ANALYSIS & TECHNICAL UPDATE TO THE

COLORADO WATER PLAN

VOLUME I

Analysis and Technical Update to the Colorado Water Plan

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COLORADO WATER PLAN

This report was assembled by the Colorado Water Conservation Board (CWCB) staff and the contract team who supported the Analysis & Technical Update to the Colorado Water Plan. However, this effort was supported by numerous stakeholder interactions that helped drive the methodologies, review and presentation of this report. CWCB staff extends its appreciation to everyone who provided input throughout this process, including the Department of Natural Resources, the Division of Water Resources, senior leadership at the CWCB, the CWCB board, the Interbasin Compact Committee, members of the Technical Advisory Groups, members of the Implementation Working Group, each of the nine basin roundtables and many other subject matter experts, and engaged community members and colleagues whose efforts were invaluable to making this report as comprehensive and grass-roots driven as possible.

It is staff's sincere hope that this effort will continue to engage stakeholders and partners across the State of Colorado and will be used, refined and enhanced in future iterations of Basin Implementation Plan Updates and, ultimately, the Water Plan itself.

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[DISCLAIMER]

The Analysis and Technical Update to the Colorado Water Plan (Technical Update) provides technical data and information regarding Colorado's water resources. The technical data and information generated are intended to help inform decision making and planning regarding water resources at a statewide or basinwide planning level. The information made available is not intended to replace projections or analyses prepared by local entities for specific project or planning purposes.

The Colorado Water Conservation Board intends for the Technical Update to help promote and facilitate a better understanding of water supply and demand considerations within the State; however, the datasets provided are from a snapshot in time and cannot reflect actual or exact conditions in any given basin or the State at any given time. While this Technical Update strives to reflect the Colorado Water Conservation Board's best estimates of future water supply and demands under various scenarios, the reliability of these estimates is affected by the availability and reliability of data and the current capabilities of data evaluation. Moreover, the Technical Update cannot incorporate the varied and complex legal and policy considerations that may be relevant and applicable to any particular basin or project; therefore, nothing in the Technical Update or the associated Flow Tool or Costing Tool is intended for use in any administrative, judicial or other proceeding to evince or otherwise reflect the State of Colorado's or the CWCB's legal interpretations of state or federal law.

Furthermore, nothing in the Technical Update, Flow Tool, Costing Tool, or any subsequent reports generated from these datasets is intended to, nor should be construed so as to, interpret, diminish, or modify the rights, authorities, or obligations of the State of Colorado or the CWCB under state law, federal law, administrative rule, regulation, guideline or other administrative provision.

Prior to the 2015 Colorado Water Plan (Water Plan), past statewide water supply analyses included data analysis, project information and policy components. After the release of the Water Plan, these elements were split between the Water Plan (policy), Basin Implementation Plans (local projects) and statewide water supply initiatives (technical data analysis). To better recognize these delineations and make the connection to the Water Plan clear, the statewide water supply initiative (often referenced as SWSI) is now being referred to as the Analysis and Technical Update to the Water Plan (or Technical Update). The new name more accurately reflects the technical nature of the evaluations described in the report and better establishes how that data will be used to inform Water Plan updates. While the Technical Update is a statewide water supply initiative and continues that legacy, the SWSI acronym will be relegated to referencing earlier efforts that proceeded the Water Plan (e.g. SWSI 2010).

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The following are definitions for key terms used throughout the Technical Update report:

1051 Data – 1051 Data is the municipal water usage data reported to the CWCB by water providers pursuant to House Bill 2010-1051.

Active vs Passive Conservation – Active water conservation measures are water-saving strategies implemented or incentivized by water providers. Active water conservation includes watering restrictions, public education campaigns, or efficiency improvements. Passive water conservation are measures associated with the installation of new water-efficient fixtures and appliances without incentives from utilities, e.g., replacing an old toilet with a new low-flush toilet.

Adoption Rate – Portion of existing (2015) population that will have water use consistent with the future gallons per capita per day (gpcd) value for a given planning scenario by the year 2050 (i.e., retrofit population).

Agricultural Diversion Demand – The amount of water that needs to be diverted or pumped to meet the full crop irrigation water requirement. Note that SWSI 2010 (see definition below) defined agricultural demand as the amount of water consumed by crops at the field level and not the amount of water that needs to be diverted or pumped.

Agricultural Gap – The amount of additional water that would need to be diverted or pumped to meet crop irrigation shortages. The results of the calculations are also referred to as the “total agricultural gap”. The “incremental agricultural gap” is a portion of the agricultural gap and is defined below. Note that Statewide Water Supply Initiative (SWSI) 2010 defined the agricultural gap as crop or field-based shortages, though it recognized river headgate diversions and pumping would need to be much larger to meet crop shortages.

Applied Water – Water that is diverted from the river, pumped from ground water, or released from reservoirs for irrigation purposes. It is also referred to as irrigation supplies. Applied water does not include or reflect precipitation consumed by crops.

Baseline M&I Demand – Reported and estimated demands representing average conditions for the Technical Update baseline year of 2015. Municipal demands are represented by the gpcd and on a volumetric basis, which is calculated from population and gpcd data.

Basin Implementation Plans (BIP) – Basin Implementation Plans provide critical input to the Colorado Water Plan. BIPs were developed by basin roundtables and demonstrate how each basin roundtable plans to meet its future municipal, industrial, agricultural, recreational, and environmental needs. The BIPs identify projects and methods to meet future water needs and develop goals and measurable outcomes, needs, and constraints and opportunities in each basin. Data and information from the Technical Update will be used by basin roundtables to update their BIPs.

Buy and Dry – The process of buying agricultural water rights and subsequently using the water rights for another purpose (typically for municipal or industrial use). The formerly irrigated agricultural lands are “dried up” and no longer irrigated by virtue of the water transfer.

Climate Change Projections – The climate change projections developed for the Colorado Water Plan and this Technical Update were built upon the foundational work of the multi-phase Colorado River Water Availability Study, Phase II (CRWAS-II). CRWAS-II identified a suite of future climate change projections intended to explore a range of water supply and demand conditions for Colorado in 2050. Three composite projections were used in the Colorado Water Plan and in the Technical Update—the “Current” (recent historical hydrology), “Hot and Dry”, and “Between 20th Century Observed and Hot and Dry” (also, “Between” or “In-Between”).

Colorado’s Decision Support Systems (CDSS) – Colorado’s Decisions Support Systems is a water management system developed by the Colorado Water Conservation Board (CWCB) and the Division of Water Resources for each of Colorado’s major river basins. The CDSS includes water-focused data sets, models, geographic information system (GIS) layers and other tools, including StateMod, StateCU, Hydrobase and others, to assist with surface water and groundwater management in Colorado.

Crop Shortages – Crop shortages are the difference between the amount of water crops needed to meet full crop consumptive use (a.k.a., irrigation water requirement [IWR]) and the amount of applied water crops consumed when irrigation supplies are insufficient to meet the full demand (a.k.a., water supply limited [WSL] consumptive use.

Distributed Water – The volume of water entering the municipal distribution system, calculated as total water production from all sources minus water exported to another water provider.

Drivers – In many contexts in the Technical Update, "drivers" refer to the nine factors identified by the Interbasin Compact Committee (IBCC) that will shape the future of water supplies and demands by the year 2050.

E&R – In the context of the Technical update, E&R refers to attributes and data products related to "environment and recreation".

Evapotranspiration – The sum of water evaporated from the soil surface and transpired through vegetation.

Flow-ecology Relationships – Flow-ecology quantifies the relationship between specific flow statistics (such as average magnitude of peak flow or the ratio of flow in August and September to mean annual flow) and the risk status (low to very high) for environmental attributes under the flow scenario being analyzed.

Gaps – In the Technical Update, gaps were calculated using water allocation models and other analysis tools (in basins where models are not currently available) and were evaluated for both agricultural and municipal and industrial (M&I) uses. Gaps were calculated as the difference between the amount of water available to meet agricultural or M&I diversion demands and the full diversion demand. In other words, gaps reflect the amount by which agricultural or municipal demands could be shorted because of inadequate supplies.

Implementation Working Group – The Implementation Working Group refers to the basin roundtable, Interbasin Compact Committee and CWCB Board members who helped inform the Technical Update recommendations as well as the next steps for the updates to the BIPs.

Incremental Agricultural Gap – The incremental agricultural gap quantifies the degree to which the gap could increase beyond what agriculture has historically experienced under water shortage conditions.

Irrigation System Efficiency – The percent of diverted or pumped water consumed by crops or stored in soil moisture, which is calculated by dividing the sum of WSL (see definition below) and water stored in soil moisture by the total applied water from all sources. System efficiency reflects the losses to applied water due to canal seepage and on-farm application losses.

Irrigation Water Requirement (IWR) – The amount of water that must be applied to crops to meet the full crop consumptive use, also referred to as the crop demand or the consumptive irrigation requirement (CIR). IWR provides an estimate of the maximum amount of applied water the crops could consume if it was physically and legally available.

Metered Municipal Water Use – Water that reaches the end use, including billed/unbilled and authorized/unauthorized uses.

Model Year – The baseline water allocation models used in the Technical Update use time series of hydrology reflective of historical conditions from 1975 to the most recent year available. For planning analyses, the historical hydrology was adjusted to reflect climate change impacts in the applicable scenarios. Demands in the baseline models reflect current conditions; planning scenario models reflect future conditions. Water allocation modeling results are a time series of stream flows, diversions, and shortages that reflect historical variability but are affected by current or future demands. The term "model year" is used to describe model output that reflects historical variability, but is not intended to reflect actual historical conditions.

Municipal Demand – Portion of distributed water attributable to uses typical of municipal systems, including residential, commercial, light industrial, non-agricultural-related irrigation, firefighting, and non-revenue water. Demands for self-supplied households not connected to a public water supply are also included in the municipal demand category. Municipal demands represent diversion demands used in the water allocation models.

M&I Demands – This refers to municipal and industrial water demands inclusive of the self-supplied industrial (SSI) demands. In the Technical Update, this is sometimes also referred to as M&SSI demands or simply "industrial demands".

M&I Gap – The difference between the amount of water available to meet M&I demands and the full M&I diversion demand. Note that the M&I gap in SWSI 2010 was based on the difference between new M&I demands that will occur in the future and the yield of projects currently being pursued to provide future supplies.

Municipal Water Efficiency Plans (WEP) – The Water Conservation Act of 2004 (HB04-1365) requires all covered entities (i.e., retail water providers that sell 2,000 acre-feet or more on an annual basis) to have a state-approved water efficiency plan that contains certain required minimum plan elements.

Non-Revenue Water – The calculated difference between distributed water and authorized metered water use. Non-revenue water thus represents system water loss.

Nonconsumptive Needs and Datasets – In prior SWSIs, "nonconsumptive" referred to "environment and recreation" datasets and analyses. For the Technical Update, these two terms can be viewed as interchangeable; however, the phrase "environment and recreation" (or E&R) will be used moving forward.

Resiliency – The ability of water systems to adapt and continue providing adequate levels of service in the face of changing circumstances and drivers.

Scenario Planning – Scenario planning is a strategic planning process that acknowledges that the future is uncertain, identifies the drivers that affect water supplies and demands, and envisions alternative water futures that reflect the potential variability of drivers. Adaptive management plans can be developed to meet future needs identified in the scenarios.

Self-Supplied Industrial (SSI) Demands – Self-supplied industrial demands are defined as the water needs of large industrial water users that have their own water supplies or lease raw water from others. Industrial needs met by municipal water providers are incorporated into municipal water demands and are not part of SSI demands. Self-supplied industrial demands are also referenced simply as "industrial" demands in the Technical Update.

Statewide Water Supply Initiative (SWSI) 2010 – Refers to the Statewide Water Supply Initiative completed in 2010 (SWSI 2010). This effort built on the earlier SWSI I and SWSI II efforts. Since the 2015 launch of the Colorado Water Plan, SWSI is now referred to as the Analysis and Technical Update to the Colorado Water Plan (or simply "Technical Update").

Systemwide Municipal Demand – Systemwide municipal demand is equivalent to distributed water as defined by 1051 data or water supplied as defined in the American Water Works Association (AWWA) Water Loss Control audit methodology. This is equal to the sum of all municipal demand categories, including residential indoor, residential outdoor, non-residential indoor, non-residential outdoor and non-revenue water.

Targeted Water Provider Outreach (Targeted Outreach) – Targeted outreach that was facilitated by CWCB staff to gather municipal water usage data and information in select counties that had no 1051, Water Efficiency Plan, or BIP data.

Technical Advisory Groups (TAG) – The Technical Advisory Groups refer to the basin roundtable members and subject matter experts who helped inform the methodologies used in the Technical Update.

Technical Update – This refers to the analysis and technical update to the Colorado Water Plan. The Technical Update is similar to prior SWSI efforts but with important differences (see Section 3 for a comparison of SWSI to the Technical Update).

Water Conservation – Water conservation is the minimization of water loss or waste. The goal of water conservation is to use only the amount of water necessary to complete a task or meet a need. Water conservation can be achieved through policies, programs, and practices designed to encourage less water use.

Water Efficiency – Water efficiency refers to strategies or technologies that facilitate using less water to accomplish an activity. Low-flow toilets and showerheads are examples of technologies that increase water efficiency. Water efficiency improvements are typically accomplished via engineered products or solutions.

Water Efficiency Plans – See Municipal Water Efficiency Plans above.

Water Future – Colorado's "water future" refers broadly to future conditions with respect to water supplies and demands, social values, condition of environmental and recreational attributes, and the types of strategies and projects that will be implemented to meet future needs.

Water Plan – Abbreviated reference to the Colorado Water Plan (also referred to as the Colorado Water Plan).

Water Supply Limited (WSL) Consumptive Use – The amount of applied water consumed by crops, also referred to as actual crop consumptive use. WSL is the minimum of the IWR and the amount of applied water that reaches crops.

ANALYSIS & TECHNICAL UPDATE TO THE COLORADO WATER PLAN

Clean and reliable water supplies are essential to our way of life. All of us—agricultural producers, urbanites, environmentalists, and recreationalists—depend on it for quality of life, a vibrant economy, and a healthy environment. These are the reasons we call Colorado home, the qualities that attract new Colorado residents, and the drivers of the Colorado Water Plan.

Colorado's water supplies are highly variable, and our demands are growing. Throughout Colorado's history, and increasingly in recent decades, we have experienced severe drought conditions, extreme flooding events, population booms, and economic recessions. These extremes often reflect larger shifts that highlight the importance of resilience in our water supplies and thoughtful, collaborative planning—the heart of the Colorado Water Plan (Water Plan).

The Water Plan provides a framework for developing resilient responses to our water-related challenges. It articulates a vision for collaborative and balanced water solutions led by the Colorado Water Conservation Board (CWCB) and our grassroots basin roundtable structure. This vision recognizes the evolving nature of water resource planning and implementation.

Following the launch of the Water Plan and Basin Implementation Plans (BIP) in 2015, the CWCB initiated the process of updating the underlying water supply and demand analyses in 2016, culminating in this report. The work began with the input of Technical Advisory Groups (TAG)—a group of representatives from across the state who provided expertise and advice on methods for the next phase of analysis. The resulting "Technical Update" (formerly known as the Statewide Water Supply Initiative or SWSI) establishes a new approach to statewide water analysis and data sharing.

The Technical Update and its related insights and tools build on a nearly 15-year legacy of CWCB water supply planning initiatives that began with the first SWSI in 2004. It also leverages a 27-year investment in statewide water modeling efforts, which began in 1992. To that end, this Technical Update provides a significant improvement in the scope, science, and approach to water supply planning (in SWSI I, SWSI II, and SWSI 2010). This approach positions Colorado for a streamlined and robust evaluation of its future water needs.

1 CHANGES IN THE APPROACH

The Colorado Water Plan set an adaptive management framework for future water planning activities and described five planning scenarios under which demands, supplies, and gaps were to be estimated. The scenarios included new considerations, such as climate change, that were not a part of prior SWSIs. In addition, the CWCB has continued to work with the Division of Water Resources to develop and refine consumptive use and surface water allocation models that were not ready for use in earlier analyses. As a result of these factors, the Technical Update takes a different and more robust approach to estimating future gaps.

The new methodology provides basin roundtables with datasets and tools that can be used to develop enhanced implementation strategies to meet Colorado's water needs.

New Analysis Needs

The Technical Update estimates future available water supplies and gaps under the five planning scenarios described in the Water Plan. Previous SWSIs were conducted prior to the Water Plan and, therefore, did not consider the scenarios. The scenarios incorporate water supply and demand drivers associated with the potential effects of climate change, population growth, and other factors.

New Planning Process

In their BIPs, the basin roundtables cataloged various projects and methods to mitigate future water supply gaps. The Technical Update focuses on developing tools and more detailed datasets to help basin roundtables update their portfolios of projects and methods for meeting future water needs in a targeted manner, with forthcoming updates to their BIPs.

New Models and Data Sets

New analysis tools and datasets have been developed since SWSI 2010. Consumptive use and surface water allocation models developed through Colorado's Decision Support Systems (CDSS) are now available in most river basins. The CDSS tools allow the evaluation of water availability gaps under a variety of hydrologic conditions. Municipal water demand and conservation data are available via HB10-1051 reporting. The availability of these new tools and datasets allows for a more robust approach to assessing future water availability and potential gaps.

REFINED OBJECTIVES

Given the new planning concepts described above, the overall objectives of the Technical Update are to:

1. Update and **recharacterize** future gaps

2. Evaluate environmental and recreational issues with new tools

3. Create user-friendly standardized tools, basin datasets, and information

2 NEW METHODS

The CWCB undertook a collaborative approach to developing methodologies for the Technical Update through the use of TAGs. Four TAGs were formed that provided input on scenario quantification, agricultural demands, municipal and industrial (M&I) demands, and environment and recreational tools (E&R). TAG participants included water stakeholders, subject matter experts, and basin roundtable members from each basin across the state.

New Features and Improved Data

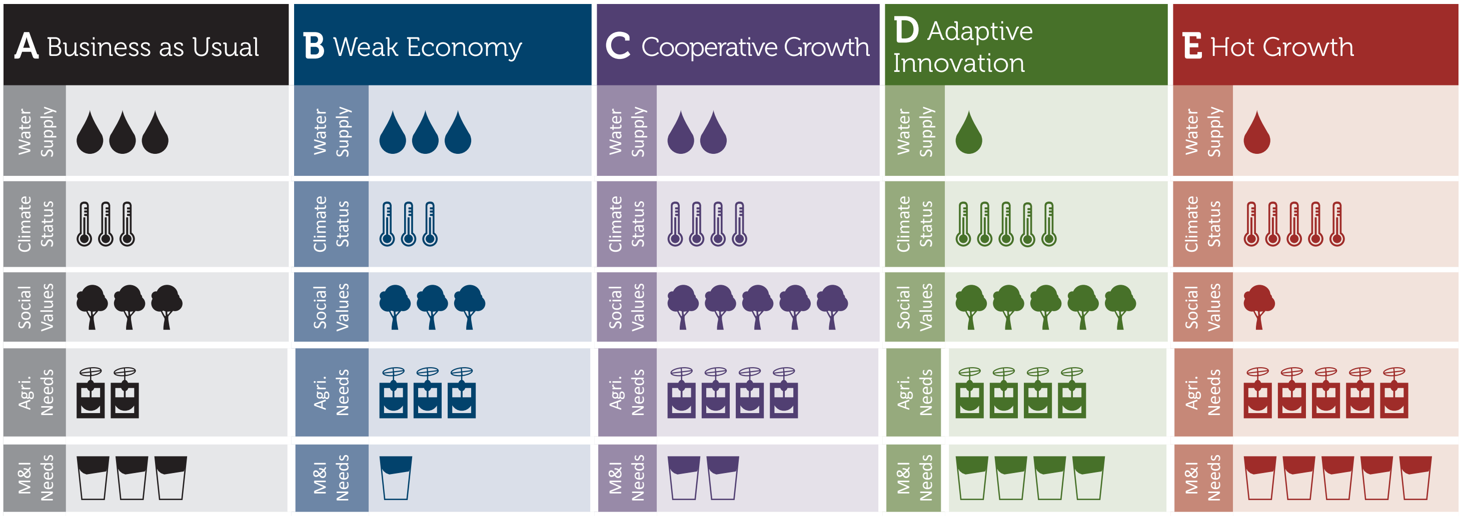
Section 2 of the Technical Update (Volume 1) summarizes the methodologies used to estimate current and future municipal and industrial (M&) and agricultural demands, water supplies and potential gaps, and tools for evaluating environment and recreation needs. Technical memoranda (see Volume 2) provide additional details.

The methodologies used for the Technical Update built on previous datasets and new and improved data sources and, to the extent possible, leveraged Colorado's investment in models developed through CDSS. Highlights of the new methodologies are described below.

Incorporation of scenario planning: Scenario planning is a new feature of the Technical Update and forms the context under which specific methodologies were developed. The five scenarios used come directly from the Colorado Water Plan (also shown on the following page).

- **"1051" water usage data:** New data describing recent municipal water usage was employed to estimate municipal water demands. The data are collected and reported by water providers pursuant to House Bill 2010-1051 ("1051"), which requires that the CWCB implement a process for reporting water use and conservation data by covered entities. This type of data was not available in prior SWSI efforts.
- **CDSS Tools:** The technical analyses made extensive use of modeling tools available through CDSS. CDSS is a water management system developed by the CWCB and the Division of Water Resources for each of Colorado's major water basins. Tools in CDSS include Hydrobase (a vast database of statewide water-related data), GIS data, surface water allocation models, and models that quantify consumptive use from crops and other vegetation. CDSS tools are available in most basins in the state. In basins where particular CDSS tools are not available, alternative methodologies were used to estimate demands and potential future gaps.
- **Consideration of climate change:** Three of the five planning scenarios include assumptions related to a hotter and drier future climate. Projections of future climate conditions were not a part of SWSI 2010 and can have a significant influence on hydrology, water use, and estimated gaps.
- **Quantification of an agricultural gap:** Water demands and shortages for irrigated crops at the field level were estimated in SWSI 2010, but were not quantified using surface water modeling. Using the full suite of modeling tools available from CDSS made it possible to estimate agricultural gaps in the Technical Update under current and planning scenario conditions. Agricultural gaps are described in two ways:
  - » *1. Total Gap:* The overall shortage of agricultural water supplies to meet diversion demands required to provide full crop consumptive uses.
  - » *2. Incremental Gap:* The degree to which the gap could increase beyond what agriculture has historically experienced under water shortage conditions.
- **Improved environment and recreation tools:** The Technical Update built on prior SWSI efforts and improved the data associated with environment and recreation attributes statewide. In addition, an Environment and Recreation (E&R) Flow Tool (Flow Tool) was developed to help assess potential flow conditions and associated ecological health in river segments in each basin. The Flow Tool was built on the framework of the Watershed Flow Evaluation Tool, a Colorado-specific application of a framework for assessing environmental flow needs at a regional scale previously developed with CWCB support. The tool uses flow data from the surface water allocation modeling developed for the Technical Update.

Figure ES.1 CWP Planning Scenarios Key Drivers Graphical Summary



A. Business as Usual

Recent trends continue into the future. Few unanticipated events occur. The economy goes through regular economic cycles but grows over time. By 2050, Colorado's population is expected to be close to 9 million. Single-family homes dominate, but there is a slow increase of denser developments in large urban areas. Social values and regulations remain the same, but streamflows and water supplies show increased stress. Regulations are not well coordinated and create increasing uncertainty for local planners and water managers. Willingness to pay for social and environmental mitigation of new water development slowly increases. Municipal water conservation efforts slowly increase. Oil-shale development continues to be researched as an option. Large portions of agricultural land around cities are developed by 2050. Transfer of water from agriculture to urban uses continues. Efforts to mitigate the effects of the transfers slowly increase. Agricultural economics continue to be viable, but agricultural water use continues to decline. The climate is similar to the observed conditions of the 20th century.

B. Weak Economy

The world's economy struggles, and the state's economy is slow to improve. Population growth is lower than currently projected, which is slowing the conversion of agricultural land to housing. The maintenance of infrastructure, including water facilities, becomes difficult to fund. Many sectors of the state's economy, including most water users and water-dependent businesses, begin to struggle financially. There is little change in social values, levels of water conservation, urban land use patterns, and environmental regulations. Regulations are not well coordinated and create increasing uncertainty for local planners and water managers. Willingness to pay for social and environmental mitigation decreases due to economic concerns. Greenhouse gas emissions do not grow as much as currently projected, and the climate is similar to the 20th century observed conditions.

C. Cooperative Growth

Environmental stewardship becomes the norm. Broad alliances form to provide for more integrated and efficient planning and development. Population growth is consistent with current forecasts. Mass transportation planning concentrates more development in urban centers and in mountain resort communities, thereby slowing the loss of agricultural land and reducing the strain on natural resources compared to traditional development. Coloradans embrace water and energy conservation. New water-saving technologies emerge. Eco-tourism thrives. Water development controls are more restrictive and require both high water-use efficiency and environmental and recreational benefits. Environmental regulations are more protective, and include efforts to re-operate water supply projects to reduce effects. Demand for more water-efficient foods reduces water use. There is a moderate warming of the climate, which results in increased water use in all sectors, in turn affecting streamflows and supplies. This dynamic reinforces the social value of widespread water efficiency and increased environmental protection.

D. Adaptive Innovation

A much warmer climate causes major environmental problems globally and locally. Social attitudes shift to a shared responsibility to address problems. Technological innovation becomes the dominant solution. Strong investments in research lead to breakthrough efficiencies in the use of natural resources, including water. Renewable and clean energy become dominant. Colorado is a research hub and has a strong economy. The relatively cooler weather in Colorado (due to its higher elevation) and the high-tech job market cause population to grow faster than currently projected. The warmer climate increases demand for irrigation water in agriculture and municipal uses, but innovative technology mitigates the increased demand. The warmer climate reduces global food production, which increases the market for local agriculture and food imports to Colorado. More food is bought locally, which increases local food prices and reduces the loss of agricultural land to urban development. Higher water efficiency helps maintain streamflows, even as water supplies decline. Regulations are well defined, and permitting outcomes are predictable and expedited. The environment declines and shifts to becoming habitat for warmer-weather species. Droughts and floods become more extreme. More compact urban development occurs through innovations in mass transit.

E. Hot Growth

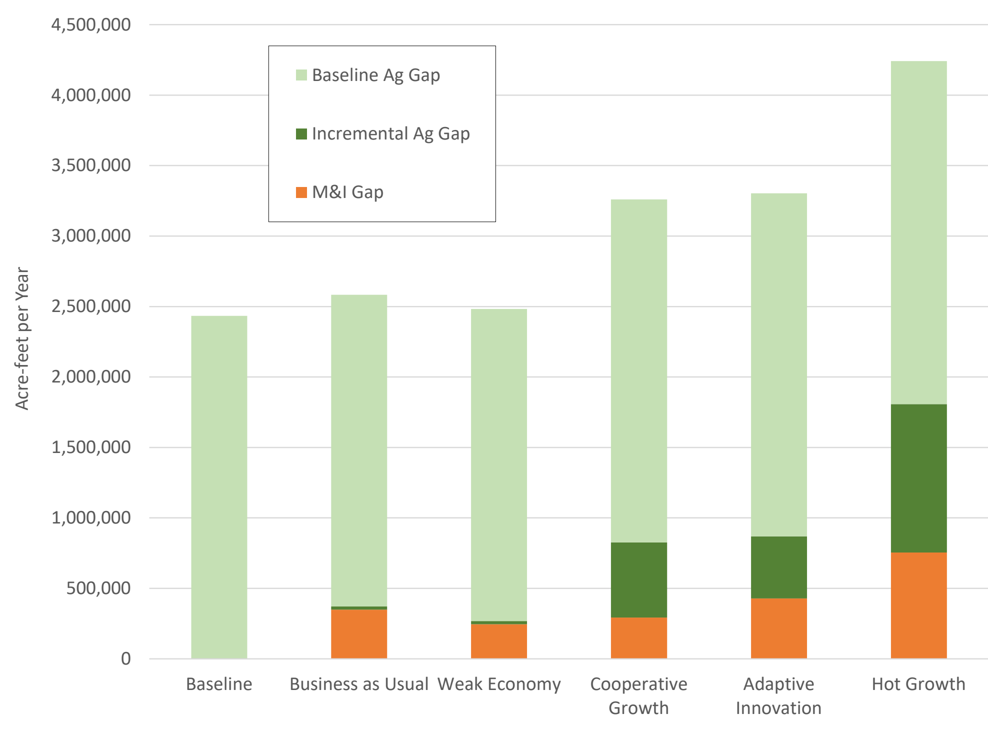
A vibrant economy fuels population growth and development throughout the state. Regulations are relaxed in favor of flexibility to promote and pursue business development. A much warmer global climate brings more people to Colorado with its relatively cooler climate. Families prefer low-density housing, and many seek rural properties, ranchettes, and mountain living. Agricultural and other open lands are rapidly developed. A hotter climate decreases global food production. Worldwide demand for agricultural products rises, which greatly increases food prices. Hot and dry conditions lead to a decline in streamflows and water supplies. The environment degrades and shifts to becoming habitat for species adapted to warmer waters and climate. Droughts and floods become more extreme. Communities struggle unilaterally to provide services needed to accommodate rapid business and population growth. Fossil fuel is the dominant energy source, and there is large production of oil shale, coal, natural gas, and oil in the state.

3 REVISITING THE GAPS

Statewide gaps may vary substantially, depending on future climate conditions and population increases, which underscores the need to take an adaptive approach to developing water management strategies and projects and methods to fill potential future gaps (see figure ES.2).

- **Agriculture** currently experiences a gap, and it is projected to increase statewide. Increases may be modest under the *Business as Usual* and *Weak Economy* scenarios but may be more substantial under scenarios that assume a hotter and drier future climate (the *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth* scenarios) due to decreasing supply and increasing crop irrigation requirements.
- **M&I** users do not currently experience a gap, but a growing population and potential impacts from climate change are projected to create gaps. Projected M&I gaps vary based on assumptions regarding future population and climate conditions but may be reduced by conservation measures.
- **E&R** gaps were not directly quantified but tools were developed to help evaluate potential risks that impact aquatic habitat, species and boating due to flow conditions. These potential future risks are documented in various sections of the Technical Update but are not a part of the gap estimates below.

Figure ES.2 Summary of Statewide Gap Estimates by Planning Scenario



COMPARING THE 2015 WATER PLAN GAP NUMBERS TO GAPS IN

THE TECHNICAL UPDATE

SIMILAR GAPS. ABSENT PROJECTS. LOWER POPULATION. LOWER DEMANDS.

1 Gaps Absent Projects

Gap projections in the Technical Update do not include estimates of basin-identified project yields. This is primarily due to a lack of specific project data that would allow projects to be modeled. Forthcoming basin plan updates will reevaluate projects and consider strategies to address gaps.

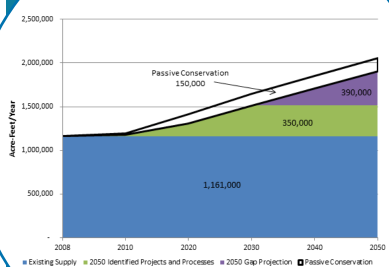
2 Gaps Across Scenarios

Unlike past projections that estimated high, medium and low gaps at 2050, the Technical Update identifies 2050 gaps for each of the Water Plan's five scenarios.

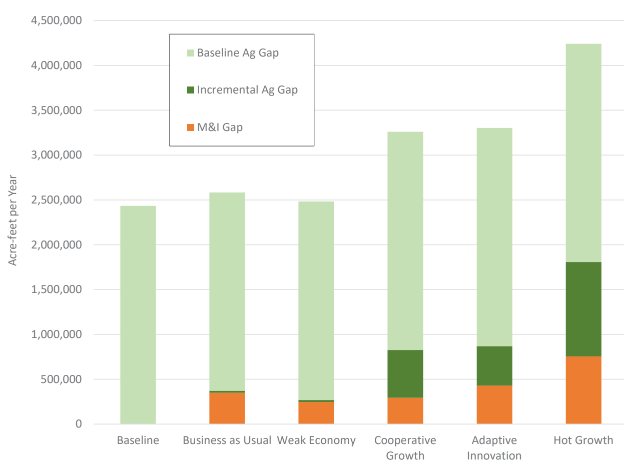
3 Gap Influences

Some of the main drivers (population, climate) and assumptions (storage operations) heavily influence the gaps in the Technical Update. Population projections, while lower than in previous analyses, remain a major driver of demands. Climate change is included in three of the five scenarios, which drives irrigation, streamflow and storage timing. Modeled storage operations maximize the use of stored water to meet demands and lower gaps.

GAPS SHOWN IN THE 2015 WATER PLAN



GAPS SHOWN IN THE 2019 TECHNICAL UPDATE



GAPS SHOWN IN THE 2015 WATER PLAN	GAPS SHOWN IN THE 2019 TECHNICAL UPDATE
190,000 - 630,000 AFY 2050 M&I GAP	250,000 - 750,000 AFY 2050 M&I GAP
1,722,000 AFY 2050 AG SHORTAGE	23,000 - 1,053,000 AFY 2050 INCREMENTAL AG GAP

4 Gap Mitigation

When basins reevaluate plans it will be important to evaluate core projects that represent low-regret actions to meet future needs under any scenario. The Adaptive Innovation scenario, for example, illustrates how adaptive actions (e.g. efficiency) can help offset impacts from climate change and population growth.

5 Gaps: Max, Average & Incremental

Gaps are shown in a manner that reflects the difference in how M&I and agriculture plan in any given year. Feedback on earlier studies suggested that agriculture gaps may have been overstated because many agricultural producers live with annual shortages (especially in over-appropriated basins).

To address this, agricultural gaps are expressed in terms of average and incremental gaps—the degree to which gaps may increase in the future. Maximum agricultural gaps can also be found in the Technical Update results. At the same time, M&I gaps are primarily expressed in terms of maximums, which is consistent with firm yield planning.

AGRICULTURAL IMPACTS

The Colorado Water Plan identifies that up to 700,000 acres of agriculture could come out of production if agricultural transfers ("buy and dry") are exclusively used to meet future M&I demands. Because the Technical Update did not quantify basin projects, roundtables will evaluate how gaps should be met in the forthcoming basin plan updates. The Technical Update indicates that where municipal boundaries expand, agriculture is likely to be lost. This urbanization could result in the loss of more than 152,400 irrigated acres. Additionally, stakeholders identified that planned agricultural to M&I water transfers could result in a loss of up to 76,000 acres of agriculture in the South Platte and Arkansas basins alone.

SIGN OF CONCERN

Scenarios with moderate and significant climate impacts show shifts to earlier runoff seasons which will likely impact storage, irrigation, and streamflows.

SIGN OF SUCCESS

The statewide baseline per capita systemwide municipal demand has decreased from 172 gpcd ito nearly 164 gpcd. That represents about a 5 percent reduction in demands between 2008 and 2015.

4 KEY RESULTS

The Technical Update generated a rich dataset throughout Colorado that describes agricultural and M&I water demands, potential gaps, and available water supply under current conditions and under each of the five planning scenarios. The data and results are provided for basin roundtables and others to use for water planning purposes.

Key results and findings of the Technical Update pertaining to statewide agricultural and M&I demands and gaps, as well as findings related to environment and recreation attributes in potential future conditions, are summarized below.

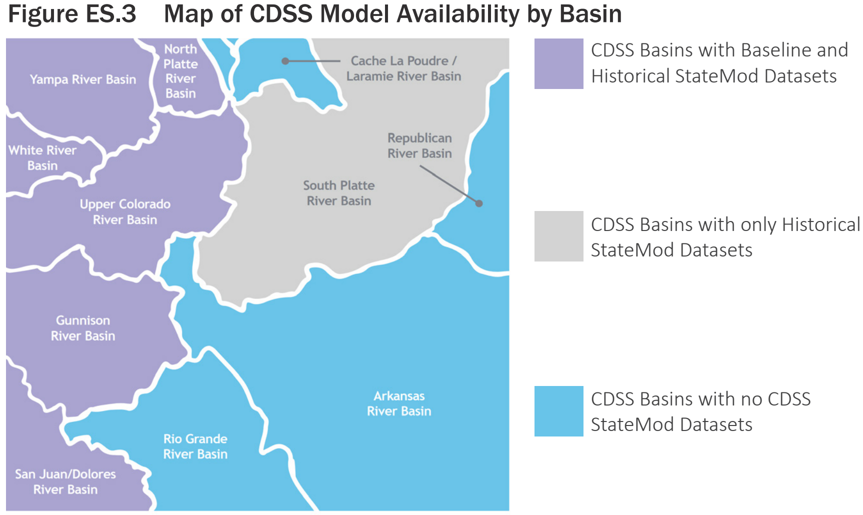
Summary of Key Statewide Results

Agricultural	Environmental and Recreational	Municipal and Industrial
• Agriculture currently experiences gaps, and gaps may increase in the future if climate conditions are hotter (which increases irrigation water demand) and supplies diminish (due to drier hydrology). • Irrigated acreage is projected to decrease in most basins due to urbanization, planned agricultural-to-municipal water transfers, and groundwater sustainability issues. • Gaps under the Adaptive Innovation scenario are significantly less than *Hot Growth* despite similar assumptions related to future climate conditions, which demonstrates the potential benefits of higher system efficiencies and emerging technologies that could reduce consumptive use; however, in return flow driven systems, conservation in one area could impact water supplies downstream, so thoughtful approaches are necessary.	• Climate change and its impact on streamflow will be a primary driver of risk to E&R assets. • Projected future stream flow hydrographs in most locations across the state show earlier peaks and potentially drier conditions in the late summer months under scenarios with climate change. • Drier conditions in late summer months could increase risk to coldwater and warmwater fish due to higher water temperatures and reduced habitat. The degree of increased risk is related to the level of stream flow decline. • Instream flow rights and recreational in-channel diversion water rights may be met less often in climate-impacted scenarios.	• Municipal and industrial users do not currently experience a gap, but increasing population and potentially hotter and drier future climate conditions will create a need for additional supply despite efforts to conserve water. • Conservation efforts, however, can create significant future benefits in lowering the gap, as demonstrated by comparing the *Adaptive Innovation* and *Hot Growth* scenarios (which have similar assumptions on population and climate).

BASIN MODELING

CDSS surface water allocation models (StateMod) were used in basins where they are available to evaluate streamflows and gaps. Baseline data sets were used to assess available water supplies under current conditions; these data sets were modified to estimate future water supplies in the planning scenarious. In basins where the CDSS program has not been fully implemented, the methodology was modified using available tools and water supply information, such as historical streamflow data.

Figure ES.3 Map of CDSS Model Availability by Basin



[An overview of each of these areas is provided on the following pages.]

Agricultural Diversion Demands

Agricultur diversion demand represents the amount of water that would need to be diverted or pumped to meet the full crop irrigation water requirement (IWR) or full crop consumptive use. The diversion demand does not reflect historical irrigation supplies because irrigators often operate under water short conditions and do not have enough supply to fully irrigate their crops.

Current statewide total agricultural diversion demand is approximately 13 million acre-feet (AF), with more than 80 percent of that demand attributable to surface water supplies (though groundwater is the primary source of supply in some basins). The South Platte, Arkansas, Gunnison, and Rio Grande basins have the highest demands for irrigation diversions.

Future agricultural diversion demands will be affected by urbanization, planned agricultural projects that add irrigated acreage, aquifer sustainability, and climate change. Emerging technologies that increase system efficiency and/or reduce crop consumptive use of water may reduce water supply shortages and potentially reduce the amount of water diverted or pumped.

Future statewide agricultural diversion demand estimates range from 10 million AF in the *Adaptive Innovation* scenario to 13.5 million AF in the *Hot Growth* scenario. Urbanization, transfers of agricultural water to municipalities, and declining aquifer levels are projected to cause reductions in irrigated lands across the state (in some basins more than others), leading to reduced overall diversion demand compared to current demand. In scenarios that assume a hotter and drier climate, the impact of acreage loss on diversion demand could be offset by higher crop water requirements, which could lead to an overall increase in demands (see the *Cooperative Growth* and *Hot Growth* scenarios). The *Adaptive Innovation* scenario has the lowest statewide agricultural diversion demand due to assumptions of higher system efficiencies and emerging technologies that reduce crop water demands.

Figure ES.4 Current Average Annual Agricultural Diversion Demand by Basin

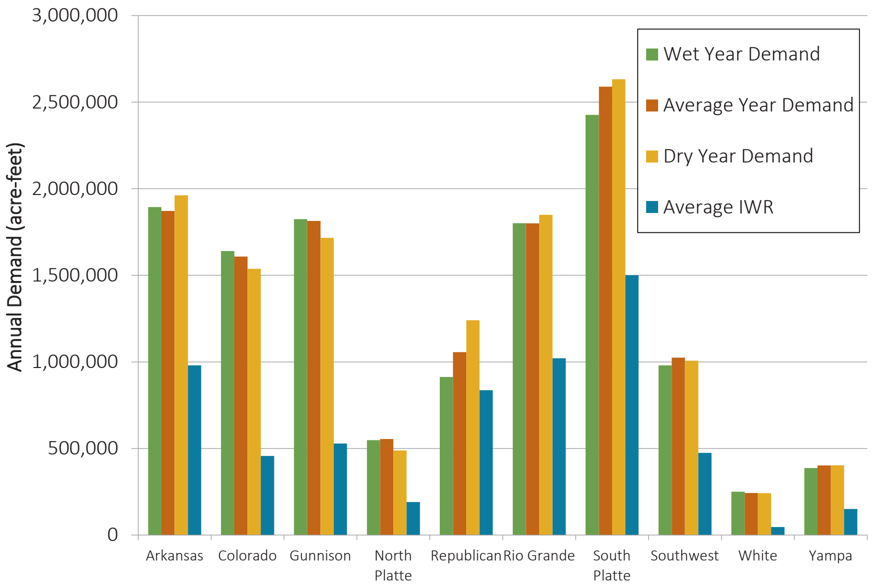
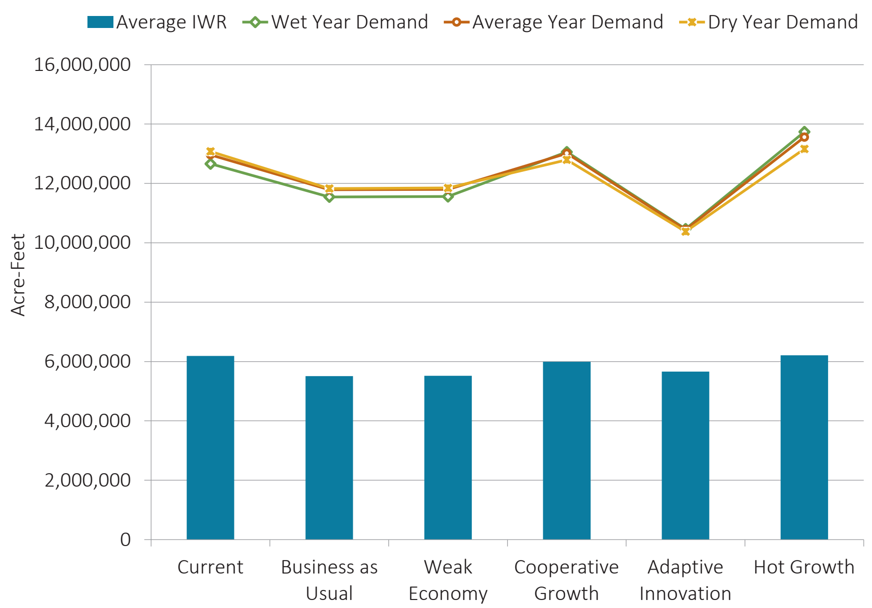
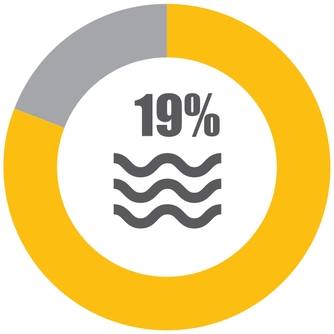


Figure ES.5 Future Statewide Average Annual Agricultural Diversion Demand Estimates for Planning Scenarios



TECHNICAL UPDATE / AGRICULTURAL FINDINGS



Demand for groundwater is approximately 19 percent of the overall demand. Groundwater demands occur primarily in the Arkansas, Republican, Rio Grande, and South Platte basins where irrigation from wells is prominent.

3 X

Based on known agricultural water transfers currently in water court or deemed to be highly likely by agricultural stakeholders, the estimates of planned buy and dry gransfers in the Technical Update (33,000 - 76,000 acres) are almost three times higher on the upper end than the data that informed the Water Plan (26,200 acres).

In all basins where significant agriculture comes out of production, diversion demands will go down due to the decrease in irrigation even as the plant demand for irrigation (were those lands to be irrigated) increases.

20% UNMET DEMAND

On average, approximately 80 percent of the overall agricultural diversion demand is currently met (and 20 percent is unmet) on a statewide basis, though this varies in each basin.

Agricultural diversion demands statewide are projected to decrease in three of the five scenarios by up to 9 percent compared to current conditions. In *Adaptive Innovation*, decreased demand from loss of irrigated lands will be offset, in part, by climate-driven irrigation demand increases; however, increased efficiency and decreased consumptive use show a 20 percent reduction in diversion demands. In *Hot Growth*, irrigated lands are projected to be lost, but climate change could more than offset that loss, resulting in an overall 5 percent increase in diversion demands.

700K ACRE LOSS STILL POSSIBLE

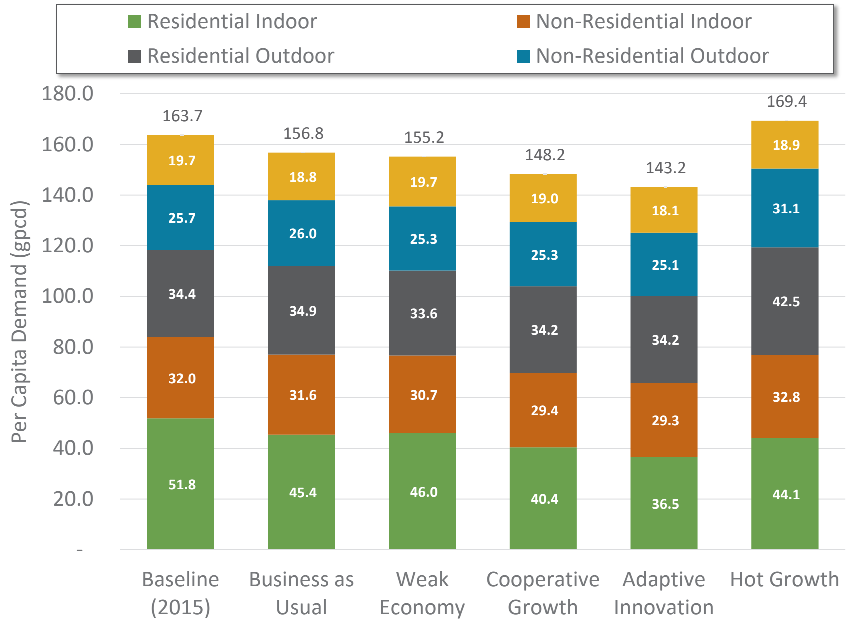
The Colorado Water Plan identifies that up to 700,000 acres of agriculture could come out of production if agricultural transfers (buy and dry) are used to meet future M&I demands. Because the Technical Update did not re-quantify basin projects, roundtables will need to evaluate how gaps could and should be met when updating projects (and project data). The Technical Update does indicate that where municipal boundaries expand, agriculture is likely to be lost. This urbanization could result in the loss of 152,400 irrigated acres.

M&I Diversion Demands

Current and future diversion demands for municipal water users are driven by population and water usage rates. Population estimates were based on State Demography Office (SDO) projections and adjusted upward or downward (depending on the scenario) based on historical growth statistics. The current population statewide is 5.7 million people and is projected to grow to 8.5 million by the year 2050 according to the SDO. High and low statewide projections developed for the Technical Update range from 7.7 million to 9.3 million people.

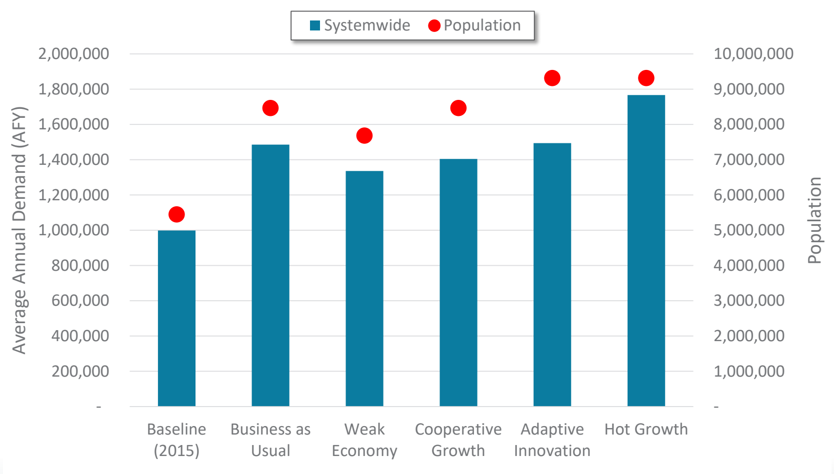
The statewide baseline per capita systemwide demand has decreased from 172 gallons per capita per day (gallons per capita per day) in SWSI 2010 to approximately 164 gpcd, which is nearly a 5 percent reduction in demand between 2008 and 2015. The reduction is associated with improved data availability, conservation efforts, and ongoing behavioral changes. Projected future per capita demands vary from 143 to 169 gpcd (see Figure ES.6), depending on the scenario. Scenario assumptions can create offsetting factors. For example, projected decreases in outdoor demand resulting from implementation of conservation measures in some scenarios was offset by increases in outdoor demand due to climate change.

Figure ES.6 Statewide per Capita Demand for Five Planning Scenarios



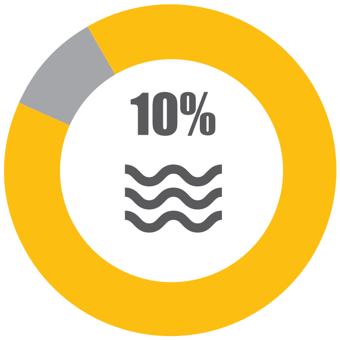
Total statewide municipal diversion demands are shown in Figure ES.7, along with population projections. In general, overall municipal demands are projected to increase and generally in proportion to population increases; however, in *Adaptive Innovation*, projected municipal demands are similar to the *Business as Usual* demands despite the increased population projections and hotter and drier climate assumed for *Adaptive Innovation*, which demonstrates the potential benefits of increased water conservation measures.

Figure ES.7 Statewide Baseline and Projected Population and Municipal Demands

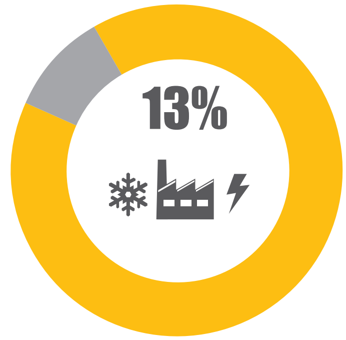


Statewide baseline SSI water demands are comprised of four major industrial uses. Baseline and projected SSI demands for all planning scenarios were calculated. With the exception of *Hot Growth*, the updated projections for all planning scenarios were below SWSI 2010 estimates, primarily due to changes in assumptions for thermoelectric demands related to regulations that require an increase in power generation from renewable sources.

TECHNICAL UPDATE / M&I FINDINGS



M&I demands comprise approximately 10 percent of the combined agricultural and M&I statewide demands that are currently met with existing water supplies and projects.



On average, SSI demands account for 13 percent of the total M&I demands. This includes snowmaking; and thermoelectric, energy development, and large industrial users.

Per capita baseline system demand has decreased from 172 to 164 gpcd—a 5 percent reduction in demands between 2008 - 2015.

Adaptive Innovation shows a 13 percent decrease in gpcd (from 164 to 143 gpcd) compared to current conditions. Total municipal demand in *Adaptive Innovation* tracks closely with *Business As Usual*. This highlights how social values that prioritize water conservation and water saving technologies could help mitigate impacts from climate and population.

35% +

While per capita usage is expected to decrease in all but *Hot Growth*, overall statewide M&I water demand is projected to increase from 35 percent in *Weak Economy* to 77 percent in *Hot Growth* over current demands. Even at that highest level, it is still lower than Water Plan due to the revised population projections, which are lower than previously estimated.

5%

Current population (5.4 million) is 5 percent less than the Water Plan's projected 2015 levels. The State Demography Office estimates that Colorado will grow to 8.5 million by 2050.

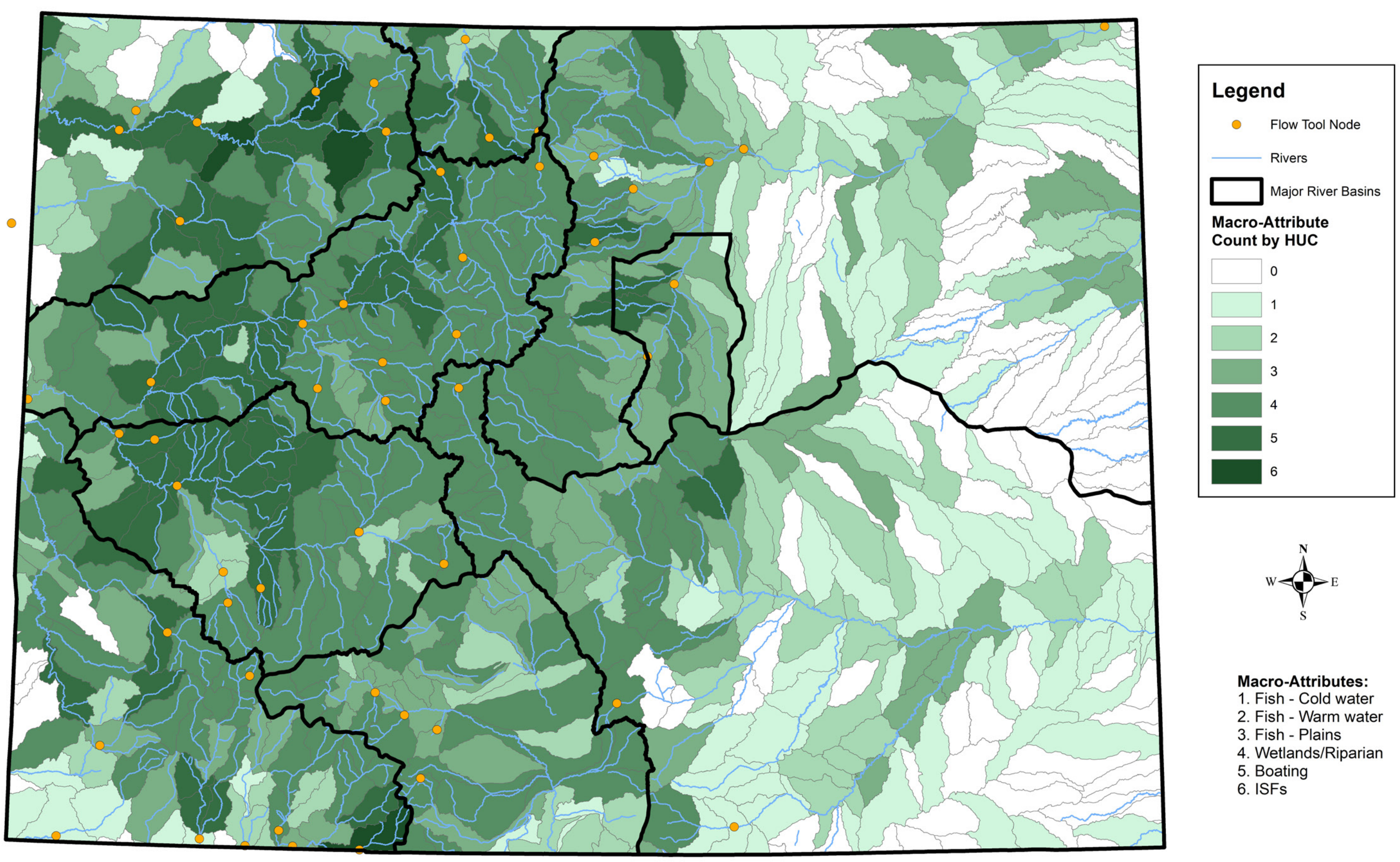
Environment and Recreation

The Colorado Environment and Recreation Flow Tool (Flow Tool) helps basin roundtables refine, categorize, and prioritize their portfolio of E&R projects and methods through an improved understanding of flow needs and potential flow impairments, both existing and projected. The Flow Tool uses hydrologic data from CDSS, additional modeled hydrologic data for various planning scenarios, and established flow-ecology relationships to assess risks to flows and E&R attribute categories at preselected gages across the state. The Flow Tool is a high-level tool that is intended to provide guidance during Stream Management Plan development and BIP development.

The Flow Tool estimates the response of E&R attributes in rivers under various hydrologic scenarios. The flow-ecology relationships in the Flow Tool were first developed as part of the Watershed Flow Evaluation Tool and were patterned after similar relationships that have been developed across the globe to inform water management. Flow-ecology science quantifies the relationship between specific flow statistics (e.g., average magnitude of peak flow, the ratio of flow in August and September to mean annual flow) and the risk status (low to very high) for environmental attributes under the flow scenario being analyzed. Data-derived relationships have been developed for riparian/wetland plants (cottonwoods), coldwater fish (trout), warmwater fish (bluehead sucker, flannelmouth sucker, and roundtail chub), and Plains fish. Other metrics were developed with basic, well-established relationships between hydrology and stream ecology. Relationships for recreational boating were also developed with stakeholders during Watershed Flow Evaluation Tool development.

The Flow Tool incorporates data from 54 nodes in the water supply and gap analysis; the tool visualizes changes in flow regime and risks to E&R attributes under existing and future conditions associated with the five planning scenarios.

Figure ES.8 Gages Included in the Flow Tool



TECHNICAL UPDATE / E&R FINDINGS

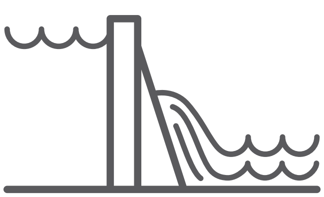
Projected future streamflow hydrographs in most locations across the state show potentially drier conditions in the late summer months under scenarios with climate change that suggest air temperatures could increase by 3.78°F to 4.15°F by 2050.

Instream Flow (ISF) and recreational in-channel diversions (RICD) water rights may be met less often in climate-impacted scenarios that see more consistent temperature increases and more variable precipitation and runoff conditions.

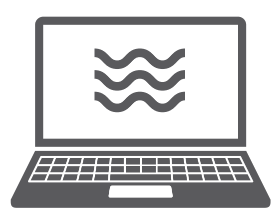
↑ 1 MONTH

Peak runoff may shift as much as one month earlier, which could lead to drier conditions in summer months and produce multiple implications for storage, irrigation and streamflow.

Under climate change scenarios, runoff and peak flows may occur earlier, and result in possible mismatches between peak flow timing and species' needs. Drier conditions in late summer months could increase risk to coldwater and warmwater fish due to higher water temperatures and reduced habitat.



In mountainous regions with infrastructure, risks to E&R assets may vary. Streams that are already depleted may see increased risks in scenarios with climate change; however, some streams may be sustained by reservoir releases, which will help moderate risks in scenarios with climate change.



The Flow Tool created as part of the Technical Update was designed to compare modeling outputs from the five planning scenarios against baseline (existing) and naturalized (unimpaired) flow conditions. Key outputs include a comparison of monthly flow regimes relative to ecological-flow indicators, building off past stakeholder-driven efforts in Colorado.

5 INSIGHTS, TOOLS & RECOMMENDATIONS

The Technical Update developed a variety of high-level analyses on the topics of public perceptions, alternative transfer methods (ATM), water reuse, storage opportunities, and economic impacts. The intent of these analyses was to provide insight into various issues that will be valuable for basin roundtables as they update their BIPs and consider solutions to address potential future gaps. Findings from these analyses are included in Section 5 of the Technical Update (Volume 1).

