

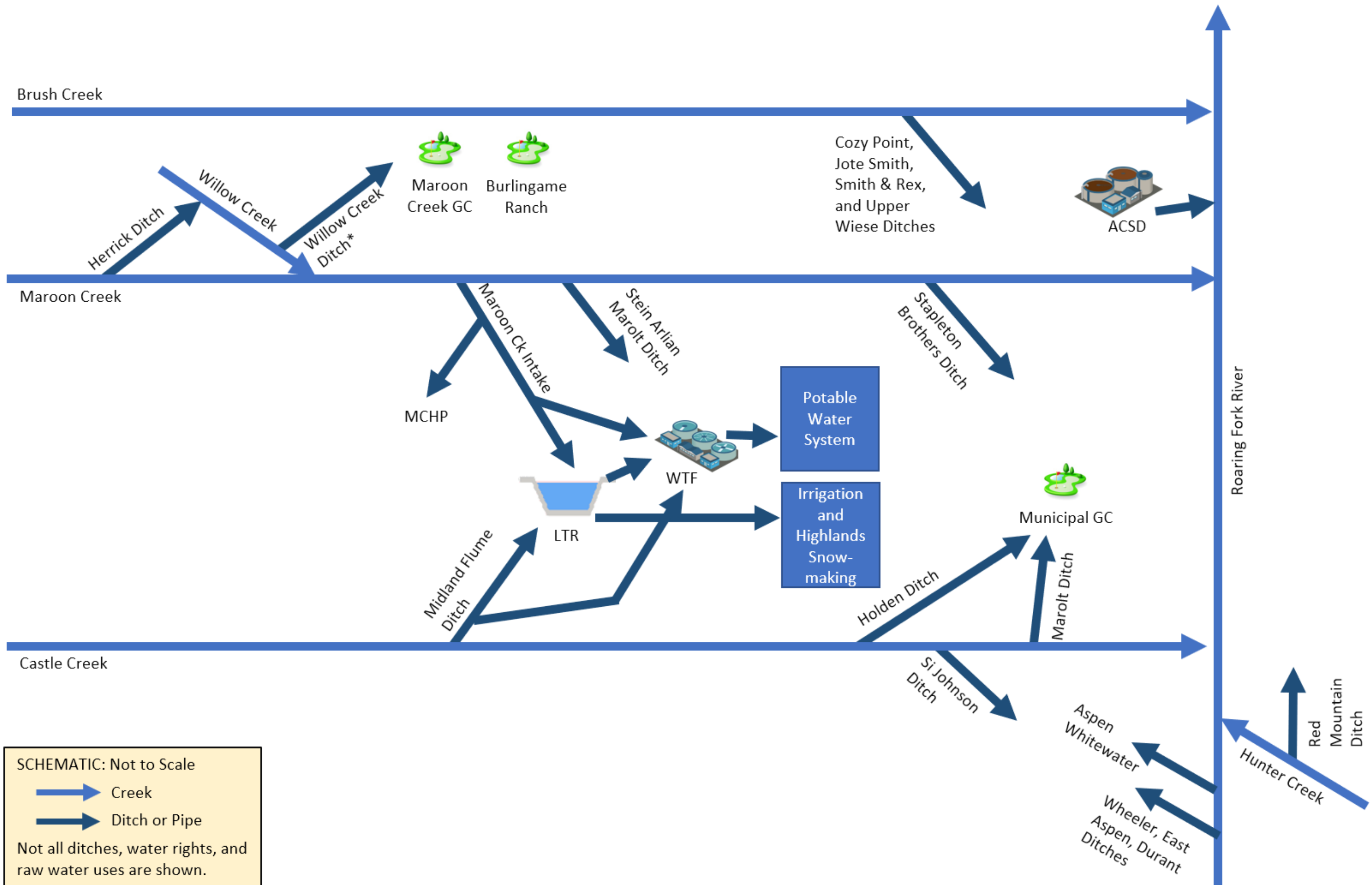
Approximately 85 percent of the City's service area is fed by gravity. The City's water distribution system consists of over 18 separate pressure zones that are supplied by about 10 to 11 MG of potable water storage in 16 water storage tanks that are fed by 16 pumping stations. Some of the distribution storage tanks are very remote and difficult to access, show signs of aging, and/or are small with little benefit. The water distribution system is comprised of approximately 73 miles of water mainlines that range in size from 4 to 24 inches in diameter.

The City is converting its water utility to Advanced Metering Infrastructure (AMI), an automated metering technology with two-way communication between a smart utility meter and the City's utility department. The goal of AMI is to provide the utility department with real-time water use data and to allow customers to make informed choices about water usage via a user-friendly customer engagement platform. The AMI project includes the upgrade of about 3,000 manual-read meters with an AMI network system that will automatically collect and store water usage data in 15-minute increments to provide data that can support efficient water use, improved water demand management, improved leak detection, and customer awareness of their water usage to promote water conservation.

The City most recently completed an analysis of the water distribution system in the 2018 Water Distribution System Model project (Bohannon Huston, 2019). Given the recent completion of this work and the IRP focus on long-term water supply reliability, the scope of this IRP did not include evaluation of the distribution system. It is recommended that the City conduct a thorough water distribution master planning effort every 5 to 10 years to develop a capital improvement plan to maintain asset renewal and reliably meet the City's service area demands. This work should be conducted in conjunction with the phased implementation of the recommended water supply system improvements identified in this IRP.

3.1.3 Non-Potable Ditch System

The City's open channel ditch system provides irrigation water and fulfills raw water agreements throughout the service area, as first discussed in Chapter 2. The ditch system is extensive; the ditches described here are a subset of the ditch system. Figure 3.1 shows a schematic of the major ditches and their surface water sources but is not intended to fully capture the entire ditch system or its ownership and operational complexities.



* Willow Creek Ditch has its own water rights and also rediverts Herrick Ditch flows.

Figure 3.1 Schematic of Selected Elements of Aspen Raw Water Supply System

The majority of the City's non-pressurized water for irrigation is diverted from Castle Creek downstream of the City's intake through three of the City's main irrigation ditches: Holden, Marolt, and Si Johnson. These ditches primarily serve the irrigation needs for open space areas, the municipal golf course, City trees, and landscaped and aesthetic areas throughout the City. The Si Johnson Ditch also provides water to customers through raw water agreements.

The Stapleton Brothers, Stein-Arlian-Marolt, and Herrick ditches divert off Maroon Creek and provide irrigation water within the region. The Willow Creek Ditch diverts off Willow Creek and provides irrigation water (in conjunction with the Herrick ditch) for the Maroon Creek Golf Course and to Burlingame. A number of ditches divert from Hunter Creek (Red Mountain) and the Roaring Fork River (Wheeler, East Aspen, Durant) to provide irrigation water throughout the City. Ditches that divert from Brush Creek (Cozy Point, Jote Smith, and Upper Wiese) provide irrigation for Cozy Point Ranch.

3.2 Existing Water Supply Sources

An overview of the City's major water supplies and how they are currently or have recently been used is provided in Table 3.1. Each supply source and typical uses are described in more detail in the following sections. Figure 3.2 provides an overview of the City's water supply sources along with locations of key water infrastructure facilities.

Table 3.1 The City's Major Water Supply Sources and Existing Typical Uses

Source	Typical Uses				
	Domestic/ Municipal	Irrigation	ISF	Hydropower	Recreation
Brush Creek		●			
Castle Creek	●	●	●		
Hunter Creek			●		
Maroon Creek	●	●	●	●	
Roaring Fork River		●	●		●
Groundwater Wells(1)		●			
Mine Water		●			

Notes:
(1) The City's three municipal groundwater wells are not currently operational.

3.2.1 Castle Creek and Maroon Creek

The City currently supplies municipal potable water demands using its senior water rights located on Castle Creek and Maroon Creek, which are snowmelt-dominated streams. As described in Section 3.1.1, the City's Castle Creek and Maroon Creek intakes divert from the creeks and deliver the water to Leonard Thomas Reservoir. The City has no raw water storage facilities on Castle Creek or Maroon Creek but has conditional storage rights for Castle Creek and Maroon Creek reservoirs as discussed elsewhere in this report. Water is also diverted from Castle and Maroon Creek for non-potable uses, as described in Section 3.1.3.

While flows in Castle Creek and Maroon Creek have historically been sufficient to meet the City's demand without significant raw water storage or supplemental supplies, projections of supply and demand indicate that flows may not be sufficient in the future. Increasing demand and the impacts of climate change on streamflow (magnitude and timing) and demands could drive future shortages. Potential scenarios for demand growth are detailed in Chapter 2.

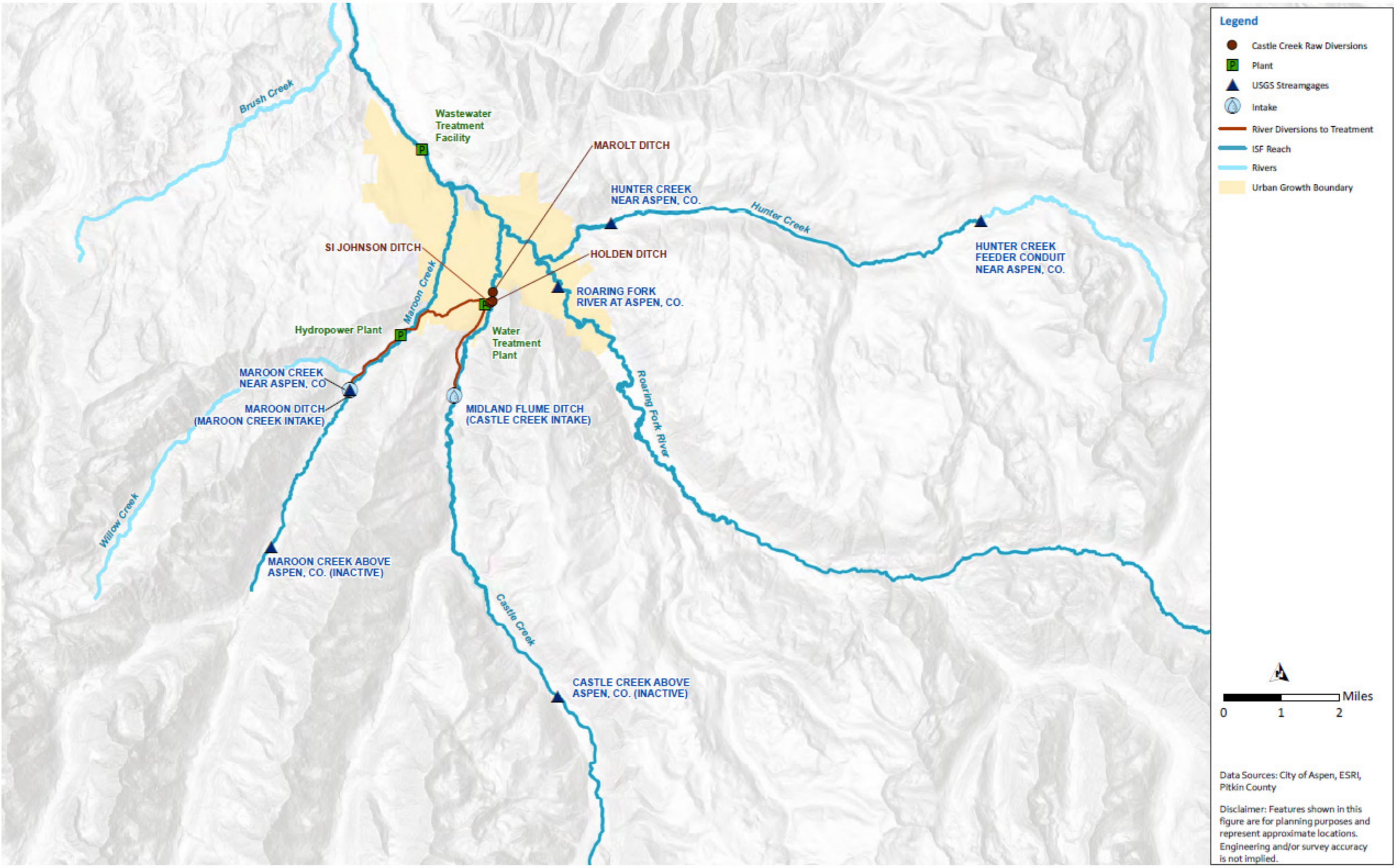


Figure 3.2 City of Aspen Water System Features Relative to UGB

To understand how water availability from Castle Creek and Maroon Creek may change due to climate change, six hydrology scenarios developed in the *City of Aspen Water Supply Availability Study 2016 Update* (WWG, 2016) were considered in this IRP. One of the six hydrology scenarios included historical hydrology at the inactive Castle and Maroon Creek USGS gage sites for the period 1970 to 1994. The other five hydrology scenarios were based on the five Coupled Model Intercomparison Project 3 (CMIP3) model runs that were used in the CWCB's *Colorado River Water Availability Study* (CWCB, 2012) and were intended to represent 80 percent of the variability represented in the full set of 112 streamflow projections used in that study. Statistics for these climate scenarios are shown in Table 3.2. Note that the identifier given to each CMIP3 model run relates to climate model forcing data, namely temperature and precipitation projections. The modeled relationship between the climate forcing factors and streamflow is not one to one and varies between models. Thus, some models that are considered less dry in terms of precipitation may still have more significant decreases in streamflow than more dry models.

Table 3.2 CMIP3 Model Scenario Statistics for Precipitation, Temperature, and Streamflow

CMIP3 Run	Change in Precipitation (%)	Change in Temperature (°C)	Castle Creek above Aspen Change in Streamflow (%)	Maroon Creek above Aspen Change in Streamflow (%)	Scenario Identifier
4	-4%	4.5	-8%	-9%	Very Hot/Very Dry
53	-1%	3.6	-16%	-19%	Warm/Slightly Dry
51	1%	3.7	-8%	-13%	Warm/Slightly Wet
13	3%	2.3	0%	-2%	Warm/Wet
12	11%	3.7	9%	2%	Warm/Very Wet

Note:
The timeframe for these climate scenarios was not explicitly stated in the *City of Aspen Water Supply Availability Study 2016 Update*; it is assumed that it is for the year 2070 based on the available data from the 2012 *Colorado River Water Availability Study* and the time horizon for the analysis completed in the *2016 Update*.

As shown in Table 3.2, the climate scenarios included in this analysis span a range of possible impacts to Castle Creek and Maroon Creek streamflow, reflecting the range of uncertainty regarding future climate conditions. The CMIP3 Run 53 scenario shows an average flow decrease of 16 percent and 19 percent for Castle Creek and Maroon Creek, respectively, while CMIP3 Run 12 shows an increase of 9 percent and 2 percent for these two creeks, respectively. Note that this range of climate impacts to streamflow is narrower than that considered in the report titled *Aspen's Water Future: Estimating the Number and Severity of Potential Future Water Shortages* (Headwaters Corporation, 2017), which evaluated climate-related streamflow impacts ranging from an increase of 10 percent to a decrease of 55 percent compared to baseline levels. Although a range of potential outcomes were considered in this IRP, climate-impacted projections of hydrology and streamflow contain significant uncertainty. Future streamflow in Castle Creek and Maroon Creek may fall within the range considered but may also be higher (wetter) or lower (drier) than predicted.

In addition to changes in average annual streamflow, climate change is expected to result in seasonal flow changes. Generally, as winters become warmer and snowpack melts earlier in the year, peak flows are expected to shift to earlier months of the year. As compared to historical streamflow patterns, by 2070 the climate-impacted runoff patterns are expected to peak in May instead of June and taper off sooner (in the late summer months of August and September). If the precipitation and streamflow decrease as indicated in the drier scenarios and streamflow decreases in late summer when demands are high, future flows in Castle Creek and Maroon Creek may not be sufficient to meet demand.

In light of these uncertainties and the range of potential future conditions, IRP analyses were based on the CMIP3 Run 53 projections. CMIP3 Run 53 represents the most significant streamflow reductions of the scenarios evaluated, without using the single worst model scenario of the 112 CMIP3 runs. As such, this represents a reasonably conservative basis for the analysis.

The climate change projections were reviewed by staff at the Aspen Global Change Institute to compare the CMIP3 Run 53 data to more recent projections available as of late 2020 and early 2021. Their analysis concluded that the CMIP3 projections included in the 2016 Update, including Run 53, are within the range of updated projections. It also indicated that the projections used for this IRP tend toward the hotter and drier end of the updated projections, suggesting that climate change impacts on supply and demand could be less severe than – or occurring at a slower pace – than may occur in the future. As such, this further reinforces the appropriately conservative approach taken in the IRP, and reiterates the value of developing a phased, trigger-based implementation plan for the IRP's water supply recommendations. It is further recommended that the City develop updated projections for climate change impacts on local water supplies and demands at a minimum interval of 10 years or every time the IRP is updated, whichever is more frequent.

3.2.2 Hunter Creek, Roaring Fork River, Brush Creek

Because the City's current potable water supply needs are being met through its Castle Creek and Maroon Creek supplies, the City does not currently need to use its Hunter Creek and Roaring Fork River supplies for potable supply. However, these additional supplies are legally decreed for municipal uses and could provide a backup for the municipal potable supply system in the future if the necessary water treatment processes and infrastructure were put into place. The City's Hunter Creek water right would be able to control the Hunter Creek diversions in winter months, but it is junior to the Red Mountain Extension Ditch rights that are controlling during the irrigation season, so the City's Hunter Creek potable supply would be limited during summer low flow periods. The Hunter Creek Flume and Pipeline right (15 cfs) has also been decreed for instream flow use by the CWCB and is currently used for instream flow purposes pursuant to the City's license agreement with the CWCB. The City had a water treatment plant located off Hunter Creek in the late 1970s, but operations were discontinued due to permitting issues.

In the past, the City has supplied irrigation water to the Red Mountain area with raw water from Hunter Creek, using overflow from the treatment plant infrastructure. Today, Hunter Creek is primarily used to support recreation and meet the decreed ISFs.

The City uses existing water rights in the Roaring Fork River to provide irrigation water via the City's ditch system. Brush Creek rights are used for irrigation at Cozy Point Ranch. The City holds rights to potable water supply from Hunter Creek and Roaring Fork, but these are not currently utilized for this purpose.

Future conditions on Hunter Creek, the Roaring Fork River, and Brush Creek were not analyzed in detail in the IRP but are assumed to include a wide range of possible impacts similar to those on Castle Creek and Maroon Creek.

3.3 Water Rights

A list of the City's absolute water rights that currently provide water for the City's potable water supply is provided in Table 3.3. These rights are decreed for multiple uses, but the treated water demands are the City's priority use of these rights. The decree date indicates the relative seniority of these rights. There is increasing concern about the potential for a Colorado River Compact call, and while the City's key water rights are pre-Compact rights, there is significant uncertainty in how such a call would be administered and the nature or extent of any impacts that would have on the City's water rights.

Table 3.3 Primary Water Rights Used for Potable System

Water Right	Source	Absolute Decree Amount (cfs)	City Ownership (cfs)	Decree Date	Current or Anticipated Use
Midland/Castle Creek Flume	Castle Creek	60.0 (Castle Creek Flume); 100 (Midland Flume)	60.0 (Castle Creek Flume); 100 (Midland Flume)	06/25/1893	Municipal supply, power, raw water irrigation, augmentation of Castle Creek Valley Ranch Properties
Maroon Ditch Consolidated with Nestell Ditch	Maroon Creek	65.0 (Maroon); 3.4 (Nestell)	65.0; 3.4	08/25/1949; 04/08/1893	Municipal supply, hydroelectric power, irrigation
Maroon Creek Pipeline Intake and Diversion Dam	Maroon Creek	68.4	68.4	06/01/1981	Municipal supply, hydroelectric power, irrigation.

A list of the City's absolute water rights that are not part of the potable water system, many of which are used to provide water to customers through raw water license agreements is provided in Table 3.4. The City obtained many of the water rights that are used in the raw water license agreements as part of the process of properties annexing into the City. The City also has raw water agreements that involve water rights that are owned by the customers and delivered by the City; these are not included in Table 3.4.

Table 3.4 Raw Water Ditch System and Groundwater Rights (Absolute Rights Only)

Water Right	Source	Decreed Amount (cfs)	City Ownership (cfs)	Decree Date(1)	City's Current or Anticipated Use
Aspen Ditch/ Spar Gulch Ditch No. 4	Roaring Fork (Spar Gulch)	2.0; 3.0 1st Enl.	2.0; 3.0 1st Enl.	7/12/1880(1); 11/05/1882(1)	Municipal irrigation via the Durant Ditch
Begley/ Spar Ditch	Roaring Fork (Durant Mine Tunnel)	1.5	1.5	06/20/1958	Municipal outdoor irrigation
Cozy Point Ditch	Brush Creek	1.5 Pr 47; 1.5 Pr 443	1.22 Pr 47 1.25 Pr 443	10/01/1882(1); 08/25/1949	Irrigation at Cozy Point Ranch
Durant Mine/ Spar Gulch	Roaring Fork River (Durant Mine Tunnel)	0.83 Pr 734; 2.0 Pr 809	0.0 Pr 734; 2.0 Pr 809	11/05/1971; 11/05/1971	Irrigation of central Aspen via Glory Hole Park
East Aspen City Ditch	Roaring Fork River	6.0	6.0	08/25/1936	Irrigation of central Aspen corridor via Glory Hole Park Lake, fountain system, malls, Art Park, various properties via raw water agreements
Electric Art Ditch	Roaring Fork River	3.0	3.0	12/30/1992	Piscatorial (fills Electric Art Pond which has a 0.3 AF storage right)

Water Right	Source	Decreed Amount (cfs)	City Ownership (cfs)	Decree Date[(1)]	City's Current or Anticipated Use
Herrick Ditch	Maroon Creek	9.3; 51.56	0.0; 6.452 Pr 683	02/05/1940; 10/24/1952	1.28 cfs must be used for Maroon Creek Golf course irrigation; remainder for irrigation at Burlingame or other locations
Highlands Water and Sanitation District Diversion System	Maroon Creek	0.22	0.22	05/18/1978	Municipal backup for customers of former Highlands Water and Sanitation District
Holden Ditch	Castle Creek	30.0	25.9	10/24/1952	Irrigation of municipal golf course
Hunter Creek Flume and Pipeline	Hunter Creek	15.0	15.0	08/25/1936	Backup municipal water supply and supports decreed ISF
J. H. Smith Warren Creek Ditch	Warren Creek	1.5	0.25	10/24/1952	Irrigation
Jote Smith Ditch	Brush Creek	2.0 Pr 29; 0.7 Pr 96	1.07 Pr 29; 0.38 Pr 96	05/14/1882[(1)]; 06/05/1884[(1)]	Irrigation at Cozy Point Ranch
Marolt Ditch	Castle Creek	18.6	14.6	07/25/1934	Irrigation of municipal golf course
Maroon Ditch Consolidated with Nestell Ditch	Maroon Creek	65.0 (Maroon); 3.4 (Nestell)	65.0; 3.4	08/25/1949; 04/08/1893	Municipal supply, hydroelectric power, irrigation
Midland/ Castle Creek Flume	Castle Creek	60.0 (Castle Creek Flume); 100 (Midland Flume)	60.0 (Castle Creek Flume); 100 (Midland Flume)	06/25/1893	Municipal supply, power, raw water irrigation, augmentation of CC Valley Ranch Properties
Mocklin Ditch	Cowenhoven Tunnel	0.40	0.40	01/31/2000	Irrigation pursuant to raw water service agreement with Mocklin HOA
Nellie Bird Ditch	Roaring Fork	3.94	0.65	08/25/1936	Irrigation pursuant to a long-term lease with Stillwater HOA
Red Mountain Ditch	Hunter Creek	2.0	0.5	05/15/1884[(1)]	Irrigation pursuant to raw water service agreement; supports decreed ISF
Red Mountain Pipeline	Hunter Creek via Red Mountain Ditch	4.26	1.33	10/24/1952	Irrigation pursuant to a raw water agreement
Riverside Ditch	Roaring Fork River	3.0	0.33	08/25/1936	Irrigation of park and open space
Si Johnson Ditch	Castle Creek	3.5 Pr 423; 2.0 Pr 435	2.63 Pr 423; 1.5 Pr 435	08/25/1936	Irrigation including raw water agreements and contract with Aspen Institute
Smith & Rex Ditch, aka Merrill	Brush Creek	0.5 Pr 64; 0.7 Pr 127; 1.5 Pr 157	0.38 Pr 64; 0.53 Pr 127; 1.13 Pr 157	05/02/1883[(1)]; 06/20/1885[(1)]; 06/05/1886[(1)]	Irrigation at Cozy Point Ranch

Water Right	Source	Decreed Amount (cfs)	City Ownership (cfs)	Decree Date[(1)]	City's Current or Anticipated Use
Stapleton Brothers Ditch	Maroon Creek	6.0	0.4	11/05/1971	City's uses are for augmentation and other municipal uses (conditional) (Aspen Ski Co. owns the majority interest, used for snowmaking)
Stein-Arlian-Marolt Ditch via Maroon Creek Pipeline	Maroon Creek	21.0 Pr 495; 4.0 Pr 667	8.625 Pr 495	10/24/1952; 06/20/1958	Irrigation
Upper Wiese Ditch	Brush Creek	0.46 Pr 251; 1.3 Pr 462	0.21 Pr 251; 0.65 Pr 462	10/29/1928; 08/25/1949	Irrigation at Cozy Point Ranch
Wheeler Ditch	Roaring Fork	10.0	10.0	09/01/1882[(1)]	Irrigation of central Aspen corridor via Glory Hole Park Lake, fountain system, malls, Art Park, various properties via raw water agreements; baseflow a Rio Grande passive storm water system; subject of Forbearance Agreements with Colorado Water Trust
Whitewater Park	Roaring Fork	270 Jun 350 Jul 30 Aug	270 Jun 350 Jul 30 Aug	08/11/2005	Recreational boating
Willow Creek Ditch	Willow Creek	3.0 Pr 129; 3.0 Pr 174 30.0 Pr 209	0.333 Pr 129; 0.443 Pr 174 4.438 Pr 209	07/01/1885[(1)]; 05/01/1887[(1)]; 06/30/1892	Irrigation of Maroon Creek Club golf course and Burlingame
Anthony Well[(2)]	Roaring Fork	0.168	0.168	11/03/1971	Previously used by the City directly or supplied as raw water for Alpine Acres lawns/aesthetic
Aspen Well No. 2, aka Spring Street, aka Rio Grande Well[(3)]	Roaring Fork	2.23	2.23	09/16/1976	Backup municipal supply[(4)]
Aspen Well No. 3, aka Mill Street Well	Roaring Fork	2.23	2.23	07/31/1975	Backup municipal supply[(4)]
Aspen Well No. 4, aka Little Nell Well	Roaring Fork	3.3 (1.06 of 3.3 is conditional)	3.3 (1.06 of 3.3 is conditional)	03/17/1973	Backup municipal supply[(4)]
Independence Exempt Well	Ground water	0.033	0.033	NA	Irrigation pursuant to a raw water agreement

Notes:

(1) The dates in this column are the decree dates except for the water rights decreed in CA132 dated May 11, 1889, for which the appropriation dates are shown to distinguish the relative priorities within the CA132 decree.

(2) The Anthony Well has been abandoned and sealed.

(3) Rio Grande Well refers to the municipal water supply well, not the dewatering well at the Rio Grande parking structure.

(4) These wells do not currently meet potable water quality requirements and therefore are not operated for potable uses; water is legally and physically available for non-potable uses and the wells could be operated for that purpose.

3.3.1.1 Conditional Storage Rights

The City also holds two conditional storage rights, the Maroon Creek Reservoir and the Castle Creek Reservoir. In the most recent diligence proceedings, the City agreed to file an application to relocate these water storage rights from their original decreed locations on Maroon Creek and Castle Creek and to limit the total amount that could be stored annually to 8,500 AF. This amount of storage was determined following a report titled *Aspen's Water Future: Estimating the Number and Severity of Potential Future Water Shortages* (Headwaters Corporation, 2017), which presents a risk assessment tool to identify shortages of water supplies available to meet demand in various future supply and demand scenarios. The analysis revealed a significant probability of shortages to the City's water system, making it vulnerable to drought without the addition of seasonal raw water storage or additional water supplies. The Aspen City Council determined that it is prudent and appropriate to plan for a shortage that is statistically likely to occur once in one hundred years with a magnitude of 2,279 AF. Shortage analyses in the IRP are generally consistent with this finding.

Associated with the storage right applications, the City's engineering consultants estimated that storage rights decreed to the Castle Creek Reservoir and the Maroon Creek Reservoir in the total amount of 8,500 AF are required to be able to fully meet the planned-for shortage of 2,279 AF. These analyses were updated as part of developing this IRP. The resulting revised estimates of the amount of storage needed to mitigate threats from periodic drought and a range of source water vulnerabilities are described in Chapters 4 and 5.

3.4 Potential Future Water Supply Sources

The City does not currently have any meaningful raw water carryover storage capacity that would allow it to retime water supplies to match water deliveries with demands, or to provide a water supply if drought or emergency conditions prevent or reduce diversions from Castle Creek or Maroon Creek. Rather, the City is dependent upon direct use of available streamflow, which is susceptible to annual variability and changing conditions, as well as seasonal and daily variability. As described in Section 3.2.1, if the climate in the Castle Creek and Maroon Creek watersheds becomes drier in the future due to climate change, the City may face additional challenges in meeting demand from streamflow diversions alone. The existing water supply is most vulnerable in late summer into early fall, after snowmelt runoff has tapered off, and while landscape irrigation demands are still high.

Lack of raw water storage makes the City's water system vulnerable to fires, floods, river contamination events, avalanches, and other threats. As described in Chapter 5, these vulnerabilities could prevent or constrain the City from diverting water through either or both of its diversions on Castle Creek and Maroon Creek and/or treating it to potable standards. The adjacent siting of the Castle Creek and Maroon Creek watersheds increases the potential that both could be impacted by the same event. Being located near the top of the watershed and far away from other municipal providers, the City does not have practical opportunities to use interconnects with other municipal systems to provide water supply system redundancy.

The following subsections describe potential measures that the City could take to supplement its current water supplies with new sources, including enhanced water conservation, groundwater, Hunter Creek, water reuse, new raw water storage, and drought management measures.

3.4.1 Enhanced Water Conservation

The City already strongly encourages water conservation practices. However, there is a potential opportunity to further reduce demand and thus increase supply resilience through enhanced conservation measures that go beyond the current and already planned measures. Reducing demand is not a "supply" per se, but it can help accomplish the same goal of matching available supplies with forecasted demands. In the

City's 2015 Water Efficiency Plan, the City identified several efficiency measures that would provide utility cost savings and reduce water demand. These include:

- Landscaping regulations for new developments,
- Water shortage ordinances,
- Water use audits,
- Price incentives for low water gardens,
- Xeriscaping seminars, and
- Ongoing community education and information distribution.

Education, cost incentives, and water use awareness are all tactics that could potentially help the City further reduce water use in the community. The practice of enhanced conservation was considered in the IRP as an optional means to further reduce the City's water demand, in conjunction with other water supply options described in the subsections below. For the purposes of this IRP, based in part on experience from other communities that already have comprehensive water conservation programs, it is assumed that enhanced water conservation could decrease indoor water use by an additional 12 percent and outdoor use by 25 percent by the end of the IRP period (2070). These reductions would be in addition to existing efficiencies and programs in place in 2020, and instead of (not in addition to) the 2 percent outdoor reductions and range of potential indoor reductions that are already embedded in each of the 2070 demand forecast scenarios.

3.4.2 Groundwater Wells

The City owns three alluvial wells located in the downtown area, referred to as the Mill Street, Little Nell, and Rio Grande wells. The locations and estimated production capacities of these wells are shown in Figure 3.3 and Table 3.5, respectively. These wells are currently not connected to the potable water distribution system because of concerns with their ability to meet drinking water standards without blending or treatment for uranium, gross alpha, and/or fluoride. The Rio Grande Well and Little Nell Well have contained uranium levels higher than the maximum contaminant level (MCL) of 30 micrograms per liter (µg/L) and the Rio Grande Well has contained fluoride levels higher than the secondary MCL of 2 milligrams per liter (mg/L), although lower than the MCL of 4 mg/L. Well water has also exceeded the gross alpha MCL of 15 picocuries per liter (pCi/L), which is correlated with the presence of uranium in the water. Advanced treatment or blending would be required to incorporate these wells into the City's potable water system. As part of a future water supply portfolio, the City could choose to connect all three of these wells or a subset of them to its potable water distribution system.

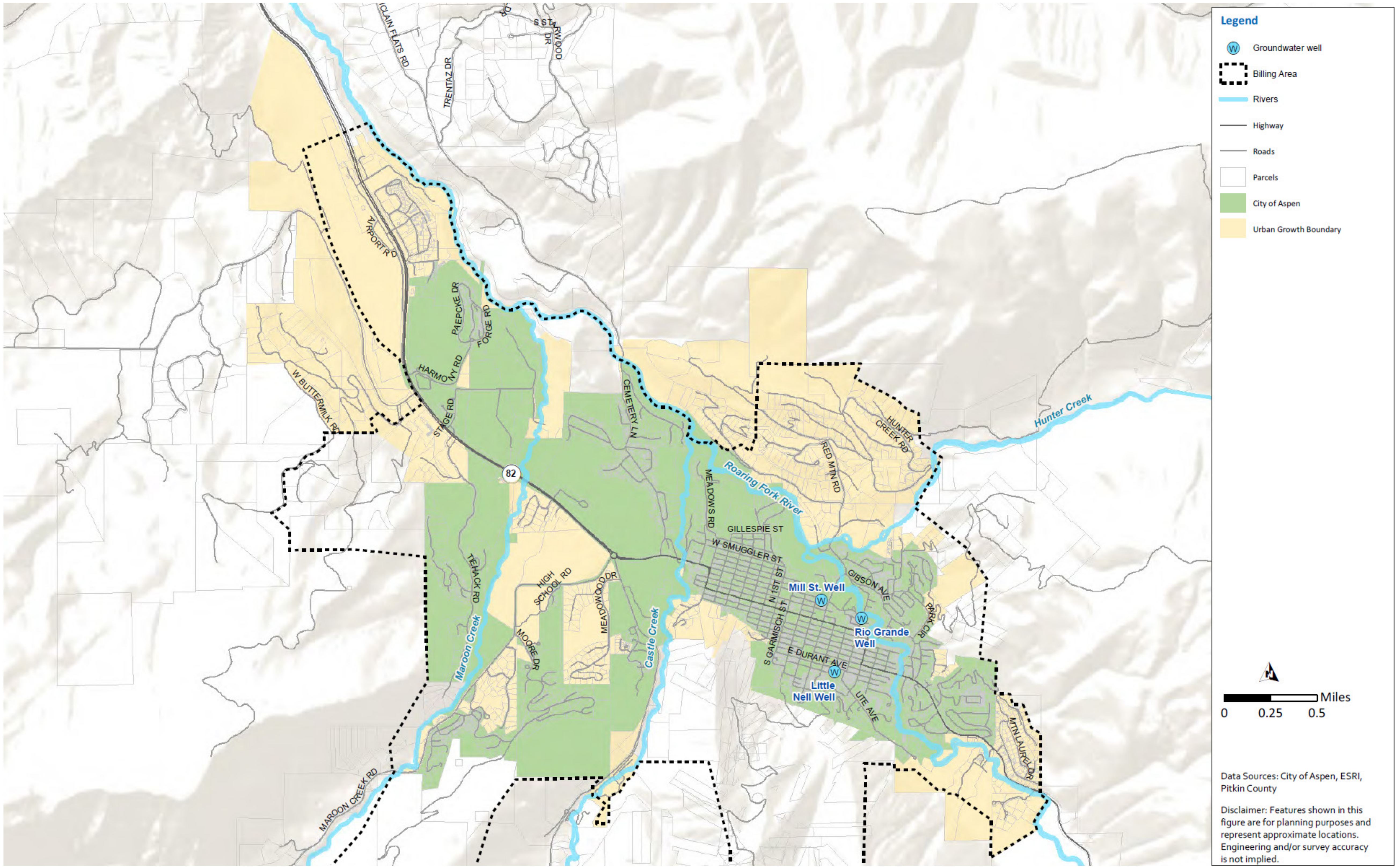


Figure 3.3 City of Aspen Groundwater Well Locations

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Table 3.5 Anticipated Groundwater Well Production

Well	Production (gpm)	Production (mgd)
Mill Street	600	0.86
Little Nell	900	1.30
Rio Grande	750	1.08

Notes:
Source: SGM, 2018.
gpm gallons per minute

In 2018, the City investigated treatment and blending approaches and estimated costs for using these three wells to supplement potable water supplies (SGM, 2018). That analysis considered several options for incorporating the wells into the City's potable water portfolio including:

- Adding permanent infrastructure for distribution system blending,
- Source water treatment at each wellhead, a new centralized treatment system, and/or
- A dedicated blend water transmission line from the City's existing treatment plan to each wellhead.

The IRP portfolio analyses described in Chapter 4 assume that if the wells were to be reinstated, potable water quality would be achieved by the construction and use of a centralized blending structure near the Mill Street Well, rather than constructing treatment systems for the wells. As described in the 2018 report, this blending structure would blend water produced from the wells with potable water from the distribution system to meet drinking water quality standards.

Groundwater blending was selected over treatment for purposes of the IRP because it was shown in the 2018 report to be more cost-effective. Treatment and blending strategies could both achieve the goal of meeting drinking water standards, and neither approach would result in the complete absence of any constituent. Blending well water is a widely practiced strategy across the United States for meeting drinking water standards.

The IRP portfolio analyses described in Chapter 4 acknowledge the potential surface water depletions associated with operating these wells, and the associated potential need for surface water augmentation. As part of implementing this supply option, additional studies should be conducted. These include:

- Confirmation of finished water quality goals and the blend ratios needed to meet those goals,
- Continued water level and water quality monitoring upon utilization of these groundwater wells,
- Further detailed analyses to assess the timing and amount of potential lagged depletions on the Roaring Fork River or its tributaries, and
- Analysis and implementation of water rights strategies to address identified surface water depletions, if applicable, along with any augmentation that might be required.

3.4.3 Hunter Creek

In the 1970s, the City constructed a potable water treatment plant with a design capacity of 0.5 mgd located off Hunter Creek Road on Red Mountain. The diversion structure was rebuilt in 1976. However, plant operations were discontinued due to permitting issues. As described previously, the Hunter Creek supply is not currently needed for potable water supply, and instead, the City's Hunter Creek water right is being used for protection of the decreed ISF pursuant to the City's license agreement with CWCB. The Hunter Creek treatment plant equipment has been removed from the site, but the building is still standing, and the site is in a long-term lease/easement agreement with the Bureau of Land Management, currently used to provide parking at the Hunter Creek trailhead.

By exercising the existing 15 cfs water right on Hunter Creek, a new treatment plant could be constructed on or adjacent to the site of the former treatment plant to treat and distribute a new supply of potable water to the community. The IRP portfolio analyses described in Chapter 4 assume that the Hunter Creek treatment plant would be used only when the water rights serving it are in priority.

3.4.4 Water Reuse

The City has decreed the right to divert and use treated wastewater effluent and has constructed portions of a reclaimed water system to exercise this right. The reclaimed water right includes the use of available treated wastewater effluent from the ACSD at a rate of up to 3 cfs, and a 19-AF reuse pond. The reclaimed water is decreed for irrigation, snowmaking, recreation, wildlife propagation, and fire protection.

Upon operational availability, the City could utilize reclaimed water supplies to serve the City of Aspen Golf Course and Burlingame housing development that are currently being irrigated with non-potable water from Castle Creek and Maroon Creek. The reclaimed water supply may allow the City to reduce its Holden and Marolt ditch diversions for irrigation at times to protect instream flows while irrigating the municipal golf course with reclaimed water. This would allow the City to use its Castle Creek supplies more efficiently and effectively.

The City is evaluating how best to develop the reclaimed water rights and has not yet completed construction of the planned water reuse project, although it has already installed nearly the entire length of the pipeline from the ACSD water reclamation facility to the municipal golf course. The 8-inch diameter HDPE reuse pipeline originates within a few hundred feet of the ACSD property line and extends approximately 2.75 miles to the south/southeast, daylighting into an irrigation pond at the golf course. It is currently unused, as it has not yet been connected to a water supply.

Completion of the reuse project will require design and construction of a pump station, a pipeline connection from the pump station to the existing 8-inch reuse pipeline, and may require a supplemental disinfection facility. Measures may also have to be taken to prevent releases of reclaimed water from the golf course pond to receiving waters, as this could constitute an unpermitted discharge per CDPHE regulatory protocol. Reuse system permitting with CDPHE will need to be completed before system operations can commence.

Recent years' dialogue between the City and ACSD regarding the reuse project has focused on how best to access reclaimed water, the potential need for supplemental disinfection to meet CDPHE reuse regulatory requirements, and a potential alternate approach of constructing a diversion and pump station from the Roaring Fork River immediately downstream of the ACSD discharge to recover the water instead of constructing a pump station on the ACSD site.

Resolution of these issues would be required prior to implementing the reuse project. In addition, implementation activities for the golf course reuse project (preliminary and final engineering design) should consider the details of whether, when, and how to extend reuse supply to irrigation at Burlingame and/or snowmaking at Buttermilk. Spur pipelines from the golf course reuse pipeline to these additional sites should be provided as appropriate, based on the findings of preliminary design evaluations.

3.4.5 New Raw Water Storage

In ongoing studies, the City's engineering consultants have evaluated several sites within the Roaring Fork valley in and around Aspen to provide raw water storage capacity for the Castle Creek and Maroon Creek Reservoir Storage Rights. The City continues to evaluate the conceptually identified sites listed in Table 3.6 in conjunction with IRP analyses and implementation planning. Each site would comprise in situ (below ground) storage except the Woody Creek and the Vagneur Gravel Pit sites, which would be open-air surface storage. Note that all sites considered in this Plan utilize Castle Creek and Maroon Creek Reservoir storage rights. The City could consider storing other supplies higher in the system in existing reservoirs such as Thomas Reservoir or Grizzly Reservoir. However, these storage sites would likely primarily be used to manage instream flows rather than provide potable water supply, and are not included in this analysis.

Table 3.6 Potential Raw Water Storage Sites

Site Name	Estimated Storage Volume(1) (AF)	Land Owner	Current Land Use
Aspen Golf Course	1,400	City of Aspen	Golf Course
Zoline Open Space	650	City of Aspen	Golf Course
Cozy Point Ranch	200	City of Aspen	Open Space
Vagneur Gravel Pit	1,200	Elam Construction, Inc.	Open Pit Gravel Mine
Woody Creek	2,000	Woody Creek Development Company	Vacant

Notes:
(1) Storage would be below ground except for the Vagneur Gravel Pit and Woody Creek, which would be open-air surface storage.

A common practice for raw water storage facilities in Colorado is to install a "slurry wall" that keys into bedrock around the perimeter of subsurface storage or gravel pit storage to prevent underground offsite migration of stored water. Storage volume is a function of the area enclosed by the slurry wall, the depth to bedrock, and (for *in situ* facilities) the porosity of the groundwater aquifer at the site.

Storage site options were evaluated based on volume, water quality, construction cost, and proximity to the existing Leonard Thomas Reservoir and WTF. As described in Chapter 4, a larger volume of new storage could be used to fully meet the City's supply needs or a smaller volume of new storage can be used in conjunction with the other potential new water supply strategies. All storage sites listed in Table 3.6 are potential options for both "operational" storage and "emergency" storage, as described in Chapter 4. Operational and emergency storage could be co-located at one or more storage sites. Regardless of siting and co-location, emergency storage volumes would be filled and maintained at their defined capacity until needed for an emergency event.

The water supply portfolio analyses described in Chapter 4 concluded that the withdrawals from storage would be needed relatively infrequently for the portfolios considered. In light of this, the capacity of the City's existing WTF, and the significant costs and operational complexities of constructing and operating a separate treatment facility, it is recommended that water withdrawn from future storage for potable supply should be pumped to the City's existing WTF instead of building a new satellite treatment facility near the storage site(s).

Detailed analyses of storage siting are ongoing, and no preferred site(s) has been identified. For purposes of estimating costs for IRP portfolios, it was assumed that storage would occur at the Vagneur Gravel Pit, the Woody Creek site, and the Cozy Point site, in decreasing order of priority. These sites have not been selected and may or may not be implemented in the future. They were used solely as "placeholder" sites assumed for purposes of infrastructure layout and costing for conveyance of water withdrawn from storage to the existing WTF. It is assumed for purposes of this IRP that the pipeline between the storage site(s) and the WTF would be operated bidirectionally, conveying untreated water from Castle/Maroon Creek to storage by gravity when supply conditions allow, and pumping it from storage to the WTF when needed.

Water supply portfolio analyses (Chapter 4) assumed that water would be withdrawn from storage sites via pumping (Vagneur Gravel Pit or Woody Creek site) or recovery wells (in situ sites) to a unified booster station at or near the Cozy Point site. To allow use of standard pressure class pipeline materials, a second booster pump station was conceptually considered and costed for construction midway along the route from the first booster station to the WTF. As the City undertakes water storage implementation, detailed engineering analyses should be conducted to determine whether to use a single booster station with high pressure class piping or multiple pumping facilities and standard pressure class piping. Siting of the booster pump stations is highly conceptual and was not defined further as part of IRP analyses.

3.4.6 Drought Management

In July 2020, the City adopted a Drought Mitigation and Response Plan (Element Water Consulting, 2020) to provide a formal framework for water use management in drought conditions. The City's drought response strategy includes normal conditions ("Watch") and four stages of drought ("Moderate" through "Exceptional") that are determined by available water supply as summarized in Table 3.7. Each stage has a corresponding demand reduction target for both systemwide demands served by potable water and outdoor demands served by a combination of potable and raw water.

Table 3.7 City of Aspen Drought Response and Water Use Reduction Categories

Category	Water Use Reduction Goals				
	WATCH Normal	MODERATE Stage 1	SEVERE Stage 2	EXTREME Stage 3	EXCEPTIONAL Emergency Response
Systemwide	Voluntary	5 to 10% Reduction	10 to 15% Reduction	15 to 25% Reduction	25 to 40% Reduction
Outdoor	Voluntary	10 to 15% Reduction	15 to 25% Reduction	25 to 60% Reduction	60%+ Reduction

In developing the future supply portfolios for the City, discussed further in Chapter 4, it was assumed that water use reductions up to Stage 3 ("Extreme") could be used to mitigate drought impacts in combination with other supplies described above. It was further assumed that these water reduction strategies could be employed for any water supply constraint, whether triggered by drought or by a different type of event. Stage 4 ("Exception") reductions are assumed to be kept in reserve for emergencies above and beyond the threats considered in this IRP. Note that the level of certainty for expected savings from water use reductions is lower than the certainty of expected water supply from other options since water use reductions are highly dependent upon customer participation and response.

Chapter 4

FUTURE SUPPLY STRATEGY

The City's current reliance on surface water supplies from two immediately adjacent watersheds, Castle Creek and Maroon Creek, increases the vulnerability of the City's water system to threats like drought, wildfire, and infrastructure failure. Moreover, these two sources may not reliably provide adequate long-term water supplies as demands are anticipated to grow and climate change is projected to negatively impact water supply availability and reliability. This chapter describes the key vulnerabilities that that the City's water supply system faces. It also documents the evaluations of potential additional water supply strategies, including drawing water from Hunter Creek, pumping local groundwater, building additional raw water storage, utilizing recycled water, and implementing enhanced water conservation programs to increase the reliability of the City's water supply system. The various water supply options were packaged into alternatives (also referred to as portfolios) of water supply that were then compared and ranked using a set of evaluation criteria that reflects Aspen's community values and priorities gathered from the stakeholder engagement process described in Chapter 1.

4.1 Water Supply Vulnerabilities

A key reliability consideration for the City's water supply system is its resilience to threats (adverse events or conditions), such as drought, infrastructure failure, or malevolent acts. The City must be able to continue to provide water to its customers in the face of these threats, which require enhancements and capital improvements to the City's existing water supply system. The following vulnerabilities, as well as potential options for mitigating the threat of each, are described in the following subsections:

- Persistent drought,
- Wildfire,
- Infrastructure failure,
- Power outage,
- Supply chain disruption,
- Malevolent acts/cybersecurity,
- Flooding,
- Treatment process outage,
- Avalanches,
- Source water contamination, and
- Staff turnover / loss of institutional knowledge.

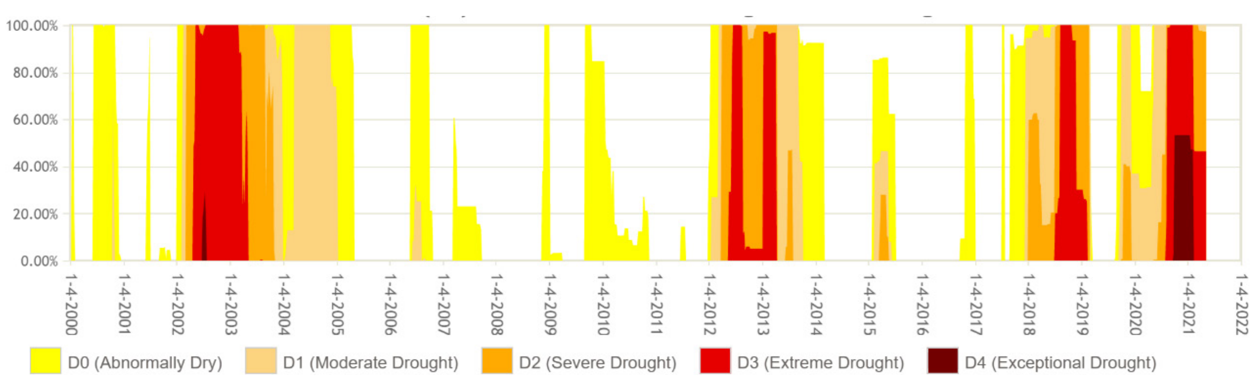
4.1.1 Persistent Drought

Droughts occur when there is a deficiency in precipitation over an extended period, resulting in a water shortage. While the definition for the period of time that constitutes a drought varies from place to place, it is typically at least a season and may continue for multiple years. Different levels of drought, as defined by the United States Drought Monitor, are shown in Figure 4.1.

Colorado regularly experiences severe or worse drought conditions, as does Pitkin County. As shown in Figure 4.2, Pitkin County has experienced severe drought in 8 of the last 20 years, extreme drought in 4 of the last 20 years, and exceptional drought in 2 of the last 20 years. This indicates that drought is a recurring concern for water utilities in Pitkin County, including the City of Aspen that may adversely impact water supply.