The Technical Update also developed several tools for basin roundtables to use when updating their BIPs. During the Technical Update, several types of data from existing BIPs were reviewed that indicated the need to improve the completeness and uniformity of basin project information. In addition, the Technical Update included the development of tools like a Project Cost Estimating Tool and E&R Flow Tool.

A list of recommendations aims to allow basins flexibility in the BIP update process to tailor approaches to best suit basin goals while at the same time providing a framework for standardization across the BIP updates. This iterative process is meant to support statewide water supply planning, cross-basin dialogue, project funding, enhanced future supply analyses, revised basin goals, and updated project lists.

Integrating Technical Update findings with the BIPs, project lists and, ultimately, the Colorado Water Plan update ensures state water planning will continue to be informed by the best available data.

SECTION 1
INTRODUCTION

Clean and reliable water supplies are essential to our way of life. All of us—agricultural producers, urbanites, environmentalists, and recreationalists—depend on it for healthy lifestyles, a vibrant economy, and a beautiful environment. These are the reasons we call Colorado home, the qualities that attract new Colorado residents, and the drivers of the Colorado Water Plan (Water Plan).

Colorado's water supplies are limited, yet our demands on those supplies continue to increase. Throughout Colorado's history, and especially in recent decades, we have experienced severe drought conditions, extreme flooding events, population booms, and economic recessions. These extremes often reflect larger shifts that highlight the importance of resiliency in our water supplies, and the need for thoughtful, collaborative planning.

The Colorado Water Plan provides a framework for developing resilient responses to our water-related challenges. It articulates a vision for collaborative and balanced water solutions led by the Colorado Water Conservation Board (CWCB) and our grassroots basin roundtable structure. The Water Plan's success will be fostered by the development of technical information and robust analysis tools that support informed decision making on how to tackle our State's challenges.

Following the 2015 launch of the Water Plan and BIPs, the CWCB began a process of updating the underlying water supply and demand analyses. The work included collaboration with TAGs, which included diverse basin roundtable representatives from each basin and subject matter experts. The TAGs helped outline the methods to be used in the Analysis and Technical Update to the Colorado Water Plan, hereafter Technical Update (formerly known as the Statewide Water Supply Initiative or SWSI), which establishes a new approach to statewide water analysis and data sharing.

While this effort stems from past water supply and demand projections (SWSI I, SWSI II, and SWSI 2010), it is markedly different in its scope and approach. Key features include more robust modeling, integration of scenario planning, incorporation of climate change, and the development of functional support tools to promote data refinement. With these enhancements, the Technical Update sets the stage for enhanced basin-level planning.

The Technical Update methods and results are described in this report, along with a description of how the study fits into the next phases of Colorado water planning. Designed for accessibility, this document summarizes the findings of the analysis and is supported by additional technical memoranda and data that can be accessed at www.colorado.gov/cowaterplan.

1.1 COLORADO'S STATEWIDE WATER PLANNING CYCLE

1.1.1 Colorado's Statewide Water Planning Cycle & Recent Water Planning Efforts

In the early 2000s, severe statewide drought, combined with increasing water demands, spurred Colorado's General Assembly to undertake long-term water planning initiatives. One key initiative established the nine basin roundtables as well as the creation of the Interbasin Compact Committee (IBCC). A second key action was the initiation of the Statewide Water Supply Initiative (SWSI). The latter, created a statewide technical analysis to quantify future demands and potential gaps in the ability to supply Colorado's water needs. The roundtables formalized a grassroots process to bolster communication and collaboration within and between major river basins.

Since the early 2000s, Colorado's statewide planning process has evolved to include additional planning phases that foster communication, transparency, and action. Updates to the SWSI data sets and analyses provided new and enhanced information for basin roundtables to use in developing strategies and tangible solutions to meet future consumptive and nonconsumptive needs.

In 2015, BIPs were completed to provide basin-focused portfolios of solutions to projected supply gaps. The BIPs provided basin-level details to the Colorado Water Plan, which sets statewide policy and implementation strategies to meet current and future water-related challenges. The timeline on the following page summarizes major water planning efforts since 2003.

2000

2002

MAJOR DROUGHT

The 2002-2003 drought and the 2002 Hayman Fire (Colorado's largest fire) trigger legislative action that focused on water supply planning and statewide collaboration.

2004

SWSI I

The first Statewide Water Supply Initiative (SWSI I) provided quantification of current and future water needs through 2030.

2005

WATER FOR THE 21st CENTURY ACT

The Water for the 21st Century Act created the nine basin roundtables and the Interbasin Compact Committee (IBCC) in an effort to build more collaborative cross-basin water planning.

2007

SWSI II

The second phase of SWSI (SWSI II) established technical roundtable groups for Conservation, Alternative Agriculture Water Transfers, Environment and Recreation, and Water Supply Gaps.

2010

SWSI 2010

SWSI 2010 incorporated SWSI II work group findings, analyzed future water needs through 2050, and served as the technical foundation for the Colorado Water Plan.

2015

THE COLORADO WATER PLAN

The Colorado Water Plan (Water Plan) brought together statewide planning objectives and local implementation activities under a common banner.

2017

RIPPLE EFFECTS

Provided an update of progress made toward meeting the actions and objectives of the Water Plan.

2019

TECHNICAL UPDATE

In keeping with goals of the Water Plan to update SWSI efforts, the Technical Update launched in Summer 2019.

2020

NEXT STEPS

Building on 2018-2019 BIP update scoping, basins will work with the CWCB to use the methodologies, findings and recommendations from the Technical Update to revise BIPs and update the Water Plan.

Moving Forward Under the Colorado Water Plan

Colorado water users understand that making specific predictions of future conditions is impossible. From precipitation to population, there are any number of possible shifts that could significantly impact water availability. Being responsive to these drivers of change requires thoughtful planning and adaptive management. This involves using the best data available to predict a range of variant futures, which helps ensure Colorado's water planning is robust and flexible enough to address future concerns. The five planning scenarios identified in the Colorado Water Plan were born from this effort and were developed through an iterative process with the basin roundtables and the IBCC.

Holistic Planning

Colorado recognizes the evolutionary nature of water resource planning and implementation. The two are not mutually exclusive, and occur simultaneously at several scales. Colorado's cyclical, statewide planning process is made up of three phases:

A **Analysis and Technical Update Phase** – includes the statewide Analysis and Technical Update to the Water Plan with standard tools, datasets, and analyses quantifying future supplies, demands, and resource gaps.

B **Basin Plan Update Phase** – includes local, basin-wide planning conducted through BIP updates that integrate information from the analysis phase and work to identify projects that address gaps and other priority basin needs.

C **Comprehensive Update Phase** – includes the Water Plan update itself with a focus on metrics, goals, timelines, and strategies that honor the values in the Water Plan and work toward implementation.

These phases occur cyclically and are, by design, iterative. To that end, the Water Plan process in its entirety (phases A, B, and C) are constantly being updated, planned for, and implemented. Each phase works in concert to refine the understanding of existing and future gaps in water supply and to identify solutions for addressing these gaps.

1.1.2 Advanced Methodologies and Refined Objectives

Advanced Methodology

The Technical Update addresses a variety of questions using new TAG-supported methodologies and analysis tools. The analysis leverages the State's 25+ year investment in Colorado's Decision Support Systems (CDSS), which has made significant gains in basin modeling since SWSI 2010. Use of CDSS and more robust modeling has been incorporated into the new analysis methodologies.

The new analysis tools help prepare for the future in a more robust manner; however, more in-depth modeling capabilities also help us shed light on new questions that previous SWSI studies were not able to accurately integrate or fully consider, such as potential effects of climate change, variable hydrology, and water rights. At the same time, several new planning concepts are being incorporated into the Technical Update that were not part of prior versions of SWSI. Most notably, incorporating the scenarios in the Water Plan offers a new way of evaluating Colorado's water needs that is significantly different from earlier versions of SWSI. A shortlist of key differences in this Technical Update and SWSI 2010 follows:

- **Scenario planning and adaptive management**

  The Colorado Water Plan developed five plausible water supply/demand year 2050 scenarios that consider varying levels of high-impact drivers such as population increase, agricultural water needs, adoption of conservation measures, social values, and climate conditions. These scenarios are foundational to the analyses and modeling in this Technical Update.

- **Climate change impacts to demand and supply**

  Climate change is a consideration in three of the five planning scenarios described in the Colorado Water Plan. The Technical Update evaluates how potential impacts from climate change affect flows, diversions, crop demand, reservoir storage and more through the use of StateMod water allocation models and StateCU consumptive use models that have been fully developed in most basins. These CDSS modeling tools enable analysis of variable supply and demand conditions and provide a broader view of gaps and how they may vary in response to changing supply and demand drivers.

- **Agricultural diversion demand gaps**

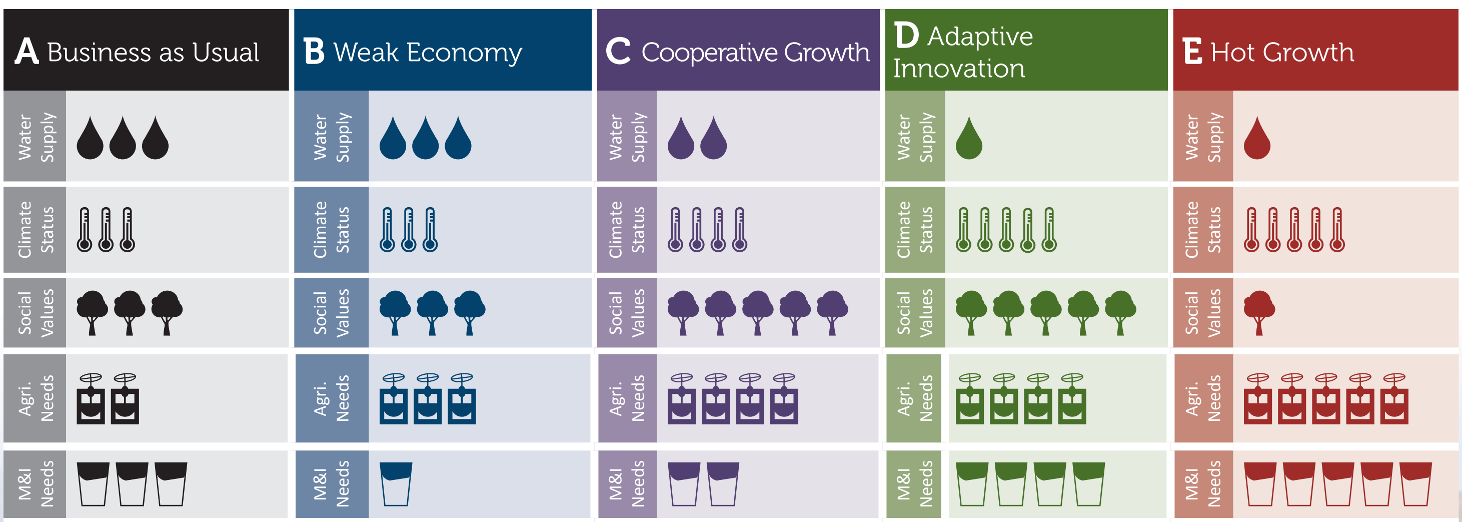
  The SWSI 2010 update quantified historical, field-level agricultural water shortages by comparing crop water demands with historical water deliveries to farms. The Technical Update takes this a step further by using CDSS consumptive use and water allocation models to estimate agricultural gaps in terms of agricultural diversion demands. Diversion demands account for crop demands, application and conveyance efficiencies, and available supply. As a result, agricultural gaps are larger than the field-level shortages quantified in SWSI 2010. The previous methodology was updated to provide basin roundtables with information and tools to use in analyzing "what if" scenarios and for evaluating the effectiveness of future projects, and to provide consistency with estimates of municipal and industrial demands.

Refined Objectives

Given the context and the new planning concepts described above, the primary objectives of the Technical Update report are to:

- Update and recharacterize future gaps and the ability to meet municipal, self-supplied industrial, and agricultural water needs. This recharacterization considers variable hydrology and variable demands in the context of five planning scenarios. The results help basin roundtables account for future uncertainties and develop planning strategies to mitigate future shortages.
- Evaluate environmental and recreational flow needs with new tools. The tools include an enhanced database of E&R attributes and a standardized tool for high-level review of future scenario impacts on streamflows.
- Create user-friendly standardized tools and data products for BIP updates, basin-level project and cost planning, and improved communication and outreach—all aimed at helping basins mitigate future shortages.

Figure 1.1.1 CWP Planning Scenarios and Key Drivers Graphical Summary



1.2 TECHNICAL ADVISORY GROUPS AND OUTREACH

The CWCB enlisted TAGs to develop analysis methodologies and modeling inputs in a collaborative manner. Four TAGs were formed consisting of stakeholders, subject matter experts, and basin roundtable members. The TAGs focused on the following four topics:

- Planning Scenarios
- Environment and Recreation
- Municipal and Self-supplied Demands
- Agricultural Diversion Demands

Each TAG evaluated proposed methodologies through a similar process. First, draft methodologies were distributed to TAG members for review. Comments were discussed at length in the first of two TAG workshops. Consultants updated draft methodologies in response to comments and active discussion and then redistributed the revised drafts to TAG members for re-review. A second meeting was held to describe changes to the methodologies and discuss any final concerns. All final technical memoranda were posted to the CWCB website. A list of TAG members, their organizations, and the basins they represent are included in Appendix D.

In addition to TAG meetings, CWCB staff used the following outreach efforts during the Technical Update process:

- Produced easy-to-read fact sheets that summarized proposed Technical Update methodologies
- Presented progress reports at CWCB board meetings and basin roundtable meetings
- Held targeted stakeholder meetings with basin stakeholders (many of whom were TAG members) to obtain basin-specific information to improve modeling input data
- Hosted webinars to present methodologies and results of various Technical Update components
- Gave presentations at water-related forums such as Colorado Water Congress, farm shows, and conventions
- Conducted live polling and surveys at various intervals to allow for real-time feedback throughout the update process
- Updated and maintained website content, including recordings of various meetings
- Sought feedback from the Implementation Working Group—a group convened by the CWCB that includes basin roundtable and Interbasin Compact Committee members—to help inform Technical Update recommendations and next steps.

SECTION 2
METHODOLOGIES

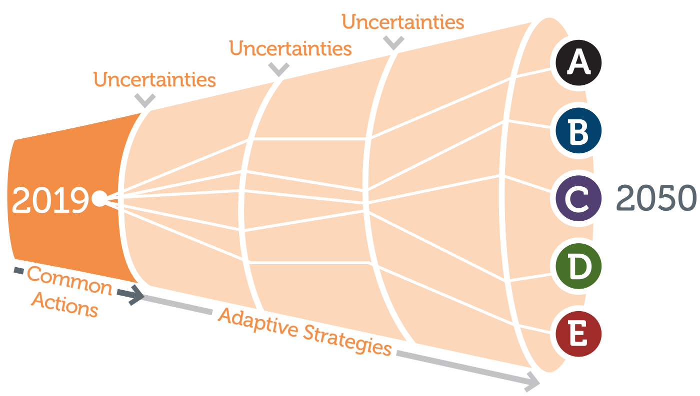
The analysis methodologies used in the Technical Update are summarized in this section. The technical memoranda describing these methodologies can be found in Volume 2. See Appendix A for a comprehensive list of technical memoranda.

2.1 SCENARIO PLANNING

2.1.1 Description of Scenario Planning

Scenario planning is a strategic foresight planning process that acknowledges the future is uncertain. Colorado's Water Plan enlists scenario planning to consider a wide range of possible futures according to the best available science and stakeholder input. The approach embraces inherent uncertainties in future climate conditions, social conditions (such as values and economics), and supply-demand conditions (e.g., energy, agricultural, and municipal needs).

Figure 2.1.1 Illustration of Scenario Planning Concepts



Scenario planning and adaptive management allow decision makers and water users the flexibility to track environmental and social changes over time that provide insights into which future conditions might become more likely as time passes (see Figure 2.1.1). The scenario planning method varies from a more simplistic application of high, medium, and low stress conditions (used in SWSI 2010) by acknowledging that the future holds a degree of uncertainty, depending on a variety of environmental and social drivers.

The scenario planning method includes the following six general steps.

Previous steps conducted by IBCC and described in the Colorado Water Plan	*Steps that are part of this Technical Update*	*Future steps that are to be completed by basin roundtables in BIP updates*
1 Develop expansive list of drivers that can influence future water planning conditions	**4** Quantify future supply and demand conditions for each scenario per identified drivers	**6** Develop projects and strategies that can be used to address gaps for each planning future
2 Identify most uncertain and most important key drivers	**5** Calculate baseline supply versus demand gaps for each scenario without considering future projects or strategies that may address the calculated gap	
3 Develop scenario narratives that define different plausible futures that warrant planning		

2.1.2 Development of the Planning Scenarios

Before developing the Colorado Water Plan, the CWCB initiated a multi-year stakeholder process in conjunction with the nine basin roundtables and the IBCC. Each roundtable developed one or more statewide water supply portfolios to respond to the projected low, medium, or high future water needs of communities. The IBCC subsequently synthesized and reduced the basin roundtable-generated portfolios into a smaller set of 10 representative portfolios to address projected low-, mid-, and high-range M&I water demands. The IBCC then developed a list of the following nine high-impact drivers that could greatly influence the direction of Colorado's water future. Using these drivers, the IBCC developed five scenarios that represent how Colorado's water future might look in 2050, knowing that the future is unpredictable and will contain a mix of multiple scenarios.

1. Population/Economic Growth
2. Social/Environmental Values
3. Climate Change/Water Supply Availability
4. Urban Land Use/Urban Growth Patterns
5. Energy Economics/Water Demand
6. Level of Regulatory Oversight/Constraint
7. Agricultural Economics/Water Demand
8. Municipal and Industrial Water Demands
9. Availability of Water-Efficient Technologies

Signpost Indicators

The adaptive management framework recognizes that the future hinges on how much the drivers (scenario variables) change over time. Major changes in the drivers could tip the still-evolving future toward one scenario or another. The tipping points serve as water management decision points, (i.e., "signposts") that can lead toward the need to implement an alternative portfolio of solutions. Signposts were defined in the Water Plan as decision points that reveal whether past uncertainties now have more clarity. Signposts are a key part of scenario planning, but signpost development was not part of the Technical Update scope. Like project lists, signposts may be unique to regions or specific industries. Signposts could be developed in collaboration with basin planning efforts to identify specific indicators and criteria that signal a need for a new suite of projects or strategies. Alternatively, signposts may be seen as the frequency by which the state and/or basin roundtables evaluate and review key indicators. Section 5 of the Technical Update describes recommendations for the future establishment of signposts.

2.1.3 Description of the Planning Scenarios

The five planning scenarios are summarized in the Water Plan with names portraying each scenario's respective depiction of the future.[1] A summary graphic (see Figure 2.1.2) shows the relative increase and decrease for five main drivers compared to current levels. A full description of each planning scenario follows.

A. Business as Usual. Recent trends continue into the future. Few unanticipated events occur. The economy goes through regular economic cycles but grows over time. By 2050, Colorado's population is close to 9 million people. Single family homes dominate, but there is a slow increase of denser developments in large urban areas. Social values and regulations remain the same, but streamflow and water supplies show increased stress. Regulations are not well coordinated and create increasing uncertainty for local planners and water managers. Willingness to pay for social and environmental mitigation of new water development slowly increases. Municipal water conservation efforts slowly increase. Oil-shale development continues to be researched as an option. Large portions of agricultural land around cities are developed by 2050. Transfer of water from agriculture to urban uses continues. Efforts to mitigate the effects of the transfers slowly increase. Agricultural economics continue to be viable, but agricultural water use continues to decline. The climate is similar to the observed conditions of the 20th century.

B. Weak Economy. The world's economy struggles, and the state's economy is slow to improve. Population growth is lower than currently projected, which is slowing the conversion of agricultural land to housing. The maintenance of infrastructure, including water facilities, becomes difficult to fund. Many sectors of the State's economy, including most water users and water-dependent businesses, begin to struggle financially. There is little change in social values, levels of water conservation, urban land use patterns, and environmental regulations. Regulations are not well coordinated and create increasing uncertainty for local planners and water managers. Willingness to pay for social and environmental mitigation decreases due to economic concerns. Greenhouse gas emissions do not grow as much as projected, and the climate is similar to the observed conditions of the 20th century.

C. Cooperative Growth. Environmental stewardship becomes the norm. Broad alliances form to provide for more integrated and efficient planning and development. Population growth is consistent with current forecasts. Mass transportation planning concentrates more development in urban centers and mountain resort communities, thereby slowing the loss of agricultural land and reducing the strain on natural resources compared to traditional development. Coloradans embrace water and energy conservation. New water-saving technologies emerge. Ecotourism thrives. Water-development controls are more restrictive and require both high water-use efficiency and environmental and recreation benefits. Environmental regulations are more protective and include efforts to reoperate water supply projects to reduce effects. Demand for more water-efficient foods reduces water use. There is a moderate warming of the climate, which results in increased water use in all sectors and in turn, affects streamflow and supplies. This dynamic reinforces the social value of widespread water efficiency and increased environmental protection.

D. Adaptive Innovation. A much warmer climate causes major environmental problems globally and locally. Social attitudes shift to a shared responsibility to address problems. Technological innovation becomes the dominant solution. Strong investments in research lead to breakthrough efficiencies in the use of natural resources, including water. Renewable and clean energy become dominant. Colorado is a research hub and has a strong economy. The relatively cooler weather in Colorado (due to its higher elevation) and the high-tech job market cause population to grow faster than currently projected. The warmer climate increases demand for irrigation water in agriculture and municipal uses, but innovative technology mitigates the increased demand. The warmer climate reduces global food production, which increases the market for local agriculture and food imports to Colorado. More food is bought locally, which increases local food prices and reduces the loss of agricultural land to urban development. Higher water efficiency helps maintain streamflow, even as water supplies decline. The regulations are well defined, and permitting outcomes are predictable and expedited. The environment declines and shifts to becoming habitat for warmer-weather species. Droughts and floods become more extreme. More compact urban development occurs through innovations in mass transit.

E. Hot Growth. A vibrant economy fuels population growth and development throughout the state. Regulations are relaxed in favor of flexibility to promote and pursue business development. A much warmer global climate brings more people to Colorado with its relatively cooler climate. Families prefer low-density housing, and many seek rural properties, ranchettes, and mountain living. Agricultural and other open lands are rapidly developed. A hotter climate decreases global food production. Worldwide demand for agricultural products rises, which increases food prices. Hot and dry conditions lead to a decline in streamflow and water supplies. The environment degrades and shifts to becoming habitat for species adapted to warmer waters and climate. Droughts and floods become more extreme. Communities struggle to provide services needed to accommodate rapid business and population growth. Fossil fuel, the dominant energy source, is supplemented by production of oil shale, coal, natural gas, and oil in the state.

2.1.4 Quantification of High-Impact Drivers in the Scenarios

Quantifying future demands, supplies, gaps, and available water under each of the five scenarios is a foundational task of the Technical Update. While the preceding narrative descriptions provide a qualitative summary, more significant interpretation was needed to determine how technical analyses could quantify the future conditions described in each based on available data and scientific best practices. Figure 2.1.2 summarizes and compares how the drivers varied across the scenarios. A more detailed explanation of how the various drivers were quantified and how the drivers relate to one another and across scenarios is shown in Tables 4 through 8 of Appendix B. The methodology sections and appendices provide more information on specific, quantitative adjustments to the drivers for each scenario and how the adjustments were implemented in various analyses.

Figure 2.1.2 Illustration of High-Impact Drivers Associated with Five Planning Scenarios

Drivers	A Business as Usual	B Weak Economy	C Cooperative Growth	D Adaptive Innovation	E Hot Growth
A. Economy/Population					
B. Urban Land use	No change in density	No change in density	Higher density	Higher density	Lower density
C. Climate Status/Water Supply	Same as 20th century observed	Same as 20th century observed	Between hot and dry and 20th century observed	Hot and dry	Hot and dry
D. Energy Water Needs	Low (no oil shale)	Moderate (no oil shale)	Low (no oil shale)	Low (no oil shale)	High (oil shale)
E. Agricultural Conditions	Total ag water demands decrease • Decrease in irrigated acres due to urbanization • Ag exports and demands lower • Ag is less able to compete with urban areas for water	Total ag water demands slightly decrease • Slight decrease in irrigated acres due to urbanization • Ag exports and demands constant • Ag is less able to compete with urban areas for water	Total ag water demands slightly higher • Slight decrease in irrigated acres due to urbanization • Ag exports down and local demands up • Ag is better able to compete with urban areas for water • Increased ET due to climate change	Total ag water demands slightly higher • Slight decrease in irrigated acres due to urbanization • Ag exports down and local demands up • Ag is better able to compete with urban areas for water • Increased ET due to climate change	Total ag water demands higher • Significant decrease in irrigated acres due to urbanization • Ag exports and demands high • Ag is better able to compete with urban areas for water • Increased ET due to climate change
F. Availability of New Water Efficiency Technology	• M&I Moderate • Ag: Efficiencies are increased	• M&I Moderate • Ag: Efficiencies are increased	• M&I High • Ag: Efficiencies are increased	• M&I High • Ag: Much higher efficiencies are implimented	• M&I Moderate • Ag: Efficiencies are increased
G. Social/Environmental Values	No change	No change	• Increased awareness • Increased willingness to protect environment and stream recreation	• Increased awareness • Increased willingness to protect environment and stream recreation	• Full use of resources • Low willingness to protect environment and stream recreation
H. Regulatory Constraints	Regulation / Deregulation No change	Regulation / Deregulation No change	Regulation / Deregulation Increased	Regulation / Deregulation Increased but expedited	Regulation / Deregulation Reduced
I. M&I Water Demands	Middle of the five scenarios	Lowest of the five scenarios	Second lowest of the five scenarios	Second highest of the five scenairos	Highest of the five scnarios

2.2 ANALYSIS METHODOLOGIES

TheTechnical Update offers a more scientifically rigorous and robust analysis compared to previous SWSI efforts, which did not include scenario planning, climate change considerations, water rights, or surface water modeling. The Technical Update leverages the state's 25-year investment in CDSS, including StateMod models that connect major waterways and tributaries in Colorado.

Hydrologic modeling allows for detailed temporal (hydrology over time) and spatial (geographic and node-specific) analyses. It incorporates inputs that reflect water availability drivers under a variety of future conditions throughout the state. Additionally, hydrologic modeling provides increased consistency in the representation of municipal and agricultural demand gaps in ways that could not be as equitably modeled in earlier methodologies (i.e., SWSI 2010). The models produce a wealth of time series data and quantifications of "hydrologic gaps" at representative locations under each planning scenario.

2.2.1 Incorporating Climate Change into Scenario Planning

Through an iterative effort with the CWCB, basin roundtables, and the IBCC, three composite climate projections were incorporated into the planning scenarios.[2] Of the five planning scenarios, three include some level of stressed future climate change (*Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*). The other two planning scenarios (*Business as Usual* and *Weak Economy)* assume similar climate conditions and variability to the observed conditions of the 20th century compared to historical natural flows for the period 1950–2013).

High stress conditions occur when runoff is low and consumptive use is high, whereas low stress conditions occur when runoff is high and consumptive use is low. The consumptive use, in this case, refers to the irrigation need (increased or decreased) for watering crops or other outdoor watering. This is expressed as the irrigation water requirement (IWR), which is synonymous with the term Crop Irrigation Requirement (CIR).

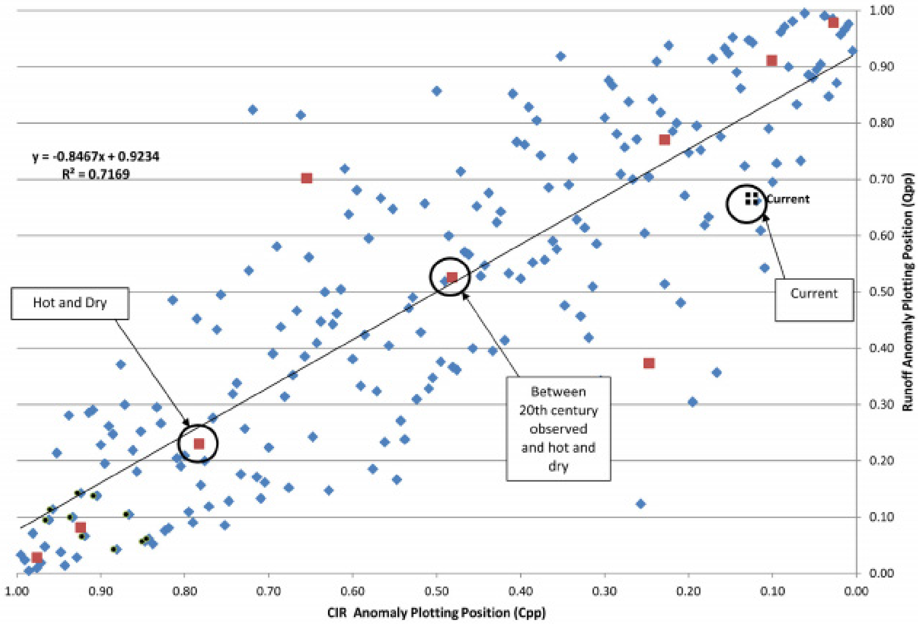
Table 2.2.1 and Figure 2.2.1 map this integration of future climate stress into the Technical Update planning scenarios. More detailed explanations of climate impacts follow and can be found in several documents such as the Colorado Climate Plan, Colorado Water Plan, and the foundational work of the multiphase Colorado River Water Availability Study (CRWAS).

Table 2.2.1 Incorporation of Climate Change into Scenario Planning

CWP Planning Scenario Name	CRWAS Climate Projection Name	Climate Stress Impact on 2050 Future Condition			
		CIR*	Runoff*	Average Annual Temperature[3]	Precipitation Change[3]
Business as Usual	Current	None	None	None	None
Weak Economy	Current	None	None	None	None
Cooperative Growth	In-Between	Moderate (50th percentile)	Moderate (50th percentile)	+ 3.78 °F (+2.0 °C)	5% increase in annual precipitation
Adaptive Innovation	Hot and Dry	High (75th percentile)	Low (25th percentile)	4.15 °F (+2.3 °C)	1% decrease in annual precipitation
Hot Growth	Hot and Dry	High (75th percentile)	(Low (25th percentile)	+ 4.15 °F (+2.3 °C)	1% decrease in annual precipitation

**See Figure 2.3 Plot of Runoff vs. Crop Irrigation Requirement (CIR)*

Figure 2.2.1 Runoff vs CIR Plotting Position



This plot of Runoff vs. CIR uses the Bureau of Reclamation's 200 composite climate scenarios. "Hot and dry" is defined as the 75th percentile of climate projections for crop irrigation requirements (water use), and the 25th percentile for natural flows. In other words, only 25 percent of projections have lower natural flows and 25 percent of projections have higher crop irrigation requirements. "Between 20th century-observed and hot and dry" is defined as the 50th percentile for both natural flows and crop irrigation requirements. This scenario represents the middle of the range in terms of severity. Baseline, or "Current" conditions, which represents no change in runoff or in crop irrigation requirements, fall at roughly the 9th and 67th percentiles; this means that 91 percent of model runs show increases in crop irrigation requirements and about two-thirds show reductions in runoff.

Turning Narrative into Numbers

Understanding how climate change could affect Colorado is key to understanding how to translate climate themes in scenario narratives into quantitative model inputs. In the Technical Update, climate stress is modeled from two dominant perspectives:

1) Supply Perspective: Output from the CRWAS-II project[4] included an extended time series of "natural flow" data developed for numerous locations throughout the state's basins (more than 300 streamflow gage locations statewide). "Natural flow" is the amount of water in the river absent the effect of humans, and serves as the foundational water supply data in the StateMod water allocation models. Although the impacts of climate projections vary across the state, natural flows under the climate projections generally show overall declines and temporal shifts to reflect earlier runoff periods. CRWAS-II project output also included a time series of climate-adjusted hydrology for both the moderate and high climate stress projections (respectively, "In-Between" and "Hot and Dry"). These datasets, also unique at more than 300 gage locations, reflect the relative change streamflow under each climate projection.

2) Demand Perspective: The runoff and IWR factors (jointly "climate factors") from both the "In-Between" and "Hot and Dry" projections reflect increased outdoor evapotranspiration (ET) rates and, therefore, increased IWR. In the Agricultural Diversion Demand methodology (Section 2.2.3) this is represented by IWR numbers that vary monthly, for every model year, for every water district. In the M&I Demand methodology (Section 2.2.4), IWR factors were applied at the county level to represent the average annual change in outdoor municipal demands. It was assumed that indoor demands and non-revenue water are not affected by climate factors.

2.2.2 CDSS Tools

The technical analyses make extensive use of CDSS modeling tools. CDSS is a water management system developed by the CWCB and the Colorado Division of Water Resources. The primary CDSS components used for the Technical Update are as follows:

- **HydroBase:** HydroBase contains historical and current water resources data, including streamflow records, historical climate data, diversion records, and water rights.
- **Geographic information system data:** Spatial data includes geographic information system (GIS) layers of diversion locations, irrigated acreage by ditch and crop type, streamflow measurement points, rivers, climate station locations, and ditch locations.
- **Surface water allocation models:** StateMod, the state's water allocation simulation program, analyzes water supplies and water demands and allocates available supply based on water rights, locations of demands, operational protocols, etc. Shortages (gaps) are calculated if supplies cannot fully meet demands. StateMod model datasets are available in most, but not all, of the river basins in the state.

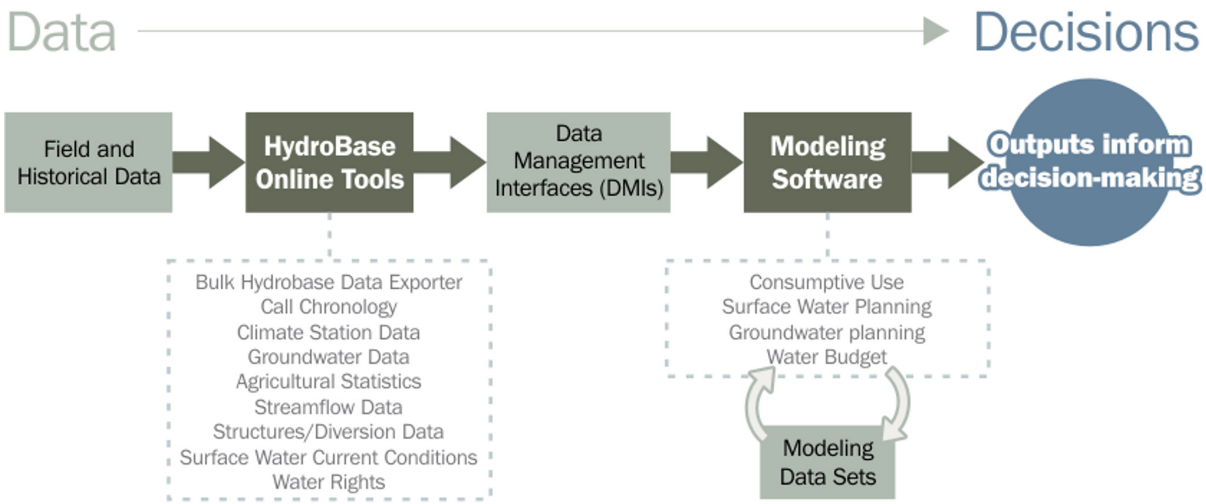
BASIN MODELING TOOLS

Many of the CDSS tools described here were not available for use when SWSI 2010 was being developed. The Technical Update has leveraged Colorado's investment in the CDSS to create a more comprehensive picture of supplies, demands, and gaps under each of the scenarios and under variable hydrologic conditions. The resulting analyses and tools are available for basin roundtables to use in updating their BIPs.

- **Consumptive use models:** StateCU, the state's crop consumptive use model, estimates the amount of water consumed by agriculture. It uses climate data (primarily temperature and precipitation), information on crop types and acreages, and water supply data to generate estimates of irrigation water requirements, consumptive use, irrigation system efficiencies, and agricultural diversion demand. StateCU model datasets are available in most, but not all, of the river basins in the state.

CDSS is foundational for statewide and basinwide water supply planning and establishes a common and accepted framework of information and tools to facilitate informed decision making. CDSS datasets and tools have been developed for use in the West Slope (Colorado; Yampa/White; Gunnison; San Juan/Dolores), North Platte, Rio Grande (consumptive use datasets only), and South Platte basins, and are being developed for the Arkansas Basin. State agencies, water users, and managers in these basins increasingly rely on CDSS as a common and efficient means for organizing, accessing, and evaluating a wide range of information and alternative water management strategies and decisions. Figure 2.2.2 illustrates the types of data and models available in CDSS and how data are incorporated and flow through the tools to facilitate informed decision making.

Figure 2.2.2 How Data and CDSS Tools Foster Informed Decision Making



2.2.3 Agricultural Diversion Demands

Agricultural demands in SWSI 2010 primarily reflected the consumptive use for crop irrigation at the field level. SWSI 2010 agricultural demands did not consider irrigation inefficiencies and ditch losses that occur as surface water diversions and/or pumped groundwater supplies are conveyed and applied to the crop. The Technical Update methodology, by accounting for crop consumptive needs plus irrigation inefficiencies, reflects the total amount of water needed to meet agricultural demands and allows for direct comparison between agricultural and municipal demands in the modeling. The updated methodology also provides information and tools for basin roundtables to use in evaluating the effectiveness of future agriculture projects. The Technical Update methodology described below was used to estimate diversion demands to meet the full irrigation needs of crops.

The Technical Update defines the current agricultural diversion demand as the amount of water that needs to be diverted or pumped to meet the full crop irrigation water requirements associated with the current levels of irrigated acreage, assuming historical climate conditions continue. In other words, the methodology assumes that irrigators will, regardless of a given delivery method's efficiency level, seek to divert enough water to meet their crops' full ET need (noting that under a range of climate patterns in water-short systems, the amount of water irrigators seek to divert is not always available). Current demand serves as the "baseline" for the Technical Update analysis and can be used to estimate the change from current to future conditions. To estimate potential future diversion demands, irrigated acreage, climate conditions, and efficiencies associated with the current agricultural diversion demand were adjusted by various factors to estimate the demands associated with the five planning scenarios that serve as the basis for the Technical Update analyses.

The results of the analyses are projected agricultural diversions and pumping required to meet the full crop requirement for each planning scenario (referred to as agricultural diversion demand). Agricultural diversion demands were incorporated into the water allocation models, which were used to determine how much water is available to meet the demands. Shortages to the agricultural diversion demands in the model are defined as an "agricultural gap".

Current Agricultural Diversion Demand

The approach used to develop the current agricultural diversion demand for the Technical Update varied based on the available data and the type of supplies (groundwater or surface water) used to meet the demand in each basin. The CWCB has developed crop consumptive use datasets using CDSS's StateCU modeling platform for most basins in the state. Two consumptive use datasets have been created for basins with full CDSS development:

> **ONGOING AGRICULTURAL SHORTAGES**
>
> Irrigators in many basins have historically operated under shortage conditions and currently experience a water supply gap in many or most years.

- **Historical Dataset.** This dataset reflects historical conditions and considers historical irrigated acreage, cropping, and climate variability. It also includes estimates of IWR associated with historical agricultural diversion demand using average system efficiency.
- **Baseline Dataset.** This dataset reflects current conditions assuming that variability in climate and hydrologic drivers will be similar to what has occurred in the past. This dataset considers current irrigated acreage and historical climate variability, and includes estimates of IWR associated with current agricultural diversion demand using average system efficiency.

For basins with both historical and baseline datasets, the following approach was used to develop the irrigated acreage, IWR, system efficiencies, and current agricultural demand:

Step	Calculation
1	Extract IWR, reflecting current acreage and crop types, from the most recent Baseline StateCU datasets
2	Develop a representative set of monthly system efficiency values for wet, dry, and average year types for each structure using information from the Historical StateCU datasets
3	Divide the monthly Baseline IWR by either the wet, dry, or average monthly system efficiency values depending on the indicator gage year type to develop the current agricultural diversion demand

The above approach was used for all basins with full CDSS datasets, though some required developing the necessary historical and/or baseline datasets, as summarized below. An additional complication pertained to the use of both surface water and groundwater supplies for irrigation in some basins. In these basins, it was necessary to partition the total agricultural diversion demand into surface diversion demand and groundwater demand. Historical groundwater demands were used to estimate current and future groundwater diversion demand patterns, assuming that the current level of groundwater pumping would likely remain the same or decrease in the future.

The basins for which full CDSS datasets are available include the West Slope basins (Colorado; Yampa/White; Gunnison; San Juan/Dolores) and the North Platte Basin (see Figure 2.2.4). In other basins, the approach was modified, or a different approach was needed based on available datasets and modeling tools. Methodologies are described in detail in Volume 2 of the Technical Update. Methodologies used in basins without full CDSS datasets are briefly summarized below:

- **South Platte and Rio Grande Basins:** Only the historical consumptive use datasets were available from CDSS. Baseline datasets were developed prior to modeling.
- **Republican Basin:** Historical and baseline StateCU models have not been developed in this basin; however, agricultural diversion demand information reflecting groundwater pumping, the source of irrigation in the Republican Basin, was available from the most recent Republican River Compact Administration (RRCA) accounting and model.
- **Arkansas Basin:** Neither historical or baseline StateCU models were available in the Arkansas Basin when the technical analysis began; however, the models are being created as a part of the Arkansas River DSS development project. Historical and baseline StateCU models were developed concurrently with the Technical Update effort and used to estimate agricultural diversion demands.

Projected Agricultural Diversion Demands in the Planning Scenarios

The Technical Update focused on several factors that can be consistently and quantitatively applied to adjust the agricultural diversion demand in each planning scenario. While there are many different factors that can impact the future of agriculture in Colorado (changing climatic conditions, new irrigation technologies, innovative crop hybrids, market fluctuations), the impact of these factors is difficult to quantify or predict with reasonable certainty. The agricultural factors that were quantified in the Technical Update are described as follows.

- **Urbanization.** Urbanization of irrigated agricultural lands will reduce agricultural demands. The approach to evaluating the impact of urbanization relied on mapping current irrigated lands, current municipal boundaries, and basinwide population projections to determine the amount of irrigated acreage that would likely be dried up and urbanized within each basin by 2050. The analysis assumed if mapped irrigated lands fall within or are directly adjacent to mapped municipal boundaries, the irrigated lands will be urbanized by 2050; however, if population projections suggested that no local increase in population will occur in a scenario, then it was assumed that irrigated lands would not be urbanized in those locations in that basin for that scenario.
- **Planned Agricultural Development Projects.** The BIPs developed by each of the basin roundtables described their current agricultural needs as well as each basin's future agricultural goals and approaches to meeting those goals. The North Platte and Yampa basins included a goal to increase agriculture in their basins by putting new lands under production. Irrigated acreage in these basins was projected to increase based on their planned agricultural projects.
- **Groundwater Acreage Sustainability.** A large portion of irrigated acreage in Colorado relies on groundwater supplies, primarily in the South Platte, Republican, Arkansas, and Rio Grande basins. Sustaining these groundwater supplies, both in terms of physical and legal availability, is necessary for preserving groundwater-irrigated acreage. If groundwater levels or augmentation supplies cannot be sustained, irrigated acreage served by groundwater in these basins will likely decrease in the future.
- **Climate.** Factors reflecting increases in IWR due to a potentially warmer and drier future climate were applied in *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*. Background on climate adjustments are provided in Section 2.2.1.

■ POTENTIAL FOR BUY & DRY

In addition to urbanization, irrigated acreage in the South Platte and Arkansas basins is anticipated to decline resulting from permanent agricultural-to-urban water right transfers (widely known as "Buy and Dry"). Meetings were held with stakeholders to estimate these future declines in the five planning scenarios.

- **Emerging Technologies.** Emerging agricultural technologies will play a significant role in future water use. Instrumentation, automation, and telemetry have improved irrigation efficiency and scheduling in many areas of Colorado and will likely continue to improve. Efficiency improvements in delivery and application of water through drip irrigation, more efficient sprinklers, ditch lining, or enclosing open ditches (or additional adoption of these technologies) may reduce water supply shortages and/or reduce the amount of water diverted or pumped. Innovations in crop hybrids have resulted in more drought tolerance while preserving or increasing yields. Two adjustments were made to provide perspective on the potential effect of these emerging technologies in the five planning scenarios:
    - » *Sprinkler Development.* The South Platte and Arkansas basins have experienced significant conversion of flood irrigation (less water efficient) practices to center-pivot sprinklers and drip irrigation systems (more water efficient) for the past several decades. Discussions with stakeholders in the basin indicated a continued likelihood of this development to varying degrees in the five planning scenarios.
    - » *Technological Innovations.* The *Adaptive Innovation* planning scenario narrative contemplates future technological innovations that mitigate potential climate-change-related increases in irrigation demand and decreases in supply. To implement this narrative in the agricultural diversion demand methodology, the impact of contemplated technological innovations was translated as reductions to IWR and improved water delivery efficiencies.

Agricultural Diversion Demand Calculation Process

In general, the adjustment factors discussed in the previous section impact either the acreage, IWR, or efficiency components of the agricultural diversion demand analyses. The following general approach was used to integrate the planning scenario factors and develop the planning scenario agricultural demand.

STEP	ADJUSTMENT	DETAILS
1	Adjust acreage by the urbanization, planned agricultural projects, and groundwater acreage sustainability factors	Using the current irrigated acreage as a starting point, irrigated acreage was increased or decreased in each basin using the acreage values associated with each factor.
2	Calculate adjusted IWR	Revise the consumptive use datasets developed for the current agricultural diversion demand effort with the adjusted acreage and simulate the models to calculate the adjusted IWR for each planning scenario in each basin.
3	Adjust the IWR by the Climate factor	Multiply the adjusted IWR from Step 2 by the adjustment factors associated with the climate change projection pertaining to each planning scenario.
4	Adjust the system efficiency by the Emerging Technologies factor	Using the historical wet, dry, and average monthly system efficiencies as a starting point, increase the system efficiency of each irrigation ditch by 10 percent. This occurs only in the *Adaptive Innovation* scenario.
5	Develop the agricultural diversion demand for the five planning scenarios	Divide the climate-adjusted IWR from Step 3 by system efficiency values to develop the agricultural diversion demand for each planning scenario.

Assumptions and Limitations

The following assumptions and limitations should be considered when reviewing the agricultural diversion demand methodologies and results:

- **Comparison to Historical Diversions.** The current agricultural diversion demands are not directly comparable to historical diversions, because historical diversions reflect changing irrigation practices, crop types, and acreage, as well as physical and legal water availability shortages.
- **Irrigated Acreage Assessments.** The current agricultural diversion demand analysis relies on the irrigated acreage assessments developed by the CWCB and DWR, generally performed every five years. While the assessments are being continually improved, some acreage delineation inconsistencies and incorrect assignment of water supplies remain.

■ CROP TYPE CONSIDERATIONS

Note that future crop types were not adjusted in the planning scenarios but could be during the BIP update process if roundtables would like to evaluate changes in diversion demand from different cropping patterns.

- **Recharge Demands.** A small number of irrigation systems in the Rio Grande Basin have decrees allowing preferential use of groundwater supplies while diverting surface water for on-farm aquifer recharge. Although the structures are legally allowed to use either surface or groundwater supplies on their acreage, designating their agricultural diversion demand as a groundwater demand for the Technical Update efforts is consistent with their current irrigation practices.
- **Shoulder Season Irrigation Practices.** The agricultural diversion demand approach relies on IWR and historical system efficiencies from wet, dry, and average year types to capture the variability of irrigation practices across changing hydrologic conditions. Although this approach allows for estimating demands that can vary based on IWR, it may not fully capture the agricultural diversion demand associated with irrigation practices during months when the IWR is very low or zero (e.g., early-season diversions associated with "wetting up" a ditch).
- **Agricultural Diversion Demands.** The agricultural diversion demand is defined as the amount of water that would need to be diverted or pumped to meet the full crop irrigation demand but does not reflect nor consider the common practice of re-diverting irrigation return flows many times within a river basin. As such, it is not appropriate to assume the total demand reflects the amount of native streamflow that would need to be diverted to meet the full crop irrigation demand.
- **Pumping Estimates.** Groundwater withdrawals have been metered and recorded in recent years, but records are generally not available over a long historical period. As a result, it was necessary to estimate groundwater-only and supplemental irrigation (co-mingled) supplies. In basins with CDSS models, pumping was initially estimated based on IWR in the StateCU datasets and then adjusted to account for historical restrictions to pumping. This approach holds supplemental/co-mingled pumping to current levels, which leaves any change of agricultural diversion demand (positive or negative) in the five planning scenarios a change in surface water agricultural diversion demand.
- **Planning Scenario Adjustments.** The five planning scenarios describe plausible futures with characteristics that require several adjustments to agricultural diversion demands; however, some of the agricultural drivers in the scenario narratives were not explicitly represented in the analyses as they could not be defensibly quantified (examples include narrative commentary on food security, crop type, and future agricultural economies). It is difficult to isolate the impact of a specific adjustment because the adjustments tend to compound and overlap within a planning scenario. If water resources planners are interested in the impact of an individual adjustment, they are encouraged to obtain the consumptive use datasets and implement the adjustments in a stepwise fashion, analyzing the results after each adjustment is implemented.

2.2.4 M&I Demands

The M&I demands were prepared on a spatial and temporal scale in ways that could be incorporated into the hydrologic modeling of future demand and supply scenarios. As with SWSI 2010, the methods used in this approach are for general statewide and basinwide planning and are not intended to replace demand projections prepared by local entities or for project-specific purposes.

Where the Technical Update uses M&I demands across five scenarios and a much more robust calculation, SWSI 2010 used a more simplistic approach that is worth explaining for context. In SWSI 2010, municipal/industrial demands were defined as water uses typical of municipal systems (including residential, commercial, light industrial, non-agricultural irrigation, non-revenue water, and firefighting) and a baseline was developed by multiplying the Colorado State Demography Office (SDO) population projections by per-capita rate of use.

Like SWSI 2010, the Technical Update uses population multiplied by per-capita rate of use (in terms of gallons per capita per day or "gpcd") in preparing a range of possibilities that reflect the uncertainties in future municipal demands.

Municipal Demand = (population) x (gallons per capita per day)

Unlike SWSI 2010, the Technical Update provides projected demands in the year 2050 for five future scenarios that each include a different level of conservation and water management that is characteristic of the scenario as defined in the Water Plan. The potential impact from drivers of climate, urban land use, technology, regulations, and social values are incorporated into the municipal demand projections through adjustments to the current gpcd rate of use.

2050 PROJECTIONS

Projected M&I demands reflect anticipated conditions in the year 2050. Demands for time periods between now and 2050 were not estimated. See Section 3 for more explanation.

The Water Plan provides relative rankings of M&I water use in the planning scenario narratives (see Figure 1.1.1 in Section 1.1.2). These rankings influenced the municipal demand projections. The rankings provide direction for how the combinations of M&I drivers affect the future volumetric demands under each scenario. They were interpreted to apply to average annual statewide volumetric demands rather than per capita demands. The rankings heavily influenced, and in some cases constrained, the combinations of drivers and population used in each scenario.

Description of Municipal Demand Methodology

Municipal diversion demands were calculated based on the factors described below.

Population

A unique population and growth pattern projection for the year 2050 was prepared for each planning scenario, as further described in the *Updated Population Projections for Water Plan Scenarios* (see Volume 2) and summarized in Table 2.2.2. The population projections were informed by the planning scenario narratives in the Water Plan.

The SDO forecast was adopted as the "medium" projection in Table 2.2.2. The variances around the SDO forecast assumed for other scenarios were estimated from the historical population growth experience of the state and each of its basins. Three sets of initial projections, with some modifications to the distribution of growth within the state, were then used to develop population forecasts consistent with the five planning scenarios.

Table 2.2.2 2050 Population Projections used for Five Planning Scenarios

	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Population Projection	Medium	Low	Medium, Adjusted	High, Adjusted	High

Only three pieces of information were required to develop probabilistic estimates of the potential range surrounding the "median" population projections produced by the SDO. The information requirements were:

- The compound average annual growth rate implied by the SDO forecast
- The historical standard deviation in population growth rates by decade
- The historical compound average annual growth rate for the area being projected

The following sequence of steps was used to implement the analysis:

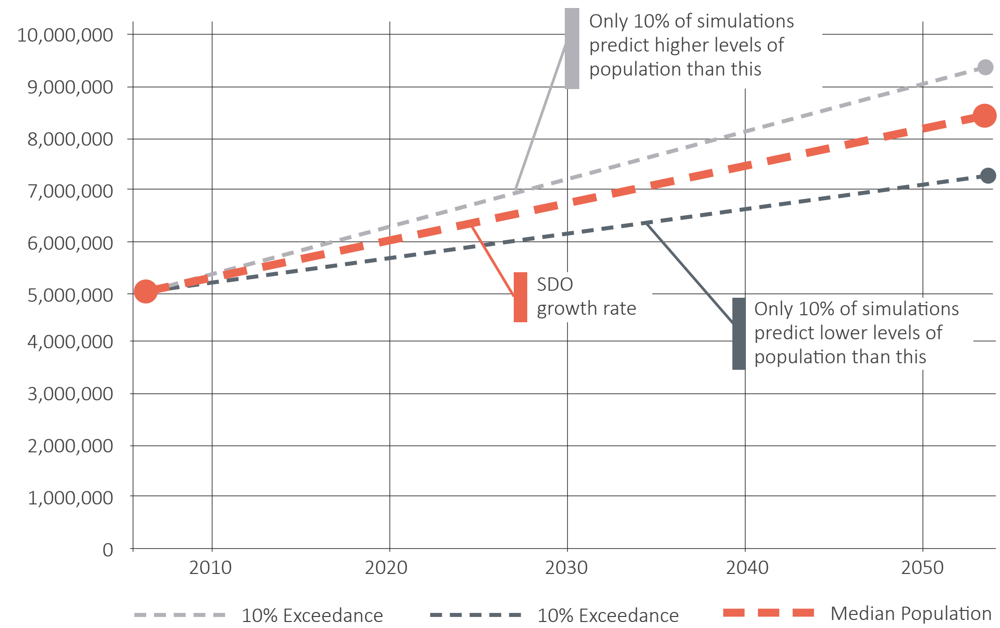
STEP	CALCULATION	DETAILS
1	Calculate median compound average annual growth rate	Calculated for the state and each basin based on the 2017 SDO projections through 2050.
2	Estimate the standard deviation in future growth rates	Based on historical standard deviation and historical and projected compound growth rates.
3	Use Monte Carlo techniques to simulate alternative future populations for each area based on baseline compound average annual growth rate and estimated standard deviation in growth rates by decade	Simulations result in thousands of alternative future populations derived from above for the state and each basin in 2050.
4	Select "High Growth" and "Low Growth" projections	CWCB selected the 10 percent exceedance probability for the "high growth" projections and the 90 percent exceedance probability for the "low growth" projections (see Figure 2.2.3).

Baseline Water Demands

Baseline municipal water demands were prepared by county, on a per-capita and volumetric basis. One of the key objectives for the Technical Update was to maximize the use of new data that were not available for SWSI 2010. The baseline (circa 2015) demands were prepared for each county using the following four data sources:

1. Data reported to the CWCB by water providers pursuant to House Bill 2010-1051[5]
2. Municipal water efficiency plans (WEP)
3. Targeted water provider outreach
4. Basin Implementation Plans

Figure 2.2.3 Projected Population Growth Through 2050



Per Capita Water Demand Projections. Projected future per capita rates of water demand in gpcd were calculated for each county by adjusting the baseline gpcd values by future demand drivers representing urban land use, technology, regulations, and social values. The potential future impact of these drivers on each of the five water demand categories was evaluated and values were developed that considered the planning scenario descriptions in the Water Plan and with input from the M&I TAG.

The residential indoor demand category was adjusted for each planning scenario to a fixed gpcd value, while percentage adjustments were applied to the other demand categories (positive values created an increase in gpcd and negative values a decrease in gpcd). The adjustment values are shown in Table 2.2.3. The adjusted future indoor and outdoor gpcd rates[6] were used to represent all new population (associated with new construction) and a portion of the existing population reflected by the adoption rates shown in Table 2.2.4 (associated with retrofits); the remainder of the existing population continues at the baseline gpcd rate. The resulting future gpcd rates used in demand modeling, therefore, include the combined effects of active and passive conservation.

Table 2.2.3 Municipal Per Capita Rate Adjustments for Planning Scenarios

Demand Category	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Residential Indoor (gpcd)	42.4	42.4	36.4	33.3	42.4
Non-Residential Indoor	0%	-5%	-10%	-10%	+5%
Outdoor	0%	-5%	-15%	-20%	+5%
Non-Revenue Water	0%	+5%	0%	-5%	0%

Table 2.2.4 Municipal Adoption Rates Applied to Indoor and Outdoor Demand Categories for Planning Scenarios

	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Adoption Rate	50%	40%	60%	70%	60%

Climate

Changes in climate primarily influence outdoor aspects of municipal demands due to impacts on landscape vegetation irrigation water needs. These impacts are typically associated with warmer temperatures that increase evapotranspiration (ET) rates and lengths of growing seasons, which increase the landscape irrigation water demand and consumptive use. For the Technical Update, it was assumed that indoor demands and non-revenue water are not affected by climate changes. ET change factors developed under the CRWAS Phase II (See Section 2.2.1) were used to estimate the impacts of changing climate on future outdoor demands for the Technical Update. These factors were applied to outdoor demands at a county level to represent the average annual change in outdoor demand in the year 2050 due to the climate status.

Municipal Demand Calculation Process

The calculation process for developing current and future municipal demands for the five planning scenarios is summarized below:

STEP	CALCULATION
1	Using water provider population, distributed water and customer water use data, prepare one population-weighted average current gpcd for each county
2	Disaggregate the representative current gpcd value into the appropriate sectoral uses
3	Adjust the current disaggregated gpcd values using the methodologies described in the sections above to prepare future gpcd values for each county under each of the five planning scenarios
4	Apply climate change factors to the 2050 outdoor municipal demand projections in *Cooperative Growth*, *Adaptive Innovation* and *Hot Growth*

Description of Industrial Demand Methodology

The Water Plan provides some narrative guidance regarding effects on self-supplied industrial (industrial) demands under the five planning scenarios, although less specific than for the municipal demands. New and updated information related to current and projected industrial demands is limited. Based on published references and data collected through outreach with the M&I TAG, SWSI 2010 values were updated where possible and appropriate as follows:

- Large Industry: Baseline large-industry demands for facilities represented in SWSI 2010 were updated using either BIP data, recent data from existing hydrologic models, or interpolated values between 2008 and 2035 in SWSI 2010. Technical Update values vary by scenario as shown in Table 2.2.5. Large industry demands in Jefferson County were not varied by scenario.

CLIMATE SHIFTS

Climate change could impact SSI water needs like thermoelectric generation, snow making, etc. Analyzing the potential impacts of climate change on the various sectors of SSI water demands would require a more complex evaluation than could be conducted in this round of Technical Update work but could be considered in future iterations or BIP updates.

- Snowmaking: Baseline demands were updated based on current snowmaking acres for each resort[7] and water use factors from SWSI 2010 and are in line with the linear increase from 2008 through 2050 reported in SWSI 2010. SWSI 2010 projections represent the best available information for *Business as Usual* demands in 2050. As with SWSI 2010, snowmaking demands are not varied by scenario for the Technical Update, in part, due to uncertainty regarding the effects of climate change.
- Thermoelectric: Baseline and *Business as Usual* thermoelectric demands for 10 of the thirteen facilities included were updated using data provided by M&I TAG participants. Baseline and *Business as Usual* demands for one facility were based on information from the Yampa-White-Green BIP. SWSI 2010 values were used to define Baseline and *Business as Usual* demands for the remaining two facilities where no updated information was available. Thermoelectric demands for all facilities were varied by scenario according to the factors in Table 2.2.5.
- Energy Development: Baseline energy development demands were updated using either BIP data or interpolating between 2008 and 2035 values used in SWSI 2010. Demand projections in the Rio Grande Basin were based on information from the BIP and did not vary by scenario. Demands in all other basins were based on low, medium, and high projections from SWSI 2010.

Table 2.2.5 Adjustments to SSI Demands for Each Planning Scenario

SSI Category	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Large Industry	-	-10%	0%	0%	10%
Snowmaking	-	0%	0%	0%	0%
Thermoelectric	-	-5%	10%	-5%	10%
Energy Development	SWSI 2010- Medium	SWSI 2010- Medium	SWSI 2010- Low	SWSI 2010- Low	SWSI 2010- High

Assumptions and Limitations

- The projected demands represent potential demands under conditions described for each scenario; however, they do not necessarily represent the full potential for water management strategies under each scenario (e.g., more aggressive active conservation programs). Basins may continue to develop water conservation efforts as part of existing and future projects that reduce consumption.
- Erroneous or suspect reported non-revenue water loss values were adjusted, using stakeholder input where possible, to provide a reasonable range of planning values for several water providers. An emphasis should continue to be placed on improving this data and understanding the associated real and apparent losses.
- Aside from the climate driver described above, per capita drivers were not modified by basin or county. Drivers were applied using the same values and methodology for each county and are intended to prepare a scenario planning approach that can be further customized at the basin level.
- Planning scenarios do not include acute drought response efforts like imposing restrictions, so comparing to other areas of the country (e.g., Southern California) is not appropriate if their current demands reflect not only aggressive active conservation, but also imposed restrictions.
- Demand projections were prepared using the same adoption rate for indoor and outdoor demands and for residential and non-residential demands. The adoption rate should be further investigated at a local level because it is highly influenced by new construction and active water conservation programs. The adoption rate also encompasses effects from the persistence of demand reductions associated with indoor and outdoor uses.
- The per capita gpcd metric is being used as a projection tool for this statewide planning project, even in areas with a significant influence from non-permanent residents, such as mountain resort communities, and is not applicable as a comparison tool between communities. It is not appropriate to compare a gpcd value from areas that have a significant influence from tourism and non-permanent residents to areas that have a primarily year-round, residential type of population. Specific characteristics about each community need to be understood when interpreting per-capita demand data.
- Urban land use changes have the potential to significantly affect future municipal (primarily outdoor) and agricultural demands. The range of impacts may not be fully reflected in the Technical Update municipal and agricultural demand projections, primarily due to a lack of information available for use in statewide planning projections. Future demand projections may be improved by collecting service area delineations and density information regarding developed and irrigated, landscaped areas under current conditions and anticipated for the future planning year (i.e., 2050).

- The climate factor adjustments described above represent the average annual change in 2050 for the climate represented in each scenario. Outdoor demands will vary annually and monthly, and this type of annual variability is not included in the hydrologic modeling for the Technical Update. This could be incorporated into future technical updates.
- The adjustments assume that amount and type of vegetative cover and irrigation methods and management remain the same in the future as today.
- The methodology assumes that the percentage reduction of current to future outdoor use found from existing programs (20 to 30 percent) remains possible and representative of the potential percentage reductions under scenarios that include climate change; however, some communities are already struggling to support healthy landscapes in response to utility rate increases. Active management will likely be required to maintain healthy landscapes in a hotter and drier future or landscapes may need to change.

2.2.5 Hydrologic Modeling and Analysis

The water supply modeling focused on physical streamflow, water available to meet projected or new demands, and the agricultural and M&I gap under a variety of hydrological conditions. While surface water availability in SWSI 2010[8] represented the amount of unappropriated streamflow that may be developed in the future in basins with available streamflow, it also found that the groundwater supplies were generally declining, and the discussion regarding these supplies focused on sustainability (as opposed to supplies that may be developed in the future). The Technical Update provides more in-depth analyses of current and climate-adjusted hydrology and analyses of water availability to meet future projected agricultural and municipal diversion demands. The analyses, discussed in more detail below, relies primarily on water allocation models to simulate how climate-adjusted hydrology will impact the existing demands, supplies and gaps, and what unappropriated supplies may be available to meet the future projected demands.

Modeling Period

The hydrologic models use 1975 to current-year (models vary in the most recent year of data depending on the basin) as the reference modeling time period, because existing transbasin diversion projects were, in general, fully operational by the mid-1970s. In addition, record keeping and data describing diversions (of all kinds) in years prior to the 1970s are of relatively low quality in some basins. Models simulating the planning scenarios use 1975 to current-year water supplies (in some scenarios, adjusted for climate change impacts), current administrative practices and infrastructure, and projected demands. The 1975 to current-year period of record provides a robust variety of hydrological conditions (i.e., high flow years and extended droughts) over which the planning scenarios can be analyzed.

Methodology to Develop Current Water Supply

Current water supply information consists of physical streamflow and water availability at key locations throughout the modeled basin. The bulk of the analysis of current water supplies relies on models and data developed under the CDSS program. In basins where the CDSS program has not been fully implemented, the methodology for those basins was modified to use available water supply information. The sections below discuss the specific methodologies that were used to evaluate current water supplies for each basin.

CDSS Basin Water Supply

StateMod water allocation models are available for several of the basins through the CDSS program (see Figure 2.2.4). For basins with full CDSS model development, two water allocation datasets were developed:

- Historical Dataset. Historical model datasets allocate water to meet historical agricultural and municipal diversion demands in each basin. They contain historical diversions and pumping that reflect administrative and operational constraints on water supply as they occurred over time. The historical models were calibrated by comparing historical measured diversions, reservoir contents, and streamflow to simulated results. Model adjustments were made until there was adequate correlation between the measured and simulated data. They are an appropriate dataset to assess historical conditions in basins over an extended period of time.
- Baseline Dataset. Baseline model datasets allocate water to meet current agricultural and municipal diversion demands assuming recent historical climatic and hydrologic conditions will continue into the future. Baseline models reflect current administrative, infrastructure, and operational conditions overlaid on the hydrology of the entire study period. For example, the model could include the operation of an existing reservoir constructed in 1985, but it would be simulated using hydrology reflective of 1975 to 2013 conditions. Baseline datasets and models are appropriate to use for "what if" planning scenarios.

For basins with both historical and baseline datasets, the following approach was used to develop the current water supply information:

Step	Procedure
1	Incorporate current agricultural diversion demands into the Baseline models.
2	Incorporate current M&I diversion demands.
3	Simulate the models.
4	Extract the monthly physical streamflow and water availability at key locations in each basin.
5	Summarize the agricultural gap and crop demand gap by Water District and by basin for on average and for critically dry years. No M&I gaps occur under current conditions.
6	Summarize total storage by water district and by basin over the modeled period.

Non-CDSS Basin Water Supply

As shown in Figure 2.2.4, StateMod water allocation models have not yet been developed for the Arkansas, Republican, Rio Grande, and Cache La Poudre/Laramie basins. As these regions are generally water supply limited, a water allocation model may not be necessary to understand future water availability in the basin. Historical data can be used to estimate current water supplies in the basin at a level sufficient for the Technical Update planning effort. Current water supply information in these basins was developed primarily using historical data:

- Current physical streamflow was based on historical data from key streamflow gages.
- Current water availability was set to zero.
- Current agricultural gap was based on historical consumptive use analyses and estimated as the difference between the current agricultural diversion demand and the historical pumping (in the Republican Basin) or the historical diversions and pumping (in the Arkansas and Rio Grande basins) on average and for critically dry years.
- Current M&I gap was set to zero, assuming the M&I demands are fully satisfied under current conditions.

Although the methodologies for estimating current water supplies in each of these basins differs from the basins with CDSS models and datasets, they provide appropriate estimates of physical streamflow, water availability, and gaps for current conditions for comparison to the five planning scenario results.

Figure 2.2.4 CDSS and Basin Modeling Map

Methodology to Develop Planning Scenario Water Supply

The planning scenario water supplies were estimated using an approach similar to that used to estimate the current water supplies. For planning scenario water supplies, agricultural and municipal diversion demands reflective of 2050 conditions specific to each of the five planning scenarios were used as was, in some scenarios, climate-adjusted hydrology. Once the planning scenario datasets were developed, results were compared to the current water supply to assess the impact of the projected demands and hydrology.

CDSS Basin Methodologies

The baseline StateMod datasets developed for the current water supply analysis served as the starting point for the planning scenario datasets. The following steps were taken to develop the planning scenario StateMod datasets and ultimately the water supply information:

Step	Procedure
1	Incorporate the appropriate planning scenario agricultural diversion demands into the planning scenario models.
2	Incorporate the appropriate planning scenario M&I diversion demands into the planning scenario models.
3	Incorporate the appropriate climate-adjusted natural flow into *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*. Note that *Business as Usual* and *Weak Economy* reflect current (or recent historical) hydrology.
4	Run the planning scenario models.
5	Extract the monthly physical streamflow and water availability at key locations in each basin.
6	Summarize the M&I gap by water district and by basin on average and for very dry years.
7	Summarize the agricultural gap and crop demand gap by water district and by basin on average and for very dry years.
8	Summarize total storage by water district and by basin over the modeled period.
9	Estimate the amount of water available from changed irrigation water rights associated with land undergoing urbanization
10	Estimate the transbasin import reductions due to changes in physical or legally available supply in the exporting basin.

The planning scenario StateMod datasets incorporate the projected hydrology and demands with the baseline representation of the basins' infrastructure and operations. Adjustments to other modeling parameters, such as order of supplies used to meet municipal diversion demands or alternative methods for conveying water, were not made in the planning scenario datasets under this effort. In addition, the models utilize existing infrastructure to the full operational potential, and no adjustments were made to limit those operations. For example, in planning scenarios that contemplate lower water supplies, simulated reservoir storage may be drawn down to lower levels and on a more frequent basis than has occurred historically. While reservoirs are being simulated within their existing operational constraints in the models, it is possible that water providers would obtain additional storage or other water rights in a drier future rather than consistently operating existing facilities at low levels.

Non-CDSS Basin Methodologies

The absence of basinwide planning models in some basins limited the options to evaluate the projected demands and hydrology. As a result, the existing analysis tools are not conducive to implementing the "what-if" planning scenario conditions; however, they do provide information on the basin operations which were used in developing the planning scenario water supply information. Various qualitative and quantitative methods were used to develop the planning scenario water supply information in these basins as described:

- **Republican Basin.** For the Republican Basin, the current level of appropriated groundwater supplies serves as the maximum available water supply in the basin into the future and assumes that no unappropriated surface or groundwater supplies will be available. Projected water supplies in the Republican Basin were estimated as follows:
  - » Current irrigation practices, in which irrigators pump less than the full amount needed by the crops, was assumed to continue into the future based on discussions with stakeholders in the basin. The current agricultural gap percentage was used to estimate the planning scenario gaps, and associated crop demand gaps, on average and for critically dry years.
  - » Planning scenario water availability was set to zero.

FREE RIVER

Some water users (primarily agriculture) have historically supplemented their water rights with additional diversions under free river conditions. The modeling assumes this will continue. As a result, available free river is first allocated to agriculture and then to other water rights. Basin roundtables could propose future projects to allocate available free river to meet M&I needs.

- » Any projected planning scenario M&I demand greater than current M&I demand was assumed to be a gap due to lack of future water availability. Planning scenario M&I gaps were estimated as the difference between the planning scenario M&I demand and the current M&I demand on average and for very dry years.

- **Arkansas and Rio Grande Basins.** The *Business as Usual* and *Weak Economy* scenarios do not include climate-adjusted hydrology or demands, therefore the anticipated changes in these scenarios result from changes in M&I demands and irrigated acreage, respectively. The approach to develop water supply information in these basins included the following assumptions:
    - » Water availability was set to zero.
    - » Historical agricultural shortages are expected to continue into the future, exacerbated by reduced supplies under climate-adjusted hydrology.
    - » Current pumping levels serve as the maximum groundwater supply available to meet projected demands.
    - » Any groundwater supplies associated with the removal of irrigated acreage due to groundwater sustainability adjustments remain in the aquifers and are not available to offset gaps experienced by other demands in the basin.
    - » Any projected planning scenario M&I demand greater than current M&I demand was assumed to be a gap, due to lack of future water availability.[9]

  In general, the current agricultural gap was used as the basis for the planning scenario agricultural gap, and further reductions in supplies due to climate-adjusted hydrology were applied to gaps. In each planning scenario, the average reduction in streamflow at indicator gages throughout the basin was used to increase the agricultural gap in *Cooperative Growth, Adaptive Innovation*, and *Hot Growth*. The M&I gap was based on the difference between the current M&I demand and the planning scenario M&I demand, assuming no additional supplies are available to meet the increased demand. Simulated streamflow under the planning scenarios with climate-adjusted hydrology was not available; however, the change in runoff (i.e., natural flow), both magnitude and timing, between current conditions and climate-adjusted conditions is provided to reflect the general impact of these projected hydrology adjustments.

- **Cache la Poudre and Laramie Basins.** Although these basins do not have the full suite of CDSS modeling tools available, model results from neighboring sub-basins with similar levels of irrigated acreage, M&I demands, storage, and transbasin supplies were used to inform and adjust the results in these basins. The planning scenario agricultural gaps in these basins were based on the current agricultural gap and then adjusted based on the gap results from neighboring sub-basins in each planning scenario. The planning scenario M&I gap in these basins was assumed to be similar to M&I gaps experienced in neighboring sub-basins, particularly in sub-basins where municipal supplies are generally similar and consist of sources like Colorado-Big Thompson supplies, changed water rights, and storage. The outflow from the Cache La Poudre River to the South Platte River was based on historical streamflow for *Business as Usual* and *Weak Economy* and adjusted with the hydrology factors in planning scenarios with climate-adjusted hydrology. The planning scenario water supply information from the Cache La Poudre and Laramie basins was then incorporated into the overall South Platte and North Platte Basin results, respectively.

Assumptions and Limitations

- Basinwide Planning Model: A primary objective of CDSS is to develop water allocation models that can be used to evaluate potential future planning issues or management alternatives based on Colorado water law at a regional level. The level of detail regarding representation of hydrology, operations, and demands in the model is appropriate for the Technical Update efforts. The models operate on a monthly time-step and, therefore, do not capture daily changes in streamflow, routing of reservoir releases, or daily accretions or depletions to the river system. One hundred percent of the consumptive use demands are represented in the model, and many are represented with their individual water rights and operations. Smaller streams are not individually represented in the model; rather the demands and contributing inflow from those tributaries are grouped and represented on larger tributaries in the model. Information used in the modeling datasets is based on available data collected and developed through CDSS, including information recorded by the State Engineer's Office. The model datasets and results are intended for basinwide planning purposes.
- Model Calibration: Each water allocation model undergoes calibration, in which the model developer adjusts model inputs to achieve better agreement between the simulated and measured streamflow, diversions, and reservoir contents. The model builds on historical water supply information, and if information is missing, errant, or there are data inconsistencies, the model cannot be well calibrated and cannot accurately predict future conditions. The models are only as good as the input.
- Representation of Water Supplies and Operations: The baseline models reflect one representation of waer users' operations associated with their current infrastructure. The representation in the model is intended to capture their typical operations; however, they are simplified and do not reflect the full suite of operations generally available to larger water providers. This representation may not capture operational adjustments or agreements implemented during drought conditions, or the maximum operational flexibility of using water supplies from multiple sources. In addition, the model allocates water according to prior appropriation, and non-decreed "gentlemen's agreements" are generally not represented in the models.

- Groundwater Pumping Levels/ Transbasin Diversions: The models reflect current levels of groundwater pumping and transbasin diversions. Noting that administration of groundwater pumping shifted due to the mid-2000s drought, post-drought groundwater pumping levels were used in the baseline and planning scenario models. Similarly, the historical transbasin diversions were used in the baseline and planning scenario models. Transbasin diversions are based on many factors, including water availability and storage in both the source and destination basins, demands, other water supplies available to the water provider, and other operational considerations like water quality. Projecting how these factors may change under the 2050 planning scenarios was beyond the Technical Update scope; therefore, transbasin diversions were set to historical levels.
- Interstate Compacts. The Technical Update modeling only takes into account Compact administration where a Compact is currently being actively administered. It does not account for or make assumptions relating to how potential future administration could occur where a Compact is not currently being administered.
- Solutions/Projects: The Technical Update is intended to develop water supply and gap information that can be used by basin roundtables for future planning efforts, including the development of potential solutions to mitigate gaps. The models can be used to evaluate the effectiveness of a future solution, though future projects and/or solutions are not currently included in the models.
- Urbanization: As agricultural lands are urbanized, the irrigation supplies on those lands could potentially be transferred to other uses, such as municipal or industrial; however, the transfer of these supplies is subject to a variety of unknowns such as seniority, type of water supply, location of supply relative to the demand, and willingness to change the use of water through water court. Potentially available supplies from urbanized agricultural lands were quantified after gap calculations were conducted and are not considered in the gap; however, the supply potentially available from these lands is described in each basin (see Section 4) and can be applied to gaps at the discretion of basin roundtables in their BIP updates.

2.2.6 Environment and Recreation

The methodologies described in this section informed the development of tools to help basin roundtables update their BIPs and evaluate and prioritize future environment and recreation projects.

NONCONSUMPTIVE USES

In prior SWSIs, the term "nonconsumptive" referred to "environment and recreation" data sets and analyses. For the purposes of the Technical Update these two terms can be viewed as interchangeable; however, the phrase "environment and recreation" (or E&R) will be used moving forward.

Background on E&R Database and Enhancements for Technical Update

Beginning with the original SWSI phases and continuing through and beyond the SWSI 2010 process, the basin roundtables first identified E&R needs, then developed and refined mapping and evaluation tools, and subsequently identified projects to address those needs. The evolution of addressing E&R issues in the state is described in the graphic below. The Technical Update advances the development of tools that can be utilized by the basin roundtables in identifying E&R needs and providing support for E&R projects and methods.

SWSI I & II

Developed E&R mapping tools.

SWSI 2010

BRTs used E&R mapping tools to develop maps for each basin showing E&R focus areas. BRTs identified projects and methods to meet E&R needs and developed maps showing: location of projects/methods, status of projects/methods, E&R focus areas that have projects/methods completed or in progress.

Post-SWSI 2010

Developed nonconsumptive needs assessment database (NCNAdb), which contains nonconsumptive attributes, projects and associated protections.

Technical Update Enhancements for E&R Database

The Technical Update focused on enhancing the Nonconsumptive Needs Assessment database (NCNAdb, now referred to as the E&Rdb). The E&Rdb was updated and will allow the CWCB and basin roundtables to better leverage E&R data, streamline data entry and reporting, and promote collaboration based upon common, consistent and reliable technology and processes. Building on the technical foundation of the existing NCNAdb, several improvements were implemented that serve to accomplish the goals described in Table 2.2.6.

Table 2.2.6 Enhancement Goals and Actions for the E&Rdb

Overall Goal	Action and Results
Enhanced Technical Foundation	Data loading processes are consistent and streamlined to add efficiency and improve data quality.
	Implement the Source Water Route Framework as a common spatial unit to provide statewide consistency.
Engaging and Meaningful User Experience	Develop Excel-based templates for data entry to improve uniformity of data and add efficiency.
	Develop standard reports to enhance consistency of data retrieval.
	Provide mapping data on the CDSS MapViewer to increase ease of use and enable visualization of database content.
	Develop a user manual and identify potential improvements through user feedback.
Integration into Colorado Water Planning Process	Improve database content and expand to include project identification, project descriptions, dates, etc. making it more useful and meaningful for planning purposes.

Updating the spatial unit of analysis was an important aspect of enhancing the technical foundation of the E&Rdb. The update occurred because of the retirement of the USGS stream segment-based spatial unit called the common ID (COMID), which had been used in the NCNAdb. The Source Water Route Framework (SWRF), a Colorado-specific spatial dataset, was included as a spatial unit of analysis for the updated E&Rdb. The updated E&Rdb also relies on the USGS's National Hydrography Dataset (NHD). Data in the database can be queried by hydrologic unit code (HUC) and/or stream segment.

Improvements were also made to the data in the E&Rdb. The prior NCNAdb included more than 100 E&R attributes compiled through stakeholder outreach in each basin. The original attributes were reviewed and quality checked to identify repetitive or unreliable data sources and datasets. Closely related attributes that provided repetitive or overlapping data were consolidated into a single attribute. Additionally, previous attributes that did not have public data sources or datasets available to confirm spatial data were archived and not included in the updated attribute list. Several attributes were also renamed to better reflect the dataset and simplify database development. The final 58 attributes were grouped into several "macro" categories that help increase organization of the E&Rdb and provide a foundational set of attributes for the E&R Flow Tool (described below).

Background on Flow Tool and Enhancements for Technical Update

In addition to the updated E&Rdb, the Technical Update includes an E&R Flow Tool (Flow Tool) designed to assess flow conditions and associated ecological health at selected nodes in each basin. The Flow Tool will serve as a resource to help basin roundtables refine, categorize, and prioritize their current portfolio of E&R projects and methods and to better understand risks to ecological attributes based on possible future flow conditions under each planning scenario.

Prior to the Technical Update, the CWCB funded the development and testing of a tool known as the Watershed Flow Evaluation Tool (WFET). To date, the WFET has been applied in the Colorado and Yampa-White-Green basins. The WFET offers an approach to conducting a watershed-scale, science-based assessment of flow-related ecological risk throughout a basin, particularly when site-specific studies are sparse.

Also prior to the Technical Update, the Historical Streamflow Analysis Tool (HSAT) was developed and made available for use in the first round of BIPs and emphasized the evaluation of hydrologic variability at gage locations across Colorado. The user interface includes a simple dropdown menu and the output included automatically generated tables and plots. Many of the basic flow summaries included in the HSAT were carried forward into the Flow Tool.

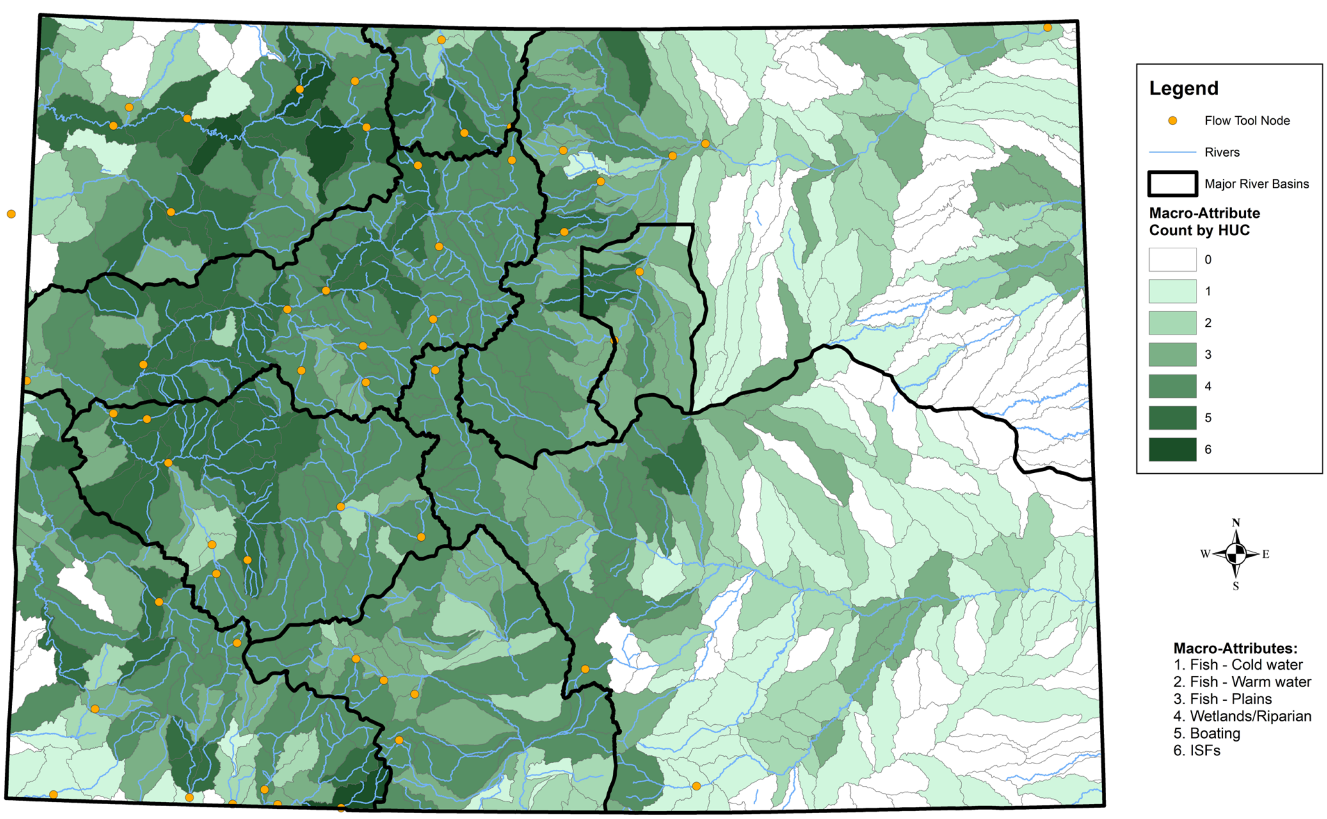
Methodology Description

The Flow Tool is built on a legacy of stakeholder involvement and was created through a methodology that was developed collaboratively with the E&R TAG and builds on the previous E&R tools described above. The Flow Tool was designed to incorporate and compare modeling output from the five planning scenarios against baseline (existing) and naturalized (unimpaired) flow condition scenarios. Key outputs include a comparison of monthly flow regimes relative to ecological-flow indicators, building off the WFET.

The Flow Tool uses monthly streamflow output from CDSS water allocation models. The Excel-based tool was designed to incorporate and compare modeling output from the five planning scenarios against historical gage data and the baseline/current conditions scenario. Key outputs include a comparison of monthly flow regimes relative to ecological-flow indicators.

The Flow Tool analyzes and produces data for 54 pre-selected model nodes corresponding to stream gages (see Figure 2.2.5). The nodes included in the Flow Tool were selected for inclusion based on a number of factors. Gages were reviewed to determine available attribute data (where key E&R attributes were located and concentrated within a basin [darker shaded HUCs in Figure 2.2.5]), to consider spatial coverage across basins, and to assess data availability.

Figure 2.2.5 Nodes in Flow Tool



The Flow Tool estimates the response of E&R attributes in rivers under various hydrologic scenarios. The flow-ecology relationships in the Flow Tool were first developed as part of the WFET and were patterned after similar relationships that have been developed across the globe to inform water management. Flow-ecology quantifies the relationship between specific flow statistics (e.g., average magnitude of peak flow, the ratio of flow in August and September to mean annual flow) and the risk status (low to very high) for E&R attributes under the flow scenario being analyzed. Data-derived relationships have been developed for riparian/wetland plants (cottonwoods), coldwater fish (trout), warmwater fish (bluehead sucker, flannelmouth sucker, and roundtail chub), and Plains fish. Other metrics were developed with basic, well-established relationships between hydrology and stream ecology. Relationships for recreational boating were developed with stakeholders during WFET development.

The Flow Tool compares historical gage records to current-conditions-modeling-output and planning-scenario-modeling-output. The comparison provides insights on where and how much monthly flow regimes are expected to change relative to ecological flow indicators related to macro-attribute categories discussed above. This comparison also highlights areas where future E&R projects and protections could be beneficial. Basin roundtables will then be able to apply their own analysis (and preferences) to determine the best way to meet these E&R needs.

Flow Tool Limitations

While the Flow Tool is intended to provide data for use in planning E&R projects and methods, it should be noted that it is not prescriptive. Tool output is currently limited to monthly timesteps, and does not designate gap values nor provide basis for any regulatory actions. The Flow Tool does not identify areas where ecological change may be associated with factors other than streamflow, nor detail results as accurately as a site-specific analysis. The tool does not evaluate potential shifts in flooding magnitude and frequency that could result from climate change.

SECTION 3
REVISITING THE GAPS

The Colorado Water Plan set an adaptive management framework for future water planning activities, and described five planning scenarios under which demands, supplies, and gaps were to be estimated. The planning scenarios included new considerations, such as climate change, that were not a part of prior SWSI analyses. The CWCB and Division of Water Resources have developed new consumptive use and surface water allocation models that were not previously available for use in prior SWSI phases. As a result of these factors, the Technical Update takes a different and more robust approach to estimating potential future gaps.

3.1 SWSI 2010 GAP METHODOLOGY

Gaps in SWSI 2010 were focused on municipal and self-supplied industrial water users and were defined as a "future water supply need for which a project or method to meet that need is not presently identified." The gaps accounted for new future water needs and also anticipated yields from Identified Projects and Processes (IPPs) projected to provide future supply. Gaps were calculated using the following formulas:

M&I Water Supply Gap = 2050 net new water needs – 2050 projects

Where:

> 2050 Net New Water Needs = (2050 low/medium/high M&I baseline demands – high passive conservation – current M&I use) + (2050 low/medium/high SSI demands – current SSI use)
>
> 2050 IPPs = Water Provider Anticipated Yield from: Agricultural Transfers + Reuse + Growth into Existing Supplies + Regional In-basin Projects + New Transbasin Projects + Firming In-basin Water Rights + Firming Transbasin Water Rights

Information on specific IPPs and estimated yields were obtained from CWCB interviews and data collected from water providers throughout the State in 2009 and 2010, the original SWSI effort in 2004, and information from basin roundtables from 2008 to 2010. The overall IPP "success" was then adjusted to create varying levels of M&I gap based on the likelihood that a specific IPP would produce its full yield

Agricultural shortages were estimated in SWSI 2010. The shortages were estimated by calculating the difference between the amount of water consumed by a full-irrigated crop and the amount of water actually consumed by crops under water short conditions. The shortages were field-based, meaning that they did not account for water needed for conveyance and other losses. Agricultural shortages were not described as gaps, in part because they were conceptually different than the infrastructure gaps calculated for M&I water uses.

CALCULATING THE GAP

Gaps calculated in SWSI 2010 were based on future water demands and accounted for the degree to which future projects might meet future demands. Gap projections in the Technical Update do not include estimates of basin-identified project yields. This is primarily due to the lack of specific project data that would allow projects to be modeled. Forthcoming basin plan updates will reevaluate projects and consider strategies to address gaps.

REGARDING PROJECTS

IPPs in SWSI 2010 referenced "Identified Projects and Processes" that were being pursued by water providers to meet future demands. The Technical Update refers to these simply as "projects."

3.2 GAP METHODOLOGY IN THE TECHNICAL UPDATE

The methodology for calculating gaps in the Technical Update is very different from that used in prior SWSIs. The new methodology was necessary to address new analysis needs, to provide basin roundtables with the tools to develop implementation strategies within the adaptive management framework, and to take advantage of new models and data sets.

New Analysis Needs

The Technical Update estimates future available water supplies and gaps under the five different planning scenarios described in the Colorado Water Plan. Previous SWSIs were conducted prior to the Water Plan and, therefore, did not consider the scenarios. The planning scenarios incorporate water supply and demand drivers associated with the potential effects of climate change, population growth, and many other factors.

New Planning Process

In the BIPs, the basin roundtables cataloged various projects and methods to mitigate future water supply gaps. The Technical Update focuses on developing tools and more detailed datasets to help the basin roundtables update their portfolios of projects and methods for meeting future water needs in a targeted manner, with forthcoming updates to their BIPs.

New Models and Data Sets

New analysis tools and data sets have been developed since SWSI 2010. Consumptive use and surface water allocation models developed through the CDSS are now available in most river basins. The CDSS tools allow the evaluation of gaps under a variety of hydrologic conditions. Municipal water demand and conservation data is available via HB10-1051 reporting. The availability of these new tools and data sets allows for a more robust approach to assessing future water availability and potential gaps.

The new gap methodology uses the CDSS tools to evaluate demands and supplies available to meet demands over a range of time and under a variety of hydrologic conditions. As a result, time series of gaps were developed to help examine how gaps change in wet, average/normal, and dry conditions at key locations in each basin (see illustration in Figure 3.2.1). In addition, the CDSS tools were used to estimate M&I and agricultural gaps on the same platform, which creates uniformity in how the respective gaps were estimated. In short, the analyses and data sets are more consistent and robust than what the CWCB was able to achieve in the past.

3.2.1 Important Considerations and General Differences

The new gap methodology has some important differences from SWSI 2010 that need to be understood and considered by basin roundtable members and others who use the findings, tools, and data from the Technical Update. Differences are summarized in Table 3.2.1 on the following page.

Figure 3.2.1 Example Time Series of Gaps

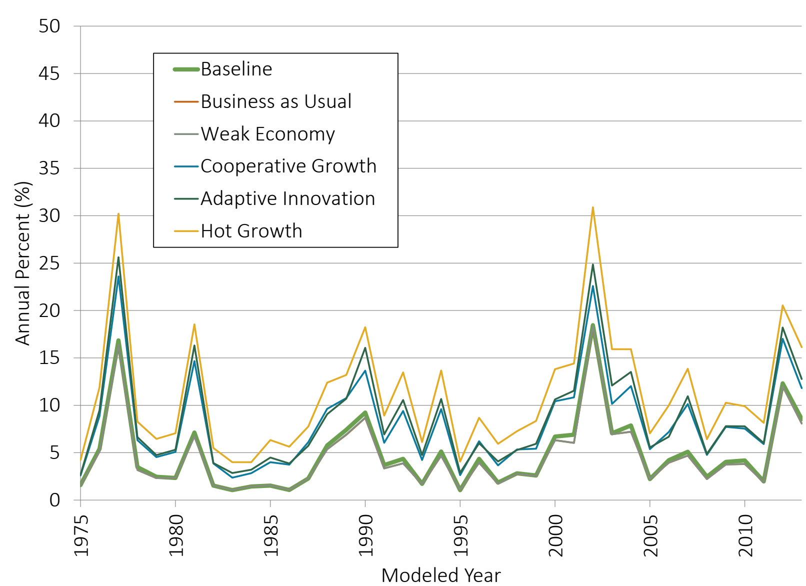


Table 3.2.1 Summary of Differences Between SWSI 2010 and Technical Update

Item	SWSI 2010	Technical Update
Consideration of alternative future conditions	✓	✓
Inclusion of yield from projects (or IPPs) in gap	✓	
Variability in future conditions (2050)		✓
Agricultural gaps using surface water modeling		✓
Quantification of livestock water demands [*]	✓	
Simultaneous consideration of active and passive municipal water conservation [**]		✓
Consideration of climate change		✓
Use of water allocation models reflecting variable supplies, demands, and river operations		✓
Simulation of existing reservoirs		✓
SDO population projections to the year 2050 [***]		✓

[*] Livestock water demands are relatively small on a basin scale and are not simulated in the CDSS tools used in the Technical Update
[**] SWSI 2010 considered active and passive conservation separately, but the Technical Update considers them jointly
[***] SWSI 2010 used complex projections to extend estimates to 2050 because SDO 2050 projections were not available at that time

Results represent 2050 conditions: The planning scenarios in the Water Plan describe assumed future conditions, but they do not contemplate the progression of changes that will occur between now and 2050. As a result, the Technical Update models and data sets represent conditions in the year 2050 and do not depict how drivers of future conditions change between now and then. For example, M&I water demands reflect the needs of Colorado's population in the year 2050 and not prior years. It should be noted that demands and supplies vary in the models, but the variation is reflective of typical ups and downs in future supplies and demands under stable hydrologic cycles, amounts of irrigated land, and population.

Climate change is considered in the Technical Update: Projections of future climate conditions were not a part of SWSI 2010 and have a significant influence on estimated gaps. Planning scenarios that consider a hotter and drier future climate have higher agricultural and municipal diversion demands (for outdoor uses) combined with lower amounts of available water supply—factors that both tend to drive larger gaps.

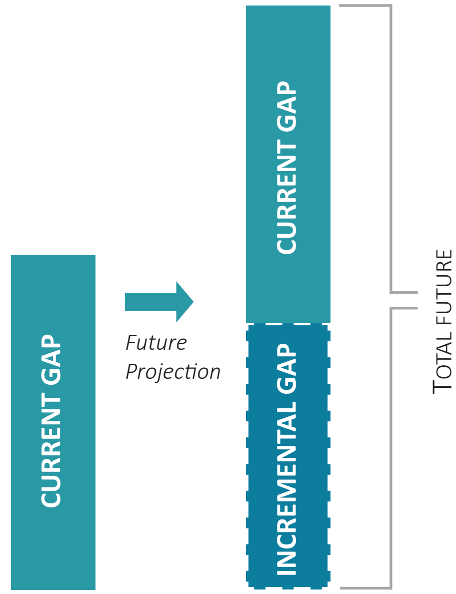
Agricultural gaps are based on diversion demands and described in new ways: The Technical Update quantifies and describes agricultural gaps differently than 2010.

- Agricultural gaps based on diversion demand: As explained in Section 2, water demands in the agricultural sector are based on diversion demands at a river headgate or wellhead. Unlike SWSI 2010, irrigation conveyance and on-farm efficiencies were considered in the agricultural demands and gaps in the Technical Update. As a result, the agricultural gap in the Technical Update will be significantly larger than the agricultural shortages described in SWSI 2010.
- Total and "incremental" agricultural gaps are provided**:** It is anticipated that basin roundtables may want to understand both the total agricultural gap and the degree to which existing agricultural gaps may increase under various scenarios. To meet this need, total and incremental gaps are provided in the Technical Update, and they are described in more detail below.
    - *Total Gap*: The total agricultural gap reflects the overall shortage of agricultural water supplies to meet diversion demands required to fully irrigated crops.
    - *Incremental Gap*: The incremental gap quantifies the degree to which the gap could increase beyond what agriculture has historically experienced under water shortage conditions.

- Total and incremental gaps are quantified as averages. Shortages in agriculture vary across irrigators depending on the seniority of their water rights and based upon hydrologic conditions and their source of supply (tributaries, main steam rivers, groundwater or surface water, etc.). Because of this variability, agricultural gap reporting focuses on averages, though maximum gaps are also presented in Section 4 results tables.

Municipal gaps focus on maximum shortages:

Water providers generally consider and plan for worst-case scenarios. As a result, M&I gaps described in the Technical Update focus on maximum annual shortages or gaps. For perspective, average gaps are presented as well.



Conservation is incorporated into the scenarios:

In SWSI 2010, active and passive conservation measures were considered separately. In the Technical Update, they were jointly considered in the context of the scenario narratives in the Water Plan. Additional levels of conservation beyond what was described in the scenario narratives would be considered a project that a basin roundtable could pursue to help eliminate future gaps.

Water allocation models provide for more robust analyses:

Water allocation models not readily available for use in SWSI 201 are used extensively in the Technical Update. The water allocation models reflect variable supplies, demands, and river operations using existing infrastructure and therefore provide for more robust analyses than prior SWSIs. Using models can lead to different gap results due to the wide variety of additional considerations that influence how supplies are used to meet demands.

3.2.2 Differences in Foundational Municipal Demand Data

In addition to the factors above, two foundational data inputs for estimating municipal water demands have changed since the publication of SWSI 2010—population projections and per capita demand. The changes in both of these data inputs tend to result in lower municipal water demands in the Technical Update than in SWSI 2010.

Population Projections

SWSI 2010 needed to extend the then-current SDO projections for 2035 out to the year 2050 using complex analyses. As noted in Table 3.2.1, the Technical Update was able to rely on newly developed SDO projections for 2050, and estimated high and low ranges based on historical growth statistics.

Figure 3.2.2 provides a comparison of the population projections between SWSI 2010 and the Technical Update. Note that results of population projections are described further in Section 4, but statewide results are shown here for comparison purposes. All of the Technical Update planning scenario projections for 2050 anticipate lower population than the SWSI 2010 high population projection. The Technical Update medium growth projection that is used for *Business as Usual* and *Cooperative Growth* is similar to the SWSI 2010 low population projection (within about 2 percent). The Technical Update high growth projection that is used for *Adaptive Innovation* and *Hot Growth* is similar to the SWSI 2010 medium population projection. Basin-level population projections vary from the comparison above due to the variable distributions under the scenario planning methodology, but mimic similar patterns of lower projections than were developed for SWSI 2010.

BASIN MODELING

In general, modeling was conducted at the basin scale. Due to model availability, some basins were more easily broken out into sub-basins. This was done for the following regions:

- YAMPA-WHITE-GREEN BASIN
  Individual models were available for the Yampa (which includes Green River operations) and White basins. Results of basin analyses were preseted for individual sub-basins and the combined Yampa-Green Basin.

- SOUTH PLATTE BASIN
  A model exists for the South Platte Basin but not the Republican Basin. The results of basin analysis were presented for the South Platte and Republican basins both separately and combined. In addition, the South Plate Basin model does not specifically represent the Metro Basin Roundtable region, and gap results for the Metro region are incorporated in the South Platte Basin Gap results; however, Metro-region M&I demands are specifically quantified and are presented individually (as well as combined with Republican and the remaining South Platte Basin regions).

Per capita and overall municipal demands. The statewide baseline per capita system-wide demand has decreased from 172 gpcd in SWSI 2010 to approximately 164 gpcd, which is nearly a 5 percent reduction in demands between 2008 and 2015. The reduction is associated with improved data availability, conservation efforts, and ongoing behavioral changes. Per capita demand reductions combined with lower population projections compared with SWSI 2010 resulted in lower overall municipal water demands in the Technical Update.

Figure 3.2.3 provides a comparison of the Technical Update results with the SWSI 2010 projected demands for 2050. Note that it is challenging to directly compare the municipal demand projections due to differences in the methodologies. The SWSI 2010 projections selected for Figure 3.2.3 are intended to show a range of the spread in the SWSI 2010 projections relative to the Technical Update projections.

The Technical Update demand projections for all planning scenarios fall within the spread of the SWSI 2010 high population demands with passive-conservation savings and the SWSI 2010 medium population growth with passive and high active-conservation savings. This result was anticipated with the Technical Update methodology, considering that the updated projections represent potential demands under conditions described for each scenario and do not necessarily represent the full potential for conservation programs under each scenario. All of the planning scenarios, with the exception of *Hot Growth*, project municipal water demands that are below the SWSI 2010 low population demands with passive conservation savings.

Figure 3.2.2 Comparison of SWSI 2010 and Technical Update Statewide Population Projections

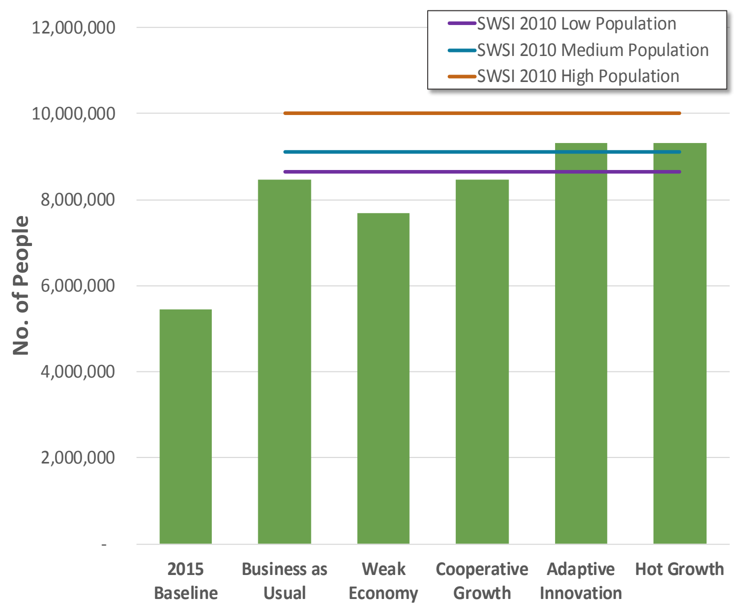


Figure 3.2.3 Comparison of SWSI 2010 and Technical Update Statewide Municipal Diversion Demands

SECTION 4
STATEWIDE & BASIN RESULTS

Statewide and basin-specific results of Technical Update analyses are described in Section 4. Statewide results are described first followed by basin-specific results. Results are described for:

- Agricultural diversion demands
- M&I diversion demands
- Agricultural and M&I gaps
- Environment and recreation conditions
- Available water supply

4.1 KEY ASSUMPTIONS AND LIMITATIONS

The analyses used to estimate demands and gaps incorporated some key assumptions and limitations that are important to consider when reviewing and using the results of the Technical Update:

- As stated in Section 3, future water supply projects (or IPPs) were not included in the Technical Update (see section 3.2.1).
- While the models used for this analysis consider a wide range of detailed information on river diversions, water provider operations, etc., the analyses were conducted and reported at a regional scale for understanding basinwide and statewide demands, supplies, and gaps. Attempting to extrapolate model results for specific water providers is not useful given the regional scale of model input data, the regional focus of the modeling, and the relatively high level of uncertainty associated with individual water provider operations under various scenarios.

Agricultural considerations:

» Livestock water demands were not included in the analysis because they are difficult to quantify, are relatively small compared to irrigation demands and are not a component of the CDSS tools used for the agricultural diversion demand analysis and gap calculations.

» The analysis did not consider different types of crops that may be grown in the future under the different scenarios; however, it accounted for future changes in crop types in a general sense in the *Adaptive Innovation* scenario and assumed that future crops would have 10 percent lower IWR.

M&I considerations:

» Projected water demands for the planning scenarios do not contemplate how municipal water providers or industrial water users would respond to acute drought conditions (e.g., implementation of watering restrictions, etc.).

Operations with respect to transbasin imports/exports:

» Imports from transbasin diversion projects were set at historical levels and reflect historical operations. To accurately reflect how the change in water availability on the Western Slope would have impacted transbasin diversions, it would have been necessary to work with the major transbasin diverters to understand how their operations may change on both the Western and Eastern Slope in response to West Slope shortages and include those operations in the assessment. The level of investigation and modeling necessary to properly assess changed operations was beyond the scope of this current effort. Agricultural and M&I gaps do not directly reflect reductions in supply that would occur if transbasin imports are reduced.

» Data presented in Section 4.2.4 show how much of the historical transbasin imported supply is projected to be potentionally reduced by 2050 in some of the planning scenarios.

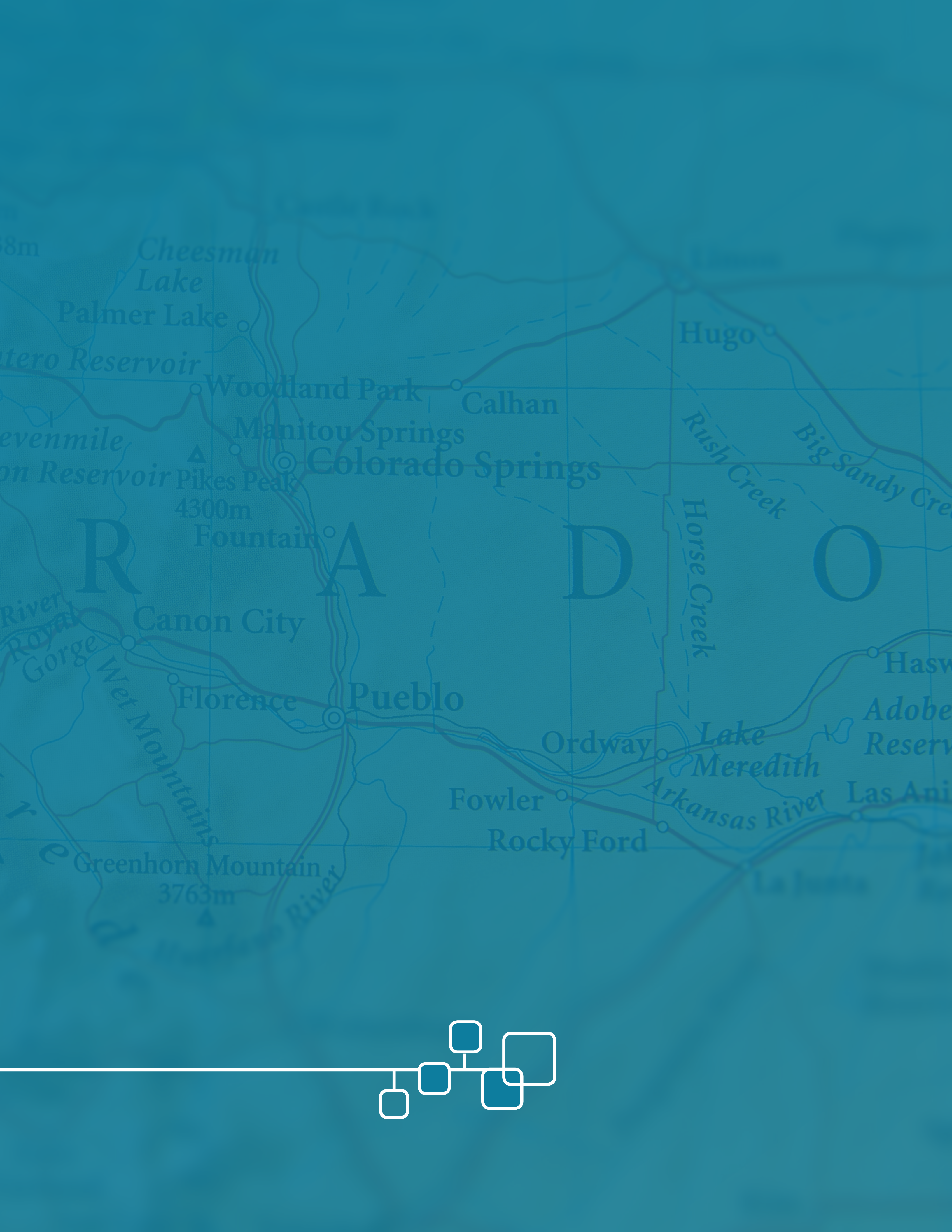
Statewide modeling results are shown in the following section followed by the results for each of the eight major river basins

CO
COLORADO STATEWIDE

- **A** — ARKANSAS BASIN
- **C** — COLORADO BASIN
- **G** — GUNNISON BASIN
- **RG** — RIO GRANDE BASIN
- **NP** — NORTH PLATTE BASIN
- **SP METRO** — SOUTH PLATTE /METRO BASIN
- **SW** — SOUTHWEST BASIN
- **YWG** — YAMPA-WHITE-GREEN BASIN

The results and findings of the Technical Update pertaining to statewide agricultural and M&I demands and gaps as well as findings related to environmental and recreational attributes and future conditions are summarized in the following section, which is followed by findings in each of the state's eight major river basins.

STATEWIDE


Cheesman Lake
Palmer Lake
Woodland Park
Calhan
Hugo
Manitou Springs
Colorado Springs
Pikes Peak
4300m
Fountain
R A D O
Rush Creek
Horse Creek
Canon City
Royal Gorge
Wet Mountains
Florence
Pueblo
Ordway
Lake Meredith
Fowler
Rocky Ford
Arkansas River
Greenhorn Mountain
3763m
River

4.2 STATEWIDE RESULTS

4.2.1 Summary of Technical Update Results

Key results and findings of the Technical Update pertaining to statewide agricultural and M&I demands and gaps, as well as findings related to environmental and recreational attributes and future conditions, are summarized below.

Agriculture

- On a statewide basis, current average annual agricultural diversion demands are approximately 13,000,000 AFY.
- Demand for groundwater is approximately 19 percent of the overall demand. Groundwater demands occur primarily in the Arkansas, Republican, Rio Grande, and South Platte basins.
- Future agricultural diversion demands will be affected by changes in irrigated acreage due to urbanization, aquifer sustainability, and agricultural to urban transfers of water.
  - » Urbanization is projected to reduce irrigated lands statewide by 5 percent. Most of the reduction will occur in the South Platte Basin, with more than 12 percent of the basin's irrigated acreage projected to be urbanized.
  - » 6 to 7 percent of irrigated acres supplied by groundwater is projected to be lost due to aquifer sustainability issues. The impacts of this will be focused in the Arkansas, Republican, and Rio Grande basins.
  - » Stakeholders in the Arkansas and South Platte basins estimated that between 33,000 and 76,000 irrigated acres may be lost due to water rights purchases that have already taken place or are very likely to take place in the future. Specific estimates in the South Platte are likely understated because stakeholders did not have a projection of acreage that is likely to be lost in the reach of the South Platte between Denver and Greeley and in the tributaries in this region. The estimated loss of agricultural lands due to permanent water transfers conducted for the Technical Update is different than the amount estimated in SWSI 2010. The SWSI 2010 estimates included water transfers contemplated in portfolios of projects to fill future M&I gaps statewide, whereas the estimates in the Technical Update were focused in the South Platte and Arkansas basins and were conducted for the purposes of reducing agricultural diversion demands based on pending transfers that are very likely to occur in the foreseeable future. Basin roundtables may expand on this in their BIP updates and consider how alternative water transfers or future permanent transfers should be considered as future water supply projects and strategies to mitigate gaps.
- On average, approximately 80 percent of the overall agricultural diversion demand is currently met on a statewide basis, though this varies in each basin.
- Agricultural diversion demands statewide are projected to decrease in three of the five scenarios. In *Business as Usual* and *Weak Economy*, loss of irrigated land is projected to reduce diversion demands by around 9 percent. In *Adaptive Innovation*, demand reductions due to losses of irrigated lands will be offset in part by increases in crop consumptive use demand due to climate change. Adoption of emerging technologies that increase efficiency and decrease consumptive use, however, are projected to reduce overall diversion demand by 20 percent relative to current demand. In *Hot Growth*, irrigated lands are projected to be lost, but climate change is projected to more than offset the demand reductions associated with loss of irrigated lands and result in an overall increase in diversion demand of 5 percent compared to current conditions.
- In basins with significant potential acreage reductions like the South Platte and Republican, diversion demands in all planning scenarios are projected to be less than current.

M&I Demands

- M&I demands currently comprise approximately 10 percent of overall statewide water demands.
- Current statewide population (as of 2015) is 5 percent less than the level projected in SWSI 2010.
- Current population is 5,448,100, and by 2050 is projected by the State Demography Office to increase by more than 3 million people to 8,461,300—a 55 percent increase. Low population projections estimate the population to increase by 41 percent (to 7,683,200 people) while high projections estimate the increase at 71 percent (to 9,312,400 people).
- The statewide baseline per capita systemwide demand has decreased from 172 gpcd in SWSI 2010 to approximately 164 gpcd, which is a nearly 5 percent reduction in demands between 2008 and 2015.
- Statewide per capita demands are projected to decrease compared to current conditions in each scenario except *Hot Growth*. *Adaptive Innovation* assumes the highest levels of conservation and has the lowest projected per capita demand at 143 gpcd, which is 13 percent lower than current per capita demand in spite of assumed hot and dry future climate conditions.
- While per capita usage is expected to decrease compared to current conditions in all but *Hot Growth*, overall statewide M&I water demand is projected to increase from current conditions to 35 percent in *Weak Economy* up to 77 percent in *Hot Growth*.

- Increase in overall M&I demand is very similar in *Adaptive Innovation* compared to *Business as Usual* despite the assumptions in *Adaptive Innovation* of high population growth and hot and dry future climate conditions. In addition, *Hot Growth* and *Adaptive Innovation* have similar assumptions related to population and climate, but *Adaptive Innovation* assumes much more aggressive conservation that result in M&I demands that are 15 percent lower than *Hot Growth*. These results demonstrate the potential benefit of aggressive conservation in managing future M&I demands.
- Self-supplied industrial demands are approximately 13 percent of overall M&I demands statewide, but are a greater proportion in certain basins.

Projected Gaps

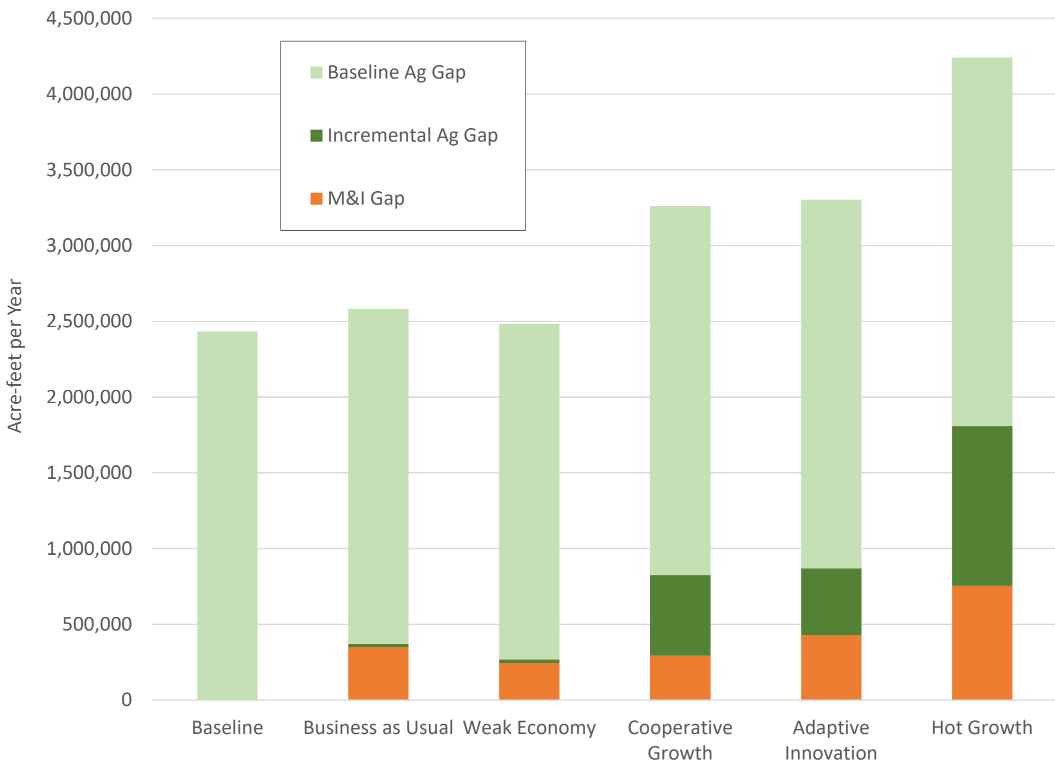
- **Agriculture**
  - » Agriculture currently experiences gaps, and gaps may increase in the future if climate conditions are hotter (which increases irrigation water demand) and supplies diminish (due to drier hydrology). Future gaps may increase by 440,000 AFY (in *Adaptive Innovation*) to 1,053,000 AFY (in *Hot Growth*) or 18 to 43 percent beyond what agriculture experiences, despite the loss of irrigated acreage.
  - » Agricultural gaps under *Adaptive Innovation* are significantly less than *Hot Growth* despite similar assumptions related to future climate conditions, which demonstrates the potential benefits of higher system efficiencies and emerging technologies that could reduce consumptive use. While conservation and efficiency improvements can be a tool for addressing future agricultural gaps, particularly in return-flow-driven systems, it is important to consider projects on a case-by-case basis.
- **M&I**
  - » Municipal and self-supplied industrial users do not currently experience a gap, but increasing population and potentially hotter and drier future climate conditions will create a need for additional supply despite efforts to conserve water. Statewide M&I gaps are projected to be from 250,000 AF (in *Weak Economy*) to 750,000 AF (in *Hot Growth*) in dry years. These gap estimates do not account for yields from water supply projects and strategies that water providers are pursuing.
  - » Municipal conservation efforts, however, create significant future benefits in lowering the gap, as demonstrated by comparing *Adaptive Innovation* and *Hot Growth* (which have similar assumptions on population and climate). Projected future gaps under *Adaptive Innovation* are 325,000 AF less than projected gaps under *Hot Growth*.
  - » Scenarios that include climate change project reduced available supplies for transbasin diversion projects. Reductions in transbasin imports will contribute to projected gaps, potentially to a greater degree than suggested in the analyses, because water providers reuse the return flows from transbasin imports.