Surface water sources like Castle Creek and Maroon Creek are particularly vulnerable to drought since they are directly reliant on local precipitation and snowmelt runoff. The risk of drought to the City's water supply system could be mitigated through the diversification of water supply sources and the introduction of drought-resistant sources such as recycled water. Groundwater, while still dependent on precipitation, is less vulnerable to drought since water stored in underground aquifers may outlast a drought that severely impacts surface water. Water reuse is considered a drought-resistant supply since the water is sourced from return flows from non-consumptive indoor water use. Increased conservation and the implementation of temporary water use restrictions can also mitigate drought impacts by decreasing the amount of water use.

Figure 4.1 United States Drought Monitor Drought Levels



Source: United States Drought Monitor, 2020

Figure 4.2 Pitkin County Drought Levels Since 2000

4.1.2 Avalanches

Avalanches occur when a mass of snow, ice, and/or rocks fall rapidly down a mountainside. Avalanches have the potential to disrupt the water supply system by impeding flow with debris or by damaging or blocking access to water supply infrastructure, such as the City's creek water intakes and/or the water treatment plant. This may disrupt water service until the infrastructure can be repaired or accessed. These disruptions could take hours, days, or weeks, depending on the location and severity of the impact. Aboveground infrastructure in the watershed, such as the City's intakes on Castle Creek and Maroon Creek, is more vulnerable to avalanches than infrastructure in the City, such as the water distribution system. Between 1998 and 2016, Pitkin County had the most avalanche fatalities of any county in Colorado. While fatalities are not directly correlated to water infrastructure vulnerability, their prevalence in Pitkin County indicates that avalanches are a relatively common and serious risk. An avalanche may also remove trees from its path, which may make the area more susceptible to landslides or mudslides after the snow melts. Landslides or mudslides may have similar impacts to infrastructure as avalanches.

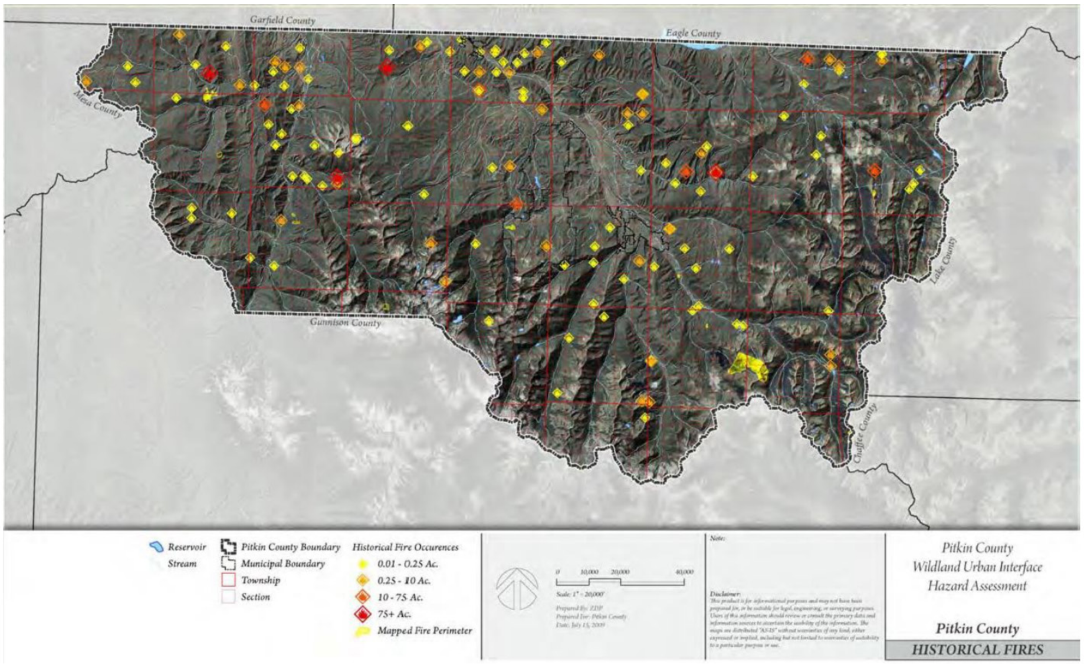
Water system vulnerability to avalanches can be reduced by diversifying supplies. If water is drawn from distinct and separate surface water, storage, groundwater, or recycled water locations, an individual avalanche is unlikely to impact all those locations. Thus, if water can be drawn from additional or alternate locations, the system will be more resilient to avalanches. Additional water storage could similarly decrease vulnerability to avalanches.

4.1.3 Wildfire

According to the 2013 *Colorado Natural Hazards Mitigation Plan* (Colorado Division of Homeland Security and Emergency Management 2013), a wildfire is "an unplanned, unwanted wildland fire including unauthorized human-caused fires, escaped wildland fire use events, escaped prescribed fire projects, and all other wildland fires where the objective is to put the fire out." In addition to human-causes, wildfires can also be triggered by natural causes, such as lightning strikes. Wildfires have the potential to damage or destroy water infrastructure and may have significant, long-term impacts on surface water quality in the source watershed. Runoff following a wildfire is likely to introduce ash, sediment, nutrients, and contaminants into the surface water supply. Experience in Colorado and across the western United States suggests that the magnitude and duration of the water quality impact, and the parameters impacted, can vary significantly depending on characteristics of the watershed/forested area and the severity of the burn.

While several large and disruptive wildfires have impacted other areas in Colorado in the past several decades, Figure 4.3 shows that wildfires in Pitkin County, particularly those near the City and surrounding watersheds, have been relatively small (10 acres or less). However, the *Pitkin County Hazard Mitigation Plan* (2018) considers wildfire a "likely" hazard to both Pitkin County as a whole and to Aspen specifically, indicating that it has an expected recurrence interval of ten years or less. Thus, there is at least a moderate wildfire hazard potential in surrounding watersheds[1]. The consequences of such a wildfire could be severe, as wildfires not only pose a risk of damaging or destroying critical water infrastructure such as the WTF but can also negatively impact raw water quality due to high turbidity from increased erosion and contamination from fire retardants and particulates in the watershed that flow into the creeks. Hence, it can be concluded that wildfires pose a significant threat to the City's water supply system.

[1] Wildfire Hazard Potential Map Viewer, U.S. Forest Service Fire Modeling Institute, 2019.



Source: Pitkin County Hazard Mitigation Plan (2018)

Figure 4.3 Historical Wildfire Occurrences in Pitkin County

Diversification of water supplies to include water supply options other than surface water from a single watershed and increased water storage outside of the watershed would reduce water system vulnerability to wildfire. Castle Creek and Maroon Creek are distinct watersheds, but because they are immediately adjacent to each other, a wildfire in one could very well spread to the other, impacting both of the City's existing surface water supply sources.

Forest management measures can be undertaken to reduce the likelihood and/or severity of a wildfire event, and there is an increasing wealth of knowledge in western watersheds between utilities, federal and state agencies, and academia regarding effective watershed management strategies. Upgrades to treatment facilities to treat water with higher levels of sediment and contaminants may also assist with mitigating wildfire impacts. Treatment upgrades are more effective when implemented prior to a wildfire event in the watershed since design and construction can take many months or years to implement.

The Colorado Post-Fire Recovery Playbook (CDPHE, 2021) provides a stepwise set of actions water utilities can take to prepare for a potential future wildfire, during a wildfire event, and throughout various phases of recovery. It is recommended that the City review this document and complete applicable portions. The City's ultimate strategy for managing wildfire risk should include a combination of watershed management, robust treatment processes, and source of supply diversification.

4.1.4 Flooding

According to the 2013 *Colorado Natural Hazards Mitigation Plan*, "A flood is a general and temporary condition of partial or complete inundation of normally dry land areas." Causes of flooding in Pitkin County include riverine flooding, stormwater ponding, flash flooding, and ice-jam flooding. Flooding could impact the City's water supply system by damaging intake structures at creeks and ditches, negatively impacting source water quality, or depositing flood debris at the intakes.

Similar to other water supply vulnerabilities, the potential impact of flooding to the City's water system could be mitigated through the diversification of supply sources or the addition of storage outside the watershed.

4.1.5 Infrastructure Failure

Infrastructure failure encompasses any physical failure that occurs within the water system that results in a temporary loss of water service. Common examples include leaks or breaks in aging pipelines or mechanical failure at treatment plants or pump stations as shown in the example (not in Aspen) in Figure 4.4.

Figure 4.4 Example of Aging Infrastructure

Risks due to infrastructure failure are best mitigated through an asset management program to monitor the age and condition of infrastructure and systematically upgrading that infrastructure as needed. System redundancy and supply diversification can also mitigate the impacts of infrastructure failure, as the system could continue to operate at partial or greater capacity if infrastructure associated with a single supply were to fail. It is recommended that the City regularly revisits the prioritization and implementation status of its asset management program and include a rehabilitation and replacement program component for both linear and above ground assets in the next water distribution master plan update.

4.1.6 Power Outage

A power outage is a loss of power supply that may last anywhere from a few minutes or several hours to several days. Power outages may be caused by equipment failure, human error, severe weather (e.g., lightning, high winds, blizzards), trees or branches falling on power lines, and various other reasons. Without proper backup power sources, a power outage can impact the City's entire potable water supply system since it relies on power supply at the water treatment plant and treated water pump stations.

Since most power outages in the City have historically lasted less than one day, outages can mostly be managed with treated water storage in the distribution system. Standby power such as backup generators at key facilities like the WTF and pump stations are key to continued water system operation through an extended power outage.

4.1.7 Source Water Contamination

Surface water can become contaminated through nutrients, chemicals, sediments, or other contaminants that enter the stream or reservoir from runoff. Castle Creek and Maroon Creek are mountain headwater watersheds and are unlikely to experience significant accidental or natural contamination but may experience some level of water quality variability from natural causes. Groundwater may experience contamination from chemicals or other contaminants in the aquifer soils, though no such issues are known to exist in the vicinity of the City's existing wells that are currently offline.

Contamination of surface waters can be mitigated through watershed protection. Impacts of contamination for both surface and groundwater sources can also be mitigated through robust treatment processes. Supply source diversification can also increase the resilience of the water supply system against contamination by switching between sources if one source is impacted.

4.1.8 Treatment Process Outage

The existing water treatment facilities use conventional processes to treat raw water from Castle Creek and Maroon Creek to produce water suitable for drinking. Untreated water is conveyed to either the West train clarifiers or the East train sedimentation basin, after pretreatment with polymer chemicals. Flocculation agglomerates particles that are settled out in these sedimentation facilities, followed by filtration using conventional sand and anthracite filters. Fluoride and chlorine are added for public health and disinfection reasons, respectively, prior to storage in clear wells and distribution to customers throughout the City's distribution area.

Although unlikely, there is the potential for mechanical failures, power outages, or other operational issues to impede the City's ability to provide treatment. Treatment process outages could occur not only at the existing treatment facilities, but also at potential future facilities such as a Hunter Creek water treatment plant. Redundant ("standby") equipment and operational protocol are industry best practices and are in place to address the most significant risks for treatment process outages. Other strategies include maintaining proper inventories of spare parts and equipment, and standardizing on equipment, parts, and manufacturers to streamline maintenance training and make more effective use of spare parts inventories.

4.1.9 Supply Chain Disruption

Operation of the City's water diversion, treatment, and distribution systems depends on a wide range of supplies, equipment, and chemicals. Interruptions at any point in the supply chain for any of these components could impact the City's ability to reliably meet demands, and such disruptions can occur at the global or local scale. For example, manufacturing issues or shipping issues domestically or internationally could impede the ability to produce and deliver spare parts for the City's treatment and pumping equipment or supplies. On a local scale, the limited access to Aspen – particularly in the winter when Highway 82 is the primary access point to the community – poses potential threats to supply chain reliability. Winter weather, wildfire events, or even traffic incidents can impede deliveries of supplies, equipment, or chemicals.

Mitigating this threat often relies on maintaining a reserve of supplies or equipment in storage in Aspen, completing regular preventive maintenance on equipment, and keeping spare parts and spare equipment on hand to expedite resolution of issues as they are encountered.

4.1.10 Malevolent Acts

Malevolent acts include terrorism, criminality, vandalism, theft, sabotage, cyber-attacks, intentional contamination, or any other acts intending to cause damage or harm. The perpetrators of malevolent acts may be outsiders such as members of a protest movement or criminals or they may be insiders such as rogue or disgruntled employees. The acts themselves could physically damage water infrastructure leaving it inoperable and in need of replacement or repair. They could also render infrastructure inoperable or inaccessible using a cyberattack. Intentional contamination could impact water quality resulting in serious illness or death of the City's customers. While no such malevolent act has occurred against the City's water system, they are becoming more common across the county. Potable water supply sources are typically more likely to be impacted by malevolent acts than non-potable sources.

Malevolent acts can be mitigated through increased physical and cyber security.

4.1.11 Staff Turnover/Loss of Institutional Knowledge

The water industry is experiencing an unprecedented challenge with an aging workforce due to retirement of the baby boomer generation. In addition, staff turnover contributes to loss of institutional knowledge regarding system-specific water supply, treatment, and distribution infrastructure and operations. Historically in the industry, it has been commonplace to have a limited number of operations staff become extremely well versed in system specifics based on years or even decades of hands-on experience. A key challenge with staff turnover and retirements lies in the ability to pass this information and insights on to future staff. This can apply to day-to-day operations, or in terms of how to respond to and mitigate an emergency condition.

The City, like many utilities, has taken steps to mitigate the threat of staff turnover. Industry best practices include strategies such as staff cross-discipline training, documentation of operational practices (hard copy and/or online operation and maintenance manuals, development of standard operating procedures), and intentional training and succession planning programs.

4.2 Supply Vulnerability Assessment

4.2.1 Methodology

To assess the vulnerability of each current and potential future supply source to each of the threats described in Section 4.1, the likelihood of the threat occurring in a way that would impact the source and the consequence of that impact were assigned to each source-threat pair on the qualitative 5-level scale shown in Table 4.1. Scores were assigned to source-threat pairs based on discussions with the City and the project team's understanding of the water supply system, professional judgment, and water supply planning experience.

Table 4.1 Likelihood and Consequence Scale for Scoring Source-Threat Pairs

Likelihood Scale	
●	Almost certain to happen during the planning horizon of the IRP
◕	More likely to happen than not during the planning horizon of the IRP
◑	Might happen during the planning horizon of the IRP
◔	Not likely to happen during the planning horizon of the IRP
○	Almost certainly will not happen during the planning horizon of the IRP
Consequence Scale	
●	Complete supply disruption, long duration impact
◕	Significant supply disruption, moderate duration impact
◑	Partial supply disruption, short duration impact
◔	Negligible supply disruption
○	No supply disruption

The likelihood and consequence scores for each source-threat pair are shown in Table 4.2, with threats shown in the first column and water supply sources or strategies shown across the top row. Importantly, this assessment was developed considering how each individual source could potentially be used as part of the City's future water supply system, rather than assessing the risks associated with its use today. For example, Hunter Creek is not currently in use for water supply and would have very low scores for the consequence of various threats under current conditions. However, those consequences rise dramatically if it were to be used as a source of surface water supply for drinking water use in the community.

Table 4.2 Source-Threat Likelihood and Consequence Scores

Threat	Consideration	Castle Creek	Maroon Creek	GW Wells	Hunter Creek	Water Reuse	Enhanced Conser-vation	Storage With-drawals
Avalanches	Likelihood	◕	◕	○	◑	○	○	○
	Consequence	◑	◑	○	◔	○	○	○
Wildfire	Likelihood	◕	◕	◔	◕	◔	◔	◑
	Consequence	●	●	◔	◕	◑	○	○
Infrastructure Failure	Likelihood	◕	◕	◑	◕	◑	○	◕
	Consequence	●	●	◑	◕	◑	○	◔
Power Outage	Likelihood	◕	◕	◕	◕	◕	○	◕
	Consequence	◕	◕	◑	◑	◑	○	◔
Treatment Process Outage	Likelihood	◑	◑	○	◑	◑	○	◑
	Consequence	◕	◕	○	◕	◑	○	◕
Staff Turnover/ Loss of Institutional Knowledge	Likelihood	●	●	●	●	●	●	●
	Consequence	◔	◔	◔	◔	◔	○	◔
Source Water Contamination	Likelihood	◔	◔	◕	◑	◕	○	◔
	Consequence	◕	◕	◑	◔	◔	○	◔
Supply Chain Disruption	Likelihood	◑	◑	○	◑	◑	○	◑
	Consequence	◕	◕	○	◕	◔	○	◕
Malevolent Acts/ Cybersecurity	Likelihood	◑	◑	◑	◑	◔	○	◑
	Consequence	●	●	◕	◕	◔	○	●
Flooding	Likelihood	◕	◕	◔	◕	◑	○	◑
	Consequence	◕	◕	◑	◕	◑	○	1
Persistent Drought	Likelihood	●	●	●	●	●	●	●
	Consequence	●	●	◑	●	◔	○	○

4.2.2 Supply Vulnerabilities

To determine the relative risk of each threat to each current and potential future supply source, the likelihood and consequence scores for each source-threat pair were considered together. Threats with a high likelihood and a significant consequence were considered to pose the greatest risk. The risk results are shown in Table 4.3, generally in order of decreasing risks. Each source-threat pair is color-coded as follows:

- Red = Threat poses a significant risk to the City's water supply.
- Orange = Threat poses a moderate risk to the City's water supply.
- Yellow = Threat is a lower risk to the City's water supply relative to the other source-threat pairs, but still poses some degree of risk.

As shown in Table 4.3, there are several significant risks to both current and potential future supply sources. Persistent drought, wildfire, and infrastructure failure are all significant risks (red dot) to the City's existing Castle Creek and Maroon Creek sources. As surface water sources, they are also moderately vulnerable to most other threats considered in this analysis. Similarly, if used as a drinking water supply source, Hunter Creek would be moderately or significantly vulnerable to most threats considered. Groundwater wells are moderately vulnerable to drought, power outages, malevolent acts, and contamination. Withdrawals from potential future storage facilities would be moderately vulnerable to supply chain disruption, malevolent acts, and treatment process outages. Water reuse and enhanced conservation are the most resilient supply strategies among all those considered, with reuse only being moderately vulnerable to power outages and enhanced conservation having no significant or moderate vulnerabilities, largely because of reduced consequences of these threats for these supply strategies.

Table 4.3 Source Vulnerability to Threats Analysis Results

Threat	Castle Creek	Maroon Creek	Ground-water Wells	Hunter Creek	Water Reuse	Enhanced Conser-vation	Storage With-drawals	Potential Risk Mitigation Options
Persistent Drought	🔴	🔴	🟠	🔴	🟡	🟡	🟡	• Diversified/drought-resistant sources • Increased conservation • Activate drought response measures
Wildfire	🔴	🔴	🟡	🟠	🟡	🟡	🟡	• Storage outside the watershed (optionally with separate WTF) • Diversification of sources
Infrastructure Failure	🔴	🔴	🟡	🟠	🟡	🟡	🟡	• Storage outside the watershed (optionally with separate WTF) • Asset management, spare parts, etc.
Power Outage	🟠	🟠	🟠	🟠	🟠	🟡	🟡	• Storage outside the watershed with separate WTF • Focused redundancy (e.g., standby power)
Supply Chain Disruption	🟠	🟠	🟠	🟠	🟡	🟡	🟠	• Local supply • Spare parts • Chemical storage
Malevolent Acts/ Cybersecurity	🟠	🟠	🟠	🟠	🟡	🟡	🟠	• Increase physical and cyber security
Flooding	🟠	🟠	🟡	🟠	🟡	🟡	🟡	• Storage outside the watershed (optionally with separate WTF) • Diversification of sources
Treatment Process Outage	🟠	🟠	🟡	🟠	🟡	🟡	🟠	• Unit process redundancy • Shelf spares • Standardize equipment/parts/mfrs
Avalanches	🟠	🟠	🟡	🟡	🟡	🟡	🟡	• Storage outside the watershed (optionally with separate WTF) • Diversification of sources
Source Water Contamination	🟡	🟡	🟠	🟡	🟡	🟡	🟡	• Watershed protection • Robust WTF processes • Source water diversification
Staff Turnover/Loss of Institutional Knowledge	🟡	🟡	🟡	🟡	🟡	🟡	🟡	• Succession planning • Training • Enhanced automation

Notes:
🔴 Threat is significant risk to the City's water supply
🟠 Threat is moderate risk to the City's water supply
🟡 Threat is lower risk to the City's water supply relative to the other source-threat pairs, but still poses some degree of risk

As discussed in Section 4.1, many of these threats can be mitigated through diversification of supply sources to allow for the reliance on alternative supply source(s) if one source is impacted by any of the threats considered. Additional strategies that may be effective for mitigating each threat are described in the subsections above that relate to each of these 11 potential water supply vulnerabilities.

4.3 Future Supply Portfolios

To mitigate the supply vulnerabilities discussed above and to avoid the potential for a water supply shortfall (demands exceeding supply), the following potential supply options were packaged into alternative water supply portfolios:

- Raw water storage,
- Hunter Creek,
- Groundwater,
- Water reuse, and
- Enhanced conservation.

Each of these supply options is locally available and could help meet the City's future needs, avoiding some of the significant costs and socioeconomic concerns that can be associated with non-local or inter-basin supply transfers. Given the availability of local supply options, non-local supply options were not considered in this IRP.

4.3.1 Methodology

Six water supply portfolios were compiled from the potential supply options based on meeting the minimum threshold of being able to fully meet maximum future potable demand (9,281 AFY in 2070, Scenario F) while maintaining decreed instream flows under the worst-case future climate condition considered in this IRP (CMIP3 Run 53). This conservative approach for projecting water supply shortages also drives a conservatively high estimate of potential water supply investments that will be needed to meet 2070 demands.

However, this IRP recommends that the City adopt an adaptive approach to implementing its water supply recommendations (see Chapter 5), using supply/demand triggers to implement additional supplies and demand management options over time in response to observed conditions. As such, the City will have a plan in place for how it will meet demands if these conservatively-assumed conditions materialize over the next 50 years, but it will only implement the components that are needed, when they are needed. Implementation timing includes sufficient lead time to allow the components to be constructed or installed and to become operational. If conditions do not require this pace of implementation, actions to implement new supply strategies can be deferred.

In addition to the supply strategies listed above, it was assumed that the City will continue to use Castle Creek and Maroon Creek as primary supplies and will utilize its existing drought restriction system (described in Section 3.4.6) as needed. Portfolios were constructed assuming that the City could implement up to "Extreme – Stage 3" drought restrictions to reduce systemwide water use by up to 25 percent when needed. The "Exceptional – Emergency Response" restrictions are assumed to be kept in reserve for emergencies above and beyond what is considered in this IRP.

To determine if a combination of supply options would meet the maximum projected 2070 potable water demands under a variety of hydrologic conditions, a model was constructed to run 25 years of available hydrology (1970-1994) for Castle Creek and Maroon Creek layered with climate change impacts. The climate-impacted stream flows from 1970 through 1994 were previously developed as part of the *City of Aspen Water Supply Availability Study 2016 Update* (WWG, 2016), as described in Section 3.2.1. As shown in

Figure 4.5, this period of record reflects drought of record (1977 to 1978) conditions in Aspen. While the analyzed time period captures a wide range of annual and seasonal hydrologic conditions, five of the worst droughts in Aspen in recorded history have occurred after 1995 (2002, 2012, 2018, 2020, 2021), indicating a recent and potentially long-term drying trend that may be consistent with certain climate change projections. It was found that if potable water demand were to reach the maximum 2070 demand projection and the climate becomes hotter and drier as modeled in the CMIP 3 Run 53 climate scenario, the City's current supplies from Castle Creek and Maroon Creek would be insufficient to meet demand across the full range of hydrologic conditions.

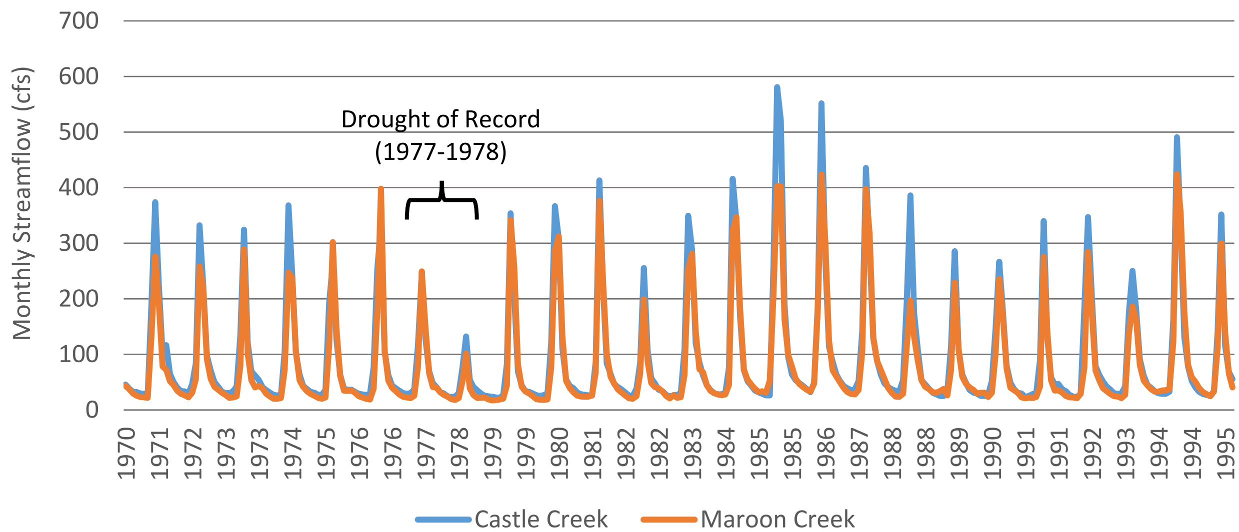


Figure 4.5 Castle and Maroon Creek Historical Hydrology at City Intakes and Drought of Record

As shown in Figure 4.6, the largest supply shortfall occurred in two consecutive dry years modeled in the 25-year hydrology (water years 1977 and 1978, modified to reflect 2070 climate change impacts under 2070 demand conditions). These conditions would produce a total potable supply shortage ("gap") of approximately 2,300 AF over the course of both years. This potential future supply gap is of similar magnitude to that identified in the 2017 *Headwaters* report and the resulting shortage amount to plan for as decided by the Aspen City Council. Thus, each supply option was added to the model and combinations of supply options ("portfolios") were tested to confirm that they could resolve this supply gap, such that no potable supply shortages would be expected under 2070 demand and climate conditions. Note that meeting potable water demand and decreed instream flows were the focus of this analysis and the development of supply portfolios. In dry years where potable supply shortages are projected, non-potable demands and hydropower generation are likely to be adversely impacted as well.

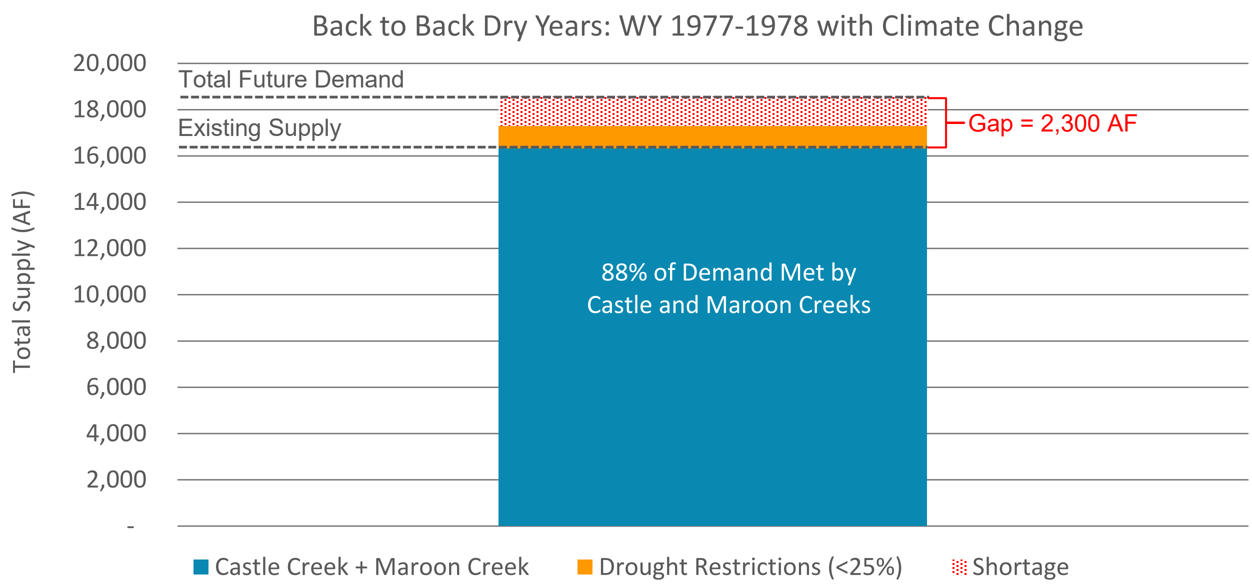


Figure 4.6 Supply Shortage with Existing Supplies and Future Demand

In summary, each viable portfolio evaluated in this IRP has the ability to meet the maximum projected 2070 demand, under hotter and drier future climate conditions, when Stage 3 drought restrictions are employed to temporarily decrease water use by up to 25 percent as needed. More detail on supply modeling assumptions and portfolio development is included in Appendix D.

4.3.2 Portfolio 1 – No Action

Portfolio 1 is the "No Action" portfolio because it assumes that potable supply is only sourced from Castle Creek and Maroon Creek, and no additional water supply options are implemented. It is important to note that this portfolio does not meet the minimum threshold for a viable portfolio, but it has been included for comparison with other portfolios to show how the existing system would perform with increased demand, climate change impacts to supply, and against the vulnerabilities described in Section 4.1. As shown in Figure 4.7, even using Extreme – Stage 3 drought restrictions would not completely alleviate the supply shortage during two consecutive dry years under 2070 demand and climate conditions.

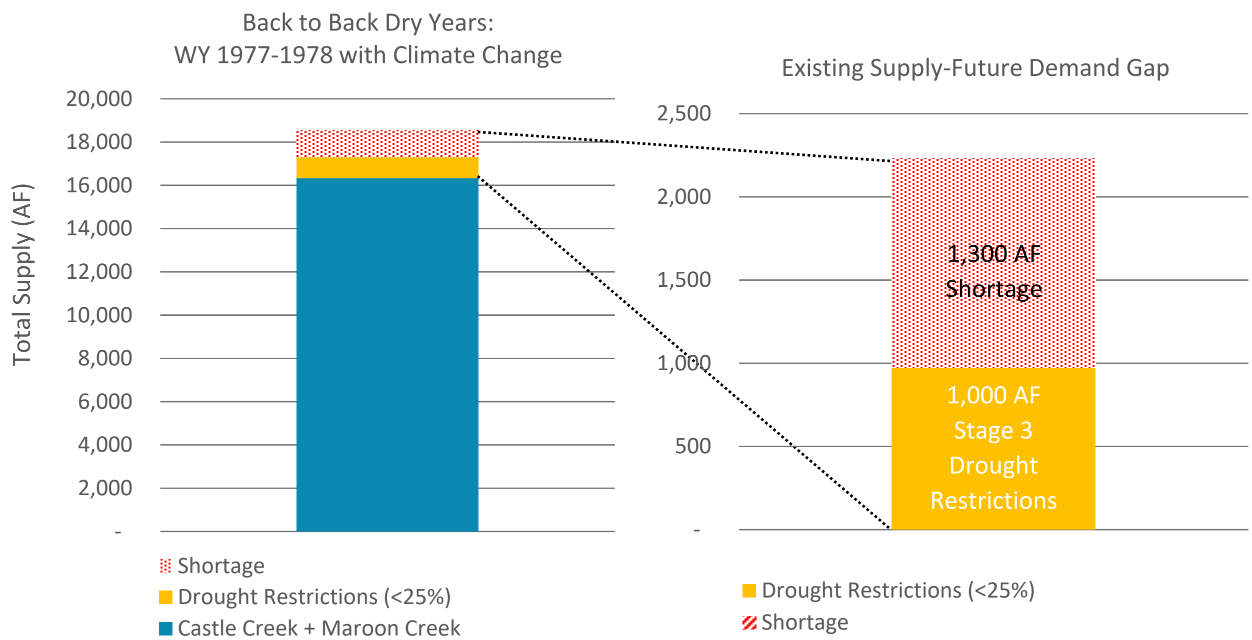


Figure 4.7 Portfolio 1 Performance Under 2070 Driest 2-Year Conditions with 2070 Demand

4.3.3 Portfolio 2 – Raw Water Storage Only

This portfolio adds operational raw water storage to the supply system. In order to meet the maximum 2070 demand under hotter and drier climate conditions, Portfolio 2 includes 2,200 AF of additional raw water operational storage. The analysis of all portfolios considered only the amount of storage that would be needed, recognizing that siting of new storage would be a necessary implementation step. As shown in Figure 4.8, this amount of storage, paired with drought restrictions in a couple of the driest months during this 2-year period, is expected to eliminate shortages under the evaluated scenario. Note that this storage amount does not include storage inefficiencies or emergency storage, which would add to the amount of storage recommended. Emergency storage is discussed in Section 4.6 for the top-ranked portfolio.

Over the 25 years of hydrology analyzed with maximum 2070 demand, Castle Creek and Maroon Creek could directly meet the full demand in most years. It is estimated that storage withdrawals would be needed in approximately 8 out of 25 years (32 percent of years); drought restrictions would be utilized in 1 out of 25 years (4 percent of years).

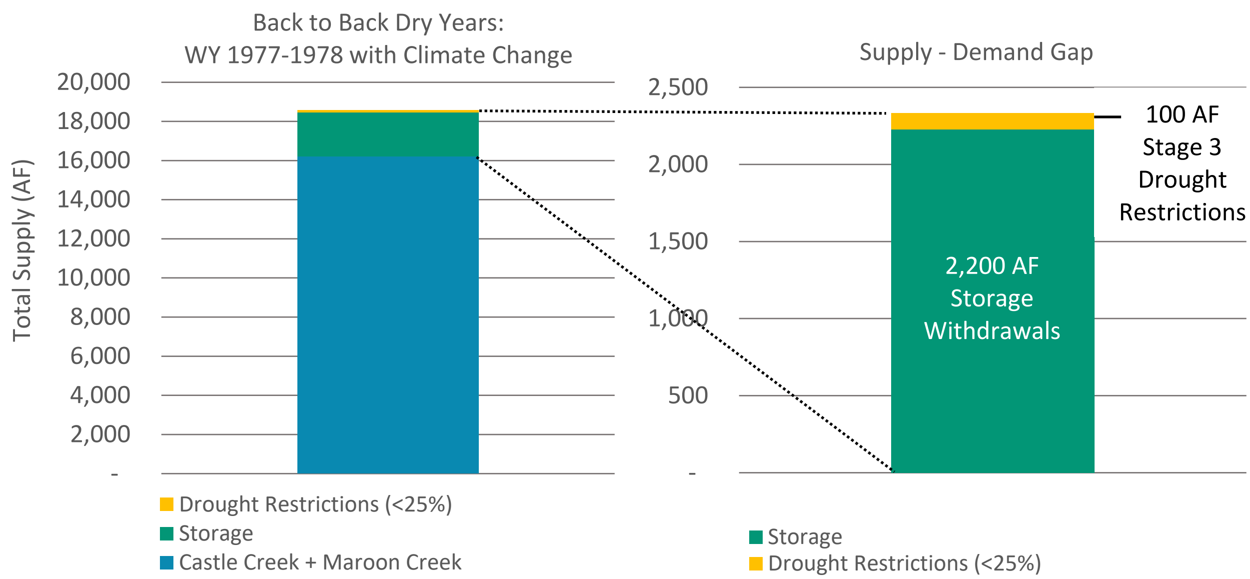


Figure 4.8 Portfolio 2 Performance Under Driest 2-Year Conditions with 2070 Demand

4.3.4 Portfolio 3 – Hunter Creek and Raw Water Storage

This portfolio utilizes diversions from Hunter Creek and adds operational raw water storage to the supply system. Even with the use of Hunter Creek, this portfolio would still require approximately 2,000 AF of operational raw water storage to meet the projected maximum 2070 demand under hotter and drier climate conditions. Note that this storage amount does not include storage inefficiencies or emergency storage (Section 4.6), which would add to the amount of storage recommended.

While the City has the right to divert up to 15 cfs from Hunter Creek, flows are often lower than this during the summer and during dry years. During dry years when Castle Creek and Maroon Creek flows are low, an analysis of historical flow data indicates that Hunter Creek flows are also expected to be low or virtually non-existent. Thus, Hunter Creek is not a practical supply option for resolving dry-year shortages. In addition, utilization of Hunter Creek requires significant and costly improvements including a new treatment plant. As shown in Figure 4.9, diversions from Hunter Creek only mitigate a small amount of the gap between supply and demand; storage withdrawals and drought restrictions would play a much more significant role. Over the 25 years of hydrology analyzed with maximum 2070 demand, Castle Creek and Maroon Creek could directly meet full demand in most years. It is estimated that Hunter Creek and operational storage would need to be utilized in approximately 6 of 25 years (24 percent of years) and drought restrictions utilized in 1 of 25 years (4 percent of years).

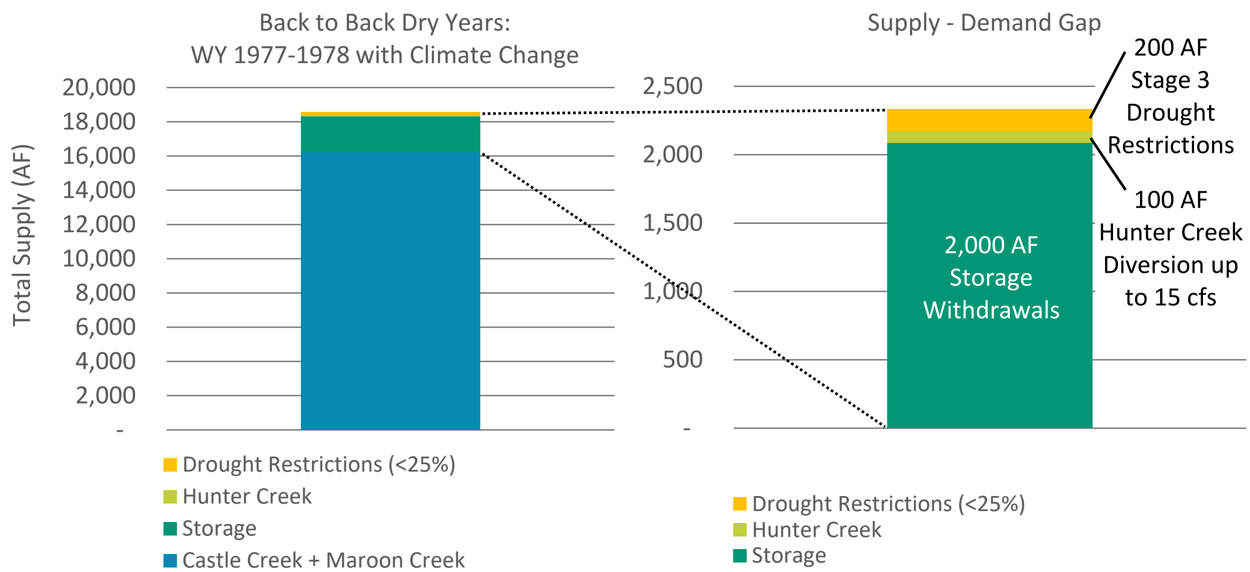


Figure 4.9 Portfolio 3 Performance Under Driest 2-Year Conditions with 2070 Demand

4.3.5 Portfolio 4 – Groundwater and Raw Water Storage

This portfolio adds operational storage to the supply system and utilizes groundwater from the three existing, but currently inactive, wells in the City. As shown in Figure 4.10, the groundwater wells have enough production capacity to eliminate most of the gap between supply and demand in the evaluated scenario. However, 800 AF of operational raw water storage is still needed along with the use of drought restrictions in a couple of the driest months in this 2-year period in order to completely eliminate shortages. Note that this storage amount does not include storage inefficiencies or emergency storage (Section 4.6), which would add to the amount of storage recommended. Over the 25 years of hydrology analyzed with maximum 2070 demand, Castle Creek and Maroon Creek could directly meet full demand in most years. It is estimated that groundwater would need to be utilized in approximately 8 of 25 years (32 percent of years), operational storage utilized in 4 of 25 years (16 percent of years), and drought restrictions in 3 of 25 years (12 percent of years).

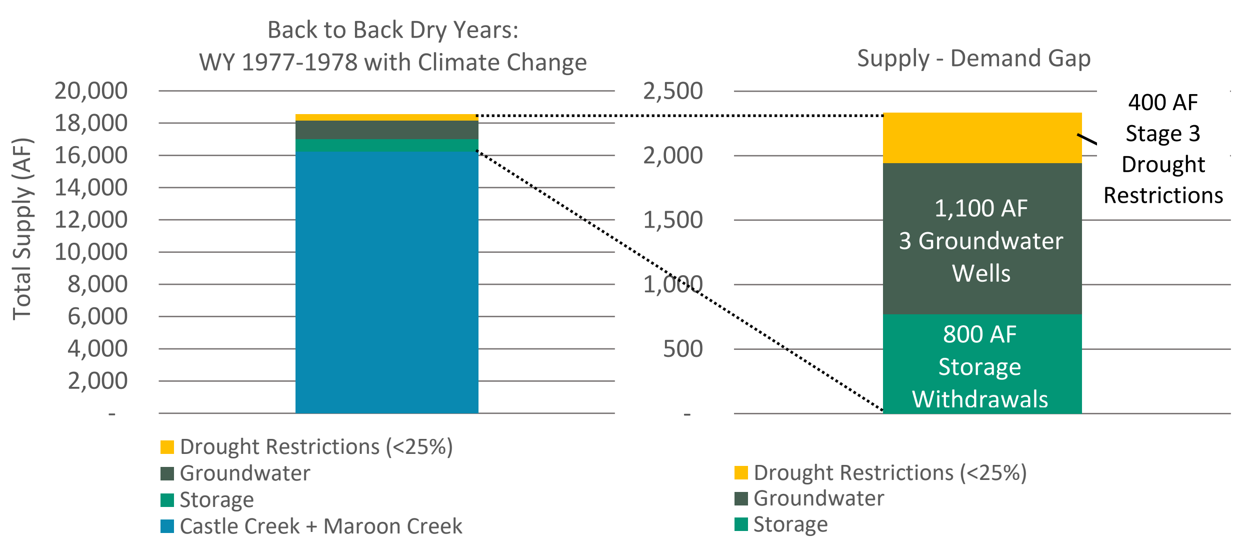


Figure 4.10 Portfolio 4 Performance Under Driest 2-Year Conditions with 2070 Demand

4.3.6 Portfolio 5 – Enhanced Conservation and Raw Water Storage

This portfolio utilizes enhanced conservation strategies to decrease demand and adds operational raw water storage to the supply system. As shown in Figure 4.11, enhanced water conservation acts as a supply strategy by decreasing the gap between supply and demand. The rest of the gap is mitigated by using 1,600 AF of operational storage and the use of drought restrictions in the driest months of the 2-year dry period. Note that this storage amount does not include storage inefficiencies or emergency storage (Section 4.6), which would add to the amount of storage recommended. Over the 25 years of hydrology analyzed with maximum 2070 demand, Castle Creek and Maroon Creek could directly meet full demand in most years. It is estimated that operational storage would need to be utilized in 7 of 25 years (28 percent of years) and drought restrictions utilized in 1 of 25 years (4 percent of years). It is assumed that enhanced conservation is ongoing and utilized in all years.

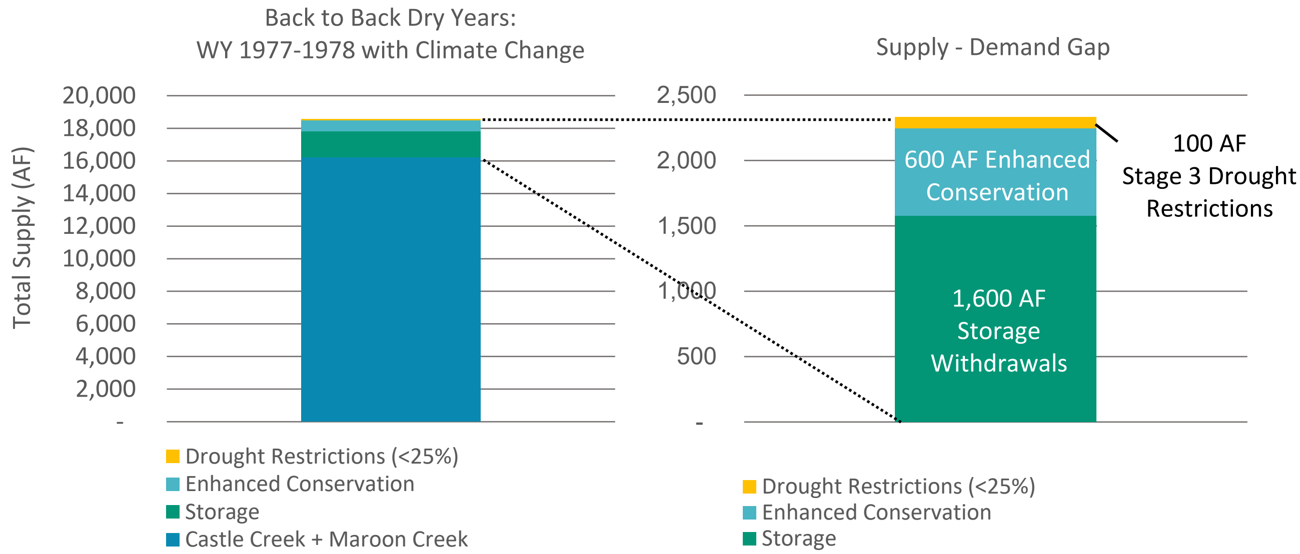


Figure 4.11 Portfolio 5 Performance Under Driest 2-Year Conditions with 2070 Demand

4.3.7 Portfolio 6 – Groundwater, Storage, Enhanced Conservation, and Non-Potable Reuse

This portfolio aims to maximize supply diversification by using multiple water supply options, including groundwater, operational raw water storage, enhanced water conservation, and non-potable reuse. Hunter Creek was not included in Portfolio 6 because it does not significantly mitigate the supply gap during dry years, as shown in Portfolio 3, while requiring significant and costly improvements such as a new treatment plant. As with Portfolio 5, enhanced water conservation acts as a supply strategy by decreasing total demand. Non-potable reuse cannot directly be used to meet potable demands, but it replaces water diverted from Castle Creek for non-potable demands and thus frees up more water from the creek to meet potable demand. Water pumped from groundwater wells eliminates the largest portion of the supply gap (Figure 4.12). With this mix of location water supply options, the amount of operational raw water storage needed is reduced to 400 AF. Drought restrictions during the driest months eliminate the rest of the gap during the driest 2-year period. Note that this storage amount does not include storage inefficiencies or emergency storage (Section 4.6), which would add to the amount of storage recommended. Over the 25 years of hydrology analyzed with maximum 2070 demand, Castle Creek and Maroon Creek could directly meet full demand in most years. It is estimated that under 2070 demand and supply conditions, groundwater would need to be utilized in 7 of 25 years (28 percent of years), operational storage withdrawals utilized in 3 of 25 years (12 percent of years), and drought restrictions utilized in 4 of 25 years (16 percent of years). It is assumed that enhanced water conservation and non-potable reuse are ongoing supply strategies that are utilized in all years.

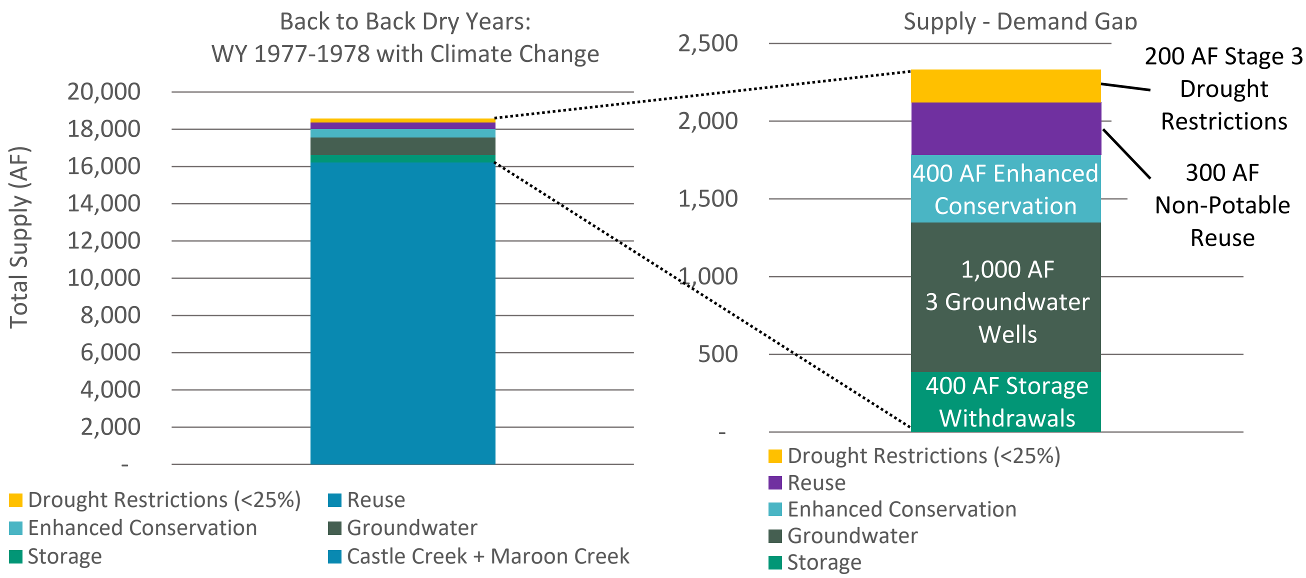


Figure 4.12 Portfolio 6 Performance Under Driest 2-Year Conditions with 2070 Demand

4.3.8 Supply Portfolio Summary

The composition of each supply portfolio is summarized in Table 4.4. Each supply portfolio focuses on one supply option paired with operational raw water storage and drought restrictions except for Portfolio 6, which maximizes supply diversification by including nearly all supply options. Operational storage is included in all supply portfolios (other than Portfolio 1, No Action) because no single supply option or combination of supply options can completely mitigate shortages in the driest 2-year period of the 25 years of hydrology analyzed without the use of at least some operational storage. However, the amount of operational storage included in each portfolio varies based on the extent to which the other supply options included in each portfolio can mitigate the supply and demand gap during the driest 2-year period analyzed. The composition of how each supply portfolio mitigates the supply-demand gap during the driest 2-year period is also graphically shown in Figure 4.13.

Table 4.4 Supply Portfolio Summary

Portfolio	Operational Storage (AF)[(1)]	Hunter Creek	Ground-water	Enhanced Conser-vation	Non-Potable Reuse
1 No Action	0	-	-	-	-
2 Storage Only	2,200	-	-	-	-
3 Hunter Creek + Storage	2,000	●	-	-	-
4 Groundwater + Storage	800	-	●	-	-
5 Enhanced Conservation + Storage	1,600	-	-	●	-
6 Groundwater + Storage + Enhanced Conservation + Reuse	400	-	●	●	●

Notes:
(1) The raw water storage amount does not include emergency storage or an allocation for storage inefficiencies, which would add to the amount of storage recommended.

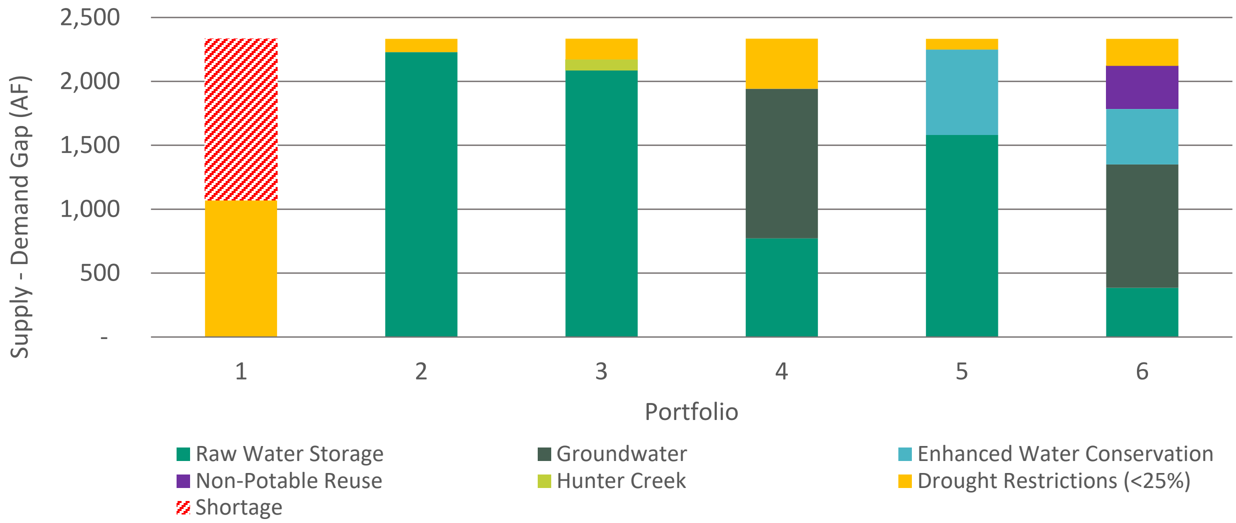


Figure 4.13 Supply Portfolio Composition to Mitigate the 2-Year Supply-Demand Gap

4.4 Evaluation Criteria

A set of criteria was developed in conjunction with the City for use in evaluating the supply portfolios. Input from the Technical Work Group and public input from a public meeting was used to further refine and define the criteria. The criteria are grouped into the following overall objectives:

- Supply availability,
- Supply resilience,
- Community and environmental benefits,
- Affordability,
- Ease of implementation, and
- Ease of operations.

4.4.1 Supply Availability

A key objective of this IRP is to develop a long-term supply strategy for the City that will provide access to adequate supply as demands increase in the future and as existing supplies may be adversely impacted by climate change. Thus, supply availability is an important criterion by which to evaluate the supply portfolios. Since all portfolios included in this analysis (excluding No Action) meet the minimum threshold of having enough supply to meet the maximum projected 2070 demand over the entire 25 years of hydrology analyzed, the focus of the criteria within this objective is the frequency and magnitude of the use of drought restrictions within each portfolio.

Although drought restrictions are an acceptable strategy for mitigating the impacts of dry periods, less frequent and less severe restrictions are preferable to frequent and/or significant restrictions because water use restrictions can have quality of life implications for the community. The evaluation criteria for the supply availability objective are:

- Drought restriction magnitude, measured by the largest annual reliance on drought restrictions (AFY) to avoid shortages.
- Drought restriction frequency, measured by the percentage of months requiring the use of drought restrictions to avoid shortages.

4.4.2 Supply Resilience

The ability to deliver supply to customers under a variety of potentially adverse events or conditions is another key objective for the City. The resilience of each supply portfolio to the threats described in Section 4.1 is evaluated under the supply resilience criteria. As discussed in Section 4.1, many of the threats considered in this IRP can be mitigated through supply diversification, which would allow the City to turn to alternative supplies if one supply is adversely impacted by a threat. The level of risk posed by threats (wildfire, infrastructure failure, etc.) to each portfolio was calculated based on the level of risk associated with each of its component supplies. The two evaluation criteria for the supply resilience objective are:

- Diversity of supply sources, measured as the percentage of supply for the largest single source in the portfolio.
- Vulnerability risk score, measured as the weighted risk scores of each supply option included in the portfolio.

4.4.3 Community and Environmental Benefits

The City and the community it serves strongly value environmental stewardship. As such, the use of responsible, sustainable, and low-impact water supply strategies is important to the City. Although meeting instream flow goals is a minimum threshold for all portfolios, minimizing surface water diversions was considered for each portfolio as a measure for the degree to which flows can be protected and maintained in local streams and rivers to provide ecological, recreational, and aesthetic benefits. This has the additional benefit of maintaining flows for use for hydroelectric power generation, an important source of renewable energy in the region. Additionally, portfolios were evaluated for water use efficiency by decreasing demand through conservation or by reusing water. Finally, the energy footprint of each portfolio is evaluated. The three evaluation criteria for community and environmental benefits are:

- Protect instream flows, measured by a qualitative score from 1 (low) to 5 (high) based on minimizing surface water diversions.
- Efficient water use, measured by a qualitative score from 1 (low) to 5 (high) based on the implementation of enhanced water conservation and/or non-potable water reuse.
- Energy footprint, measured by estimated average amount of energy (kilowatt-hours [kWh]) used to produce 1 AF of water (kWh/AF).

4.4.4 Affordability

The City aims to be fiscally responsible and wants to minimize financial impacts to rate payers. The affordability objective considers the capital cost and life cycle cost of each portfolio. The two evaluation criteria for the affordability objective are:

- Capital cost, measured by the estimated upfront cost of construction the supply options within each portfolio ($).
- Life cycle cost, measured by the net present value cost of constructing, operating, and maintaining the supply options within each portfolio ($).

4.4.5 Ease of Implementation

The criteria within the ease of implementation objective aim to evaluate how feasible each portfolio is by considering construction and permitting complexity and the ability to phase supply capacity. The ability to phase capacity is important so the City can implement supply options as supply and demand conditions evolve over time, and so the City can avoid over-investing in supply options that could be deferred if demand does not reach the maximum projected levels in 2070. The two criteria within the ease of implementation objective are:

- Construction and permitting complexity, measured by a qualitative score from 1 (low) to 5 (high) based on the number of components within each portfolio and the amount of construction required outside the core City area.
- Ability to phase capacity, measured by a qualitative score from 1 (low) to 5 (high) based on the flexibility of each portfolio to implement parts of the portfolio to meet demand as needed.

4.4.6 Ease of Operations

Streamlining City operations or avoiding additional operational complexity is considered beneficial to the City so the City can operate the supply system without the need to significantly expand staffing or training for staff. The ease of operation objective includes one criterion:

- Degree of operational simplicity, measured by a qualitative score from 1 (low) to 5 (high) based on the number of components, particularly treatment or blending facilities, included in each portfolio.

4.4.7 Criteria and Weighting

The water supply goals described in Section 1.3 were adopted as objectives for evaluating the portfolios in the IRP. For each of the six major objectives, criteria were defined to help characterize and measure how well the portfolios accomplish the objective.

In any decision-making process, individuals and organizations place different levels of importance on each criterion – reflecting local values and recognizing the trade-offs between the choices at hand. In order to use the criteria to evaluate supply portfolios, the relative importance, or weight, of each objective and criterion was established by the City. A total of 100 percentage points was allocated to the six objectives to indicate the relative importance of each objective. The relative importance of the criteria within each objective is reflected by allocating the points for each objective to its supporting criteria. These weightings were initially developed by the consulting team in collaboration with City staff, then refined and updated to reflect community feedback from IRP community meetings and technical work group meetings.

Since supply availability is the main driver of this planning effort, the criteria within this objective were given the highest weights at 15 percent (out of 100) each. Supply resilience, and specifically mitigating vulnerability to identified risks, is also a key driver and thus was also given a weight of 15 percent. Life cycle cost and the protection of instream flows are considered the next most important criteria and were assigned weights of 10 percent each. All other criteria were weighted as 5 percent each. The weight for each criterion and total weight for each objective are shown in Table 4.5.

Table 4.5 Evaluation Criteria, Metrics, and Relative Weighting

Objective | Evaluation Criteria	Metrics	Relative Weight (%)
Supply Availability		**30**
Drought Restriction Magnitude	Largest annual reliance on drought restrictions (AFY)	15
Drought Restriction Frequency	% of months with drought restrictions	15
Supply Resilience		**20**
Diversity of Supply Sources	% of supply from largest single source	5
Vulnerability Risk Score	Weighted risk score	15
Community and Environmental Benefits		**20**
Protect Instream Flows	Qualitative score	10
Efficient Water Use	Qualitative score	5
Energy Footprint	kWh/AF	5
Affordability		**15**
Capital Cost	$M (2021 dollars)	5
Life Cycle Cost	Net Present Value (NPV) $M (2021 dollars)	10
Ease of Implementation		**10**
Construction and Permitting Complexity	Qualitative score	5
Ability to Phase Capacity	Qualitative score	5
Ease of Operations		**5**
Degree of Operational Simplicity	Qualitative score	5
	TOTAL WEIGHT	**100**

4.5 Supply Alternatives Evaluation

Each supply portfolio was evaluated using the weighted criteria described in Section 4.4 and Table 4.5 to compare and rank the portfolios and recommend a portfolio. This section describes the methodology used to score the portfolios and presents the results of that evaluation.

4.5.1 Methodology

The criteria used to evaluate supply portfolios were scored using four primary tools: a water supply model, the supply vulnerability assessment, cost estimates, and qualitative scoring.

4.5.1.1 Water Supply Model

As described in Section 4.3.1, a water supply model was built in Microsoft Excel to correctly size portfolios to meet the minimum threshold of providing enough supply for the maximum projected 2070 demand under the driest modeled climate conditions with the use of up to Stage 3 drought restrictions. This same model was used to evaluate the supply availability criteria and informed the scoring for the affordability criteria. The model was constructed in Excel as a monthly mass-balance model that compared the projected 2070 demands to the supply available over 25 years of climate change-impacted modeled hydrology in Castle Creek and Maroon Creek. The potential supply options included in each portfolio were added to the model to be used if the modeled supply in Castle Creek and Maroon Creek was not sufficient to meet projected demand.

The model showed how much and how often each supply strategy would be used to meet demand. This included the frequency and magnitude of the need to use drought restrictions with each portfolio, which provided the scores for the supply availability criteria. For example, the supply model showed that the largest annual reliance on drought restrictions for Portfolio 2 was 104 AFY. This is a better score for the drought restriction magnitude criteria than that for Portfolio 4, which was 225 AFY. Similarly, Portfolio 2 only utilized drought restrictions on 0.7 percent of all months in the 25-year modeled hydrology, which is a better drought restriction frequency score than that of Portfolio 4, which utilized drought restrictions in 1.3 percent of the months in the modeled hydrology.

The average use of each supply option across the 25 years of modeled hydrology also informed the affordability criteria since the frequency and magnitude of use of each supply option impacted project infrastructure sizing and operating costs. For a complete description of supply modeling assumptions, see Appendix D.

4.5.1.2 Supply Vulnerability Assessment

The supply vulnerability assessment described in Section 4.2. was utilized to score the supply resilience criteria for each portfolio. As described in Section 4.2, a total risk score was calculated for each source-threat pair based on the likelihood of the threat impacting the source and the consequence that the threat would inflict on the supply source. To score each portfolio against the vulnerability risk score criteria, first the risk score for each supply source was calculated as the average of all threats for that source. Then, the risk scores for each portfolio were calculated by weighting the risk scores of the component sources within that portfolio. Since sources were utilized differently from year to year within each portfolio, the source weighting was calculated for this criterion, assuming that the City would attempt to rely on its least vulnerable sources.

For example, Portfolio 2 includes two supply sources: Castle Creek/Maroon Creek and withdrawals from storage. Withdrawals from storage in Portfolio 2 could account for up to 24 percent of average annual demand under the maximum projected 2070 demand scenario if needed and this supply source had an average risk score of 3.0. Diversions from Castle Creek and Maroon Creek would make up the other 76 percent of supply and have an average risk score of 8.3. Thus, the weighted average risk score for Portfolio 2 is:

$$(3.0 * 24\%) + (8.3 * 76\%) = 7.0$$

This is a less favorable score for the vulnerability risk score criteria than that of Portfolio 6, which is 4.9, since Portfolio 6 relies less on Castle Creek and Maroon Creek and more on other supply sources that are less vulnerable to identified threats and thus have lower risk scores.

The percentage of total demand that could be met with each was used for the diversity of supply sources criteria. For example, Portfolio 6 includes a variety of supply sources and would receive a better score for the diversity of supply sources criteria than that achieved by Portfolio 2, which is still heavily reliant on Castle Creek and Maroon Creek to meet demand.

4.5.1.3 Cost Estimates

Cost estimates were prepared for each portfolio considering both the up-front capital expenditure and the long-term costs required for each portfolio. Capital estimates were developed at a conceptual level of detail, consistent with an AACE Class 5 level of expected accuracy. Actual costs are anticipated to vary by as much as +50 percent to -30 percent for Class 5 estimates. Estimates were prepared in current-day dollars at the time the estimates were developed (2020), and financial planning exercises should escalate these costs to the year of anticipated implementation. Costing assumptions and details of the costing for each portfolio are documented in Appendix E.

4.5.1.4 Qualitative Scoring

The community and environmental benefits, ease of implementation, and ease of operation criteria were scored on scales from 1 to 5. These scores were assigned for each portfolio for each criterion based on the guidance described in Section 4.4, the project team's understanding of conditions in the City, and the team's prior water supply planning experience.

4.5.2 Criteria Scores

The portfolios were scored against the criteria as described above. Raw criteria scores are shown in Table 4.6. For some criteria (such as cost), a lower score is better, while higher scores are better for most criteria. For example, lower scores are better for the affordability, supply availability, supply resilience, and energy footprint scores. Higher scores are better for all criteria that use the 1 to 5 qualitative scoring metrics.

The No Action portfolio scored well in affordability and ease of operations, but poorly in all other criteria. Portfolio 2 scored well in supply availability and ease of operations and moderately well across all other criteria. Portfolio 3 scored moderately well across most criteria but very poorly for the affordability criteria. Portfolios 4, 5, and 6 scored well across nearly all criteria.

Table 4.6 Raw Criteria Scores

Criteria | Objective	Unit of Measure	Weight (points out of 100)	Portfolio Raw Scores					
			Portfolio 1	Portfolio 2	Portfolio 3	Portfolio 4	Portfolio 5	Portfolio 6
			No Action	Operational Storage Only	Hunter Creek + Operational Storage	Groundwater + Operational Storage	Enhanced Conservation + Operational Storage	Enhanced Conservation + Groundwater + Non-Potable Reuse + Operational Storage
Affordability								
Capital Cost	$M (2021 dollars)		$0	$306	$409	$201	$259	$153
Life Cycle Cost	NPV $M (2021 dollars)		$20	$341	$468	$240	$290	$189
Supply Availability								
Drought Restriction Magnitude	AFY		1910	104	163	225	84	176
Drought Restriction Frequency	(% of months)		5.3%	0.7%	0.3%	1.3%	0.3%	1.3%
Supply Resilience								
Diversity of Supply Sources	(% of demand)		50%	38%	25%	30%	34%	27%
Vulnerability Risk Score	(weighted risk score)		8.3	7.0	6.6	5.9	6.2	4.9
Ease of Operations								
Degree of Operational Simplicity (Qualitative Score)			5	4	1	3	3	2
Community and Environmental Benefits								
Protect Instream Flows (Qualitative Score)			1	3	3	4	4	5
Efficient Water Use (Qualitative Score)			1	1	1	1	4	5
Energy Footprint (kWh/AF)			210	235	226	230	229	229
Ease of Implementation								
Construction and Permitting Complexity (Qualitative Score)			5	3	2	2	3	1
Ability to Phase Capacity (Qualitative Score)			1	4	2	5	5	5

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4.5.3 Results

To complete the evaluation, the raw criteria scores and the criteria weights were input into a Criterium DecisionPlus (CDP) model, a commercially available software platform that normalizes the criteria scores and applies the criteria weights to compare portfolios. Portfolios that score well against the most important criteria receive a higher decision score, which indicates a preferable portfolio. The normalized total decision score for each portfolio ranges from 0 to 1, with 1 being a perfect score across all criteria. The results of the weighted-criteria analysis are shown in Figure 4.14. As shown, Portfolio 6 scored the highest, followed by Portfolios 5 and 4. Portfolio 1 scored the worst, clearly confirming that "no action" is not a viable approach.

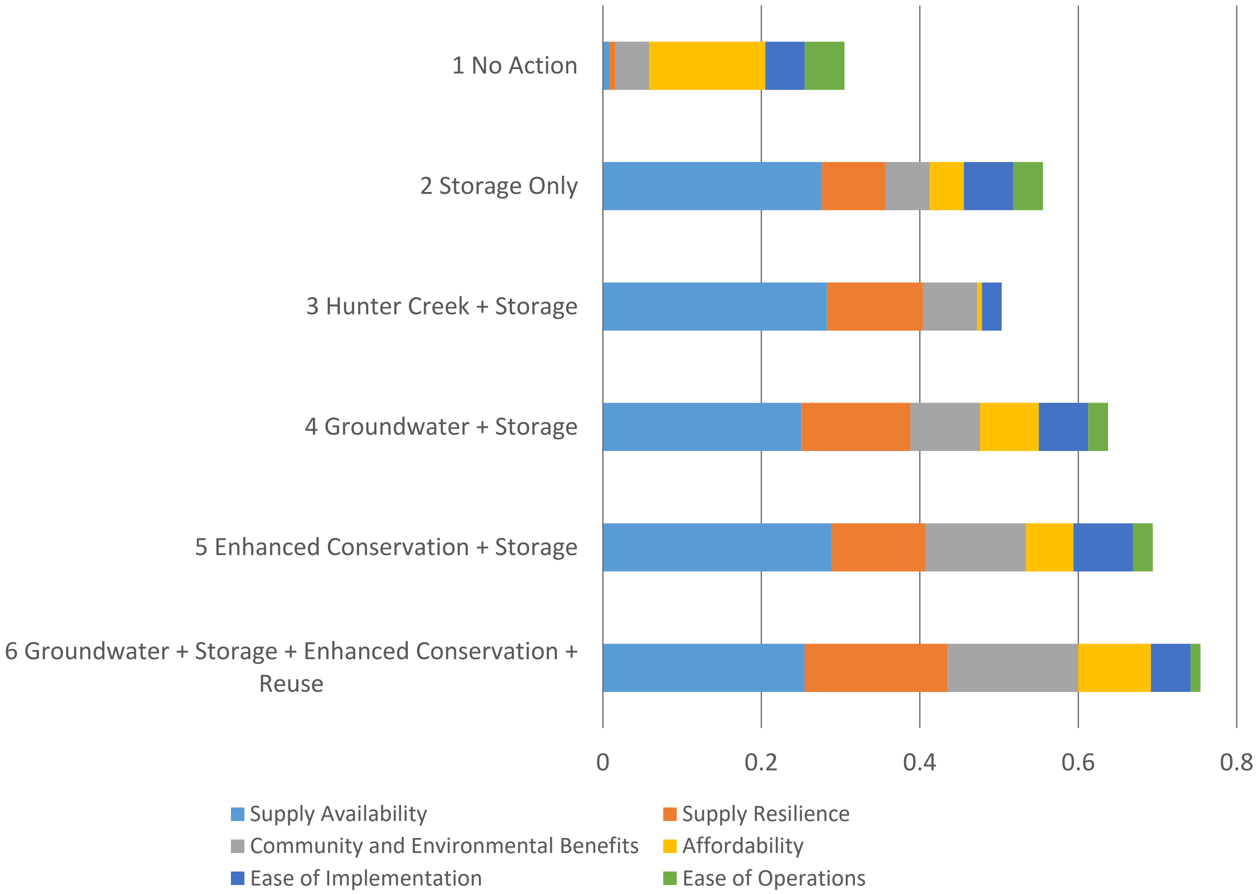

Figure 4.14 Portfolio Evaluation Results

Feedback solicited from the Technical Work Group and an IRP public meeting regarding the relative importance (weight) of each criterion generally validated the weighting profile, although there was a wide range of input that suggested increasing or decreasing the weights for each of the individual criterion. A sensitivity analysis was conducted to assess the implications of modifying the weight of each criterion (plus or minus 10 points each). These modifications did not change the relative ranking of the portfolios, meaning Portfolio 6 remained the highest scoring and preferred alternative in all iterations with varying criteria weights. This helped confirm that Portfolio 6 is a robust solution that best addresses the full range of objectives and criteria.

While Portfolio 6 does not have the highest supply availability score, it does meet the minimum availability threshold of eliminating shortages under the maximum projected 2070 demand. It has the highest supply resilience and community and environmental benefits scores and the second highest affordability score. It scored only moderately well in ease of implementation and ease of operation, but its strength in the other more heavily weighted criteria elevated this portfolio to the highest overall score. Thus, Portfolio 6 is recommended for implementation. The recommended sequencing and phasing of implementing the components of Portfolio 6 is described in Chapter 5.

4.6 Emergency Raw Water Storage for the Top-Ranked Portfolio

The operational raw water storage needs described in Section 4.3 are intended to be used in conjunction with other supply options to eliminate the potential seasonal gap between supply and demand in particularly dry years. Operational raw water storage helps buffer natural seasonal and annual fluctuations in available supply from Castle Creek and Maroon Creek to allow the City to continue to serve customers if creek supplies fall below demand.

In contrast, emergency raw water storage is intended to be used when the capacity of the City's water supply sources cannot meet demand due to a temporary emergency situation. This may occur due to one of the supply vulnerabilities discussed in Section 4.2, such as wildfire or critical infrastructure failure. Emergency storage needs increase total storage needs above and beyond operational raw water storage. In order for emergency storage to be effective, it must be "full" and ready for use when the need arises; its quantity should be considered to be separate and distinct from (not "shared" with) operational storage, which could result in less water available in storage than needed when an emergency event occurs. However, operational storage and emergency storage could be co-located within a single storage facility, with separate "paper" tracking of stored volumes.

The recommended amount of emergency storage was determined by assessing the amount of additional supply needed if the City's largest supply source for the top-ranked portfolio is unavailable due to the worst-case threat scenario. Under Portfolio 6, the largest supply source will continue to be direct diversions from Castle Creek and Maroon Creek, even after diversification of supplies. Reinstating the City's three groundwater wells in central Aspen will reduce the need for emergency storage, because they will be able to meet a portion of the community's demands. However, they are subject to blending requirements – meaning groundwater cannot operate as the sole source of potable water for the community at any point, and some amount of treated water sourced from Castle Creek, Maroon Creek, or storage will be required at all times.

An analysis of emergency storage needs for the top-ranked water supply portfolio was conducted with the following assumptions:

- Emergency storage needs were calculated for the 2070 demand scenario (Scenario F) and estimated for the 2040 demand scenario, assuming a constant (linear) rate of demand increase between now and 2070.
- All supply strategies of Portfolio 6 will be implemented. Reactivation of the groundwater wells is the most important element for reducing the size of emergency storage needed to protect against potential interruptions in Castle Creek and Maroon Creek diversions. Groundwater wells will be operated to reduce the amount of emergency storage needed.
- Stage 3 drought restrictions can and will be successfully employed to temporarily reduce potable water demands by 25 percent when Castle Creek or Maroon Creek emergency supply interruptions occur.
- Castle Creek and Maroon Creek diversions could be interrupted simultaneously under a severe emergency event.

- Interruptions in Castle Creek and Maroon Creek diversions could occur in the highest-demand months and could last between 1 and 12 months. Scenarios evaluated include supply interruptions for 1 month (July), 2 consecutive months (July to August), 3 consecutive months (July to September), 6 consecutive months (May to October), and 12 consecutive months.
- Storage estimates include a 30 percent allocation for storage inefficiencies – storage capacity from which water cannot easily or quickly be withdrawn when needed. This is consistent with the City's analyses of potential water storage sites in recent years.

Emergency raw water storage sizing for projected 2040 and 2070 demand levels is summarized in Figure 4.15 for these assumed conditions as a function of the duration of Castle Creek and Maroon Creek diversion interruptions. If demands increase at a slower rate, emergency storage needs would be lower and expansions could be deferred. Faster growth (or failure to meet the target use reductions via enhanced water conservation) would accelerate the need for emergency storage expansions. The need for emergency storage is not delayed until 2040; 2040 was selected as an interim year for illustrating the increasing need for and importance of storage in protecting against emergency conditions.

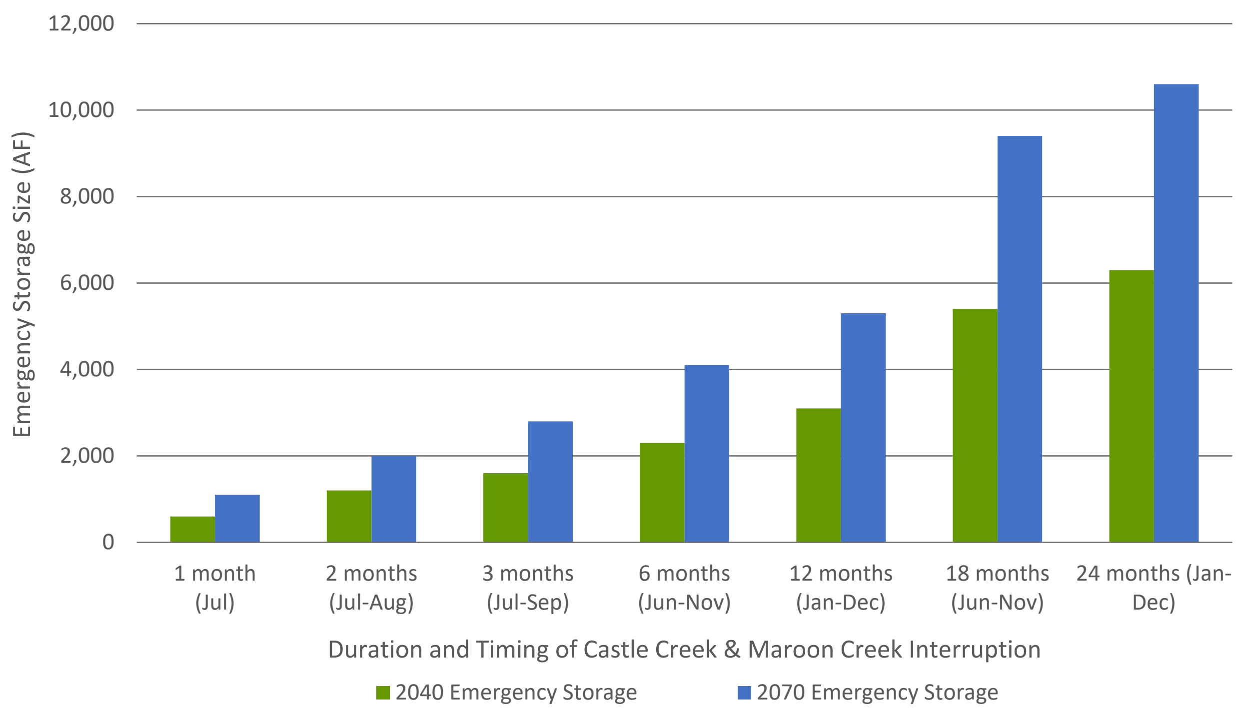

Figure 4.15 Emergency Storage Sizing as a Function of Castle Creek and Maroon Creek Diversion Interruption

Both the amount of emergency storage capacity and the maximum rates of withdrawal from emergency storage are reduced by the availability of other sources of supply, such as the recommended reactivation of the groundwater wells. The maximum withdrawal rate drives sizing of pumping and pipeline infrastructure to convey stored raw water to the WTF. Using the same basis of analysis, the maximum potential withdrawal rate would occur in July, equal to 475 AF/month under 2040 demand conditions and 831 AF/month in 2070. Infrastructure sizing for emergency storage was based on these withdrawal rates, after peaking to meet the maximum day demand within the month from emergency storage and considering the availability of other sources to meet the maximum day demand. The corresponding pump station and pipeline sizing is summarized in Table 4.7.

Table 4.7 Conveyance Sizing for Emergency Storage Withdrawals

Parameter	Units	Sizing for 2040 Conditions(1)	Sizing for 2070 Conditions
Maximum Monthly Withdrawal Rate	AF/month	475	831
Maximum Day Withdrawal Rate(2)	mgd	7.6	12.2
Pump Station Power(3)	hp	1,320	2,200
Pipeline Diameter(4)	inch	30	30

Notes:
(1) Approximated values for 2040, contingent on the rate of increase in potable water demand.
(2) Sized to meet the peak day demand in July, after full use of groundwater wells' capacity.
(3) Estimated based on pumping from the storage site to Leonard Thomas Reservoir through a 30-inch diameter, 8.1-mile-long pipeline with 765 feet of static head. Actual values will depend on final siting of storage facility.
(4) Assumes pipeline will be built for 2070 capacity as part of the first phase of implementing emergency storage.

Clearly, increasing the emergency storage capacity brings greater levels of protection against emergency events (i.e., source interruptions with longer durations). However, the cost of constructing storage and conveyance infrastructure from the storage site to the WTF quickly escalates with increasing size.

Wildfires in a source watershed can have long-lasting impacts on water quality and treatability, ranging from aesthetics (taste and odor) to a reduced treatment capacity or temporary inability to meet drinking water standards. Industry experience in the western United States suggests that water quality impacts from wildfires can last for years, most severely in the near-term aftermath of a fire and subsequent storm events. Moreover, supply chain limitations have become increasingly evident through the 2020-2021 global pandemic, illustrating weaknesses in reliability and timeliness for replacement materials and equipment. Considering the range of water supply risks as a whole, the following strategies are recommended:

- Over the long term, construct emergency storage sufficient to offset 12 consecutive months of interruptions in Castle Creek and Maroon Creek diversions.
- Identify methods of "hardening" treatment processes at the WTF against wildfire water quality impacts as part of a WTF Master Plan.
- Construct the identified WTF improvements for wildfire treatment resilience. An assumed capital cost of $5 million for these improvements is included in the capital improvement plan (Chapter 5), which should be defined and updated as part of the WTF Master Plan.

Total raw water storage needs for 2070 conditions include a minimum of 520 AF for operational storage (400 AF plus a 30 percent allocation for storage inefficiencies) and 5,300 AF to provide up to 12 months of emergency storage (including storage inefficiencies). Together, this 5,820 AF of raw water storage will provide coverage for seasonal and annual fluctuations in Castle Creek and Maroon Creek flows and 12 months of emergency interruptions in Castle Creek and Maroon Creek diversions. An accelerated rate of increasing demand (or incomplete implementation of other components of Portfolio 6, such as reinstating groundwater wells) would increase and accelerate the need for storage, and vice versa. Phased construction of these storage amounts is defined in Chapter 5 of this IRP.

The amount of storage identified in this IRP is less than in some previous planning efforts due to the recommended implementation of other alternative supplies, such as groundwater and enhanced conservation, and less conservative estimates for the utilization of storage water rights and storage losses. If other supply options are determined to not be viable following additional study, or if demands are greater than projected or future climate is drier than projected, additional storage may be needed.

While 12 months of emergency storage is recommended in this IRP as a balance between extreme-scenario resilience and capital costs, some Colorado utilities have constructed raw water storage for as much as 3 years of demand. Moreover, it should be recognized that there is significant uncertainty in future demand projections and supply conditions (particularly regarding climate change), and that the IRP projects needs only through 2070. Application of a safety factor and planning for conditions beyond 2070 could increase the storage need beyond the 5,820 AF value identified here.

The storage needs should be periodically reviewed in light of water demand trends and updated as part of future updates to this IRP. With the exception of the Woody Creek site and Vagneur Gravel Pit, each of the raw water storage sites considered in the IRP would be constructed as *in situ* (subsurface) storage. The Woody Creek and Vagneur Gravel Pit sites could be developed as open (surface) storage.


INTEGRATED WATER RESOURCE PLAN

Chapter 5

IMPLEMENTATION PLAN

Water supply system enhancements should be implemented in a prioritized, phased manner to continue to reliably meet water demands and reduce system vulnerabilities while being mindful of surges in capital expenditures. The implementation plan includes a near-term (10-year) CIP and an approach for later phases of system improvements beyond 2030 to maintain a reliable water supply system through 2070.

5.1 Preferred Supply Options

The preferred portfolio for a resilient, sustainable, long-term water supply identified in Chapter 4 includes the following components:

- Continued use of Castle Creek and Maroon Creek as the primary sources of supply,
- Continued use of existing water conservation programs and measures,
- Enhanced conservation programs and measures, beyond those in use today and planned already,
- Non-potable water reuse for irrigation and potential future snowmaking at Buttermilk Mountain,
- Reactivating the City's three groundwater wells in central Aspen by constructing a blending facility, and
- Constructing emergency storage and operational storage with necessary conveyance facilities.

The recommended sequence of implementation of the new water supply components is listed in Table 5.1, in order of decreasing priority.

Table 5.1 Implementation of New Water Supply Components

Water Supply Component	Rationale for Priority	Implementation Trigger
Water Reuse	Majority of necessary system infrastructure is already in place.	Near-term implementation to further enhance water use efficiency with irrigation reuse at Aspen Municipal Golf Course; subsequent expansion to additional sites covered by the decreed reuse water right.
Groundwater Wells Reactivation with Blending Facility	Cost-effective, substantial supply diversification capacity that will significantly reduce system vulnerabilities.	Near-term implementation to diversify supply and reduce vulnerability to supply threats. Completion of detailed analysis of hydrogeological connection with Roaring Fork River and its tributaries and the potential need and strategies for augmentation.
Enhanced Conservation	Relatively inexpensive programmatic investment but with uncertain yield returns due to dependence on customer behavioral changes.	7-year update of 2015 Water Efficiency Plan (WEP) (2022) to reflect demand trends and identify best management practices with largest conservation potential.

Water Supply Component	Rationale for Priority	Implementation Trigger
WTF Resilience Improvements	Enhance ability to treat wildfire-impacted water quality; avoid extended interruption of Castle Creek/Maroon Creek diversions and costs of additional Emergency Storage capacity.	Completion of WTF Master Plan; confirmation of improvements and capital costs and benefits.
Emergency Storage	Costly and time consuming to implement, but substantial protection against a variety of supply threats; volume needed grows over time with growth in demand.	Completion of storage siting evaluations, preliminary design, and permitting, land acquisition, and financing.
Operational Storage	Costly and time consuming to implement but provides protection against prolonged droughts by buffering variability of Castle Creek and Maroon Creek flows versus demand patterns. Phased implementation to match volume needed as demands increase over time.	Potable demand consistently exceeds approximately 5,200 AFY and climate is showing a drying trend (Castle Creek and Maroon Creek stream flow annual average decreases more than 10 percent from historical average). Completion of storage siting evaluations, preliminary design, and permitting activities.

5.2 Implementation Plan Overview

This IRP serves as a guiding document for the planning and implementation of water supply improvements to accommodate future water supply needs through year 2070. The City deliberately chose a planning period of approximately 50 years to reflect the long-lasting implications of water resources decisions, such as siting storage for the Castle Creek and Maroon Creek water storage rights, and the time it can take to plan, permit, construct, and implement water projects.

Interim-year demand projections between 2020 and 2070 were not developed in this study because of the lack of detailed forecasts of service area population, coupled with significant uncertainty regarding the pace at which climate change impacts will be observed between now and the projected 2070 condition. Instead, demands in interim years can be approximated by linear interpolation between 2020 and 2070, and can be verified by ongoing monitoring of demands and periodic updates to demand forecasts and this IRP over time. The IRP uses adaptive planning to define the system improvements needed to reliably meet demands in 2070, coupled with a trigger-based approach that provides for phased implementation of those improvements when conditions develop to the point that the improvements become necessary. The implementation plan is summarized in Figure 5.1 and discussed in the sections that follow.

It is important to recognize that the timing of each of these improvements – particularly after the near-term CIP period (2022 through 2030) – will be affected by factors such as water use patterns and amounts, and by water supply and snowmelt runoff patterns. The result could be a need to accelerate or an opportunity to delay implementation of each project.

5.3 Project Implementation Components

Implementation of the following projects is recommended to address near-term priority water supply needs in the City's water supply system and longer-term investments to reflect conditions over time as water demands increase and climate change impacts intensify. Figure 5.2 shows the geographic location and implementation timeframe for each capital project element recommended in this IRP.

	Est. Capital Cost 2022-2030 (in 2021 $M)	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031-2050	2051-2070
Capital Projects												
WR1: Water Reuse at Aspen Municipal Golf Course	$4.0											
WR2: Water Reuse Expansion	$0.2											
GW1: Groundwater Blending Facility	$8.1											
EC1: Enhanced Conservation Phase 1	$4.0											
EC2: Enhanced Conservation Phase 2	$0											
EC3: Enhanced Conservation Phase 3	$0											
WT1: Water Treatment Facility Resilience Improvements	$5.0											
ES1: Emergency Storage Phase 1	$10.9	Planning/Siting		Preliminary Design	Permitting/Financing					Final Design		
ES2: Emergency Storage Phase 2	$0											
ES3: Emergency Storage Phase 3	$0											
OS1: Operational Storage Phase 1	$0											
OS2: Operational Storage Phase 2	$0											
Master Planning												
Water Efficiency Plan Update	$0.05 per update											
Transmission/Distribution Master Plan	$0.1											
Water Treatment Plant Master Plan	$0.1											

Phase Key:
- Study/Planning
- Design/Bidding
- Construction/Implementation

Figure 5.1 Implementation Plan Summary

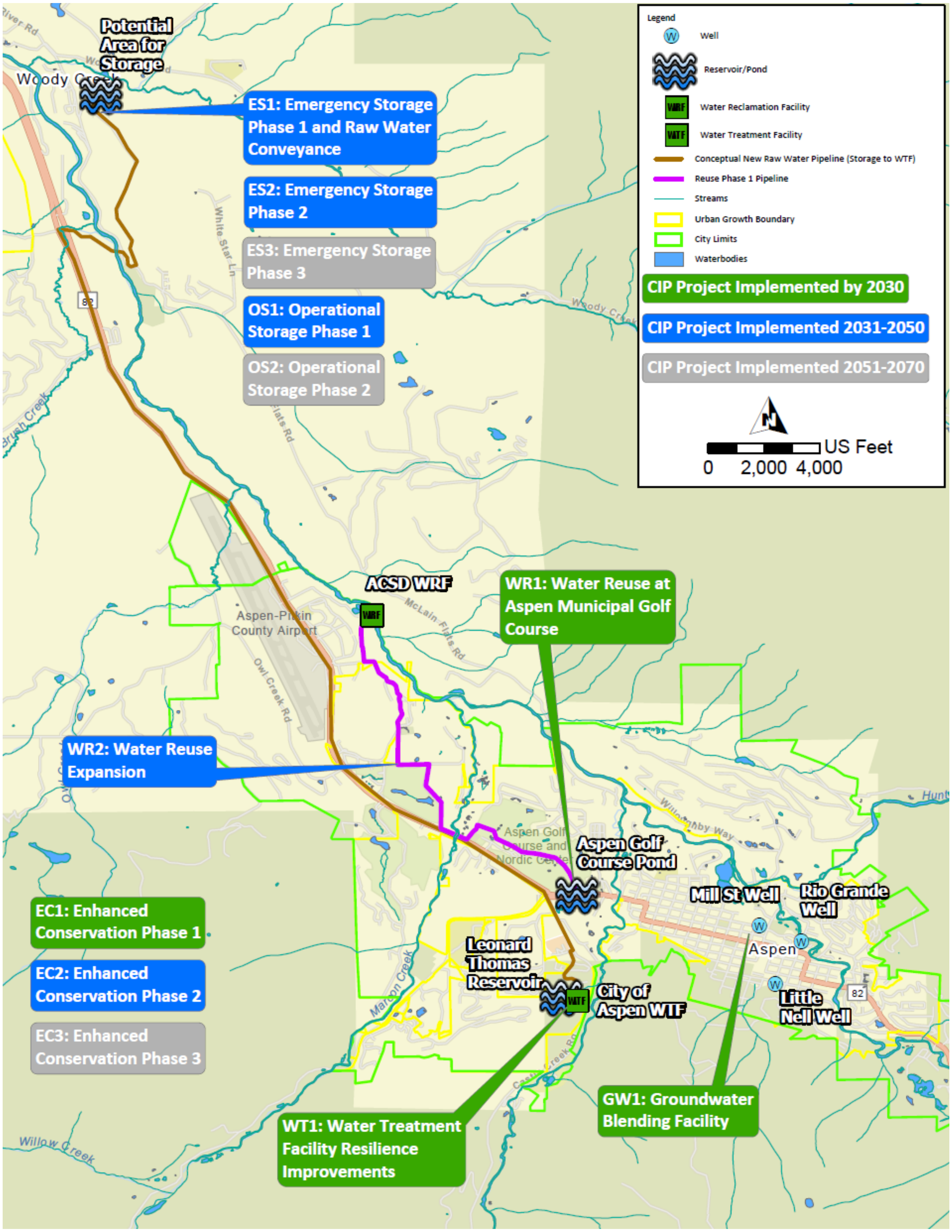

Figure 5.2 Overview of IRP Water Supply Projects

5.3.1 Water Reuse Phases 1 and 2 (Projects WR1 and WR2)

The City's proposed water reuse system has been the subject of extensive planning efforts over the past several years. Given the opportunity to enhance the efficient use of the City's existing water resources, and the fact that the pipeline to convey reclaimed water has already been constructed, this project is prioritized for near-term implementation.

The first phase of the water reuse project (Project WR1) consists of supplying reclaimed water to the Aspen Municipal Golf Course. This is prioritized because the majority of the pipeline is already in place and the project will provide a near-term increase in water management efficiency in Aspen. An expansion of the water reuse system (Project WR2) can be initiated in the late 2020s, starting with detailed planning and design to convey reclaimed water to additional sites and building on the operational history and community engagement associated with the first phase.

The initial phase of the reuse system (WR1) will include delivery of reclaimed water from the ACSD facility to the golf course pond using the existing 8-inch diameter pipeline to supply reclaimed water for irrigation at the Aspen Municipal Golf Course. The existing reuse pipeline extends from a few hundred feet outside the ACSD water reclamation facility property line to a point of discharge to the golf course pond. Although the pipeline is in place, the following elements must be confirmed, sited, designed, permitted, and constructed before operations can begin:

- Reuse pump station and
- Supplemental disinfection facility.

The ACSD water reclamation facility is sited at a lower elevation than the golf course pond, requiring pumping of reclaimed water to the pond. Water efficiency improvements in the golf course irrigation system reduced the annual irrigation demand to about 55 million gallons, or 168 AFY. In 2014, the City prepared preliminary design documents for a pump station located onsite at the ACSD facility to serve multiple reuse customer sites. However, continuing dialogue between the City and ACSD highlighted ACSD's concerns with siting the pump station onsite at the facility, particularly with respect to City staff access to the facility and potential onsite storage of chemicals for supplemental disinfection. A series of fact sheets prepared in December 2018 document six infrastructure and administrative options for the reuse system (Carollo, 2018b). In 2019, the City evaluated the potential for constructing a river diversion and pump station immediately downstream of the ACSD effluent discharge to the Roaring Fork River (Deere & Ault, 2019), to recapture the City's return flows for subsequent non-potable reuse.

Whether sited onsite at the facility or along the banks of the Roaring Fork River, the pump station will feed reclaimed water to the existing reuse pipeline to the golf course pond via a new connection pipeline between the pump station and the upstream terminus of the existing reuse pipeline to the golf course pond.

Water quality requirements for pathogens are more stringent for non-potable reuse systems (per CDPHE Reclaimed Water Regulation 84) than ACSD is required to meet for its discharge to the Roaring Fork River. In previous years' dialogue, ACSD staff indicated they would not commit to meeting the Regulation 84 pathogen limits. As such, the City may need to construct and operate a supplemental disinfection facility. Supplemental disinfection could occur at the reuse pump station or along the reuse pipeline route. Supplemental disinfection strategies and approaches for regulatory administration (e.g., designation of "treater" and "user" entities under Regulation 84) were evaluated and documented in 2018 (Carollo, 2018a).

The following near-term activities are necessary to implement reuse system deliveries to the Aspen Municipal Golf Course as part of Project WR1:

- Confirm reuse pump station siting and sizing. Initiate additional inter-utility dialogue with ACSD and engineering analyses to determine whether to site the reuse pump station onsite at the ACSD facility or adjacent to a new Roaring Fork River diversion immediately downstream of the ACSD discharge.
- Acquire land and/or easements for the reuse pump station and connecting pipeline segment as needed.
- Conduct community outreach and engagement regarding the proposed use of reclaimed water for irrigation at the golf course.
- Design, permit, and construct the reuse pump station and new pipeline segment connecting the pump station to the upstream end of the existing 8-inch diameter reuse pipeline, including supplemental disinfection if necessary.
- Determine and implement a method to prevent reclaimed water releases or overflows from the golf course irrigation pond to receiving waters (to prevent unpermitted discharges to waters of the state).
- If the reuse system diverts directly from the ACSD water reclamation facility, the system will be subject to CDPHE Regulation 84 requirements, and the City will need to permit the reuse system with CDPHE. If the reclaimed water is instead diverted directly from the Roaring Fork River, Regulation 84 and CDPHE permitting requirements do not apply, but it is recommended that the City voluntarily follow relevant best management practices to maintain protection of public health and the environment (e.g., providing supplemental disinfection).
- Initiate reuse system deliveries to the Aspen Municipal Golf Course.

The reuse conveyance system can be expanded in future years with Project WR2, which consists of a pipeline extension to serve additional demands that can use non-potable water. The City's decreed water right for water reuse allows use of reclaimed water for irrigation at the Burlingame housing complex and snowmaking at the Buttermilk Ski Area, in addition to irrigation at the Aspen Municipal Golf Course. Expanding the reuse system will further enhance the efficient use of the City's water resources and expand reuse beyond the summer irrigation season. Elements of implementing Project WR2 include:

- Characterize water demand amounts and patterns for irrigation at Burlingame and snowmaking at the Buttermilk Ski Area.
- Conduct community outreach and engagement regarding the proposed additional uses of reclaimed water.
- Develop preliminary design, secure land and/or easements, and design and construct pipeline extension(s) from the existing reuse pipeline to the Burlingame site and the Buttermilk Ski Area.

Total capital costs for Project WR1 and Project WR2 are estimated at $4 million and $2.1 million, respectively, in 2021 dollars. Project WR2 is sequenced to follow implementation of Project WR1 by several years, with startup of the expanded system in the early 2030s. Although the expansion could be implemented sooner, this timing allows the City to conduct additional public outreach for the reuse system, provides time to learn from operation and administration of the first phase, and defers capital costs to assist with cash flow considerations.

5.3.2 Groundwater Blending Facility (Project GW1)

Reactivating the City's three central Aspen groundwater wells via a new Groundwater Blending Facility (Project GW1) is also prioritized for near-term implementation because of the critical benefit it can provide to diversify the water supply portfolio for normal operations and in response to emergency conditions. If the project's detailed implementation planning is initiated in early 2022, construction of the infrastructure improvements can be sequenced to follow construction of Water Reuse Project WR1 and the associated expenditures. This sequencing will help moderate capital expense surges in the early- to mid-2020s.

The wells are currently offline due to marginally elevated concentrations of fluoride and uranium. This condition can be mitigated with construction of a new centralized blending facility, where groundwater would be blended with distribution system water sourced from Castle Creek/Maroon Creek diversions or storage withdrawals. As documented in the City's 2018 assessment of reinstating use of the wells (SGM, 2018), the blending facility could be located near the Mill Street Well and would be capable of blending water from the existing Mill Street, Little Nell, and Rio Grande Wells to meet potable water quality standards. Hence, this project will also require new dedicated pipelines to convey groundwater from each of the three wells to the blending facility.

Water quality considerations should be confirmed as part of preliminary design of the blending facility. Steps should include:

- Collecting additional water quality data from the wells and the City's existing potable water system to confirm the range of blending ratios needed to meet potable water standards.
- Modification of fluoride concentration requirements. The 2018 study noted that the City should modify the current regulatory framework for fluoride, by allowing variable concentrations from 0.3 to 1.6 mg/L (80 percent of the secondary maximum contaminant level [SMCL] of 2 mg/L, which is a recommended but not legally-enforceable standard). According to the U.S. Environmental Protection Agency, concentrations in excess of the SMCL can cause tooth discoloration.
- Confirmation of disinfection requirements approach. In consultation with CDPHE, the City should further evaluate approaches for disinfecting water produced from the wells, including the potential use of wellhead chlorination and contact time in the pipeline from each well to the centralized blending facility.
- Compatibility analyses. Water chemistry compatibility analyses should be conducted to assure compatibility of the well water with Castle Creek/Maroon Creek water, to avoid triggering lead or copper corrosion issues in the distribution system.

It is possible that reinstating pumping of the wells could cause lagged depletions to surface water in the Roaring Fork River and/or its tributaries. Previous evaluations have estimated the potential impact of pumping these three wells on streamflow in the Roaring Fork River. Preliminary estimates of potential depletions to the Roaring Fork River associated with the maximum anticipated pumping of these wells (i.e., Portfolio 6 in 2070) were prepared as part of IRP development, as documented in Appendix F. The City should conduct more detailed analyses to further define the location, magnitude, and timing of such depletions under a range of groundwater pumping scenarios as part of detailed project implementation activities. Depending on the outcome of those evaluations, the City may need to define and implement water rights management strategies to augment surface water depletions.

Upon confirmation of these elements, design, permitting, and construction of the blending facility and the pipelines from each well to the blending facility should be initiated. Design and permitting of the blending structure and pipelines from each well to the structure could be initiated in 2024, allowing construction of the blending structure and the well connection pipelines in 2025. Pipelines from each of the three wells to the blending facility could be constructed in a phased manner, but all three wells should be connected to the blending facility to achieve the full benefit of this added supply source.