Environment and Recreation

- Climate change and its impact on streamflow will be a primary driver of risk to E&R attributes.
- Projected future streamflow hydrographs in most locations across the state show earlier peaks and potentially drier conditions in the late summer months under scenarios with climate change.
- Under climate change scenarios, runoff and peak flows may occur earlier, resulting in possible mis-matches between peak flow timing and species' needs.
- Climate change may lead to more frequent flooding events, especially in disturbed areas, including fire scars. Stream and watershed health may be impacted by these events and thresholds may be crossed, resulting in impaired ecosystem structure and function. While these are important considerations, they were beyond the scope of this analysis.
- Drier conditions in late summer months could increase risk to coldwater and warmwater fish due to higher water temperatures and reduced habitat. The degree of increased risk is related to the level of streamflow decline.
- In many mountainous regions without significant influence of infrastructure, peak flow and low flows are projected to be sufficient to sustain low to moderate risk for riparian plants and fish, but risks are projected to increase in scenarios with climate change.
- In mountainous regions with infrastructure, risks to E&R attributes may vary. Streams that are already depleted may see increased risks in scenarios with climate change; however, some streams may be sustained by reservoir releases, which will help moderate risks in scenarios with climate change.
- Instream flow water rights and recreational in-channel diversion water rights may be met less often in climate-impacted scenarios.

Results describing current and potential future statewide M&I and agricultural gaps are summarized in Figure 4.2.1 and Table 4.2.1. Statewide gaps may vary substantially depending on future climate conditions and population increases, which underscores the need to take an adaptive approach to developing water management strategies, and projects and methods, to fill potential future gaps.

Figure 4.2.1 Summary of Statewide Gap Estimates by Planning Scenario



Results of calculations and analyses that support estimates of the statewide gap are presented in the subsections below.

INCREMENTAL GAP

The incremental agricultural gap quantifies the degree to which the gap could increase beyond what agriculture has historically experienced under water shortage conditions.

Table 4.2.1 Summary of Statewide Gap Results

Basin	Gap	Baseline	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Arkansas	Ag- Average annual gap (AFY)	617,300	586,400	585,200	701,700	734,800	819,500
	Ag- Average annual incremental gap (AFY)	0	0	0	84,400	117,500	202,200
	M&I- Max annual gap (AF)	0	68,500	53,100	58,500	62,900	108,700
Colorado	Ag- Average annual gap (AFY)	45,300	44,000	44,000	76,200	61,500	103,800
	Ag- Average annual incremental gap (AFY)	0	0	0	30,900	16,200	58,500
	M&I- Max annual gap (AF)	0*	4,200	3,300	5,300	6,600	15,800
Gunnison	Ag- Average annual gap (AFY)	87,300	77,200	77,300	157,600	112,600	222,000
	Ag- Average annual incremental gap (AFY)	0	0	0	70,300	25,300	134,700
	M&I- Max annual gap (AF)	0*	2,300	700	3,500	4,300	11,500
North Platte	Ag- Average annual gap (AFY)	85,700	108,000	107,900	177,900	168,100	231,100
	Ag- Average annual incremental gap (AFY)	0	22,200	22,200	92,100	82,400	145,400
	M&I- Max annual gap (AF)	0	0	0	0	0	0
Rio Grande	Ag- Average annual gap (AFY)	683,900	655,800	661,500	737,400	741,900	826,400
	Ag- Average annual incremental gap (AFY)	0	0	0	53,500	58,000	142,500
	M&I- Max annual gap (AF)	0	3,400	0	2,400	4,000	8,100
Southwest	Ag- Average annual gap (AFY)	126,600	120,300	119,800	276,700	219,000	355,100
	Ag- Average annual incremental gap (AFY)	0	0	0	150,100	92,400	228,400
	M&I- Max annual gap (AF)	0*	7,500	1,800	7,700	13,800	24,800
South Platte /Metro *(and Republican)*	Ag- Average annual gap (AFY)	773,500	606,300	604,000	610,900	577,600	665,400
	Ag- Average annual incremental gap (AFY)	0	0	0	0	0	0
	M&I- Max annual gap (AF)	0*	257,000	184,500	213,300	333,700	543,500
Yampa-White-Green	Ag- Average annual gap (AFY)	14,500	14,800	14,800	66,200	62,300	155,800
	Ag- Average annual incremental gap (AFY)	0	400	300	51,700	47,800	141,400
	M&I- Max annual gap (AF)	0*	5,600	1,600	2,600	3,800	41,700
Statewide Total	**Ag- Average annual gap (AFY)**	**2,434,200**	**2,212,800**	**2,214,500**	**2,804,500**	**2,677,800**	**3,379,100**
	Ag- Average annual incremental gap (AFY)	**0**	**22,600**	**22,500**	**533,000**	**439,600**	**1,053,000**
	M&I- Max annual gap (AF)	**0**	**348,500**	**245,100**	**293,300**	**429,200**	**754,200**

* *CDSS water allocation models in these basins calculate small baseline M&I gaps, but they are either due to calibration issues or they are reflective of infrequent, dry-year shortages that are typically managed with temporary demand reductions such as watering restrictions.*

4.2.2 Statewide Agricultural Diversion Demands

Current Diversion Demands

Currently, 3.28 million acres of agricultural land are irrigated statewide. Irrigated agriculture supports a wide network of agribusiness in Colorado from producers of agricultural goods to those that process and deliver those goods to consumers. Agricultural production in Colorado is a large part of the state's economy, with agribusiness contributing $41 billion annually and employing nearly 173,000 people.[10] Working agricultural operations also remain the economic backbone of many of Colorado's rural communities and provide important ecosystem services such as open space and wildlife habitat.

Figure 4.2.2 Proportion of Statewide Irrigated Acreage in Each Basin

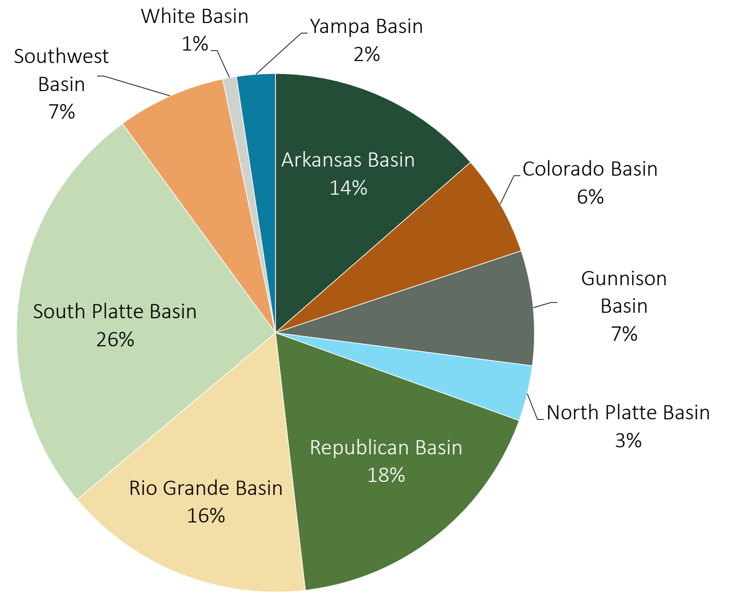
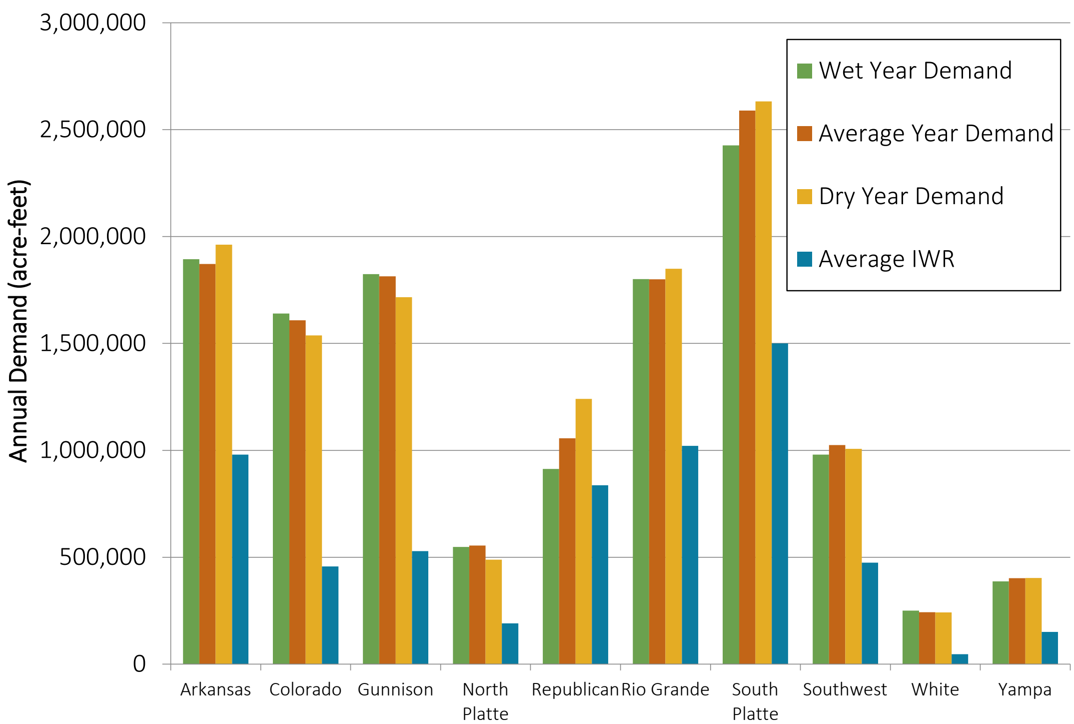


Figure 4.2.2 shows the proportion of statewide irrigated acreage in each basin. Over a quarter of the irrigated acreage in Colorado is located in the South Platte Basin. The Arkansas, Rio Grande, and Republican Basins also have significant acreage, each with approximately 15 percent of the statewide total. Grass pasture is the predominant crop grown in the state, particularly in the West Slope basins; however, irrigators also grow alfalfa, wheat, cereals/grains, fruits, and vegetables. Much of the irrigated acreage supports ranching operations, either through grass hay production for livestock operations or grazing of irrigated pastures. Refer to the basin-specific results summaries for more information on crops grown in each basin.

Tables 4.2.2 and 4.2.3 and Figure 4.2.3 show the agricultural diversion demand for surface and groundwater supplies summarized by basin for wet, dry, and average hydrological year types compared to average IWR. Results are displayed over a range of hydrological year types to illustrate both how demands and system efficiencies change under different climatic/hydrological conditions and when different types of supplies are used.

Figure 4.2.3 Current Agricultural Diversion Demand by Basin



As discussed in Section 2, the agricultural diversion demand is calculated by dividing the IWR by system efficiency. In dry years for example, IWR is generally higher due to increased temperatures, lower precipitation, and decreased available surface water supplies for irrigation. In these types of years, many irrigators implement additional operational measures to be more efficient with the limited surface water irrigation supplies, resulting in a lower overall dry-year diversion demand. For irrigators with groundwater supplies, the groundwater demand generally increases in response to higher IWR in dry years. System efficiencies range across basins and year types due to availability of irrigation supplies; irrigation practices (i.e., sprinkler or flood applications); and on-farm conditions such as ditch/lateral alignments, soil types, and field topography. Refer to the basin-specific results for more information on conditions that impact the system efficiency and the agricultural diversion demand.

DIVERSION DEMAND

The diversion demand represents the amount of water that would need to be diverted or pumped to meet the full crop IWR and does not reflect historical irrigation supplies. Irrigators often operate under water-short conditions and do not have enough supply to fully irrigate their crop.

Table 4.2.2 Current Irrigated Acreage, Average Annual IWR, and Diversion Demand

Basin	Acreage	Average IWR (AF)	Unit IWR (feet)	Total Diversion Demand (AF)		
				Wet Year	Average Year	Dry Year
Arkansas	445,000	980,000	2.20	1,894,000	1,872,000	1,962,000
Colorado	206,700	456,500	2.21	1,640,000	1,608,000	1,538,000
Gunnison	234,400	528,200	2.25	1,824,000	1,814,000	1,716,000
North Platte	113,600	191,100	1.68	548,000	555,000	489,000
Rio Grande	515,300	1,021,000	1.98	1,801,000	1,800,000	1,849,000
South Platte/Metro (and Republican)	1,433,100	2,337,000	1.63	3,340,000	3,645,000	3,873,000
Southwest	222,500	474,900	2.13	980,000	1,025,000	1,007,000
Yampa-White-Green	107,000	197,000	1.84	637,000	645,000	645,000
Total	**3,280,000**	**6,190,000**	**1.89**	**12,664,000**	**12,964,000**	**13,079,000**

Table 4.2.3 Current Agricultural Diversion Demand for Surface and Groundwater Supplies

Basin	Surface Water Demand (AF)			Groundwater Demand (AF)		
	Wet Year	Average Year	Dry Year	Wet Year	Average Year	Dry Year
Arkansas	1,567,000	1,497,000	1,501,000	327,000	375,000	461,000
Colorado	1,640,000	1,608,000	1,538,000	-	-	-
Gunnison	1,824,000	1,814,000	1,716,000	-	-	-
North Platte	548,000	555,000	489,000	-	-	-
Rio Grande	1,237,000	1,172,000	1,195,000	564,000	628,000	654,000
South Platte/Metro (and Republican)	2,078,000	2,186,000	2,108,000	1,262,000	1,459,000	1,765,000
Southwest	980,000	1,025,000	1,007,000	-	-	-
Yampa-White-Green	637,000	645,000	645,000	-	-	-
Total	**10,511,000**	**10,502,000**	**10,199,000**	**2,153,000**	**2,462,000**	**2,880,000**

As reflected in the Tables 4.2.2 and 4.2.3 (on previous page), the current statewide total agricultural diversion demand is approximately 13 million acre-feet, with more than 80 percent of that demand attributable to surface water supplies.

Future Diversion Demands

The following graphics and tables summarize the acreage, IWR, and the agricultural diversion demand attributable to surface and groundwater supplies in each basin calculated for the five planning scenarios based on the adjustment factors and approach discussed in Section 2. Future agricultural diversion demands were adjusted to reflect:

- Urbanization
- Planned Agricultural Projects
- Groundwater Acreage Sustainability
- Climate
- Emerging Technologies

The two factors anticipated to have substantial statewide impact are urbanization and climate. Table 4.2.4 reflects basin-specific and statewide historical urbanization, projected urbanized acreage and current levels of irrigated acreage for context. Between the late 1980s and early 1990s to present, more than 58,000 irrigated acres were urbanized (based on historical irrigated acreage assessments and current municipal boundaries). By 2050, approximately 152,500 additional irrigated acres are projected to be taken out of production due to urbanization (based on irrigated lands within or intersecting current municipal boundaries). This is approximately 5 percent of the total irrigated land statewide. The largest amount of urbanization is expected in the South Platte Basin, with more than 12 percent of the irrigated acreage in basin projected to be urbanized.

Table 4.2.4 Projected Loss of Irrigated Acreage Due to Urbanization

Basin	Historically Urbanized Irrigated Acreage	Projected Urbanized Irrigated Acreage	Current Irrigated Acreage
Arkansas	N/A*	7,240	445,000
Colorado	6,060	13,590	206,700
Gunnison	2,380	14,600	234,400
North Platte	2	40	113,600
Rio Grande	N/A*	4,010	515,300
South Platte/Metro (and Republican)	49,400	107,310	1,433,100
Southwest	100	3,800	222,500
Yampa-White-Green	135	1,860	107,000
Total	**58,060**	**152,450**	**3,277,600**

* *Neither a 1987 nor a 1993 basin-wide acreage assessment has been developed.*

Future agricultural diversion demands will be affected by climate conditions. Section 2 described two climate projections with warmer and drier futures ("Hot and Dry" and "In Between" projections) that are incorporated into three of the five planning scenarios. Figure 4.2.4 shows annual factors used to adjust IWR and reflect future conditions in "Hot and Dry" and "In Between". The factors in Figure 4.2.4 were averaged across the West Slope and East Slope basins. "Hot and Dry" and "In Between" generally predict warmer summer conditions in basins at higher elevations. Consequently, the West Slope factors are generally higher than those developed for the East Slope basins. Additionally, projections tend to show warmer conditions during years that were historically cooler and/or had higher precipitation, resulting in higher IWR adjustment factors. The opposite occurs during drought periods, when some warming may occur, but during periods that are expected to already be hot and dry. As a result, IWR adjustment factors during drought years tend to be lower (for example, 2002 or 2012).

Statewide Results

Future statewide agricultural diversion demand estimates range from 10 million AFY in *Adaptive Innovation* to 13.5 million AFY in *Hot Growth*. For basins with limited acreage adjustments, such as the Colorado, Gunnison, and Southwest basins, the agricultural diversion demands in *Business as Usual* and *Weak Economy* are projected to be similar to current demand. In these basins, climate change projections and efficiency adjustments had a significant impact on results, showing more variable demands in *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*. For basins with significant irrigated acreage reductions, such as the South Platte and Republican basins, demands in all planning scenarios are projected to be lower than current demand. The largest variation in most basins occurred in the *Adaptive Innovation.* scenario due to the 10 percent reduction in IWR and 10 percent increase to system efficiency. In some basins, such as the Southwest basin, the combined impact of the *Adaptive Innovation* scenario adjustments resulted in lower projected agricultural diversion demands than current.

Figure 4.2.4 Average IWR Change Factors

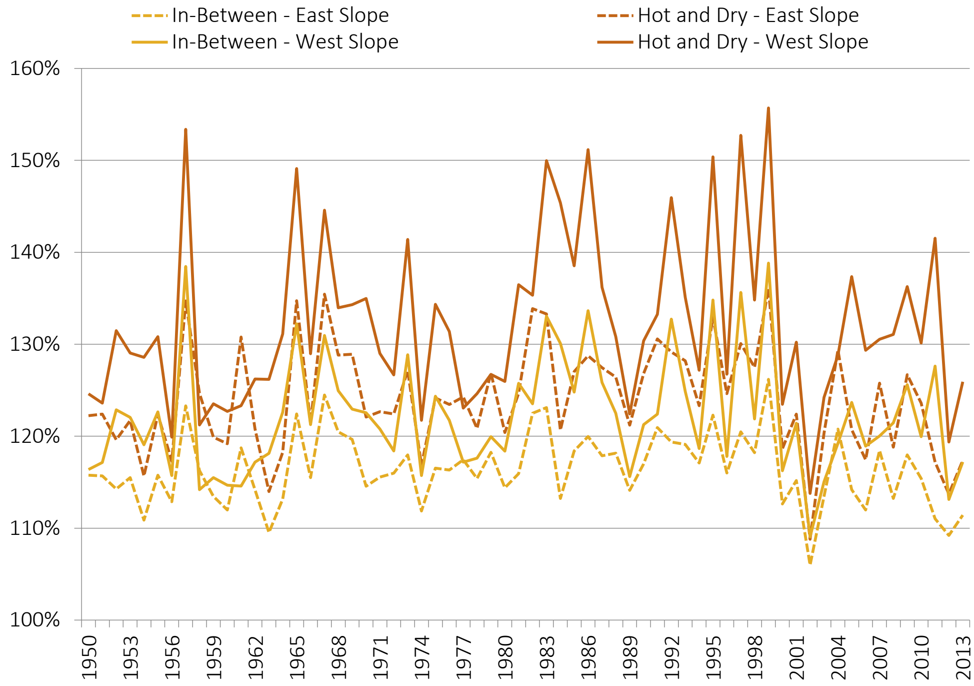
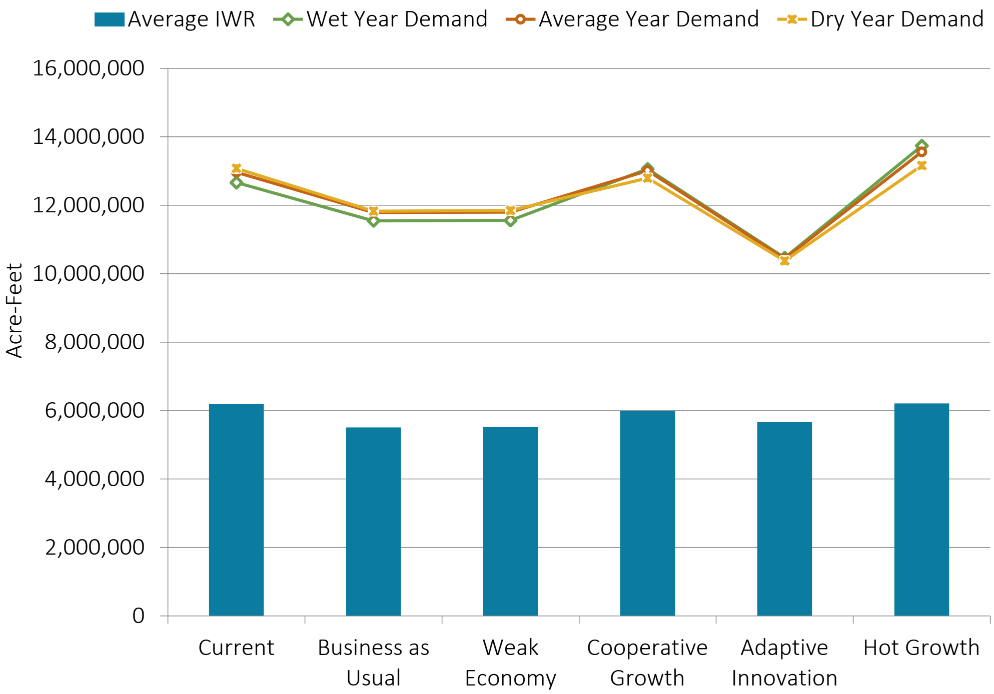


Figure 4.2.5 Statewide Agricultural Diversion Demand Estimates for Scenarios



RETURN FLOWS

Irrigation return flows (irrigation water not consumed by crops) return to streams and are part of the supply that downstream irrigators divert. In effect, diverted irrigation water can be used and reused several times in a basin. The agricultural diversion demand is the amount of water that would need to be diverted or pumped to meet the full crop irrigation demand, it but does not consider the re-diversion of return flows. As a result, it is not appropriate to assume the total diversion demand reflects the amount of native streamflow that would need to be diverted to fully irrigate crops.

Table 4.2.5 Statewide Summary of Projected Agricultural Diversion Demands

Planning Scenario	Acreage	Average IWR (AF)	Total Diversion Demand (AF)		
			Wet Year	Average Year	Dry Year
Current	3,280,000	6,190,000	12,664,000	12,964,000	13,079,000
Business as Usual	2,890,000	5,510,000	11,544,000	11,786,000	11,829,000
Weak Economy	2,890,000	5,520,000	11,559,000	11,802,000	11,846,000
Cooperative Growth	2,840,000	5,990,000	13,059,000	13,012,000	12,796,000
Adaptive Innovation	2,820,000	5,660,000	10,465,000	10,442,000	10,377,000
Hot Growth	2,780,000	6,210,000	13,736,000	13,561,000	13,163,000

Table 4.2.6 Statewide Summary of Projected Surface Water and Groundwater Diversion Demands

Basin	Surface Water Demand (AF)			Groundwater Demand (AF)		
	Wet Year	Average Year	Dry Year	Wet Year	Average Year	Dry Year
Current	10,511,000	10,502,000	10,199,000	2,153,000	2,462,000	2,880,000
Business as Usual	9,755,000	9,714,000	9,393,000	1,789,000	2,072,000	2,436,000
Weak Economy	9,775,000	9,735,000	9,415,000	1,784,000	2,067,000	2,431,000
Cooperative Growth	11,226,000	10,899,000	10,369,000	1,833,000	2,113,000	2,427,000
Adaptive Innovation	8,771,000	8,492,000	8,164,000	1,694,000	1,950,000	2,213,000
Hot Growth	11,848,000	11,399,000	10,723,000	1,888,000	2,162,000	2,440,000

4.2.3 Statewide M&I Diversion Demands

The updated M&I diversion demands include baseline demands (estimated for the year 2015) and projected future demands for the year 2050 for the five planning scenarios. Results of population projections, water usage rates, total municipal demands and total SSI demands are described below.

Population Projections

Approximately 88 percent of the state's population lives along the Front Range in either the Arkansas or South Platte Basins (which includes the "Metro" sub-basin). The statewide baseline population, which is based on 2015, is less than the amount that SWSI 2010 projected for the year 2015. While most basins have increased in population, the Gunnison, North Platte, Rio Grande, and Yampa-White basins have decreased. A basin-level summary is provided in Table 4.2.7.

As described in Section 2, population projections for the five planning scenarios were derived from 2017 SDO population projections and statistically-derived high and low growth projections for each basin. Population projections based on these methodologies are shown in Table 4.2.7.

DROUGHT RESPONSE

M&I demand projections do not represent drought conditions when more aggressive conservation may occur or associated responses to drought when measures such as watering restrictions may be imposed.

POPULATION GROWTH PROJECTIONS

Business as Usual:	Medium
Weak Economy:	Low
Cooperative Growth:	Medium, Adjusted
Adaptive Innovation:	High, Adjusted
Hot Growth:	High

Table 4.2.7 Current and Projected Future Population (in number of people unless otherwise indicated)

Basin	SWSI 2010 Projection for 2015*	SWSI Update Baseline (2015)		Planning Scenarios				
		Population	% of state total	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Arkansas	1,067,000	1,008,400	19%	1,509,500	1,462,800	1,544,400	1,626,000	1,568,000
Colorado	366,000	307,600	6%	515,500	456,300	549,200	572,900	577,800
Gunnison	125,000	103,100	2%	162,600	123,100	158,600	196,000	204,900
North Platte	1,600	1,400	0%	1,300	1,100	1,200	1,400	1,500
Rio Grande	54,000	46,000	1%	55,100	42,300	52,100	63,000	67,300
South Platte/Metro ** (and Republi-can)	3,964,000	3,829,800	70%	5,954,300	5,433,200	5,884,400	6,492,400	6,507,700
Southwest	123,000	108,000	2%	195,800	125,800	201,000	264,200	282,100
Yampa-White-Green	53,000	43,700	1%	67,300	38,600	70,500	96,600	103,200
Statewide	**5,754,600**	**5,448,100**	**100%**	**8,461,300**	**7,683,200**	**8,461,300**	**9,312,400**	**9,312,400**

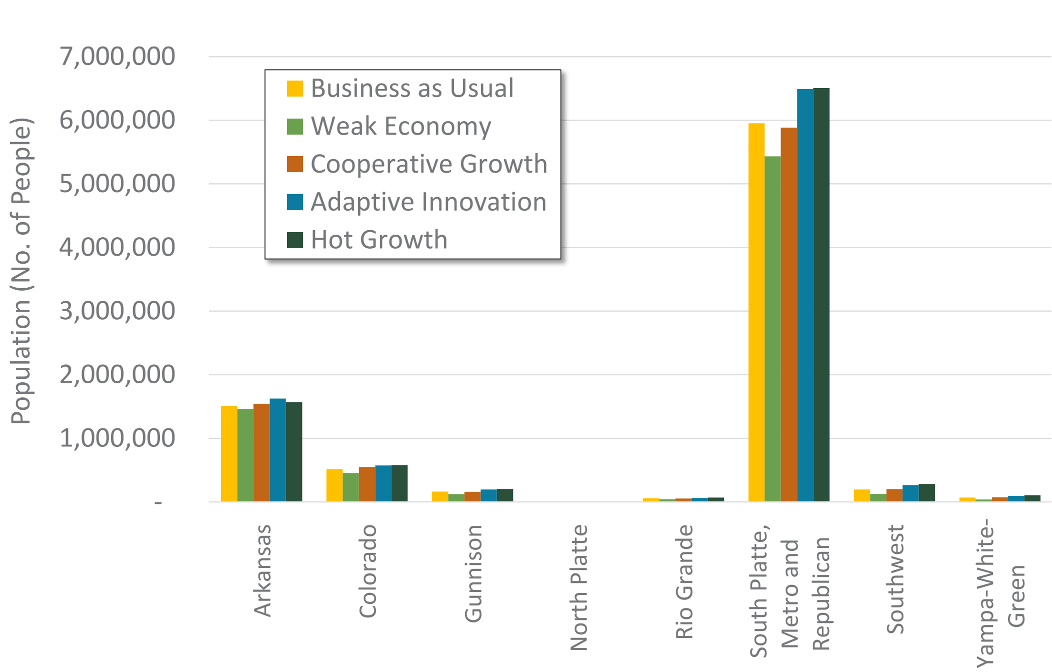
* *SWSI 2010 Appendix H, Exhibit 36 (CWCB, 2010a)*

** *Metro region was reported separately in SWSI 2010*

Note: Due to rounding, the statewide total may not precisely match the sum of basin results shown in the table above

Figure 4.2.6 shows population projections for 2050, summarized by river basin. Between the years 2015 and 2050, the population is projected to grow from approximately 5.5 million to between 7.7 million to 9.3 million in the low and high scenarios, respectively, which is an increase of about 41 to 71 percent.

Figure 4.2.6 2050 Projected Population by Scenario by Basin



Municipal Demands

Municipal demands were calculated for each county and then summarized by river basin. Water demands for counties located in multiple basins were distributed between basins by using the portion of the county population located within each basin to prorate the water demands.

The statewide baseline water demands were largely based on water provider-reported data, with approximately 70 percent of the baseline population demands represented by 1051 data as shown in Figure 4.2.7. The figure also shows the sources of other demand data.

The statewide baseline per capita systemwide demand has decreased from 172 gpcd in SWSI 2010 to approximately 164 gpcd, which is nearly a 5 percent reduction in demands between 2008 and 2015. The reduction is associated with improved data availability, conservation efforts, and ongoing behavioral changes. There are more significant differences from SWSI 2010 at a basin level and these are described in Volume 2 titled *Current and Projected Planning Scenario Municipal and Self-Supplied Industrial Water Demands*.

Figure 4.2.7 Statewide Baseline Municipal Demand Data Sources

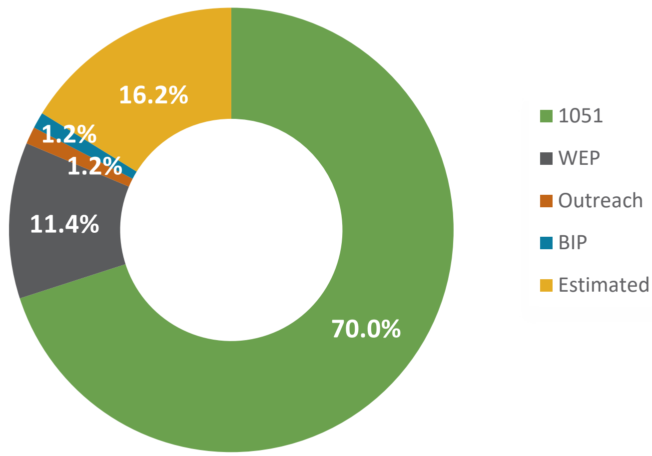


Table 4.2.8 shows baseline and projected per capita demands for basins throughout the state for the five planning scenarios. *Adaptive Innovation* has the lowest per capita demands, and *Hot Growth* has the highest per capita demands, both statewide and within each basin. Note that the statewide per capita demand projections do not match the Water Plan scenario ranking and they were not intended to do so. For example, *Adaptive Innovation* results in the lowest per capita demand, but coupling this with the highest population projection results in the second highest overall demand volume across the scenarios, as further described below.

Table 4.2.8 Per Capita Demand Projections by Planning Scenario for Each Basin (gpcd)

Basin	SWSI 2010 Projection for 2015 *	2015 Baseline	Planning Scenarios				
			Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Arkansas	185	194	179	179	170	164	192
Colorado	182	179	153	156	145	136	165
Gunnison	174	158	146	149	140	133	160
Metro	155	141	138	135	130	126	148
North Platte	310	264	245	254	242	232	270
Rio Grande	314	207	194	198	188	177	209
Republican	see note**	245	236	236	221	214	251
South Platte	188	181	176	174	164	158	190
Southwest	183	198	181	186	173	166	199
White	see note***	252	240	254	240	231	269
Yampa	230	224	172	197	161	150	180
Statewide	**172**	**164**	**157**	**155**	**148**	**143**	**169**

* *SWSI 2010 per capita values from SWSI 2010 Appendix L, Tables 8, 14, 15, and 16 (CWCB, 2011b)*
** *The Republican Basin demands were included in the South Platte Basin demand reporting for SWSI 2010*
*** *The White Basin demands were included with the Yampa Basin demand reporting for SWSI 2010.*

Statewide baseline municipal water demands are comprised of the water use classes shown in Figure 4.2.8. Residential indoor is the largest category of municipal demand statewide followed by residential outdoor and non-residential indoor.

For each planning scenario, residential indoor demands represent the largest category of water demand, starting at nearly 52 gpcd for the 2015 Baseline. The projected residential indoor demands vary greatly across planning scenarios, from 46 gpcd in *Weak Economy* to 36.5 gpcd in *Adaptive Innovation*. Other demand categories show less variability across the scenarios, as shown in Figure 4.2.9.

Adjustments related to climate change that increase demand tended to offset reductions in outdoor use that decreased demand, especially in *Cooperative Growth* and *Adaptive Innovation*. In spite of climate change impacts, however, *Adaptive Innovation* projects the lowest total per capita demand.

CONSERVATION POTENTIAL

The indoor and outdoor demand driver adjustments, coupled with the adoption rate methodology, generally result in higher per-capita demand projections than the active conservation savings projected in SWSI 2010. Unlike SWSI 2010, the Technical Update demand projections are not intended to capture the full range of future active conservation potential. Additional future conservation may still be achieved under each planning scenario through identified projects and processes.

CONSERVATION & GROWTH

The planning scenarios often paired high water-savings drivers with high population growth or low demand reductions with low growth, resulting in a narrowing of the range in demand projections.

Figure 4.2.8 Statewide Baseline Municipal Demand Category Distribution

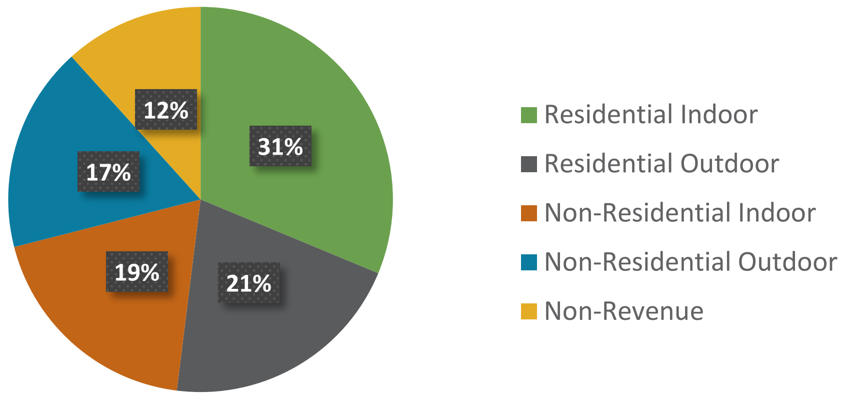


Figure 4.2.9 Statewide per Capita Demand for Five Planning Scenarios by Demand Category

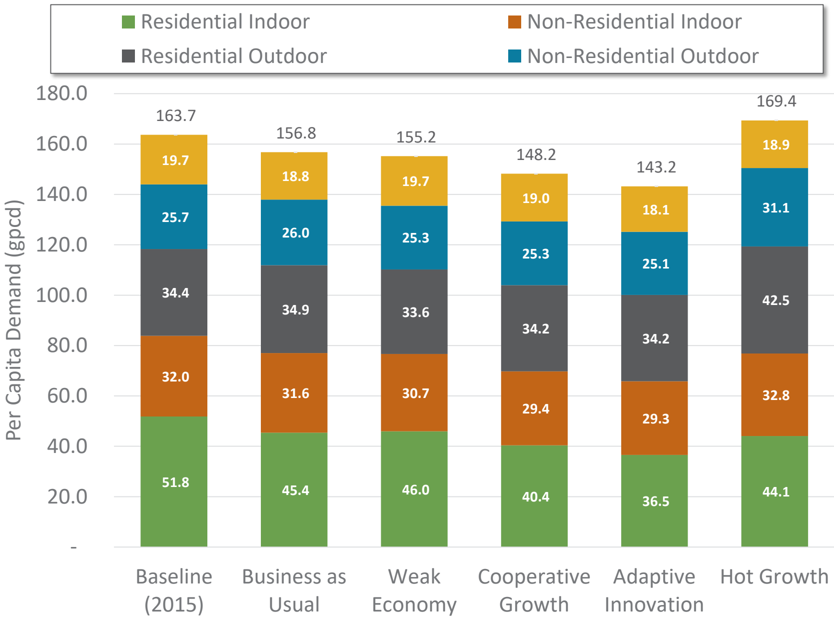


Table 4.2.9 presents baseline and projected demands for basins throughout the state, showing the combined effect of population and per capita demands. The municipal demands are projected to grow from approximately 1.0 million AFY in 2015 to between 1.34 and 1.77 million AFY in 2050.

Table 4.2.9 Statewide Municipal Baseline and Project Demands by Basin (AFY)

Basin	Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Arkansas	219,200	303,400	293,800	294,500	298,100	337,200
Colorado	61,800	88,600	79,900	89,000	87,500	106,600
Gunnison	18,300	26,700	20,500	24,900	29,100	36,800
North Platte	400	400	300	300	400	400
Rio Grande	10,600	11,900	9,400	11,000	12,500	15,700
South Platte/Metro (and Republican)	653,300	1,001,600	896,600	932,800	999,900	1,185,200
Southwest	24,000	39,800	26,200	38,900	49,200	62,900
Yampa-White-Green	11,200	13,500	8,800	13,300	17,200	21,900
Statewide	**998,700**	**1,485,800**	**1,335,500**	**1,404,700**	**1,493,900**	**1,766,700**

Note: Due to rounding, the statewide total may not precisely match the sum of basin results shown in the table above

Figure 4.2.10 Statewide Baseline and Projected Population and Municipal Demands

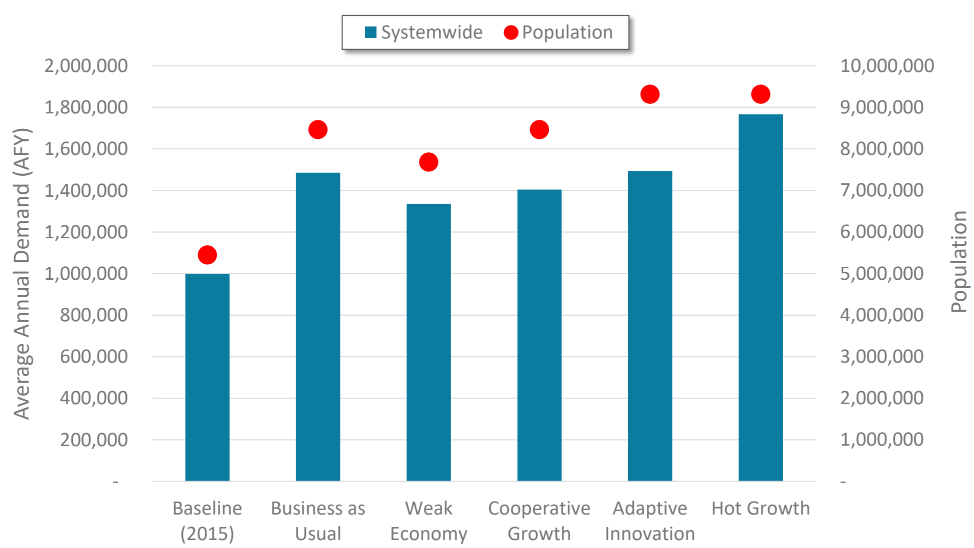


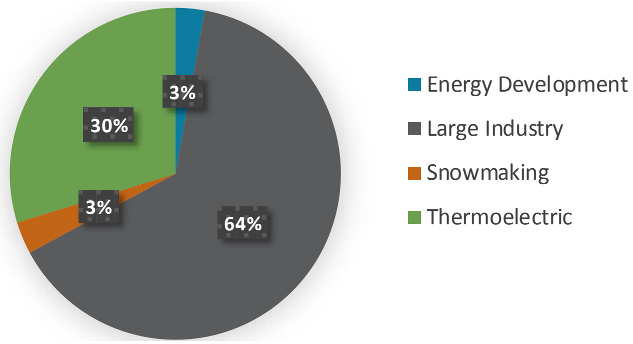
Figure 4.2.10 compares municipal water demands with population projections for each of the planning scenarios. *Business as Usual* and *Cooperative Growth* both use the medium population projection on a statewide basis, with different distributions between counties. Similarly, *Adaptive Innovation* and *Hot Growth* both use the high population projection on a statewide basis, with different distributions between counties. The influence of the population is so significant that the demand projections for all scenarios are relatively similar aside from *Hot Growth*, which has high population coupled with climate change. *Adaptive Innovation* stands out among the others in that it has the greatest reductions in per capita demand but is paired with both the highest population and "Hot and Dry" climate projection. Even with the high population projection and high outdoor demands due to hot and dry future climate conditions, the water-saving measures included in *Adaptive Innovation* are projected to reduce demands to just above *Business as Usual*, demonstrating the benefits of increased conservation.

Self-Supplied Industrial Diversion Demands

As with municipal diversion demands, the updated SSI demands include both baseline demands (estimated as 2015 demands) and demands in the year 2050 for the five planning scenarios. The demand projections do not reflect drought conditions or associated responses. SSI demands were calculated at the county level and then summarized by river basin. No county-level SSI demands had to be distributed between multiple basins.

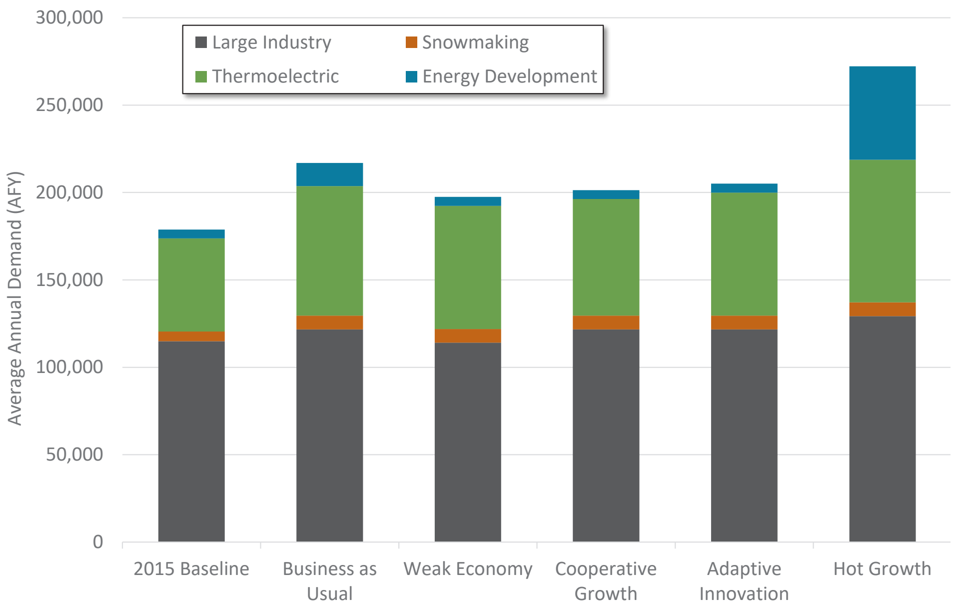
Statewide baseline SSI water demands are comprised of four major industrial uses, as shown on Figure 4.2.11.

Figure 4.2.11 Statewide Baseline SSI Sub-Sector Distribution



The projected demands for all planning scenarios were calculated based on the methodology described in Section 2. The results of the calculations are illustrated in Figure 4.2.12 and shown in Table 4.2.10. With the exception of *Hot Growth*, the updated projections for all planning scenarios were below SWSI 2010 estimates, primarily due to changes in assumptions for thermoelectric demands related to regulations that require an increase in power generation from renewable sources (the assumption was based on input from M&I TAG participants). Thermoelectric demand accounts for a large component of total SSI demand, and the methodology changes had a relatively large effect on the results. Large industry, snowmaking, and energy development projections are generally comparable to the ranges projected in SWSI 2010. There is little variation in the projections aside from *Hot Growth*.

Figure 4.2.12 Statewide Baseline and Projected SSI Demands



Total M&I

Table 4.2.10 and Figure 4.2.13 show statewide municipal and industrial baseline 2015 and projected 2050 water demands for the five planning scenarios. Total statewide M&I demands projected for 2050 range from approximately 1.5 million AFY (*Weak Economy*) to 2.0 million AFY (*Hot Growth*).

For all basins except for the Yampa, municipal demands exceed the self-supplied industrial demands for every planning scenario. Statewide, self-supplied industrial demands are around 15 percent to 18 percent of the municipal demands.

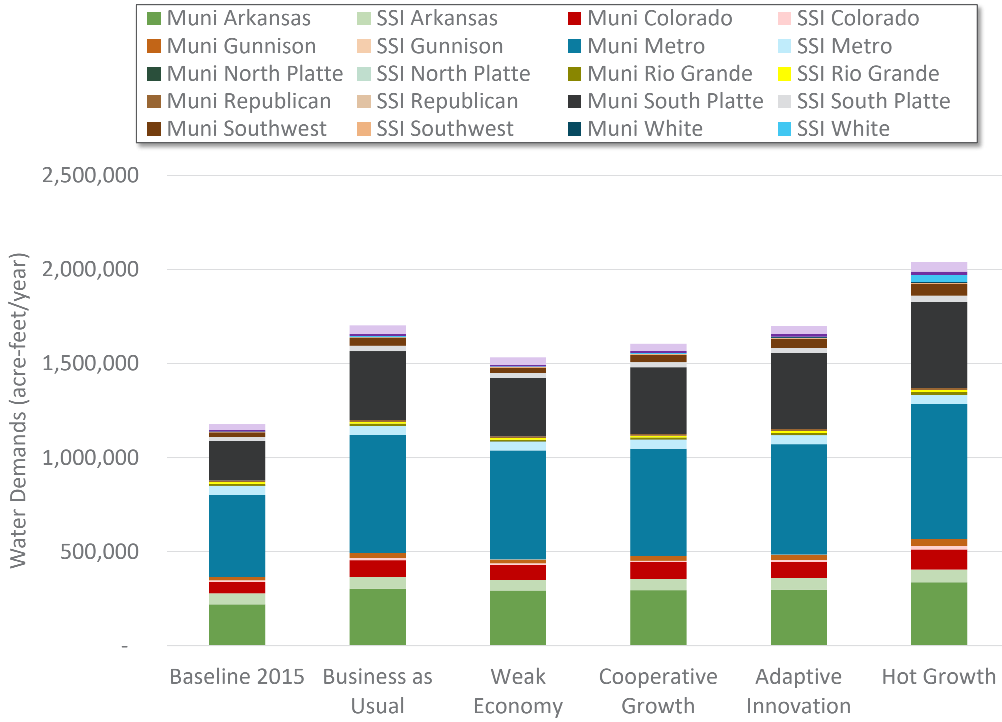
As discussed previously, the Water Plan rankings were the guiding objective in preparing average annual statewide volumetric demands. Statewide municipal projections followed the Water Plan rankings; however, industrial and combined M&I demands deviated to a limited degree, with *Business as Usual* demands exceeding *Adaptive Innovation* demands. These results show that *Business as Usual* and *Adaptive Innovation* futures may be similar, which indicates innovative conservation program measures have the potential to significantly offset the higher population and much warmer climate in *Adaptive Innovation* scenario.

Table 4.2.10 Summary of M&I Demands for Each Basin and Statewide (AFY)

Basin	Demand Type	Baseline 2015	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Arkansas	Municipal	219,200	303,400	293,800	294,500	298,100	337,200
	SSI	58,700	61,700	56,200	60,500	61,100	67,900
	Total	277,900	365,100	350,000	355,000	359,200	405,100
Colorado	Municipal	61,800	88,600	79,900	89,000	87,500	106,600
	SSI	7,800	12,300	7,600	7,800	7,800	18,500
	Total	69,600	100,900	87,500	96,800	95,300	125,000
Gunnison	Municipal	18,300	26,700	20,500	24,900	29,100	36,800
	SSI	300	700	700	700	700	700
	Total	18,500	27,300	21,200	25,500	29,800	37,400
North Platte	Municipal	400	400	300	300	400	400
	SSI	-	-	-	-	-	-
	Total	400	400	300	300	400	400
Rio Grande	Municipal	10,600	11,900	9,400	11,000	12,500	15,700
	SSI	7,900	9,900	9,000	9,900	9,900	10,800
	Total	18,500	21,800	18,300	20,900	22,400	26,500
South Platte /Metro (and Republi-can)	Municipal	653,300	1,001,600	896,600	932,800	999,900	1,185,200
	SSI	72,200	78,200	76,300	75,700	76,900	81,500
	Total	725,500	1,079,800	972,900	1,008,500	1,076,900	1,266,700
Southwest	Municipal	24,000	39,800	26,200	38,900	49,200	62,900
	SSI	2,300	4,300	4,100	3,900	4,100	4,700
	Total	26,300	44,100	30,400	42,800	53,300	67,600
Yampa-White-Green	Municipal	11,200	13,500	8,800	13,300	17,200	21,900
	SSI	29,600	49,800	43,700	43,000	44,600	88,300
	Total	40,800	63,300	52,400	56,300	61,800	110,200
Statewide	**Municipal**	**998,700**	**1,485,800**	**1,335,500**	**1,404,700**	**1,493,900**	**1,766,700**
	SSI	**178,800**	**216,900**	**197,500**	**201,400**	**205,100**	**272,200**
	Total	**1,177,500**	**1,702,700**	**1,533,000**	**1,606,100**	**1,699,000**	**2,039,000**

Note: Due to rounding, the statewide total may not precisely match the sum of basin results shown in the table above

Figure 4.2.13 Baseline and Projected M&I Demands by Basin



4.2.4 East Slope Transbasin Imports

Water from the West Slope of Colorado is a significant source of supply to East Slope municipal and agricultural water users in the South Platte and Arkansas basins. In the future, historical levels of West Slope supply may not be available, and a portion of the demand could go unmet depending on future climate conditions. Table 4.2.11 below provides combined demands for West Slope supplies for both the South Platte and Arkansas basins and combined unmet demands in these basins for the planning scenarios. The amount of unmet demand for West Slope supplies would increase the gap in these basins, likely in an amount that is more than the unmet demand, because municipalities reuse their return flows from water imported from the West Slope.

The focus of this section and Table 4.2.11 is on East Slope transbasin imports, but transbasin imports occur in other basins aside from the South Platte and Arkansas; however, the amount of water associated with these other basin transfers are significantly less. While data describing other transbasin imports and potential changes in the planning scenarios is not presented in the Technical Update report, the modeling data will be available to basin roundtables that choose to evaluate potential future changes to transbasin imports.

Table 4.2.11 Transbasin Demands in the South Platte and Arkansas Basins

	Scenario					
	Baseline	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average Annual Import Demand (ac-ft)	515,000	515,000	515,000	515,000	515,000	515,000
Average Annual Unmet Demand (ac-ft)	0*	0*	0*	26,000	50,000	55,000
Import in Max East Slope Gap Year (ac-ft)	495,000	495,000	495,000	560,000	467,000	467,000
Unmet Demand in Max East Slope Gap Yr (ac-ft)	0*	0*	0*	57,000	122,000	158,000
Percent Unmet Demand in Max East Slope Gap Year	0%	0%	0%	10%	26%	34%

**CDSS water allocation models calculate unmet demands in the baseline and Business as Usual and Weak Economy scenarios. Because historical values were used for import demand, the unmet demands in these scenarios indicate a calibration issue in the source basin.*

4.2.5 Water Availability

The projected availability of future water supplies varies across the state and is influenced by basin-specific hydrology and water uses, geographic location within basins, and compact constraints. As a result, it is difficult to generalize future water availability on a statewide basis and can be complicated to describe within basins. The following general observations can be made:

- No water is currently available or will be available in the future to meet additional needs in the Republican, Arkansas, and Rio Grande basins.
- Water availability is projected to decrease in *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth* due to the impacts of warmer and drier climate conditions. Peak flows are projected to occur earlier in the runoff season, and streamflows may be diminished later in the summer.
- In locations where available flows occur only periodically under current conditions (mainly during wet years), it may be available less frequently and in lower volumes. If the climate becomes warmer and drier, droughts and periods of low to no flow availability in these basins may be longer in duration.
- In basins where water is generally available every year, volumes of annual available flow may decrease overall and timing may change (peak flows may occur earlier in the runoff season).

4.2.6 Yield of Future Projects

As described in Section 3, the Technical Update analyses did not include future water supply projects and strategies that will help mitigate M&I and agricultural gaps; however, water providers are contemplating a wide variety of projects and strategies to meet their future needs. SWSI 2010 provided information on future projects and strategies that were then being pursued by water providers to meet future demands. The types of projects and strategies included agricultural water transfers (traditional and alternative), reuse, growth into existing supplies, regional in-basin projects, new transbasin projects, firming in-basin water rights, and firming transbasin rights. Ranges of potential yields for these projects and strategies by type and by basin were presented assuming 100 percent and also lower rates of success in achieving the contemplated yield of the projects. Table 4.2.12 shows the amount of yield in each basin for various rates of success that were included in the gap calculations in SWSI 2010.

The data in Table 4.2.12 were not updated in the Technical Update, and yields of future projects in SWSI 2010 were not developed considering future potential impacts of the planning scenarios. Nevertheless, the data in the table show that water providers are currently pursuing significant water supply projects and strategies that will help fill future gaps. Basin roundtables will be encouraged to update and improve the quality of their data describing future projects and strategies during upcoming BIP updates (see Section 5 for more details).

Table 4.2.12 Yields of Identified Projects and Processes from SWSI 2010

	SWSI 2010 Estimated Yield of Identified Projects and Processes (AFY)		
	100% IPP Success Rate (low)	**Alternative IPP Success Rate (medium)**	**Status Quo IPP Success Rate (high)**
Arkansas	88,000	85,000	76,000
Colorado	42,000	49,000	63,000
Gunnison	14,000	14,000	16,000
Metro	140,000	97,000	100,000
North Platte	100	200	300
Rio Grande	5,900	6,400	7,700
South Platte	120,000	78,000	58,000
Southwest	14,000	13,000	15,000
Yampa-White-Green	10,000	11,000	13,000
Statewide	**430,000**	**350,000**	**350,000**

This table reflects data from Table 5-12 in the SWSI 2010 report.

4.2.7 Environment and Recreation Conditions

Future conditions and risks for E&R attributes vary across the state depending on location and planning scenario. Future E&R conditions will be influenced by basin-specific hydrology, water uses, and geographic location within basins. As a result, it is difficult to precisely characterize future E&R conditions and risks on a statewide basis (regional specific observations are included in basin summaries). The following general observations can be made:

- Climate change and its impact on streamflow will be a primary driver of risk to E&R attributes.
- Projected future streamflow hydrographs in most locations across the state show earlier peaks and potentially drier conditions in the late summer months under scenarios with climate change.
- Under climate change scenarios, runoff and peak flows may occur earlier, resulting in possible mismatches between peak flow timing and species' needs.
- Drier conditions in late summer months could increase risk to coldwater and warmwater fish due to higher water temperatures and reduced habitat. The degree of increased risk is related to the level of streamflow decline.
- In many mountainous regions without significant influence of infrastructure, peak flow, and low flows are projected to be sufficient to sustain low to moderate risk for riparian plants and fish, but risks are projected to increase in scenarios with climate change.
- In mountainous regions with infrastructure, risks to E&R attributes may vary. Streams that are already depleted may see increased risks in scenarios with climate change. However, some streams may be sustained by reservoir releases, which will help moderate risks in scenarios with climate change.
- Instream flow water rights and recreational in-channel diversion water rights may be met less often in climate-impacted scenarios.

Modeling results for each of the eight major river basins are listed alphabetically in the following sections.

The Arkansas River originates in the central mountains of Colorado near Leadville, then travels eastward through the southeastern part of Colorado toward the Kansas border. The Arkansas Basin is spatially the largest river basin in Colorado, covering slightly less than one-third of the state's land area. A large amount of land is devoted to agriculture, with one-third of agricultural lands requiring irrigation. Increasing urbanization is occurring throughout portions of the Arkansas Basin, and in the recent past, persistent drought has heavily affected the basin.

The Arkansas River Compact of 1948 apportions the waters of the Arkansas River between Colorado and Kansas, while providing for the operation of John Martin Reservoir. Since the early 20th century, Colorado and Kansas have litigated claims concerning Arkansas River water, which has led to the development of rules and regulations to administer the basin's water resources for compliance with the compact.

ARKANSAS


LIMON
KIT CARSON
Big Sandy Creek
Rush Creek
Nee Noshe Reservoir
Adobe Creek Reservoir
District 17
Arkansas - Fowler to Las Animas
District 67
Arkansas - Las Animas to Stateline
Meredith Lake
Horse Creek Reservoir
LAMAR
ROCKY FORD
LA JUNTA
Apishapa River
Timpas Creek
Purgatoire River
Two Butte Creek
PRITCHETT
District 19
Purgatoire River
District 66
Cimarron River

4.3 ARKANSAS BASIN RESULTS

4.3.1 BASIN CHALLENGES

The Arkansas Basin will face several key opportunities and challenges pertaining to water management issues and needs in the future. These were described in Colorado's Water Plan and are summarized below.

Table 4.3.1 Key Future Water Management Issues in the Arkansas Basin

<table>
<tr><th>Agriculture</th><th>Environment and Recreation</th><th>Municipal and Industrial</th><th>Compacts and Administration</th></tr>
<tr><td>• Concerns over permanent agricultural transfers and the effects on rural economies are substantial in the lower portion of the basin downstream of Pueblo Reservoir.</td><td>• As the most rafted river in the world, the Arkansas River Voluntary Flow Agreement provides a benchmark for cooperative integration of municipal, agricultural, and recreational solutions in support of recreational boating and a gold-medal fishery.</td><td>• Replacement of municipal water supplies that depend on the non-renewing Denver Basin aquifer and declining water levels in designated basins is becoming critical, exacerbated by continued growth in groundwater-dependent urban areas.
• Rural areas within the Arkansas Basin have identified water needs but face challenges in marshalling resources to identify and implement solutions.</td><td rowspan="2">• All new uses require augmentation. Increasing irrigation efficiency, i.e., conversion from flood to center-pivot irrigation for labor and cost savings, will require 30,000 to 50,000 AF of augmentation water in the coming years.
• Regional solutions are emerging, like the Southeastern Colorado Water Conservancy District (SECWCD) Regional Water Conservation Plan, which can serve as a model for future regional initiatives to address the needs of the Arkansas Basin.</td></tr>
<tr><td colspan="3">• Collaborative solutions, as demonstrated in the Super Ditch and alternative transfer methods pilot projects, are needed to forestall or minimize loss of irrigated acreage in agriculture.
• Concerns over water quality include drinking water in the Lower Valley and the impact of fires and floods in the Fountain Creek watershed.
• The great majority of surface storage reservoirs in the Arkansas Basin were constructed between 1890 and 1930. Many of these facilities are in need of repair or restoration.</td></tr>
</table>

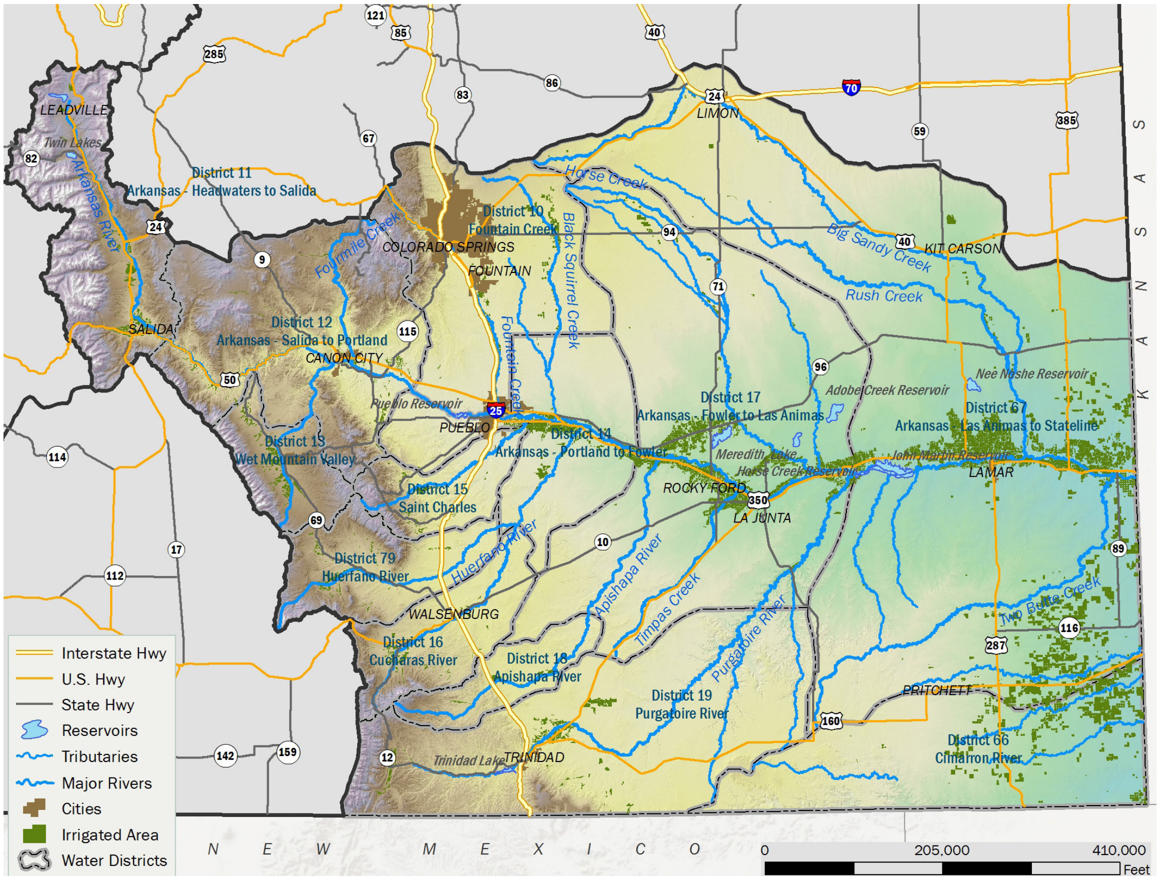


Figure 4.3.1 Map of Arkansas Basin

4.3.2 Summary of Technical Update Results

Key results and findings of the Technical Update pertaining to agricultural and M&I demands and gaps as well as findings related to environment and recreation attributes and future conditions are summarized in Table 4.3.2 below.