Total capital costs for Project GW1 are estimated at $8.1 million in 2021 dollars. Prioritizing reactivation of the wells will dramatically diversify the City's water resources portfolio and significantly reduce vulnerability to drought and other existing threats to water supply reliability. However, groundwater alone cannot provide a 100 percent backup supply to Castle Creek and Maroon Creek because of the need for blending to meet drinking water standards. The 2018 study indicated that the combined capacity of the three wells of 2,250 gpm (3.2 mgd) would need at least 1,870 gpm of blend water sourced from the WTF to comply with the SMCL for fluoride. This equates to a maximum 55:45 ratio of well:blend water. That is, at full use of all three groundwater wells' capacity, about 5.9 mgd of potable water production could be achieved if Castle Creek and Maroon Creek (or withdrawals from stored Castle Creek/Maroon Creek diversions) could provide 45 percent of the flow (about 2.7 mgd) to blend with 3.2 mgd of groundwater. Lower total production rates are also possible, provided that groundwater does not comprise more than 55 percent of the blended total flow.

5.3.3 Enhanced Conservation (Projects EC1, EC2, and EC3)

The City's 2015 WEP sets the course for programs and measures to reduce water use in the community. The 2015 report recommends that the City update the WEP every 7 years. Future updates of the WEP in 2022, 2029, and beyond should evaluate the effectiveness and adoption (saturation) rate of existing water conservation measures, refine existing measures based on those findings, and evaluate the potential effectiveness and target areas of potential new water conservation strategies in the community.

This program of enhanced conservation should be continuously monitored for its effectiveness in reducing unit water demands in the community, and continuously adjusted to reflect those findings. Analyzing water use trends by customer class and geospatially across the City's service area can help inform the effectiveness of existing programs and approaches for additional programs. It can also provide valuable information regarding where and how to engage the community in efforts to further reduce indoor and outdoor water use.

The effectiveness of existing conservation measures can be tracked and used as a foundation and information resource for updating the WEP in 2022 and every 7 years thereafter. The 2022 WEP update should identify and evaluate best practices from the City's peers as industry leaders in water efficiency, such as the cities of Santa Fe, NM, Boulder, CO, and Tucson, AZ. The degree to which the enhanced conservation strategies are effective in reducing demands will directly translate to the potential to defer the timing of investments to implement additional water supply strategies.

Altogether, Enhanced Conservation targets about a 1,300 AFY reduction in 2070 potable water use. The implementation plan breaks this down into three phases, each targeting about 440 AFY of reductions at an estimated unit cost of $9,000 per AFY saved based on industry experience in Colorado communities with existing conservation programs.

Enhanced Conservation Phase 1 (Project EC1) is recommended for 2025 to implement new conservation programs and measures identified in the 2025 WEP update. Total capital costs for Project EC1 are estimated at $4 million in 2021 dollars. A second and third phase of programs and measures for Enhanced Conservation (Projects EC2 and EC3) can be implemented in the 2031 to 2050 and the 2051 to 2070 timeframes, respectively, toward achieving the target reduction in water demands between now and 2070. Projects EC2 and EC3 each are estimated to cost $4 million in 2021 dollars.

5.3.4 WTF Resilience Improvements (Project WT1)

WTF Resilience Improvements (Project WT1) represents retrofits that will allow the WTF to more effectively treat wildfire-impacted raw water quality. This project consists of the design, permitting, and construction of WTF retrofits. As noted in Section 4.6, the IRP includes a placeholder capital project of $5 million for these process upgrades, which will be identified and costed in detail as part of the 2023 WTF Master Plan. This project will allow the City to continue to deliver potable water following a wildfire (which could impair water quality for months or years), and will ultimately be used in conjunction with emergency storage (once it is online) to enhance the City's supply reliability.

5.3.5 Emergency Raw Water Storage (Projects ES1, ES2, and ES3)

Water storage is an important strategy in support of the City's commitment to a reliable, resilient water supply system. As noted in Section 3.4.2, the City's water supply vulnerabilities will be reduced – but not eliminated – by reactivating the City's three existing groundwater wells in central Aspen. Because the groundwater requires blending with another source to meet drinking water standards, the City will continue to be at risk of a significant supply interruption (in the event the WTF cannot produce potable blending water due to a treatment plant outage, water quality constraints, and/or raw water supply disruption) until the Emergency Storage system is in place.

Emergency raw water storage will make the community's water supply significantly more resilient, by using withdrawals from stored water during emergency conditions to replace water that would otherwise be diverted from Castle Creek and Maroon Creek. Water withdrawn from emergency storage will be conveyed from the storage site by a new pipeline and pump station system to the WTF for treatment to potable standards.

A first phase of Emergency Storage (Project ES1) will take time to plan and permit and will require significant capital expenditures for constructing the storage facility, fill/draw infrastructure, and a pipeline and pump station facilities to convey raw water to the WTF. The City's ongoing storage siting analyses can be informed by the sizing needs identified in this IRP in support of a multi-criteria approach to selecting one or more sites. For purposes of estimating infrastructure costs in the IRP, storage siting was assumed to be in the general area of the Vagneur Gravel Pit and Woody Creek sites.

It is very important to recognize that no storage site has been selected by the City, and siting is subject to further analysis. The area assumed in the IRP was solely used to guide potential capital costing, as one of the more distant (and thus, conservatively costed) sites under consideration by the City. Siting should be finalized as part of the City's separate ongoing analyses and preliminary planning for Project ES1 that will be ongoing for the next several years.

Near-term activities toward implementing Project ES1 should include the following:

- Detailed siting analyses (now through 2023) to determine the optimal location for Emergency Storage, considering geological conditions, land use and availability of land acquisition or easements for the storage facility, construction costs, distance and conveyance from the site to the WTF, community values, and other economic and non-economic factors.
- Preliminary planning and preliminary design (in 2024) of the storage system, including the storage facility and pipeline/pump station conveyance of raw water from storage to the WTF.
- Permitting and acquisition of property and/or easements necessary to construct the systems (2025 to 2029).
- Permitting as required by CDPHE and the State Engineer's Office (2025 to 2029).
- Final design development (2030).

While planned for three-phase implementation, emergency storage could be subdivided into additional implementation phases, adding smaller increments of Emergency Storage each time. It is assumed that the pipeline built as part of Project ES1 will be sized for ultimate capacity needs, and thus will not need to be paralleled or upsized when storage capacity is expanded in Project ES2 or ES3. However, the pump station capacity would need to be expanded as part of Project ES2 and ES3.

It is important to note that the City will continually reassess and incrementally implement water supply solutions, including the sizing and timing of water storage construction. The schedule depicted for construction could be accelerated or deferred depending on conditions encountered in the coming years, and depending on the pace at which siting analyses, permitting, land acquisition, and financing can be completed. Recent history across Colorado shows that it could take decades to implement a storage project, even after sizing and siting analyses are completed. Therefore, reservoir planning must start immediately.

For cost estimating purposes, Project ES1 includes an assumed initial storage capacity of 500 AF, an 8.1-mile, 30-inch diameter pipeline and an assumed 500-horsepower (hp) pump station. A single bidirectional pipeline is assumed to be used for conveying water to storage (gravity flow from Castle Creek and Maroon Creek diversions to the storage site) and to withdraw water from storage (pumped flow to the WTF). It was assumed that the pipeline would be designed at a high-pressure class to avoid the need for multiple booster stations. The cost of injection and extraction wells, which would be required if a site utilizing *in situ* storage were selected, was not included in this cost estimate. The sizing and cost estimate for this project will need to be revisited upon selection of a storage site or sites.

Emergency Storage capacity should be expanded (Project ES2) when the level of protection afforded by the first phase capacity becomes unacceptably low. This could occur prior to 2040 if demands and climate change projections track with highest estimated demand values and driest estimated climate values used in this analysis. It may not be necessary until some point beyond 2040 if the pace of growth in demand is slower than the highest demand projected, or if protection against fewer than 12 months of Castle Creek/Maroon Creek diversion downtime is determined to be appropriate.

Project ES2 can be planned, designed, and constructed in the mid- to late-2030s to expand capacity to meet 2040 needs. Project ES2 will expand emergency storage to 3,100 AF (a 2,600-AF expansion) and expand the raw water pump station to 1,320 hp (an 820-hp expansion) to meet needs through 2040, with a peak pumped flow of 7.6 mgd.

Project ES3 can be planned, designed, and constructed in the 2051 to 2070 timeframe to expand capacity to meet 2070 needs. Project ES3 will expand emergency storage to 5,300 AF (a 2,200-AF expansion) and expansion of the raw water pump station to 2,200 hp (an 880-hp expansion) to meet needs through 2070, with a peak pumped flow of 12.2 mgd.

If Project ES2 or ES3 would be located at a different site than Project ES1, separate pump station and pipeline infrastructure may be needed, which would drive costs higher.

All told, construction of 5,820 AF of storage and its associated conveyance infrastructure could cost over $400 million in 2021 dollars as it is implemented over the coming decades (via Projects ES1, ES2, and ES3 at $105 million, $189 million, and $169 million in 2021 dollars, respectively). Emergency storage capital costs directly correlate to the amount of storage and the resulting level of water supply reliability. Greater amounts of storage would increase the costs and the amount of reliability provided, whereas smaller investments would reduce the reliability benefit. Phased design and construction of storage provides the City the flexibility to further assess these tradeoffs and conduct financial planning in the coming years.

5.3.6 Operational Raw Water Storage (Projects OS1 and OS2)

Raw water storage needs will grow as the community's need for water increases and as climate change has an increasingly significant impact on water supplies. Implementing the supply diversification improvements described above reduces sizing of Operational Storage and defers its implementation. Operational Storage is expected to first be needed in the mid-2030s and can be implemented in two (or more) phases, similar to Emergency Storage. Unlike Emergency Storage, which is intentionally not tapped in most years, Operational Storage levels may vary from month to month and from year to year to buffer seasonal gaps between stream flow and water demand. Emergency Storage and Operational Storage can be co-located at the same storage facility or facilities, but stored volumes should be tracked with separate accounting for each type of storage.

The first phase of Operational Storage (Project OS1) should be sized with a capacity of 130 AF to provide the desired buffer between seasonal/annual flow variability in Castle Creek and Maroon Creek (with groundwater wells in operation). Project OS1 could be implemented concurrently with Project ES2 in the mid- to late-2030s. As with Emergency Storage, changes in the pace of demand growth will affect the sizing and/or timing of Operational Storage needed. A second phase (Project OS2) should expand Operational Storage by 390 AF to a combined total of 520 AF to meet the community's Operational Storage needs through 2070.

For cost estimating purposes, it was assumed that Operational Storage would be collocated with Emergency Storage, and the pumping and conveyance infrastructure implemented for Project ES1 could be used for withdrawals from either type of storage. The sizing and cost estimate for this project will need to be revisited upon selection of a storage site. If Project OS1 and/or Project OS2 would be located at a different site than Project ES1, separate pump station and pipeline infrastructure may be needed.

Total project costs for Projects OS1 and OS2 are estimated at $7.6 million and $22.5 million, respectively, in 2021 dollars.

5.4 Additional Recommendations

In support of the capital projects described in Section 5.3 and as part of continued stewardship of the City's water supplies and infrastructure, the following additional projects are recommended:

- WTF condition assessment and master plan in 2023, including recommendations for Project WT1 to modify treatment processes to better accommodate water quality constraints following wildfires in the Castle Creek and Maroon Creek watersheds.
- Groundwater level monitoring and water quality monitoring upon reactivation of the groundwater wells.
- WEP Update in 2022 and every 7 years thereafter.
- Water Transmission and Distribution Master Plan building on the 2018 hydraulic modeling project (Bohannon Huston, 2019), including demand updates and a condition assessment to support asset management on the City's linear water assets and storage facilities, in 2025 and updated at least every 10 years.
- IRP updates every 10 years, including climate change supply availability analysis updates.
- Updated Rate Study following completion of master plans for the WTF and Transmission and Distribution systems.

5.5 Capital Improvement Plan Summary

A summary of capital project expenditures through 2030 is provided in Table 5.2. Near-term investments in water reuse and groundwater blending will enhance the City's water use efficiency and reduce existing vulnerabilities in the Castle Creek and Maroon Creek sources. Altogether, the near- and long-term investments identified in this IRP will result in a resilient, reliable water supply for the Aspen community for the next 50 years.

Table 5.2 Near-Term CIP Summary

Project	Expenditure (2021 $M unless noted otherwise)								
	2022	2023	2024	2025	2026	2027	2028	2029	2030
Capital Projects(1)	**$0.3**	**$1.8**	**$4.2**	**$8.1**	**$5.0**	**$0.5**	**$0.5**	**$0.6**	**$11.1**
WR1: Reuse at Aspen Municipal Golf Course	$0.1	$1.2	$2.6						
WR2: Reuse Expansion								$0.03	$0.2
GW1: Groundwater Blending Facility	$0.1	$0.1	$0.8	$7.1					
EC1: Enhanced Conservation Phase 1		$0.5	$0.5	$0.5	$0.5	$0.5	$0.5	$0.5	$0.5
WT1: Water Treatment Facility Resilience Improvements				$0.5	$4.5				
ES1: Emergency Storage Phase 1 and Raw Water Conveyance	$0.04	$0.04	$0.25	$0.04	$0.04	$0.04	$0.04	$0.04	$10.4
Master Planning	**$0.1**	**$0.1**	**$0.0**	**$0.1**	**$0.0**	**$0.0**	**$0.0**	**$0.1**	**$0.0**
WTF Master Plan		$0.1							
Water Efficiency Plan Update	$0.05							$0.05	
Transmission/Distribution Master Plan				$0.1					
Total Expenditures (2021 $M)	**$0.3**	**$1.9**	**$4.2**	**$8.2**	**$5.0**	**$0.5**	**$0.5**	**$0.6**	**$11.1**
Total Expenditures (Escalated $M)(2)	**$0.3**	**$2.0**	**$4.6**	**$9.3**	**$5.8**	**$0.6**	**$0.7**	**$0.8**	**$14.5**

Notes:
(1) Projects initiated in 2031 and beyond are not detailed in this table; see Figure ES.5 for schedule and Section 5.3 for narrative descriptions.
(2) Escalation to future years at assumed 3% annual rate.

Appendix A
REFERENCES

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Appendix B
COMMUNITY ENGAGEMENT

Engagement 1

The first IRP Technical Work Group meeting and the first IRP Community Meeting were held on October 28, 2020 and November 18, 2020, respectively. These meetings addressed the following content and goals:

- Elevating participants' understanding of the IRP process.
- Informing participants on current conditions of Aspen's water supply and risks and opportunities.
- Engaging participants to gather perspectives on the planning process and current water supply conditions.
- Gathering feedback on key interests, concerns, values, and opportunities for inclusion in the water supply alternatives evaluation.

Engagement 2

A second meeting of the IRP Technical Work Group meeting and the second IRP Community Meeting were held separately on January 14, 2021. This engagement was used to update participants and get input mid-way through the IRP development process. These meetings addressed the following content and goals:

- Elevate participants' understanding of the continued IRP process.
- Inform participants on water supply gaps, vulnerabilities, and options, and
- Engage participants to gather feedback and perspectives on projected shortages and potential supply options.

Engagement 3

The third and final engagement was held toward the end of the IRP development process, providing an opportunity for participants to help guide selection of the best approach for meeting Aspen's future water needs. The third IRP Technical Work Group meeting and the third IRP Community Meeting were held separately on March 3, 2021. These meetings addressed the following content and goals:

- Elevate participants' understanding of the ongoing IRP process.
- Inform participants on future supply options, supply evaluation, and approach to selecting the preferred supply strategy.
- Engage participants to gather feedback and perspectives on selecting a preferred supply strategy.

City of Aspen Community Water Plan: Stakeholder Interview Synthesis

Background

The City of Aspen is currently preparing its Community Water Plan. Development includes reviewing the current water supply approach, analyzing future demands for water, and evaluating future supply opportunities. The analysis will result in a roadmap, referred to as an Integrated Water Resources Plan, which will guide the City in providing water services for the community now and in the future. As part of the planning process, the City is engaging stakeholders to understand and reflect in the Water Plan key community water-related interests, needs, and priorities. This stakeholder engagement has included 14, one-on-one interviews with community members and organizations (see Appendix A for list of interview participants). Ross Strategic has prepared this synthesis to reflect the major highlights from the interviews. The themes that emerged from these interviews are organized under the following categories: community priorities; key challenges; and differing perspectives.

Community Priorities for the City of Aspen's Long-term Water Future

Interview participants were asked to share both their sense of priorities for Aspen's long-term water future, as well as those they believed, are prevalent within the Aspen community. Substantial overlap exists among the perspective provided with six areas emerging as prominent for water plan consideration: water for human consumption and equity of access; ecosystem health; recreation; water system resiliency; clarity and transparency in the planning process; and business and development.

Water for Human Consumption and Equity of Access

Maintaining a reliable and resilient supply of water for human consumption was a consistent top priority/value among interviewees. Interview participants identified a hierarchy of water uses and consistently placed water for human consumption at the top. Within that context, the equitable access to quality and reliable water and water services was identified as a priority. Interviewees signaled that equitable access to drinking water for both residents and visitors is needed. One participant indicated, "If Aspen is to create a long-term plan, they should think about all the people that are on the receiving end of the water, including the people that work, but do not live, in the city. The water should be the same for everybody."

Ecosystem Health

The role of water in ecosystem health emerged across the interviews as an important priority. One interviewee commented, "There must be a balance between the needs of the community and the needs of the river." Interviewees signaled a desire to think about water in a broader ecological context, and a consistent theme was the need to achieve a balance between community needs and ecosystem needs. Within this context, sustainability and water conservation were consistently identified as critical values. A greater focus on reducing consumption and reusing water was both a priority and perceived as a current weak point for the community. Water usage efficiency is a key focus. The beauty of the City of Aspen was highlighted as one of the key attractions for residents and visitors alike. Thus, access to the outdoors and the health of surrounding nature is vital to the community and the brand of Aspen.

Recreation

Supporting and maintaining recreational uses was consistently identified as a priority. With recreation acting as a large economic and cultural component of Aspen, the prioritization of recreation activities was a constant theme. Multiple interviewees highlighted the importance of recreation sharing, "Our rafting community is interested in water levels and water flows. Our fishing community is interested in the health of the Roaring Fork. The outdoor recreation industry cares about water, with specific user groups paying more attention to the reliability of our water resources." The relative priority of recreational uses of water did vary among interview participants. Nevertheless, there was consistent support for the importance of recreation as an integral component of the city's identity. One interviewee captured some of the mixed perspectives related to supporting recreational uses with this observation: "To plan water around people's desire to recreate seems ill-conceived. Ecosystem services are more important, but if recreation can be used as a method to protect ecosystem services, then I would support that."

Water System Resiliency

Interviewees linked redundancy to the foundation of a reliable water supply. Redundancy must be built into the system. One interviewee commented, "When designing critical functions, we should look to back up our critical functions in at least three ways. For example, if all our water is coming from the same place, we need at least two back-up sources. Our systems must not rely on one input and our water resource needs many lives."

Clarity and Transparency in the Planning Process

Conducting a robust and detailed process that clearly identifies needs (future demand) and resources available (water supply) was a commonly shared value among interview participants. Clarity and transparency in the planning process are key priorities for interview participants irrespective of their specific take on, for example, the priority of uses. Interview participants voiced the desire for value judgments and trade-offs to be made clear. Additionally, participants observed that to engage the community in a meaningful way, the input must be valued and reflected in the planning decision-making process. One interviewee commented, "When you spend hours and work on alignment and agreement (in a planning process) and resulting recommendations are not taken into account, that makes people never want to partake in the process again." Interviewees also identified certain existing plans they believed are important to formulating the water plan: Maroon Creek Caucus Master Plan: Water Section; City of Aspen Master Plan; Aspen Center for Environmental Studies Forest Health Report.

Development and Business

With demand increasing as supply continues to decrease, new development pressures on water were highlighted by some interview participants as a focal point for the planning process, specifically regarding land use planning, associated patterns of development, and resulting future water demand. Interview participants signaled that there are two dimensions of water use closely tied to development and business interests in Aspen. First, there is the basic need to safely and reliably meet the direct water operational needs of local businesses. Second, from the business community perspective, the right amount of water must be flowing to ensure the vitality of the city. Overall, water demand estimates need to reflect the interplay between business operational needs and maintaining the vibrancy of Aspen. One interview participant indicated an important priority should be water for local food production with an emphasis on targeting the resiliency of local food systems.

Challenges/Concerns Related to the City of Aspen's Water System and Planning Process

Interview participants consistently indicated that they do not have concerns about current quality in the Aspen drinking water system and that they believed the system is well maintained. One participant did express an interest in the exploration of biological treatment methods (e.g., constructed wetlands) as an alternative to chemical disinfection. Regarding the current quality of water and the water system, interviewees shared the following observations:

- "In my 30 years of being here, I have found the City of Aspen water supply to be of high quality. My understanding of what I have seen over the years is that acid mine drainage is not an issue. Heavy metals are not an issue. There are no temperature, chlorine, or turbidity issues. By the time the water gets to the user, it is high quality."
- "The City does a good job of taking care of the water. We have some of the best headwaters, and I believe they have been maintaining it and taking care of the pipes and pumps. I know that the City of Aspen has been working as a utility to take care of our water and system."

Even as there was comfort with current water systems operations, interview participants identified a series of challenges/concerns for attention during the planning process. These are water reliability, climate change impacts, and awareness of and incentives for conservation.

Water Security

Interviewees highlighted a concern related to water security and reliability, with a short safety window (I.e., limited storage in the system) and a lack of focus on reuse raising concerns among some interviewees. Interviewees expressed concern that increasing population, shifts in water demand, and supply pressures will increase pressure on reliability in the future. One interview participant observed, "Certainty of more demand and less supply in the future needs to be at the center of the planning process." Additionally, increased diversions were cited as a threat to Aspen's water supply, with increasing demand from the Front Range as population growth continues. Comments included, "All of our water ends up on the front range" and "Transcontinental diversions are causing the tunnels in our watershed to go dry."

Climate Change Impacts

Interview participants consistently identified the effects a changing climate will have on the community's water supply. Interview participants cited lower than average snowpack, changing patterns in snowmelt, more acute forest fire conditions (and forest fire impacts on water quality and soil water storage) as important drivers of pressure on water quantity and source water quality. Some participants indicated the need to pay more attention to forest health due to the link to water quality and storage.

Awareness of and Incentives for Water Conservation

Improving demand management was consistently identified as an important aspect of an overall water plan. Interview participants identified several aspects of moving conservation efforts forward while acknowledging that the city has been proactive in encouraging water use efficiency.

- *Water Pricing*: Interview participants emphasized the role water rate structures can play in influencing conservation behavior, as well as the link of pricing to water equity and affordable access. Some participants indicated a belief that water is too cheap, citing significant water use during the drought for aesthetic purposes (e.g., green lawns). In this context, there was interest in further advancing conservation pricing ("align the cost to customers with the city's prioritization of water conservation") during the planning process, while also remaining sensitive to impacts on affordability and access. At the same time, participants indicated that potentially much of the Aspen residential user community (affluent second homeowners) will have limited responsiveness to conservation pricing. This sets up the need for exploring how to motivate behavior change outside of monetary penalties.

- *Water Scarcity Ethic*: Several interview participants drew a distinction between full-time Aspen residents who live full time with and have adopted (and adapted to) a water scarcity ethic, and part-time Aspen residents, some of whom come from communities that do not have a well-developed water scarcity ethic. Full-time residents with limited land and lower irrigation needs live with a low water footprint and are sensitive to water usage from an access and affordability standpoint. One interviewee shared, "You will see a different perspective if you ask these residents about water. They will have a different understanding of how to take care of it. They have buckets in their bathrooms for saving water and appreciate the clean water access." At the same time, an uptick in the number and duration of part-time resident visits to Aspen is seen as a potential cause of a water demand increase. Part-time residential dwellings are, on average, higher water use properties occupied by more affluent and less water-sensitive individuals. One interviewee observed, "There is a sense of lushness around Aspen that makes it hard to be clear that this is a drought-prone area." These circumstances were viewed as creating a challenging context for promoting water conservation behavior.
- *Disincentives to Conservation*: Interview participants identified several systemic challenges to greater conservation behavior, including "use it or lose it" water rights requirements and tax credits granted for certain forms of land-use practices (e.g., ranching) that can require irrigation water use to demonstrate eligibility. One interviewee shared, "Irrigating to grow hay for cows so that property owners can get tax credits for being a ranch, when they are not, seems like a poor use of limited water."
- *Basic Water Literacy*: Interview participants indicated that Aspen residents lack an understanding of how much water is in the system and how much water is being used. One interviewee shared, "Creating a connection between every drop of water that you use in the town and water being directly pulled out of rivers and streams is key." Due to residents' varying relationships with water in the community, interviewees voiced interest in further education on conservation and water usage.
- *Non-Resident Workers*: Interviewees signaled there is a difference within the Aspen community between those that live in Aspen and those that work in Aspen. Those that work in Aspen but live in surrounding communities were viewed as having a strong sense of both water scarcity and affordability. These sensitivities create an opportunity to work with a community that is receptive to water conservation and efficiency messaging. From a water equity perspective, concerns were raised regarding the potential for Aspen to secure its water future at the expense of surrounding communities. Exclusivity found in Aspen created a red flag for some regarding the extent to which the City's planning efforts will consider neighboring cities in the water planning process. The hope is that, even as each city has its own water system, it will avoid competition and will act in a collaborative/partnership way.
- *Reuse Opportunities*: Considering water scarcity in Aspen, certain interviewees expressed an interest in the plan examining water reuse opportunities. At the same time, interviewees indicated that the local authorizing environment for water reuse initiatives is challenging. An interviewee shared, "Our county put out an ordinance that allows for greywater reuse, but we have been advised by a specialist to not touch the ordinance because it will be so expensive."

Potential Differing Perspectives within the Aspen Community

During the interviews, participants were asked to identify differences of opinions that are likely to exist within the Aspen community relevant to the city's water future. In response, interview participants identified four areas: growth (water as an enabler of further growth); aesthetic uses (lush, non-native plantings or natural landscaping); storage (how much, where, and to what purpose); and balancing priorities (sorting what uses will receive how much support). As a counter-weight to an emphasis on differences of opinion, one interviewee did share, "Any process that is not trying to pit people against each other but wants to keep this magical place called Aspen thriving for future generations- that is a value we all align with."

Growth

Participants shared a continuum of perspectives regarding further growth and development in Aspen and the role water availability plays in enabling growth and the influence on water scarcity. At the center of these perspectives was the collective sense that it will be helpful for the planning process to explore clearly what are the water-related limits to growth to better develop appropriate policies and related expectations. The continuum of perspectives, not surprisingly, ran from ensuring water availability to support growth, to de-prioritizing water for growth (and prioritizing water for supporting current human consumption needs and other public health, ecosystem health, and recreation purposes).

Aesthetics

Interview participants indicated that a continuum also exists across the Aspen community relative to the use of water for aesthetic purposes, including fountains and other water features, landscaping, etc. On one hand, there is a sense that part of the Aspen brand is that it is a lush, green city and that requires water to support non-native plants. On the other hand, there is interest in moving to natural landscaping consistent with the more arid local environment. Interview participants indicated that many in the Aspen community question the use of water for landscaping purposes at a time of increasing water scarcity and concern over meeting minimum in-stream flows for critical habitat and species. Interviewees indicated that the downtown area has high water-use plantings that provide for the lush, green aesthetic while placing pressure on water supplies. One interviewee commented, "People run their sprinklers every day. We have a lot of landscapers who want lush flowers and green lawns. All that comes at a cost." Another shared, "We shouldn't be using treated water for irrigation or landscaping in any case."

Storage

Interview participants indicated a belief that there is general recognition across the Aspen community of the need for more storage, while differing opinions exist across the community regarding the amount of storage needed, appropriate location(s) for storage, and the existence of more storage enabling growth. Climate change was cited as a key driver for the need for more storage, as well as improving water system resiliency. Even with community agreements already in place, interview participants signaled that storage remains a sensitive topic with storage location and priority of uses of stored water as potentially contentious topics during planning. There is also a need to clearly demonstrate the need for storage as part of the planning analytical work.

Balancing Priorities

As the Community Priorities section indicated, interview participants identified a range of potentially competing uses for water, creating a need for an explicit prioritization (or balancing) of water uses in the context of the Aspen water plan. For example, institutions such as hospitals must maintain public health as a priority and, at times, this can come at the cost of water efficiency measures. One interviewee noted that "We are a high user of water within the Aspen community, and reliability of service is paramount. We would like to use water as responsibly as we can, but we have a duty to not make people sick." Other recognized key users included the ski resorts (that make snow in part using water provided by the utility) and agricultural operations that in part feel pressure to use water consistent with maintaining current water rights. Overall, there was recognition of the need for the water system to adapt to climate change and that expectations for the role some organizations and individuals will play on conservation need to be muted.

Appendix A: Interviewees

- Lisa MacDonald and Laura Makar, *Pitkin County Healthy Rivers and Streams*
- Heather Lewin, *Roaring Fork Conservancy*
- Chris Lane, *Aspen Center for Environmental Studies*
- Adam McCurdy, *City of Aspen Open Space Board*
- Eden Vardy, *The Farm Collaborative*
- Mona Newton*, Community Office for Resource Efficiency*
- Debbie Braun, *Aspen Chamber Resort Association*
- Marcella Larsen, *Maroon Creek Caucus*
- Joe Wells, *Castle Creek Caucus*
- Alejandra Magana, *Valley Settlement*
- Jon Albers, *Aspen Valley Hospital*
- Nicholas Vesey, *Aspen Chapel*
- Michael Monroney, *Aspen Historical Society*
- Ellen Walbert, *Aspen Thrift Store*

City of Aspen Community Water Plan:
Engagement Synthesis

On October 28th and November 18th, the City of Aspen hosted a technical working group and public engagement session to gather community input regarding the development of the Aspen Community Water Plan.

Technical Working Group #1 *October 28, 2020 1:00-4:00 pm MT*

In advance of the engagement, technical working group (TWG) members (*Attachment A)* were provided with a meeting agenda (*Attachment B)*. Following the engagement, the TWG was provided with the slide deck presentation detailing the IRP process, Aspen water landscape, and engagement objectives. This meeting summary provides highlights from the presentations and discussions from the October 28, 2020 meeting.

1. Introductions and Engagement Objectives *Tyler Christoff, City of Aspen*

a. *Introductions*

Twelve TWG members introduced themselves and their organizations. Interest from the TWG membership centered around serving as representatives for individual respective organizations, involvement with Aspen stream flow, and understanding the current water conditions and integrated resource planning process. For a full list of attendees, see Attachment A.

b. *Engagement Objectives*

Tyler Christoff provided an overview of the objectives of the engagement process, meeting objectives, and background context. Engagement objectives included: 1. Elevating technical working group understanding of the IRP process; 2. Informing TWG members on current conditions of Aspen water supply and risks and opportunities; 3. Engaging members to gather perspectives on planning process and current water supply conditions; and 4. Gathering feedback on key interests, concerns, values, and opportunities for inclusion in alternatives evaluation.

2. Aspen Water Overview *Steve Hunter, City of Aspen*

Steve Hunter provided an overview of the Aspen water utility, highlighting its mission, function, operational goals, existing supplies, current conditions, and decision-making process. One of the outcomes of the integrated resource planning process is that it will help Aspen identify vulnerabilities to the city water supply system and support building long term resiliency, incorporating the residents' goals and values.

Audience questions addressed average demand and gallons per day per capita used. It was highlighted that as a resort community, the Aspen population is often transient. Thus, water usage varies from 2 million gallons per day to upwards of 10 million gallons during peak demand with irrigation flows and maximum visitation.

3. **Why and Why Now?** *John Rehring and Inge Wiersema, Carollo*

a. ***Integrated Resources Planning Background***

The presentation focused on the integrated water resources planning process, including drivers, timeline, and challenges and opportunities. Carollo highlighted the established planning horizon of 2070 to ensure the appropriate amount of time to see uncertainties associated with growth and climate change and address complex solutions 50 years out. The presentation further addressed supply options, demand forecasting, and the development of criteria to compare alternative plan options. The planning process will include examining water reuse opportunities, the role of deep and shallow ground water supplies, and water conservation strategies that Aspen may implement on top of current practices. Key challenges were identified as limited storage and determining locations for conditional storage. It was also noted that the integrated plan will look at all demands, all sources, and the ways it can meet demands with potable and non-potable water, surface water, and ground water.

b. ***Participant Discussion***

In response to this overview, TWG members made the following observations:

- *What are your touchpoints with water? From your perspective what does this mean for the planning process?*

  Perspectives on this question varied between individual members. However, the common threads of the discussion highlighted maintaining municipal supply and environmental stream flows, prioritizing alternative transfer mechanisms, addressing storage concerns, and preserving habitats and sustainable systems. The discussion further centered on water use efficiency, ecology, and the ways in which these values can be reflected in the IRP process. A potential gap in the evaluation process was identified; it was recommended that watershed management be incorporated into the evaluation process. The following key points were further discussed:

  - Concern about stream flow, particularly Maroon, Hunter, and Upper Roaring Fork Creek
  - Effect of Ruedi reservoir on City of Aspen's hydropower capabilities
  - Implementing water conservation efficiency programs for new and existing developments
  - Alternative transfer mechanism project and water sharing and collaboration opportunities
  - Forecasting supply and planning for demand reduction if supply isn't sufficient
  - Maintaining fish habitat connection to support wildlife and recreation

- *What issues do you see today and into the future regarding water supply or water quality? What do you see as helpful refinements to the characterization of current conditions, drivers, and challenges affecting water resource management for Aspen?*

  TWG participants highlighted a range of challenges affecting water resource planning in the City of Aspen. Among these, common issues included low stream flow, increased water demand, lack of storage, habitat conservation, climate change effects, and water quality issues. Thematic comments around shifting community thinking and climate change adaptation emerged. It was highlighted as critical to change community expectations about how water is used in the Aspen area. Participants also expressed concern around low flow levels in both Hunter and Roaring Fork, with forecasted shortages in Castle and Marron Creek. The resulting water quality issues that come from low flow posed further concern. With supply variations and an increasing population, low water levels will only be exacerbated. Suggestions including storage improvements, cloud seeding, ground water injections, and water use education were suggested by TWG participants. Taking advantage of years with strong water supply and storing water for years with more demand was an additional recommendation. Further concerns and suggested solutions included:

    - Lack of connection to wildlife conservation and suggested partnership with fisheries to address water allocation for critical habitats
    - Addressing increased fires and decreased snowpack effects through flexibility in management, diverse supplies, and increased storage
    - Preparing the community for extended periods of low base flows by talking to the residents about tradeoffs (e.g., restricting landscaping)
    - Addressing drought impacts on soil moisture through developing a greater understanding of how soil moisture affects water supply and recreation
    - Developing plans to assist neighboring communities by integrating regional water needs into the supply plan by ensuring redundant clean sources
    - Moving past stationarity and creating adaptive climate change models that consider a full range of assumptions about climate impacts

4. Community Interests and Priorities

TWG members provided perspectives on community interests and priorities related to challenges, drivers, and solutions affecting water resource management. Top priorities included:

- Climate Change: The effects of a changing climate and an increase in droughts was a top priority for TWG members.
- Public Communication: There was interest in exploring the methodology for communicating with the public about the state of the immediate water supply and health of the watershed. It was noted that, members of the Aspen community have a great deal of institutional knowledge leading to a key interest to effectively engaging them. Giving information about trade-offs can provide an opportunity to make community members direct participants in water management and build transparency and trust with those that are supplying and those that are receiving water.

- Equity of Access: TWG participants highlighted that the City may be leaning too much on pricing to drive water conservation, which can have a disproportionate impact on lower income residents, while not creating a sufficient disincentive to other residents to reduce water use. As Aspen is a hotspot for tourism, especially among affluent individuals, TWG members suggested there are likely opportunities for further outreach. Thinking about water in terms of public health, rather than public works, was an important priority. Additional interests addressed setting rate structures that met the needs of both value and affordability. Thinking about water and how it related to the affordable housing program and ensuring that the cost of supply is meeting the basic needs of residents was highlighted. Potential for subsidies to help with the high cost of living or creating a water cap was also identified by TWG members. Interest was expressed in shifting burden from across the community to the subset of high-volume water users.
- Flexibility in Planning: TWG members identified flexibility in both the planning process and legal system as a priority for the planning process. Identifying critical processes with a need for flexibility could be a useful exercise moving forward.

5. Conclusion and Next Steps

During the conclusion, Ross Strategic guided the TWG through next steps and upcoming dates in the engagement process. Closing the meeting, Carollo noted their appreciation for the TWG member input. The City shared that at this phase, input will help to inform the integrated resources plan alternatives discussion, fill information gaps, and determine focus areas for future planning. The City of Aspen thanked TWG members for their time and feedback.

Public Engagement #1 *November 18, 2020 5:00-6:00 pm MT*

In advance of the engagement, community members were provided a practice poll to prepare for the public session. Following the engagement, the public was notified that a recording of the presentation could be found on the Aspen Community Voice website. This meeting summary provides highlights from the presentations and discussions from the November 18, 2020 meeting. The meeting agenda can be found in *Attachment C.*

1. **Aspen Water Overview** *Steve Hunter, City of Aspen*

Steve Hunter provided an overview of the Aspen water utility, highlighting its mission, function, operational goals, existing supplies, current conditions, and decision-making process. One of the outcomes of the integrated resource planning process is that it will help Aspen identify vulnerabilities to the city water supply system and support building long term resiliency, incorporating the residents' goals and values.

2. **Why and Why Now?** *John Rehring and Inge Wiersema, Carollo*

a. *Integrated Resources Planning Background*

The presentation focused on the integrated water resources planning process, including drivers, timeline, and challenges and opportunities. Carollo highlighted the established planning horizon of 2070 to ensure the appropriate amount of time to see uncertainties associated with growth and climate change and address complex solutions 50 years out. Plan considerations included potential new development/redevelopment and service area changes, both of which will inform demand forecasting. Key challenges were identified as limited storage and determining locations for conditional storage. It was also noted that the integrated plan will look at all demands, all sources, and the ways it can meet demands with potable and non-potable water, surface water, and ground water.

b. *Participant Discussion*

Participant questions and observations focused on prioritizing water reuse as a potential enhancement to water conservation efforts, as well as considerations regarding the role of the Aspen sanitation plan in the availability of water supply. It was highlighted that Aspen currently has reuse as a part of its water management portfolio. However, approaches to reuse vary depending on locale. Options included a direct return to the potable system for drinking water and reuse for irrigation augmentation. Potable reuse options include placing recycled water into an environmental buffer and later pumping the water to augment drinking water supplies. It was also noted that, in Colorado, the context of water rights must also be taken into account, as the ability to reuse water is specific to the nature of the local water rights context. Regarding the sanitation plan, it was highlighted that flow from the sanitation plan would be the source of water for potential reuse.

3. Community Interests and Priorities

The Poll Everywhere platform was used to engage the public around key values and priorities for the Aspen Community Water Plan. The following answers were submitted:

a. *What issues do you see today and into the future regarding water supply or water quality?*

- Wildfire and drought, influx of part-time residents not believing in climate change, community values
- Changing City of Aspen priority to perennial over plants in Community Office for Resource Efficiency (CORE), serves as an education opportunity
- Large event/busy time of year influxes beyond predictions
- Emergencies like wildfire, power outages, severe droughts, climate change
- Changing beliefs of the new Aspen pandemic demographic
- Avalanches into the watershed
- Population and residential growth in Roaring Fork Valley
- Climate change as a broad perceived cause to reduced supply
- City supply of water to Ski Co. for snowmaking
- Regulations requiring more irrigation to come from surface water or reclaimed water rather than domestic water

b. *What community values require consideration during the planning process?*

- Residents came for natural beauty and stay to protect it
- Recognizing the changing demographics
- In this together over personal desires
- Limits to growth
- Limiting irrigation from domestic water
- Environmental preservation balances with recreation and economy
- Landscape water usage should closely reflect the natural environment with less commitment to artificial landscapes
- Connection to the valley's fragile system by visitors, limits to growth

4. Conclusion and Next Steps

During the conclusion, Ross Strategic guided the public through next steps and upcoming dates in the engagement process. The engagement team shared that the presentation would be posted to the Aspen Community Voice Community Water Plan page. The City shared that at this phase, input will help to inform the integrated resources plan alternatives discussion, fill information gaps, and determine focus areas for future planning. The City of Aspen thanked the public for their time and feedback.

Attachment A: Technical Working Group Roster

Technical Working Group

NAME	Title	Organization
Elise Osenga	Community Science Manager	Aspen Global Change Institute
Lisa Tasker	Citizen Advisory Board Member	Pitkin County: Healthy Rivers Board
Laura Makar	Assistant Attorney	Pitkin County: Healthy Rivers Board
April Long	Executive Director	Ruedi Water and Power Authority
Guy Whol	Program Coordinator of Emerging Solutions	Rocky Mountain Institute
John Schroeder	Data Scientist	Rocky Mountain Institute
Laura Belanger	Senior Water Resources Engineer & Policy Advisor	Western Resources Advocates
Rob Viehl	Senior Water Resource Specialist	Colorado Water Conservation Board
Mickey O'Hara	Director of Programs	Colorado Water Trust
Timothy Miller	Hydrologist	Bureau of Reclamation
Tom Moore	President	Salvation Ditch Company
Kendall Bakich	Aquatic Biologist	Colorado Parks and Wildlife

Engagement Team

NAME	Organization
Tyler Christoff	City of Aspen
Steve Hunter	City of Aspen
Mitzi Rapkin	City of Aspen
John Rehring	Carollo
Inge Wiersema	Carollo
Rob Greenwood	Ross Strategic
Sarah Shadid	Ross Strategic
Micaela Unda	Ross Strategic
Tori Bahe	Ross Strategic

Attachment B: Technical Working Group Agenda

Duration	Session	Discussion Lead	Materials
(10 min)	Introduction to Technology Platform and Agenda Review	Ross Strategic	
(15 min) (30 min)	Introductions and Engagement Objectives • Elevate technical working group understanding of IRP process • Inform technical working group on current conditions of Aspen water supply and risks and opportunities • Engage technical working group to gather perspectives on planning process and current water supply conditions • Gather feedback on key interests, concerns, values, and opportunities for inclusion in alternatives evaluation Aspen Water Overview • Historical snapshot of Aspen water utility: its mission, function, operational goals, existing supplies, and current conditions • Participant Q&A	City of Aspen - Tyler Christoff City of Aspen - Steve Hunter	Aspen Water System overview map and general system characterization

(70 min)	Why and Why Now?
	• Provide context on IRP goals and process
	  ○ Planning drivers
	  ○ IRP vision, goals, and anticipated outcomes
	  ○ Planning area
	  ○ Planning horizon: 2070
	  ○ Elements of IRP development
	  ○ Planning elements and considerations
	  ○ City of Aspen characterization of challenges and opportunities
	• 10 Minute Break
	• Participant Q&A and Discussion
	  ○ What are your touchpoints with water? From your perspective what does this mean for the planning process?
		City of Aspen and Carollo	Planning team initial analysis of drivers and project plan overview
			Map with key information (city limits, service area, future service area)

Duration	Session	Discussion Lead	Materials
	○ What issues do you see today and into the future regarding water supply or water quality? ○ What do you see as helpful refinements to the characterization of current conditions, drivers, and challenges affecting water resource management for Aspen?		
(45 min)	**Community Interests and Priorities** • Review of interview process and input received • Participant discussion: ○ What are important community interests and priorities the planning process should consider? ○ What opportunities would you like to see explored?	Ross Strategic and Community	Synthesis of interview findings
(10 min)	**Conclusion and Next Steps**	City of Aspen and Ross Strategic	Flow chart indicating process going forward with key milestones and check in points for the Technical Group

Attachment C: Public Engagement Agenda

Duration	Session	Discussion Lead	Materials
(10 min)	Introduction to Technology Platform and Agenda Review • Elevate community understanding of water planning process • Gather feedback from community on key interests, needs, concerns, values, and opportunities • Inform community on current conditions of Aspen water supply and risks and opportunities	Ross Strategic and City of Aspen	
Background Information			

(25 min)	Aspen Water Overview
	• Historical snapshot of Aspen water utility and its mission, function, operational goals, existing supplies, and current conditions
	• Provide context on IRP process
	  o Planning drivers
	  o IRP vision, goals, and anticipated outcomes
	  o Planning area
	  o Planning horizon: 2070
	  o Elements of IRP development
	  o Challenges and Opportunities
	  o Q&A
		City of Aspen
		
		Carollo
			IRP development process, current conditions, drivers and challenges, water resource planning timeline

Gather Feedback from Community			

(20 min)	Community Interests and Priorities
	• Review of interview process and input received
	• Participant discussion:
	  o What issues do you see today and into the future regarding water supply or water quality?
	  o What community values require consideration during the planning process?
		Ross Strategic and Community	Interview synthesis, Website input, Poll Everywhere

Wrap-Up			
(5 min)	Conclusion and Next Steps	City of Aspen	Milestones chart from Technical Workgroup meeting

City of Aspen Community Water Plan:
Engagement 2 Synthesis

On January 14th, the City of Aspen hosted separate technical working group and public engagement sessions to gather community input regarding the development of the Aspen Community Water Plan.

Technical Working Group #2 *January 14th, 2021 1:00-4:00 pm MT*

In advance of the engagement, technical working group (TWG) members (*Attachment A)* were provided with a meeting agenda (*Attachment B)*. Following the engagement, the TWG was provided with the slide deck presentation detailing the IRP process, Aspen water landscape, and engagement objectives. This meeting summary provides highlights from the presentations and discussions from the January 14, 2021 meeting.

1. **Introductions and Engagement Objectives** *Tyler Christoff, City of Aspen*

   a. ***Introductions***

   Tyler Christoff introduced the members of the Aspen, Carollo, and Ross Strategic team. Nine TWG members joined the second round of engagement. For a full list of attendees, see Attachment A.

   b. ***Engagement Objectives***

   Tyler Christoff provided an overview of the objectives of the engagement process, meeting objectives, and background context. Engagement objectives included: 1) Elevate TWG understanding of continued IRP process; 2) Inform TWG group on gaps, vulnerabilities, and supply options; and3) Engage the TWG to gather feedback and perspectives on projected shortages and potential supply options

2. **Aspen Water Overview and Community Priorities** *Steve Hunter, City of Aspen; Rob Greenwood, Ross Strategic*

   a. ***Aspen Water Overview***

   Steve Hunter provided an overview of the Aspen water utility, highlighting its function, operational goals, existing supplies, and current conditions. The overview shared that the city's potable water supply is primarily sourced from senior water rights on Castle and Maroon Creeks, where it is then conveyed to the town reservoir. The City is constantly monitoring diversions to ensure that water demands are met. One of the outcomes of the integrated resource planning process is that it will help Aspen identify vulnerabilities to the city water supply system and support building long term resiliency and seeking to reflect the residents' goals and values.

b. *Community Priorities*

Rob Greenwood reviewed the priorities shared by the community and TWG during Engagement 1. It was noted that participants expressed high confidence in the Aspen water system in terms of quality of product, maintenance of the system, and preparation for water shortages. The public expressed highest concern around water security, particularly regarding the reliability of supply. The notion of a differing water scarcity ethic between permanent residents and visitors to Aspen was a further concern. Responses to polling questions posed in Engagement 1 highlighted overarching priorities of ensuring a reliable water supply and protecting the natural beauty of the Aspen region.

3. Gap Analysis *Inge Wiersema, Carollo*

a. *Integrated Resources Planning Purpose and Process*

The presentation focused on the integrated water resources planning process, including drivers, timeline, gaps, and supply options. Inge Wiersema reiterated that the main purpose of the IRP process is to develop a comprehensive assessment of future demands and existing supply capabilities, as well as to identify any future supply opportunities to address the water supply gap. The presentation further addressed supply options, demand forecasting, and the development of criteria to compare alternative plan options. The planning process will include assessing these alternatives and defining criteria with a triple-bottom line lens, looking at social, environmental, and economic factors. Carollo highlighted the established planning horizon of 2070 to ensure the appropriate amount of time to understand and factor into the plan important uncertainties associated with growth and climate change and address complex solutions 50 years out. This will ultimately result in a long-term strategy with a comprehensive time horizon.

b. *Gap Analysis Presentation*

Inge Wiersema began the presentation by defining “gap,” explaining it to mean when demand exceeds supply. The presentation emphasized that as you look farther into the future, uncertainty increases posing challenges for the planning process. In response, the team will utilize adaptive planning that identifies “triggers” (i.e., emergent conditions that signal a need for the plan to adapt) to implement a flexible and responsive water roadmap for the City of Aspen. This will ensure that the city will not only focus on actions that are needed, but also make the right investments at the right time. The triggers act as a mechanism for the City of Aspen to determine when recommendations need to be implemented. As a result, the plan will be a living document and updated as the City of Aspen revisits its assumptions.

Throughout the IRP process, Carollo has identified a variety of factors that are anticipated to impact future water demands, including hotel occupancy rates, climate change, and non-revenue water needs. With the City of Aspen’s current potable demand of approximately 4,300 acre feet/year, Carollo explained the six different scenarios they are examining to fulfill Aspen’s water usage needs, with a range from between 5,000-8,500 acre feet/year for potential supply.

Carollo additionally explained that the City of Aspen currently uses water supplies for a variety of purposes, including domestic consumption, raw water irrigation, in-stream flow goals in the Maroon and Castle creeks, and for hydropower generation. They noted that City of Aspen is not currently generating hydropower due to insufficient in-stream flow levels, signaling a current water supply shortage as not all potential demands can be met at the same time. Over time, the potential for seasonal supply variability can exacerbate the water supply shortages. To address this shortage, Carollo spoke to potential supply options later in the technical working group presentation.

c. ***Questions and Answers***

The TWG had clarifying questions on the presentation regarding the City of Aspen's water rights to Castle and Maroon Creek and what factors were informing the water supply scenarios under consideration. Both Carollo and the City of Aspen clarified that the City does not own all the water rights to Castle and Maroon Creek and that water rights are a key factor still being incorporated into the scenario planning. Other factors under consideration include climate change severity, hotel occupancy rates, and conservation levels. Additional questions regarding the City of Aspen's service area were raised. The City clarified that that the scope of the plan will cover building out to the urban growth boundary.

4. Potential Supply Options *John Rehring, Carollo*

a. ***Potential Supply Options Presentation***

John Rehring shared that the preliminary numbers presented as a part of the gap analysis provide a baseline to inform supply options. Carollo recognized that there is a certain degree of uncertainty related to demand, supply, and related shortages reflective of such variables as hotel occupancy and climate change. To address the gap and related uncertainty, the IRP process is analyzing a variety of solutions. Castle Creek and Maroon Creek have variable availability of water with seasonal water and carry over storage affecting supply. Beyond the creeks, Carollo shared that three ground water wells currently offline for water quality reasons could be incorporated to address supply. New water storage was an additional method to address the water supply gap. This included subsurface sites that would provide underground storage, storing up to 8,500-acre feet. Other methods to increase supply included water reuse, water restrictions, enhanced water conservation, and evaluating the water rights for Hunter Creek.

b. ***Questions and Answers***

The TWG had questions related to the influence of COVID on occupancy rates and the impact of wells on stream flows. Tyler Christoff and Carollo addressed each question, sharing that COVID had led to a peak in visitation and a larger permanent population, which in turn has affected demand. It was also clarified that the wells, should any combination of them be brought online, would likely operate as seasonal back-up supply and have limited, if any, impact on surface water flows.

5. **Vulnerability Assessment** *John Rehring, Carollo*

a. ***Vulnerability Assessment Presentation***

John Rehring shared the range of water supply vulnerabilities specific to the City of Aspen. By identifying potential vulnerabilities, the IRP process can calculate risk and the resulting potential impact on the City of Aspen's water supply.

Vulnerabilities included:

- *Avalanches*: Avalanches in the Castle Creek or Maroon Creek watershed could result in temporary interruption to water supply. Avalanches can further result in downed trees, which can increase the severity of wildfires and can contribute to water quality issues in the watershed.
- *Wildfire*: Wildfires have become increasingly common in Colorado. A wildfire in the Castle Creek or Maroon Creek watersheds has the potential to create significant water quality issues feeding into the City's water treatment facility for months or even years.
- *Infrastructure Failure*: Infrastructure failures can occur in source water diversion and conveyance systems, water treatment facilities, or treated water distribution piping and pumping systems. Infrastructure failure can have a range of potential causes, such as ageing infrastructure.
- *Power Outages*: A power outage can impact treatment, distribution systems, or groundwater pumping. An extended power outage could have more severe implications.
- *Water Treatment Plant Outage*: Water treatment plant outages can occur from individual unit process failures. Ongoing maintenance and asset management is therefore key.
- *Source Contamination*: Source contamination, whether in surface water supplies or groundwater, can have a wide range of causes. This in turn can impact the ability of existing processes to treat water to potable quality.
- *Supply Chain:* Supply chain disruption can impact the ability to maintain operations, whether associated with chemicals used to treat and disinfect the water, or in the ability to access supplies and equipment such as spare parts. Supply chain issues can be local or global.
- *Malevolent Acts:* Malevolent acts, including physical disruption, water quality impacts, or cybersecurity can pose potential threats to water supply, treatment, and delivery systems.
- *Staff Turnover:* Ongoing training is critical for maintaining institutional knowledge in the water system.

b. ***Vulnerability Assessment Polling***

The Poll Everywhere platform was used to engage the TWG around priorities and highest concern vulnerabilities in the Aspen water supply. The questions and responses included:

What other factors should guide our water supply decisions?

- *Wildfires:* Climate change and resulting wildfires was among the top concerns for TWG members. This concern had increased following the most recent fire season.
- *Supply Chain Disruptions*
- *Urban Runoff*
- *Infrastructure Failure*
- *Power Outages*
- *Drought*: Drought topped the list as a continuous concern threatening the Aspen water supply.
- *Malevolent Actions*: Given the recent alleged tampering with gas lines in Aspen, concern for potential malevolent acts/contamination had increased.

Which supply considerations are most important to you?

- *Wildfires:* Wildfires received 5 upvotes and topped the list as the highest priority consideration.
- *Source Contamination:* Source contamination received 4 upvotes and was a key consideration established by TWG members.
- *Water Treatment Plant Outages:* TWG members also cited power outages, especially within the water treatment plant as a consideration for future water planning.

6. Potential Supply Portfolios and Considerations

a. ***Potential Supply Portfolios and Considerations Polling***

The Poll Everywhere platform was used to engage the TWG around factors that should guide the City of Aspen's water planning decisions. The questions and responses included:

What other factors should guide our water supply decisions?

The TWG members discussed a range of factors that they suggested as key components in decision-making around the City of Aspen's water supply. A primary factor included ensuring that the river systems remain healthy and resilient with proper stream flow. TWG members suggested that responsible water use should be used to guide decision-making, with water conservation and stream connectivity as a priority. Beyond these, TWG members recommended that the ecological impacts of source choice be factored into decision-making, with multi-benefit solutions being an end goal.

Which supply considerations are most important to you?

The prevalent priorities among TWG members included instream flow protection and supply reliability/robustness. Ensuring adaptability and reliability, especially for in-house domestic needs, was a key consideration. Other important supply considerations included building resilience into the system to address the effects of climate change and ensuring that rivers remained healthy and water quality remained high.

b. ***Breakout Group Discussion***

Following a 20-minute breakout, the three breakout groups returned to the main session and shared the results of their discussion based off the following questions. Each breakout group was facilitated by a member of the engagement team (Rob Greenwood, Inge Wiersema, and John Rehring).

- What vulnerabilities are the greatest priority and what strategies would be effective in addressing these concerns?
- Which potential new supply sources appear most attractive to you and why?
- Which other considerations should be included in the future water supply evaluation?

Breakout Group 1

- Breakout group one highlighted wildfires as a priority vulnerability to address. Potential solutions included establishing a redundant supply and ensuring dynamic variability of the natural flows. The breakout group recommended integrating in-stream flow considerations to address necessary riparian modifications.
- Storage water options discussed included considering placement and the resulting implications for beneficial leakage. Off channel storage could create a benefit for nearby riparian habitat. With recharge credits from leakage available, the City of Aspen could incentivize these strategies. Other potential supply strategies included developing a diversity of supplies and conserving natural systems to create better base flow conditions.
- TWG members also discussed the shape of the hydrograph and preserving its function and the surface water systems.

Breakout Group 2

- The second breakout group highlighted climate change and resulting risks (wildfires, avalanches, drought), as well as non-point source contaminants as the greatest priority vulnerabilities for the City of Aspen. New supply options were recommended as a solution.
- TWG members recommended water conservation and additional storage sites as supply strategies. It was noted that conservation methods would require community buy-in. Wells were suggested as a further solution. However, TWG members expressed the need to understand the effect of wells on surface water flows. There was further interest in additional raw water storage sites, especially in the North Star Nature reserve due to the potential for instream benefits to the Roaring Fork River.

- Other water supply evaluation considerations raised by the breakout group included maintaining minimum instream flow levels, both seasonally and across multiple years.

Breakout Group 3

- The third breakout group identified wildfires in two connected watersheds as an extreme vulnerability. The lack of a redundant supply on two direct diversions was a further concern.
- Suggestions for potential supply sources included implementing new storage, reactivating wells, promoting reuse, and increasing water budgets for conservation.
- TWG members discussed constraints on the ability to increase conservation savings due to the insensitivity of users to price incentives. It was flagged that this may therefore not be an effective mechanism for water conservation. Breakout group members further recommended the consideration of rainwater harvesting as a factor in supply evaluation. Non-potable reuse was flagged as low hanging fruit, as limitations on potable reuse may pose challenges.

7. Conclusion and Next Steps

During the conclusion, Ross Strategic guided the TWG through next steps and upcoming dates in the engagement process. Closing the meeting, Carollo noted their appreciation for the TWG member input. The City shared that at this phase, input will help to inform the integrated resources plan supply scenarios, fill information gaps, and determine focus areas for future planning. The City of Aspen thanked TWG members for their time and feedback.

Public Engagement #2 *January 14, 2020 5:00-6:00 pm MT*

Following the engagement, the public was notified that a recording of the presentation could be found on the Aspen Community Voice website. This meeting summary provides highlights from the presentations and discussions from the January 14th meeting. The meeting agenda can be found in *Attachment C.*

1. **Aspen Water Overview** *Steve Hunter, City of Aspen; Rob Greenwood, Ross Strategic*

   Steve Hunter provided an overview of the Aspen water utility, highlighting its function, operational goals, existing supplies, and current conditions. One of the outcomes of the integrated resource planning process is that it will help Aspen identify vulnerabilities to the city water supply system and support building long term resiliency and seeking to reflect the residents' goals and values.

   Rob Greenwood reviewed the priorities shared by the community during Engagement 1. It was noted that there is high confidence from residents in terms of quality of product, maintenance of the system, and preparation for water shortages. Past polling questions highlight overarching priorities of ensuring a reliable water supply and protecting the natural beauty of the Aspen region.

2. **Gap Analysis, Supply Options, Vulnerabilities, Important Considerations** *John Rehring and Inge Wiersema, Carollo*

   a. *Gap Analysis*

   Inge Wiersema began the presentation by defining "gap," explaining it to mean when demand exceeds supply. Inge Wiersema gave an overview this gap in the context of the gap analysis and strategic planning process. Wiersema explained that considerations in the IRP process include key factors of hotel occupancy rates, population growth, non-revenue water needs, and climate change. Adaptive planning and a trigger-based implementation strategy is used to help the city make the right investments and the right time. Carollo further shared that the plan is a living document, and the City of Aspen is committed to updating it periodically.

   Carollo additionally explained that the City of Aspen currently uses water supplies for a variety of purposes, including domestic consumption, irrigation, in-stream flow goals in the Maroon and Castle creeks, and for hydropower generation. They noted that the City of Aspen is not currently generating hydropower due to insufficient in-stream flow levels, signaling a current water supply shortage as not all potential demands can be met at the same time.

   b. *Supply Options*

   Carollo began the presentation by emphasizing that the Aspen community does a tremendous job of conserving water and has reduced water use on a per capita basis overtime. John Rehring shared the variety of alternative supply options to address the supply gap spoken to above. These options include:

   - *Enhanced Water Conservation*: It was distinguished that water conservation differs from water restrictions. Water conservation occurs on a day-to-day basis regardless of demands. Restrictions are placed only in emergency situations.

- *Wells*: Wells are currently offline due to water quality issues related to fluoride. Such issues can be solved through blending other water in the distribution system to lower fluoride concentrations. The well water could further be used for snowmaking where there is no requirement for potable water. However, temperature levels might be a concern for this use context. Wells could provide up to 3000 AFY and would address a significant portion of the current water supply gap.
- *Hunter Creek*: The City of Aspen has existing water rights on Hunter Creek, which are currently used to support instream flow. A water treatment plant could be installed and dedicated to treating water from Hunter Creek. However, this would require addressing instream flow requirements. The Red Mountain ditch extension, which also has water rights on the creek, would need to be taken into account.
  - *New Raw Water Storage*: There is potential to store Maroon and Castle Creek supplies lower in the valley for additional storage or supply in emergency conditions. Alternatively, a new water treatment plant could be built to avoid pumping the water. Pumping considerations further include piping cost, elevation gain/loss, and the energy involved for transport from storage to the treatment facility. New raw water storage would provide for enhanced system reliability.
  - *Water Reuse:* Water could be transferred from the sanitation district to the wastewater treatment plant, where it would be treated and reused. This water would be viable for municipal golf course irrigation or for snowmaking. Considerations include the cost of implementing the system and developing agreements between sanitation district and the City of Aspen. Non potable reuse is an important part of the water portfolio across Colorado.
  - *Water restrictions*: Water restrictions provide a temporary approach to acute supply shortages. They are currently in place through the drought mitigation response plan. This includes 5 stages of increasingly severe drought conditions. These temporary use restrictions can be implemented in different stages, with the City of Aspen currently falling in Stage 2 with a 10-15% reduction.

c. *Vulnerabilities*

John Rehring shared the range of water supply vulnerabilities specific to the City of Aspen. By identifying potential vulnerabilities, the IRP process can calculate risk and the resulting potential impact on the City of Aspen's water supply.

Vulnerabilities included:

- *Avalanches*: Avalanches in the Castle Creek or Maroon Creek watershed could result in temporary interruption to water supply. Avalanches can further result in downed trees, which can increase the severity of wildfires and can contribute to water quality issues in the watershed.
- *Wildfire*: Wildfires have become increasingly common in Colorado. A wildfire in the Castle Creek or Maroon Creek watersheds has the potential to create significant water quality issues feeding into the City's water treatment facility for months or even years.

- *Infrastructure Failure*: Infrastructure failures can occur in source water diversion and conveyance systems, water treatment facilities, or treated water distribution piping and pumping systems. Infrastructure failure can have a range of potential causes, such as ageing infrastructure.
- *Power Outages*: A power outage can impact both treatment, distribution systems, or groundwater pumping. An extended power outage could have more severe implications.
- *Water Treatment Plant Outage:* Water treatment plant outages can occur from individual unit process failures. Ongoing maintenance and asset management is therefore key.
- *Source Contamination*: Source contamination, whether in surface water supplies or groundwater, can have a wide range of causes. This in turn can impact the ability of existing processes to treat water to potable quality.
- *Supply Chain:* Supply chain disruption can impact the ability to maintain operations, whether associated with chemicals used to treat and disinfect the water, or in the ability to access supplies and equipment such as spare parts. Supply chain issues can be local or global.
- *Malevolent Acts:* Malevolent acts, including physical disruption, water quality impacts, or cybersecurity can pose potential threats to water supply, treatment, and delivery systems.
- *Staff Turnover:* Ongoing training is critical for maintaining institutional knowledge in the water system.

d. *Questions and Answers*

The public had questions in response to the potential supply portfolio and its impact on surface water sources. There were further questions regarding the potential use of grey water and the current water restrictions on the City of Aspen. Tyler Christoff and Carollo addressed each question, sharing that there is a connection between the wells and Roaring Fork River and that the City of Aspen will ensure that there is no concern in using the wells for water supply. Rehring further elaborated that there are important clarifications and distinctions between municipal water reuse, which addresses utilizing treated water from sanitation and using, for example, for irrigation (i.e., non-potable reuse of treated wastewater), versus residential scale water reuse (e.g., greywater reuse for home irrigation purposes). Greywater has a different potential, although both reuse and greywater are considered tools in the toolbox of meeting the supply gap.

3. Community Interests and Priorities

The Poll Everywhere platform was used to engage the public around key values and priorities for the Aspen Community Water Plan. The following answers were submitted:

a. *What supply vulnerabilities are of most concern to you?*

- Sustained drought
- A lack of water in storage

- Pollution
- Wildfires
- Avalanches
- Terrorism
- Seasonal times of year where supply is unable to meet demand
- Need for public water education
- Climate change
- Instream flow levels

b. *What values are most important when considering supply options?*

- Consideration of partnerships with other water systems to maximize existing infrastructure and production
- Minimizing evaporation
- 3-Generation thinking
- Preventing diversions
- Conservative water use ethic
- Finding supply of non-potable water for irrigation
- Healthy riparian ecosystem
- System reliability
- Maintaining wilderness while creating enough water storage for future

Carollo remarked that the polling results resonated with the team and will provide a focus on in terms of what is important to the community.

4. Conclusion and Next Steps

During the conclusion, Ross Strategic guided the public through next steps and upcoming dates in the engagement process. The engagement team shared that the presentation would be posted to the Aspen Community Voice Community Water Plan page. The City shared that at this phase, input will help to inform the integrated resources plan alternatives discussion, fill information gaps, and determine focus areas for future planning. The City of Aspen thanked the public for their time and feedback.

Attachment A: Technical Working Group Roster

Technical Working Group

NAME	Title	Organization
David Graf	Community Science Manager	Colorado Department of Natural Resources
Lisa Tasker	Citizen Advisory Board Member	Pitkin County: Healthy Rivers Board
Laura Makar	Assistant Attorney	Pitkin County: Healthy Rivers Board
April Long	Executive Director	Ruedi Water and Power Authority
Guy Whol	Program Coordinator of Emerging Solutions	Rocky Mountain Institute
John Schroeder	Data Scientist	Rocky Mountain Institute
Laura Belanger	Senior Water Resources Engineer & Policy Advisor	Western Resources Advocates
Rob Viehl	Senior Water Resource Specialist	Colorado Water Conservation Board
Mickey O'Hara	Director of Programs	Colorado Water Trust

Engagement Team

NAME	Organization
Tyler Christoff	City of Aspen
Steve Hunter	City of Aspen
Mitzi Rapkin	City of Aspen
John Rehring	Carollo
Inge Wiersema	Carollo
Rob Greenwood	Ross Strategic
Micaela Unda	Ross Strategic

Attachment B: Technical Working Group Agenda

Duration	Session	Discussion Lead	Materials/Tactics
(10 min)	**Technology Platform and Agenda Overview**	Ross Strategic	

(15 min)	**Introductions, Engagement Objectives, and Quick Review**
	• Engagement Objectives
	    ○ Elevate technical working group understanding of continued IRP process
	    ○ Inform technical working group on gaps, vulnerabilities and supply options
	    ○ Engage technical working group to gather feedback and perspectives on projected shortages and potential supply options
	• Aspen Community Water Plan Overview
	    ○ Aspen water system highlights
	    ○ Key Background Information from Engagement 1
	    ○ Community priorities
		City of Aspen: Tyler Christoff
		
		City of Aspen: Steve Hunter
		Ross Strategic: Rob Greenwood	

(20 min)	**Gap Analysis**
	• IRP purpose and process
	• Gap Analysis Presentation (10 min)
	    ○ Demand and supply projections
	    ○ Definition of shortage
	    ○ Anticipated shortages of magnitude
	• Participant Q&A (10 min)
		Carollo	Gap analysis materials and solutions and alternatives evaluation

Duration	Session	Discussion Lead	Materials/Tactics

(20 min)	Potential Supply Options
	• Existing Supplies and Future Supply Gap & Potential New Water Supplies (10 mins)
	  o Capacity
	  o Potential Use
	  o Considerations (Pros/Cons)
	• Participant Q&A (10 min)
		Carollo	

10 min	**Break**		

(25 min)	**Vulnerability Assessment**
	• Presentation (10 mins)
	  o Potential Supply Threats
	  o Vulnerability Assessment
	• Vulnerabilities Polling (15 mins)
	  o Are there any other supply vulnerabilities that you are concerned about?
	  o What supply vulnerabilities are of most concern to you?
		Carollo
		
		Ross Strategic
			Poll Everywhere

(70 min)	**Potential Supply Portfolios & Considerations**
	• Considerations for Evaluating Supply Options (15 mins)
	  o What other factors should guide our water supply decisions?
	  o Which supply considerations are most important to you?
	• Breakout Group Discussion: Supply Options, Vulnerabilities, and Considerations (20 mins)
	  o What vulnerabilities are the greatest priority and what strategies would be effective in addressing these concerns?
	  o Which potential new supply sources appear most attractive to you and why?
	  o Which other considerations should be included in the future water supply evaluation?
	• Breakout Report-outs and Discussion (30 mins)
	• Wrap-up (5 mins)
		Carollo & Ross Strategic	Poll Everywhere
			Breakout Groups

(10 min)	**Conclusion and Next Steps**	City of Aspen and Ross Strategic	Flow-chart graphic

Attachment C: Public Engagement Agenda

Duration	Session	Discussion Lead	Materials
(10 min)	Introduction to Technology Platform and Agenda Review *Objectives* • Inform the community on current conditions of Aspen water supply and risks and opportunities • Gather feedback from community on potential gaps, vulnerabilities, and supply options • Develop accurate reflection of community water resource priorities solution input	Ross Strategic and City of Aspen	
1. Background Information			
(25 min)	Aspen Community Water Plan Overview (5 min) • Aspen water system highlights; snapshot of Aspen water utility and its mission, function, operational goals, existing supplies, and current conditions • Community priorities Gap Analysis, Supply Options, Vulnerabilities, and Important Considerations (15 min) • Characterize demand and supply projection and anticipated shortages and vulnerabilities • Review existing supply options, future supply gap, potential use and considerations Participant Q&A (5 min)	City of Aspen Carollo Ross Strategic	Slides from Engagement 1 regarding Aspen Water Supply Gap analysis materials and solutions evaluation Chat Function
2. Gather Feedback from Community			

(20 min)	Community Interests and Priorities
	• Polling Questions
	    o What supply vulnerabilities are of most concern to you?
	    o What values are most important when considering supply options?
		Ross Strategic	Poll Everywhere

3. Wrap up and Next Steps			
(5 min)	Conclusion and Next Steps	Ross and City of Aspen	Flow-chart graphic

City of Aspen Community Water Plan: *Engagement 3 Synthesis*

On March 3rd, the City of Aspen hosted separate technical working group and public engagement sessions to gather community input regarding the development of the Aspen Community Water Plan.

Technical Working Group #3 *March 3rd, 2021 1:00-4:00 pm MT*

In advance of the engagement, technical working group (TWG) members (*Attachment A)* were provided with a meeting agenda (*Attachment B)* and presentation slide deck. This meeting summary provides highlights from the presentations and discussions from the March 3, 2021 meeting.

1. Introductions and Engagement Objectives *Tyler Christoff, City of Aspen*

a. Introductions

Tyler Christoff introduced the members of the Aspen, Carollo, and Ross Strategic team. Nine TWG members joined the third round of engagement. For a full list of attendees, see Attachment A.

b. Engagement Objectives

Tyler Christoff provided an overview of the objectives of the engagement process, meeting objectives, and background context. Engagement objectives included: 1) Elevate TWG understanding of continued IRP process; 2) Inform TWG group on future supply options, supply evaluation, and preferred supply strategy; and 3) Engage the TWG to gather feedback and perspectives on supply strategy.

2. Aspen Community Water Plan Overview *Steve Hunter, City of Aspen*

a. Aspen Water Overview

Steve Hunter provided an overview of the Aspen water utility, highlighting its function, operational goals, existing supplies, and current conditions. The overview shared that the city's potable water supply is primarily sourced from senior water rights on Castle and Maroon Creeks, where it is then conveyed to the town reservoir. The City is constantly monitoring diversions to ensure that water demands are met. One of the outcomes of the integrated resource planning process is that it will help Aspen identify vulnerabilities to the city water supply system and support building long term resiliency and seeking to reflect the residents' goals and values. To support these goals, the City is exploring a portfolio with enhanced water conservation programs, ground wells, water reuse, and emergency storage.

3. Supply Evaluation *John Rehring, Carollo*

a. *Integrated Resources Planning Purpose and Process*

The presentation focused on the integrated water resources planning process, including drivers, timeline, gaps, and supply options. John Rehring reiterated that the main purpose of the IRP process is to develop a comprehensive assessment of future demands and existing supply capabilities, as well as to identify any future supply opportunities to address the water supply gap. The presentation further addressed supply options, demand forecasting, and the development of criteria for comparing alternative plan options. The planning process included assessing these alternatives and defining criteria with a triple-bottom line lens, looking at social, environmental, and economic factors. Carollo highlighted that previous TWG and general public engagement feedback was used to develop the criteria for evaluation and resulting portfolio options. The supply strategy will ultimately result in a phased implementation plan within the IRP report.

b. *Supply Evaluation Presentation*

John Rehring began the presentation introducing the factors that affect water demand, including population, occupancy rates, climate change, water use efficiency, and unmetered water usage. The presentation emphasized that as the City looks farther into the future, uncertainty increases posing challenges for the planning process. In response, the team will utilize adaptive planning that identifies "triggers" (i.e., emergent conditions that signal a need for the plan to adapt) to implement a flexible and responsive water roadmap for the City of Aspen. The triggers act as a mechanism for the City of Aspen to determine when recommendations need to be implemented. As a result, the plan will be a living document and updated as the City of Aspen revisits its assumptions. Carollo emphasized that the IRP will be both flexible and adaptable to changing water demand conditions.

Carollo additionally explained that conservation and efficiency are factors already built into Aspen's water supply strategy, highlighting that current work is building on existing measures and a robust mindset for conservation in the community. Although the community is conscious of conservation needs, Carollo noted that the City of Aspen is not currently generating hydropower due to insufficient in-stream flow levels, signaling a current water supply shortage as not all potential demands can be met at the same time. However, with seasonal variability, the City of Aspen can fill storage when instream flows are greater than the water supply need. Carollo explained that seasonal storage is used to mitigate normal stream flow variability. Additional options to meet demand included emergency storage, which creates a supply buffer to mitigate emergency conditions such as impacts from wildfire or avalanches. To address this shortage, Carollo spoke to the supply portfolios they had developed later in the technical working group presentation.

c. ***Questions and Answers***

The TWG had clarifying questions on the presentation regarding the City of Aspen's water rights to Castle and Maroon Creek. Both Carollo and the City of Aspen clarified that the City does not own all the water rights to Castle and Maroon Creek and that water rights are a key factor in scenario planning. However, Carollo explained that the Maroon Creek and Castle Creek water rights are both senior and conditional and that the flow coming from the creeks could fulfill seasonal and emergency needs. Additional questions were posed around what different drought types were used in the scenario development. Carollo explained that the analysis looked at 5 different scenarios that ranged from hot and dry to warm and wet seasons.

4. Supply Strategy *Rachel Gross, Carollo*

a. ***Potential Supply Options Presentation***

The presentation began by defining "portfolios" as a group of water supply options that can meet a higher future demand. "No action" portfolios maintain the status quo. As a part of the evaluation process, Carollo established six portfolios that utilized a range of water sources and storage methods. These included:

- *Portfolio 1:* No action portfolio illustrated business as usual operations.
- *Portfolio 2:* This portfolio adds in seasonal and emergency storage. Some levels of drought restrictions will also be in effect.
- *Portfolio 3:* For portfolio three, Hunter Creek is incorporated, which works to mitigate the amount of drought restrictions needed. However, as there is not a significant amount of water in Hunter Creek to divert, this portfolio offers only some relief.
- *Portfolio 4:* This portfolio maximizes ground water wells, which make up a significant amount of the potential gap in the water supply. A small amount of drought restrictions is further included.
- *Portfolio 5:* For portfolio five, enhanced conservation is added, which targets decreasing demand. Through increased conservation, shortage is minimized.
- *Portfolio 6:* Portfolio six, referred to as the "kitchen sink" portfolio, incorporated numerous building blocks towards mitigating the supply gap. The portfolio includes groundwater wells, which make up the biggest proportion of supply needed. Other strategies in the portfolio include seasonal conservation, water restrictions, and storage.

b. ***Questions and Answers***

The TWG had questions related the City of Aspen's water rights on Hunter Creek and whether the amount of water available would fulfill supply need. Carollo clarified that the City's rights on Hunter Creek are not the most senior and that during dry years where diversions are minimal, other supply sources may be needed. Additional questions surrounded non-potable supply. Rachel Gross explained that the gap discussed only addressed the potable supply gap, as the raw water gap lacks sufficient data for analysis.

5. **Portfolio Evaluation** *Inge Wiersema, Carollo*

a. *Vulnerability Assessment Presentation*

Inge Wiersema shared that the portfolio evaluation presented is not for emergency operations. Prior to addressing emergency conditions, the best supply mix for normal conditions is determined. From here, emergency conditions and supplies needed are added to consider additional vulnerabilities. Carollo developed six emergency criteria to determine the level of drought restrictions needed to supplement supply mixes implemented. Supply sources were further examined by their vulnerability risk score to ensure resilience in the water supply portfolio.

Portfolios were weighed with capital and lifestyle cost in mind, as well as the ease of implementation and operations for the city. Key takeaways from the analysis included that with more sources comes more availability. However, this further leads to increasingly complex operations needed to manage the system. Other considerations included how often it is acceptable to impose drought restrictions on the City's residents compared to the strategy of adding more supplies.

Following the vulnerability assessment presentation, Inge Wiersema shared preliminary findings. An asset management approach was used to develop portfolios and consider the risk profile for each source. From here, Carollo will develop a final supply strategy and phased implementation plan as a part of the integrated resource plan process.

b. *Vulnerability Assessment Polling*

The Poll Everywhere platform was used to engage the TWG related to the criteria used to evaluate the alternative Aspen water supply portfolios. The questions and responses included:

Do the relative weights assigned to the criteria make for a robust evaluation of the alternatives?

- Yes: 75%
- No: 25%

If no, which of the criteria should be weighed more heavily?

- Supply Resilience: 25%
- Supply Availability: 17%
- Community and Environmental Benefits: 58%

6. Discussion

Following the presentation, the TWG participated in a discussion session covering the following questions.

- Looking at the portfolio evaluation results, what direction would you recommend for meeting future water needs?
- To reduce the community's susceptibility to supply vulnerabilities, should we implement additional storage, additional supplies, or a different approach? Why?
- Stepping back and looking across the solutions we've discussed today, do you see any missed opportunities?

Participants addressed all three questions in their responses. Key takeaways from the discussion included a preference towards groundwater diversification. Participants suggested including alluvial sites when integrating groundwater into storage and managing aquifer recharge programs. This practice would provide secondary benefits and would further include recapture.

There was a shared sense among the TWG members that portfolio 6 represented the most resilient and diverse portfolio. The "kitchen sink" portfolio resonated with TWG members as it included conservation and reuse, but also diverse sources to protect against any vulnerabilities. Other suggestions for supply management included looking at opportunities upstream in the watershed that could benefit the flow regime in the Roaring Fork and ease the water stress conditions it can experience. Others suggested examining inter-portfolio prioritization to ensure the most resilient system possible.

7. Conclusion and Next Steps

During the conclusion, the City of Aspen guided the TWG through next steps in the IRP process. Closing the meeting, Carollo noted their appreciation for the TWG member input. The City shared that at this phase, input will help to continue to inform the integrated resources plan, preferred portfolio, and vulnerability priorities. The City ensured that they are working to create a realistic phased implementation plan that meets community values and reacts appropriately and responsibly to rate payers in the broader community. The City of Aspen thanked TWG members for their time and feedback.

Public Engagement #3 *March 3rd, 2020 5:00-6:30 pm MT*

Following the engagement, the public was notified that a recording of the meeting presentations could be found on the Aspen Community Voice website. This meeting summary provides highlights from the presentations and discussions from the March 3rd meeting. The meeting agenda can be found in *Attachment C.*

1. **Aspen Community Water Plan Overview** *Steve Hunter, City of Aspen*

   Steve Hunter provided an overview of the Aspen water utility, highlighting its function, operational goals, existing supplies, and current conditions. The overview shared that the city's potable water supply is primarily sourced from senior water rights on Castle and Maroon Creeks, where it is then conveyed to the town reservoir. One of the outcomes of the integrated resource planning process is that it will help Aspen identify vulnerabilities to the city water supply system and support building long term resiliency and seeking to reflect the residents' goals and values.

2. **Supply Evaluation** *John Rehring, Carollo*

   a. ***Integrated Resources Planning Purpose and Process***

      The presentation focused on the integrated water resources planning process, including drivers, timeline, gaps, and supply options. John Rehring reiterated that the main purpose of the IRP process is to develop a comprehensive assessment of future demands and existing supply capabilities, as well as to identify any future supply opportunities to address the water supply gap. The presentation further addressed supply options, demand forecasting, and the development of criteria for comparing alternative plan options. The planning process included assessing water supply portfolio alternatives using criteria reflecting a triple-bottom line lens, looking at social, environmental, and economic factors. Carollo highlighted that previous public engagement feedback was used to develop the criteria for evaluation and resulting water supply portfolio options. The supply strategy will ultimately result in a phased implementation plan contained within the IRP report.

   b. ***Supply Evaluation Presentation***

      John Rehring began the presentation introducing and defining the factors that affect water demand, including population, occupancy rates, climate change, water use efficiency, and unmetered water usage.

      - *Population:* Addresses anticipated future population growth, including how much of the urban growth boundary the city water department will need to serve
      - *Occupancy Rates:* Directly affects water demands and needed supply, and plays a large overall role in Aspen's water demand
      - *Climate Change:* Affects supply and demand, including amount, timing, and intensity of flow
      - *Water Use Efficiency:* Affects the nature of water demand included in the portfolio planning
      - *Unmetered Water Usage:* Encompasses water usage that the City of Aspen does not invoice

The presentation emphasized that as the City looks farther into the future, uncertainty increases posing challenges for the planning process. In response, the team will utilize adaptive planning that identifies "triggers" (i.e., emergent conditions that signal a need for the plan to adapt) to implement a flexible and responsive water roadmap for the City of Aspen. The triggers act as a mechanism for the City of Aspen to determine when recommendations need to be implemented. As a result, the plan will be a living document and updated as the City of Aspen revisits its assumptions. Carollo emphasized that the IRP will be both flexible and adaptable to changing demand and supply conditions.

Carollo additionally explained that conservation and efficiency are factors already built into Aspen's water supply strategy, highlighting that the current planning work is building on existing measures and a robust mindset for conservation in the community. Although the community is conscious of conservation needs, Carollo noted that the City of Aspen is not currently generating hydropower due to insufficient in-stream flow levels, signaling a current water supply shortage as not all potential demands can be met at the same time. However, with seasonal variability, the City of Aspen can fill storage when instream flows are greater than the water supply need. The City sees variability over the course of the year with irrigation and outdoor water uses higher in summer, resulting in demand peaks. Carollo explained that seasonal storage is used to mitigate stream flow variability. Additional options to meet demand included emergency storage, which creates a supply buffer to mitigate emergency conditions such as impacts from wildfire or avalanches. To address this shortage, Carollo spoke to the supply portfolios they had developed later in the technical working group presentation.

3. Supply Strategy *Inge Wiersema, Carollo*

a. *Potential Supply Options Presentation*

The presentation began by defining "portfolios" as a group of water supply options that meet a higher future demand. "No action" portfolios maintain the status quo. As a part of the evaluation process, Carollo established six portfolios that utilized a range of water sources and storage methods. These included:

- *Portfolio 1:* No action portfolio illustrated business as usual operations.
- *Portfolio 2:* This portfolio adds in seasonal and emergency storage. Some levels of drought restrictions will also be in effect.
- *Portfolio 3:* For portfolio three, Hunter Creek is incorporated, which works to mitigate the amount of drought restrictions needed. However, as there is not a significant amount of water in Hunter Creek to divert, this portfolio offers only some relief.
- *Portfolio 4:* This portfolio maximizes ground water wells, which make up a significant amount of potential gap in the water supply. A small amount of drought restrictions is further included.
- *Portfolio 5:* For portfolio five, enhanced conservation is added, which targets decreasing demand. Through increased conservation, shortage is minimized.

- *Portfolio 6:* Portfolio six, referred to as the "kitchen sink" portfolio, incorporated numerous building blocks towards mitigating the supply gap. The portfolio includes groundwater wells, which make up the biggest proportion of supply needed. Other strategies in the portfolio include seasonal conservation, water restrictions, and storage.

4. Portfolio Evaluation *Inge Wiersema, Carollo*

a. *Supply Criteria*

Carollo introduced the portfolio evaluation process by walking through the various criteria used to evaluate supply. These included:

- *Supply Availability:* Addresses how often water supply is insufficient and drought restrictions are needed
- *Supply Resilience:* Addresses how much the City is relying on specific supply sources, incorporating vulnerability risk scores
- *Community and Environmental Benefits:* Addresses instream flows, efficient water use, GHG emissions, and energy cost
- *Affordability:* Addresses capital costs needed to develop new pipeline, treatment plant, etc. Further addresses lifecycle cost included in operations, maintenance, labor, and chemical usage
- *Ease of Implementation:* Addresses phasing of investments, with larger upfront costs scoring lower
- *Ease of Operations:* Addresses the degree of difficulty to operate components of a supply strategy together

b. *Vulnerability Assessment Presentation*

Inge Wiersema shared that the portfolio evaluation presented is not for emergency operations. Prior to addressing emergency conditions, the best supply mix for normal conditions is determined. From here, emergency conditions and supplies needed are added to address additional vulnerabilities. Carollo developed six emergency criteria to determine the level of drought restrictions needed to supplement supply mixes implemented. Supply sources were further examined by their vulnerability risk score to ensure resilience in the water supply portfolio.

Portfolios were weighed with capital and lifecycle cost in mind, as well as the ease of implementation and operations for the city. Key takeaways from the analysis included that more sources in the water supply mix, provide greater availability and reliability. However, the more diverse water supply portfolio makes for a more complex operating environment for the city to manage. Other considerations included how often it is acceptable to impose drought restrictions on the City's residents compared to a strategy of adding more supplies.

Following the vulnerability assessment presentation, Inge Wiersema shared preliminary findings. An asset management approach was used to develop portfolios and consider the risk profile for each source. From here, Carollo will develop a final supply strategy and phased implementation plan as a part of the integrated resource plan process.

c. ***Questions and Answers & Discussion***

Public engagement participants were invited to ask clarifying questions regarding the presentation. Participants posed questions regarding whether the threat assessment is a component of the weighted portfolio scores. Carollo explained that for each supply source, there is an associated risk score incorporated. For example, if 50% of the water were to come from Maroon Creek and the other 50% from groundwater, Carollo would weigh the risks on how both would be used during a hydrological cycle. Further questions addressed the potential of rooftop collection. John Rehring explained that rooftop capture is a growing trend in the industry, however there is a constraint from water rights. By intercepting water from runoff, residents downstream do not receive proper flows. However, there are allowances at a state level for rooftop capture for irrigation purposes.

Following the Q&A period, public engagement participants responded the following discussion questions.

- Which sources should be emphasized in Aspen's future water supply strategy? Why?
    - Storage and community conservation
    - Building a resilient community
    - Combination of instream flow and groundwater wells in the upper valley
- To reduce the community's susceptibility to supply vulnerabilities, should we implement additional storage, additional supplies, or a different approach? Why?
    - Best to handle with a variability of supply options. With two or more sources to meet community demands, the City is protected from risk.
- Stepping back and looking across the solutions we've discussed today, do you see any missed opportunities?
    - Consider partnerships with upper-valley smaller domestic water systems

5. Conclusion and Next Steps

During the conclusion, the City of Aspen guided the public through next steps in the IRP process. Closing the meeting, Carollo noted their appreciation for the input. The City shared that at this phase, input will help to continue to inform the integrated resources plan, preferred portfolio, and vulnerability priorities. Tyler Christoff explained that the City will evaluate storage and back-up measures and identify potential solutions to scale up as demand or vulnerability increases. The City ensured that they are working to create a realistic phased implementation plan that meets community values and reacts appropriately and responsibly to rate payers in the broader community. The City of Aspen thanked participants for their time and feedback.

Attachment A: Technical Working Group Roster

Technical Working Group

NAME	Title	Organization
David Graf	Community Science Manager	Colorado Department of Natural Resources
Lisa Tasker	Citizen Advisory Board Member	Pitkin County: Healthy Rivers Board
Laura Makar	Assistant Attorney	Pitkin County: Healthy Rivers Board
April Long	Executive Director	Ruedi Water and Power Authority
Elise Osenga	Research and Education Coordinator	Aspen Global Change Institute
Tim Miller	Hydrologist	Bureau of Reclamation
Laura Belanger	Senior Water Resources Engineer & Policy Advisor	Western Resources Advocates
Rob Viehl	Senior Water Resource Specialist	Colorado Water Conservation Board
Mickey O’Hara	Director of Programs	Colorado Water Trust

Engagement Team

NAME	Organization
Tyler Christoff	City of Aspen
Steve Hunter	City of Aspen
Mitzi Rapkin	City of Aspen
John Rehring	Carollo
Inge Wiersema	Carollo
Rachel Gross	Carollo
Rob Greenwood	Ross Strategic
Micaela Unda	Ross Strategic

Attachment B: Technical Working Group Agenda

Duration	Session	Discussion Lead	Materials/Tactics
(10 min)	Technology Platform and Agenda Overview	Ross Strategic	

(10 min)	Introductions, Engagement Objectives, and Quick Review
	• Engagement Objectives
	  ○ Elevate technical working group understanding of continued IRP process
	  ○ Inform technical working group on future supply options, supply evaluation, and preferred supply strategy
	  ○ Engage technical working group to gather feedback and perspectives on supply strategy
	• Aspen Community Water Plan Overview
	  ○ Aspen water system highlights
	  ○ Key Background Information from Engagement 2
		City of Aspen: Tyler Christoff
		
		City of Aspen: Steve Hunter	

(30 min)	Supply Evaluation • IRP purpose and process • Forecasting Water Demand to 2070 • Participant Q&A	Carollo	Supply overview materials

<table>
<tr><th>Duration</th><th>Session</th><th>Discussion Lead</th><th>Materials/Tactics</th></tr>
<tr><td>(10 min)</td><td>Technology Platform and Agenda Overview</td><td>Ross Strategic</td><td></td></tr>
<tr><td>(15 min)</td><td>Introductions, Engagement Objectives, and Quick Review
• Engagement Objectives
  ○ Elevate technical working group understanding of continued IRP process
  ○ Inform technical working group on gaps, vulnerabilities and supply options
  ○ Engage technical working group to gather feedback and perspectives on projected shortages and potential supply options
• Aspen Community Water Plan Overview
  ○ Aspen water system highlights
  ○ Key Background Information from Engagement 1
  ○ Community priorities</td><td>City of Aspen: Tyler Christoff

City of Aspen: Steve Hunter
Ross Strategic: Rob Greenwood</td><td></td></tr>
<tr><td>(20 min)</td><td>Gap Analysis
• IRP purpose and process
• Gap Analysis Presentation (10 min)
  ○ Demand and supply projections
  ○ Definition of shortage
  ○ Anticipated shortages of magnitude
• Participant Q&A (10 min)</td><td>Carollo</td><td>Gap analysis materials and solutions and alternatives evaluation</td></tr>
<tr><td>(20 min)</td><td>Potential Supply Options
• Existing Supplies and Future Supply Gap & Potential New Water Supplies (10 mins)
  ○ Capacity
  ○ Potential Use
  ○ Considerations (Pros/Cons)
• Participant Q&A (10 min)</td><td>Carollo</td><td></td></tr>
</table>

Duration	Session	Discussion Lead	Materials/Tactics
10 min	Break		

(25 min)	**Vulnerability Assessment**
	• Presentation (10 mins)
	    o Potential Supply Threats
	    o Vulnerability Assessment
	• Vulnerabilities Polling (15 mins)
	    o Are there any other supply vulnerabilities that you are concerned about?
	    o What supply vulnerabilities are of most concern to you?
		Carollo
		
		Ross Strategic
			Poll Everywhere

(70 min)	**Potential Supply Portfolios & Considerations**
	• Considerations for Evaluating Supply Options (15 mins)
	    o What other factors should guide our water supply decisions?
	    o Which supply considerations are most important to you?
	• Breakout Group Discussion: Supply Options, Vulnerabilities, and Considerations (20 mins)
	    o What vulnerabilities are the greatest priority and what strategies would be effective in addressing these concerns?
	    o Which potential new supply sources appear most attractive to you and why?
	    o Which other considerations should be included in the future water supply evaluation?
	• Breakout Report-outs and Discussion (30 mins)
	• Wrap-up (5 mins)
		Carollo & Ross Strategic	Poll Everywhere
			
			Breakout Groups

(10 min)	**Conclusion and Next Steps**	City of Aspen and Ross Strategic	Flow-chart graphic

Attachment C: Public Engagement Agenda

<table>
<tr><th>Duration</th><th>Session</th><th>Discussion Lead</th><th>Materials</th></tr>
<tr><td>(10 min)</td><td>Introduction to Technology Platform and Agenda Review

Objectives
Inform the community on current conditions of Aspen water supply and continued Community Water Plan development
Gather feedback from community on supply evaluation, and preferred supply strategy
Develop accurate reflection of community water resource priorities</td><td>Ross Strategic and City of Aspen</td><td></td></tr>
<tr><td colspan="4">1. Background Information</td></tr>
<tr><td>(55 min)</td><td>Aspen Community Water Plan Overview
Aspen water system highlights; snapshot of Aspen water utility and its mission, function, operational goals, existing supplies, and current conditions
Key Background from Engagement 1&2
Supply Evaluation and Strategy
Portfolio Overview
Intent and Purpose
Recap
Portfolio Description
Participant Q&A
Supply Evaluation
Portfolio Evaluation
Intent and Purpose</td><td>City of Aspen

Carollo</td><td>Slides from Engagement 2 regarding Aspen Water Supply

Supply evaluation and strategy materials</td></tr>
</table>

Duration	Session	Discussion Lead	Materials
	◦ Criteria ◦ Preliminary Results ◦ Trade-Off Decisions • **Polling Question** ◦ Which of the 6 criteria are most important in selecting a future water supply strategy? • **Participant Q&A**		Chat Function/Open Dialogue
	2. Gather Feedback from Community		
(20 min)	**Community Interests and Priorities Related to Supply Options** Discussion Questions • Which sources should be emphasized in Aspen's future water supply strategy? Why? • To reduce the community's susceptibility to supply vulnerabilities, should we implement additional storage, additional supplies, or a different approach? Why? • Stepping back and looking across the solutions we've discussed today, do you see any missed opportunities?	Ross Strategic	Chat Function/Open Dialogue
	3. Wrap up		
(5 min)	**Conclusion and Next Steps**	Ross and City of Aspen	Flow-chart graphic

Appendix C
WATER DEMAND FORECAST REPORT

MEMO

TO: Lee Ledesma and Steve Hunter, City of Aspen

FROM: ELEMENT Water Consulting

DATE: March 30, 2021

RE: City of Aspen Water Demand Projection Update

ELEMENT Water Consulting (ELEMENT) previously provided services to the City of Aspen (Aspen or City) to prepare the City's Municipal Water Efficiency Plan, which was finalized in 2015 (2015 WEP). At that time, we evaluated the City's potable water demands for the years 2009 through 2013, based primarily upon metered water use data. We used the data to represent the then-current "baseline" water demands, which were the basis for water demand projections that we prepared for the year 2035. One of the demand projections reflected the reduction in demand that could be achieved through implementing the water efficiency program that is outlined in the 2015 WEP.

Since that time, the City has implemented many of the recommended water efficiency programs and has been monitoring water use data. Some new water use trends have emerged, and the City has expressed interest in evaluating potential new efficiency programs. The City is also extending its future demand projection to the year 2070, for use in the Integrated Resources Plan (IRP) that is being prepared by Carollo Engineers, Inc., with assistance from ELEMENT. We have prepared the information in this technical memorandum as an interim draft work product to support these efforts.[1]

1. Historical Water Demands

This section describes an updated historical water demand analysis that extends through the year 2019[2]. ELEMENT used the updated data to make recommendations for efficiency programs that are described in Section 2, below. The data were also used to prepare a current baseline water demand and demand projections for the year 2070 that are provided in Section 3, below.

1.1 Potable Water Demands

Aspen currently uses two river sources of water supply for its potable, i.e., treated, water system. The primary supply intake for water delivered to the water treatment plant is on Castle Creek, and another intake, on Maroon Creek, is generally used as a supplemental supply. These diversions are conveyed to the Leonard Thomas Reservoir, which is a small operational reservoir at the Aspen water campus, before undergoing treatment at the City's water treatment plants.

[1] Whereas ELEMENT has reviewed the City's metered potable water delivery data under prior efforts, ELEMENT has not completed a data validation of the "Other" potable water use, non-potable water use, and production data, which was beyond the scope of this project.

[2] Although this memorandum was finalized in 2021, the technical analyses were largely completed in mid-2020, at which time the analysis dataset extended through 2019.

1.1.1 Service Area and Customer Characteristics

Aspen provides potable water service to a total of approximately 3,960 customer connections within the City's water service area. The City's current billing area is shown in **Figure 1**. It includes the City of Aspen and some areas outside of the municipal boundary that are within the Urban Growth Boundary (UGB). Portions of unincorporated Pitkin County that lie within the UGB include Red Mountain, East of Aspen neighborhoods, the Airport Business Center, the airport, Buttermilk Base area, and portions of the Castle Creek and Maroon Creek valleys, including extraterritorial service areas such as North Spruce and Rubey Subdivision.

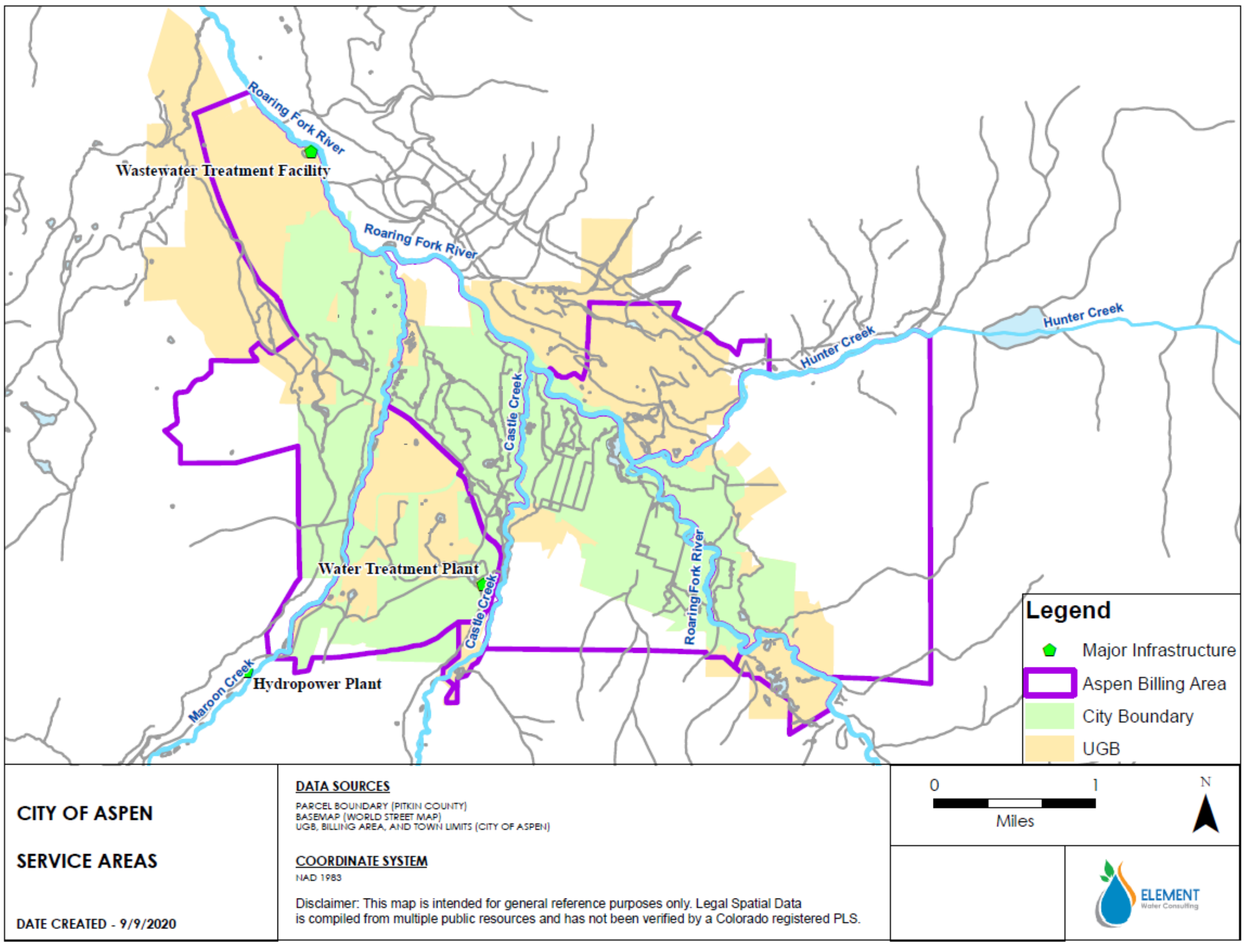

Figure 1: Aspen Municipal Boundary and Service Area.