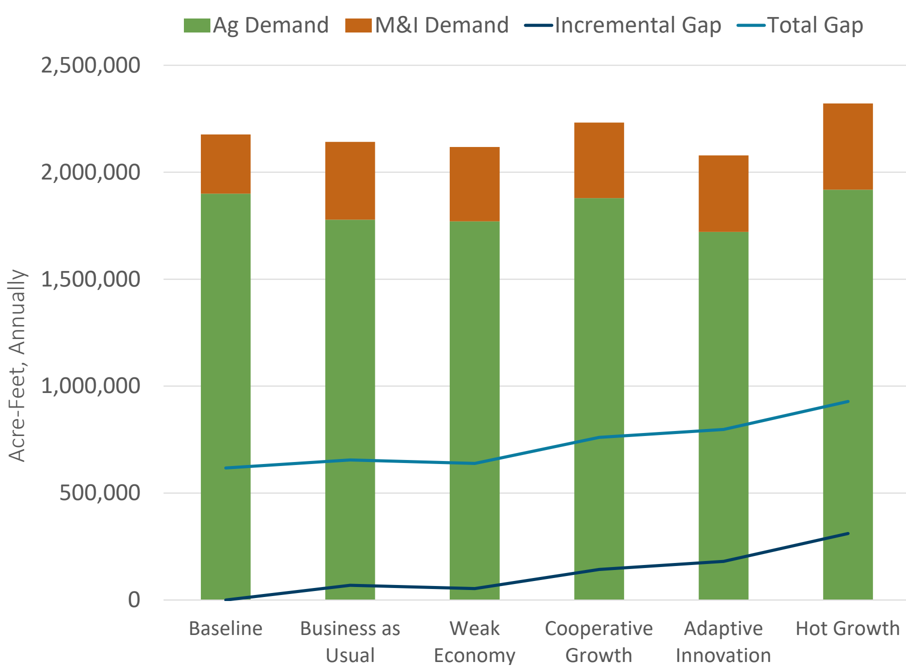
Table 4.3.2 Summary of Key Results in the Arkansas Basin

Agriculture	Environment and Recreation	Municipal and Industrial
• Agricultural demand will remain steady or be slightly reduced due to urbanization (20,000 acres), additional reduction of acres in the Southern High Plains Groundwater Basin, and increased sprinkler use (note that return flow reductions from increased sprinkler use would need to be mitigated). • Agricultural diversion demand gaps may increase due to a warmer climate as much as 10 percent.	• At high elevations, flow magnitude is not projected to significantly change under climate-impacted scenarios, but the annual hydrograph may shift with earlier snowmelt. Risks to riparian and fish habitat would remain low to moderate. • At montane elevations (between 5,500 and 8,500 feet), flow magnitude in climate-impacted scenarios is projected to drop significantly, creating high risk for riparian and fish habitat during the runoff season.	• M&I demand in this basin will grow to become a higher percentage of overall demand (from 13 to 17 percent). At the same time, municipal per capita use is projected to decline by various amounts depending on the scenario. • Municipal demand is driven by population growth in the Colorado Springs and Pueblo area, as well as modest increases in large industry and thermoelectric demand. • Gaps may be exacerbated by reductions in West Slope supplies.

Table 4.3.3 Summary of Diversion Demand and Gap Results in the Arkansas Basin

	Current (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average Annual Demand						
Agricultural (AFY)	1,899,900	1,778,300	1,770,200	1,878,900	1,721,200	1,918,000
M&I (AFY)	276,700	363,300	347,900	353,200	357,600	403,500
Gaps						
Ag (avg %)	32%	33%	33%	37%	43%	43%
Ag (incremental- AFY)	-	-	-	84,400	117,500	202,200
Ag (incremental gap as % of current demand)	-	-	-	4%	6%	11%
M&I (max %)	0%	19%	15%	17%	18%	27%
M&I (max-AF)	0	68,500	53,100	58,500	62,900	108,700

Figure 4.3.2 Summary of Diversion Demand and Gap Results in the Arkansas Basin



Summary of Environmental and Recreational Findings

- A surface water allocation model was not available in the Arkansas Basin, so the available flow dataset only includes natural flows and natural flows as impacted by climate drivers; no management drivers are factored in. Management drivers impact river flows in the eastern plains. Because a water allocation model that incorporates management is not available, no data-based insights into flow change and risk to non-consumptive attributes in the eastern plains could be developed.
- At high elevation locations (e.g., near Leadville), peak flow magnitude is not projected to change substantially, but April and May streamflow may increase, and June flows may decrease under "In-Between" and "Hot and Dry" climate projections. Subsequent risk for riparian/wetland plants and fish habitat would remain low or moderate. Mid- to late-summer streamflow is projected to decrease by 30 to 40 percent, and risk for trout could change from low (current) to moderate (under all climate-driven scenarios).
- At montane locations (elevation approximately 5,500 ft to 8,500 ft), peak flow magnitude is projected to drop 40 to 60 percent under "In-Between" and "Hot and Dry" climate projections, putting riparian/wetland plants and fish habitat at high to very high risk. Mid- to late-summer flows are projected to drop 25 to 45 percent, keeping cold water fish risk low or moderate, although the risk may be higher in July and/or during dry years.

4.3.3 Notable Basin Considerations

Section 4.1 described several analysis assumptions and limitations that apply to all basins and should be considered when reviewing and interpreting analysis results. Additional considerations specific to the Arkansas Basin are listed below:

- Agricultural and M&I gaps in the Arkansas Basin could increase due to reductions in transbasin imports. The gap increase could be more than the reduction in transmountain imports because return flows from transmountain imports are used to extinction within the Arkansas Basin (by either the importing entity or by downstream agricultural and M&I water users).
- Water allocation models were not available in the Arkansas Basin; however, the StateCU portion of the ArkDSS was used to estimate agricultural diversion demands. The ArkDSS is being developed and will allow more robust modeling in the future.
- The analysis assumed that there is no unappropriated water available for new uses. As a result, increased demands in various scenarios contributed directly to the gap. Because of this, increases in demand in one sector will lead to decreases in supply in another sector.
- Agricultural diversion demands were calculated based on irrigated acreage and crop water needs. Because no unappropriated water is available in the basin, the gap evaluation focused on historical water shortages and additional future demands. In other words, given the lack of additional supply, the analysis focused on physical shortages and did not need to consider the presence of junior water rights and whether those rights were fulfilled. Additional future diversion demands contribute directly to the gap because no unappropriated supplies are available in the basin.
- Basin stakeholders have cautioned that large reductions in irrigated land could result in socio-economic impacts that cause a reduction of municipal population in rural areas.
- The analysis does not consider specific alternative crops that may be grown in the future under the different scenarios; however, it accounts for future changes in crop types in a general sense in *Adaptive Innovation* and assumed that future crops would have 10 percent lower IWR.

4.3.4 Agricultural Diversion Demands

Agricultural Setting

Producers irrigate more than 472,000 acres in the Arkansas Basin, with nearly half of these acres located along the river between Pueblo Reservoir and the state line. The fertile soils in the river valley support a wide variety of crops, including pasture grass, alfalfa, corn, grains, wheat, fruits, vegetables, and melons. Many of the large irrigation systems in this area rely on surface water diversions from the mainstem Arkansas River, supplemented with groundwater and Fryingpan-Arkansas Project deliveries. Pasture grass is the primary crop grown outside of the Arkansas River Valley, with concentrated areas of irrigated acreage under the Trinidad Project on the Purgatoire River, along Fountain Creek downstream of Colorado Springs, and in the southeastern corner in the Southern High Plains Ground Water Management District.

The basin also provides water to three of the fastest growing municipalities in the state—Colorado Springs, Aurora, and Pueblo—and competition for water is high. An over-appropriated basin, coupled with the constraints of developing new water supplies under the Arkansas River Compact, have historically led municipalities to purchase and transfer irrigation water rights to municipal uses to meet their growing needs. Beginning in the 1970s, large transfers of irrigation water rights in the Colorado Canal (including Twin Lake shares) resulted in the dry up of 45,000 acres in Crowley County alone, which contributed to socioeconomic and environmental impacts in the Lower Arkansas River Valley. More recently, however, the basin has been proactive at looking for solutions to share water supplies and has been one of the front runners in developing alternative transfer methods such as lease/fallow pilot projects and interruptible supply agreements in which irrigation rights can be temporarily leased to municipalities for a limited number of years (e.g., three years out of every 10 years).

Planning Scenario Adjustments

Section 2 described ways in which inputs to agricultural diversion demand estimates were adjusted to reflect the future conditions described in the planning scenarios. Discussions with stakeholders in the Arkansas Basin regarding what agriculture in the basin may look like by 2050 focused on three major areas: additional dry up of acreage for municipal purposes, declining groundwater aquifer levels in the Southern High Plains region, and irrigation practices. As discussed in more detail below, dry up of acreage and declining aquifer levels impact the amount of projected 2050 irrigated acreage. In addition, irrigation practices affect projected 2050 efficiencies.

Population projections by 2050 in the basin reflect significant increases for Colorado Springs and Pueblo. With limited acreage in close proximity, smaller amounts of irrigated acreage are expected to be urbanized by their growth compared to urbanization that may occur around smaller agricultural towns such as Salida, Canon City, and Lamar. Portions of two irrigation ditches, Fort Lyon Canal and Bessemer Ditch, have been purchased by municipalities, and their water rights are in the process of being transferred for municipal uses. It is anticipated that portions of these ditches, totaling 12,600 irrigated acres, will be dried up by 2050. Although additional purchase of irrigation water rights is expected, the stakeholders in the basin are hopeful that leasing agreements or other solutions may limit the permanent dry up of irrigated acreage in the future.

From a groundwater sustainability perspective in the basin, more than 85,000 acres in the southeast corner of the basin are irrigated by groundwater pumped from a series of deep aquifers, including the Ogallala, Dakota/Cheyenne, and Dockum aquifers. This area is largely disconnected from the mainstem of the Arkansas River and is managed as the Southern High Plains Designated Groundwater Basin (SHPDGWB). After review of groundwater reports documenting downward trends in groundwater levels, discussions with stakeholders, and conversations with landowners in the area, the acreage in this area was reduced between 10 and 33 percent across the planning scenarios. This range reflects the uncertainty associated with estimating the future water availability in the basin and the potential for increased pumping as projected climate change increases crop demands in the area.

Table 4.3.4 summarizes the planning scenario adjustments described above and other adjustments that impact agricultural diversion demands in the various scenarios, including constraints on improved irrigation efficiencies in the lower basin.

Table 4.3.4 Planning Scenario Adjustments to for Agricultural Demands in the Arkansas Basin

Adjustment Factor*	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Change in Irrigated Land due to Urbanization & Municipal Transfers	19,840 Acre Reduction	19,840 Acre Reduction	19,840 Acre Reduction	19,840 Acre Reduction	19,840 Acre Reduction
GW Acreage Sustainability	10% Acre Reduction (SHPDGWB)	15% Acre Reduction (SHPDGWB)	20% Acre Reduction (SHPDGWB)	33% Acre Reduction (SHPDGWB)	33% Acre Reduction (SHPDGWB)
IWR Climate Factor	-	-	18%	26%	26%
Emerging Technologies	20% Increased Sprinkler Use (H-I Area)	20% Increased Sprinkler Use (H-I Area)	20% Increased Sprinkler Use (H-I Area) 100% use of Sprinklers (SHPDGWB)	20% Increased Sprinkler Use (H-I Area) 100% use of Sprinklers (SHPDGWB) 10% IWR Reduction	20% Increased Sprinkler Use (H-I Area) 100% use of Sprinklers (SHPDGWB)

** See Section 2.2.3 for descriptions of adjustment methodologies and assumptions*

Agricultural Diversion Demand Results

Table 4.3.5 and Figure 4.3.3 summarize the acreage, IWR, and the agricultural diversion demand for surface water supplies in the Arkansas Basin for current conditions and the five planning scenarios. The largest variation in the basin occurred in *Adaptive Innovation* due to a 10 percent reduction in IWR and a 10 percent increase to system efficiency, both of which reduce diversion demands. In this basin, several planning scenarios projected less agricultural demand than the current demand, mainly due to reduced irrigated acres and resulting decreased IWR. Only *Hot Growth* had a slightly increased demand over baseline.

SYSTEM EFFICIENCY

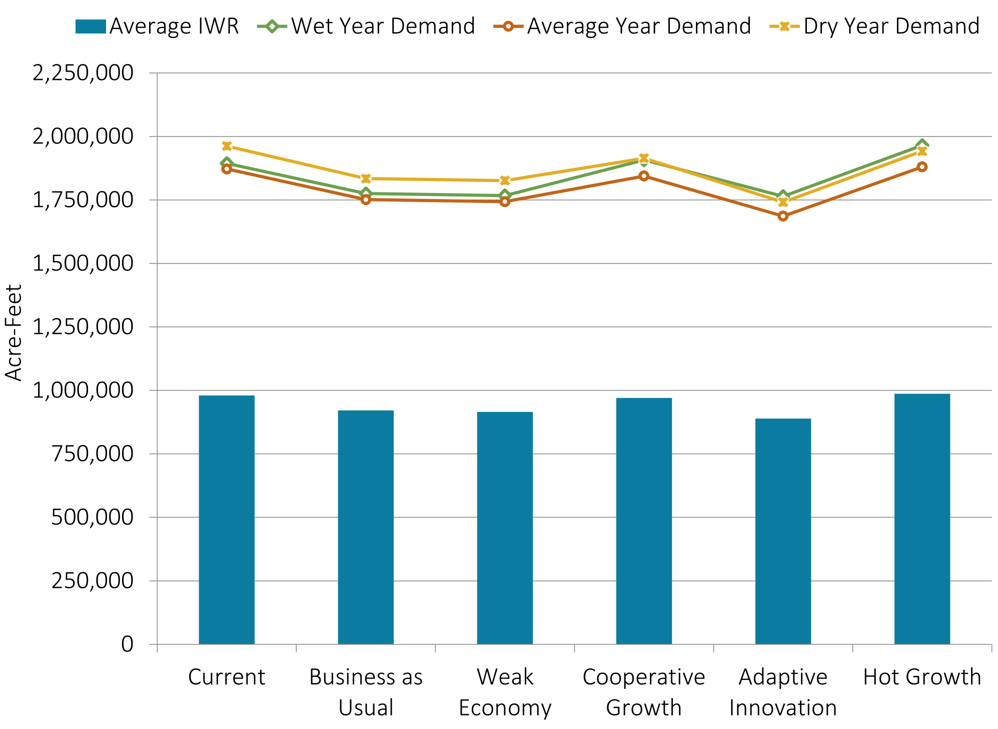
In some cases, diversion demands can be higher in wet years because system efficiency decreases due to the relative abundance of supply.

Table 4.3.5 Summary of Agricultural Diversion Demand Results in the Arkansas Basin

	Current (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Irrigated Acreage (acres)	445,000	417,700	413,600	409,500	398,900	398,900
Average IWR (AFY)	980,000	921,000	915,000	970,000	889,000	987,000
Diversion Demand						
Average Year (AFY)	1,872,000	1,751,000	1,743,000	1,844,000	1,686,000	1,880,000
Wet Yr. Change	1%	1%	1%	3%	5%	5%
Dry Yr Change	5%	5%	5%	4%	3%	3%

Average agricultural diversion demand was calculated using the average hydrologic years (i.e., years classified as neither wet or dry) from 1950-2013

Figure 4.3.3 Agricultural Diversion Demands and IWR Results in the Arkansas Basin



4.3.5 Municipal and Industrial Demands

Population Projections

The Arkansas Basin includes about 19 percent of the statewide population. Between the years 2015 and 2050, it is projected to grow from approximately 1.0 million to between 1.46 million and 1.63 million people in the low and high growth projections, respectively, which is an increase in population of 45 to 61 percent. Table 4.3.6 shows how population growth is projected to vary across the planning scenarios for the Arkansas Basin.

Table 4.3.6 Arkansas Basin 2015 and Projected Populations

2015 Population	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
1,008,400	1,509,500	1,462,800	1,544,400	1,626,000	1,568,000

Current Municipal Demands

In the Arkansas Basin, baseline water demands were largely based on 1051 data as shown on Figure 4.3.4.

Figure 4.3.5 summarizes the categories of municipal, baseline water usage in the Arkansas Basin. On a basin scale, the residential outdoor demand as a percentage of the systemwide demands is one of the lowest reported throughout the state, at approximately 17 percent. Conversely, the baseline non-revenue water demand is one of the highest statewide, at approximately 18 percent of the systemwide demands.

Figure 4.3.4 Sources of Water Demand Data in the Arkansas Basin

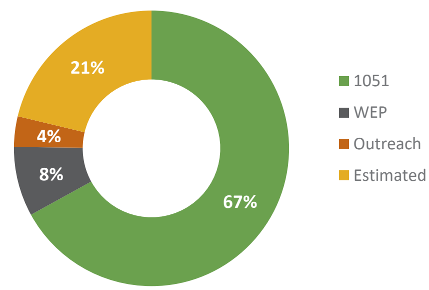
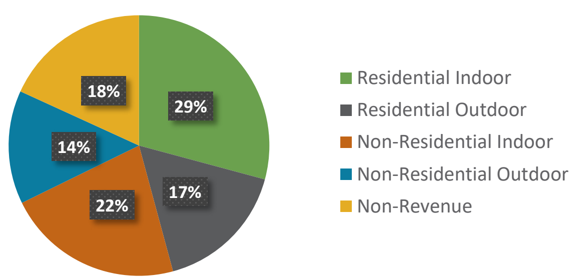


Figure 4.3.5 Categories of Water Usage in the Arkansas Basin



DEMANDS

The Arkansas Basin average baseline per capita system wide demand has increased from 185 gpcd in SWSI 2010 to approximately 194 gpcd.

Projected Municipal Demands

Figure 4.3.6 provides a summary of per capita baseline and projected water demands for the Arkansas Basin. Systemwide, all of the projected per capita demands decrease relative to the baseline. Th *Hot Growth* is projected to be nearly as high as the baseline, with lower residential indoor but higher residential and non-residential outdoor demands that are significantly influenced by hotter and drier climate conditions.

The Arkansas Basin municipal baseline and projected diversion demands in Table 4.3.7 show the combined effect of population and per capita demands. Municipal demands are projected to grow from approximately 219,000 AFY in 2015 to between 294,000 and 337,000 AFY in 2050. El Paso County accounts for around half of the baseline demand, followed by Pueblo County at about one-third of basin demand.

Figure 4.3.6 Arkansas Basin Municipal Baseline and Projected Per Capita Demands by Water Demand Category

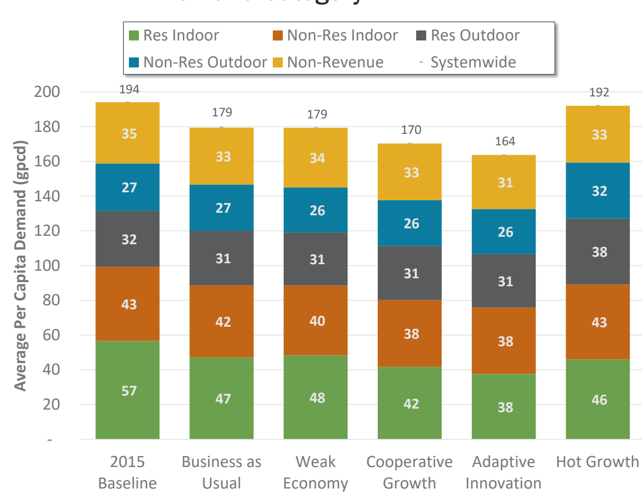


Table 4.3.7 Arkansas Basin Municipal Baseline and Projected Demands (AFY)

Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
219,200	303,400	293,800	294,500	298,100	337,200

The baseline and projected demand distributions are shown on Figure 4.3.7, which also shows how the population varies between the scenarios. All of the planning scenarios result in an increase relative to the baseline. Except *Hot Growth*, the systemwide demand projections are similar, which demonstrates how the pairing of drivers and population can offset each other and narrow the range of results. Higher levels of conservation associated with *Adaptive Innovation* help limit the impacts of the "Hot and Dry" climate projection and higher population.

Self-Supplied Industrial Demands

The Arkansas Basin includes about 33 percent of the statewide SSI demand. SSI demands in this basin are associated with the large industry and thermoelectric sub-sectors, with no demands projected for snowmaking or energy development sub-sectors. Basin-scale SSI demands are shown on Figure 4.3.8 and summarized in Table 4.3.8.

Total M&I Diversion Demands

Arkansas Basin combined M&I demand projections for 2050 range from approximately 350,000 AFY in *Weak Economy* to 405,000 AFY in *Hot Growth*, as shown on Figure 4.3.9. SSI demands account for 16 to 17 percent of the projected M&I demands. On a basin scale, the demand projections do not follow the statewide sequence of the scenario rankings described in the CWP, with *Adaptive Innovation* falling out of sequence.

Figure 4.3.7 Arkansas Basin Baseline and Projected Population and Municipal Demands

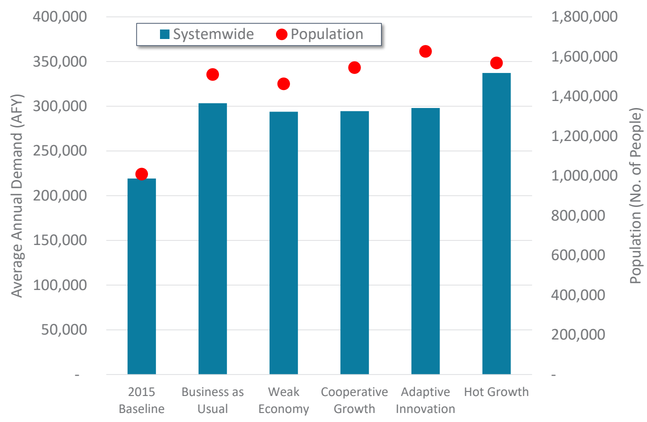


Figure 4.3.8 Arkansas Basin Self-Supplied Industrial Demands

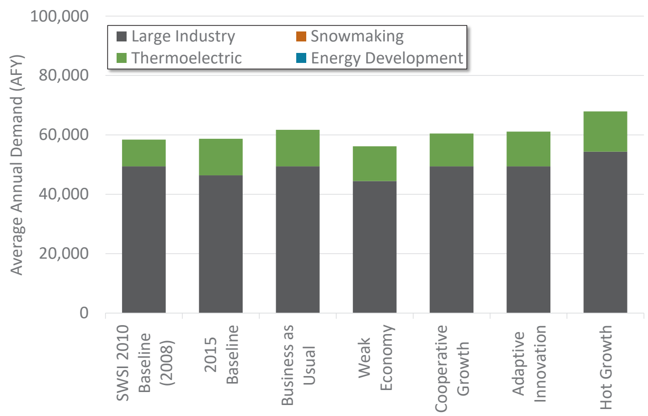


Figure 4.3.9 Arkansas Basin Municipal and Self-Supplied Industrial Demands

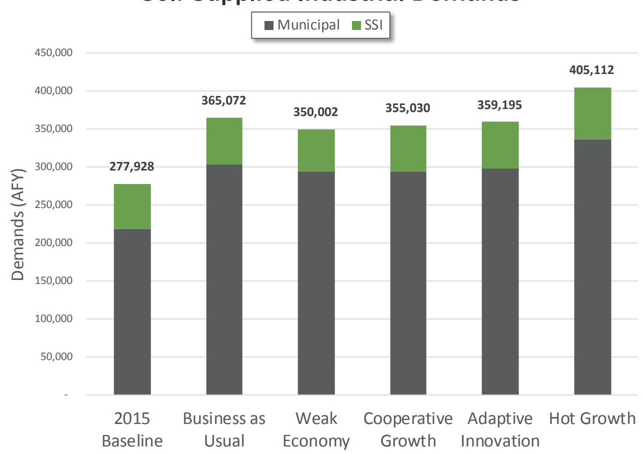


Table 4.3.8 Arkansas SSI Baseline and Projected Demands (AFY)

Sub-sector	Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Large Industry	46,400	49,400	44,460	49,400	49,400	54,340
Snowmaking	-	-	-	-	-	-
Thermoelectric	12,320	12,320	11,700	11,090	11,700	13,550
Energy Development	-	-	-	-	-	-
Sub-Basin Total	58,720	61,720	56,160	60,490	61,100	67,890

4.3.6 Water Supply Gaps

The agricultural and M&I diversion demands were compared against available water supply modeled for current conditions and the five planning scenarios. Gaps were calculated when water supply was insufficient to meet demands.

Agricultural

The Arkansas Basin agricultural diversion demands, demand gaps, and consumptive use gaps for the baseline and planning scenarios are presented in Table 4.3.9 and illustrated on Figure 4.3.10. An annual time series of gaps in terms of percent of demand that was unmet is shown on Figure 4.3.11.

INCREMENTAL GAP

The incremental agricultural gap quantifies the degree to which the gap could increase beyond what agriculture has historically experienced under water shortage conditions.

Table 4.3.9 Arkansas Basin Agricultural Gap Results (AFY)

		Scenario					
		Scenario	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average	Average Annual Demand	1,899,900	1,778,300	1,770,200	1,878,900	1,721,200	1,918,000
	Average Annual Gap	617,300	586,400	585,200	701,700	734,800	819,500
	Average Annual Gap Increase from Baseline	-	-	-	84,400	117,500	202,200
	Average Annual Percent Gap	32%	33%	33%	37%	43%	43%
	Average Annual CU Gap	313,100	297,100	296,400	362,500	381,500	425,300
Maximum	Demand in Maximum Gap Year	2,303,900	2,152,100	2,141,500	2,149,300	1,932,700	2,157,900
	Gap in Maximum Gap Year	1,446,400	1,369,600	1,366,600	1,532,000	1,566,100	1,749,800
	Increase from Baseline Gap	-	-	-	85,600	119,700	303,400
	Percent Gap in Maximum Gap Year	63%	64%	64%	71%	81%	81%

Study period for Water Supply analysis is 1975-2013, reflecting different baseline demand than described in Agricultural Diversion Demands section.

Figure 4.3.10 Projected Averages Annual Agricultural Diversion Demand, Demand Met, and Gaps in the Arkansas Basin

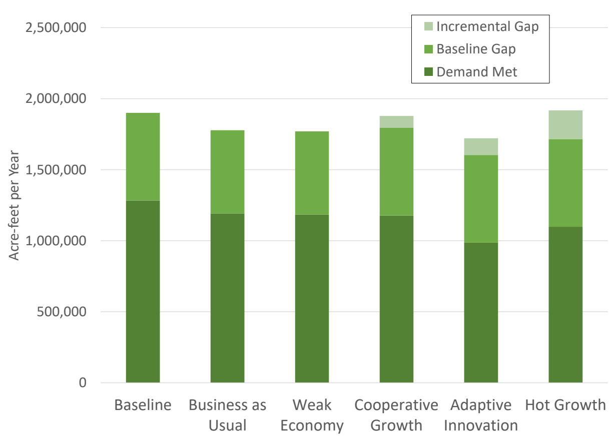
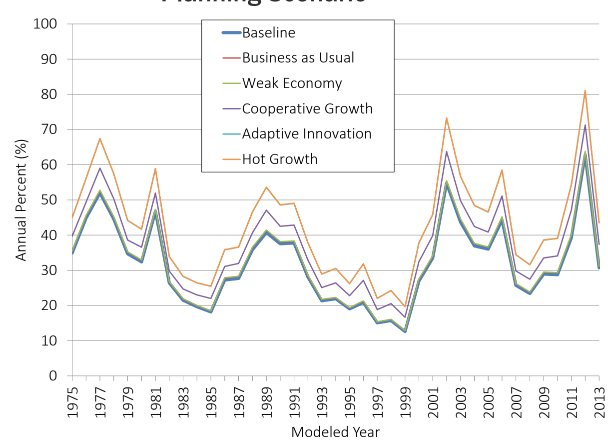


Figure 4.3.11 Annual Agricultural Gaps (expressed as a percentage of demand) for Each Planning Scenario



The following are observations on agricultural diversion demands and gaps:

- Agricultural diversion demands are projected to be similar or even reduced as compared to baseline in all five planning scenarios due to urbanization, transfers of agricultural water rights to municipal uses, and declining aquifer levels in the Southern High Plains, all resulting in reduced irrigated acres.
- The agricultural gap as a percent of demand is relatively large in this basin (32 to 43 percent). Current farming practices help to minimize this gap, which is projected to remain consistent in *Business as Usual* and *Weak Economy*; however, climate changes reflected in *Cooperative Growth*, *Adaptive Innovation* and *Hot Growth* are projected to increase water supply gaps up to 40 percent of demand.

M&I

The diversion demand and gap results for M&I uses in the Arkansas Basin are summarized in Table 4.3.10 and illustrated on Figure 4.3.12. Note that annual time series of M&I gaps are not available for the Arkansas Basin due to the lack of available CDSS tools.

The following are observations on M&I diversion demands and gaps:

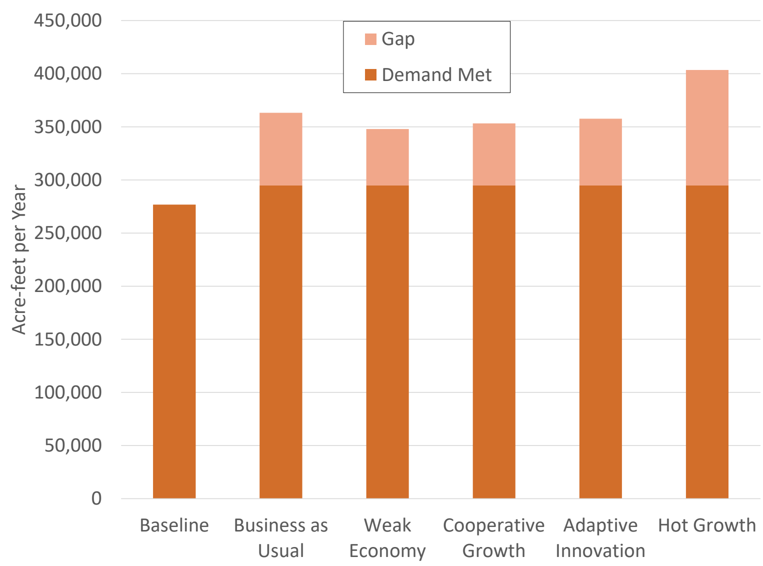
- M&I diversion demand in this basin is projected to grow to become a higher percentage of overall demand (from 13 to 17 percent).
- Municipal demand is driven by population growth in the Colorado Springs and Pueblo area, as well as modest increases in large industry and thermoelectric demand.
- The M&I gap in *Adaptive Innovation* is projected to be less than in *Business as Usual* even with high levels of projected population growth and increased outdoor water demands due to a hotter and drier climate.
- M&I gaps may be exacerbated by reductions in transbasin imports in planning scenarios that include considerations of climate change.

Table 4.3.10 Arkansas Basin M&I Gap Results

		Scenario					
		Scenario	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average	Average Annual Demand	276,700	363,300	347,900	353,200	357,600	403,500
Average	Average Annual Gap	0	68,500	53,100	58,500	62,900	108,700
Average	Average Annual Percent Gap	0%	19%	15%	17%	18%	27%
Maximum	Demand in Maximum Gap Year	276,700	363,300	347,900	353,200	357,600	403,500
Maximum	Gap in Maximum Gap Year	0	68,500	53,100	58,500	62,900	108,700
Maximum	Percent Gap in Maximum Gap Year	0%	19%	15%	17%	18%	27%

Study period for Water Supply Analysis is 1975-2013, reflecting different baseline demand than described in M&I Demand section.
Baseline demand also may vary slightly from previous section due to differences in geographic distribution of demand for counties that lie in multiple basins.

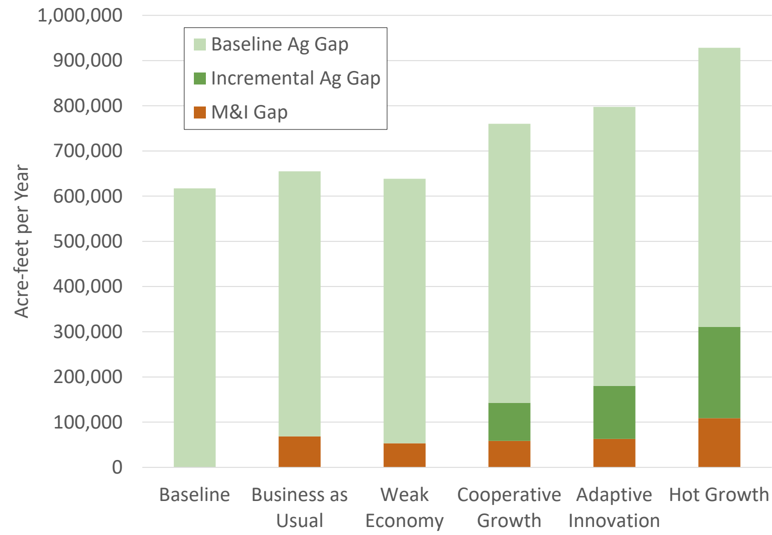
Figure 4.3.12 Projected Maximum Annual M&I Demand Met and Gaps in the Arkansas Basin



Total Gap

Figure 4.3.13 illustrates the total combined agricultural and M&I diversion demand gap in the Arkansas Basin. The figure combines the average annual baseline and incremental agricultural gap and the maximum M&I gap. In *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*, gaps are driven by both agricultural and municipal demands, which increase in the "Hot and Dry" climate projection.

Figure 4.3.13 Projected Average Annual Agricultural Gaps and Maximum M&I Diversion Demand Gaps in the Arkansas Basin



Supplies from Urbanized Lands

By 2050, irrigated acreage in the Arkansas Basin is projected to decrease by more than 19,000 acres due to urbanization or lands that are no longer irrigated because of planned water right transfers from agricultural to municipal use in the Arkansas Basin. Irrigation supplies for these lands could potentially be used for M&I needs in the future (subject to a variety of unknowns such as seniority and type of water supply, willingness to change the use of water through water court, etc.). Acreage associated with planned transfers was derived based on stakeholder input.

The average annual historical consumptive use associated with potentially urbanized acreage and planned water right transfers for each scenario is reflected in Table 4.3.11. The data in the table represent planning-level estimates of this potential supply and has not been applied to the M&I gaps. The data in the table do not represent supplies from permanent water transfers that may be considered by a basin roundtable as a future strategy to meet gaps (note that SWSI 2010 included estimates of permanent transfers beyond those currently planned as a strategy for meeting potential future M&I gaps).

Table 4.3.11 Estimated Consumptive Use from Lands Projected to be Urbanized by 2050 and Planned Transfers in the Arkansas Basin

	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Urbanized Acreage and Lands Subject to Planned Transfers (acres)	19,800	19,800	19,800	19,800	19,800
Estimated Consumptive Use (AFY)	29,600	29,700	29,400	25,200	27,900

4.3.7 Available Supply

For the purposes of the Technical Update, it was assumed that due to compact constraints, there are no available water supplies now or in the future that can meet new demands.

4.3.8 Environment and Recreation

A surface water allocation model is not currently available in the Arkansas Basin. As a result, hydrologic datasets in the Flow Tool include only naturalized flows and naturalized flows as impacted by climate change. A total of three water allocation model nodes were selected for the Flow Tool within the Arkansas Basin (Figure 4.3.14). The figure also shows subwatersheds (at the 12-digit HUC level) and the relative number of E&R attributes located in each subwatershed.

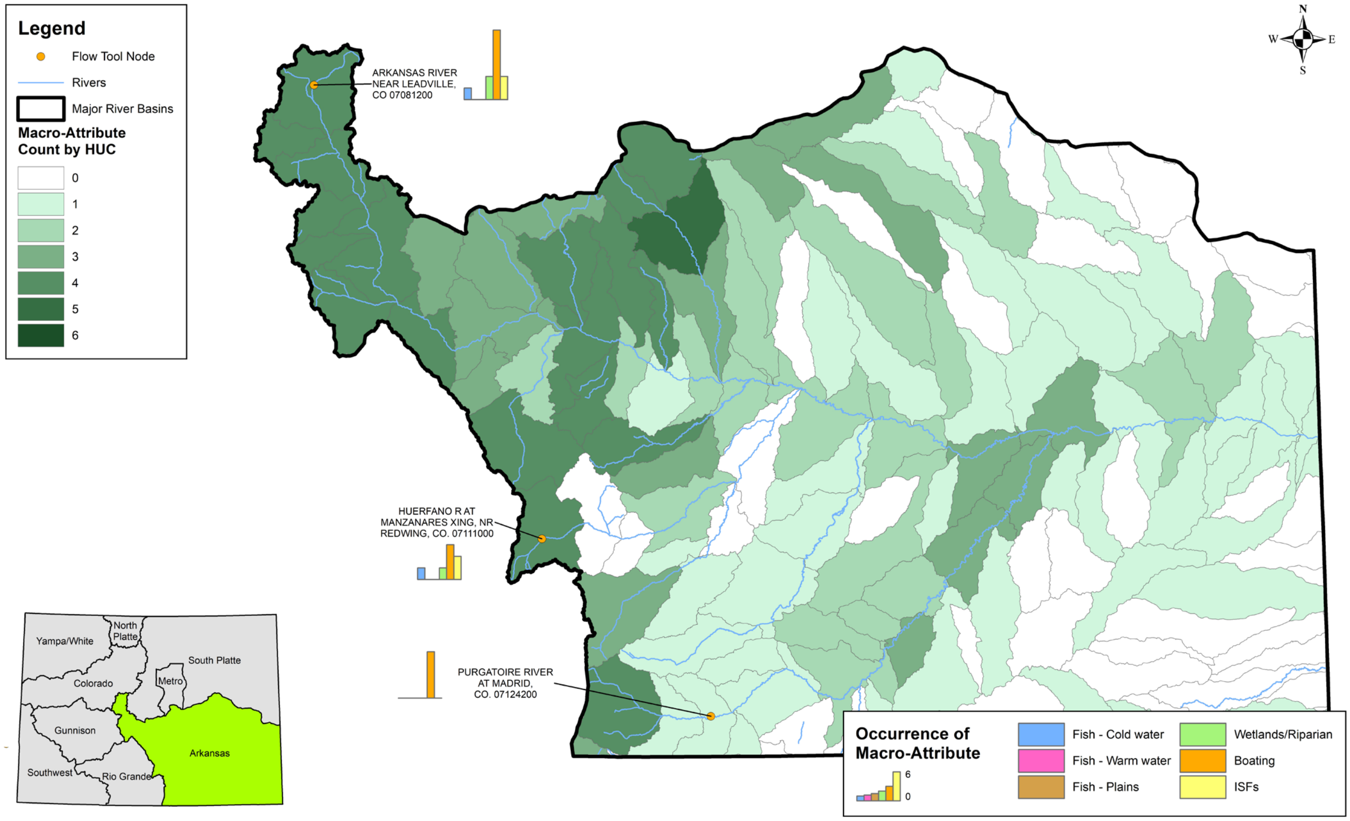
- Arkansas River near Leadville, Colorado (07081200)
- Huerfano River at Manzanares Crossing, near Redwing, Colorado (07111000)
- Purgatoire River at Madrid, Colorado (07124200)

The sites were selected because they are above major supply and demand drivers, and because future flow changes would likely be associated only with climate-change factors. Management drivers impact river flows on the eastern plains. Because a water allocation model that incorporates management is not available, no data-based insights into potential flow changes and risks to E&R attributes could be developed at this time. The Flow Tool results for the Arkansas Basin include only naturalized flows and naturalized flows as impacted by climate change factors ("In-Between" and "Hot and Dry" climate projections). These data do not represent changes in flow due to irrigation, transbasin imports, and/or storage.

NATURALIZED FLOW

Naturalized flows reflect conditions that would occur in the absence of human activities. Baseline flows reflect current conditions as influenced by existing infrastructure and river operations. While observations regarding naturalized flows may be informative, baseline flows reflect actual conditions and the diverse operations of the river's many users.

Figure 4.3.14 Flow Tool Nodes Selected for The Arkansas Basin



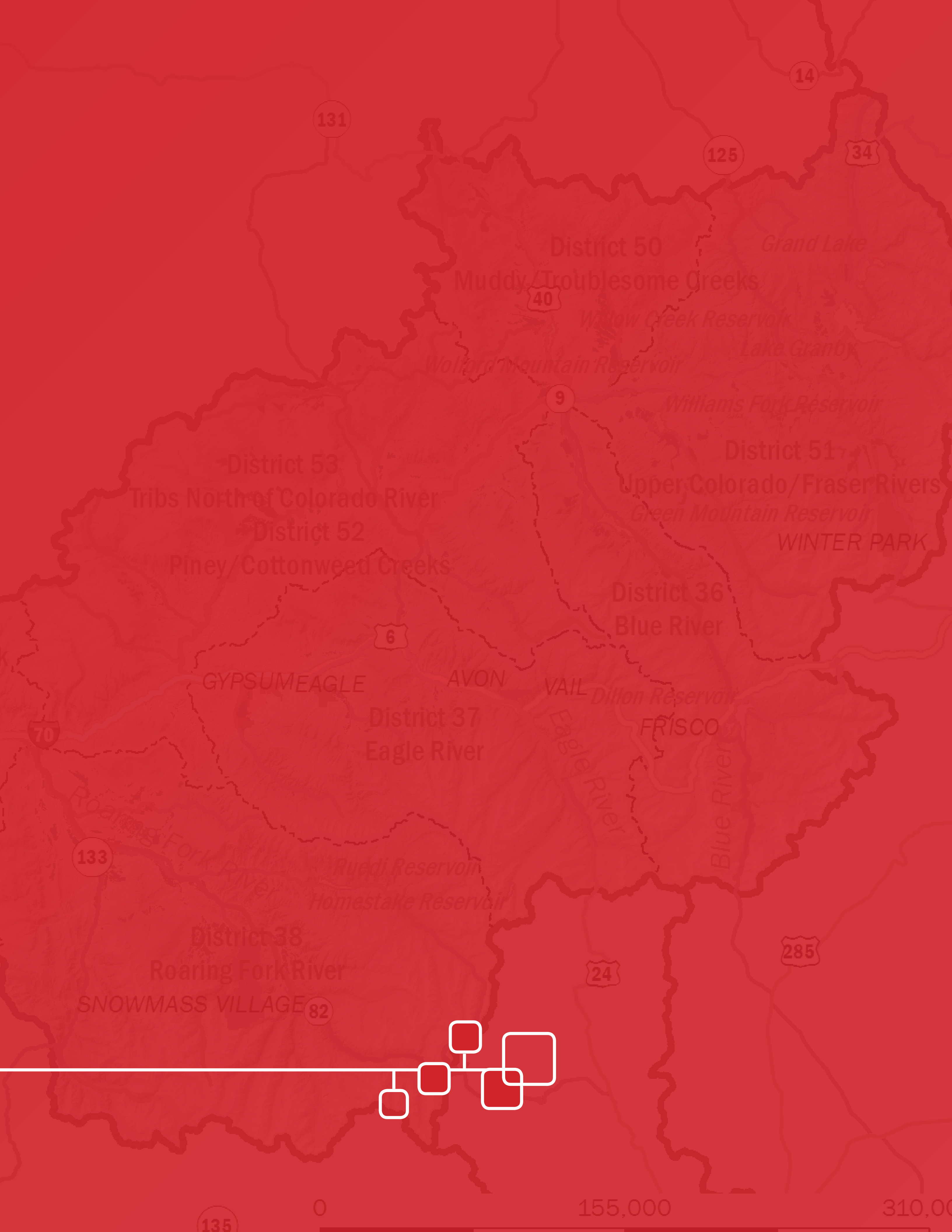
Results and observations from Flow Tool analyses using flow data developed in the water supply and gap analyses for baseline conditions and the planning scenarios are described in Table 4.3.12.

Table 4.3.12 Summary of Flow Tool Results in the Arkansas Basin

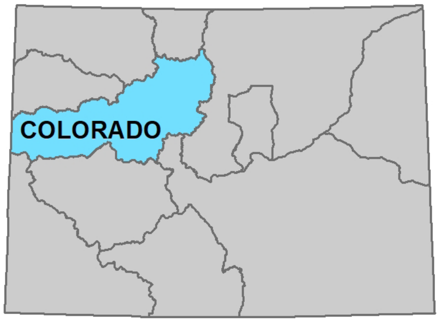
Category	Observation
Projected Flows	At high elevation locations (e.g., near Leadville), peak flow magnitude are not projected to change substantially. However, the timing of peak flow may shift to earlier in the year, with April and May flow magnitudes rising and June flows decreasing under the In-Between and Hot and Dry climate change projections.
	At montane and foothills locations (elevation range from approximately 5,500 feet to 8,500 feet), peak flow magnitude will likely drop under the In-Between and Hot and Dry climate change projections.
	Across all locations, mid- and late-summer streamflow is projected to decrease due to climate change.
Ecological Risk	At high elevations, peak-flow related risk for riparian/wetland plants and fish habitat remains low or moderate under future climate change projections.
	At lower elevations, the decline in peak flow magnitude is projected to increase the risk status for riparian/wetland plants and fish habitat. The reduction in peak flow may also adversely affect recreational boating.
	Metrics for coldwater fish (trout) indicate that even with climate-induced changes to mid- and late-summer flows, flows are projected to be sufficient to keep risk low or moderate, though risk may be higher in July and/or during dry years.
E&R Attributes	Because future flows under the five scenarios were not modeled in the Arkansas Basin, projected changes to flow at the selected nodes and the associated changes in risk to E&R attributes are entirely attributable to projected changes in climate. These climate-induced changes are similar to the general pattern seen in many parts of Colorado: earlier peak flow and reduced mid- and late-summer flows, with reduced peak flow magnitudes in some locations.

The mainstem Colorado Basin in Colorado encompasses approximately 9,830 square miles and extends from Rocky Mountain National Park to the Colorado-Utah state line. Elevations range from more than 14,000 feet to about 4,300 feet. Snowpack in the high country is an important water source to both sides of the Continental Divide, as the state's largest transbasin diversions are here. Ranching and livestock production typify agriculture in the upper reaches, while the Grand Valley has a long history of fruit and vegetable production. With major ski areas as well as boating and fishing opportunities, water drives a robust recreation and tourism economy throughout the basin.

COLORADO


District 50
Muddy/Troublesome Creeks
District 51
Upper Colorado/Fraser Rivers
District 53
Tribs North of Colorado River
District 52
Piney/Cottonwood Creeks
District 36
Blue River
District 37
Eagle River
District 38
Roaring Fork River
Grand Lake
Willow Creek Reservoir
Lake Granby
Wolford Mountain Reservoir
Williams Fork Reservoir
Green Mountain Reservoir
WINTER PARK
GYPSUM
EAGLE
AVON
VAIL
Dillon Reservoir
FRISCO
Eagle River
Blue River
Roaring Fork River
Ruedi Reservoir
Homestake Reservoir
SNOWMASS VILLAGE
131
14
125
34
40
9
6
70
133
82
24
285
135
0
155,000

4.4 COLORADO BASIN RESULTS

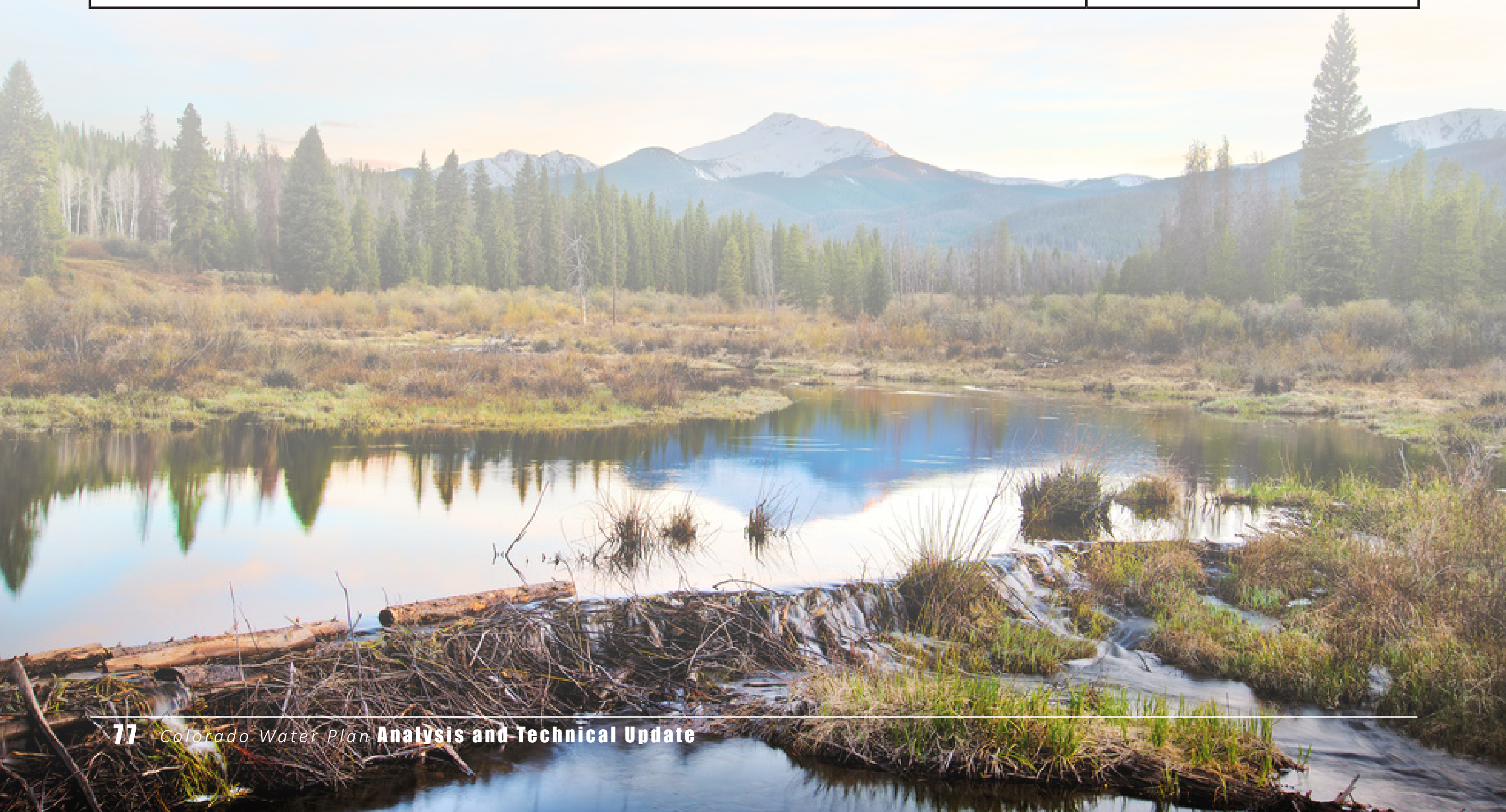


4.4.1 BASIN CHALLENGES

Key future water management issues in this basin include competing resources for agriculture, tourism and recreation, protection of endangered species, and the threat of a Colorado River Compact call. These challenges are described in Colorado's Water Plan and summarized below in Table 4.4.1.

Table 4.4.1 Key Future Water Management Issues in the Colorado Basin

Agriculture	Environment and Recreation	Municipal and Industrial	Compacts and Administration
• Despite the importance of agriculture, continued urbanization of agricultural lands could reduce irrigated acres in the basin.	• Success of the Upper Colorado River Endangered Fish Recovery Program is vital to the river's future. The program is designed to address the needs of endangered fish while protecting existing and future use of Colorado River water. • Recreational use and environmental conservation are major drivers in the basin and are important for economic health and quality of life.	• Development of conditional transbasin water rights is a concern, and Colorado must consider the effect on in-basin supplies.	• There is concern over a potential compact shortage during severe and sustained drought and the potential effects to in-basin supplies. Demand management to conserve water per the recently signed Drought Contingency Plan is a pressing issue.
• Selenium and salinity are of concern in parts of the basin.			



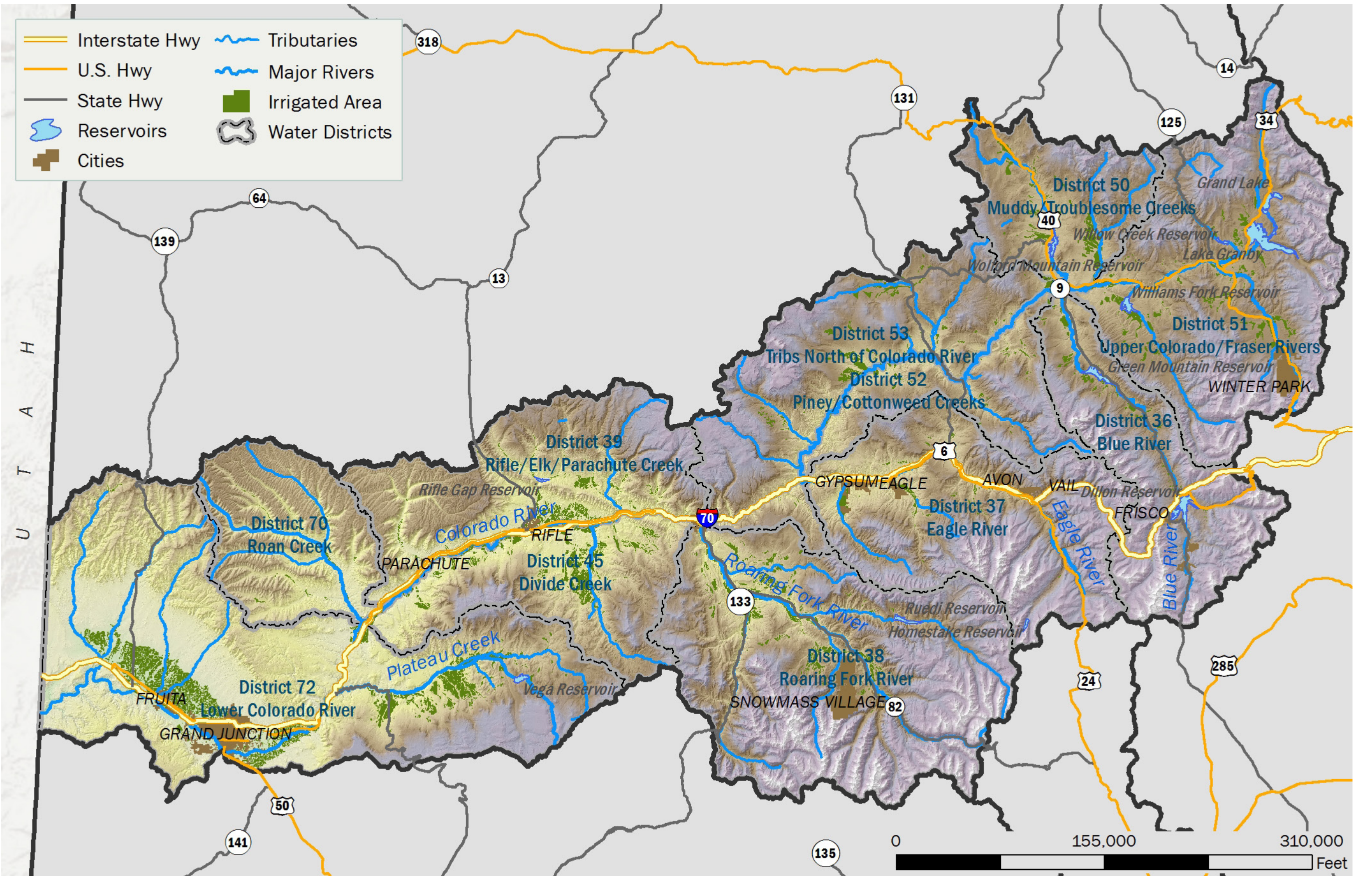


Figure 4.4.1 Map of the Colorado Basin

4.4.2 SUMMARY OF TECHNICAL UPDATE RESULTS

Key results and findings of the Technical Update pertaining to agricultural and M&I demands and gaps, as well as findings related to environmental and recreational attributes and future conditions, are summarized below in Table 4.4.2.

Table 4.4.2 Summary of Key Results in the Colorado Basin

Agriculture	Environment and Recreation	Municipal and Industrial
• Although irrigated area is estimated to decrease by 13,600 acres as cities expand onto irrigated land, IWR may increase in a warmer future climate. • Emerging technology, including adoption of higher system efficiencies, may mitigate climate impacts and reduce demand below baseline. • The future incremental gap ranges from 0 to 4 percent of baseline demand • Scenarios that assume current climate conditions (Business as Usual and Weak Economy) have agricultural gaps around 3 percent of demand. Gaps (as a percentage of demand) increase in scenarios that assume a warmer and drier future climate.	• In climate-impacted scenarios, peak flow generally moves earlier in the year. • Aquatic and riparian attributes may be affected differently based on location and potential changes in stream flow magnitude and timing.	• Per capita municipal usage is projected to decrease in the future. • Municipal demand is projected to increase for all scenarios due to increased population; however, except for Hot Growth, the systemwide demand projections for all future scenarios are similar, showing that pairing of drivers and population can offset each other and even out the results. • Increases in SSI demands in Business as Usual and Hot Growth represent anticipated energy development.

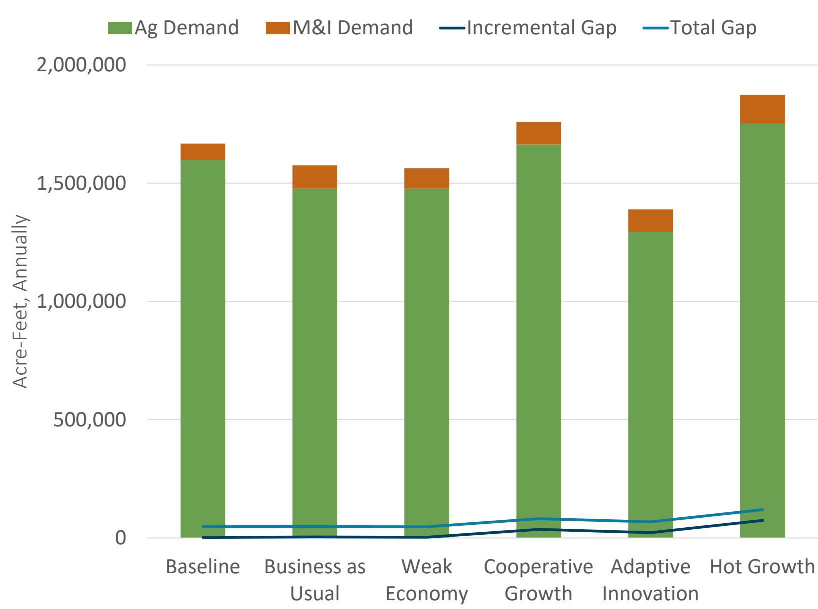
Results describing current and potential future M&I and agricultural demands and gaps are summarized in Table 4.4.3 and in Figure 4.4.2.