The City uses the following customer category assignments for most of its potable water service accounts that are metered and billed (referred to herein as Metered Customer Categories):

- Single-family residential (detached single-family homes)
- Multi-family with 2-4 units
- Multi-family with greater than 5 units
- Commercial/industrial

- City facilities[3]
- Irrigation Only

Approximately 7 percent of the potable water that Aspen produced in 2019 was provided for "Other" purposes as described below:

- Snowmaking – The City provides potable water to Aspen Skiing Company for snowmaking at Aspen Mountain through a bulk treated water agreement[4]. Water for snowmaking is delivered from the City's potable water pipelines. Water delivery is measured at the Aspen Skiing Company Primary Pump Station.
- Buttermilk Metro District – The City provides potable water to West Buttermilk, located east of Aspen's service area, for indoor and outdoor uses, which is metered in bulk by the City and provided to Buttermilk Metro District pursuant to a Bulk Water Service Agreement. Water is delivered by Buttermilk Metro District through individual meter connections to 77 residential customers plus two commercial taps. Some of these accounts have individual septic systems.
- Billed Unmetered – The City has unmetered customers who are billed at a flat, rather than tiered, rate. This usage typically involves service to construction projects before a permanent meter is installed. The amount of water is estimated monthly by City staff based on the number of active construction permits.
- Unbilled Unmetered Authorized – This category is estimated by City staff to account for less than 1 percent of the Other uses and includes the following types of uses:
    - Hydrant draw permits[5].
    - Commercial fire system testing.
    - Maintenance and construction system flushing.
    - Water quality flushing.
    - Fire hydrant usage by Aspen Fire Department.

1.1.2 Potable Water Demands

The City Water Department regularly compiles and evaluates its potable water usage using an Excel-based tracking tool referred to as the AWWA M36 Tracker, which was developed as part of the City's potable water audits and loss control program. This tool was first prepared around the year 2018 and has become the City's primary potable water use data repository, supporting consistency in water data reporting. City staff enter and review data each month and conduct a full annual review before submitting to the Colorado Water Conservation Board (CWCB) certain data that are required by the statute that was created from House Bill 10-1051. The AWWA M36 Tracker contains data back to the year 2012 that were incorporated into the tracking to provide historical water use information.

[3] This category has historically included water uses associated with a variety of properties owned by the City, which include but are not limited to employee housing, municipal buildings, and parks. In the future, Aspen plans to reassign these uses into the other major Metered Customer Categories.

[4] The City also provides raw water to Aspen Skiing Company for snowmaking at Aspen Highlands Ski Area.

[5] The City historically issued a small number of hydrant draw permits each year under bulk sale agreements, typically related to construction. These uses were estimated by City staff through 2018. A fill station was installed and uses began being metered and billed starting in 2019. For this 2012 through 2019 analysis, the uses are included in the "Other - Unbilled Authorized" category for consistency with historical data categories. Future construction water use will be billed and reported under the "Metered Customer Categories."

We used the historical monthly production and potable water use billing data for the recent 8-year period of 2012 through 2019 to update prior analyses prepared for the 2015 WEP. Some of the data have been updated and are different from the data that were available when we prepared the 2015 WEP. The City has reviewed all of the data in the AWWA M36 Tracker and has concluded that it contains the most accurate representation of historical potable water uses.

In the process of evaluating historical water demands for the recent period of 2012 through 2019, we have updated key tables and figures from the 2015 WEP, which are provided below. The table titles below are denoted "Updated WEP," followed by the table or figure number corresponding with the 2015 WEP table or figure number. Clarifications have been made where possible. The total potable water demand for Aspen's system, including potable water supplies for the Other accounts, has averaged approximately 3,027 acre-feet per year (AF/yr) over this period, as shown in **Table 1,** below. It has remained relatively constant over the past eight years, even though there has been some growth through redevelopment and new development.

The 2015 WEP reported that single-family and multi-family residential water demand accounted for approximately 68 percent of the annual potable water demand, and commercial use accounted for 24 percent of the potable demand. The updated data analysis for 2012 through 2019 is nearly identical. Residential demand has held at approximately 68 percent, and commercial use has increased only slightly, to 25 percent of the annual potable water demand. A pie chart showing the distribution of water usage in 2019, including the Other water sales, is presented in **Figure 2,** below.

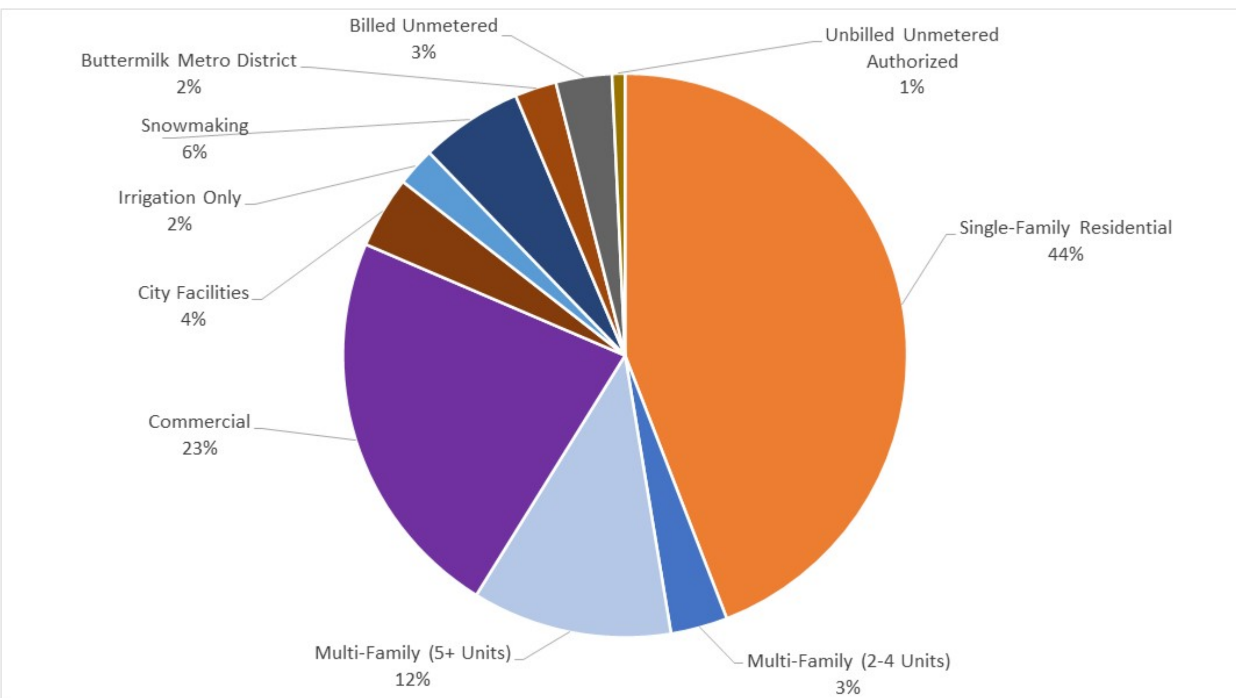

Figure 2: Updated WEP Figure 7. Potable Water Use Distribution in 2019.

Table 1: Updated WEP Table 1. Annual Potable Water Use from 2012 through 2019.

Year	Metered Customer Accounts (AF/yr)							Other (AF/yr)				Total (AF/yr)
	Single-Family Residential	Multi-Family (2-4 Units)	Multi-Family (5+ Units)	Commercial	City Facilities	Irrigation Only	Total	Snow-making	Buttermilk Metro District	Billed Unmetered	Unbilled Unmetered Authorized	
2012	1391	101	387	650	124	85	**2739**	113	79	208	47	**3185**
2013	1217	99	380	623	124	72	**2514**	169	73	92	42	**2891**
2014	1267	98	365	646	99	80	**2555**	200	68	92	50	**2966**
2015	1180	94	362	666	107	79	**2489**	194	66	92	55	**2895**
2016	1257	97	352	639	112	84	**2541**	227	70	92	62	**2993**
2017	1307	130	354	650	124	92	**2658**	127	93	92	210	**3180**
2018	1397	98	341	664	113	84	**2697**	247	75	92	117	**3228**
2019	1263	93	328	647	118	63	**2513**	183	68	92	21	**2878**
Average	**1285**	**101**	**359**	**648**	**115**	**80**	**2588**	**183**	**74**	**107**	**75**	**3027**

1.1.2.1 Metered Customer Category Use

The City's municipal water efficiency program has historically focused on the major customer categories within the billed metered accounts, which represent approximately 93 percent of the potable water use and are further described in this section. An estimated breakdown of indoor and outdoor potable water use within the Metered Customer Categories, based on monthly data from the City's AWWA M36 Tracker, is shown in **Table 2,** below. Indoor and outdoor demands were estimated using a standard average winter consumption (AWC) methodology, in which indoor use from the winter months (January, February, and December), when typically no outdoor irrigation occurs, is used to estimate monthly indoor use for the entire year. Estimated indoor use is then deducted from the total annual use to estimate the outdoor use. There are some challenges in using this method for Aspen, considering that the population fluctuates throughout the year with non-permanent residents, visitors, and commuters. The results were verified using average daily influent flow data from the Aspen Consolidated Sanitation District wastewater treatment plant (WWTP), which represents the waste flows from indoor uses. The average calculated indoor use between these two methodologies was within about 1 percent over the study period. The AWC method was used so that it could also be applied on a customer category scale. Without having separate indoor and outdoor meters to measure actual usage, this method is reasonable for planning purposes. Since the 2015 WEP was prepared, the estimated average outdoor use for the Metered Customer Categories has increased slightly, from 43 percent in the 2015 WEP to 45 percent over the period 2012 through 2019.

Table 2: Updated WEP Table 2. Estimated Total Potable Indoor and Outdoor Water Use of Metered Customer Categories from 2012 through 2019.

Year	Estimated Indoor Use Using WWTP Influent Data Method (AF/yr)	Estimated Use Using AWC Method			
		Indoor Use (AF/yr)	Outdoor (AF/yr)	% Indoor	% Outdoor
2012	1,382	1,522	1,217	56%	44%
2013	1,364	1,407	1,107	56%	44%
2014	1,379	1,424	1,131	56%	44%
2015	1,398	1,432	1,057	58%	42%
2016	1,471	1,388	1,153	55%	45%
2017	1,515	1,434	1,223	54%	46%
2018	1,437	1,490	1,207	55%	45%
2019	1,457	1,386	1,127	55%	45%
Average	**1,425**	**1,435**	**1,153**	**55%**	**45%**

Aspen's potable water use data were further disaggregated for each Metered Customer Category as shown in **Table 3**, below. The total outdoor use for Metered Customer Categories averages around 45 percent, yet the single-family residential customer account outdoor use averages around 64 percent and has increased from 62 percent in 2012 to as high as 67 percent in 2017 and 2019. Outdoor uses are generally consumptive whereas return flows from indoor uses are generally assumed to return to the Roaring Fork River after being treated at the Aspen Consolidated Sanitation District, which results in some relatively minor losses.

Table 3: Updated WEP Table 3. Seasonal Potable Water Deliveries for Metered Customer Categories from 2012 through 2019.

	Single-Family Residential (AF/yr)		Multi-Family (2-4 Units) (AF/yr)		Multi-Family (5+ Units) (AF/yr)		Commercial (AF/yr)		City Facilities (AF/yr)		Irrigation Only (AF/yr)	Total (AF/yr)
Year	**Indoor**	**Outdoor**	**Indoor**	**Outdoor**	**Indoor**	**Outdoor**	**Indoor**	**Outdoor**	**Indoor**	**Outdoor**	**Outdoor**	
2012	522	869	63	38	312	75	557	94	69	56	85	**2,739**
2013	448	768	59	40	290	90	545	79	65	59	72	**2,514**
2014	469	798	62	36	289	77	543	103	62	37	80	**2,555**
2015	432	748	61	32	286	76	587	79	65	42	79	**2,489**
2016	441	817	63	34	273	79	546	94	66	46	84	**2,541**
2017	437	871	92	38	273	82	562	89	72	53	92	**2,658**
2018	518	880	59	39	277	64	563	102	75	39	84	**2,697**
2019	421	843	56	37	261	67	586	62	63	55	63	**2,513**
Average	**461**	**824**	**64**	**37**	**283**	**76**	**561**	**88**	**67**	**48**	**80**	**2,588**

Aspen's potable demands are higher during the summer months due to outdoor water use. **Figure 3,** below, shows the average monthly metered potable water demands from 2012 through 2019 for the City's Metered Customer Categories. The demand pattern is similar to the pattern shown in the 2015 WEP, with demands typically peaking in July. Multi-family residential and commercial water usage increases during summer months to a lesser degree than usage in the single-family residential and City facilities categories. The distribution of potable water uses between the Metered Customer Categories in Aspen are also consistent between years, as shown in **Figure 4,** below.

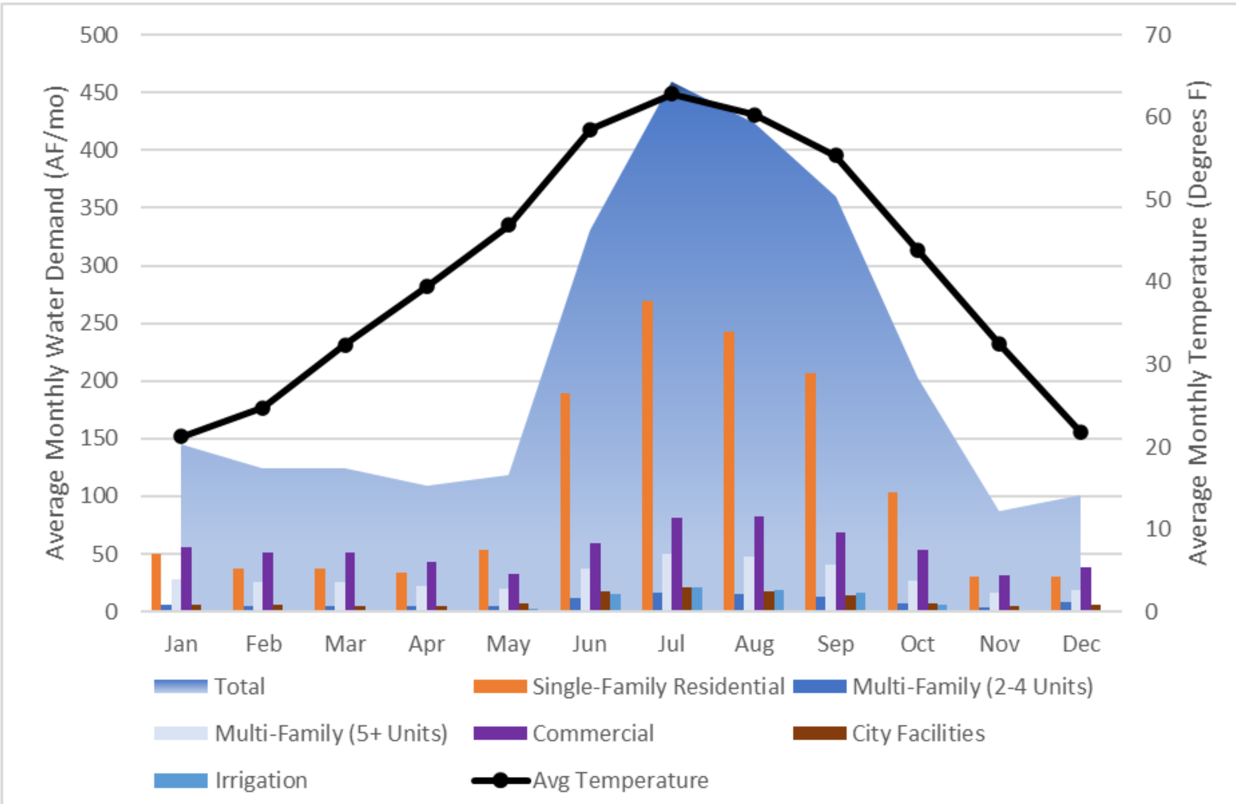

Figure 3: Updated WEP Figure 5. Average 2012 through 2109 Monthly Metered Potable Demands by Customer Category.

3%

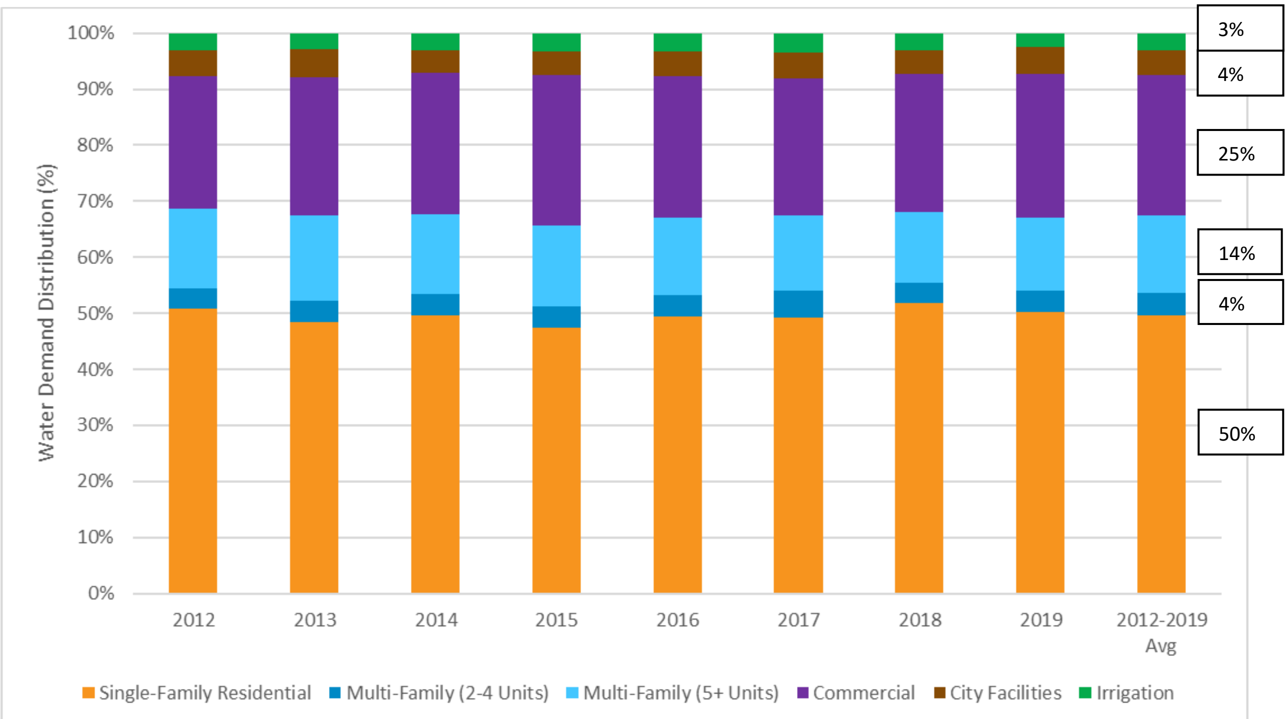

Figure 4: Updated WEP Figure 6. Metered Customer Category Potable Demand Distribution from 2012 through 2019.

1.1.2.2 Metered Customer Individual Account Analysis

Water use data, particularly metered potable water use for the residential project sector, are often "normalized" by population to create a per-capita water usage rate value that can be used to evaluate the water use relative to water efficiency benchmarks. For example, indoor residential sector efficiency benchmarks are commonly expressed as water usage per person, i.e., gallons per capita per day (gpcd). These methods are less effective for evaluating the efficiency of water uses in Aspen, where occupancy rates of second homes and lodging, as well as influences of commuters and visitors, are highly variable throughout the year. Aspen does not have an accurate representation of the seasonal or year-to-year variability in second home occupancy rates, making it impossible to compare residential indoor water use to these types of efficiency standards.

An alternative method of normalizing Aspen metered water use data is to use the equivalent capacity unit (ECU) assignment. The ECU assigned to each customer account reflects the capacity of the water system necessary to serve a given customer account and is calculated by the City based on the number and type of water fixtures, maximum irrigated area, certain cooking facilities, or other water demand factors as set forth under Section 25.08.090 of the City's Municipal Code Title 25. As a result of tracking water demand factors for building permits for all new construction and remodels, as well as limiting the total water demand in new extraterritorial water service contracts, the City has an estimate of existing and anticipated near-term future ECUs. Aspen's Water Department has determined that one (1) ECU can be approximated by a one-bedroom, one-bathroom home with a fully equipped kitchen, an exterior hose bib, and a ¾-inch domestic service line, and that a typical residential unit is equivalent to approximately 2.6 ECU[6]. The inventory of ECUs connected to the system as of February 2014 was approximately 17,500, including wholesale supply contract deliveries[7]. Considering the number of second homes in Aspen that continue to have outdoor use even when unoccupied, it could be particularly useful to normalize outdoor use by ECU rather than population.

Changes in seasonal or year-to-year occupancy may still introduce complications in using this method to normalize indoor water use data. Two customer accounts with the same ECU assignment may have different occupancy patterns, influencing different water usage amounts and patterns. Still, the ECU factor can be used as a water use evaluation tool to help screen potentially inefficient or wasteful water uses. If the water use for a given account is relatively low because the residence or lodging units are not being fully and/or continuously occupied, then the water use per (divided by) assigned ECU will be relatively low. If the water use per ECU is relatively high, then that usage may warrant further evaluation. We have prepared the following evaluations to support the City's investigation of water use efficiency.

Individual monthly billed customer account data were evaluated to identify the ten customer accounts with the highest annual potable water use in 2018[8]. To maintain anonymity, the individual account numbers and names of customers are not provided in this document. Note that all of the top water-using accounts within the commercial customer category are hotel facilities. The highest ten water users are summarized in **Table 4,** below.

Table 4: Top Ten Individual Account Usage Within the Metered Customer Category.

Account	Customer Category	2018 Water Use (gal)	2018 Water Use (AF)	ECU	2018 Water Use per ECU (AF/ECU)	2018 Water Use per ECU (gal/ECU)
A	Commercial	17,590,000	54.0	303.24	0.18	58,000
B	Commercial	10,554,000	32.4	118.26	0.27	89,000
C	Multi-Family (5+ units)	8,160,000	25.0	87.31	0.29	93,000
D	City Facilities	7,722,000	23.7	20.00	1.18	386,000
E	Commercial	7,618,000	23.4	146.31	0.16	52,000
F	Commercial	6,720,000	20.6	125.07	0.16	54,000
G	Single-Residential	6,546,000	20.1	4.66	4.31	1,405,000
H	Single-Residential	5,856,000	18.0	10.05	1.79	583,000
I	Multi-Family (5+ units)	5,560,000	17.1	87.52	0.19	64,000
J	Commercial	5,560,000	17.1	90.79	0.19	61,000

The top three accounts within each customer category are shown in **Table 5**, below**.**

[6] This value was used in the 2015 WEP and has been used by City staff through 2020. City staff have indicated that this may need to be reevaluated with more recent data.
[7] The value referenced in the 2015 WEP was 17,300 ECU.
[8] This analysis was completed using 2018 data, prior to the City's providing 2019 data.

Table 5: Top Three Individual Account Usage Within Each Metered Customer Category.

Customer Category	2018 Water Use (gal)	2018 Water Use (AF)	ECU	2018 Water Use per ECU (AF/ECU)	2018 Water Use per ECU (gal/ECU)
Commercial	17,590,000	54.0	303.24	0.18	58,000
	10,554,000	32.4	118.26	0.27	89,000
	7,618,000	23.4	146.31	0.16	52,000
Single-Family Residential	6,546,000	20.1	4.66	4.31	1,405,000
	5,856,000	18.0	10.05	1.79	583,000
	3,852,000	11.8	4.76	2.48	809,000
Multi-Family Residential (2-4 Units)	482,000	1.5	2.86	0.52	169,000
	454,000	1.4	4.00	0.35	114,000
	428,000	1.3	2.35	0.56	182,000
Multi-Family Residential (5+ Units)	8,160,000	25.0	87.31	0.29	93,000
	5,560,000	17.1	87.52	0.19	64,000
	5,404,000	16.6	160.00	0.10	34,000
City Facilities	7,722,000	23.7	20.00	1.18	386,000
	4,446,000	13.6	1.00	13.64	4,446,000
	1,888,000	5.8	10.89	0.53	173,000
Irrigation Only	3,653,000	11.2	8.00	1.40	457,000
	3,502,000	10.7	4.00	2.69	876,000
	2,216,000	6.8	20.55	0.33	108,000

Accounts with high total water use should be reviewed to better understand the usage characteristics and identify ways the City may be able to incentivize these customers through targeted outreach to increase efficiency. It is also informative to evaluate water use per ECU. Higher use per ECU, particularly within the same customer category, on certain accounts indicates that the account may not be appropriately rated or that the account's water use is high relative to other accounts in the same customer category. For example, the single-family residential and City facilities accounts shown in Table 4 and Table 5, above, have much higher water usage per ECU than the commercial and multi-family accounts, and residential account G is more than double that of residential account H. Particularly between the residential accounts, this information may indicate that account G is less efficient or that the ECU rating assigned to customer G is too low.

The annual water use of individual customer accounts was also evaluated for each Metered Customer Category. **Figure 5,** below, shows a histogram of single-family residential account water use in 2018. Just over 20 percent of all residential accounts used more than 1 AF/yr of water, and about 10 percent of the accounts used more than 2 AF/yr of water. That includes two accounts at the far right of the chart with significantly higher usage, which are the same two single-family residential accounts included in the top 10 overall water users. On average, Aspen's single-family residential accounts use under 0.2 AF/yr indoors, indicating that many of these higher water-using customers may be applying 2 AF/yr or more outdoors. Figure 5 shows a fairly wide distribution of water use throughout the single-family residential customer category. The City is aware of higher outdoor water use within certain residential areas of its service area and has begun an irrigable area investigation to further analyze water use at an account level. Using that irrigated area information and account-level water use data, the City can develop and incentivize a targeted residential conservation program designed to reduce these customers' outdoor water use, particularly any identified water waste. Conservation from the highest water users could have the largest impact on overall water use reductions.

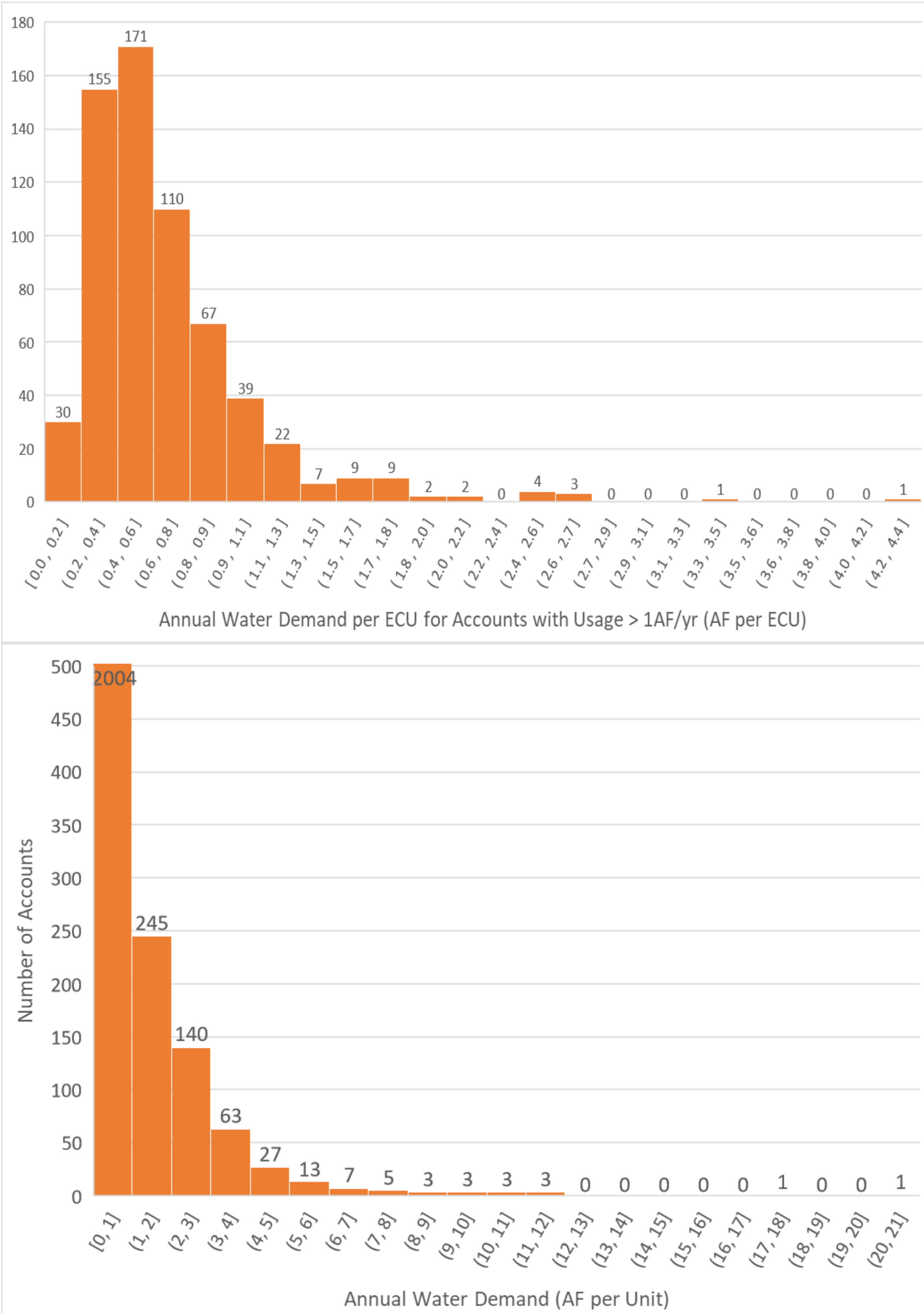

Figure 5: Individual Single-Family Residential Customer Account Annual Water Use Histograms, 2018.

ELEMENT also prepared a histogram of commercial accounts to identify those that used greater than 2 AF/yr, as shown in **Figure 6,** below. Aspen's commercial category water use is extremely variable at an account level. Just over 20 percent of active accounts used greater than 2 AF/yr, with 11 of those accounts using more than 8 AF/yr. We recommend that Aspen further investigate the type of use occurring at the highest water using commercial account properties and, depending upon the results of that review, work with the account holders to strategize about measures to increase water efficiency and eliminate any identified water waste.

Approximately 70 out of more than 2,500 single-family residential accounts and 9 out of 400 commercial accounts show water use higher than 1 AF/yr per ECU. Further investigation of water use normalized to ECU ratings should be conducted to determine if targeted outreach to customers with high water usage per ECU may help focus Aspen's water efficiency program efforts. If the ECU ratings are indicative of the originally anticipated impact on the water supply system, then it may be more effective for Aspen to focus first on the highest single-family residential accounts. An update to the ECU rating designations should also be considered.

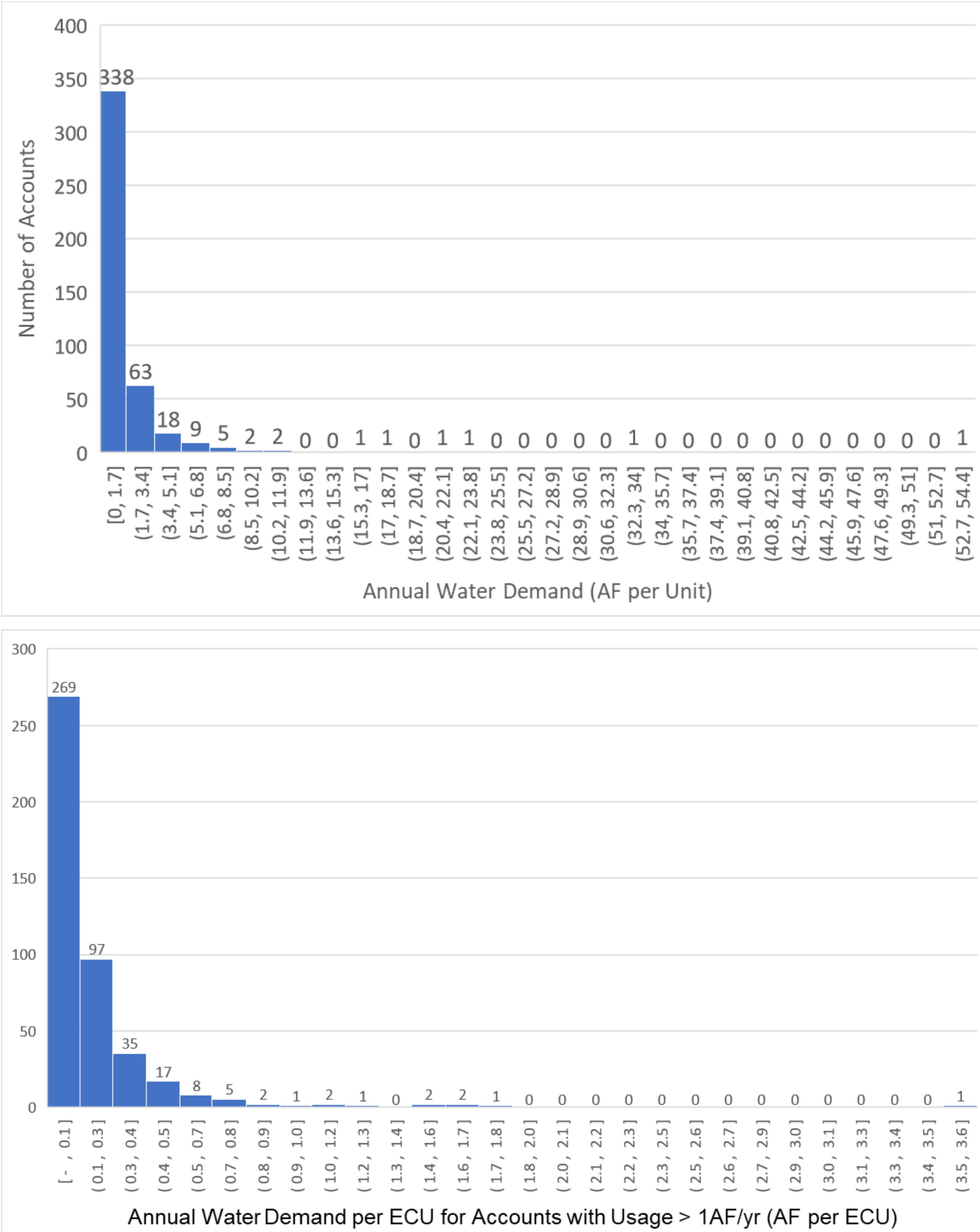

Figure 6: Individual Commercial Customer Account Annual Water Use Histogram, 2018.

1.1.2.3 "Other" Account Use

Most of the uses in this category either are consumptive or do not get treated at the Aspen Consolidated Sanitation District treatment plant. **Figure 7,** below, shows the average monthly demands by the Other use category for the period of 2012 through 2019. Snowmaking is the highest use, occurring primarily during the winter months of November through January. The demands are shown in the month in which the meters are read, and some adjustments may be needed to represent the timing of actual use. Snowmaking, for example, primarily occurs during November and December, but some measurements taken in January may represent use for December.

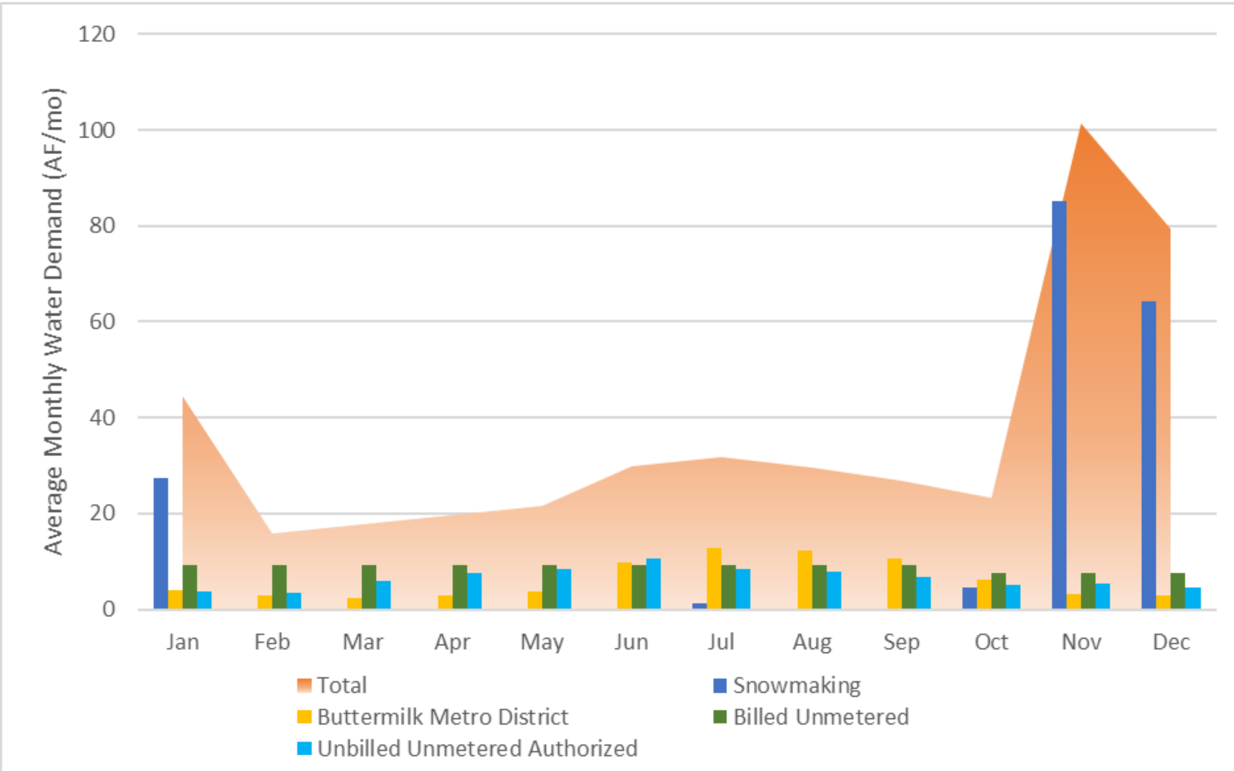

Figure 7: Average 2012 through 2019 Monthly Potable Demands for the "Other" Use Category.

1.1.3 Potable Water Production

Maximum day and average day production values were provided by Aspen and used to calculate peaking factors. A summary of Aspen's annual and peak water production values from 2012 through 2019 is presented in **Table 6**, below. The data indicate that the average daily production from 2012 through 2019 is 3.84 million gallons per day (MGD), with an average maximum daily flow of 8.09 MGD. Note that the average and maximum day flows increased through 2017 and then declined over the next two years. That is discussed in more detail later in this memorandum and shows the increasing trend in production over this period. These data indicate that a peaking factor of approximately 2.0 (measured as the maximum day production divided by the annual average daily production within a given calendar year) is typically representative for Aspen.

Aspen experiences a "second peak" during the winter, influenced by snowmaking and increased visitor populations. Since 2012, this second production peak has occurred in November or December each year. Although the ratio of the maximum winter (October through April) daily flow to the average winter daily flow is similar to the ratio of the maximum and average daily flows on an annual basis, the average winter daily flow is significantly lower than the average annual daily flow, as shown in Table 6.

Table 6: Updated WEP Table 4. Potable Water Production Characteristics from 2012 through 2019.

	Annual Peaking Calculations						Winter (October through April) Peaking Calculations			
Year	**Annual Production (AF/yr)**	**Annual Production (MG)**	**Average Daily Flow (MGD)**	**Maximum Daily Flow (MGD)**	**Peaking Factor**	**Peak Day**	**Average Daily Flow (MGD)**	**Maximum Daily Flow (MGD)**	**Winter Peaking Factor**	**Winter Peak Day**
2012	3,681	1,200	3.29	7.6	2.3	6/21/2012	1.97	3.84	1.9	12/15/2012
2013	3,314	1,080	2.96	8.0	2.7	7/24/2013	1.81	4.19	2.3	12/4/2013
2014	3,942	1,284	3.52	7.0	2.0	7/20/2014	2.42	5.02	2.1	11/17/2014
2015	4,386	1,429	3.92	8.3	2.1	7/3/2015	2.99	5.04	1.7	12/1/2015
2016	4,928	1,606	4.40	8.1	1.8	7/29/2016	3.39	6.35	1.9	12/2/2016
2017	5,378	1,752	4.80	9.8	2.0	7/7/2017	3.60	6.39	1.8	12/7/2017
2018	4,780	1,558	4.27	8.7	2.0	6/23/2018	3.04	5.71	1.9	11/8/2018
2019	4,039	1,316	3.61	7.2	2.0	7/12/2019	2.60	5.22	2.0	11/30/2019
Average	**4,306**	**1,403**	**3.84**	**8.09**	**2.13**		**2.73**	**5.22**	**1.94**	

The City's water supply modeling efforts documented in the City of Aspen Water Supply Availability Study 2016 Update (WWG 2016) relied upon 2012 as a representative year to characterize the City's water demands. As shown in **Figure 8**, below, unlike in most recent years, demands in 2012 peaked in June before a significant decline in demands through October. Aspen declared a Stage 1 Drought in June 2012, which called for voluntary water-use reductions from customers, placed water use restrictions on public facilities, and increased water rates for the City's highest billing tiers. The decline in water use starting in July 2012 may reflect a reduction in use influenced by the Stage 1 declaration, which continued through the summer of 2013, likely influencing demands through the conclusion of the declaration, in September 2013. For all subsequent years, peak production has occurred in July. Starting in 2014, production patterns show higher uses continuing through September before notably decreasing in October, before a small upswing in November and December for snowmaking and the beginning of ski season tourism. The water use volumes indicate that the irrigation season has been extending further into September in more recent years. This could relate to climate change, with customers responding to warmer temperatures, which are extending further into late summer and early fall than historically. A potential shift in timing is important to consider for planning, as the data may be indicating a change in climate and/or customer behaviors that may impact the City's future operations.

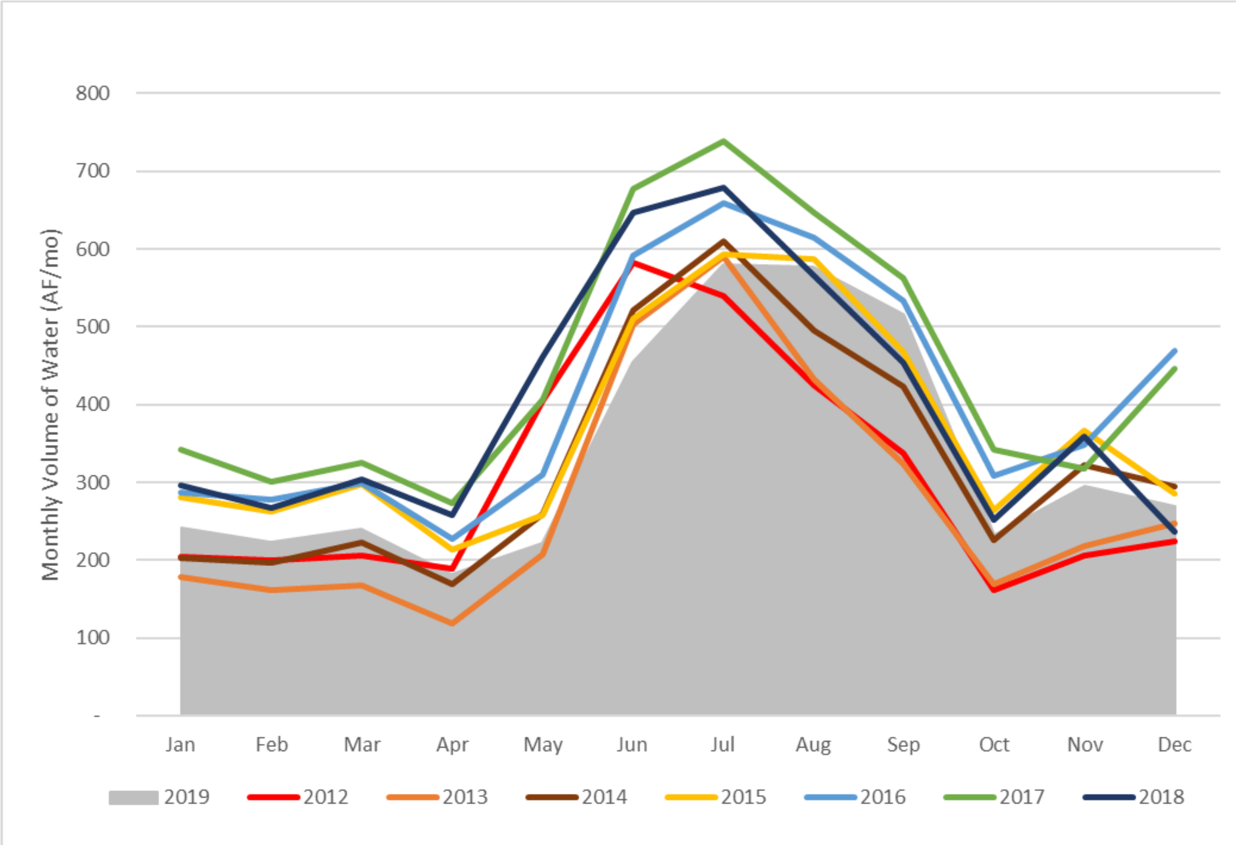

Figure 8: Historical Monthly Water Production.

1.1.4 Non-Revenue Water

After completing the 2015 WEP, the City noted a deviation between total annual potable water production and billed metered water use, as shown in **Figure 9,** below. Consequently, the non-revenue water, which is calculated as the difference between the amount of water that is treated, i.e., "produced," at the City's water treatment plants and the total billed authorized (metered and unmetered) water use, also began increasing. The calculated non-revenue water peaked in 2017, at around 2,200 AF/yr.

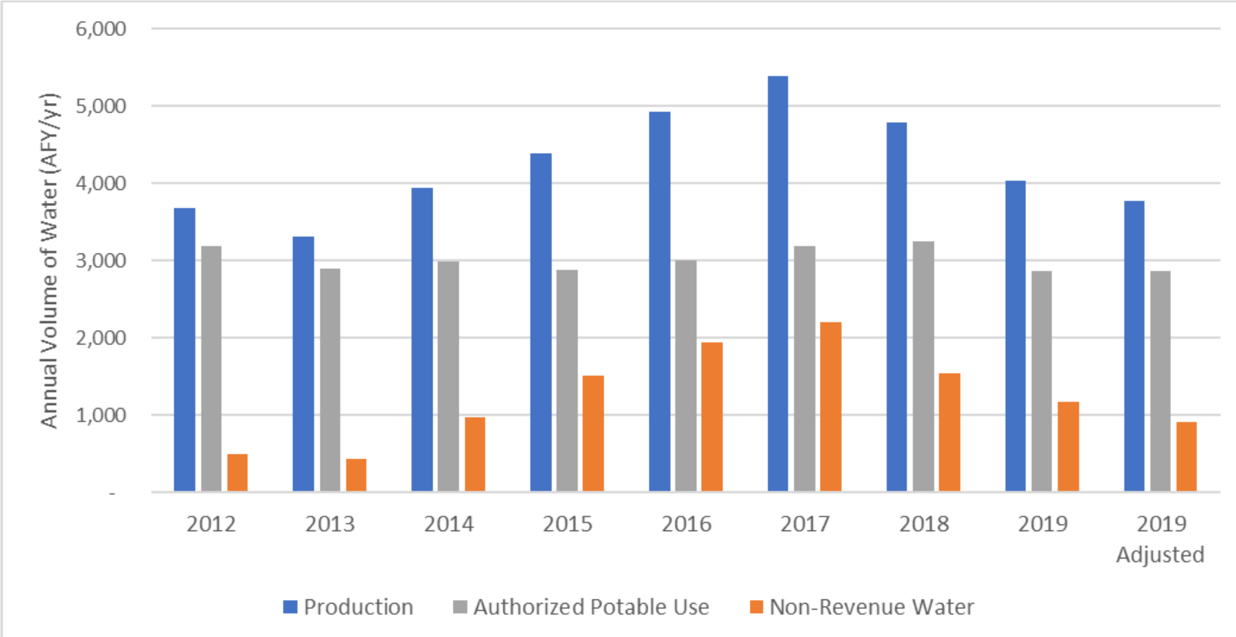

Figure 9: Annual Production, Authorized Potable Use, and Non-Revenue Water.

Based on the general trends and the physical condition of infrastructure, the City more closely scutinized the data to investigate these initial findings. One of the recommendations from the 2015 WEP was for the City to implement an enhanced water loss control program, including an annual water audit using the AWWA M36 methodology. The City subsequently completed several efforts under this program, including the following:

a. The City began preparing data and participating in the CWCB's free M36 training in 2016 and conducted water loss audits using the M36 methodology annually from 2016 through 2019. Through these audits, the City identified water loss, most of which was identified as a real loss, with portions attributed to apparent loss and unbilled consumption. The audits provided recommendations for further water loss investigations, including volumetric testing and calibration of the production water meters, advanced leak management, and water use data investigations.

b. Portions of the water identified as an apparent loss were further evaluated in 2019 through a water data review conducted by ELEMENT. Part of this data review included investigating the different demand datasets that had been relied upon for City planning efforts, and determining how the City could more effectively review and manage data to ensure consistent datasets were being used. ELEMENT investigated water use trends for available periods and recommended best practices for data management and validation moving forward. This led to the AWWA M36 Tracker becoming the City's water production and potable demand data repository, with some updates. Ongoing data review has resulted in some water use data corrections, which have been resolved and are reflected in the dataset used for the analyses in this memorandum.

c. The trending increase in non-revenue water influenced Aspen to pursue advanced leak detection and system testing. Aspen retained a third-party vendor to complete an acoustic leak survey in 2019. While this survey yielded several actionable repairs, the third-party vendor found no significant infrastructure deficiencies and noted Aspen's system to be in good repair. Aspen estimates a total savings of 570,500 gallons in 2019 for 13 repairs that were completed in response to a reactive leak repair program.

d. In 2020, the City contracted with Water Systems Optimization, Inc. (WSO) to test the City's potable water production meter. In January, WSO completed a volumetric displacement test to evaluate the production meter accuracy at low flows. In July, the production meter was tested at higher flows. Based on preliminary results, WSO identified an overread of about 6.7 percent of production, on average over the year.

The 2019 production data in Figure 9 were adjusted by 6.7 percent to reflect the preliminary findings by WSO during the production meter testing. The prior year's production data may need to be similarly adjusted.

1.2 Non-Potable Water Demands

The City uses raw, i.e., non-potable, water to meet irrigation demands at the City of Aspen golf course and certain municipal parks, for use by private landowners under raw water agreements, for maintenance of aesthetic features such as fountains, City malls, and many of the City's street trees along an open-channel ditch system. The City also uses its non-potable water supplies to produce hydroelectric power, provide non-potable water to Aspen Skiing Company for snowmaking at Aspen Highlands, and for a whitewater park. The City's commitment to supporting decreed instream flows is also described further below.

The City holds raw water agreements with customers for irrigation and snowmaking uses. Customers are either served through the City's pressurized non-potable water system or a non-pressurized open-channel ditch system. Water supplies delivered through these agreements may be owned by the City or by the customer, with the City delivering the customer's water. Customers served through the City's pressurized non-potable water system, which is supplied through Leonard Thomas Reservoir releases, are metered and billed based on measured water use. Customers served through the City's non-pressurized system are billed based on estimated water usage, but deliveries are not measured. The raw water agreements state that non-potable water service to customers is interruptible.

The following information for characterizing the City's non-potable water system was available: recent annual non-potable water billing data, non-potable water agreement GIS shapefiles, and recent daily diversion data for water rights managed by the City. Each of these data sources provided useful information, but none were fully complete or overlapping with the other datasets in a way that could provide a complete story.

1.2.1 Non-Potable Irrigation

The City serves approximately 60 irrigation customers through a non-pressurized open-channel ditch system and 11 irrigation customers through a pressurized non-potable water system via releases from Leonard Thomas Reservoir. The supply is typically available between mid-May through mid-October. Based on our understanding of the City's non-potable water uses at the time of this evaluation, the supplies in the non-pressurized system can be used legally only to meet irrigation demands.

The City bills its non-pressurized system customers using an estimated seasonal irrigation demand that it calculates by approximating the irrigation area and an estimated irrigation demand of 15 gallons per irrigated square-foot, unless otherwise specified by the raw water license agreement. The City uses this method to estimate irrigation water deliveries at the point of use; the City does not use measured or estimated river diversion for billing these customers.

Metering is mandatory for all customers on the City's pressurized non-potable water system. The City has indicated that two pressurized non-potable customers currently have inoperable meters, and it is working with those customers to resolve the issue. Totalizing meters are read intermittently, and the timing of the readings does not necessarily reflect the timing of the water use. For example, the snowmaking meter is sometimes read toward the end of the ski season whereas most of the water was used to make snow much earlier in the season.

Table 7, below, shows the water use attributed to irrigation accounts for the pressurized and non-pressurized systems in 2019. A monthly or seasonal water use pattern could be approximated from the diversion record patterns, such as the representative pattern provided in **Figure 10,** below.

Table 7: Summary of 2019 Non-Potable Water Use for Billed Irrigation Customers.

Billed Non-Potable Water Usage	AF/yr
Total Non-Pressurized via Open-Channel Ditch System	1,047
Total Pressurized via Leonard Thomas Reservoir	142

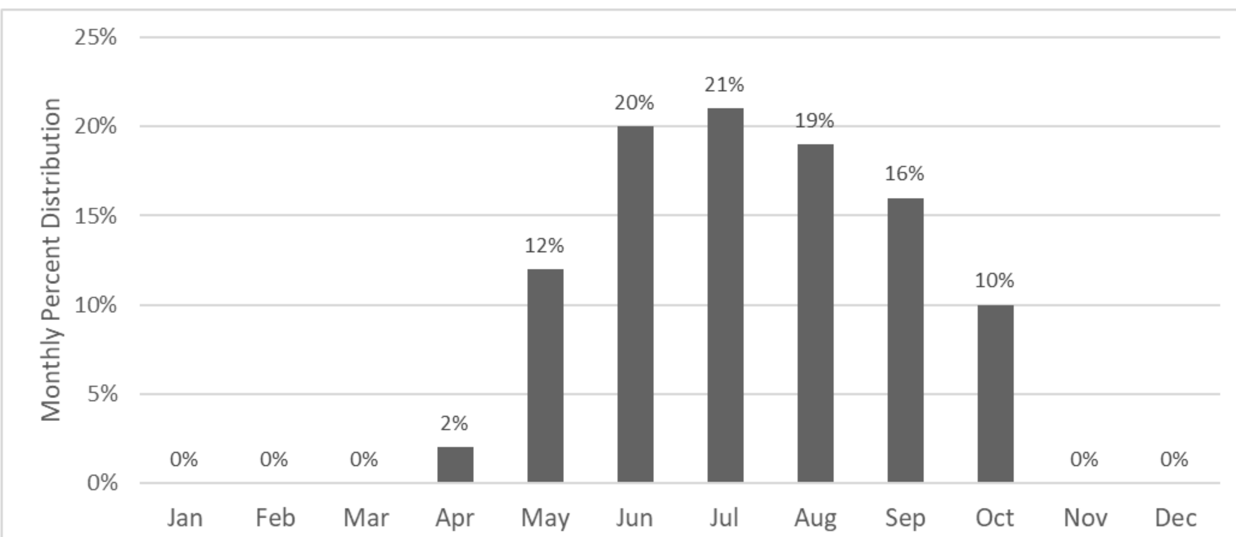

Figure 10: Average Monthly Non-Potable Water Diversions for Irrigation.

The top users under the City's non-pressurized non-potable water system include private residences, golf course irrigation[9], multi-family residence irrigation, and City facilities. The Duroux Ditch Company (the "Ditch Company") has the highest single billed demand, at over 70 percent of the City's non-pressurized billings, although the City does not own an interest in the Duroux Ditch. The City has agreed

[9] The Maroon Creek Club golf course leases water from the City's Herrick Ditch and Willow Creek Ditch water rights under a long-term lease agreement. A ditch company (not controlled by Aspen) delivers the water. The use is not included in the City of Aspen's raw water billing data.

to convey the Ditch Company's water rights through the City's Hunter Creek Flume and Pipeline diversion structure to the Ditch Company's "waterfall" area, where it enters a ditch system and is delivered to the Ditch Company's shareholders. Non-potable water customers under the pressurized system include the hospital, the Aspen school district, the Aspen Skiing Company, and housing or metro district facilities. Aspen is actively investigating its raw water agreements and customer compliance with the terms of those agreements.

Figure 11, below, was prepared from a GIS shapefile provided by the City containing attribute data for property locations associated with raw water agreements and some of the City's parks and schools that are irrigated with non-potable water. A comparison of the GIS land coverage and attribute data with the City's non-potable water billing indicates that most, but not all, locations irrigated with non-potable water from the City are shown. For example, the Aspen Golf Club (the City of Aspen golf course) is billed for and receives non-potable water for irrigation but is not designated as having a raw water agreement in this GIS coverage. Additionally, the GIS coverage combined with the billing information does not appear to represent irrigation demands associated with all of the City's irrigation ditch systems. For example, none of the City's Brush Creek water rights and only some of the City's Roaring Fork water rights are included in the GIS coverage and/or billing information. The billing data do not indicate the specific source of the water supply, but by comparing billing addresses to the shapefile, we estimate that on the order of 77 percent of billed non-potable demands are shown in Figure 11. While certainly not the largest non-potable delivery agreement land area shown in Figure 11, the majority of the billed water data is associated with Hunter Creek water that is owned by and delivered to the Duroux Ditch Company through service agreements with the City.

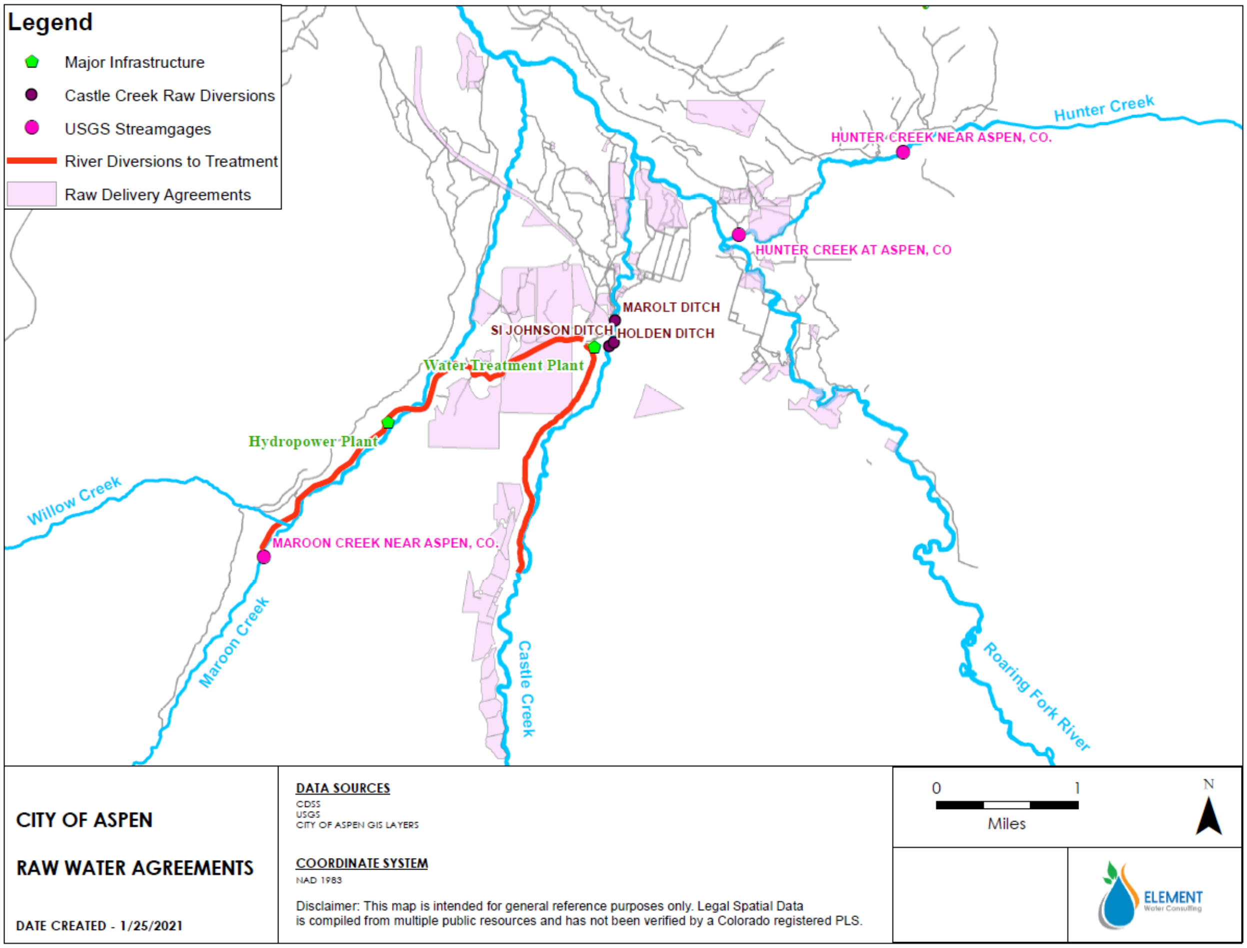

Figure 11: Aspen Raw Water Agreements.

1.2.2 Hydroelectric Power Generation

Aspen owns and operates the Maroon Creek Hydropower Plant (MCHP), which is a 400-kilowatt hydroelectric generation facility. Aspen was the first city west of the Mississippi to have hydroelectric-powered streetlights. It was built to service the mines in the area, and municipal power was an afterthought. Today, the City's electric system uses 100 percent renewable energy, of which 46 percent is hydroelectric.

The MCHP is located along the Maroon Creek Pipeline, upgradient of the City's water treatment facility, and relies entirely on water supplies from Maroon Creek. Supplies delivered to the MCHP for hydropower generation are dependent upon the physical and legal availability of Maroon Creek diversions and municipal demand needs, which vary significantly between years and throughout each year. The City voluntarily operates its senior Maroon Creek water rights to bypass the decreed instream flow (14 cfs) at its Maroon Creek intake. This may result in decreased hydroelectric diversions at times of low flows in Maroon Creek. **Figure 12** and **Figure 13,** below, show monthly and annual total deliveries of Maroon Creek water to the MCHP for hydropower generation. Note that the City did not separately account for flows to the MCHP until 2013. As shown in Figure 13, the annual hydropower diversions are regularly on the order of 20,000 AF/yr. Operationally, Maroon Creek supplies are used as supplemental supplies to meet potable demands if needed to supplement Castle Creek supplies. Flow is delivered from Maroon Creek to the Leonard Thomas system for either treatment or non-potable water deliveries through the City's pressurized system. All remaining available Maroon Creek supplies go to hydropower generation.

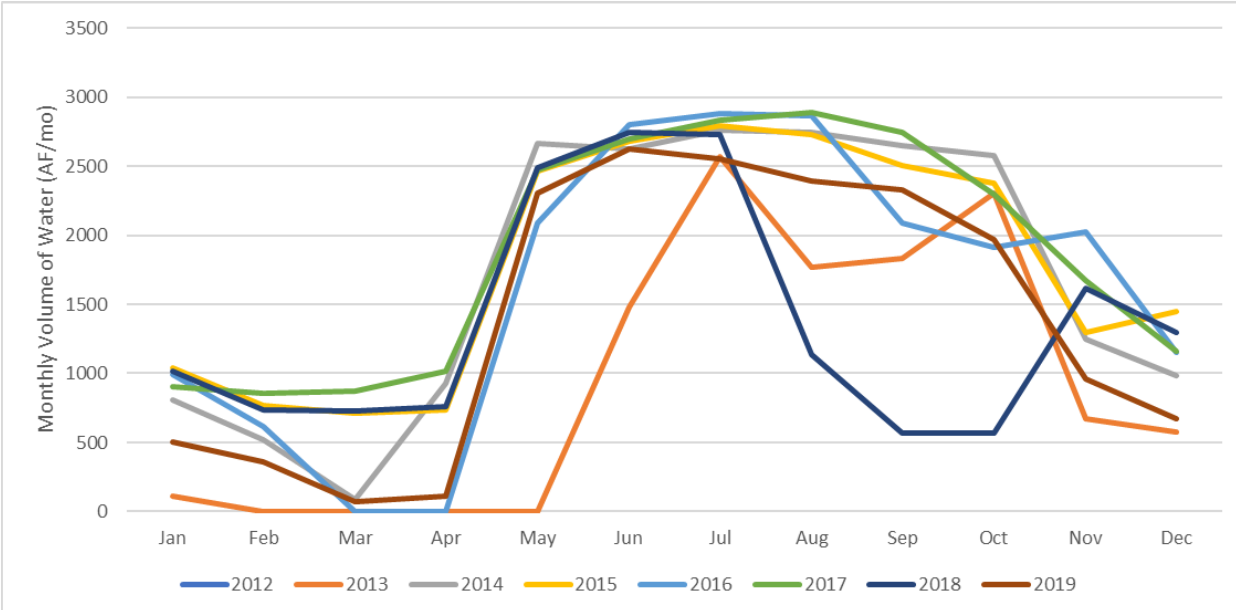

Figure 12: Monthly Diversions to Maroon Creek Hydropower Plant.

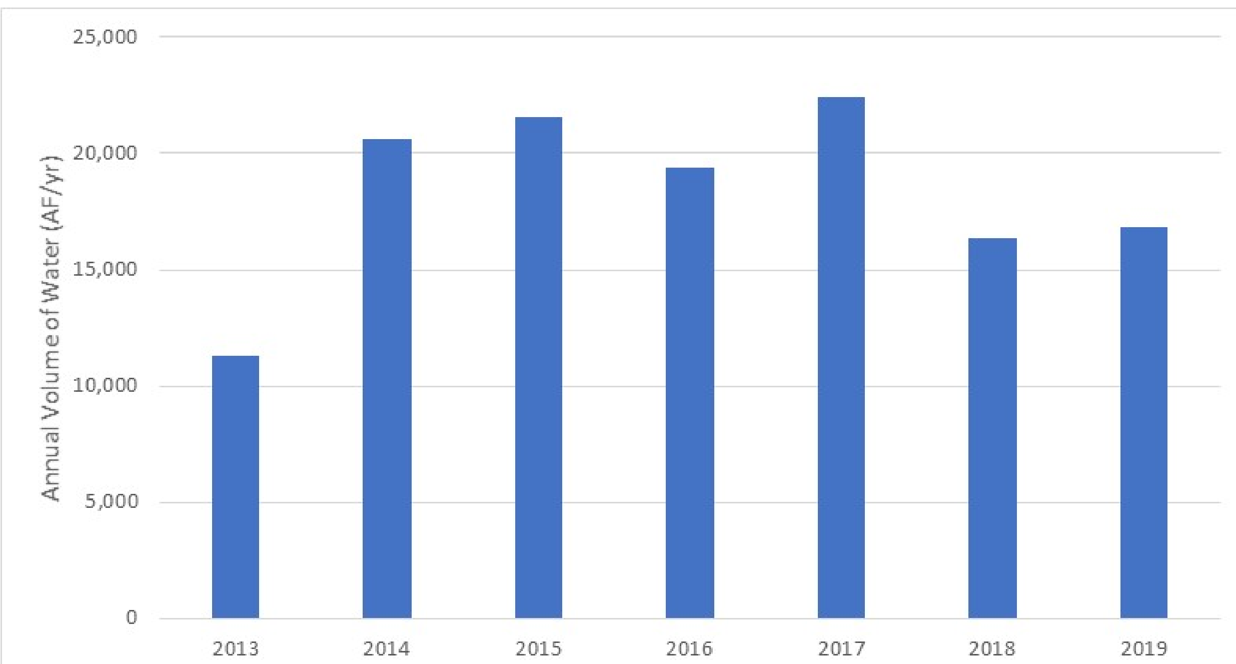

Figure 13: Annual Deliveries to Maroon Creek Hydropower Plant.

1.2.3 Snowmaking

The City has a raw water agreement with the Aspen Skiing Company to provide a non-potable water supply for snowmaking for the Aspen Highlands Ski Area. This water is supplied through a pressurized and metered connection that is read annually, near the end of the ski season. Water use for snowmaking predominantly occurs in November and December, and non-potable water is supplied to the customer meter from Maroon Creek via the Leonard Thomas Reservoir raw water outlet. Seasonal totals are available; however, the breakdown between monthly usage is inconsistent year to year and has not always been recorded. For the 2019 season, approximately 90 AF were delivered to the Aspen Highlands Ski Area for snowmaking. This is a separate location and service agreement from the snowmaking agreement for bulk potable water that was previously described above.

Additionally, the Parks department is responsible for Nordic snowmaking and seeks opportunities to use non-potable water to supply this snowmaking operation. The City has not operated the Nordic snowmaking for the past couple of years and is evaluating the potential use of existing infrastructure to support future Nordic snowmaking.

1.2.4 Whitewater Park

The City owns an absolute water right decreed for recreational boating use that supplies the Aspen Whitewater Park. The whitewater park is located adjacent to the Roaring Fork River, and diversions reenter the stream less than a quarter of a mile from the channel entrance, as depicted in **Figure 14,** below.

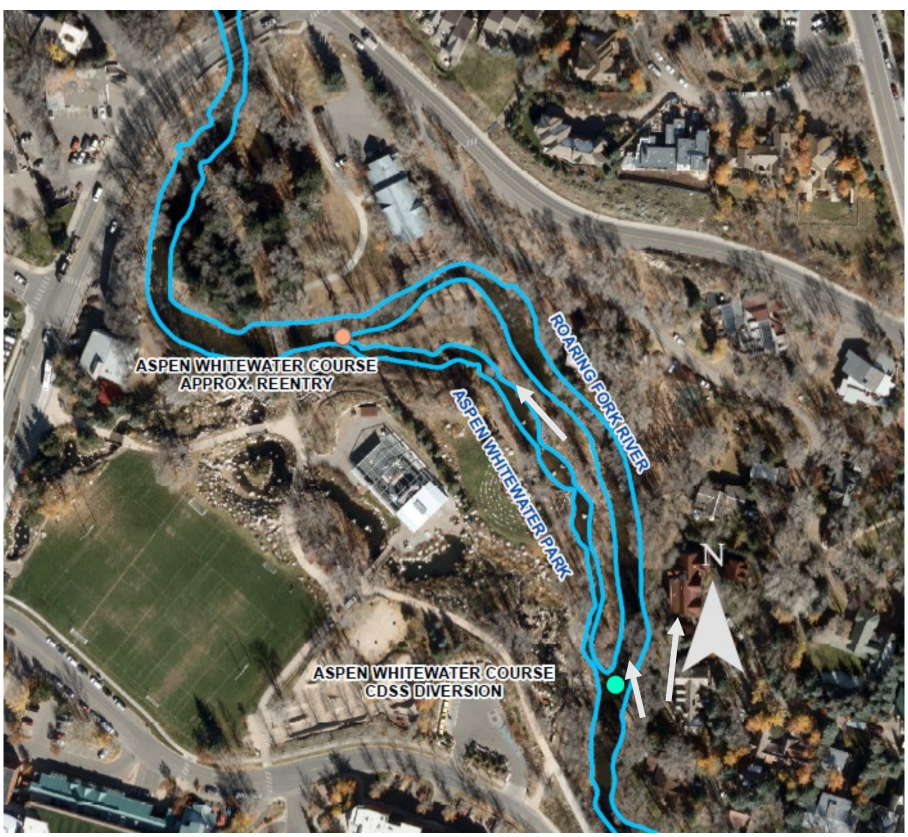

Figure 14. Aspen Whitewater Park Diversion and Return to Roaring Fork River.

The City's water right is limited to diversion from June through August, and the historical maximum recorded diversion was approximately 350 cubic feet per second (cfs) in July 2007. Diversion records for the whitewater park are shown in **Figure 15,** below.

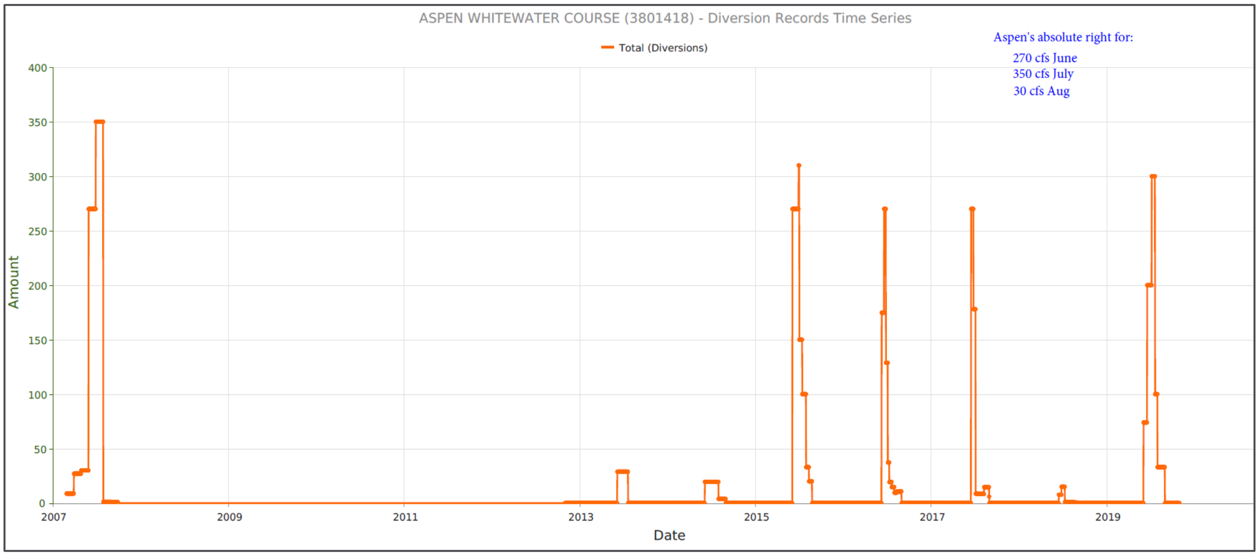

Figure 15: Aspen Whitewater Course Daily Diversions in Cubic Feet per Second.

1.3 Decreed Instream Flows

As described in the 2015 WEP, in 1980 Aspen entered into an agreement with the CWCB to allow the City's very senior 15 cfs Hunter Creek Flume and Pipeline water right to be used for instream flows on Hunter Creek, and the water court approved that use. Then, in 1993, the City Council adopted water management policies intended to provide for current and future municipal water needs while at the same time maintaining streamflow in the creeks downstream of its diversion structures at flow rates at or above the CWCB's decreed instream flow rights, for the protection of the fishery and associated aquatic habitats in those streams. This is reflected in the objectives and operating principles described in Aspen's Drought Mitigation and Response Plan, which was completed in 2020.

Aspen has an intergovernmental agreement with the CWCB to protect the natural environment of Castle Creek by operating the City's water rights on Castle Creek in a manner that will allow the decreed minimum streamflow of 12 cfs to be maintained under all conditions excepting the most severe drought conditions or emergencies. An additional 1.3 cfs flowrate is maintained below the Marolt Ditch headgate. That is not decreed but has been accepted as a rate that will maintain and protect habitat along this reach. Although Aspen does not have a similar agreement regarding Maroon Creek, Aspen also operates its senior Maroon Creek water rights in a way that protects the decreed instream flow at 14.0 cfs. More recently, Aspen negotiated temporary "forbearance agreements" with the Colorado Water Trust, in 2013 and 2014, under which Aspen agrees to not divert a portion of its senior Wheeler Ditch water right during the irrigation season, when the CWCB's decreed instream flow in the Aspen reach of the Roaring Fork River is not being satisfied.

Even though the City does not divert water to these flows in the same manner that it diverts water to meet potable and non-potable water demands, the instream flows are a priority for the City and directly affect the City's water system operations. At times, Aspen limits its river diversions to prioritize the protection of environmental flows.

2. Potable Water Efficiency Program

Aspen has implemented many of the programs that were identified in the 2015 WEP as well as the 2015 Roaring Fork Watershed Regional WEP (2015 Regional WEP). Those plans provided anticipated water savings estimates for programs described in the WEPs, and Aspen submits 1051 water use and conservation data reporting to the CWCB annually. In early 2020, ELEMENT assisted the City in developing a water efficiency program monitoring tool (Efficiency Monitoring Tool) to track and evaluate its active water efficiency programs to support City planning. The Efficiency Monitoring Tool incorporated programs and estimated savings identified in the 2015 WEP, the 2015 Regional WEP, 1051 reporting, and other City water efficiency programs. Programs were summarized and available data were populated to estimate water savings for 2019 for each active program. Potential water savings were used to help prioritize programs planned for implementation in 2020. A description of each program was prepared and qualitative and quantitative data were developed to support ongoing program evaluations. The intent is that Aspen will maintain this Efficiency Monitoring Tool in-house and update it annually to develop recommendations to continue, modify, or terminate each efficiency program.

From 2014 to 2019, Aspen has reduced its annual authorized potable demands by 115 AF/yr, or about 4 percent, as compared to the City's 2019 demands. However, savings have not been consistent from year to year, with potable demands increasing from 2014 through 2017 before decreasing in 2018 and 2019. Based on a review of the City's 2015 WEP, the 2015 Regional WEP, recent water usage and information in the City's Efficiency Monitoring Tool report for 2019, and evaluation of the City's recent top water users, ELEMENT has provided a list of recommended updates to the City's existing efficiency programs and new programs.

- Continue investigating sources of non-revenue water; if sources are identified and resolved, the City may be able to significantly reduce potable water production.
- Focus on efficiency measures that contribute the most toward targeted reductions in outdoor water use during the late summer irrigation months, when a gap between available supplies and water demand is most likely to occur. These strategies provide valuable contributions to the management of the City's water supplies and minimize the need for infrastructure investments, particularly storage. As shown in Table 3, above, the single-family customer category has the most potential for significant outdoor reductions.
- Continue investigating water use per ECU to evaluate whether ECU ratings are appropriately assigned and whether normalizing water use data by ECUs may provide a useful efficiency evaluation metric. Aspen's tiered billing rate system uses ECUs, and any improvements to ECU assignments may help influence a reduction in water use under the higher-use tiers. It could also help to recover water service costs.
- Review both the total water use and customer ECU rating to investigate high water use accounts. If water use is identified as potentially wasteful, work directly with those customers to prepare targeted, individualized plans to support water efficiency. If cases are identified in which the irrigated square footage exceeds the amount allowed under binding legal agreements, the City may be able to significantly reduce outdoor usage by enforcing contractual limits.

- Consider adding a fifth billing tier and apply aggressively high rates for the highest water-using customers. Utilize revenue from this tier to fund the City's water policy development.
- Update the City's Water Efficient Landscaping Standards to include non-potable water customers and existing potable customers. Creating outdoor water use efficiency requirements for existing development, paired with a potentially new billing tier at the highest uses, would influence current users to shift behaviors toward replacing higher water use landscaping and using more efficient irrigation practices. This program could be supported with the addition of an outdoor incentives program to help customers transition to meet the new standards. Incentives could include a turf replacement program, e.g., cash for grass and smart irrigation controller rebates.
- Complete irrigation assessment efforts to review whether customers are complying with their raw water license agreements.

3. Future Demand Projections

Future water demand projections are often created by scaling the current water use rates, e.g., values expressed in gpcd, by population projections. For this analysis, we also considered using an ECU-based method. However, long-range "build-out" type of land use planning is not currently available. The City staff provided ELEMENT with a list of the anticipated near-term projects, which total approximately 700 housing units. The associated population is well within all of the planning projection scenarios described below. If land-use planning information becomes available in the future, it may be useful to also evaluate projections based upon the anticipated number and types of residential units, commercial and non-residential space, and irrigated landscape. For this analysis, we updated the population-based method that was used for the 2015 WEP, as further described below. Multiple projections were prepared to provide a demand "envelope" for 2070 planning.

3.1 Potable Water Projections

The following sections document the methodology that was used in Aspen's 2015 WEP to prepare 2035 potable water demand projections and the updated methods that we used to prepare a 2070 potable water demand envelope for this project.

3.1.1 Aspen 2015 Municipal Demand Projections for 2035

Population is a major driver of municipal potable water demands and is one of the most common factors upon which to base future water demand projections. Aspen's demands are strongly influenced by the population of its full-time residents, water use for second homes that are not occupied year-round, visitors who come to Aspen for seasonal attractions including skiing and summer festivals and may be renting residential units or staying in hotels, and commuters working in Aspen but living outside of the service area. The 2015 WEP projection methodology accounted for all of these populations increasing into the future and assumed that similar occupancy levels would continue, along with a similar proportion of permanent-to-seasonal population relationship that existed at that time.

The 2010 Census reported the full-time population within Aspen's municipal boundary (area labeled as "City Limits" in Figure 1) at 6,658 people. The City also provides water service to areas outside of the municipal boundary that are located within the UGB[10] shown in Figure 1. The City first adopted a UGB as

[10] The portions of unincorporated Pitkin County in the UGB include Red Mountain, East of Aspen neighborhoods, the Airport Business Center, the Airport, Buttermilk Base area, and portions of the Castle Creek and Maroon Creek valleys.

part of the 2000 Aspen Area Community Plan (2000 AACP), and updated it in the 2012 Aspen Area Community Plan (2012 AACP), to delineate the boundary within which growth should be accommodated. The full-time resident population for all of Aspen's potable water customers was estimated using data from the 2012 AACP, which indicated a full-time residential population within the UGB of 9,780 in the years 2007/2008[11].

Aspen's peak population can more than triple due to seasonal fluctuations influenced by local tourism and large-scale events, including the Winter X-Games, the Food & Wine Classic, and music festivals. The peak monthly population including full-time residents plus commuters, visitors staying in second homes, and commercial lodging was estimated by using information provided by the City.

For the 2015 WEP, the average 2009 through 2013 baseline water demands were normalized by the estimated full-time population plus peak seasonal population attributed to commuters, visitors, and occupants of second homes. The baseline water demand per person was multiplied by a future population projection that increased at a rate of 1.2 percent[12] per year to develop a future baseline projection, assuming that the water use patterns of 2009 through 2013 would continue without change. All of the population categories were assumed to increase at the same 1.2 percent per year rate through the year 2035. A second 2035 potable water demand projection was prepared that included the impact of anticipated passive water use efficiencies, and a third projection was prepared to reflect the anticipated impact of the City's planned water efficiency program measures described in the 2015 WEP. The 2035 projections were prepared on an annual basis, and because occupancy rates and visitor days were assumed to remain similar into the future, the seasonal and monthly patterns of usage were assumed to remain similar to the baseline. Potential future outdoor use reductions associated with the City's water efficiency program were included in the average annual projections. However, the monthly patterns of outdoor use were assumed to remain similar to the past, and the projections did not account for impacts on water demands from future climate change conditions beyond the impacts reflected in the then-current water use data.

3.1.2 Updated Projections for 2070

As part of this analysis, a baseline demand projection and six (6) demand scenarios were developed to provide a demand envelope of potential potable water demands in 2070. For each of the six projection scenarios, four separate demand components were used to adjust the Metered Customer Category demands under future conditions:

1. Population Growth and Visitor Occupancy
2. Climate Change
3. Efficiency and Conservation
4. Non-Revenue Water

Adjustments to Aspen's "Other" categories are described in more detail below.

[11] Calculated from the 2012 AACP appendix "Population Segments Chart" as the sum of "UGB population in Affordable Housing (Owners + renters)" and "UGB population in local-owned free market residences (Owners + renters)." It is unclear from the report whether the reference to "2007/2008" is the average of 2007 and 2008 or a period spanning between 2007 and 2008.
[12] At the time of the 2015 WEP, the City was using a long-term planning growth rate of 1.2 percent per year.

3.1.2.1 Population

A more detailed analysis of how population and occupancy levels may influence future demands in 2070 was prepared for this updated analysis. The Colorado Department of Local Affairs State Demography Office (SDO) has historical full-time population data tabulated by county and municipality from 1980 through 2018. As shown below, in **Table 8,** Aspen's full-time population averaged approximately 40 percent of the Pitkin County reported population from 2010 through 2018. Over this period, the Aspen and Pitkin County full-time populations grew fairly similarly year to year except for 2015 and 2016, when Aspen had notably higher annual growth than Pitkin County. Aspen's full-time population annual growth rate calculated from the SDO data has varied from -0.4 percent to 4.6 percent between individual years and has averaged 1.3 percent over these 9 years, which is close to and supports the use of Aspen's long-term planning value of 1.2 percent. Using the 1.2 percent growth rate, Aspen's 2020 full-time population is estimated to be around 7,500 people.

Table 8: Full-Time Population Data and Estimates from 2010 through 2018.

Area	2010	2011	2012	2013	2014	2015	2016	2017	2018
Colorado	5,050,332	5,123,692	5,195,943	5,272,942	5,352,866	5,454,707	5,542,951	5,616,567	5,694,311
Pitkin County	17,156	17,176	17,300	17,469	17,722	17,946	17,953	17,941	17,882
Aspen	6,659	6,652	6,695	6,758	6,887	7,206	7,435	7,405	7,385
Aspen as % of Pitkin County	39%	39%	39%	39%	39%	40%	41%	41%	41%
Pitkin County Annual Growth Calculated		0.12%	0.72%	0.98%	1.45%	1.26%	0.04%	-0.07%	-0.33%
Aspen Annual Growth Calculated		-0.11%	0.65%	0.94%	1.91%	4.63%	3.18%	-0.40%	-0.27%

The SDO full-time population data for Aspen does not include the full-time population within the UGB that is located outside of the municipal boundary. The SDO data and 2012 AACP were used to investigate the relationship between these full-time populations, and the data sources indicate that the full-time population located within Aspen's UGB around the year 2010 was approximately 1.5 times Aspen's full-time municipal boundary population. Assuming the same relationship, the 2020 UGB population is estimated to be around 11,000 people.

The full-time population has a year-round water demand. Water demands for the non-full-time population are less clear and depend upon influences of the duration and seasonality of occupancy. There were no readily available growth projections for the Aspen UGB to rely upon for this analysis. Therefore, in addition to the SDO data, we reviewed the following data sources to investigate the relationship between Aspen's full-time and non-full-time populations:

1. The 2012 AACP includes estimated full-time and non-full-time populations, assumptions regarding the duration of an average visitor stay, and visitor occupancy levels during peak months.
2. Wastewater flows and biological oxygen demand loading patterns are an indicator of indoor water use. Aspen staff provided this data along with staff's internally developed conversions that relate both of these wastewater factors to a representative population on a monthly scale and can be used as an indicator of seasonal peaks associated with visitors.

3. Information from RPI Consulting LLC provides estimates of full-time population, commuters, overnight accommodations occupants, and part-time residents in Pitkin County. Multiple categories of the population are represented as “annual demand units,” which is consistent with the full-time equivalent population approach described below.
4. The Colorado Water Plan Technical Update (Colorado Water Plan Technical Update 2019) provides 2050 Pitkin County full-time population projections for five future demand scenarios, including scenarios that reflect more movement to mountain communities, partly in response to climate change.
5. Aspen staff observations, such as the duration of stays for non-full-time population having extended in the recent years and anticipating the trend to continue.

The recent peak season UGB population is reported to be approaching 40,000 people, and based on the references reviewed, this averages over the year to an equivalent population of almost 27,800 people. For this analysis, the 2020 annual total population within the UGB is assumed to be approximately 2.5 times the full-time UGB population.

The SDO provides a 2050 projection of full-time population for each county, and the Colorado Water Plan Technical Update provides a total of five full-time population projections for 2050. We used the historical growth rate relationships between Aspen and Pitkin County, the relationship between the Aspen municipal boundary and UGB full-time population, the historical relationship between Aspen full-time and non-full-time populations, the 2050 county projections, and staff observations to prepare a range of 2070 growth rates. The range of growth rates is included in the demand projection scenarios presented in Section 3.1.3, below. This method does not require distinguishing demands between full-time and non-full-time populations.

Table 9, below, provides a demonstration of the range of populations that could be represented by the growth rates. For example, prior planning studies have applied up to a 1.8 percent growth rate, compounded annually, to the potable water demands. This growth rate could result in a 2070 full-time population of around 27,500 people, which is near the baseline average annual total population of around 27,800 people. Alternatively, it could represent a 2070 full-time population that is less than 27,500 people, with a non-full-time population that is more than 40,000 people, for example, if non-permanent residents and their guests occupy second homes for longer portions of the year.

Table 9. Population Scenarios for 2070 Demand Projections.

UGB Population Category & Growth Rate	2020 Baseline	2070 @ 1.2% FT Growth, Current NFT	2070 @ 1.2% FT & NFT Growth	2070 @ 1.8% FT Growth, Current NFT	2070 @ 1.8% FT & NFT Growth
Full-Time (FT) Pop.	11,300	20,500	20,500	27,500	27,500
Non-Full-Time (NFT) Pop.*	16,500	16,500	30,000	16,500	40,400
Annual Avg Total Pop.*	27,800	37,000	50,500	44,000	67,900
Growth Rate	NA	0.57%	1.2%	0.92%	1.8%

*The estimated breakdown between FT and NFT population is provided to demonstrate relative magnitudes. The growth rate factor, rather than the population breakdown, is applied in the demand projection.

For the demand projection analysis, the growth rates are applied to baseline water demand volumes and represent the impact of growth associated with population and occupancy changes on water demands relative to baseline demands. Using this method, it is not critical to precisely estimate the current distribution between full-time and non-full-time populations. The broad range of potential population values shown in Table 9, particularly at the upper end, encompasses approaches used in prior water supply planning and reflects the uncertainty in occupancy rates that could have a substantial influence on water demands. We recommend that the City continue focusing on this topic, improving information about the current occupancy rates, and preparing long-range planning that can be used to prepare land-use-based water demand projections in the future. Recent influences of the COVID-19 global pandemic on water usage amounts and patterns in response to changes in population and occupancy rates may provide a new perspective on this topic.

3.1.2.2 Climate Change

Local climate change projections are not available for Aspen. Therefore, studies representing future climate-influenced conditions for Pitkin County, the Colorado River Basin, and western Colorado areas were reviewed for regional perspective. The studies indicate a range of future increases in temperature and changes in precipitation amounts and patterns under various climate scenarios that have been used to estimate the potential net increase in evapotranspiration rates and irrigation water requirements. Additionally, the Colorado Water Plan Technical Update provides county-level outdoor demand factors that can be used to project impacts to crop irrigation requirements under two warmer and drier future climate conditions in the year 2050. These factors were derived from global climate models used to generate the Coupled Model Intercomparison Project (CMIP) 3 and CMIP5 datasets, which have been used for the CWCB's Colorado River Water Availability Studies and other statewide and local planning efforts. The Pitkin County factors are: a) 21 percent increase in landscaping demands under a "Hot and Dry" future (the scenario represented by the 75th percentile of runoff projected under the combination of CMIP3 and CMIP5), and b) 13 percent increase in landscaping demands for a "between 20th century observed and hot and dry" future (the scenario represented by the 50th percentile of runoff projected under the combination of CMIP3 and CMIP5). These factors can be used to project the landscape irrigation demand increase[13] in 2050 relative to today.

Similar landscape demand adjustment factors are not currently available for the year 2070. Relating the projected climate change factors between Pitkin County and information from the Colorado River Water Availability Studies for the western Colorado region, we selected a 25 percent increase in outdoor water demand for this analysis to investigate the potential increase in landscaping demand due to climate change between the baseline and 2070. The influence of a warmer and drier future climate is considered under future scenarios by applying this percent increase to the current outdoor water demands. This provides a demand scenario in which customers respond to a warmer and drier future climate that increases irrigation water requirements by using more water to irrigate landscapes. The impacts of climate change in 2070 could be even greater. Landscaping transformations may also be made to incorporate lower water use landscaping that can survive under hotter and drier conditions, offsetting the need to apply as much water to landscapes. These possibilities were considered in selecting the 25 percent adjustment factor for this analysis.

[13] These factors should be applied to irrigation water demands (i.e., usage). For non-potable irrigation demands supplied by ditch systems, the irrigation demand should be adjusted and then the ditch conveyance loss added to estimate river diversions.

The 25 percent climate factor adjustment described above is used to project the 2070 average annual outdoor demand. Regardless of the climate status, there will be annual (as well as monthly) variability in outdoor demands, resulting in demands being higher than average in some years and lower than average in others. Figure 1-2 from the Colorado Water Plan Technical Update, shown on the right, provides an illustrative example of the historical annual variability in modeled irrigation water demands under a full water supply for bluegrass at representative climate stations throughout the state, presented as a relative change from the average demand over the historical period. This chart was summarized from an analysis that ELEMENT completed for each county. For Pitkin County, the maximum annual historical irrigation water requirement was estimated to be 27 percent higher than the historical average, indicating even more annual variability in irrigation water requirements at this location than others throughout the Colorado River Basin. Aspen's history of drought declaration has influenced outdoor water use and kept the City from experiencing as much increase in outdoor use during drought periods as it would have without the drought declaration. However, in addition to the 25 percent climate factor that is used in the analysis below to project average annual demands in 2070, water supply planning should consider the annual variability of demands that will result in even higher outdoor demands (e.g., 27 percent higher than shown below) in future hot and dry years and lower demands in future cooler and wetter years, averaging out to the projections provided below.

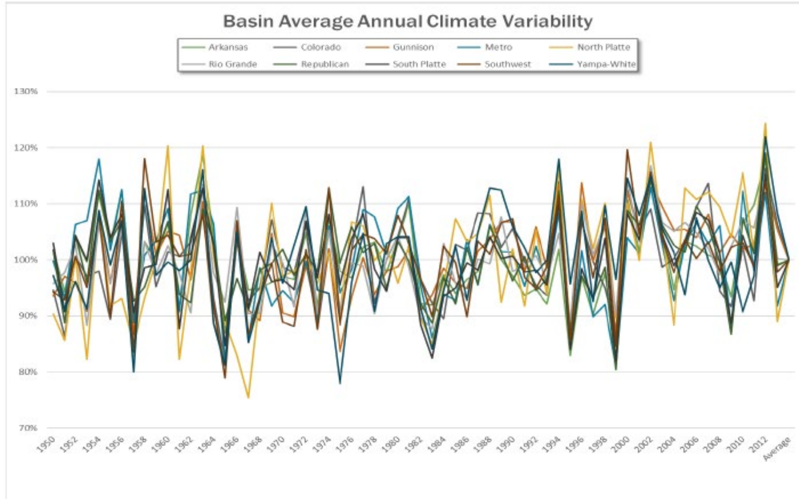

Figure 1-2: Basin Average Annual Variability in Bluegrass ET.

3.1.2.3 Efficiency and Conservation

Aspen's water efficiency program is designed to meet relatively near-term water use reduction goals. A set of new recommended conservation and efficiency programs is described above and focuses predominantly on outdoor water use, particularly programs that can result in outdoor water use reductions during the late summer irrigation season. Aspen staff and customers have historically demonstrated a high level of dedication to the efficient use of natural resources, including water, and it is anticipated this commitment will continue. For the 2070 demand projections, it is assumed that Aspen will continue to advance its conservation initiatives and efforts beyond the programs defined herein. Considering that Aspen's current indoor use is already relatively low and that Aspen staff report a significant amount of remodeling throughout the City that has resulted in updates to higher efficiency plumbing fixtures and appliances, a modest level of additional indoor savings of 2 percent was included in each of the 2070 projection scenarios. A combination of low (5 percent), medium (10 percent), and high (20 percent) levels of outdoor savings are evaluated for ongoing and future outdoor efficiency programs, which is consistent with the range used for the Colorado Water Plan Technical Update. Although these values are reasonable for planning purposes at this time, additional indoor and outdoor water savings are likely possible through the implementation of a more advanced water efficiency program. For example, substantial outdoor water savings may be achievable through expanding the landscape ordinance to include existing landscapes, a fundamental shift in landscaping choices and/or strict irrigated lawn-reduction rules, and ongoing enforcement of water budgets.

3.1.2.4 Reduction in Non-Revenue Water

For the 2070 demand projections, non-revenue water is represented as a percent of the future water production, which is different than the categories that apply a percentage increase or decrease to a future baseline demand. Future scenarios with the lowest non-revenue water percent reflect aggressive efforts to reduce Aspen's non-revenue water over time. The City has already implemented annual water loss audits and advanced investigations, so it is reasonable to assume these efforts will continue and support a sustained 15 percent non-revenue water value. Although it is also possible that the non-revenue volume and percentage of total production could decrease in the future, until the sources of non-revenue water are more clearly identified, the City's water supply planning should recognize the possibility of a future decrease in the non-revenue category being related to end uses that are not currently metered or that currently have metering inaccuracies. With the inherent uncertainty in non-revenue water projections, medium (20 percent) and higher (25 percent) percentages of non-revenue water were included in some of the scenarios.

3.1.2.5 Adjustments to "Other" Use Categories

Using information provided by the City, ELEMENT applied the following projected demands for the "Other" potable water use categories to all of the projection scenarios:

- The City anticipates that the Aspen Skiing Company may expand its future snowmaking coverage from approximately 172 acres up to about 340 acres, which would cover approximately half of Aspen Mountain's current acreage. Based on an estimated water demand of 1.07 AF per acre (AF/acre), the future potable water demand for snowmaking is estimated at around 360 AF/yr.
- The Buttermilk Metro District future delivery is estimated at 108 AF/yr, which is the maximum volume in the City's bulk treated water delivery agreement with the District.
- The unmetered and unbilled authorized uses are estimated using the average historical demand between 2012 and 2019. No compelling information is available at this time to develop an adjustment to this category.

3.1.3 Demand Projection Envelope

The average annual water use data over the period 2012 through 2019 were used to develop a "current" (2020) baseline water demand. There has been relatively little variability in the metered water use for this period, even though there has been more variability in the production data. Averaging the years with relatively low and high non-revenue water results in a baseline that reflects the more recent decreased non-revenue water volume while still capturing the elevated levels over recent years that had not been observed during the WEP development.

Recognizing that the future is unpredictable, ELEMENT prepared six unique 2070 demand projections using reasonable combinations of the critical demand drivers described above to support the City's water planning efforts. The demand projection scenarios and the respective demand drivers shown in **Table 10** were applied to the 2020 baseline demands to create a 2070 demand envelope. These drivers were applied to all Metered Customer Categories. The potable water demands categorized as "Other" uses were projected as described in Section 3.1.2.5, above. The resulting total projected 2070 annual UGB demands are shown in **Figure 16,** below.

Table 10: Metered Customer Category Drivers for 2070 Demand Projections.

Drivers	Growth Rate	Climate Change Impact	Efficiency & Conservation		Non-Revenue
Potential Level of Future Demand Relative to Baseline	% Increase to Metered Customer Demands	% Increase to Outdoor Demands	% Decrease to Indoor Demands	% Decrease to Outdoor Demands	% of Total Production
Scenario A	0.57%	0%	2%	10%	20%
Scenario B	1.20%	25%	2%	5%	25%
Scenario C	1.20%	25%	2%	15%	25%
Scenario D	0.92%	25%	2%	5%	20%
Scenario E	0.92%	25%	2%	15%	15%
Scenario F	1.80%	25%	2%	5%	20%

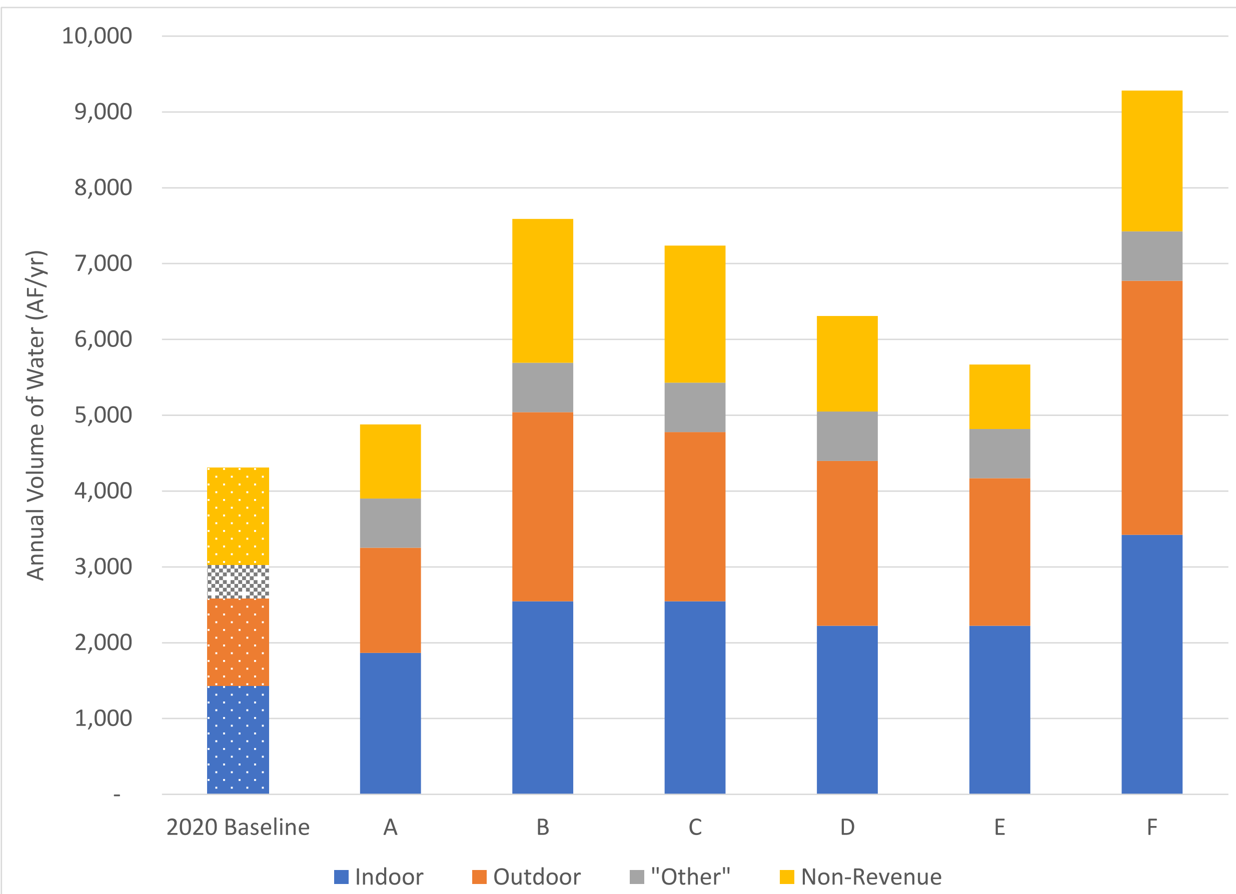

Figure 16: 2020 Baseline and Projected Potable Water Production in 2070 for the UGB.