Table 4.4.3 Summary of Diversion Demand and Gap Results in the Colorado Basin

	Current (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average Annual Demand						
Agricultural (AFY)	1,598,900	1,476,800	1,476,800	1,663,800	1,294,900	1,751,600
M&I (AFY)	68,500	98,400	85,800	95,400	94,500	121,400
Gaps						
Ag (avg %)	3%	3%	3%	5%	5%	6%
Ag (incremental-AFY)	-	-	-	30,900	16,200	58,500
Ag (incremental gap as % of current demand)	-	0%	0%	2%	1%	4%
M&I (max %)	0%	4%	4%	6%	7%	13%
M&I (max-AF)	0*	4,200	3,300	5,300	6,600	15,800

**CDSS water allocation model in this basin calculates small baseline M&I gaps, but they are either due to calibration issues or they are reflective of infrequent, dry-year shortages that are typically managed with temporary demand reductions, such as watering restrictions.*

Figure 4.4.2 Summary of Diversion Demand and Gap Results in the Colorado Basin



Summary of Environmental and Recreational Findings

- In climate-impacted scenarios, peak flow is projected to move earlier in the year, with March, April and May flows increasing substantially and June flows decreasing; possible mis-matches between peak flow timing and species' needs may occur. Flow magnitude could decrease some, but peak-flow risk for plants and fish is projected to remain moderate.
- In some areas (e.g., Crystal River above Avalanche Creek near Redstone), peak flow magnitude is projected to increase substantially, potentially over-widening the creek channel and causing habitat issues during low-flow periods.
- Under *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*, mid- and late-summer flows may be reduced by 60 to 70 percent and create high risk for fish from loss of habitat and, in trout regions, high water temperatures.
- Downstream from major reservoirs (e.g., Frying Pan, Green Mountain), diminished peak flows could create high to very high risk for riparian/wetland vegetation and fish habitat if sediment is not flushed, while consistent mid- and late-summer flows could keep risk to fish low to moderate.

- Several recreational in-channel diversions and Instream Flow water rights may be unmet more often with diminished June to August flows.
- In critical habitat for endangered species, highly reduced flows in mid- and late-summer will make it more difficult to meet flow recommendations.

4.4.3 NOTABLE BASIN CONSIDERATIONS

Section 4.1 described several analysis assumptions and limitations that apply to all basins and should be considered when reviewing and interpreting analysis results. Additional considerations specific to the Colorado Basin are listed below:

- The Colorado River Model includes operations that allow Ruedi Reservoir, Wolford Mountain Reservoir, and Green Mountain Reservoir to make releases from their contract accounts to meet M&I demands aggregated by location throughout the basin. In most years, these contract supplies are sufficient to meet the projected M&I demands in the planning scenarios.
- Historical transbasin diversions from the Colorado Basin are included in the model as an export demand. In certain planning scenarios, the export demand cannot be fully met as a result of changed hydrology or increased agricultural demands of senior water users. When this occurs, the export demand is shorted in the Colorado Basin model, and that shortage is reflected on the East Slope as reduction in transbasin imports.
- Water demands for energy development were based primarily on SWSI 2010 data and were varied based on the language in each scenario. The demand data were not updated per Technical Advisory Group input because estimates of water needs have varied substantially, and defendable updated datasets are not currently available.

4.4.4 AGRICULTURAL DIVERSION DEMANDS

The irrigated agriculture industry across the Colorado Basin is highly diverse. Large ranching operations dominate agriculture in the basin's higher elevations, particularly around the towns of Kremmling, Collbran, and Rifle. Farming regions focused on the cultivation of fruits, vegetables, and alfalfa are more prevalent in the lower basin due to a longer growing season and warmer summer temperatures. The largest of these farming operations, the Grand Valley Project, irrigates about a quarter of the 206,700 acres irrigated in the entire basin. Mixed between these agricultural operations are many growing municipalities, such as Grand Junction.

Planning Scenario Adjustments

Section 2 described ways in which inputs to agricultural diversion demand estimates were adjusted to reflect the future conditions described in the planning scenarios. Adjustments in the Colorado Basin focused on urbanization, potential future climate conditions, and implementation of emerging technologies.

2050 population projections reflect significant increases for counties across the Colorado Basin. The impact of urbanization, however, is tied to the proximity of existing municipalities to agricultural operations. The impact of urbanization to resort communities, such as the towns of Winter Park, Breckenridge, Glenwood Springs, Snowmass Village, Vail and Avon, is limited due to lack of adjacent irrigated acreage to urbanize. The impact of urbanization is expected to be much larger in agricultural-based communities, such as Fruita, Grand Junction, Palisade, Eagle, and Rifle. In total, nearly 14,000 acres of irrigated land are expected to be urbanized, with one-third of that expected to occur in municipalities located within the Grand Valley Project and Grand Valley Irrigation Company service areas.

IWR could increase in this basin due to climate change by 20 percent and 31 percent on average in the "In-Between" and "Hot and Dry" climate projections, respectively.

In *Adaptive Innovation*, in addition to assuming reduced IWR, the average irrigation efficiency was assumed to increase by 10 percent. Irrigation systems efficiencies vary across the Colorado Basin depending upon irrigation infrastructure and practices, averaging just under 30 percent basinwide. System efficiencies were increased by 10 percent for ditches that provide water solely for irrigation purposes in *Adaptive Innovation*. Structures that carry water both for irrigation and for other purposes (e.g., power operations) were not adjusted.

Table 4.4.4 summarizes the planning scenario adjustments described above and other adjustments that impact agricultural diversion demands in the various scenarios.

Table 4.4.4 Planning Scenario Adjustments for Agricultural Demands in the Colorado Basin

Adjustment Factor	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Change in Irrigated Land due to Urbanization	13,600 Acre Reduction	13,600 Acre Reduction	13,600 Acre Reduction	13,600 Acre Reduction	13,600 Acre Reduction
IWR Climate Factor	-	-	20%	31%	31%
Emerging Technologies	-	-	-	10% IWR Reduction 10% System Efficiency Increase	-

See section 2.2.3 for descriptions of adjustment methodologies and assumptions.

Agricultural Diversion Demand Results

Table 4.4.5 and Figure 4.4.3 summarize the acreage, IWR, and the agricultural diversion demand for surface water supplies in the Colorado Basin for current conditions and the five planning scenarios. Demand is lower than current conditions in *Business as Usual* and *Weak Economy*, because irrigated acreage is projected to be urbanized. Although *Cooperative Growth* and *Hot Growth* feature the same reduction in irrigated acres, higher IWR could drive demand above current levels. In *Adaptive Innovation*, the reduction in IWR, increase in system efficiency, and reduction in acreage results in the lowest demand among all scenarios even with the potential effects of a hotter and drier climate.

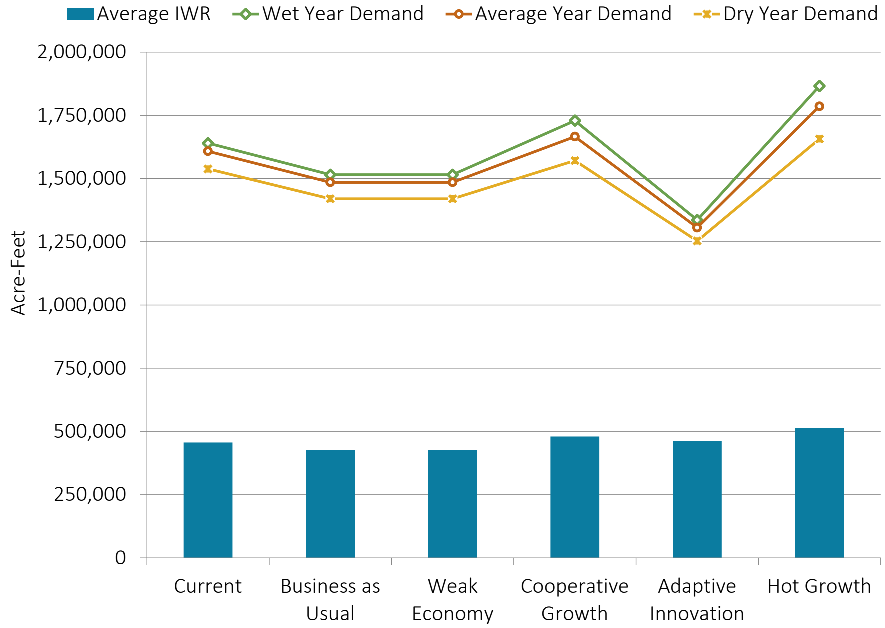
SYSTEM EFFICIENCY

In some cases, diversion demands can be higher in wet years because system efficiency decreases due to the relative abundance of supply.

Table 4.4.5 Summary of Agricultural Diversion Demand Results in the Colorado Basin

	Current (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Irrigated Acreage (acres)	206,700	193,100	193,100	193,100	193,100	193,100
Average IWR (AFY)	456,500	426,000	426,000	480,000	463,000	514,000
Diversion Demand						
Average Year (AFY)	1,608,000	1,485,000	1,485,000	1,666,000	1,306,000	1,786,000
Wet Yr. Change	2%	2%	2%	4%	2%	4%
Dry Yr. Change	-4%	-4%	-4%	-6%	-4%	-7%

Figure 4.4.3 Agricultural Diversion Demands and IWR Results in the Colorado Basin



4.4.5 Municipal and Self-Supplied Industrial Diversion Demands

Population Projections

The Colorado Basin includes about 6 percent of the statewide population. Between the years 2015 and 2050, it is projected to grow from approximately 310,000 to between 460,000 and 580,000 people in the low and high growth projections, respectively. Using the specific numbers, this is an increase in population of 48 percent to 88 percent. Table 4.4.6 shows how population growth is projected to vary across the planning scenarios for the Colorado Basin.

Table 4.4.6 Colorado Basin 2015 and Projected Populations

Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
307,600	515,500	456,300	549,200	572,900	577,800

Current Municipal Demands

The Colorado Basin baseline water demands were largely based on water-provider-reported data, with approximately 43 percent of the baseline population demands represented by WEPs, 25 percent from 1051 data, and 9 percent from BIPs. The remaining baseline water demand had to be estimated. Figure 4.4.4 shows the proportions of each data source among all sources.

Figure 4.4.4 Sources of Water Demand Data in the Colorado Basin

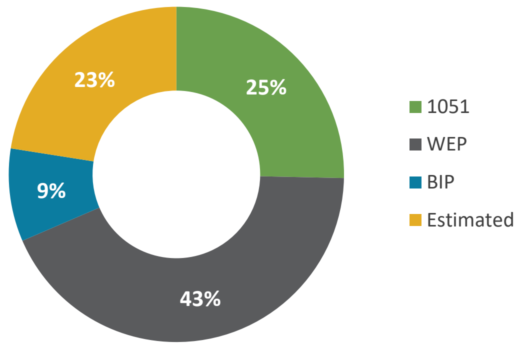


Figure 4.4.5 shows the proportion of each category of municipal baseline water usage in the Colorado Basin. On a basin scale, the residential indoor demand as a percentage of the systemwide demands are relatively high, at 44 percent of the systemwide demands.

Figure 4.4.5 Categories of Municipal Water Usage in the Colorado Basin

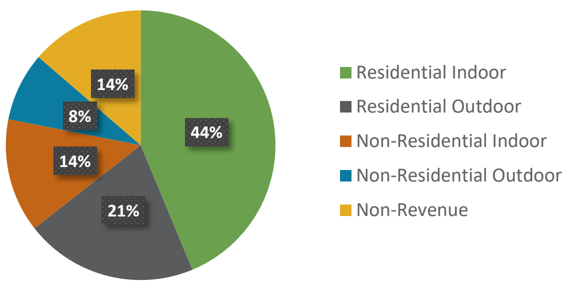
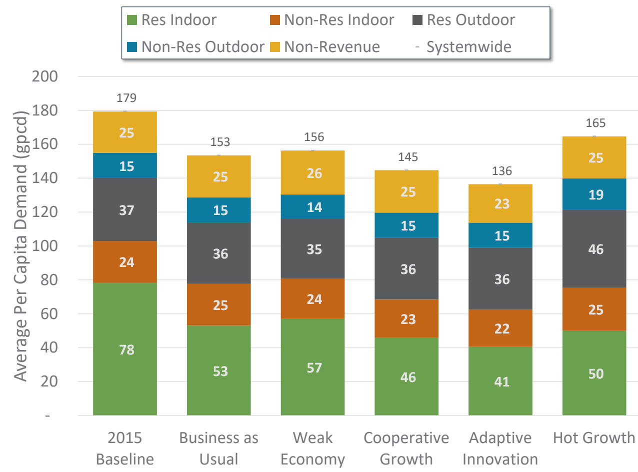


Figure 4.4.6 Colorado Basin Municipal Baseline and Projected per Capita Demands by Water Demand Category



Projected Municipal Demands

Figure 4.4.6 provides a summary of per capita baseline and projected water demands for the Colorado Basin.

Systemwide, all of the projected total per capita demands are projected to decrease relative to the baseline. Consistently across all scenarios, residential indoor demand is the greatest individual demand category while non-residential outdoor is the lowest. Aside from *Hot Growth*, there is minimal variation in outdoor demands across scenarios. This is due to the scenario pairing of water demand reductions and climate drivers, particularly for *Adaptive Innovation,* which has high outdoor reductions coupled with the "Hot and Dry" climate. Outdoor demands increased significantly for the *Hot Growth* scenario, due to an increase in outdoor demands coupled with the "Hot and Dry" climate.

The Colorado Basin municipal baseline and projected diversion demands provided in Table 4.4.7 show the combined effect of population and per capita demands. Municipal demands are projected to grow from approximately 62,000 AFY in 2015 to between 80,000 and 107,000 AFY in 2050. Mesa County accounts for about 28 percent of the baseline demand, followed by Garfield County at about 23 percent of the basin demand.

Table 4.4.7 Colorado Basin Municipal Baseline and Projected Demands (AFY)

Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
61,800	88,600	79,900	89,000	87,500	106,600

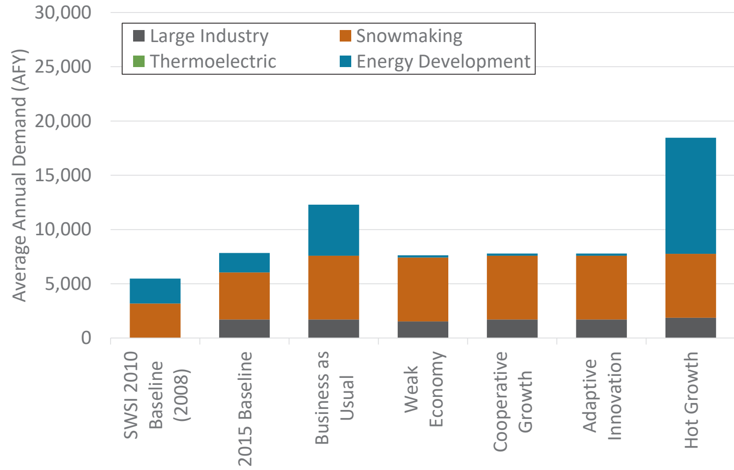
Figure 4.4.7 shows baseline and projected diversion demand by scenario, as well as population for each scenario. All projection scenarios result in an increase relative to the baseline. Except for *Hot Growth*, the systemwide demand projections for all the Colorado Basin scenarios are similar, which demonstrates how the pairing of drivers and population can offset each other and even out the results.

Figure 4.4.7 Colorado Basin Baseline and Projected Population and Municipal Demands

Self-Supplied Industrial Demands

The Colorado Basin currently includes about 4 percent of the statewide SSI demand. SSI demands in this basin are associated with the large industry, snowmaking, and energy development sub-sectors, with no demands projected for the thermoelectric sub-sector. Basin-scale SSI demands are shown on Figure 4.4.8 and summarized in Table 4.4.8.

Figure 4.4.8 Colorado Basin Self-Supplied Industrial Demands



Large-industry demands are related to a mining facility in Grand County. This facility was not represented in SWSI 2010 but was added because it is a significant use. Projected large-industry demands range from 1,530 AFY to 1,870 AFY.

The baseline snowmaking demand is 4,340 AFY as compared to 3,180 AFY in SWSI 2010. Projected demands increase to 5,890 AFY under all scenarios.

Energy development demands are located in Garfield and Mesa counties. The baseline energy development demand in the Colorado Basin has been updated to 1,800 AFY from 2,300 AFY in SWSI 2010. Projected demands range from 200 AFY to 10,700 AFY.

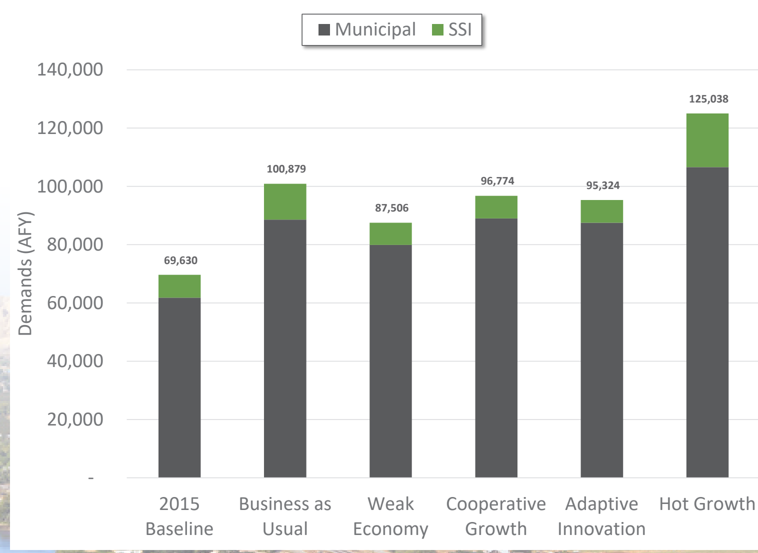
Table 4.4.8 Colorado Basin SSI Baseline and Projected Demands (AFY)

Sub-sector	Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Large Industry	1,700	1,700	1,530	1,700	1,700	1,870
Snowmaking	4,340	5,890	5,890	5,890	5,890	5,890
Thermoelectric	0	0	0	0	0	0
Energy Development	1,800	4,700	200	200	200	10,700
Sub-Basin Total	7,840	12,290	7,620	7,790	7,790	18,460

Total M&I Diversion Demands

Colorado Basin combined M&I diversion demand projections for 2050 range from approximately 88,000 AFY in *Weak Economy* to 125,000 AFY in *Hot Growth*, as shown in Figure 4.4.9. SSI demands account for between 8 and 15 percent of M&I demands. On a basin scale, the demand projections do not follow the statewide sequence of the scenario rankings described in the Water Plan, with *Adaptive Innovation* falling out of sequence.

Figure 4.4.9 Colorado Basin Municipal and Self-Supplied Industrial Demands



4.4.6 Water Supply Gaps

The agricultural and M&I diversion demands were compared against available water supply modeled for current conditions and the five planning scenarios. Gaps were calculated when water supply was insufficient to meet demands.

INCREMENTAL GAP

The incremental agricultural gap quantifies the degree to which the gap could increase beyond what agriculture has historically experienced under water shortage conditions.

Agricultural

The Colorado Basin agricultural diversion demands, demand gaps, and consumptive use gaps for the baseline and planning scenarios are presented in Table 4.4.9 and illustrated on Figure 4.4.10. An annual time series of gaps in terms of percent of demand that was unmet is shown on Figure 4.4.11.

Table 4.4.9 Colorado Basin Agricultural Gap Results (AFY)

		Scenario					
		Scenario	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average	Average Annual Demand	1,598,900	1,476,800	1,476,800	1,663,800	1,294,900	1,751,600
Average	Average Annual Gap	45,300	44,994	43,000	76,200	61,500	103,800
Average	Average Annual Gap Increase from Baseline	-	-	-	30,900	16,200	58,500
Average	Average Annual Percent Gap	3%	3%	3%	5%	5%	6%
Average	Average Annual CU Gap	25,100	24,400	24,400	42,400	40,400	57,800
Maximum	Demand in Maximum Gap Year	1,598,800	1,477,500	1,477,500	1,587,200	1,258,000	1,668,300
Maximum	Gap in Maximum Gap Year	148,000	141,100	141,000	166,500	131,400	210,400
Maximum	Increase from Baseline Gap	-	-	-	18,500	-	62,400
Maximum	Percent Gap in Maximum Gap Year	9%	10%	10%	10%	10%	13%

Study period for Water Supply analysis is 1975-2013, reflecting different baseline demand than described in Agricultural Diversion Demands section.

Figure 4.4.10 Projected Average Annual Agricultural Diversion Demand, Demand Met, and Gaps in the Colorado Basin

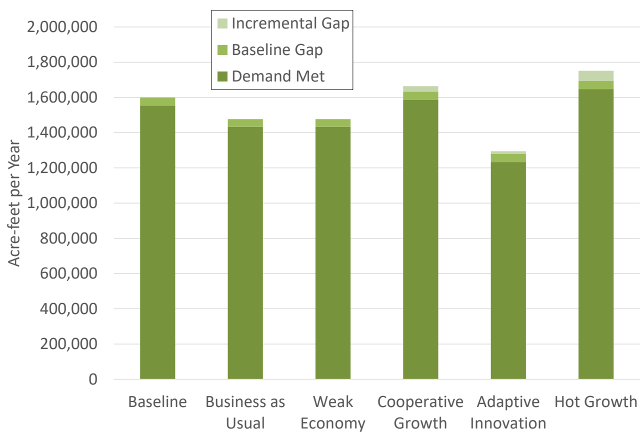
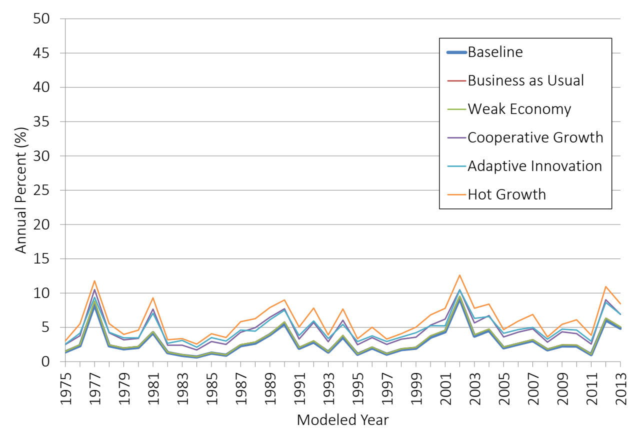


Figure 4.4.11 Annual Agricultural Gaps (expressed as a percentage of demand) for Each Planning Scenario



The following are observations on agricultural diversion demands and gaps:

- Although irrigated area is estimated to decrease by 13,600 acres as cities expand onto irrigated land, basin-wide IWR and diversion demand may increase in a warmer future climate.
- Emerging technologies, including the adoption of more efficient irrigation practices, modernizing irrigation infrastructure (e.g., automation) and crops with lower irrigation requirements, may mitigate climate impacts and reduce demand below baseline.
- The future incremental gap ranges from 0 to 4 percent of baseline demand.
- Scenarios that assume current climate conditions (*Business as Usual* and *Weak Economy*) have agricultural gaps around 3 percent of demand. Gaps (as a percentage of demand) increase in scenarios that assume a warmer and drier future climate.

M&I

The diversion demand and gap results for M&I uses in the Colorado Basin are summarized in Table 4.4.10 and illustrated in Figure 4.4.12. An annual time series of gaps in terms of percent of demand that was unmet is shown in Figure 4.4.13.

Table 4.4.10 Colorado Basin M&I Gap Results (AFY)

		Scenario					
		Scenario	**Business as Usual**	**Weak Economy**	**Cooperative Growth**	**Adaptive Innovation**	**Hot Growth**
Average	Average Annual Demand	68,500	98,400	85,800	95,400	94,500	121,400
	Average Annual Gap	0*	1,200	800	1,900	2,300	4,700
	Average Annual Percent Gap	0%	1%	1%	2%	2%	4%
Maximum	Demand in Maximum Gap Year	68,500	98,400	85,800	95,400	94,500	121,400
	Gap in Maximum Gap Year	0*	4,200	3,300	5,300	6,600	15,800
	Percent Gap in Maximum Gap Year	0%	4%	4%	6%	7%	13%

**CDSS water allocation model in this basin calculates small baseline M&I gaps, but they are either due to calibration issues or they are reflective of infrequent, dry-year shortages that are typically managed with temporary demand reductions such as watering restrictions.*

Figure 4.4.12 Projected Maximum Annual M&I Demand Met and Gaps in the Colorado Basin

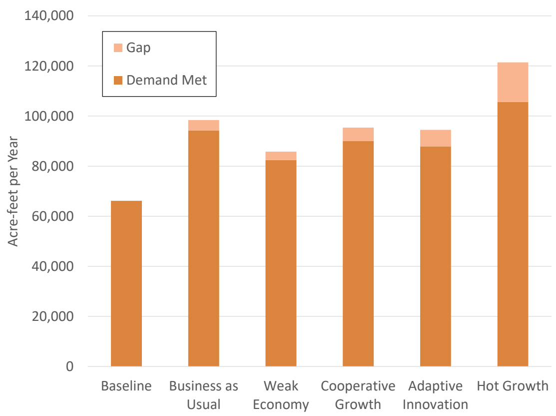
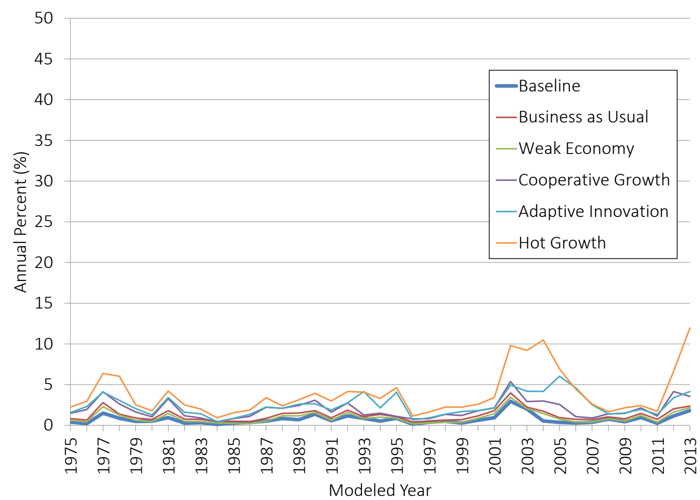


Figure 4.4.13 Annual M&I Gaps (expressed as a percentage of demand) for Each Planning Scenario



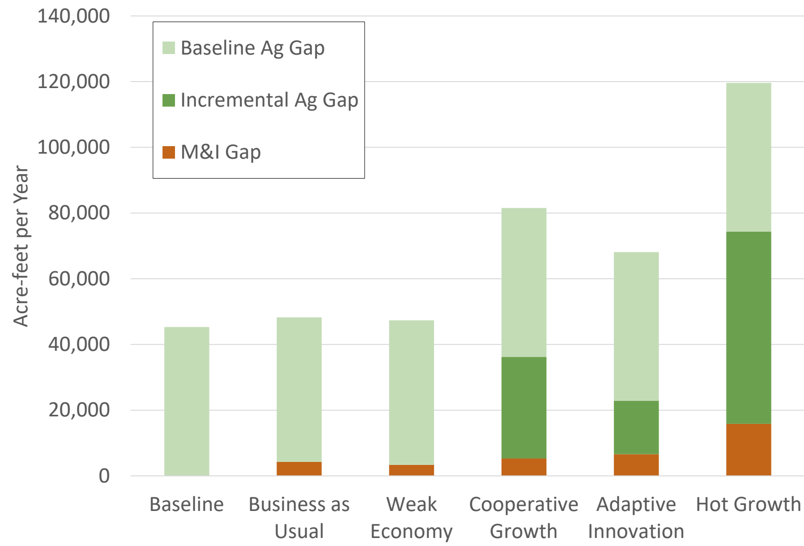
The following are observations on the M&I diversion demands and gaps:

- Average annual M&I gap in the Colorado Basin is far less than the agricultural gap, ranging from 500 AF to more than 4,700 AF.
- The maximum M&I gap for the five planning scenarios ranges from 2,300 AF to nearly 16,000 AF.
- Per capita municipal usage is projected to decrease.
- Overall municipal demand is projected to increase for all scenarios due to increased population; however, except for *Hot Growth*, the systemwide demand projections for all future scenarios are similar.
- Increase in SSI demand in *Business as Usual* and *Hot Growth* represent anticipated energy development.

Total Gap

Figure 4.4.14 illustrates the total combined agricultural and M&I diversion demand gap in the Colorado Basin. The figure combines average annual baseline and incremental agricultural gap and the maximum M&I gap. In *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*, gaps were driven by agricultural demands, which increase in the "In Between" and "Hot and Dry" climate projections.

Figure 4.4.14 Projected Average Annual Agricultural Gaps and Maximum M&I Diversion Demand Gaps in the Colorado Basin



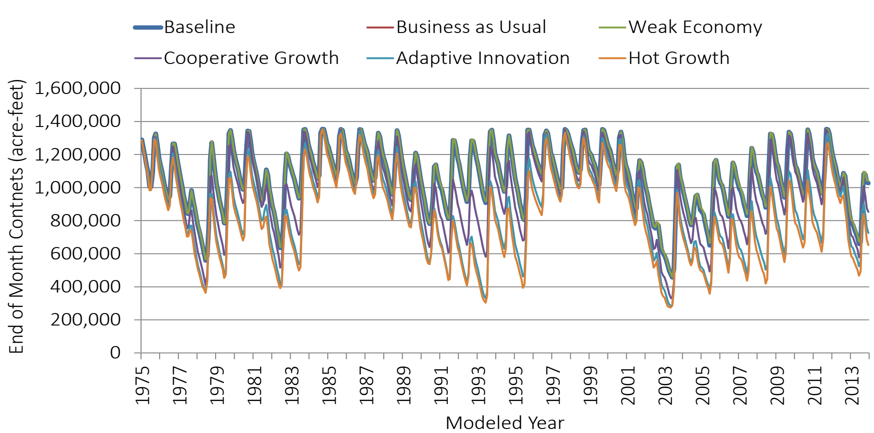
Supplies from Urbanized Lands

By 2050, irrigated acreage in the Colorado Basin is projected to decrease by 13,600 acres due to urbanization. Irrigation supplies for these lands could potentially be used for M&I needs in the future (subject to a variety of unknowns such as seniority and type of water supply, willingness to change the use of water through water court, etc.). The average annual historical consumptive use associated with potentially urbanized acreage for each scenario is reflected in Table 4.4.11. The data in the table represent planning-level estimates of this potential supply and has not been applied to the M&I gaps.

Table 4.4.11 Estimated Consumptive Use from Lands Projected to be Urbanized by 2050 in the Colorado Basin

	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Urbanized Acreage (acres)	13,600	13,600	13,600	13,600	13,600
Estimated Consumptive Use (AFY)	28,300	28,300	30,800	29,700	32,100

Figure 4.4.15. Total Simulated Reservoir Storage in the Colorado Basin



Storage

Total simulated reservoir storage from the Colorado water allocation model is shown on Figure 4.4.15. Baseline conditions show the highest levels of water in storage (in general) and the lowest is in *Hot Growth*. *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth* show lower amounts of water in storage during dry periods than the two scenarios that do not include the impacts of a drier climate; however, storage levels generally recover from dry periods back to baseline levels. Storage in the Colorado Basin is critical to minimizing gaps as described in Section 4.4.3 and as demonstrated by the large degree of fluctuation in basin-wide storage amount.

4.4.7 Available Supply

Figures 4.4.16 through 4.4.19 show simulated monthly available flow for the Colorado Basin at locations representative of the Shoshone Power Plant diversion (near Dotsero) and the "Cameo Call", which are generally the controlling rights on the mainstem of the Colorado River. Streamflow and available flow nearly double between the upstream and downstream locations due to inflows from the Roaring Fork, Parachute Creek, and Rifle Creek. The figures show that flows are projected to be available each year, though the amounts will vary annually and across scenarios (available flows under the scenarios impacted by climate change are less than in other scenarios). Peak flows are projected to occur earlier in the year under scenarios impacted by climate change.

Figure 4.4.16 Simulated Hydrographs of Available Flow at Colorado River near Dotsero, CO

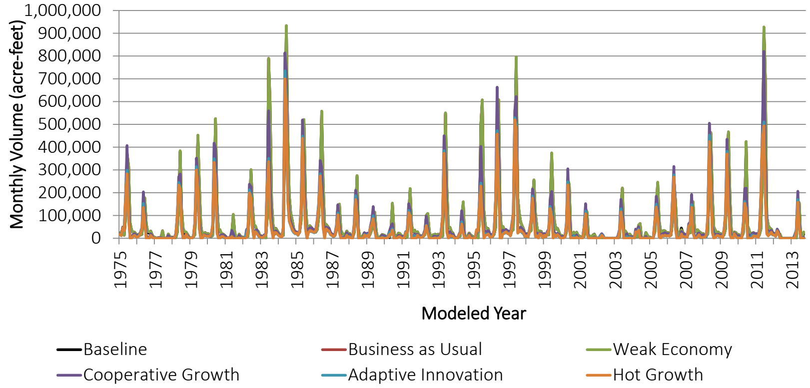


Figure 4.4.17 Average Monthly Simulated Hydrographs of Available Flow at Colorado River near Dotsero, CO

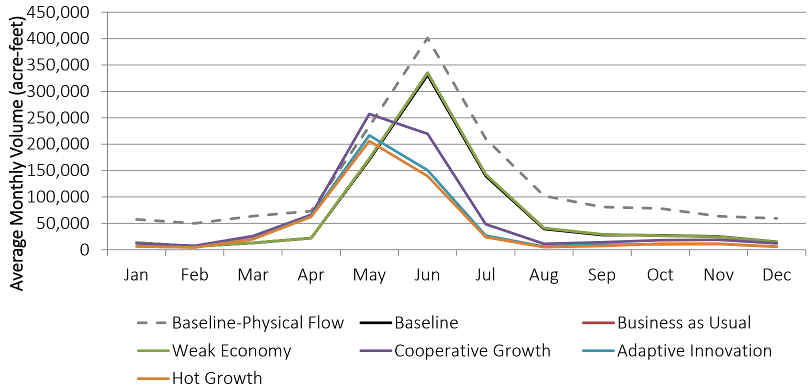


Figure 4.4.18 Simulated Hydrographs of Available Flow at Colorado River near Cameo, CO

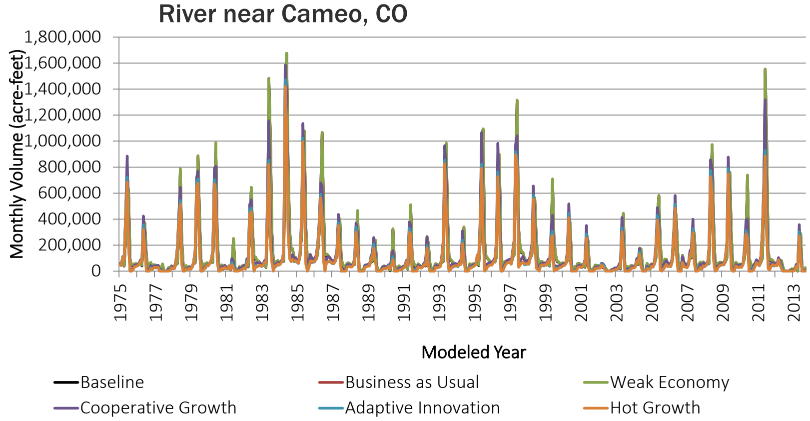
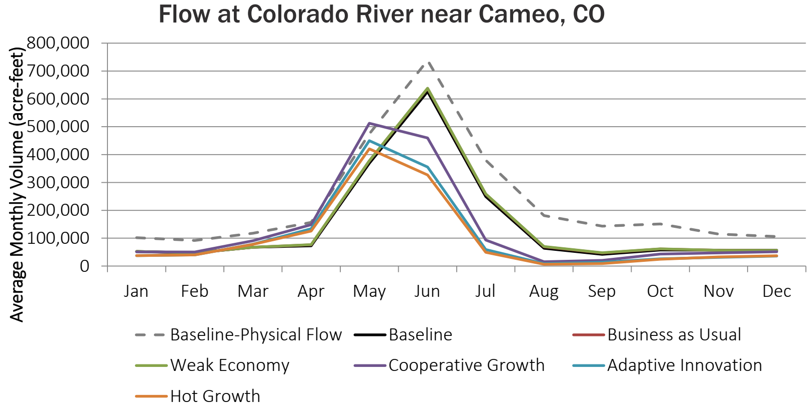


Figure 4.4.19 Average Monthly Simulated Hydrographs of Available Flow at Colorado River near Cameo, CO



4.4.8 Environment and Recreation

A total of eleven water allocation model nodes were selected for the Flow Tool within the Colorado Basin (see Figure 4.4.20). In addition to nodes, Figure 4.4.20 also shows subwatersheds (at the 12-digit HUC level) and the relative number of E&R attributes located in each subwatershed.

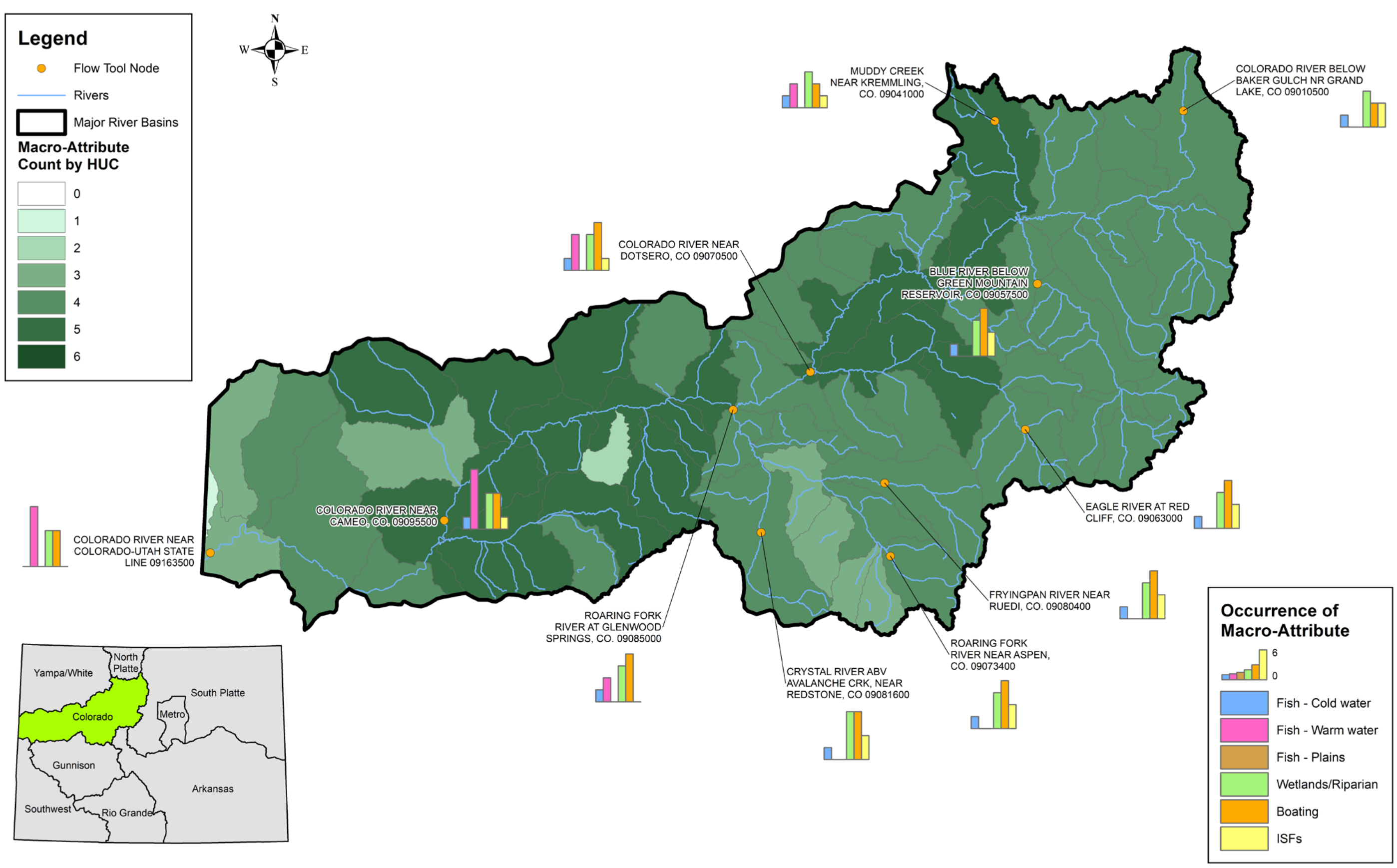
Nodes include:

- Colorado River below Baker Gulch near Grand Lake, Colorado (09010500)
- Muddy Creek near Kremmling, Colorado (09041000)
- Blue River below Green Mountain Reservoir, Colorado (09057500)
- Eagle River at Red Cliff, Colorado (09063000)
- Colorado River near Dotsero, Colorado (09070500)
- Roaring Fork River near Aspen, Colorado (09073400)
- Fryingpan River near Ruedi, Colorado (09080400)
- Crystal River above Avalanche Creek, near Redstone, Colorado (09081600)
- Roaring Fork River at Glenwood Springs, Colorado (09085000)
- Colorado River near Cameo, Colorado (09095500)
- Colorado River near Colorado-Utah State Line (09163500)

NATURALIZED FLOW

Naturalized flows reflect conditions that would occur in the absence of human activities. Baseline flows reflect current conditions as influenced by existing infrastructure and river operations. While observations regarding naturalized flows may be informative, baseline flows reflect actual conditions and the diverse operations of a river's many users.

Figure 4.4.20 Flow Tool Nodes Selected for the Colorado Basin



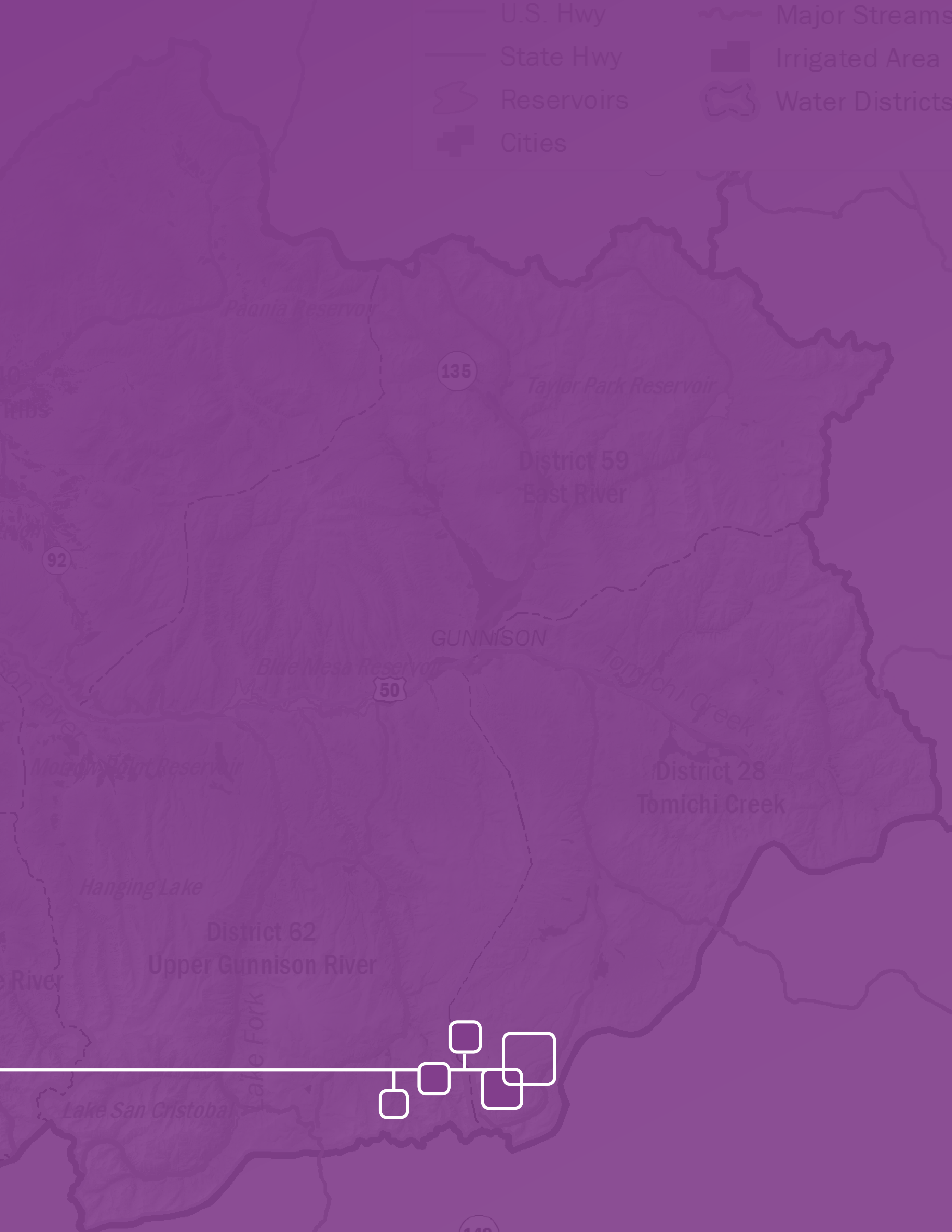
Results of Flow Tool analyses using flow data developed in the water supply and gap analyses for baseline conditions and the planning scenarios are described below.

Table 4.4.12 Summary of Flow Tool Results in Colorado Basin

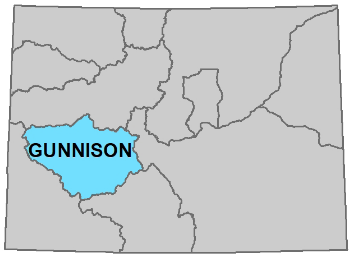
Category	Observation
Projected Flows	Annual flow in headwaters (Colorado River below Baker's Gulch) under baseline conditions is below natural conditions, and this departure increases under climate change scenarios. Moving downstream through Dotsero, Cameo, and to the state line, annual flow under baseline conditions rebounds slightly closer to naturalized conditions.
	Under climate change scenarios (*Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*), annual depletions are projected to increase from headwaters to the state line.
	Similar to the alterations in annual flows, peak flow magnitudes on the Colorado River under baseline conditions are below natural conditions from the headwaters through Dotsero, and are closer to natural conditions at lower elevations (Cameo and State Line).
	Under climate change scenarios (*Collaborative Growth*, *Adaptive Innovation*, and *Hot Growth*), peak flow magnitudes on the Colorado River are projected to decrease further below natural conditions. Decreases in peak flows (from naturalized to baseline) are more pronounced at locations below large reservoirs (e.g., Blue River below Green Mountain Reservoir, Fryingpan River below Reudi Reservoir). This dampening of peak flows is projected to worsen under climate driven scenarios. In some locations (notably, Crystal River above Avalanche Creek), peak flow magnitude is projected to increase under some scenarios.
	Under the scenarios with climate change influences, snowmelt and timing of peak flow is projected to shift earlier in the year. In many areas from headwaters to lower elevations, June flows are projected to decrease well below naturalized conditions, while April and May flows could similar to baseline or increase slightly.
	Under baseline conditions, mid- and late-summer flows in headwaters subject to transbasin exports are currently depleted compared to naturalized conditions. The difference between baseline and naturalized conditions lessens farther downstream.
	Under scenarios with climate change, mid- and late-summer flows in headwaters are projected to drop well below naturalized, but farther downstream, this drop is projected to be less pronounced. In many locations, mid- and late-summer flows under climate change scenarios are projected to be well below naturalized. The Fryingpan below Reudi Reservoir is an exception to the large projected decreases in mid- and late-summer flows, because releases are made steadily from the reservoir.
Ecological Risk	Decreased peak flows that are prevalent across the basin under baseline conditions create risk for riparian/wetland plants and fish habitat.
	This risk increases under climate change scenarios. Projected decreases in mid- and late-summer flows create risk for fish from loss of habitat and, in trout regions, increased water temperatures. Downstream from major reservoirs (e.g., Fryingpan, Green Mountain), projected diminished peak flows create increased risk for riparian/wetland vegetation and fish habitat if sediment is not flushed, while projected consistent mid- and late-summer flows keep risk to fish low to moderate.
ISFs and RICDs	Several Instream Flows (ISFs) throughout the basin and Recreational In-channel Diversion (RICD) are likely to be regularly unmet if June-August flows decrease as projected under climate change scenarios.
	In critical habitat for endangered species, projected reduced flows in mid- and late-summer will make it more difficult to meet flow recommendations. For example, projected August flows under climate change scenarios on the Colorado River at Cameo suggest that flow recommendations for endangered fish will not be met during August in approximately one-third of years.
E&R Attributes	Under baseline, *Business as Usual*, and *Weak Economy*, current flow issues related to E&R attributes arise from timing/water delivery issues.
	Under climate change scenarios, the shift in the timing of peak flow, reductions in total runoff, and increasing demands for consumptive uses contribute to reductions in mid- and late-summer flows. Several water management programs implemented in the context of the Upper Colorado Endangered Fish Program (e.g., Coordinated Reservoir Operations Program) have demonstrated that flow timing and magnitude, along with stream temperature, can be improved through water management that explicitly considers the needs of E&R attributes.

The Gunnison Basin stretches across more than 8,000 square miles of western Colorado, extending from the Continental Divide to the confluence of the Gunnison and Colorado rivers near Grand Junction. The basin is largely forested, with forest covering approximately 52 percent of the total basin area. About 5.5 percent of the basin is classified as planted or cultivated land, and these lands are primarily concentrated in the Uncompahgre River Valley between Montrose and Delta with additional pockets near Gunnison and Hotchkiss. Key future water management issues in this basin as described in The Colorado Water Plan include agricultural water shortages and increased growth and tourism in the headwaters region.

GUNNISON


U.S. Hwy
State Hwy
Reservoirs
Cities
Major Streams
Irrigated Area
Water Districts
Paonia Reservoir
135
Taylor Park Reservoir
District 59
East River
92
GUNNISON
Blue Mesa Reservoir
50
Tomichi Creek
Morrow Point Reservoir
District 28
Tomichi Creek
Hanging Lake
District 62
Upper Gunnison River
Lake Fork
Lake San Cristobal

4.5 GUNNISON BASIN RESULTS



4.5.1 BASIN SUMMARY

Key future water management issues in this basin as described in The Colorado Water Plan include agricultural water shortages and increased growth and tourism in the headwaters region.

Table 4.5.1 Key Future Water Management Issues in the Gunnison Basin

<table>
<tr><th>Agriculture</th><th>Environment and Recreation</th><th>Municipal and Industrial</th><th>Compacts and Administration</th></tr>
<tr><td>• Addressing agricultural water shortages in the upper portion of the basin is an important goal of the community. Lack of financial resources is an impediment.</td><td>• The Gunnison River Basin faces a complex set of environmental issues associated with water quality, water quantity and associated impacts to fish and wildlife habitat in the context of regulatory drivers associated with the Endangered Species Act (ESA) and the Clean Water Act (CWA).</td><td>• Growth in the headwaters region will require additional water management strategies.</td><td rowspan="2">• Possible future transbasin diversions have been a concern, along with the potential effect this might have on existing uses within the basin.</td></tr>
<tr><td colspan="3">• The area between Ouray and Montrose is rapidly growing. Tourism is important in the headwaters areas, but agriculture is dominant in the Uncompahgre Valley. A rapid influx of retirees and growth in the Uncompahgre Valley may dramatically change agricultural uses and other land uses in the area.</td></tr>
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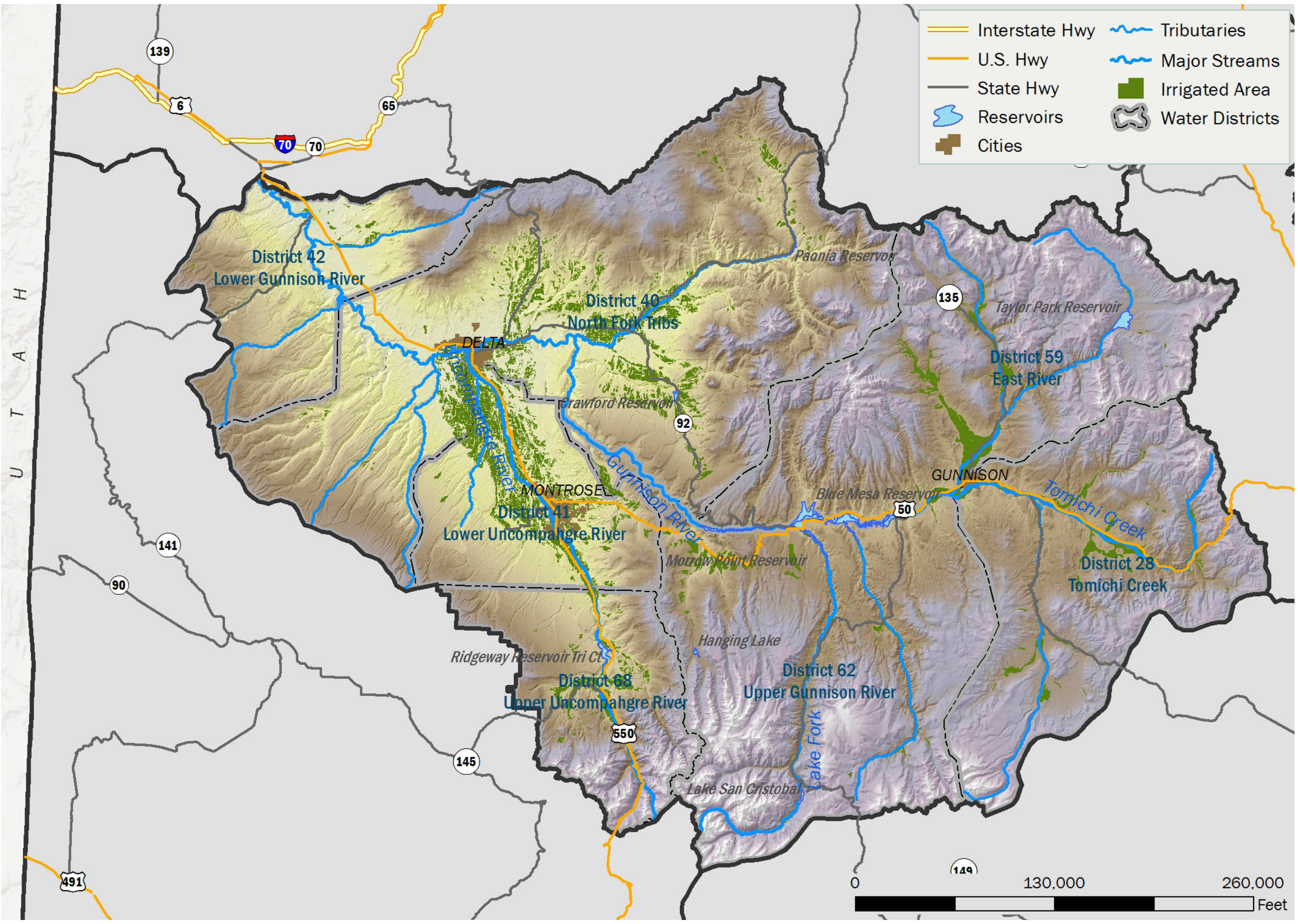


Figure 4.5.1 Map of the Gunnison Basin

4.5.2 SUMMARY OF TECHNICAL UPDATE RESULTS

Key results and findings of the Technical Update pertaining to agricultural and M&I demands and gaps as well as findings related to environmental and recreational attributes and future conditions are summarized below in Table 4.5.2.

Table 4.5.2 Summary of Key Results in the Gunnison Basin

Agriculture	Environment and Recreation	Municipal and Industrial
• Agricultural demand is a major factor in this basin and represents 99% of the total water demand. • Increases in agricultural demand and gaps will occur with a warmer and drier climate. • Increases in system efficiency and reductions in irrigation water requirements significantly reduce diversion demand and the gap in Adaptive Innovation.	• Aquatic and riparian attributes may be affected differently based on location and potential changes in streamflow magnitude and timing. • Flow recommendations, Instream Flow water rights, and recreational in-channel diversions may be met less often in climate-impacted scenarios.	• Population increases are the main driver for increased M&I demands in the planning scenarios, as per capita water use decreased for every scenario except Hot Growth. • Growth in Montrose County accounts for 50% of the M&I demand. • The only SSI use in the basin is snow-making, and it is a relatively small proportion of demands.

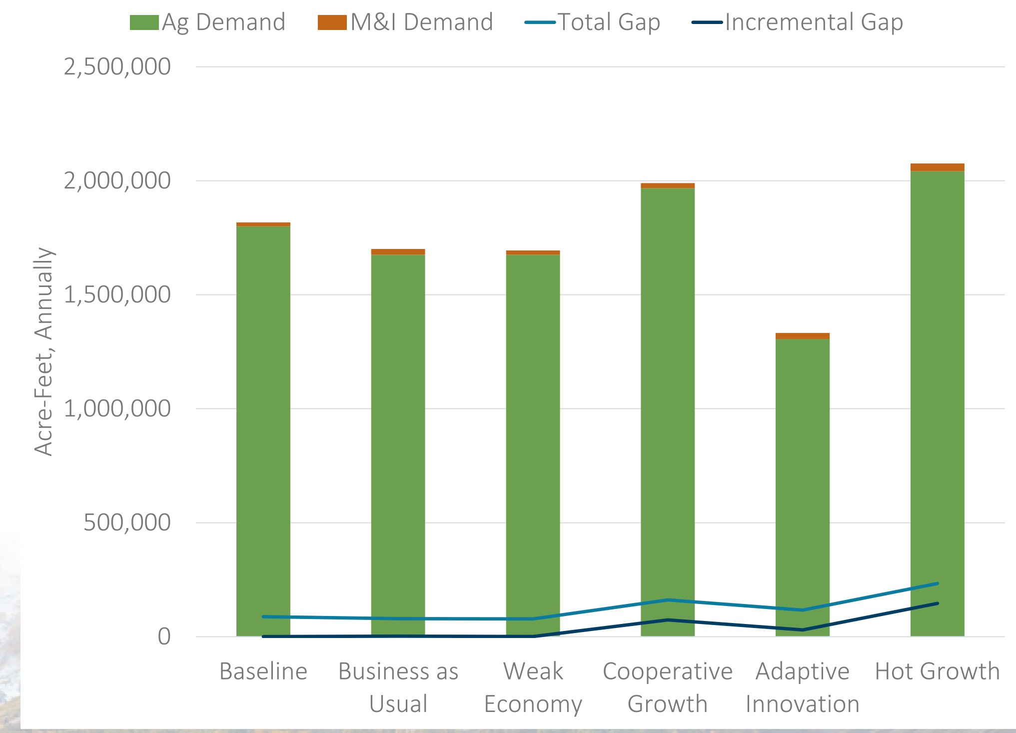
Results describing current and potential future M&I and agricultural demands and gaps are summarized in Table 4.5.3 and in Figure 4.5.2.

Table 4.5.3 Summary of Diversion Demand and Gap Results in the Gunnison Basin

	Current (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average Annual Demand						
Agricultural (AFY)	1,800,200	1,675,500	1,675,500	1,967,200	1,305,700	2,041,500
M&I (AFY)	17,000	24,800	19,100	22,900	26,400	34,100
Gaps						
Ag (avg %)	5%	5%	5%	8%	9%	11%
Ag (incremental-AFY)	-	-	-	70,300	25,300	134,700
Ag (incremental gap as % of current demand)	-	-	-	4%	1%	7%
M&I (max %)	0%	9%	4%	15%	16%	34%
M&I (max-AF)	0*	2,300	700	3,500	4,300	11,500

*CDSS water allocation model in this basin calculates small baseline M&I gaps, but they are either due to calibration issues, or they are reflective of infrequent, dry-year shortages that are typically managed with temporary demand reductions such, as watering restrictions.