The Scenario B projection is very close to the result of using a 1.2 percent growth rate without applying the water efficiency and climate drivers, indicating that the water efficiency and non-revenue water management could nearly offset impacts from climate change under a 1.2 percent growth scenario. Scenario F is provided here for a comparison to the prior planning. The total 2070 projected volume for Scenario F would be similar to the total 2050 projected volume under the highest growth rate scenario used in the City of Aspen Water Supply Availability Study 2016 Update if the climate adjustment were not applied to Scenario F (the City of Aspen Water Supply Availability Study 2016 Update analysis did not include a climate adjustment).

The climate references relied upon for this analysis are currently available only for the year 2050, and therefore we provided a recommendation for 2070 planning values. No reliable references are available to provide interim-year projections at this time. There is uncertainty in whether demands will grow linearly between the baseline and 2070 projections. However, for water supply planning purposes, it may be useful to use interim projections, e.g., linearly interpolated decadal projections, to monitor demands and inform future planning projections. Certain water supply planning decisions may be clear under all of the projections while others can be delayed and informed by the ongoing monitoring and updated demand and supply projections.

3.1.4 Projected Demand Pattern

The seasonal timing of demands will also have a strong influence on whether Aspen can meet its projected future demands. Monthly demand patterns are likely to shift in the future in response to a changing climate, with warm weather starting earlier and continuing later each season, extending the irrigation season both during the runoff season and late into the summer months, when river supplies are low. Aspen staff have reported observing this late-season irrigation shift over more recent years, with irrigation continuing well into September, increasing the vulnerability to a water supply shortage. **Figure 17**, below, demonstrates the variability in timing between years. As additional local climate change information becomes available, Aspen should continue evaluating whether to plan for a more significant shift in monthly demand patterns.

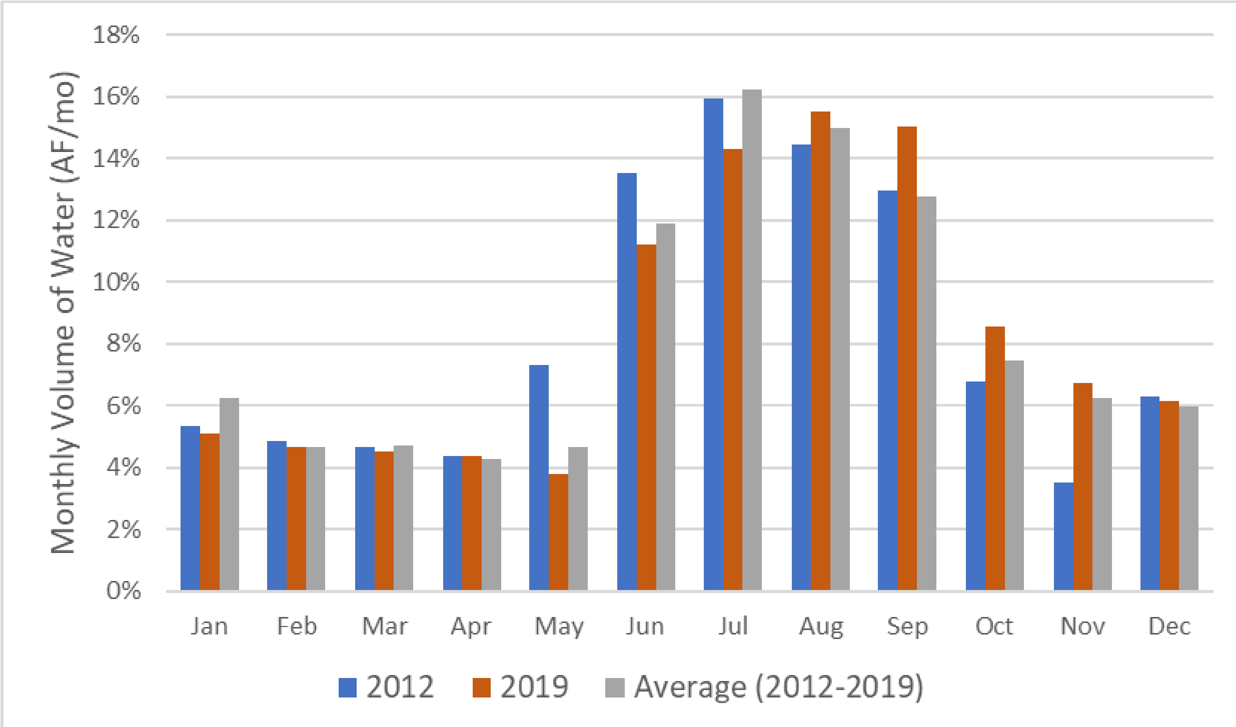

Figure 17: Monthly Potable Metered Water Demand Pattern.

3.2 Non-Potable Water Projections

The 2015 WEP addressed only potable water demands. The methods used to project future potable demands are not directly transferable to non-potable demands for several reasons, including data availability and that many of the non-potable demands are constrained by legal agreements and water court decrees. The following sections document potential approaches and limitations in developing a 2070 non-potable water demand projection for specific non-potable water use categories. Suggestions for representing non-potable demands in the IRP are provided in a separate technical memorandum from ELEMENT to Carollo Engineers.

3.2.1 Non-Potable Irrigation

According to the City's 1984 Raw Water Supply Update, growth in the use of the non-potable water irrigation system was not expected to keep pace with the growth in the potable water demand, partly because a large portion of the diverted flows was to satisfy aesthetic uses. The 1984 report projected an overall increase in diversions of 20 percent for the year 2005. We have reviewed the information available at this time and conclude that it is insufficient to make a similar type of projection. The following information supports this conclusion.

Based on our correspondence with City staff, Aspen anticipates that its customers' interest in non-potable water will likely increase in the future as current potable customers explore opportunities to use non-potable water for irrigation. Assuming these are current customers of the City, the overall demand on the river would not necessarily change. Rather, the source of water supply would change. This could help mitigate the need to increase potable water infrastructure capacity in the future and may have other water quality benefits by using fewer chemicals to treat water that is used for landscaping. Any customers transitioning to raw water agreements for irrigation will need to be located along the City's non-potable water delivery system, which may limit the expansion of non-potable water use without modification to the delivery system.

Readily available information for existing and potential future non-potable water demands within the City's system is incomplete at this time, making it challenging to specify additional areas that could be served by non-potable water in the future. The City's current mapping files do not identify all of the locations with current raw water agreements for irrigation, and some of the City's non-potable water supplies that are likely being used for irrigation are not attributed in these files, making it difficult to identify the current or potential future location of use. Cross-referencing the accounts in the City's billing data tracker with the mapping files indicates that not all non-potable water irrigation use is represented in either data source. Additionally, both sources include water use for customers with raw water agreements for delivery through which the City delivers the water but does not own the water rights subject to an agreement. To support future non-potable water demand planning efforts, the City's non-potable water billing data and mapping files should be reviewed together and updated to reflect all non-potable irrigation and to designate current non-potable water irrigation use from the City-owned water rights.

The City's water rights accounting and diversion records, available through the Colorado Division of Water Resources, were also considered. If historical diversions and accounting data are complete, it could be possible to pro-rate the diversions based on the City's water rights ownership, estimate ditch losses, and estimate a landscape irrigation efficiency to calculate historical non-potable water irrigation with the City's rights. However, advanced investigations including ditch operations would be needed for this type of historical use analysis. Future hydrologic conditions, water rights terms and conditions, and the ability to expand areas of non-potable water irrigation on each ditch system would need to be considered before projecting future non-potable water irrigation demands using this data. Because each ditch system's hydrologic conditions, ditch operations, and water rights terms and conditions are unique, ELEMENT recommends a separate analysis of non-potable water irrigation demands that also considers the legality of increasing future uses by the expansion of irrigated areas. Decrees for each water right should be evaluated alongside the original and current service areas for each ditch to evaluate historical and current use to determine the opportunity to legally expand non-potable irrigation.

3.2.2 Hydroelectric Power Generation

Water use at the MCHP is operated as a variable demand dependent on supply availability and operational constraints. The City has defined hydropower production as its lowest water use priority within the City's system. This means that all potable demands and decreed instream flows on Maroon Creek must be met before water is delivered to the MCHP. Hydraulic limitations on the Maroon Creek Pipeline system constrain how much water can be delivered to the MCHP at the same time water is being delivered to the WTP. This operational limitation could potentially be resolved in the future through infrastructure expansion and improvements.

Future hydrology impacts from climate change will directly influence the City's operations to meet potable demands and continue to support decreed instream flows that are prioritized over the City's hydroelectric power generation. This will likely reduce the amount of water available for hydroelectric power generation in the future. Prior water supply planning and modeling efforts did not explicitly characterize hydroelectric power generation demands in the water supply gap analysis, but extensive logic was built into the City's water supply model to further investigate operational impacts to supply availability at the MCHP (WWG 2016). We recommend that the City rehabilitate its water supply model to further investigate future water supply availability for hydroelectric power generation.

3.2.3 Snowmaking

Based on current snowmaking operations and planning, the City has estimated that in the future Aspen Skiing Company may expand its snowmaking coverage at the Aspen Highlands from approximately 253 acres up to about 505 acres, which accounts for approximately half of the Aspen Highland's acreage. Based on an estimated 1.07 AF/acre, this is approximately 540 AF/yr of non-potable water for snowmaking at Aspen Highlands in the future. The Aspen Highlands is currently supplied using non-potable water through the City's pressurized system. Additionally, the City has expressed a desire to supply non-potable water for snowmaking at the City of Aspen Nordic park. Aspen estimates this demand to peak by 2050, with approximately 37 acres of coverage for snowmaking, resulting in a future demand of approximately 40 AF/yr. These two demands would result in a total projected snowmaking demand through the City's non-potable water system of about 580 AF annually by 2070.

3.2.4 Whitewater Park

Water use associated with the City's whitewater park represents a non-consumptive demand that returns directly back to the Roaring Fork a short distance downstream from the diversion location. The water right associated with this use is defined as recreational and is decreed for use at the existing location. Because this use will not contribute to a municipal demand gap, future demand is not projected under this evaluation.

4. Conclusions

The City's 2015 WEP relied upon potable water demand data from 2009 through 2013 and provided demand projections for the year 2035. Since that time, the City has experienced consistent population growth, continued to implement water efficiency programs and measures, and identified an increase in non-revenue water that was not accounted for in prior planning. For this evaluation, we relied upon more recent potable water demand data, using the period of 2012 through 2019 to develop a new baseline demand that reflects more recent water demand conditions. ELEMENT reviewed the City's current water efficiency program and provided recommendations for near-term updates. Aspen's potable demands are expected to continue growing through 2070 (the selected projection year for the IRP) and beyond, influenced by full-time population growth, increased visitor rates, and potential increases in outdoor water use driven by hotter and drier climate conditions. For this study, we applied a range of demand drivers to the updated demand baseline to create a 2070 demand projection envelope that will support the City's ongoing planning efforts.

Planning related to the City's population-influenced demands is particularly complex, due to the variable nature of its non-permanent residents, visitors, and commuters. We recommend that the City continue to obtain information on this topic, including occupancy rates of permanent and non-permanent residences and lodging, and develop long-range land use planning that can be used to better inform future growth rates and water demand projections. Climate change and its impacts on evapotranspiration rates and irrigation water requirements are also anticipated to have a significant impact on the City's future demands. The impact is anticipated to require more outdoor water use if landscaping remains similar to today's.

Climate change modeling is constantly advancing, and we recommend the City continue working with experts in this field, as well as monitor climate change indicators such as weather factors that influence evapotranspiration rates (e.g., temperature, solar radiation, wind, humidity), snowpack, irrigation-season precipitation, soil moisture, and types of landscaping being irrigated by the City and its customers. We also recommend the City continue to advance its water efficiency programs into the future, monitor its water use, and update its demand planning as new data and science becomes available. These actions will support sustainable growth and protect natural conditions and stream health in the Aspen valley as the City continues to grow and thrive. Through its dedication to water efficiency programs and ongoing water planning efforts, the City will continue to meet the needs of its customers while maintaining its environmental stewardship.

It should be noted that reductions in potable demand that are achieved through the City's water efficiency program and changes to raw water demand diversion amounts and timing, such as reducing raw water irrigation, may impact the supply system. If less water is diverted into ditches, there will be fewer delayed return flows from ditch seepage and irrigation return flows. Depending on the amount, timing, and location, those delayed return flows could have historically returned to the stream at a location and time when the water was needed. The benefit from diverting less water during high flow periods may not be as great as the benefit from late-season delayed return flows. This topic should also be further investigated as the City continues to advance its water supply planning.

5. References

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WEP 2015: City of Aspen Municipal Water Efficiency Plan. Prepared for the City of Aspen by ELEMENT Water Consulting Inc. and WaterDM. October 2015.

WWG 2016: City of Aspen Water Supply Availability Study 2016 Update. Prepared for the City of Aspen by Wilson Water Group. June 2016.

Appendix D
WATER SUPPLY MODEL DETAILS

PROJECT MEMORANDUM

INTEGRATED RESOURCE PLAN

City of Aspen

Date:	November 2021
Project No.:	11690B.00

Prepared By:	Rachel Gross
Reviewed By:	John Rehring
Subject:	Aspen Supply Modeling Assumptions

Introduction

This memorandum documents the basic modeling structure, data sources, and assumptions used in the supply model built for the 2021 *Aspen Integrated Resource Plan*. The primary purpose of the model is to assemble and characterize water supply portfolios that meet the minimum threshold of avoiding shortages in the year 2070 through the use of supply options and drought restrictions.

Model Structure

The water supply model is built in Microsoft Excel. It has a monthly timestep and covers the 25-year hydrologic period from 1970 to 1995. This hydrologic period was used in the model because this is the period of historical hydrology and associated climate change projections available from the *2016 Water Supply Availability Study Update* (WWG, 2016). Annual calculations in the model follow the water year (WY) calendar (October through September) rather than the calendar year (January through December). Each timestep includes available water supply from current and future supplies including:

- Castle Creek,
- Maroon Creek,
- Hunter Creek,
- Groundwater,
- Reuse,
- Storage, and
- Drought restrictions.

Each timestep also includes total potable demand from the WTP as well as non-potable demand served from the Leonard Thomas Reservoir (LTR). If demand exceeds all available supplies, the difference between demand and supply is counted as a shortage. This includes the ability to satisfy instream flow goals on Castle Creek and Maroon Creek, but it does not reflect the ability or inability to provide water to the Maroon Creek Hydroelectric Plant because that facility is typically operated only when water availability allows.

Castle Creek flows, Maroon Creek flows, and water demand are included in every scenario. Hunter Creek, groundwater, reuse, storage, and drought restrictions (based on the City's existing drought restriction stages) can be turned on or off to create different water supply portfolio scenarios. Enhanced conservation can be considered in the model through using the appropriate demand scenario.

Demand Scenarios and Enhanced Conservation

Six different potable demand projections were developed for this analysis by Element Water in the 2021 *City of Aspen Water Demand Projection Update*. Any of these six projections can be used in the model by the user inputting the corresponding number (Scenarios 1 through 6) into the model. Additional scenarios include the worst-case future demand that includes enhanced conservation (Scenario 7) and current demands (Scenario 8). Selecting a scenario will cause the model to reference the monthly demand projections associated with that demand scenario. Projected 2070 demands are used for each year in the 25-year timeframe of the model and are constant from year to year.

Castle Creek

Castle Creek total flow at the intake for the historical scenario and five climate projection scenarios was provided by Element Water based on the *2016 Water Supply Availability Study Update* (WWG, 2016). These flows are based on the old USGS Castle Creek gage (Castle Creek Above Aspen) and have been translated to represent flows at Aspen's Castle Creek Intake. The model starts with the Castle Creek flow from the selected hydrologic scenario and then subtracts downstream non-potable demands that must bypass the intake and instream flows. Downstream non-potable demands on Castle Creek were developed by Element Water and area seasonal, starting in May, peaking in June, and ending in October. Instream flow goals are a constant 13.3 cubic feet per second (cfs), including the 12 cfs Colorado Water Conservation Board (CWCB) decreed flows on Castle Creek and the additional 1.3 cfs flowrate maintained below Marolt Ditch headgate, which is the accepted rate that will maintain and protect habitat along this reach. Following the removal of the downstream non-potable demands and the instream flows, an additional 5 percent of flow is assumed to be lost through conveyance and/or while in storage at LTR. Thus, the net available supply from Castle Creek is the total flow at the City's Castle Creek Intake minus downstream non-potable demands, instream flows, and conveyance losses.

Note that the 4.5 cfs "kicker" demand included in some previous water supply modeling was not included in this model based on discussions with the City and Element Water. The "kicker" demand represented historical operations that required over-diversion of flow to supply the desired flow rate to LTR and the water treatment facility. Upgrades to the system have eliminated the need for such over-diversions.

Maroon Creek

Available supply from Maroon Creek is modeled similarly to available supply from Castle Creek. The model starts with total flow at Maroon Creek based on the selected hydrologic scenario. This flow was provided by Element Water based on the *2016 Water Supply Availability Study Update* (WWG, 2016), which translates Maroon Creek streamflow at the old USGS Maroon Creek gage (Maroon Creek Above Aspen) to the flow at the City's Maroon Creek intake. This flow already accounts for the typical bypass of senior water rights. The 14 cfs of CWCB-decreed instream flows is subtracted from the flow at the Maroon Creek Intake. Finally, five percent of the remaining flow is assumed to be lost in conveyance and/or while in storage at LTR. Thus, the net available supply from Maroon Creek is the total flow at the Maroon Creek Intake (which considers typical senior rights bypass) minus instream flows and conveyance losses.

As described above, the 4.5 cfs "kicker" included in some previous water supply modeling was not included in this model based on discussions with the City and Element Water.

Hunter Creek

Streamflow data for Hunter Creek are somewhat limited, but the most complete USGS dataset from the Hunter Creek at Aspen USGS stream gage is from 2009 through 2020. This does not overlap with the 1970 through 1995 hydrology used for Castle Creek and Maroon Creek, so a synthetic hydrograph for Hunter

Creek was created for this period using quantile analysis. The available years of Hunter Creek hydrology were sorted into five year types: Very Dry, Dry, Average, Wet, and Very Wet. These year types were then assigned to Castle Creek and Maroon Creek so that the Hunter Creek synthetic hydrograph followed the same hydrologic pattern as Castle Creek and Maroon Creek. For example, both water WY 2010 and WY 2015 were considered "Wet" years for Hunter Creek. Therefore, the average flow from WY 2010 and WY 2015 was used to define a Wet year for Hunter Creek. WY 1971 was a Wet year for Castle Creek and Maroon Creek, so the Wet year Hunter Creek hydrology was used for WY 1971. There is a 2 cfs senior water right on Hunter Creek that is subtracted from the Hunter Creek streamflow to determine available supply from Hunter Creek. Similar to Castle Creek and Maroon Creek, five percent of the Hunter Creek flow is assumed to be lost through conveyance to the WTP. The City's water right to Hunter Creek is limited to 15 cfs, so available supply cannot exceed 15 cfs in any given month. Thus, the available supply from Hunter Creek is equal to the streamflow in Hunter Creek minus senior water rights and losses, up to 15 cfs.

In the model, Hunter Creek flows only get used if there is not enough flow in Castle Creek and Maroon Creek to meet demand, so the model calculates how much Hunter Creek flow is used on a monthly and annual basis for each portfolio it is included in.

Hunter Creek hydrology used in the model does not include climate change impacts.

Groundwater

For the purposes of this model, available groundwater supply is assumed to be the supply available if all three groundwater wells were operated continuously at their maximum capacity of 5.0 cfs (2,250 gallons per minute [gpm]). This maximum flow rate for the use of all three groundwater wells is based on the analysis done in the *City of Aspen Mill Street, Rio Grande, & Little Nell Well Use Evaluation* (SGM, 2018). Similar to Hunter Creek, groundwater can be turned on or off in the model to create different water supply portfolios, and groundwater supply only gets utilized if flows from Castle Creek and Maroon Creek are insufficient to meet demand. The model calculates how much groundwater gets used on a monthly and annual basis.

Reuse

In portfolios that include reuse, available supply from non-potable reuse is assumed to be available for five irrigation-season months of the year, from June through October. The flow rate of 0.56 cfs over these 5 months is equivalent to 168 AFY. This is the amount of reuse that the City is currently planning to implement to irrigate the City of Aspen Golf Course. While this is a non-potable supply, it is assumed to replace Castle Creek non-potable demands that could then be freed up for use as potable supplies.

Storage

Available storage capacity for each portfolio is determined by the user and input into the model. The amount of water being input into storage, currently in storage, and being withdrawn from storage is calculated at every time step (monthly) in the model. If supply from other sources is greater than demand, then that excess supply is assumed to be available to be put into storage if storage is not already full. If demand exceeds supplies from other sources, that water from storage is withdrawn to the extent available or needed. The amount of storage used is calculated on a monthly and annual time step.

It is assumed that some amount of water is lost from storage due to seepage. This loss is assumed to be 25 percent of water currently in storage on an annual basis. Additionally, 30 percent of water stored is assumed to be "dead" storage or inaccessible for use. These factors are consistent with the City's recent-year analyses of potential storage opportunities in the Aspen valley. The amount of storage input by the user is the total usable storage capacity; the model calculates the total storage capacity needed based on the amount input by the user and the addition of dead storage.

Drought Restrictions

The maximum percentage of demand that can be offset by drought restrictions is input by the user. For this analysis, it is generally assumed that the maximum systemwide demand reduction from drought restrictions is 25 percent of demand, corresponding to "Extreme" (Stage 3) restrictions in the City's July 2020 Drought Mitigation and Response Plan. This percentage of demand is the available drought restriction capacity, which is then used if demand exceeds all other available supplies. The level of drought restriction used is calculated on a monthly and annual basis.

User Inputs

To run the model, the user makes the following inputs:

- Usable storage capacity (acre-feet [AF]).
- Demand scenario (1-8).
- Hunter Creek use (1 for yes, 0 for no).
- Groundwater use (1 for yes, 0 for no).
- Reuse use (1 for yes, 0 for no).
- Maximum drought restriction (%).

Model Outputs

As discussed in the sections above, the model calculates how much of each of the new supply options in a given supply portfolio (including Hunter Creek, groundwater, reuse, and/or storage) and drought restrictions are used on both a monthly and annual basis. The model also calculates shortages on a monthly and annual basis. The primary purpose of the model is to assemble water supply portfolios that meet the minimum threshold of avoiding shortages through the use of supply options and drought restrictions. This was done by combining different supply options and different levels of storage to determine which combinations of options would be sufficient to eliminate shortages. Once the supply portfolios were developed, each one was modeled to determine the frequency and magnitude with which each supply option and drought restrictions were used.

References

Element Water Consulting, 2021. *City of Aspen Water Demand Projection Update*. January 25, 2021.

SGM, 2018. *City of Aspen Mill Street, Rio Grande, & Little Nell Well Use Evaluation.* Well Blending and Treatment Study. December 2018.

Wilson Water Group (WWG), 2016. *City of Aspen Water Supply Availability Study 2016 Update*. June 2016.

Appendix E
COST ASSUMPTIONS AND DETAILS

Aspen IRP
Unit Cost Factors and Related Information
June 2021

Water pipeline as a function of diameter and installation

Diameter (in)	Maximum flowrate mgd	gpm	Cost $/LF
4	0.3	215	$269
6	0.7	484	$279
8	1.2	860	$275
10	1.9	1344	$305
12	2.8	1935	$320
14	3.8	2634	$330
16	5.0	3440	$370
18	6.3	4354	$380
20	7.7	5376	$420
24	11.1	7741	$515
30	17.4	12095	$565
36	25.1	17417	$651
42	34.1	23706	$737
48	44.6	30964	$892
54	56.4	39188	$998
60	69.7	48381	$1,137

Reference: Aspen area contractor quotes; Denver area cost estimating manual;
adjusted for inflation and mountain construction,

Max pipe flow velocity	5.5	ft/s
High pressure class material	2.0	x standard pressure class cost

Pump Station Costing and Sizing

Unit cost $25,000 per HP

Reference: Denver area bid history, adjusted for inflation and mountain construction

H-W coefficient:	140	assumed
Pump efficiency:	80%	assumed

ENR Construction Cost Index and Escalation Rates

City	Date	ENR Value	Notes
Denver	Dec-17	7412	For storage cost adjustment
Denver	Dec-18	7514	For well cost adjustment
Denver	Feb-21	7655	Basis of Aspen IRP costs

Assumed escalation rate: 3% per year (alternative to ENR escalation)

New Water Treatment Plant

Net unit cost for WTP: $8 per gpd of capacity
$8,000,000 per mgd of capacity

Reference: Denver area bid history, adjusted for inflation and mountain construction

Enhanced Conservation Unit Cost

Estimated unit cost for additional conservation: $9,000 /AF

Reference: Adapted from CWCB Conservation Levels Analysis Report 2010, Aspen Water Efficiency Plan (2015)
for mature conservation program, adjusted for inflation

Aspen IRP
Portfolio 2 Capital Cost Estimate
June 2021

Consistent with AACE Class 5 Estimate

	Quantity	Units	Unit Cost	Total Cost	Basis / Notes
Operational Storage and Raw Water Conveyance					
Construct new Operational Storage (Sites 8, 7, 6, and Additional)	2,860	AF	$30,302	$86,664,000	1
Pump Station 1 to midpoint Pump Station 2	1,020	HP	$25,000	$25,500,000	2
Pump Station 2 to Leonard Thomas Reservoir	1,020	HP	$25,000	$25,500,000	2
30" raw water pipeline from new Operational Storage to Thomas Resv.	39,600	LF	$565	$22,374,000	2
Subtotal				**$160,038,000**	
Design Development Contingency			30%	$48,011,000	
Escalation: All project costs are presented in 2021 dollars			0%	$0	
Insurance: Builders Risk (0.95%) and General Liability (0.55%)			1.5%	$2,401,000	
Cost of Work Subtotal				**$210,450,000**	
Contractor Fees (6% GCs and expenses + 7% fee)			13%	$27,359,000	
Contractor Bonds			0.9%	$2,140,000	
Construction Cost				**$239,949,000**	
Engineering			10%	$23,995,000	
Construction Management			10%	$23,995,000	
Project Administration			7.50%	$17,996,000	
Total Project Cost Estimate (2021 $)				**$305,935,000**	

Basis / Notes
1 Storage costs escalated from Deere & Ault "Table 1" - unit cost shown is weighted average for assumed storage sites.
2 Conveyance sized for 2070 peak day use. Assumed use of 2 pump stations to stay within standard pipeline pressure classes.

Aspen IRP
Portfolio 3 Capital Cost Estimate
June 2021

Consistent with AACE Class 5 Estimate

	Quantity	Units	Unit Cost	Total Cost	Basis / Notes
Operational Storage and Raw Water Conveyance					
Construct new Operational Storage (Sites 8, 7, 6, and Additional)	2,600	AF	$29,842	$77,590,000	1
Pump Station 1 to midpoint Pump Station 2	980	HP	$25,000	$24,500,000	2
Pump Station 2 to Leonard Thomas Reservoir	980	HP	$25,000	$24,500,000	2
30" raw water pipeline from new Operational Storage to Thomas Resv.	39,600	LF	$565	$22,374,000	2
Treatment and Blending Facilities					
New Hunter Creek WTP and rehab previous diversion	8.1	mgd	$8,000,000	$64,786,000	3
Subtotal				**$213,750,000**	
Design Development Contingency			30%	$64,125,000	
Escalation: All project costs are presented in 2021 dollars			0%	$0	
Insurance: Builders Risk (0.95%) and General Liability (0.55%)			1.5%	$3,206,000	
Cost of Work Subtotal				**$281,081,000**	
Contractor Fees (6% GCs and expenses + 7% fee)			13%	$36,541,000	
Contractor Bonds			0.9%	$2,859,000	
Construction Cost				**$320,481,000**	
Engineering			10%	$32,048,000	
Construction Management			10%	$32,048,000	
Project Administration			7.50%	$24,036,000	
Total Project Cost Estimate (2021 $)				**$408,613,000**	

Basis / Notes

1 Storage costs escalated from Deere & Ault "Table 1" - unit cost shown is weighted average for assumed storage sites.
2 Conveyance sized for 2070 peak day use. Assumed use of 2 pump stations to stay within standard pipeline pressure classes.
3 Unit cost for WTP based on Colorado project history, adjusted for capacity, inflation, and mountain construction.

Aspen IRP
Portfolio 4 Capital Cost Estimate
June 2021

Consistent with AACE Class 5 Estimate

	Quantity	Units	Unit Cost	Total Cost	Basis / Notes
Operational Storage and Raw Water Conveyance					
Construct new Operational Storage (Site 8)	1,040	AF	$34,900	$36,296,000	1
Pump Station 1 to midpoint Pump Station 2	890	HP	$25,000	$22,250,000	2
Pump Station 2 to Leonard Thomas Reservoir	890	HP	$25,000	$22,250,000	2
24" raw water pipeline from new Operational Storage to Thomas Resv.	39,600	LF	$515	$20,394,000	2
Treatment and Blending Facilities					
Well Blending Facility	1	LS	$1,117,000	$1,117,000	3
12 inch blending pipeline	5,000	LF	$320	$1,600,000	3
12 inch raw water pipeline from Mill St Well to Blending Facility	500	LF	$320	$160,000	3
12 inch raw water pipeline from Rio Grande Well to Blending Facility	1,200	LF	$320	$384,000	3
12 inch raw water pipeline from Little Nell Well to Blending Facility	2,700	LF	$320	$864,000	3
Subtotal				**$105,315,000**	
Design Development Contingency			30%	$31,595,000	
Escalation: All project costs are presented in 2021 dollars			0%	$0	
Insurance: Builders Risk (0.95%) and General Liability (0.55%)			1.5%	$1,580,000	
Cost of Work Subtotal				**$138,490,000**	
Contractor Fees (6% GCs and expenses + 7% fee)			13%	$18,004,000	
Contractor Bonds			0.9%	$1,408,000	
Construction Cost				**$157,902,000**	
Engineering			10%	$15,790,000	
Construction Management			10%	$15,790,000	
Project Administration			7.50%	$11,843,000	
Total Project Cost Estimate (2021 $)				**$201,325,000**	

Basis / Notes

1 Storage costs escalated from Deere & Ault "Table 1" - unit cost shown is weighted average for assumed storage sites.
2 Conveyance sized for 2070 peak day use. Assumed use of 2 pump stations to stay within standard pipeline pressure classes.
3 Blending facility and related items costs per SGM Dec. 2018 draft report, escalated to 2021$. Pipeline costs updated to match others.

Aspen IRP
Portfolio 5 Capital Cost Estimate
June 2021

Consistent with AACE Class 5 Estimate

	Quantity	Units	Unit Cost	Total Cost	Basis / Notes
Operational Storage and Raw Water Conveyance					
Construct new Operational Storage (Sites 8, 7, 6, and Additional)	2,080	AF	$28,578	$59,442,000	1
Pump Station 1 to midpoint Pump Station 2	840	HP	$25,000	$21,000,000	2
Pump Station 2 to Leonard Thomas Reservoir	840	HP	$25,000	$21,000,000	2
30" raw water pipeline from new Operational Storage to Thomas Resv.	39,600	LF	$565	$22,374,000	2
Conservation					
Programs to achieve enhanced conservation	1,318	AFY	$9,000	$11,862,000	3
Subtotal				**$135,678,000**	
Design Development Contingency			30%	$40,703,000	
Escalation: All project costs are presented in 2021 dollars			0%	$0	
Insurance: Builders Risk (0.95%) and General Liability (0.55%)			1.5%	$2,035,000	
Cost of Work Subtotal				**$178,416,000**	
Contractor Fees (6% GCs and expenses + 7% fee)			13%	$23,194,000	
Contractor Bonds			0.9%	$1,814,000	
Construction Cost				**$203,424,000**	
Engineering			10%	$20,342,000	
Construction Management			10%	$20,342,000	
Project Administration			7.50%	$15,257,000	
Total Project Cost Estimate (2021 $)				**$259,365,000**	

Basis / Notes
1 Storage costs escalated from Deere & Ault "Table 1" - unit cost shown is weighted average for assumed storage sites.
2 Conveyance sized for 2070 peak day use. Assumed use of 2 pump stations to stay within standard pipeline pressure classes.
3 Conservation quantity is the difference in demand between full demand and enhanced conservation demand (9281-7963 AFY).

Aspen IRP
Portfolio 6 Capital Cost Estimate
June 2021

Consistent with AACE Class 5 Estimate

	Quantity	Units	Unit Cost	Total Cost	Basis / Notes
Operational Storage and Raw Water Conveyance					
Construct new Operational Storage (Site 8)	520	AF	$34,900	$18,148,000	1
Pump Station 1 to midpoint Pump Station 2	540	HP	$25,000	$13,500,000	2
Pump Station 2 to Leonard Thomas Reservoir	540	HP	$25,000	$13,500,000	2
20" raw water pipeline from new Operational Storage to Thomas Resv.	39,600	LF	$420	$16,632,000	2
Groundwater Blending Facility					
Well Blending Facility	1	LS	$1,117,000	$1,117,000	3
12 inch blending pipeline	5000	LF	$320	$1,600,000	3
12 inch raw water pipeline from Mill St Well to Blending Facility	500	LF	$320	$160,000	3
12 inch raw water pipeline from Rio Grande Well to Blending Facility	1,200	LF	$320	$384,000	3
12 inch raw water pipeline from Little Nell Well to Blending Facility	2,700	LF	$320	$864,000	3
Conservation					
Programs to achieve enhanced conservation	1,318	AFY	$9,000	$11,862,000	4
Reuse					
New diversion at or below ACSD WRF	1	LS	$687,000	$687,000	5
New pump station at or below ACSD WRF	40	HP	$25,000	$1,000,000	
12 inch pipeline connection at ACSD PS	800	LF	$320	$256,000	6
Golf Course Pond improvements (lining, outlet cutoff, etc.)	1	LS	$200,000	$200,000	
Subtotal				**$79,910,000**	
Design Development Contingency			30%	$23,973,000	
Escalation: All project costs are presented in 2021 dollars			0%	$0	
Insurance: Builders Risk (0.95%) and General Liability (0.55%)			1.5%	$1,199,000	
Cost of Work Subtotal				**$105,082,000**	
Contractor Fees (6% GCs and expenses + 7% fee)			13%	$13,661,000	
Contractor Bonds			0.9%	$1,069,000	
Construction Cost				**$119,812,000**	
Engineering			10%	$11,981,000	
Construction Management			10%	$11,981,000	
Project Administration			7.50%	$8,986,000	
Total Project Cost Estimate (2021 $)				**$152,760,000**	

Basis / Notes

1 Storage costs escalated from Deere & Ault "Table 1" - unit cost shown is weighted average for assumed storage sites.
2 Conveyance sized for 2070 peak day use. Assumed use of 2 pump stations to stay within standard pipeline pressure classes.
3 Blending facility and related items costs per SGM Dec. 2018 draft report, escalated to 2021$. Pipeline costs updated to match others.
4 Conservation quantity is the difference in demand between full demand and enhanced conservation demand (9281-7963 AFY).
5 Construction cost before contingency $648K per Deere & Ault 2/15/19 letter report, escalated to 2021$
6 Est. 800 LF from site of river diversion d/s of ACSD to fenceline connection to existing reuse pipeline (already daylights to GC Pond).

Aspen IRP
Implementation Plan Capital Cost Estimate
June 2021

Consistent with AACE Class 5 Estimate

	Quantity	Units	Unit Cost	Total Cost	Basis / Notes
WR1: Reuse at Aspen Municipal Golf Course					
Planning and Permitting	1	LS	$50,000	$50,000	1
New diversion at or below ACSD WRF	1	LS	$687,000	$687,000	2
New pump station at or below ACSD WRF	40	HP	$25,000	$1,000,000	
12 inch pipeline connection at ACSD PS	800	LF	$320	$256,000	3
Golf Course Pond improvements (lining, outlet cutoff, etc.)	1	LS	$100,000	$100,000	1
WR2: Reuse Expansion					
Planning and Permitting	1	LS	$25,000	$25,000	1
8 inch pipeline extension to new sites (approx. length)	4,000	LF	$275	$1,100,000	4
GW1: Groundwater Blending Facility					
Planning and Permitting	1	LS	$200,000	$200,000	1
Well Blending Facility	1	LS	$1,117,000	$1,117,000	5
12 inch blending pipeline	5,000	LF	$320	$1,600,000	5
12 inch raw water pipeline from Mill St Well to Blending Facility	500	LF	$320	$160,000	5
12 inch raw water pipeline from Rio Grande Well to Blending Facility	1,200	LF	$320	$384,000	5
12 inch raw water pipeline from Little Nell Well to Blending Facility	2,700	LF	$320	$864,000	5
WT1: Water Treatment Facility Resilience Improvements					
Improvements for Wildfire Treatability Resilience	1	LS	$5,000,000	$5,000,000	1
EC1: Enhanced Conservation Phase 1					
Programs to achieve enhanced conservation	439	AFY	$9,000	$3,954,000	6
EC2: Enhanced Conservation Phase 2					
Programs to achieve enhanced conservation (~33% of reduction 2020-2070	439	AFY	$9,000	$3,954,000	6
EC3: Enhanced Conservation Phase 3					
Programs to achieve enhanced conservation (~33% of reduction 2020-2070	439	AFY	$9,000	$3,954,000	6
ES1: Emergency Storage Phase 1 and Raw Water Conveyance					
Planning and Permitting; Preliminary Design	1	LS	$500,000	$500,000	1
Construct new Storage (Phase 1)	500	AF	$30,000	$15,000,000	7, 8
Pump Station from Vagneur Gravel Pit to WTP	500	HP	$25,000	$12,500,000	7
20 in raw water pipeline from new Storage to Thomas Resv.	42,800	LF	$630	$26,964,000	9
ES2: Emergency Storage Phase 2					
Planning and Permitting	1	LS	$500,000	$500,000	1
Construct additional Storage (Phase 2)	2,600	AF	$30,000	$78,000,000	7, 8
Expand Pump Station	820	HP	$25,000	$20,500,000	7
ES3: Emergency Storage Phase 3					
Planning and Permitting	1	LS	$500,000	$500,000	1
Construct additional Storage (Phase 3)	2,200	AF	$30,000	$66,000,000	7, 8
Expand Pump Station	880	HP	$25,000	$22,000,000	7
OS1: Operational Storage Phase 1					
Planning and Permitting	1	LS	$100,000	$100,000	1
Construct new Storage	130	AF	$30,000	$3,900,000	7, 8
OS2: Operational Storage Phase 2					
Planning and Permitting	1	LS	$100,000	$100,000	1
Construct additional Storage	390	AF	$30,000	$11,700,000	7, 8
Master Planning					
Water Treatment Facility Master Plan	1	LS	$100,000	$100,000	1
Water Efficiency Plan Update	1	LS	$100,000	$100,000	1
Transmission/Distribution Master Plan	1	LS	$100,000	$100,000	1
Subtotal (excluding Planning and Projects EC1, EC2, EC3, WT1)				**$264,332,000**	
Design Development Contingency			30%	$79,300,000	
Escalation: All project costs are presented in 2021 dollars			0%	$0	
Insurance: Builders Risk (0.95%) and General Liability (0.55%)			1.5%	$3,965,000	
Cost of Work Subtotal				**$347,597,000**	
Contractor Fees (6% GCs and expenses + 7% fee)			13%	$45,188,000	
Contractor Bonds			0.9%	$3,535,000	
Construction Cost				**$396,320,000**	
Engineering			10%	$39,632,000	
Construction Management			10%	$39,632,000	
Project Administration			7.50%	$29,724,000	
Subtotal Design and Construction				**$505,308,000**	
Planning and Projects EC1, EC2, EC3, WT1 from Above				**$18,637,000**	
Total Project Cost Estimate (2021 $)				**$523,945,000**	

Basis / Notes

1 Allocation
2 Construction cost before contingency $648K per Deere & Ault 2/15/19 letter report, escalated to 2021$
3 Est. 800 LF from site of river diversion d/s of ACSD to fenceline connection to existing reuse pipeline (already daylights to GC Pond).
4 Estimated spur off existing pipeline to Burlingame and Buttermilk
5 Blending facility and related items costs per SGM Dec. 2018 draft report, escalated to 2021$. Pipeline unit costs updated to match others. Costs for augmentation supplies and infrastructure not included.
6 Acre-feet reduction estimated as 1/3 of reduction 2020-2070 (9281-7963 AFY).
7 See report text for decription of phasing. Assumes a centralized single PS will be used for pumping all Emergency and Operational Storage to WTF.
8 Storage unit cost is approx. avg. from Deere & Ault "Table 1" ~$30K/AF - actual cost will depend on site(s) ultimately selected. Costs for land acquisition not included.
9 Unit cost escalated by 50% to account for high-pressure segment (~2X unit cost for ~50% of pipeline length). Pipe sized for 2070 flow.

Appendix F

ESTIMATED STREAMFLOW DEPLETIONS FROM GROUNDWATER PUMPING

PROJECT MEMORANDUM

INTEGRATED WATER RESOURCE PLAN

City of Aspen

Date:	10/5/2021
Project No.:	11690B.00

Prepared By:	Rachel Gross
Reviewed By:	John Rehring
Subject:	Estimated Streamflow Depletions from Groundwater Pumping

Introduction

This memorandum documents the data and calculations used to estimate depletions to the Roaring Fork River due to pumping groundwater from Aspen's Little Nell, Mill Street, and Rio Grande wells. This analysis was completed for the City of Aspen as part of the 2021 *Integrated Water Resource Plan* (IRP).

Methodology, Data, and Assumptions

The maximum amount of pumping required from each well was estimated using the spreadsheet model developed for the IRP (detailed in Appendix D), looking at the driest two-year historical flow period for Castle Creek and Maroon Creek (1977 and 1978) and assuming that IRP supply Portfolio 6 has been implemented. Note that supply Portfolio 6 was developed for the maximum 2070 demand projection and the driest climate projection considered in the IRP; it also includes the implementation of enhanced conservation, non-potable water reuse, and operational storage, as well as the use of up to Stage 3 drought response measures in dry years. Groundwater supply is expected to be used to augment surface water supply only in dry years; 7 of the 25 years of hydrology modeled as part of IRP Portfolio 6 included the use of groundwater.

The amount and timing of stream depletion is calculated using the *Stream Depletion Analysis for Little Nell, Mill Street, and Rio Grande Wells*, completed in 1997 by HRS Water Consultants as well as the *Alluvial Well Stream Depletion Timing Table* developed in 2016 by HRS Water Consultants. The HRS Water Consultants analyses shows that at least 95 percent of the lagged depletions from pumping the Little Nell, Mill Street, and Rio Grande wells impact the Roaring Fork River within three, eight, and four months, respectively, of when the pumping occurs. HRS Water Consultants prepared a unique set of depletion factors for each well by incorporating (wrapping) 100 percent of the lagged depletions into these representative periods, such that all of the depletions can be accounted for within the 3- to 8-month periods. For more information regarding the development of the depletion factors for each well, please reference the 1997 HRS report. The 1997 and 2016 analysis and calculations were used as-is for purposes of developing an initial estimate of potential surface water depletions, with no modifications or independent verification of the methods.

Well capacity information from the *City of Aspen Mill Street, Rio Grande, & Little Nell Well Use Evaluation* (SGM, 2018) was used as the basis for the groundwater well supply option developed in the IRP, as shown in Table F.1. For this analysis, it is assumed that all three wells are operating at or near capacity for three months of the two-year historical low flow timeframe (1977-1978), from August 1977 through October 1977. Only one other month in this two-year timeframe requires groundwater supply: 50 af in January 1978. Since the groundwater need in this month only requires the use of one well, it is assumed that the Mill Street well would be pumped as it is the closest well to the blending vault and also has the longest, most disperse stream depletion lag time.

Table F.1 Well Capacity

Well	Capacity		
	gpm	mgd	AFY if run 24/7/365
Rio Grande	750	1.08	1,210
Mill Street	600	0.86	968
Little Nell	900	1.30	1,452
All 3 Wells Combined	2,250	3.24	3,629

Results

The results of the analysis are shown in Figure F.1 and Table F.2. The peak monthly stream depletion is estimated to be approximately 284 AF, occurring during the third continuous month of pumping. For the pumping scenario analyzed here (associated with late-summer pumping to supplement water supply), that peak stream depletion is simulated to occur in October. Depletions are expected to rapidly decline following the cessation of pumping. While there is a short lag in depletions relative to pumping, the majority of stream depletions are expected to occur during pumping months.

Given the level of connectedness between the Aspen groundwater wells and the Roaring Fork River, more detailed analysis on stream depletions and the potential need for required streamflow augmentation is recommended as the City moves toward reinstating the use of these wells. It is also recommended that the City initiate investigations into how best to meet streamflow augmentation requirements, to the extent it is determined that would be required.

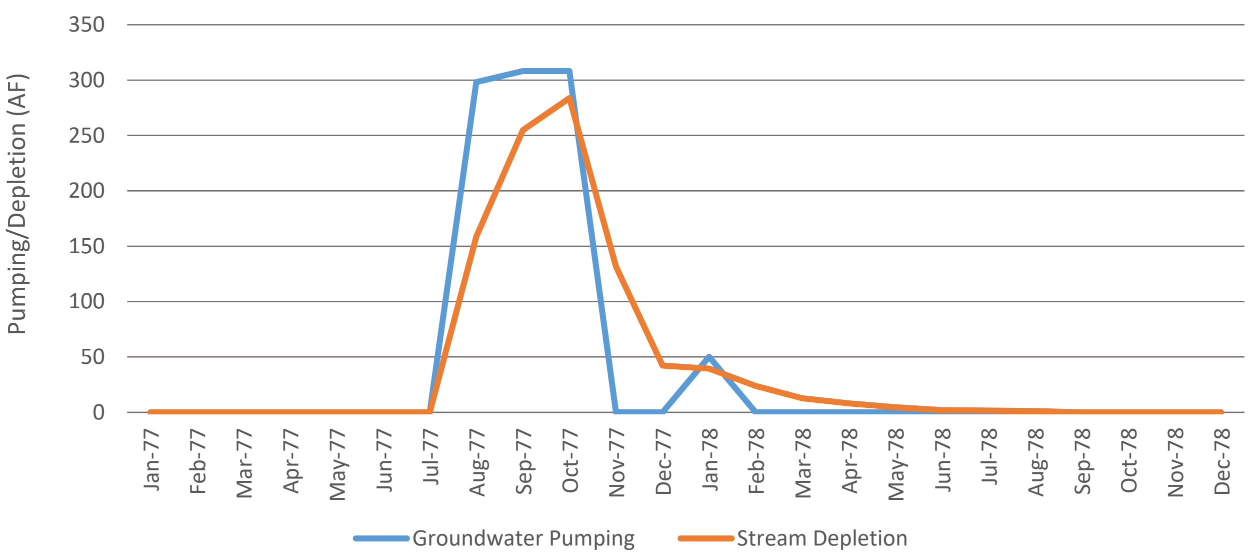

Figure F.1 Groundwater Pumping and Stream Depletion

Table F.2 Groundwater Pumping and Stream Depletion

Date	Groundwater Pumping (AF)				Stream Depletion (AF)			
	Little Nell	Mill Street	Rio Grande	Total	Little Nell	Mill Street	Rio Grande	Total
Jan-77	0	0	0	0	0	0	0	0
Feb-77	0	0	0	0	0	0	0	0
Mar-77	0	0	0	0	0	0	0	0
Apr-77	0	0	0	0	0	0	0	0
May-77	0	0	0	0	0	0	0	0
Jun-77	0	0	0	0	0	0	0	0
Jul-77	0	0	0	0	0	0	0	0
Aug-77	**98**	**81**	**119**	**298**	**41**	**33**	**84**	**159**
Sep-77	**102**	**83**	**123**	**308**	**90**	**56**	**109**	**255**
Oct-77	**102**	**83**	**123**	**308**	**101**	**65**	**117**	**284**
Nov-77	0	0	0	0	**59**	**37**	**36**	**132**
Dec-77	0	0	0	0	**11**	**18**	**14**	**42**
Jan-78	**0**	**50**	**0**	**50**	0	**34**	**6**	**39**
Feb-78	0	0	0	0	0	**24**	0	**24**
Mar-78	0	0	0	0	0	**13**	0	**13**
Apr-78	0	0	0	0	0	**8**	0	**8**
May-78	0	0	0	0	0	**5**	0	**5**
Jun-78	0	0	0	0	0	**2**	0	**2**
Jul-78	0	0	0	0	0	**2**	0	**2**
Aug-78	0	0	0	0	0	**1**	0	**1**
Sep-78	0	0	0	0	0	0	0	0
Oct-78	0	0	0	0	0	0	0	0
Nov-78	0	0	0	0	0	0	0	0
Dec-78	0	0	0	0	0	0	0	0
Total	**302**	**297**	**366**	**965**	**302**	**297**	**366**	**965**

References

HRS Water Consultants, 1997. *Stream Depletion Analysis for Little Nell, Mill Street, and Rio Grande Wells.* February 1997.

HRS Water Consultants, 2016. *Alluvial Well Stream Depletion Timing Table.* Excel Spreadsheet. October 2016.

SGM, 2018. *City of Aspen Mill Street, Rio Grande, & Little Nell Well Use Evaluation.* December 2018.