Figure 4.5.2 Summary of Diversion Demand and Gap Results in the Gunnison Basin



Summary of Environmental and Recreational Findings

- Reduced peak flows below major reservoirs on the Uncompahgre and Gunnison mainstems under baseline conditions create high risk to riparian/wetland habitat and may not support sediment dynamics needed to maintain fish habitat.
- Across most locations, mid- and late-summer flows drop, but risk to fish remains moderate; however, the metric used to assess risk for fish does not include the month of July because historically July flows have been sufficient. Under *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*, July flows drop substantially, which increases the risk for fish.
- In several locations, Instream Flow water rights may be met less often. At least one RICD may be met less often.
- In critical habitat for endangered species, much reduced flows in mid- and late-summer will make it more difficult to meet flow recommendations.
- In at least one location (Cimarron River), winter flows become extremely low and puts fish at risk.

4.5.3 NOTABLE BASIN CONSIDERATIONS

Section 4.1 described several analysis assumptions and limitations that apply to all basins and should be considered when reviewing and interpreting analysis results. An additional consideration with respect to the Gunnison Basin is that agricultural system efficiencies in this basin are generally lower than in other basins due to factors described in the next section. The associated return flows, however, become the supplies for downstream irrigators and are reused.

4.5.4 AGRICULTURAL DIVERSION DEMANDS

Agricultural Setting

Agriculture in the Upper Gunnison Basin, above Blue Mesa Reservoir, is dominated by large cattle ranches located along the tributaries and mainstem river. Ranchers generally rely on flood irrigation to fill the alluvial aquifer during the runoff season, as supplies are typically scarce later in the irrigation season. Agricultural diversion demands are higher in this basin due to the presence of gravelly soils, which leads to generally lower irrigation efficiencies than in other basins.

Several Bureau of Reclamation Projects provide supplemental irrigation supplies for much of the irrigated acreage in the Lower Gunnison Basin. The most notable irrigation projects in the area include the Uncompahgre, Paonia, Smith Fork, Fruitland Mesa, Bostwick Park, and the Fruitgrowers Dam projects. Lower elevations and warmer temperatures in the Lower Gunnison Basin provide conditions to grow a variety of fruits, vegetables, corn grain, and root crops on more than 185,000 acres of the total 234,000 irrigated acres in the basin.

Planning Scenario Adjustments

Section 2 described ways in which inputs to agricultural diversion demand estimates were adjusted to reflect the future conditions described in the planning scenarios. Adjustments in the Gunnison Basin focused on urbanization, potential future climate conditions, and implementation of emerging technologies.

Many of the municipalities in the basin are surrounded by or near irrigated lands, and many counties in the basin are projected to have significant population increases by 2050. The resulting urbanization of irrigated acreage from this growth was estimated to be approximately 14,600 acres, primarily around Gunnison, Montrose, Delta, and the corridor between Cedaredge and Orchard City.

Table 4.5.4 summarizes the planning scenario adjustments described above and other adjustments that impact agricultural diversion demands in the scenarios.

Table 4.5.4 Planning Scenario Adjustments for Agricultural Demands in the Gunnison Basin

Adjustment Factor*	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Change in Irrigated Land due to Urbanization	14,600 Acre Reduction	14,600 Acre Reduction	14,600 Acre Reduction	14,600 Acre Reduction	14,600 Acre Reduction
Increase in IWR due to Climate	-	-	22%	30%	30%
Emerging Technologies	-	-	-	10% IWR Reduction; 10% System Efficiency Increase	-

**See Section 2.2.3 for descriptions of adjustment methodologies and assumptions.*

Agricultural Diversion Demand Results

Table 4.5.5 and Figure 4.5.3 summarize the acreage, IWR, and the agricultural diversion demand for surface water supplies in the Gunnison Basin for current conditions and the five planning scenarios. The largest variation in the basin occurred in the *Adaptive Innovation* scenario due to 10 percent reduction in IWR and 10 percent increase to system efficiency, both of which reduce diversion demands. The combined effect of the *Adaptive Innovation* scenario adjustments resulted in an agricultural diversion demand that is lower than the current demand. Diversion demands increased in *Cooperative Growth* and *Hot Growth* due to higher IWR resulting from a warmer and drier future climate.

SYSTEM EFFICIENCY

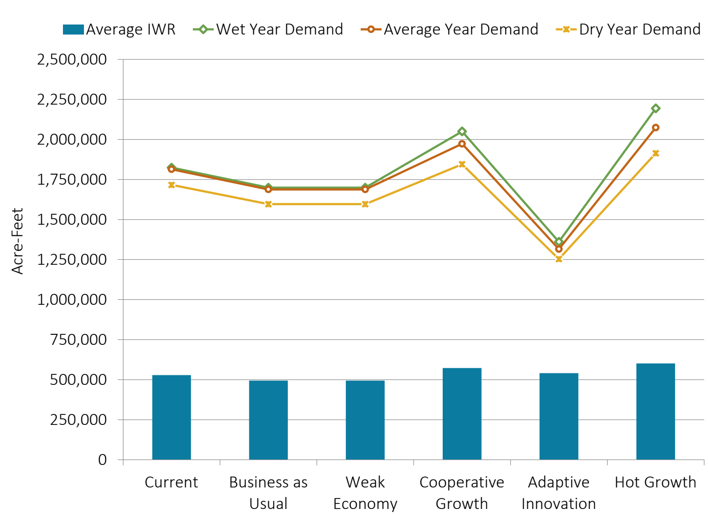
In some cases, diversion demands can be higher in wet years because system efficiency decreases due to the relative abundance of supply.

Table 4.5.5 Summary of Agricultural Diversion Demand Results in the Gunnison Basin

	Current (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Irrigated Acreage (acres)	234,400	219,800	219,800	219,800	219,800	219,800
Average IWR (AFY)	528,200	494,000	494,000	573,000	541,000	601,000
Diversion Demand						
Average Year (AFY)	1,814,000	1,688,000	1,688,000	1,973,000	1,315,000	2,074,000
Wet Yr. Change	1%	1%	1%	4%	3%	6%
Dry Yr Change	-5%	-5%	-5%	-6%	-5%	-8%

Average agricultural diversion demand was calculated using the average hydrologic years (i.e., years classified as neither wet or dry) from 1950-2013

Figure 4.5.3 Agricultural Diversion Demands and IWR Results in the Gunnison Basin



Municipal and Self-Supplied Industrial Diversion Demands

Population Projections

The Gunnison Basin includes about 2 percent of the statewide population. Between the years 2015 and 2050, it is projected to grow from approximately 100,000 to between 120,000 and 200,000 people in the low and high growth projections, respectively, which is an increase in population of 19 to 99 percent. Table 4.5.6 shows how population growth is projected to vary across the planning scenarios for the Gunnison Basin.

Table 4.5.6 Gunnison Basin 2015 and Projected Populations

Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
103,100	162,600	123,100	158,600	196,000	204,900

Current Municipal Demands

Sources of water demand data such as 1051 or WEP data made up less than 50 percent of the available information in the Gunnison Basin, and baseline water demands were largely estimated as shown on Figure 4.5.4.

Figure 4.5.5 summarizes the categories of municipal, baseline water usage in the Gunnison Basin. On a basin scale, the residential indoor demand as a percentage of the systemwide demands are relatively high, at almost 40 percent of the systemwide demands.

Figure 4.5.4 Sources of Water Demand Data in the Gunnison Basin

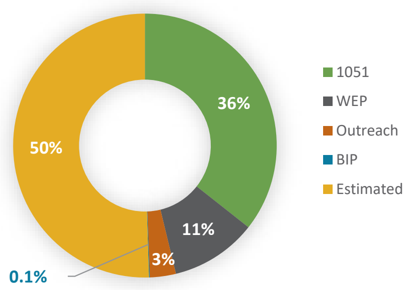
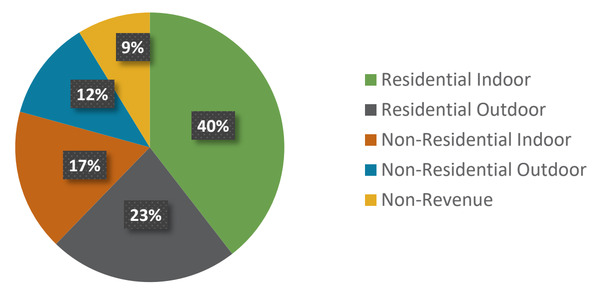


Figure 4.5.5 Categories of Water Usage in the Gunnison Basin



Projected Municipal Demands

Figure 4.5.6 provides a summary of per capita baseline and projected water demands for the Gunnison Basin. Systemwide, the per capita demands are projected to decrease relative to the baseline except for *Hot Growth*. Outdoor demands are projected to increase significantly for *Hot Growth* due to hotter and drier climate conditions.

The Gunnison Basin municipal baseline and projected diversion demands provided in Table 4.5.7 show the combined effect of population and per capita demands. Municipal demands are projected to grow from approximately 18,000 AFY in 2015 to between 21,000 and 37,000 AFY in 2050. Montrose County accounts for almost half of the baseline demand, followed by Delta County at about one-fifth of the basin demand.

Figure 4.5.6 Gunnison Basin Municipal Baseline and Projected per Capita Demands by Water Demand Category

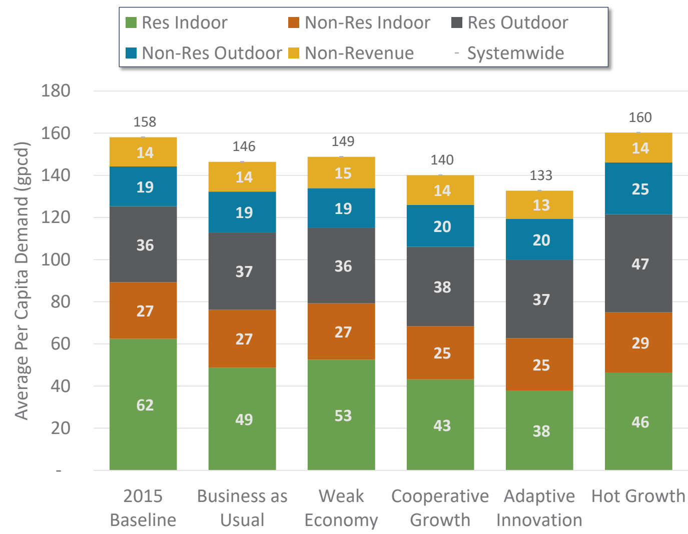
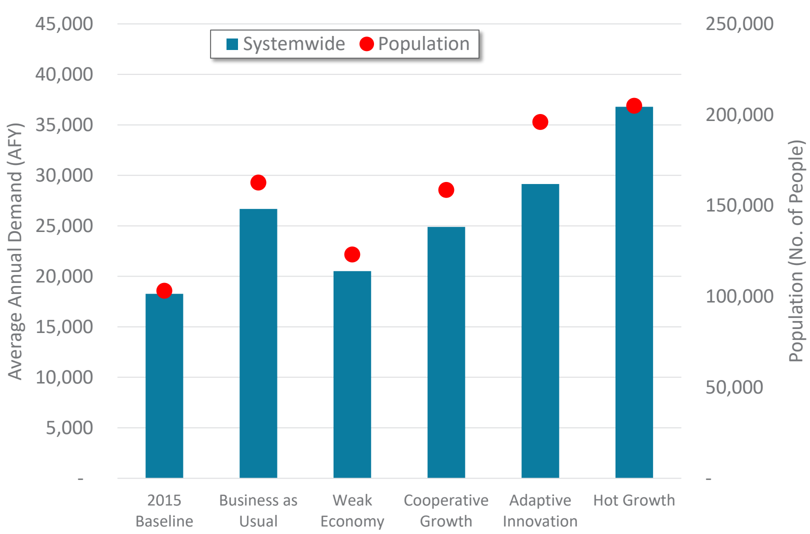


Table 4.5.7 Gunnison Basin Municipal Baseline and Projected Demands (AFY)

Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
18,300	26,700	20,500	24,900	29,100	36,800

The baseline and projected demand distributions are shown on Figure 4.5.7, which also shows how the population varies between the scenarios. All of the planning scenarios show an increase relative to the baseline. Demands generally follow the population patterns; however, increased outdoor demands for the "Hot and Dry" climate projection have a greater impact on gpcd, resulting in higher demands for *Hot Growth*. Higher levels of conservation associated with *Adaptive Innovation* help limit the impacts of the "Hot and Dry" climate projection and higher population.

Figure 4.5.7 Gunnison Basin Baseline and Projected Population and Municipal Demands



Self-Supplied Industrial Demands

The Gunnison Basin currently includes less than one percent of the statewide SSI demand. SSI demands in this basin are associated exclusively with the snowmaking sub-sector. There are no demands projected for the large industry, thermoelectric, or energy development sub-sectors. Basin-scale SSI demands are shown on Figure 4.5.8 and summarized in Table 4.5.8.

The baseline snowmaking demand is 270 AFY as compared to 260 AFY in SWSI 2010. All snowmaking occurs in Gunnison County. Projected SSI demands increase to 650 AFY under all scenarios.

Figure 4.5.8 Gunnison Basin Self-Supplied Industrial Demands

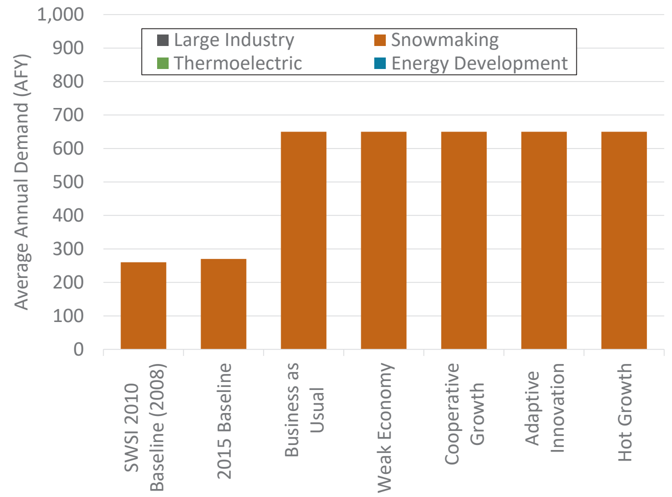


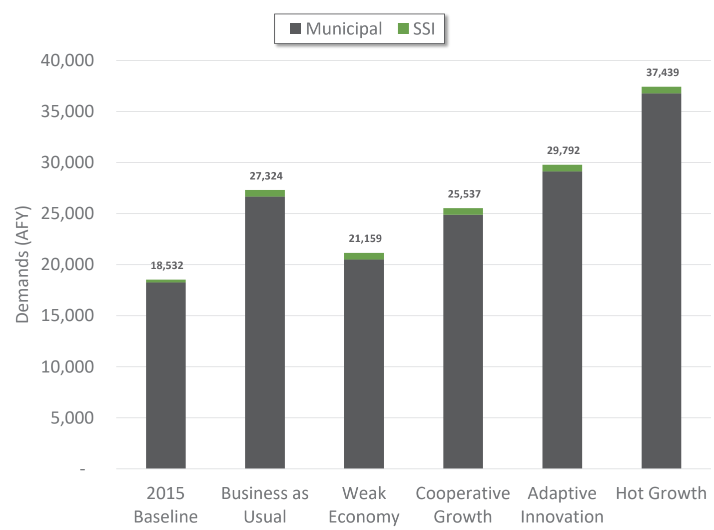
Table 4.5.8 Gunnison SSI Baseline and Projected Demands (AFY).

Sub-sector	Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Large Industry	-	-	-	-	-	-
Snowmaking	270	650	650	650	650	650
Thermoelectric	-	-	-	-	-	-
Energy Development	-	-	-	-	-	-
Sub-Basin Total	**270**	**650**	**650**	**650**	**650**	**650**

Total M&I Diversion Demands

Gunnison Basin combined M&I demand projections for 2050 range from approximately 21,000 AFY in *Weak Economy* to more than 37,000 AFY in *Hot Growth* as shown on Figure 4.5.9. Under every planning scenario, municipal demands are the majority (at least 97 percent) of the total M&I demands. On a basin scale, the demand projections follow the statewide sequence of the scenario rankings described in the CWP.

Figure 4.5.9 Gunnison Basin Municipal and Self-Supplied Industrial Demands



4.5.5 Water Supply Gaps

The agricultural and M&I diversion demands were compared against available water supply modeled for current conditions and the five planning scenarios. Gaps were calculated when water supply was insufficient to meet demands.

Agricultural

The Gunnison Basin agricultural diversion demands, demand gaps, and consumptive use gaps for the baseline and planning scenarios are presented in Table 4.5.9 and illustrated in Figure 4.5.10. An annual time series of gaps in terms of percent of demand that was unmet is shown on Figure 4.5.11.

INCREMENTAL GAP

The incremental agricultural gap quantifies the degree to which the gap could increase beyond what agriculture has historically experienced under water shortage conditions.

Table 4.5.9 Gunnison Basin Agricultural Gap Results (AFY)

		Scenario					
		Scenario	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average	Average Annual Demand	1,800,200	1,675,500	1,675,500	1,967,200	1,305,700	2,041,500
	Average Annual Gap	87,300	77,200	77,300	157,600	112,600	222,000
	Average Annual Gap Increase from Baseline	-	-	-	70,300	25,300	134,700
	Average Annual Percent Gap	5%	5%	5%	8%	9%	11%
	Average Annual CU Gap	43,200	38,200	38,300	74,800	64,700	104,000
Maximum	Demand in Maximum Gap	1,841,100	1,713,900	1,713,900	1,833,600	1,247,600	1,912,700
	Gap in Maximum Gap Year	339,700	313,500	314,800	432,600	319,600	590,800
	Increase from Baseline Gap	-	-	-	93,000	-	251,100
	Percent Gap in Maximum Gap Year	18%	18%	18%	24%	26%	31%

Study period for Water Supply analysis is 1975-2013, reflecting different baseline demand than described in Agricultural Diversion Demands section

Figure 4.5.10 Projected Average Annual Agricultural Diversion Demand, Demand Met, and Gaps in the Gunnison Basin

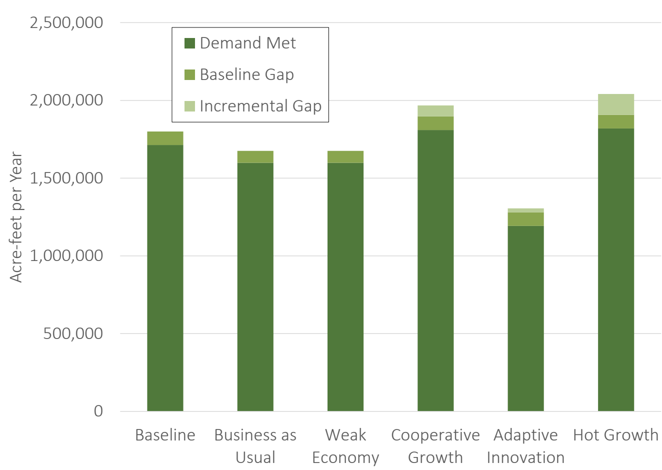
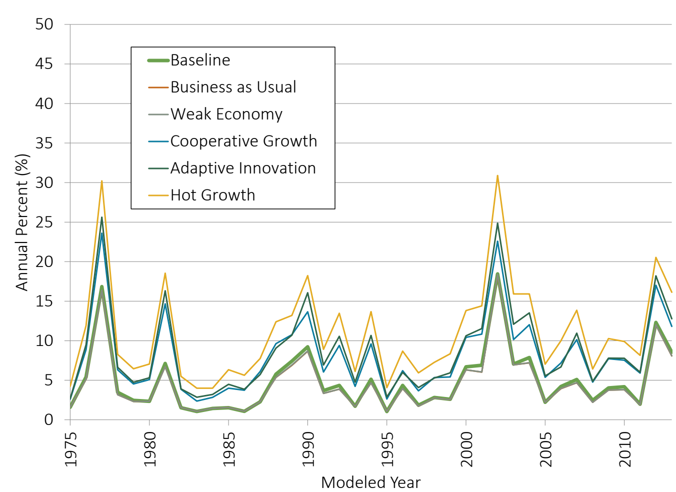


Figure 4.5.11 Annual Agricultural Gaps (expressed as a percentage of demand) for Each Planning Scenario



The following are observations on agricultural diversion demands and gaps:

- Agricultural diversion demands are projected to decrease in three of the five planning scenarios due to urbanization and the associated reduction of irrigated acres and the adoption of emerging agricultural technologies (in *Adaptive Innovation*).
- Agricultural diversion demands are projected to increase by 9 to 13 percent above current in *Cooperative Growth* and *Hot Growth* due to climate impacts.
- Agricultural gaps are projected to increase beyond existing gaps in the climate-impacted planning scenarios.
- While the gap as a percent of demand is projected to be relatively small in average years (5 to 11 percent), it may nearly triple (in terms of percent of demand) in maximum gap years.

M&I

The diversion demand and gap results for M&I uses in the Gunnison Basin are summarized in Table 4.5.10 and illustrated on Figure 4.5.12. An annual time series of gaps in terms of percent of demand that was unmet is shown on Figure 4.5.13.

Table 4.5.10 Gunnison Basin M&I Gap Results (AFY)

		Scenario					
		Scenario	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average	Average Annual Demand	17,000	24,800	19,100	22,900	26,400	34,100
	Average Annual Gap	0*	1,000	200	1,400	2,200	5,000
	Average Annual Percent Gap	0%	4%	1%	6%	8%	16%
Maximum	Demand in Maximum Gap Year	17,000	24,800	19,100	22,900	26,400	34,100
	Gap in Maximum Gap Year	0*	2,300	700	3,500	4,300	11,500
	Percent Gap in Maximum Gap Year	0%	9%	4%	15%	16%	34%

******CDSS water allocation model in this basin calculates small baseline M&I gaps, but they are either due to calibration issues or they are reflective of infrequent, dry-year shortages that are typically managed with temporary demand reductions, such as watering restrictions.*

Study period for Water Supply Analysis is 1975-2013, reflecting different baseline demand than described in M&I Demand section. Baseline demand also may vary slightly from previous section due to differences in geographic distribution of demand for counties that lie in multiple basins.

Figure 4.5.12 Projected Maximum Annual M&I Demand Met and Gaps in the Gunnison Basin

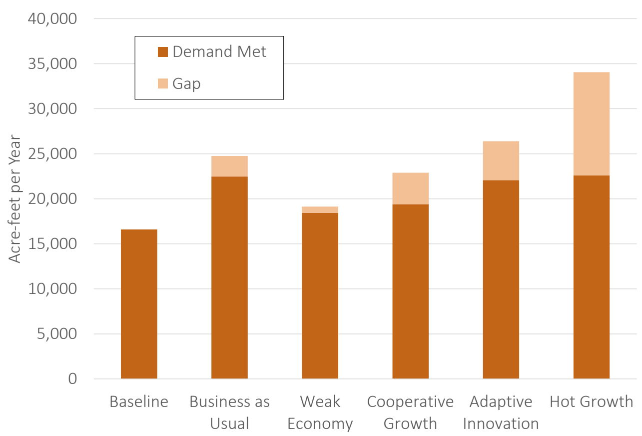
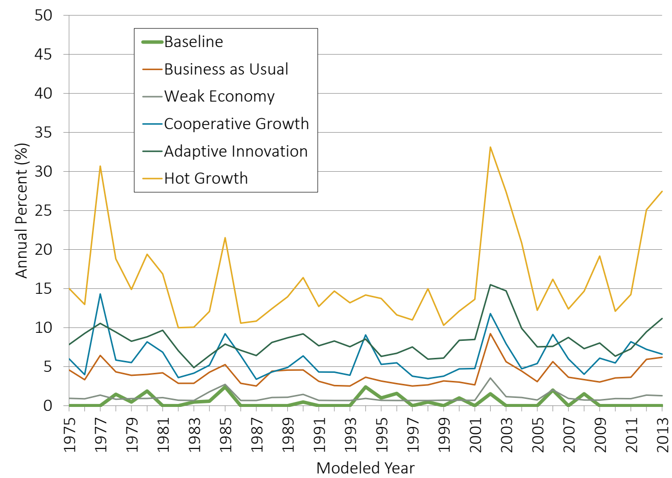


Figure 4.5.13 Annual M&I Gaps (expressed as a percentage of demand) for Each Planning Scenario



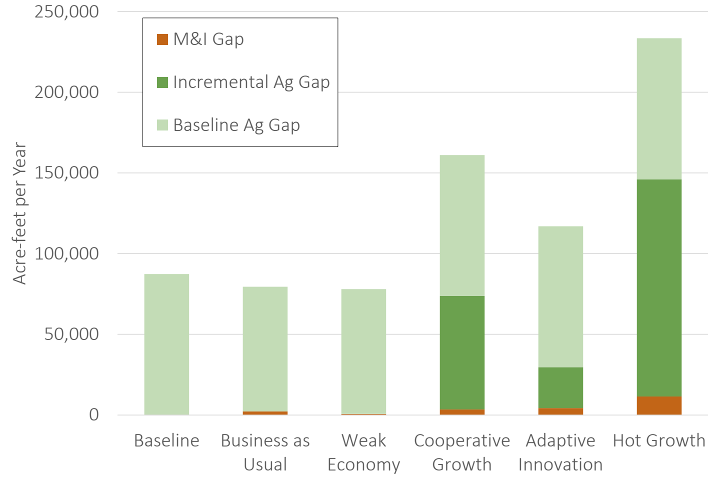
The following are observations on M&I diversion demands and gaps:

- The average annual M&I gap in the Gunnison Basin is projected to be less than the agricultural gap, ranging from 200 AF to over 5,000 AF.
- The maximum M&I gap for the five planning scenarios is projected to range from 700 AF to more than 11,000 AF.
- Population increases are the primary driver for increased M&I demands in the planning scenarios, as per capita water use is projected to decrease for every scenario except *Hot Growth*.
- The only SSI use in the basin is snowmaking, which is not projected to increase over baseline.
- For *Hot Growth*, the maximum M&I gap is much larger than other scenarios (at 34 percent of demand), which reflects lower supplies, large population growth, and less conservation.

Total Gap

Figure 4.5.14 illustrates the total combined agricultural and M&I diversion demand gap in the Gunnison Basin. The figure combines the average annual baseline and incremental agricultural gaps and the maximum M&I gap. In *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*, gaps were driven by agricultural demands, which increase in the *"Hot and Dry"* climate projection.

Figure 4.5.14 Projected Average Annual Agricultural Gaps and Maximum M&I Diversion Demand Gaps in the Gunnison Basin



Supplies from Urbanized Lands

By 2050, irrigated acreage in the Gunnison Basin is projected to decrease by 14,600 acres due to urbanization. Irrigation supplies for these lands could potentially be used for M&I needs in the future (subject to a variety of unknowns such as seniority and type of water supply, willingness to change the use of water through water court, etc.). The average annual historical consumptive use associated with potentially urbanized acreage for each scenario is reflected in Table 4.5.11. The data in the table represent planning-level estimates of this potential supply and has not been applied to the M&I gaps.

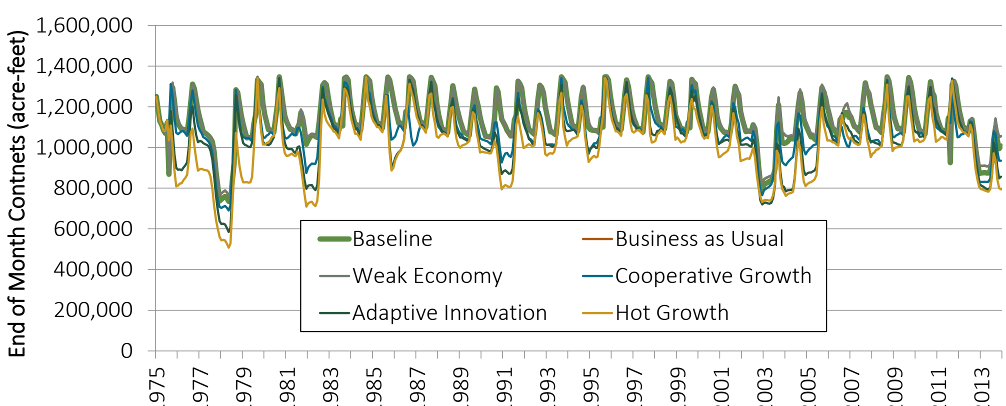
Table 4.5.11 Estimated Consumptive Use from Lands Projected to be Urbanized by 2050 in the Gunnison Basin

	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Urbanized Acreage (acres)	14,600	14,600	14,600	14,600	14,600
Estimated Consumptive Use (AFY)	30,300	30,300	33,100	31,600	33,000

Storage

Total simulated reservoir storage from the Gunnison River water allocation model is shown in Figure 4.5.15. Baseline conditions show the highest levels of water in storage (in general), and the lowest is in *Hot Growth*. *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth* show lower amounts of water in storage during dry periods than the two scenarios that do not include the impacts of a drier climate; however, storage levels generally recover back to baseline levels after dry periods.

Figure 4.5.15 Total Simulated Reservoir Storage in the Gunnison Basin



4.5.6 Available Supply

Figures 4.5.16 and 4.5.17 show estimated simulated monthly available flow in the Gunnison River at a location below the Aspinall Unit and Gunnison Tunnel diversions but upstream of the Redlands Canal, which is the primary calling right in the lower basin. The canal diverts for power and irrigation, and return flows accrue to the Colorado Basin, which reflects a total depletion to the Gunnison River.

The figures show that flows are projected to be available in many years, though the amounts will vary greatly on an annual basis and across scenarios (available flows under the scenarios impacted by climate change are less than in other scenarios). In *Hot Growth* and *Adaptive Innovation*, very little flow may be available at this location for long periods of time during dry times. Peak flows are projected to occur earlier in the year under scenarios impacted by climate change.

Figure 4.5.16 Simulated Hydrographs of Available Flow at Gunnison River Below Gunnison Tunnel

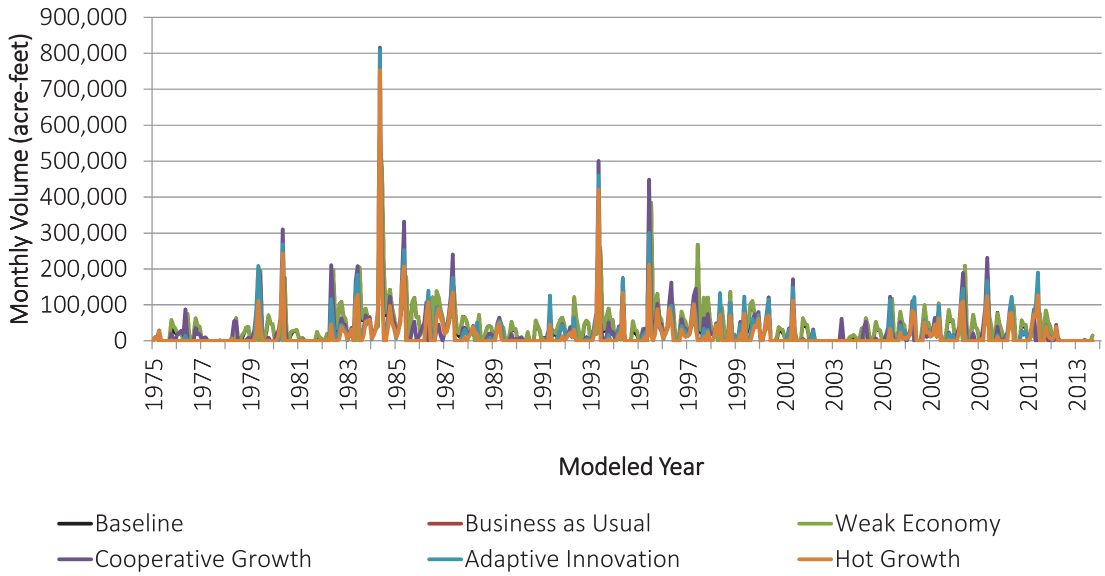
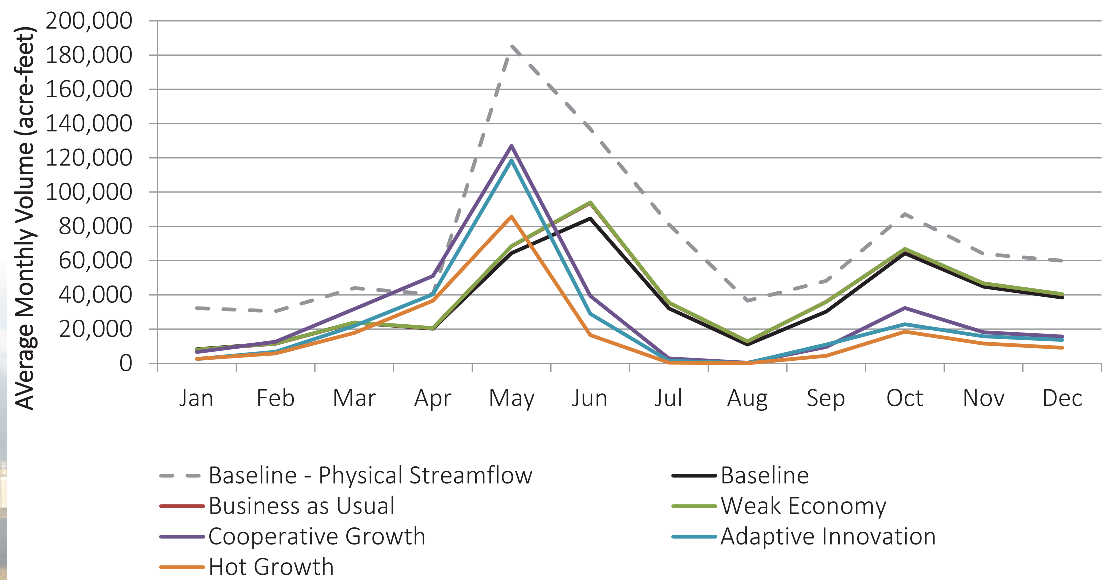


Figure 4.5.17 Average Monthly Simulated Hydrographs of Available Flow at Gunnison River Below Gunnison Tunnel



4.5.7 Environment and Recreation

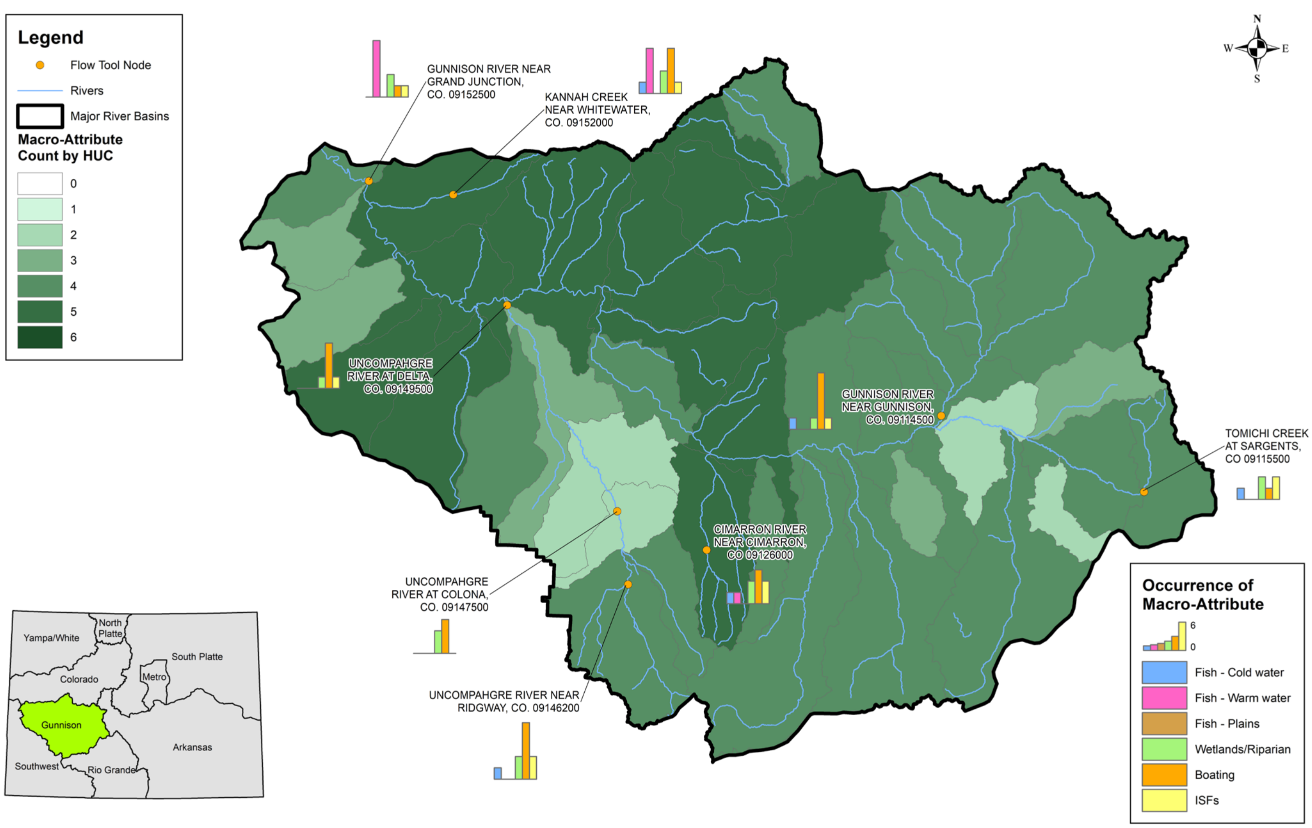
A total of eight water allocation model nodes were selected for the Environmental Flow Tool in the Gunnison Basin (see list below and Figure 4.5.18). Figure 4.5.18 also shows subwatersheds (at the 12-digit HUC level) and the relative number of E&R attributes located in each watershed.

- Gunnison River near Gunnison, Colorado (09114500)
- Tomichi Creek at Sargents, Colorado (09115500)
- Cimarron River near Cimarron, Colorado (09126000)
- Uncompahgre River near Ridgway, Colorado (09146200)
- Uncompahgre River at Colona, Colorado (09147500)
- Uncompahgre River at Delta, Colorado (09149500)
- Kannah Creek near Whitewater, Colorado (09152000)
- Gunnison River near Grand Junction, Colorado (90152500)

NATURALIZED FLOW

Naturalized flows reflect conditions that would occur in the absence of human activities. Baseline flows reflect current conditions as influenced by existing infrastructure and river operations. While observations regarding naturalized flows may be informative, baseline flows reflect actual conditions and the diverse operations of a river's many users.

Figure 4.5.18 Flow Tool Nodes Selected for the Gunnison Basin



Results of Flow Tool analyses using flow data developed in the water supply and gap analyses for baseline conditions and the planning scenarios are described below.

In the Gunnison Basin, pattern of flow varies as a function of elevation, major diversions, and location relative to reservoir storage. Observations related to projected changes in flow, potential ecological risks, etc. are provided in Table 4.5.12.

Table 4.5.12 Summary of Flow Tool Results in the Gunnison Basin

Category	Observation
Projected Flows	At higher elevations (e.g., Gunnison River at Gunnison), mean annual flow under baseline conditions are close to naturalized conditions. Under climate-impacted scenarios (*Cooperative Growth*, *Adaptive Innovation*, *Hot Growth*), annual flows are projected to decrease.
	At locations lower in the basin (e.g., Gunnison River near Grand Junction), baseline annual flows are further depleted, and under climate change scenarios, depletions continue to grow.
	In some locations (e.g., Gunnison River at Gunnison), peak flow magnitude under baseline conditions is below naturalized conditions, but under climate change scenarios, peak flow magnitudes increase. As a general rule, however, peak flows change little from baseline under *Business as Usual* and *Weak Economy* scenarios but decrease more substantially under climate change scenarios.
	Below major reservoirs on the Uncompahgre and Gunnison mainstems, peak flow under baseline conditions can be half of the naturalized condition. Peak flows continue to decrease from naturalized under climate change scenarios.
	Under all climate change scenarios in all locations, runoff and peak flows occur earlier, with June flows decreasing and April and May flows increasing. This change in peak flow timing may cause mis-matches between flow dynamics and the flows needed to support species.
	At higher locations in the Gunnison Basin, mid- and late-summer flows under baseline conditions are 0 to 20 percent depleted from naturalized conditions. Under climate change scenarios, these flows drop further below naturalized.
	At lower elevations on mainstem rivers (e.g., Uncompahgre at Delta; Gunnison River near Grand Junction), mid- and late-summer flows under baseline conditions are 30 to 50 percent below naturalized. Under climate change scenarios, these flows are also projected to fall further below naturalized.
Ecological Risk	Ecological risk (riparian/wetland plants and fish habitat) related to projected changes in peak flow magnitude is generally low to moderate at higher elevations. Under climate change scenarios this risk is projected to increase at most locations.
	At lower elevations and on mainstems, peak flows are already reduced in general and reductions are projected to increase under climate change scenarios.
	Mid- and late-summer flows are projected to decline under climate change scenarios, though flow-related risk to coldwater fish (trout) is projected to remain moderate. However, the metric used to assess risk for fish does not include the month of July because historically, July flows are sufficient. Under *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*, July flows are predicted to drop, increasing risk for fish by reducing habitat and increasing stream temperatures. In at least one location (Cimarron River), winter flows are projected to become low, also putting fish at risk.
ISFs and RICDs	In several locations, ISFs may be met less often, and at least one RICD (in Gunnison), may be met less often. In critical endangered species habitat, lower mean annual flows and reduced flows in mid- and late-summer will make it more difficult to meet flow recommendations.
E&R Attributes	Under baseline conditions and the *Business as Usual* and *Weak Economy* scenarios, current flow issues related to E&R attributes arise from in-basin diversions and storage of peak flows in reservoirs.
	Under climate change scenarios, the shift in the timing of peak flow, reductions in total runoff, and increasing consumptive demands are projected to contribute to reductions in mid- and late-summer flows. Several water management programs implemented in the context of the Upper Colorado Endangered Fish Program, including on the Gunnison River below the Apsinall Unit, have demonstrated that flow timing and magnitude can be planned in a way that better meets the needs of E&R attributes.

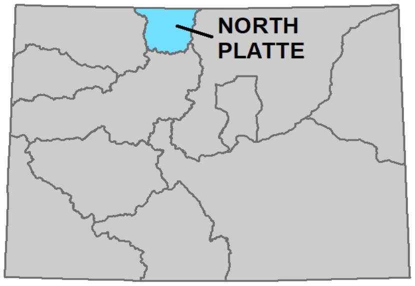
The North Platte Basin, also known as North Park, is a high-altitude valley covering about 2,000 square miles in north-central Colorado. It includes all of Jackson County and the small portion of Larimer County that contains the Laramie River watershed. Both the North Platte and Laramie Rivers flow north into Wyoming and are subject to use-limitations described in Supreme Court decrees.

The basin is also affected by the Platte River Recovery Implementation Program (PRRIP), which was developed to manage endangered species recovery efforts on the Platte River in Central Nebraska. Water use in the basin is dominated by irrigated pastures associated with ranching operations. The basin also has a major wildlife refuge in addition to numerous public lands and recreational opportunities. The basin exports a portion of North Platte water—approximately 4,500 AFY—to the Front Range.

NORTH PLATTE


District 76
Sand Creek
Sand Creek
127
District 48
Laramie River
Laramie River
Lost Lake
Barnes Meadow Reservoir
Chambers Lake
14
34
36

4.6 NORTH PLATTE BASIN RESULTS



4.6.1 BASIN CHALLENGES

The North Platte Basin will face several key issues and challenges pertaining to water management, endangered species, and resource development in the future. These are described in The Colorado Water Plan and summarized below.

Table 4.6.1 Key Future Water Management Issues in the North Platte Basin

<table>
<tr><th>Agriculture</th><th>Environment and Recreation</th><th>Municipal and Industrial</th><th>Compacts and Administration</th></tr>
<tr><td>• Gaining knowledge of the basin’s consumptive uses and high-altitude crop coefficients.</td><td>• Maintaining healthy rivers through the strategic implementation of projects that meet prioritized nonconsumptive needs.
• Enhancing forest health and management efforts for wildfire protection and beetle-kill effects.</td><td>• Increasing economic development and diversification through strategic water use and development.</td><td rowspan="2">• Maintaining compliance with the equitable apportionment decrees on the North Platte* and Laramie** rivers that quantify the amount of available water and lands that can be irrigated.
• Successfully resolving endangered species issues on the Platte River in Central Nebraska through the PRRIP in a manner that does not put pressure on water users to reduce existing uses.
• Promoting water-rights protection and management through improved streamflow-gaging data.</td></tr>
<tr><td colspan="3">• Continuing to restore, maintain, and modernize critical water infrastructure to preserve current uses and increase efficiencies.
• Quantifying and strategically developing available unappropriated waters within the basin.</td></tr>
</table>

**The North Platte decree limits total irrigation in Jackson County to 145,000 acres and allows 17,000 AF reservoir storage annually during the irrigation season. In addition, the decree limits exports from the basin within Colorado to 60,000 AF over 10 years.*
***The Laramie River decree limits Colorado's total diversions and exports from the Laramie River to 39,750 AFY, divided among specific water facilities.*

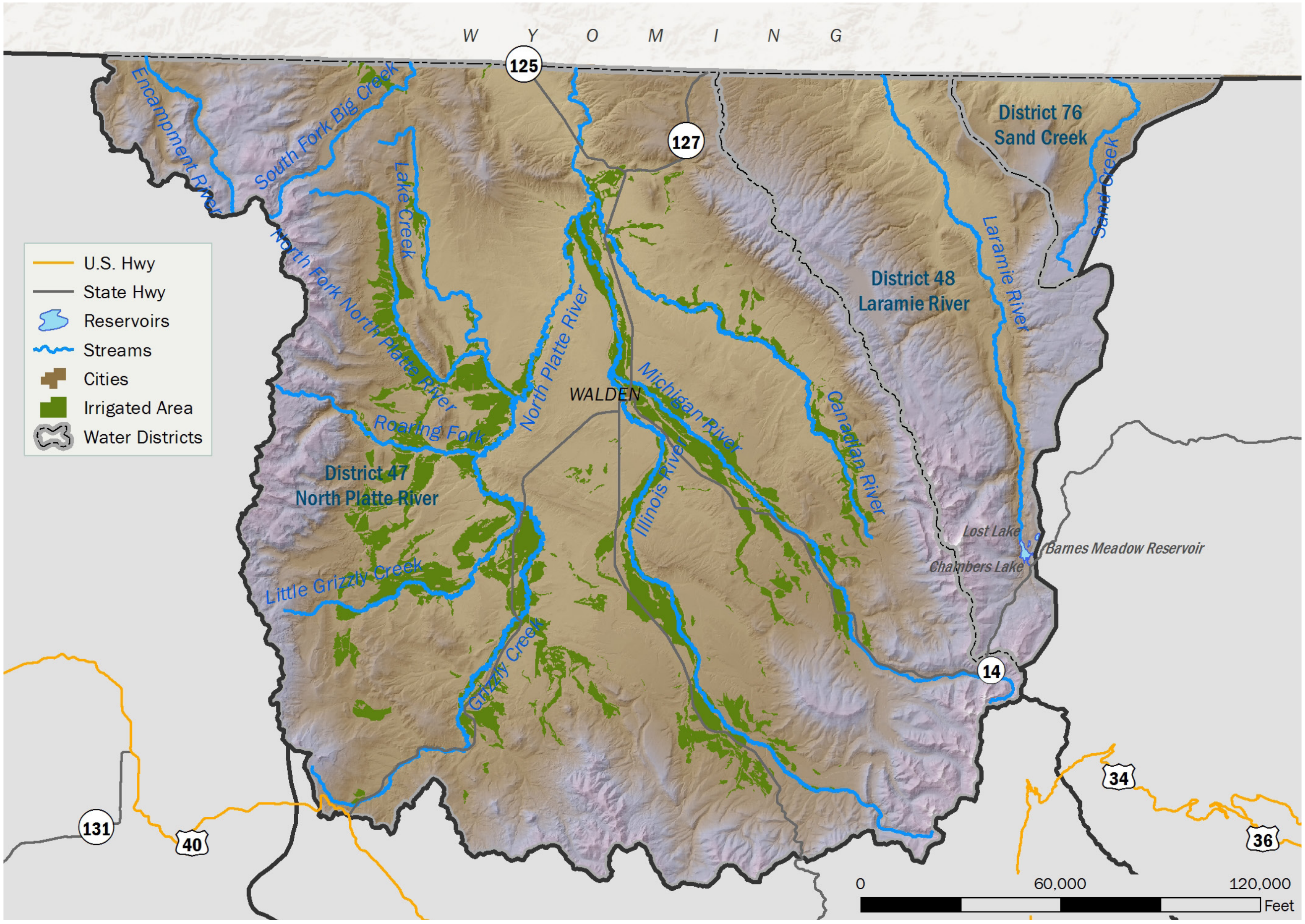


Figure 4.6.1 Map of the North Platte Basin

4.6.2 SUMMARY OF TECHNICAL UPDATE RESULTS

Key results and findings of the Technical Update pertaining to agricultural and M&I demands and gaps, as well as findings related to environmental and recreational attributes and future conditions, are summarized in Table 4.6.2 below.

Table 4.6.2 Summary of Key Results in the North Platte Basin

Agriculture	Environment and Recreation	Municipal and Industrial
• An additional 10,600 acres will increase agricultural demand in the future. • Although some technology improvements may occur, climate impacts may increase the agricultural demands and gap by 8 to 14 percent.	• In climate-impacted scenarios, peak flow generally moves earlier in the year. • Risks for trout increase in climate-impacted scenarios.	• Relatively small M&I demands are a reflection of the rural nature of this basin. There is little anticipated municipal growth, and no SSI water demand now or projected for the future.

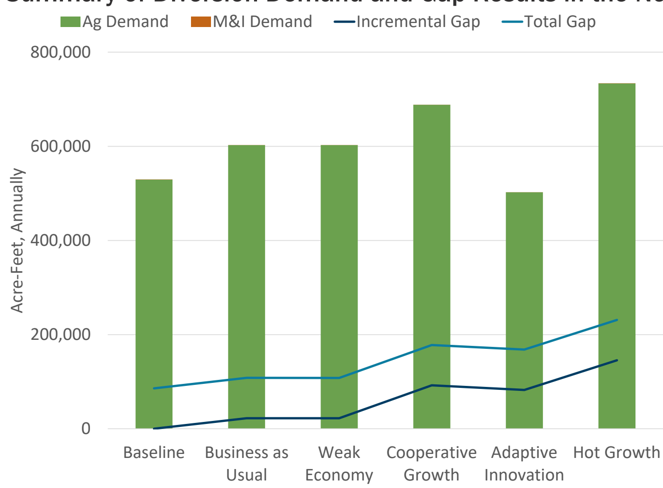
Results describing current and potential future M&I and agricultural demands and gaps are summarized in Table 4.6.3 and in Figure 4.6.2.

Table 4.6.3 Summary of Diversion Demand and Gap Results in the North Platte Basin

	Current (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average Annual Demand						
Agricultural (AFY)	529,200	602,400	602,400	688,300	502,300	733,500
M&I (AFY)	400	400	300	300	400	500
Gaps						
Ag (avg %)	16%	18%	18%	26%	33%	32%
Ag (incremental-AFY)	-	22,200	22,200	92,100	82,400	145,400
Ag (incremental gap as % of current demand)	-	4%	4%	17%	16%	27%
M&I (max %)	0%	4%	4%	4%	5%	10%
M&I (max-AF)	0*	20	10	10	20	50

**CDSS water allocation model in this basin calculates small baseline M&I gaps, but they are either due to calibration issues or they are reflective of infrequent, dry-year shortages that are typically managed with temporary demand reductions, such as watering restrictions.*

Figure 4.6.2 Summary of Diversion Demand and Gap Results in the North Platte Basin



Environmental and Recreational Findings

- Peak flows are projected to shift earlier in the year (April and May flows increase, offsetting June flow decreases) while magnitude may remain similar, keeping riparian/wetland and risk to fish habitat low to moderate. Possible mis-matches between peak flow timing and species needs may occur.
- Mid- and late-summer flows in North Park are moderate risk for trout under natural conditions, moderate to high risk under baseline conditions, and are projected to become high and very high risk for trout under *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth.*

4.6.3 NOTABLE BASIN CONSIDERATIONS

- Irrigation demands reflect full season demand, but basin irrigators generally end irrigation earlier in the season. In general, North Platte Basin irrigators tend to get a first cutting of grass/hay around mid-July; falling stream flow conditions in late summer and, in some years, early frosts can make it difficult to get a second cutting. In addition, many farmers do not have access to supplemental storage that would provide late-season supplies. If this trend continues, agricultural gaps may not be as large as projected.
- The Technical Update used water allocation models that reflect a strict application of water administration. In the North Platte Basin, some water users refrain from placing a call to share the benefit of available supplies, but these practices are not reflected in the models
- SSI water demands for fracking are not included in the overall M&I diversion demands. Water demand data for fracking was researched, but reliable sources of data were not found. The M&I diversion demands technical memorandum includes a recommendation to improve this dataset.

4.6.4 AGRICULTURAL DIVERSION DEMANDS

Agricultural Setting

Ranchers in the North Platte River and Laramie River basins irrigate more than 113,000 acres of grass and hay to support numerous cow-calf operations throughout the basin. These high mountain meadows are generally flood irrigated, and with limited storage in the basin irrigators rely on diversions of spring and summer runoff for supplies. With low population projections for the basin, future agricultural diversion demands in the basin will be most impacted by the ability to maintain and even increase irrigated acreage and potential impacts from climate change.

Planning Scenario Adjustments

Section 2 described ways in which inputs to agricultural diversion demand estimates were adjusted to reflect the future conditions described in the planning scenarios. The North Platte BIP identifies parcels of historically irrigated or potentially irrigable land that may be irrigated in the future if infrastructure improvements are made and water rights secured. Altogether, the North Platte BIP identified seven planned agricultural development projects throughout the basin that totalled a potential increase of 10,576 irrigable acres. Due to a short growing season and the prevalence of irrigated pasture grass related to ranching operations in the basin, it is reasonable to assume that these planned agricultural projects will also be operated for hay and cattle ranching. The North Platte basin roundtable consistently emphasizes the importance of maintaining and increasing irrigated acreage in the basin allowable under the Nebraska v. Wyoming Equitable Apportionment Decree and foresees implementing the planned agricultural projects in all planning scenarios.

Table 4.6.4 summarizes the planning scenario adjustments described above and other adjustments that impact agricultural diversion demands in the various scenarios, including increased irrigated acres.

Table 4.6.4 Planning Scenario Adjustments for Agricultural Demands in the North Platte Basin

Adjustment Factor*	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Change in Irrigated Land due to Urbanization	-	-	-	40 Acre Reduction	40 Acre Reduction
Planned Agricultural Development Projects	10,576 Acre Increase	10,576 Acre Increase	10,576 Acre Increase	10,576 Acre Increase	10,576 Acre Increase
IWR Climate Factor	-	-	25%	39%	39%
Emerging Technologies	-	-	-	10% IWR Reduction 10% System Efficiency Increase	-

** See Section 2.2.3 for descriptions of adjustment methodologies and assumptions*

Agricultural Diversion Demand Results

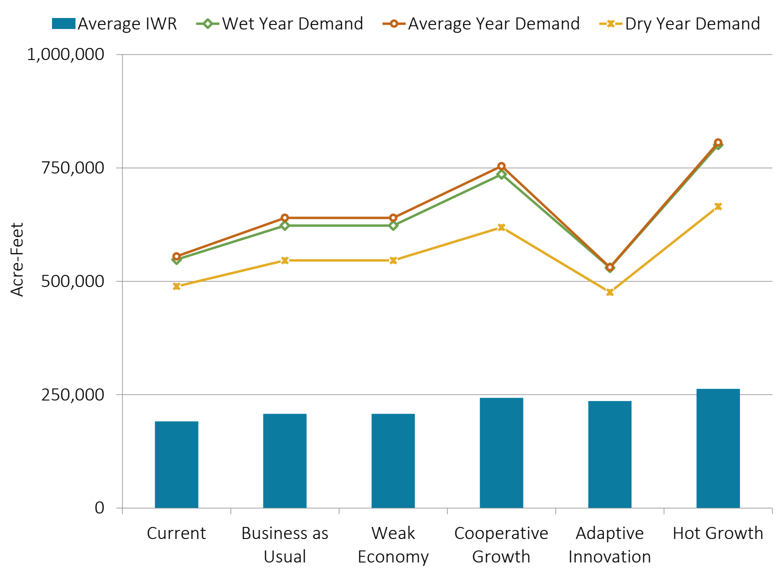
Table 4.6.5 and Figure 4.6.3 summarize the acreage, IWR, and the agricultural diversion demand for surface water supplies in the North Platte Basin for current conditions and the five planning scenarios. Agricultural diversion demands are projected to increase by 2050 due to additional irrigated acres; however, despite increased irrigated acres, *Adaptive Innovation* projects decreased demands as compared to baseline due to 10 percent reduction in IWR and 10 percent increase to system efficiency. *Hot Growth* projected the largest increase in demand due to higher IWR resulting from a warmer and drier future climate.

Table 4.6.5 Summary of Agricultural Diversion Demand Results in the North Platte Basin

	Current (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Irrigated Acreage (acres)	113,600	124,200	124,200	124,200	124,200	124,200
Average IWR (AFY)	191,100	208,000	208,000	243,000	236,000	263,000
Diversion Demand						
Average Year (AFY)	555,000	640,000	640,000	754,000	531,000	806,000
Wet Yr. Change	-1%	-3%	-3%	-2%	0%	-1%
Dry Yr Change	12%	15%	15%	18%	10%	17%

Average agricultural demand is calculated from the average of the "average" hydrologic years from 1950-2013

Figure 4.6.3 Summary of Agricultural Diversion Demand Results in the North Platte Basin



4.6.5 Municipal and Self-Supplied Industrial Diversion Demands

Population Projections

The North Platte Basin includes about 0.02 percent of the statewide population. Between the years 2015 and 2050, it is projected to change from approximately 1,400 to between 1,100 and 1,500 people in the low and high growth projections, respectively. This ranges from a 22 percent decrease in population to an increase of 8 percent. On a basin scale, the North Platte Basin represents the lowest baseline population and the lowest basinwide growth in the state. Table 4.6.6 shows how population growth is projected to vary for the North Platte Basin under each planning scenario.

Table 4.6.6 North Platte Basin 2015 and Projected Populations

Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
1,353	1,279	1,055	1,210	1,364	1,457

Current Municipal Demands

The North Platte Basin baseline demands relied entirely on estimated data from neighboring counties. No municipal data were available for utilities within Jackson County, which is the only county in the North Platte Basin.

Figure 4.6.4 summarizes the categories of municipal, baseline water usage in the North Platte Basin. Because there was no water provider-reported data available for Jackson County, the statewide weighted average demand category distribution was used for the North Platte Basin.

Projected Municipal Demands

Figure 4.6.5 provides a summary of per capita baseline and projected water demands for the North Platte Basin. Systemwide, the projected per capita demands are projected to decrease relative to the baseline except for *Hot Growth*. The residential indoor demand is the greatest demand category in the baseline, but the residential outdoor demand exceeds the residential indoor demand in *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*. Outdoor demands increased significantly for *Hot Growth* due to an increase in outdoor demands driven by the "Hot and Dry" climate factor (described in Section 2).

The North Platte Basin municipal baseline and projected demands provided in Table 4.6.7 show the combined effect of population and per capita demands. Municipal demands are projected to grow from approximately 400 AFY in 2015 to between 300 and 440 AFY in 2050.

The baseline and projected municipal demands are shown in Figure 4.6.6, which also shows how the population varies between the scenarios. *Hot Growth* is the only planning scenario in which the projected demands increase from the baseline; all other planning scenarios show an overall decrease in demands by 2050.

DECREASING GPCD

The North Platte Basin average baseline per capita systemwide demand has decreased from 310 gpcd in SWSI 2010 to approximately 264 gpcd.

Figure 4.6.4 Categories of Water Usage in the North Platte Basin

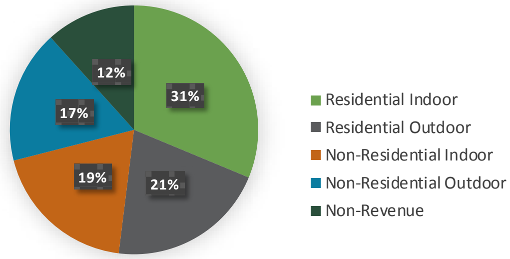


Figure 4.6.5 North Platte Basin Municipal Baseline and Projected Per Capita Demands by Water Demand Category

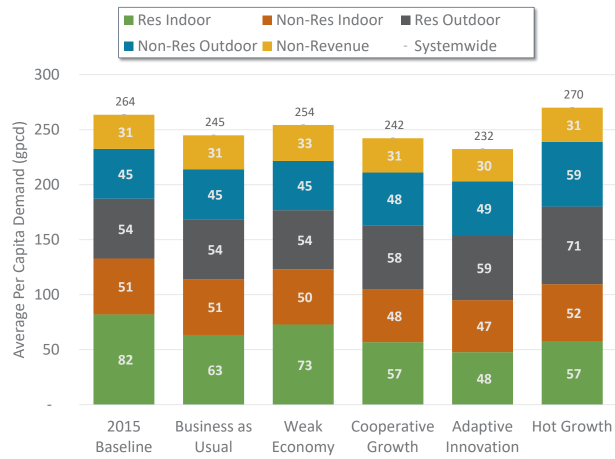


Figure 4.6.6 North Platte Basin Baseline and Projected Population and Municipal Demands

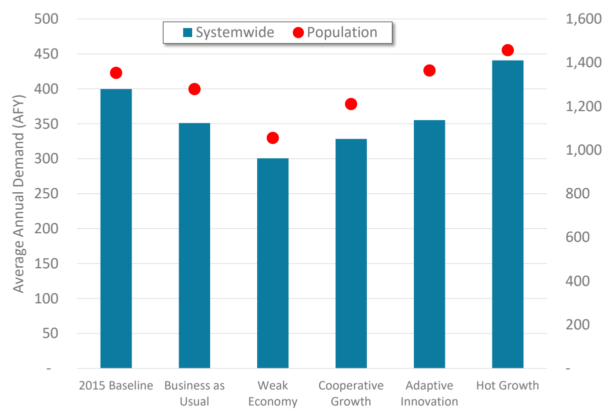


Table 4.6.7 North Platte Basin Municipal Baseline and Projected Demands (AFY)

Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
400	350	300	330	360	440

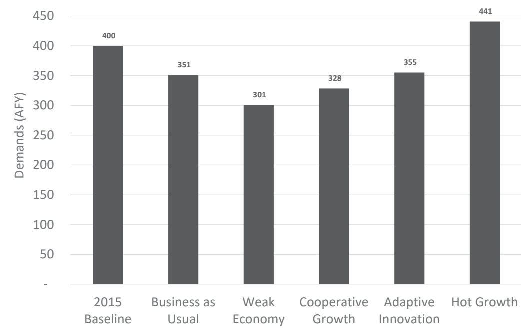
Self-Supplied Industrial Demands

The analysis does not include baseline and projected industrial demands in the North Platte Basin. Water demands for fracking occur in the basin, but no reliable sources of data were identified that could be used to quantify the water demands.

Total M&I Diversion Demands

North Platte Basin combined M&I demand projections for 2050 range from approximately 300 AFY under *Weak Economy* to 440 AFY in *Hot Growth*, as shown in Figure 4.6.7. On a basin scale, the demand projections follow the statewide sequence of the scenario rankings described in the CWP.

Figure 4.6.7 North Platte Basin Municipal and Self-Supplied Industrial Demands



4.6.6 Water Supply Gaps

The agricultural and M&I diversion demands were compared against available water supply modeled for current conditions and the five planning scenarios. Gaps were calculated when water supply was insufficient to meet demands.

Agricultural

The North Platte Basin agricultural diversion demands, demand gaps, and consumptive use gaps for the baseline and planning scenarios are presented in Table 4.6.8 and illustrated on Figure 4.6.8. An annual time series of gaps in terms of percent of demand that was unmet is shown on Figure 4.6.9.

INCREMENTAL GAP

The incremental agricultural gap quantifies the degree to which the gap could increase beyond what agriculture has historically experienced under water shortage conditions.

Table 4.6.8 North Platte Basin Agricultural Gap Results (AFY)

		Scenario					
		Scenario	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average	Average Annual Demand	529,200	602,400	602,400	688,300	502,300	733,500
	Average Annual Gap	85,700	108,000	107,900	177,900	168,100	231,100
	Average Annual Gap Increase from Baseline	-	22,200	22,200	92,100	82,400	145,400
	Average Annual Percent Gap	16%	18%	18%	26%	33%	32%
	Average Annual CU Gap	40,300	50,800	50,800	83,600	92,000	108,500
Maximum	Demand in Maximum Gap Year	521,600	582,400	582,400	659,400	494,900	694,000
	Gap in Maximum Gap Year	296,900	336,700	336,700	394,800	320,800	441,000
	Increase from Baseline Gap	-	39,800	39,700	97,900	23,800	144,100
	Percent Gap in Maximum Gap Year	57%	58%	58%	60%	65%	64%

Study period for Water Supply Analysis is 1975-2013, reflecting different baseline demand than described in Agricultural Diversion Demands section

Figure 4.6.8 Projected Average Annual Agricultural Diversion Demand, Demand Met, and Gaps in the North Platte Basin

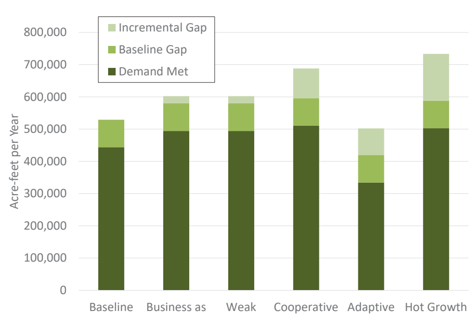
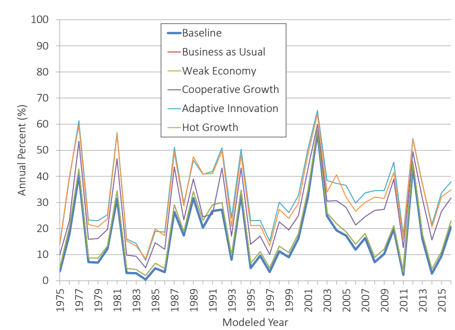


Figure 4.6.9 Annual Agricultural Gaps (expressed as a percentage of demand) for Each Planning Scenario



Observations on agricultural demands and gaps include:

- An additional 10,600 acres will increase agricultural diversion demand in the future.
- Although some technology improvements may occur, climate impacts will serve to increase the agricultural gap by 8 to 16 percent.
- Annual agricultural gaps can vary significantly and are more pronounced in dry years.

M&I

The diversion demand and gap results for M&I in the North Platte Basin are summarized in Table 4.6.9 and illustrated on Figure 4.6.10. An annual time series of gaps in terms of percent of demand that was unmet is shown on Figure 4.6.11.

Table 4.6.9 North Platte Basin M&I Gap Results (AFY)

		Scenario					
		Scenario	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average	Average Annual Demand	400	370	310	350	380	460
	Average Annual Gap	0	0	0	1	2	21
	Average Annual Percent Gap	0%	0%	0%	0%	1%	5%
Maximum	Demand in Maximum Gap Year	400	370	310	350	380	460
	Gap in Maximum Gap Year	0*	15	13	13	18	45
	Percent Gap in Maximum Gap Year	0%	4%	4%	4%	5%	10%

* *CDSS water allocation model in this basin calculates small baseline M&I gaps, but they are either due to calibration issues or they are reflective of infrequent, dry-year shortages that are typically managed with temporary demand reductions, such as watering restrictions.*
Study period for Water Supply Analysis is 1975-2013, reflecting different baseline demand than described in M&I Demand section.

Figure 4.6.10 Projected Maximum Annual M&I Demand Met and Gaps in the North Platte Basin

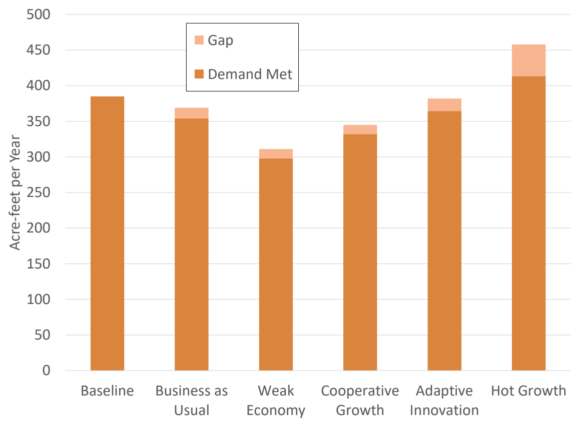
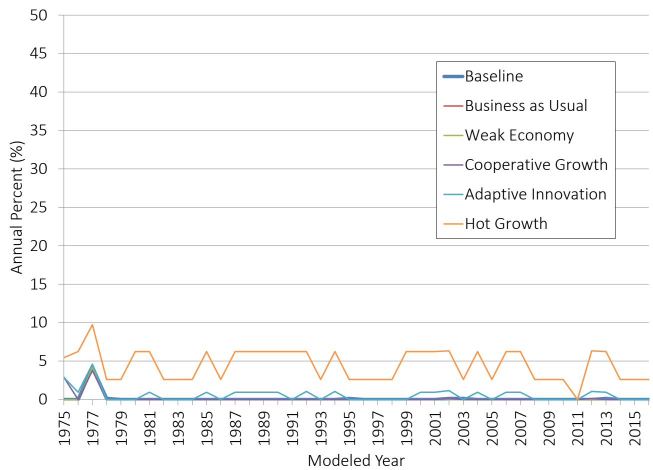


Figure 4.6.11 Annual M&I Gaps (expressed as a percent of demand) for Each Planning Scenario



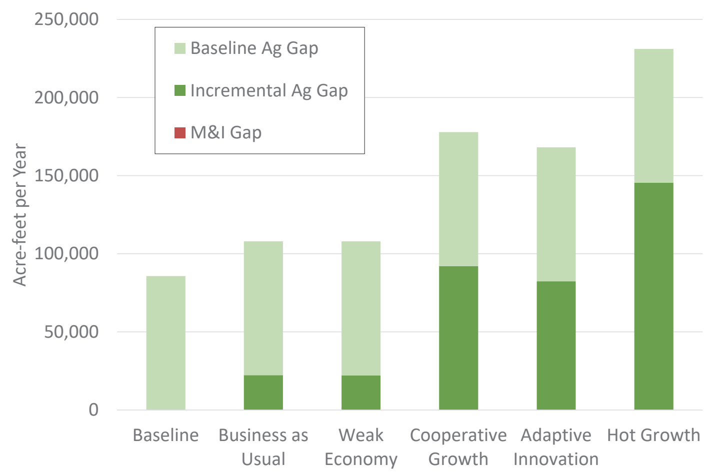
The following are observations on M&I diversion demands and gaps:

- Relatively small M&I demands are a reflection of the rural nature of this basin. There is little anticipated municipal growth.
- Consistent M&I gaps are only present in *Hot Growth*.

Total Gap

Figure 4.6.12 illustrates the total combined agricultural and M&I diversion demand gap in the North Platte Basin. The figure combines the average annual baseline and incremental agricultural gaps and the maximum M&I gap. In all future scenarios, gaps are driven by agricultural demands, which increase due to more irrigated acres and climate impacts.

Figure 4.6.12 Projected Average Annual Agricultural Gaps and Maximum M&I Diversion Demand Gaps in the North Platte Basin (AFY)



Supplies from Urbanized Lands

By 2050, irrigated acreage in the North Platte Basin is projected to decrease by only 40 acres due to urbanization, reflecting the rural nature of the basin. These decreases are only projected to occur in *Adaptive Innovation* and *Hot Growth*. Irrigation supplies for these lands could potentially be used for M&I needs in the future (subject to a variety of unknowns such as seniority and type of water supply, willingness to change the use of water through water court, etc.). The average annual historical consumptive use associated with potentially urbanized acreage for each scenario is reflected in Table 4.6.10. The data in the table represent planning-level estimates of this potential supply and has not been applied to the M&I gaps.

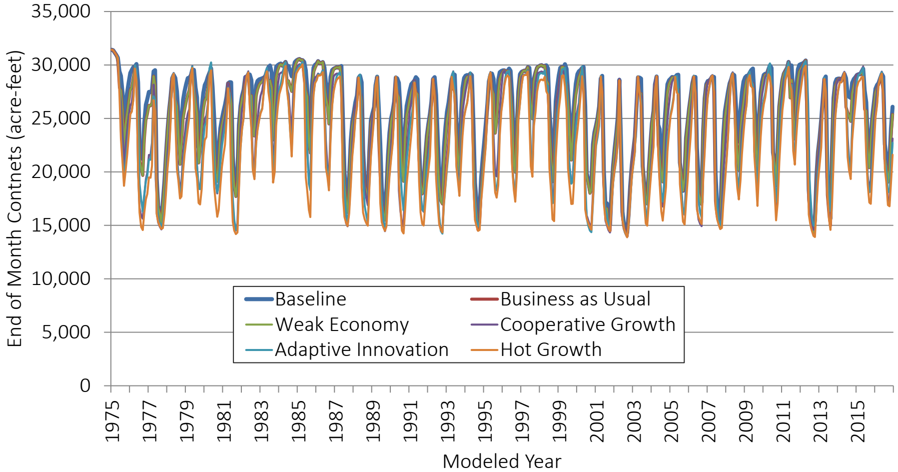
Table 4.6.10 Estimated Consumptive Use from Lands Projected to Be Urbanized by 2050 in the North Platte Basin

	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Urbanized Acreage (acres)	-	-	-	40	40
Estimated Consumptive Use (AFY)	-	-	-	50	50

Storage

Total simulated reservoir storage from the North Platte River water allocation model is shown in Figure 4.6.13. Baseline and *Weak Economy* scenarios show the highest levels of water in storage (in general) and the lowest is in *Hot Growth*; however, storage levels for all future scenarios track closely with baseline throughout the study period.

Figure 4.6.13 North Platte Basin Total Simulated Storage



4.6.7 Available Supply

Figures 4.6.14 and 4.6.15 show simulated available flow at a location on the Lower Michigan River upstream of the confluence with the North Platte River. The location represents water availability near the senior calling rights, which include the Hiho Ditch, Kiwa Ditch, and diversions to storage in Carlstrom Reservoir. Water availability is only moderately impacted by the calling rights, and flows are projected to be available in most years (but vary greatly on an annual basis). Peak flows are projected to increase at this location but could diminish in the late summer in climate-impacted scenarios.

Figure 4.6.14 Simulated Hydrograph of Available Flow at Michigan River at Cumberland Ditch

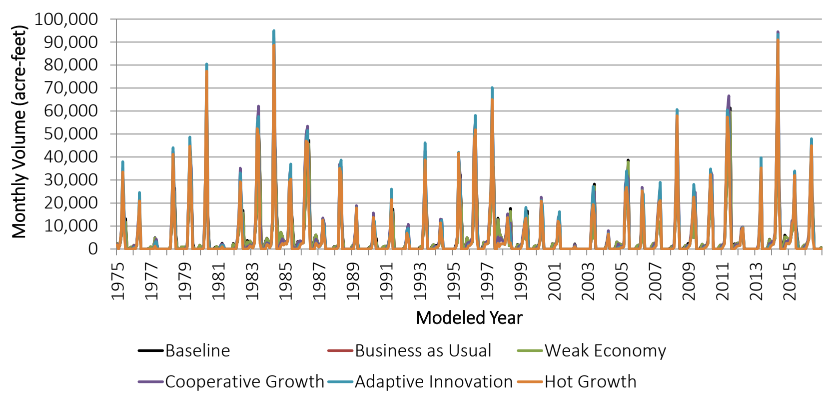
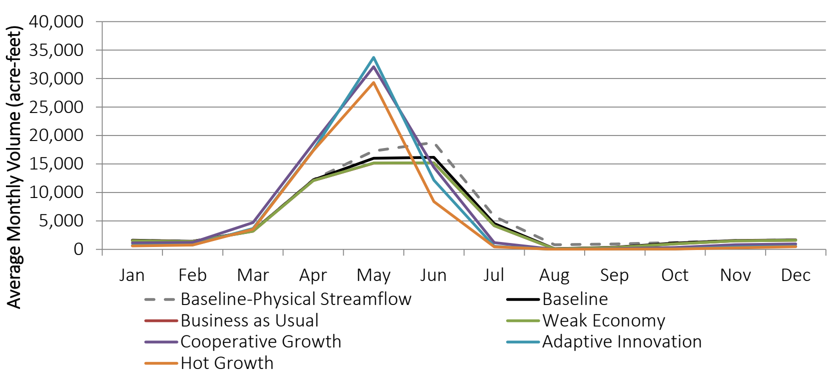


Figure 4.6.15 Average Monthly Simulated Hydrographs of Available Flow at Michigan River at Cumberland Ditch



4.6.8 Environment and Recreation

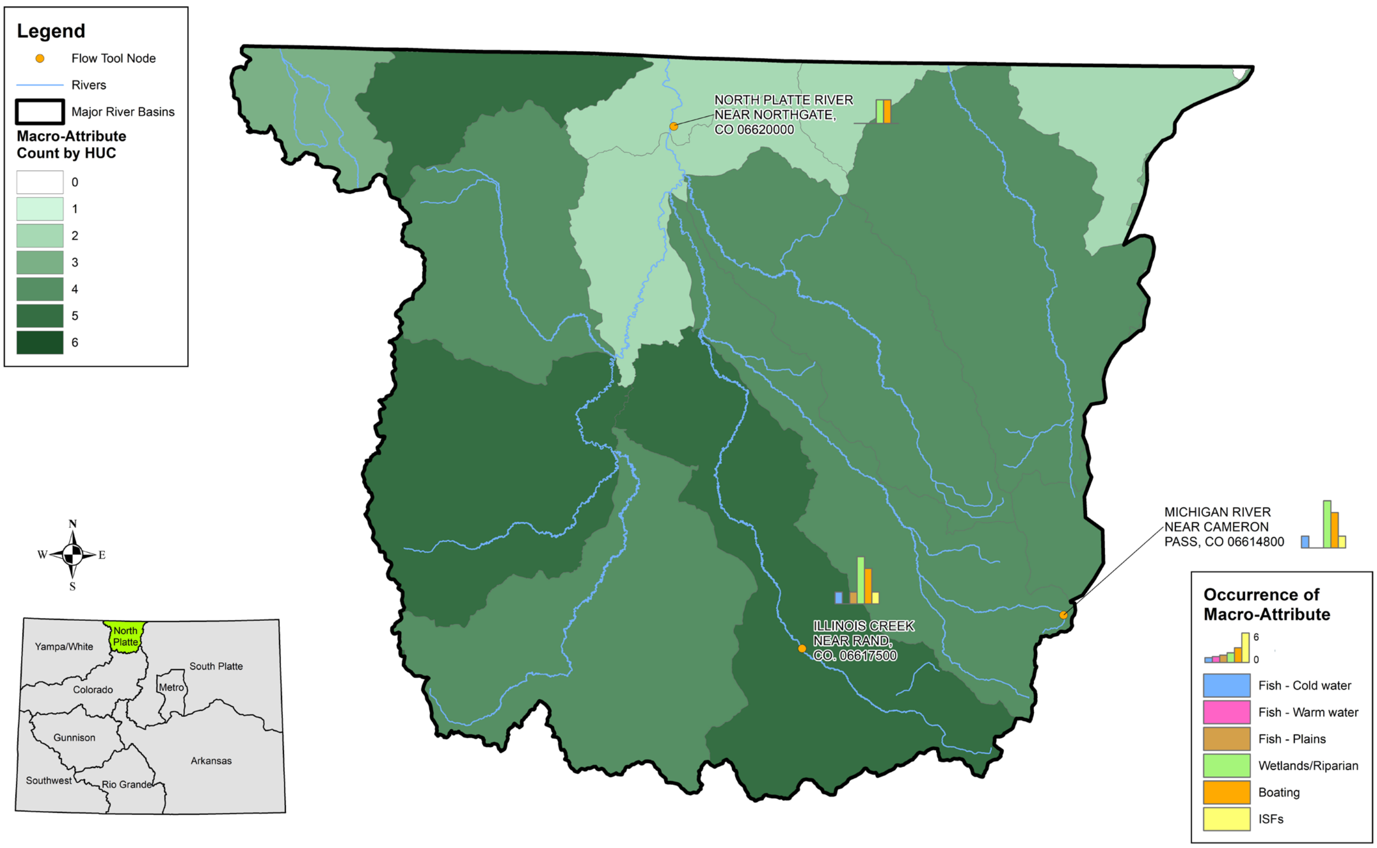
A total of three water allocation model nodes were selected for the Flow Tool within the North Platte Basin (see list below and Figure 4.6.16). Figure 4.6.16 also shows subwatersheds (at the 12-digit HUC level) and the relative number of E&R attributes located in each subwatershed.

- Michigan River near Cameron Pass, Colorado (06614800)
- Illinois Creek near Rand, Colorado (06617500)
- North Platte River near Northgate, Colorado (06620000)

NATURALIZED FLOW

Naturalized flows reflect conditions that would occur in the absence of human activities. Baseline flows reflect current conditions as influenced by existing infrastructure and river operations. While observations regarding naturalized flows may be informative, baseline flows reflect actual conditions and the diverse operations of a river's many users.

Figure 4.6.16 Flow Tool Nodes Selected in the North Platte Basin



Results and observations describing Flow Tool analyses using flow data developed in the water supply and gap analyses for baseline conditions and the planning scenarios are described in Table 4.6.11.

Table 4.6.11 Summary of Flow Tool Results in the North Platte Basin

Category	Observation
Projected Flows	Mean annual flows in North Platte Basin under baseline conditions are 20 to 35 percent below naturalized conditions.
	Unlike all other basins analyzed, mean annual flow changes little under all scenarios, including climate change scenarios.
	Although there is little projected change in mean annual flow in future scenarios compared to baseline, peak flows do change. Peak flow magnitude under baseline conditions are approximately 15 percent below naturalized conditions at higher elevations and decrease further below naturalized conditions where the North Platte leaves Colorado near North Gate.
	Under *Business as Usual* and *Weak Growth*, projected peak flows change little. Under scenarios with climate change, peak flow magnitude may increase slightly. The timing of peak flows is also projected to change, shifting earlier in the year (April and May flows increase, offsetting June flow decreases).
	Under baseline conditions, mid- and late-summer flows in North Park are 30 to 60 percent below naturalized conditions, depending on location. This condition may not be as ideal for trout as many other locations in Colorado at similar elevation. Under climate change scenarios, mid- and late-summer flows are likely to decline further.
Ecological Risk	Baseline peak flow magnitudes create some risk for maintaining riparian/wetland plants and fish habitat, but this risk may lessen under climate change scenarios as peak flow magnitude increases. However, earlier and larger peak flows may lead to lower mid- and late-summer flows, and these lower flows could increase risk for trout under *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*. Also, the change in peak flow timing under climate change scenarios may lead to mis-matches between peak flows and species' needs.

The Rio Grande drainage basin in Colorado is bound by the San Juan Mountains to the west, the Sangre de Cristo Range to the north and east, the Culebra Range to the southeast, and the Colorado-New Mexico state line to the south. Between the mountains lies the San Luis Valley, an expansive, generally flat area with an average elevation of 7,500 feet and precipitation of less than eight inches per year. Despite the low precipitation, agriculture has long been the basis of the Rio Grande basin economy. Principal crops are potatoes, followed by alfalfa, native hay, barley, wheat, and small vegetables like lettuce, spinach and carrots. Mountainous areas of the basin are forested and sparsely populated.

The northern third of the valley is a closed basin, meaning runoff from the surrounding mountains and diversions from the Rio Grande recharge the basin's two stacked aquifers, known as the unconfined and confined aquifers, rather than contributing or returning to the Rio Grande. Irrigated agriculture in the Rio Grande Basin relies on well pumping from the aquifers as well as surface deliveries from the Rio Grande and Conejos River. These diversions are both applied directly to crops and, in the closed basin, recharged into the unconfined aquifer.

The Rio Grande Compact establishes Colorado's obligations to ensure water delivery at the New Mexico state line with some allowance for credits and debits via accounts in Elephant Butte Reservoir. The compact dictates that Colorado calculate its delivery obligation based on the flow at indexed stations, which effectively caps Colorado's allowable consumptive use even in wet years. Key future water management issues in this basin center around sustainability of the groundwater supply, but also include maintaining and providing domestic supply for new growth and operating within the constraints of the Rio Grande Compact.

RIO GRANDE

District 25
San Luis Creek
285
69
MOFFAT
Saguache Creek
17
San Luis Creek
112
150
MONTE VISTA
15
ALAMOSA
370
District 35
Trinchera Creek
Terrace Reservoir
Trinchera Creek
District 21
Alamosa La Jara
SAN LUIS
District 24
Culebra Creek
District 22
Conejos River

4.7 RIO GRANDE BASIN RESULTS

4.7.1 BASIN CHALLENGES

Key future water management issues in this basin center around sustainability of the groundwater supply, but also include maintaining and providing domestic supply for new growth and operating within the constraints of the Rio Grande Compact. These challenges are described in the Colorado Water Plan and are summarized below.

Table 4.7.1 Key Future Water Management Issues in the Rio Grande Basin

Agriculture	Environment and Recreation	Municipal and Industrial	Compacts and Administration
• Groundwater use for agriculture is currently at unsustainable levels. • Community-based solutions offer best hope of minimizing effects of reducing irrigated acres.	• The Rio Grande Basin has an abundance of terrestrial and aquatic wildlife populations, rare and important habitats, diverse ecosystems, and exceptional recreational opportunities; however, the increasingly water-short nature of the Basin makes sustaining these attributes challenging.	• All cities and towns are supplied by groundwater wells and must comply with the State Engineer's Well Rules and Regulations. • Growth of commercial uses throughout the basin, new homes near Alamosa, and second homes in the surrounding mountains are creating a need for additional water supplies and well augmentation.	• The Rio Grande Compact and sustained drought make the objective of groundwater sustainability difficult.
• Groundwater is a key component of water supply in the basin for both M&I and agriculture. Groundwater management presents an ongoing challenge.			

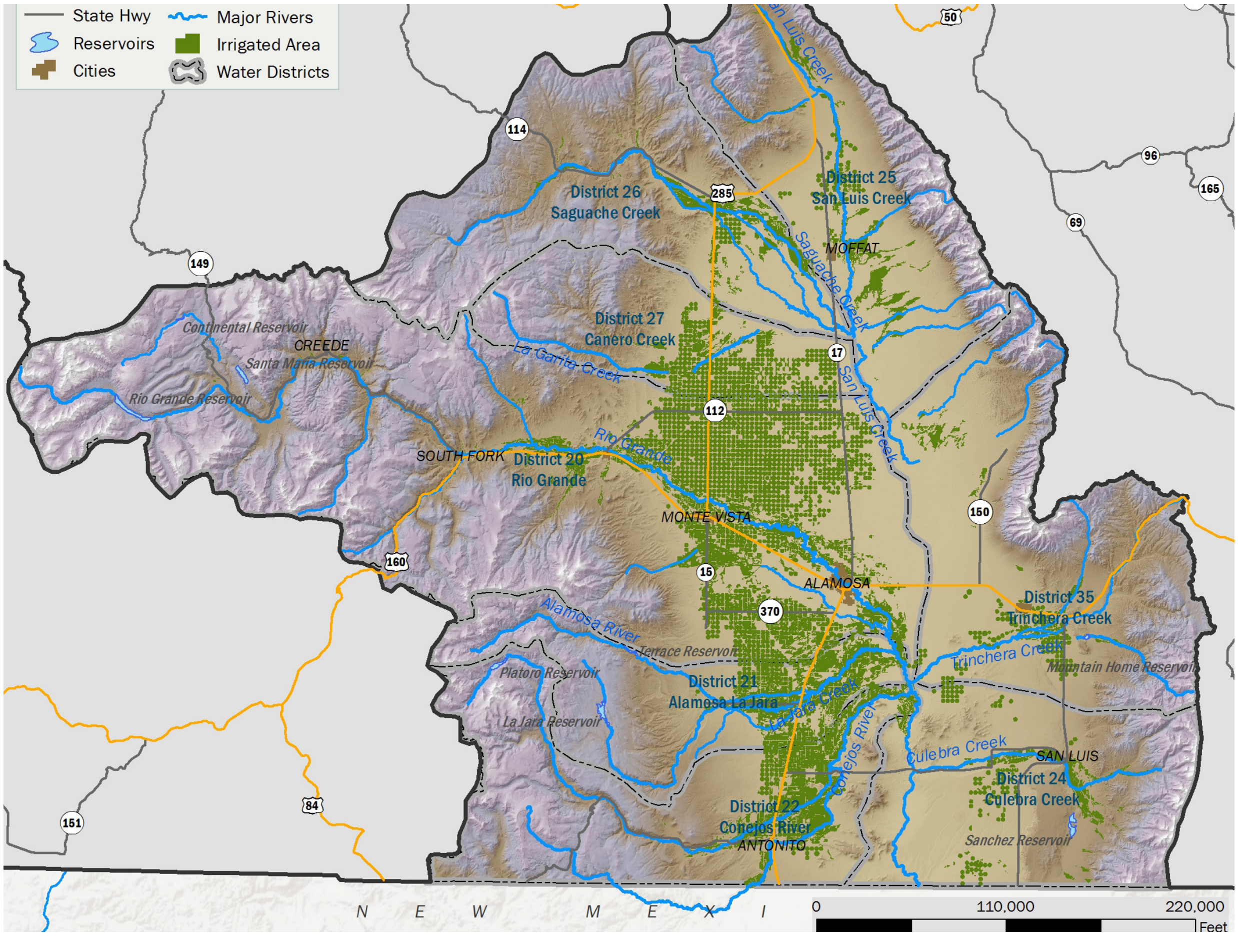


Figure 4.7.1 Map of the Rio Grande Basin

4.7.2 SUMMARY OF TECHNICAL UPDATE RESULTS

Key results and findings of the Technical Update pertaining to agricultural and M&I demands and gaps, as well as findings related to environmental and recreational attributes and future conditions, are summarized below in Table 4.7.2.

Table 4.7.2 Summary of Key Results in the Rio Grande Basin

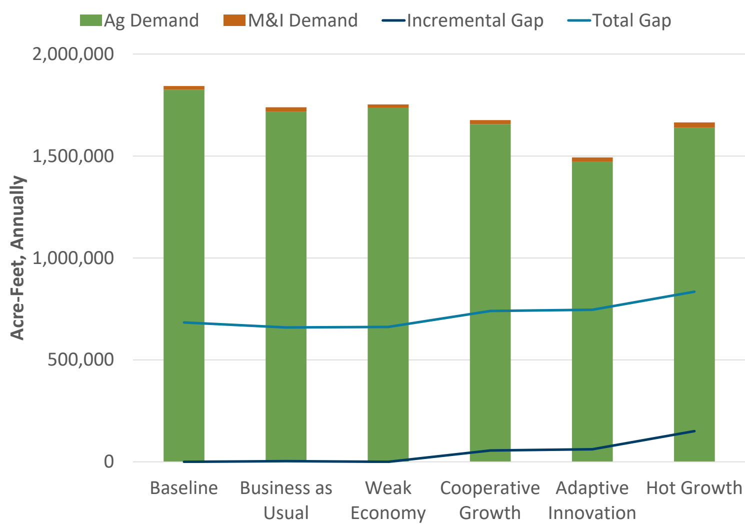
Agriculture	Environment and Recreation	Municipal and Industrial
• Future agricultural demand is lower than baseline, based on current and future acreage reductions due to groundwater administration and need to restore and sustain aquifer levels. • Agricultural demand in the scenarios is related to acreage reductions to offset climate-induced increases in IWR. Demand under Adaptive Innovation is lower than other scenarios, reflecting a higher system efficiency and reduction in IWR from emerging technologies. • As a percentage of demand, the gap is similar for Baseline, Business as Usual, and Weak Economy but larger larger for remaining scenarios despite lower demand.	• Flow magnitude in mountainous areas is not projected to significantly change under climate-impacted scenarios, but the annual hydrograph may shift with earlier snowmelt. Risks to riparian and fish habitat would remain low to moderate in most cases.Mid- and late-summer streamflow is projected to drop substantially in mountainous regions represented in the Flow Tool. Risk to cold water fish may remain moderate but increase in July and/or dry years.	• Both per capita use and total demand are significantly lower in the Technical Update baseline than in the SWSI 2010 baseline. • Aside from *Hot Growth*, outdoor demands are similar for all scenarios. This is due to the scenario pairing of water demand reductions and climate drivers.

Results describing current and potential future M&I and agricultural demands and gaps are summarized in Table 4.7.3 and in Figure 4.7.2.

Table 4.7.3 Summary of Diversion Demand and Gap Results in the Rio Grande Basin

	Current (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average Annual Demand						
Agricultural (AFY)	1,825,200	1,717,800	1,735,700	1,656,300	1,471,400	1,638,900
M&I (AFY)	17,700	21,100	17,700	20,100	21,700	25,800
Gaps						
Ag (avg %)	37%	38%	38%	45%	50%	50%
Ag (incremental-AFY)	-	-	-	53,500	58,000	142,500
Ag (incremental gap as % of current demand)	-	-	-	3%	3%	8%
M&I (max %)	-	16%	0%	12%	18%	31%
M&I (max-AF)	0	3,400	0	2,400	4,000	8,100

Figure 4.7.2 Summary of Diversion Demand and Gap Results in the Rio Grande Basin



Summary of Environmental and Recreational Findings

- A surface water allocation model was not available in the Rio Grande Basin, so the available flow dataset only includes natural flows and natural flows as impacted by climate drivers in mountainous areas; no management drivers are factored in.
  - » Management drivers impact river flows in areas downstream of mountainous areas in the Rio Grande and Conejos basins. Because a water allocation model that incorporates management is not available, no data-based insights into flow change and risk to non-consumptive attributes could be developed.
- In general, overall peak flow magnitude is not projected to change substantially under climate-impacted scenarios, but the peak may shift to earlier in the year (April/May streamflow magnitude may increase and June streamflow magnitude may decrease). Subsequent risk for riparian/wetland and fish habitat may remain low or moderate in most cases, although there are some indications that risk could increase in smaller streams.
- Mid- and late-summer streamflow is projected to drop substantially in all locations, with July streamflow decreasing 40 to 60 percent on the Rio Grande and tributaries and up to 70 percent on the Conejos River under the “In-Between” and “Hot and Dry” climate projections. Risk to cold water fish due to decreasing streamflow may remain moderate in most years but could be higher in July and/or during dry years.

4.7.3 NOTABLE BASIN CONSIDERATIONS

Section 4.1 described several analysis assumptions and limitations that apply to all basins and should be considered when reviewing and interpreting analysis results. Additional considerations specific to the Rio Grande Basin are listed below:

- The analysis assumed that there is no available water for meeting new uses. As a result, additional future M&I demands contribute directly to gaps.
- Basin stakeholders have cautioned that large reductions in irrigated land could result in socio-economic impacts that cause a reduction of municipal population.
- Stakeholder input was the basis of projected decreases in irrigated land due to groundwater sustainability and climate change.
- The Rio Grande Basin average baseline per capita systemwide demand has decreased significantly from 314 gpcd in SWSI 2010 to approximately 207 gpcd. The BIP was the primary source of water demand data.
- Aquifer sustainability will be a primary focus of future water management strategies and activities in this basin.
- The analysis did not consider specific different types of crops that may be grown in the future under the different scenarios; however, it accounted for future changes in crop types in a general sense in *Adaptive Innovation* and assumed that future crops would have 10 percent lower IWR. This is in line with the Rio Grande BIP recommendation to explore opportunities to reduce pumping through alternative cropping rather than drying up productive farm ground.

4.7.4 AGRICULTURAL DIVERSION DEMANDS

Agricultural Setting

Irrigated acreage in the Rio Grande Basin, particularly in the San Luis Valley, is inherently tied to the basin's unique surface and groundwater supplies. Surface water supplies diverted from streams fed by snowmelt are highly variable from year to year, with annual runoff in high flow years yielding up to eight times[11] more than in drought years. Groundwater from the upper unconfined aquifer and the deeper confined aquifer provides a more consistent irrigation supply. Although recharge to the unconfined aquifer occurs relatively quickly, decades of withdrawals greater than recharge have severely depleted it. Although the deeper confined aquifer supplies fewer wells than the unconfined aquifer due to its depth, it also experiences withdrawals that exceed recharge. Daily administration of the Rio Grande Compact, which primarily restricts surface water diversions through curtailment to meet compact deliveries, further impacts water availability in the basin. Surface and groundwater supplies combined support the irrigation of approximately 515,000 acres in the basin, predominantly in potatoes, grass, alfalfa, and small grains; however, the future of agriculture in the basin is threatened by more frequent periods of drought and declining aquifer levels.

Spurred by the drought in the early 2000s, declining levels of the unconfined aquifer in the Closed Basin, reduced confined aquifer pressure valleywide, and passage of Senate Bill 04-222 mandating the promulgation of groundwater rules and regulations by the Division of Water Resources (DWR), the Rio Grande Water Conservation District (RGWCD) created the first Special Improvement District of the Rio RGWCD (Subdistrict No. 1). Subdistrict No. 1 operates to replace injurious stream depletions caused by the subdistrict wells, recover aquifer levels, and maintain a sustainable irrigation water supply in the unconfined aquifer. The impacts to streams covered by the subdistricts are derived from a basin-wide groundwater model, developed through the Rio Grande Decision Support System (RGDSS).[12]

Subdistrict No. 1 began operations in 2012 and includes approximately 174,000 irrigated acres in the Closed Basin area. Subdistrict No. 2 covering the Rio Grande Alluvium and Subdistrict No. 3 covering the Conejos area began operating in 2019. Subdistricts No. 4, No. 5 and No. 6 covering the San Luis Creek, Saguache, and Alamosa/La-Jara Creek areas, respectively, are under development.

Due to the large amount of acreage in the subdistrict areas, management of these subdistricts will likely shape how irrigated agriculture will look by 2050.

Planning Scenario Adjustments

Section 2 described ways in which inputs to estimates of agricultural diversion demands were adjusted to reflect the future conditions described in the planning scenarios. Adjustments in the Rio Grande Basin focused on urbanization, groundwater sustainability, potential future climate conditions, and implementation of emerging technologies.

Population projections for the basin indicate that under all scenarios except *Weak Economy*, the basin's population will increase modestly and municipal water demands will grow. Irrigated acreage surrounding small towns in the basin is vulnerable to urbanization. For all scenarios other than *Weak Economy*, approximately 4,010 acres were estimated to come out of production due to urbanization of irrigated lands in the basin.

Much more significant are reductions in irrigated acreage to reach water use levels that the aquifers can sustainably support. In total, 40,000 irrigated acres were removed from the Subdistrict No.1 area, and 5,000 irrigated acres were removed across the basin in all planning scenarios.

IWR in the Rio Grande Basin is projected to increase on average by 15 percent under the *In-Between* climate projection and 18 percent on average under the "Hot and Dry" climate projection. Faced with this information, stakeholders in the basin discussed what the ultimate effects on the basin may be if IWR increases to these levels, particularly in light of the Rio Grande Compact. The group decided that as the compact will continue to limit surface water availability, any increase in IWR would likely lead to irrigated acreage being taken out of production because there would not be sufficient surface water supplies to meet these increased demands.

To account for this future potential outcome, it was assumed that the percent increase in IWR by Water District would result in the same percent decrease in irrigated acreage. With basinwide unit IWR historically averaging 2 AF per year and crop consumptive use in the basin historically averaging 1.3 AF per year, this is potentially an underestimate of the total acreage that may come out of production under potential future climate conditions. This approach, however, resulted in the removal of approximately 70,000 acres in *Cooperative Growth* and approximately 81,000 acres in *Adaptive Innovation* and *Hot Growth* across the basin. Note that IWR is reduced by 10 percent in *Adaptive Innovation* to account for technological innovations that may mitigate the increased IWR due to climate adjustments.

Table 4.7.4 summarizes the planning scenario adjustments described above and other adjustments that impact agricultural diversion demands in the various scenarios.

Table 4.7.4 Planning Scenario Adjustments for Agricultural Demands in the Rio Grande Basin

Adjustment Factor*	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Change in Irrigated Land due to Urbanization	4,010 Acre Reduction	-	4,010 Acre Reduction	4,010 Acre Reduction	4,010 Acre Reduction
Change in Irrigated Land for Groundwater Sustainability	45,000 Acre Reduction	45,000 Acre Reduction	45,000 Acre Reduction	45,000 Acre Reduction	45,000 Acre Reduction
IWR Climate Factor	-	-	15% 70,000 Acre Reduction	18% 81,000 Acre Reduction	18% 81,000 Acre Reduction
Emerging Technologies	-	-	-	10% IWR Reduction	-

**See section 2.2.3 for descriptions of adjustment methodologies and assumptions*

Agricultural Diversion Demand Results

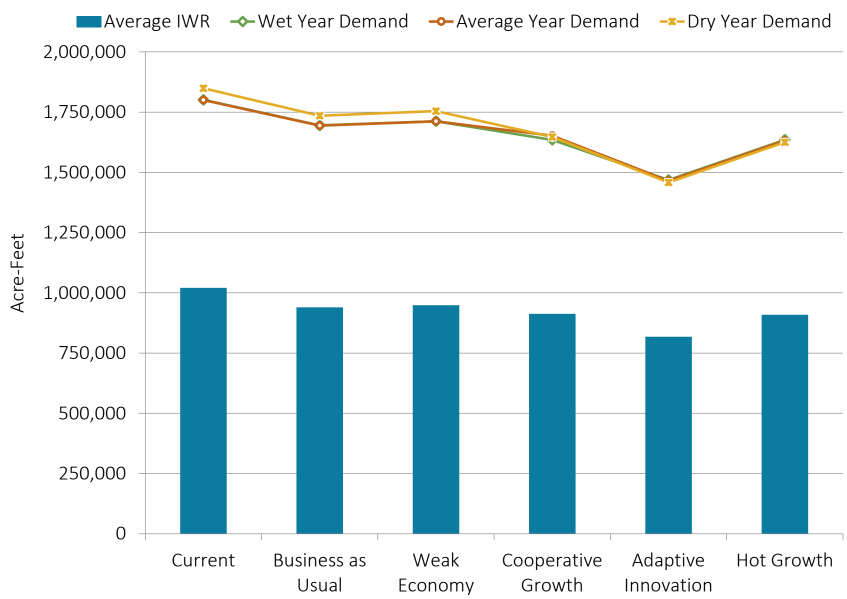
Table 4.7.5 and Figure 4.7.3 summarize the acreage, IWR, and the agricultural diversion demand for surface water supplies in the Rio Grande Basin for current conditions and the five planning scenarios. All scenario demands are lower than Baseline, because of irrigated acreage reduction to better manage the aquifer. Demand in climate impacted scenarios (*Cooperative Growth*, *Adaptive Innovation* and *Hot Growth*) is no higher than in *Business as Usual* and *Weak Economy* because compensating reductions in irrigated acreage are assumed to be implemented.

Table 4.7.5 Summary of Agricultural Diversion Demand Results in the Rio Grande Basin

	Current (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Irrigated Acreage (acres)	515,300	466,300	470,300	396,500	385,200	385,200
Average IWR (AFY)	1,021,000	940,000	949,000	913,000	818,000	909,000
Total Surface and Groundwater Diversion Demand						
Average Year (AFY)	1,800,000	1,694,000	1,712,000	1,652,000	1,465,000	1,632,000
Wet Yr. Change	0%	0%	0%	-1%	0%	0%
Dry Yr Change	3%	2%	3%	0%	-1%	0%

Average agricultural diversion demand was calculated using the average hydrologic years (i.e. years classified as neither wet or dry) from 1950-2013

Figure 4.7.3 Agricultural Diversion Demands and IWR Results in the Rio Grande Basin



4.7.5 Municipal and Self-Supplied Industrial Diversion Demands

Population Projections

The Rio Grande Basin currently includes less than 1 percent of the statewide population. Between the years 2015 and 2050, it is projected to change from approximately 46,000 people to between 42,000 and 67,000 people in the low and high growth projections, respectively. This ranges from an 8 percent decrease in population to an increase of 46 percent. Table 4.7.6 shows how population growth is projected to vary across planning scenarios.

Table 4.7.6 Rio Grande Basin 2015 and Projected Populations

Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
46,000	55,100	42,300	52,100	63,000	67,300

Current Municipal Demands

Approximately 79 percent of the baseline municipal demands were derived from BIP data, which represents the highest reliance on BIP data for any basin in the state. Data from WEPs represent demands for another 9 percent of the population, requiring about 12 percent of the basin's baseline population demands to be estimated (see Figure 4.7.4).

The BIP data did not include breakdowns of water use by demand category. Because there was insufficient demand category data available to apply county-specific distributions, the statewide weighted average demand category distribution was used for the Rio Grande Basin, as shown on Figure 4.7.5.

Figure 4.7.4 Sources of Water Demand Data in the Rio Grande Basin

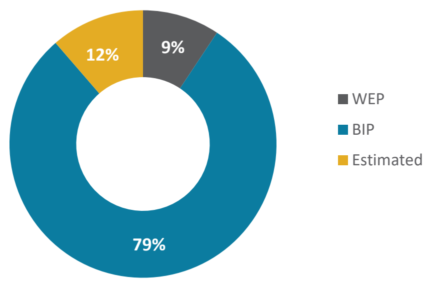
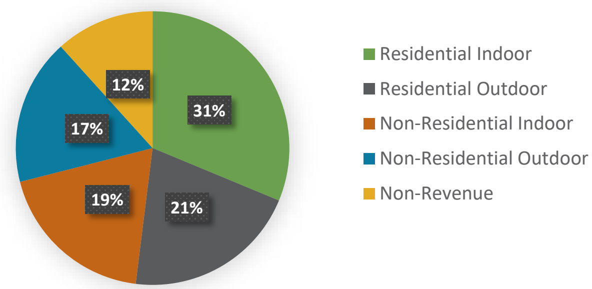


Figure 4.7.5 Categories of Municipal Water Usage in the Rio Grande Basin



Projected Municipal Demands

Figure 4.7.6 provides a summary of per capita baseline and projected water demands for the Rio Grande Basin. Systemwide, projected per capita demands decrease relative to the baseline except for *Hot Growth*. Residential indoor demand is generally the greatest demand. Outdoor demands increased significantly for *Hot Growth*, due to a general increase in outdoor demands coupled with the "Hot and Dry" climate.

The Rio Grande Basin municipal baseline and projected diversion demands provided in Table 4.7.7 show the combined effect of population and per capita demands. Municipal demands are projected to change from approximately 11,000 AFY in 2015 to between 9,000 and 16,000 AFY in 2050. Alamosa County accounts for around one-third of the baseline demand, followed by Conejos and Rio Grande counties, each at about one-quarter of the basin demand.

Figure 4.7.6 Rio Grande Basin Municipal Baseline and Projected Per Capita Demands by Water Demand Category (pgcd)

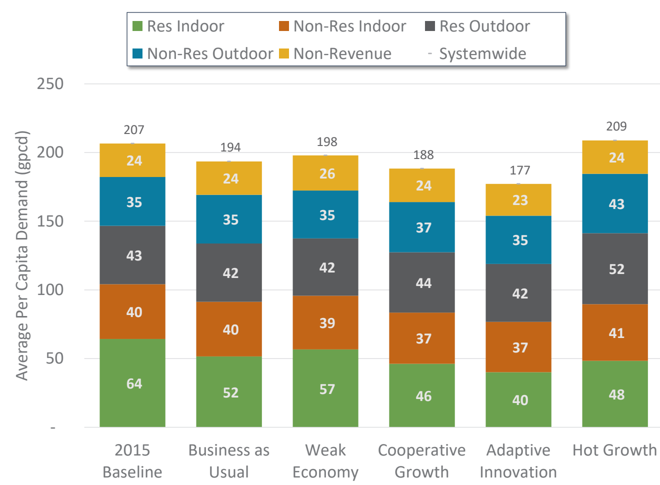
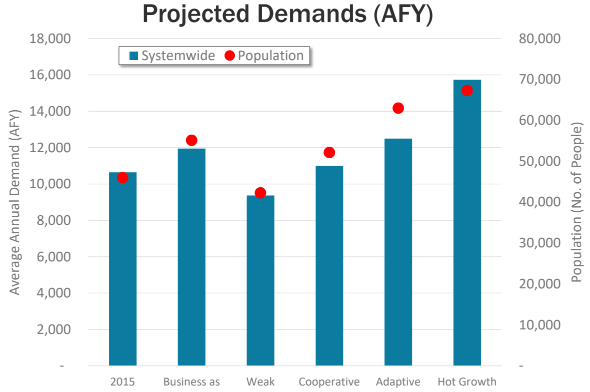


Table 4.7.7 Rio Grande Basin Municipal Baseline and Projected Demands (AFY)

Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
10,600	11,900	9,400	11,000	12,500	15,700

Figure 4.7.7 Rio Grande Basin Municipal Baseline and Projected Demands (AFY)



The baseline and projected demand distributions are shown in Figure 4.7.7, which also shows how the population varies across scenarios. All of the projection scenarios except for the *Weak Economy* result in an increase in systemwide demand relative to the baseline.

DECREASING GPCD

The Rio Grande Basin average baseline per capita systemwide demand decreased from 314 gpcd in SWSI 2010 to approximately 207 gpcd.

Self-Supplied Industrial Demands

The Rio Grande Basin includes about 4 percent of the statewide SSI diversion demand. SSI demands in this basin are associated with Large Industry (fish and aquaculture, agricultural product processing) and Energy Development (solar power generation and future oil and gas development), with no demands projected for the thermoelectric sub-sector. A minor amount of snowmaking occurs in the basin, but the required amount of water is insignificant compared to other SSI demands, and it was not considered in the demand analysis. Basin-scale SSI demands are shown in Figure 4.7.8 and tabulated in Table 4.7.8.

Figure 4.7.8 Rio Grande Basin SSI Baseline and Projected Demands (AFY)

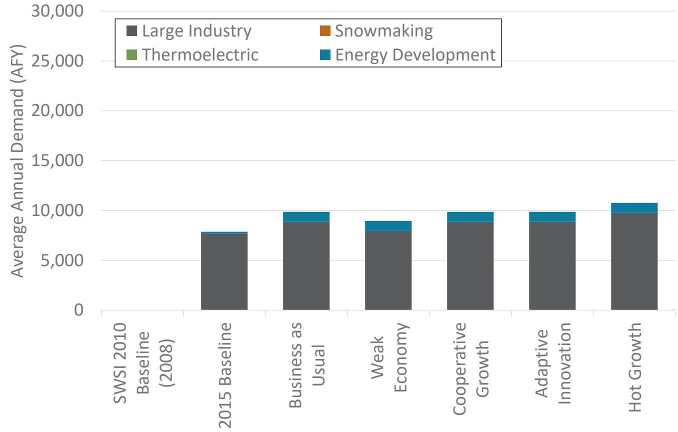


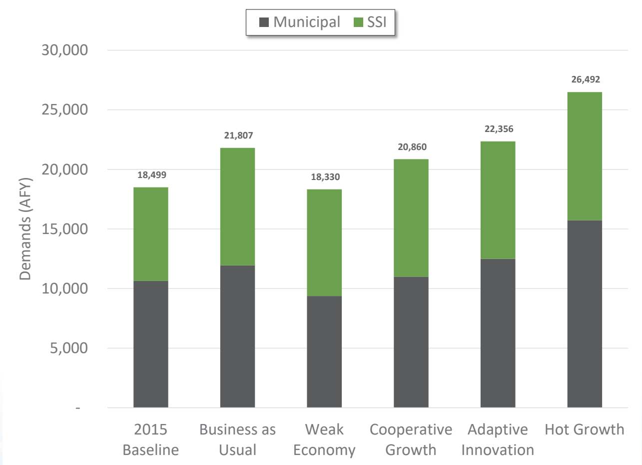
Table 4.7.8 Rio Grande Basin SSI Baseline and Projected Demands (AFY)

Sub-sector	Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Large Industry	7,660	8,860	7,960	8,860	8,860	9,760
Snowmaking	0	0	0	0	0	0
Thermoelectric	0	0	0	0	0	0
Energy Development	200	1,000	1,000	1,000	1,000	1,000
Sub-Basin Total	7,860	9,860	8,960	9,860	9,860	10,760

Total M&I Diversion Demands

Rio Grande Basin combined M&I demand projections for 2050 range from approximately 18,000 AFY in *Weak Economy* to 26,000 AFY in *Hot Growth*, as shown in Figure 4.7.9. SSI demands account for about 40 to 50 percent of the M&I demands. On a basin scale, the demand projections follow the statewide sequence of the scenario rankings described in the CWP.

Figure 4.7.9 Rio Grande Basin Municipal and Self-Supplied Industrial Demands



4.7.6 Water Supply Gaps

The agricultural and M&I diversion demands were compared against available water supply for current conditions and the five planning scenarios.

Agricultural

Because the Rio Grande Compact limits agricultural water use and because the system is over appropriated, current water supply was assumed to be equal to historical diversions and pumping, with no additional supply available. The current agricultural gap was estimated as the difference between the current agricultural diversion demand and historical diversions and pumping for wet, dry, and average years.

> **INCREMENTAL GAP**
>
> The incremental agricultural gap quantifies the degree to which the gap could increase beyond what agriculture has historically experienced under water shortage conditions.

The Rio Grande Basin agricultural diversion demands, demand gaps, and consumptive use gaps for the baseline and planning scenarios are presented in Table 4.7.9 and illustrated in Figure 4.7.10. An annual time series of gaps in terms of percent of demand that was unmet is shown in Figure 4.7.11.

Table 4.7.9 Rio Grande Basin Agricultural Gap Results (AFY)

		Scenario					
		Scenario	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average	Average Annual Demand	1,825,200	1,717,800	1,735,700	1,656,300	1,471,400	1,638,900
	Average Annual Gap	683,900	655,800	661,500	737,400	741,900	826,400
	Average Annual Gap Increase from Baseline	-	-	-	53,500	58,000	142,500
	Average Annual Percent Gap	37%	38%	38%	45%	50%	50%
	Average Annual CU Gap	348,300	333,400	336,300	374,600	376,900	419,800
Maximum	Demand in Maximum Gap Year	2,058,800	1,935,400	1,956,200	1,814,100	1,605,700	1,789,700
	Gap in Maximum Gap Year	1,059,702	1,017,391	1,026,351	1,112,661	1,110,956	1,238,485
	Increase from Baseline Gap	-	-	-	52,959	51,254	178,783
	Percent Gap in Maximum Gap Year	51%	53%	52%	61%	69%	69%

Study period for Water Supply Analysis is 1975-2013, reflecting different baseline demand than described in Agricultural Diversion Demands section

Figure 4.7.10 Projected Average Annual Agricultural Diversion Demand, Demand Met, and Gaps in the Rio Grande Basin

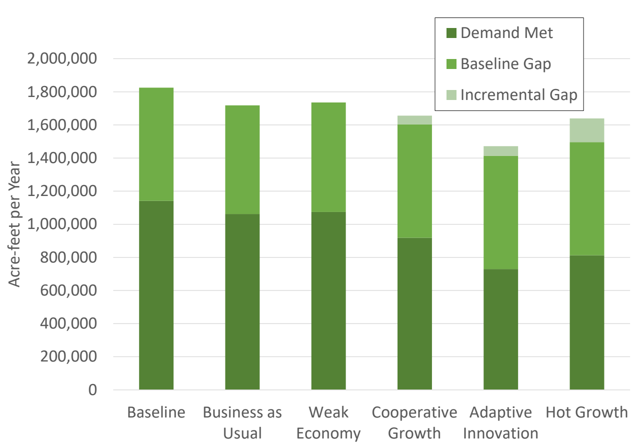
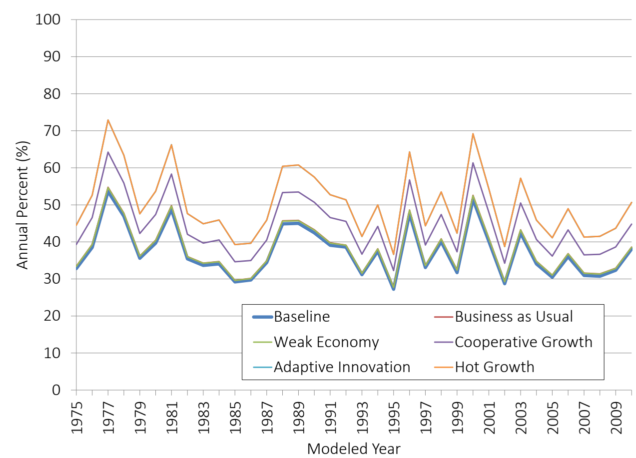


Figure 4.7.11 Annual Agricultural Gaps (expressed as a percentage of demand) for Each Planning Scenario



The following are observations on agricultural diversion demands and gaps:

- *Business as Usual* and *Weak Economy* do not include climate-adjusted hydrology or demands; therefore, changes in these scenarios relative to baseline are related strictly to changes in irrigated acreage and their impact on diversion demands.
- The inclusion of climate-adjusted hydrology and demands in *Cooperative Growth*, *Adaptive Innovation* and *Hot Growth* complicates the analyses for these scenarios. The analysis looked at the projected water supply under different year types available to senior and junior water rights in the basin and identified water rights that may no longer have constant supplies under the projected hydrology.
- Agricultural diversion demand is a major factor in this basin, with M&I demand only 1 to 1.5 percent of agricultural demand.
- Although agricultural diversion demand is expected to fall, gaps in excess of 650,000 AFY persist regardless of the planning scenario. Between 38 and 50 percent of agricultural demand is projected to be unmet in the planning scenarios.
- Despite reduced demand, the size of the gap is projected to increase relative to baseline in the three scenarios that are climate-impacted, because the available supply is forecast to be reduced.

M&I

The M&I gap for each scenario was estimated as the difference between the projected diversion demands and the current levels of municipal diversions and pumping. The diversion demand and gap results for M&I uses in the Rio Grande Basin are summarized in Table 4.7.10 and illustrated in Figure 4.7.12. Time series of M&I gaps were not developed in the Rio Grande Basin, because a CDSS water allocation model is not available at this time.

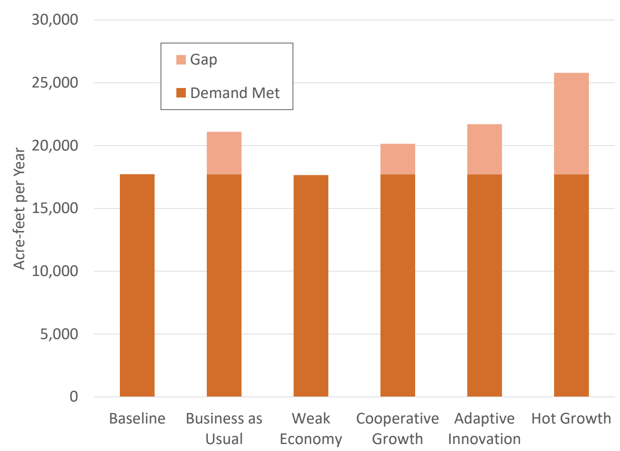
Table 4.7.10 Rio Grande Basin M&I Gap Results (AFY)

		Scenario					
		Scenario	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average	Average Annual Demand	17,700	21,100	17,700	20,100	21,700	25,800
	Average Annual Gap	-	3,400	-	2,400	4,000	8,100
	Average Annual Percent Gap	-	16%	-	12%	18%	31%
Maximum	Demand in Maximum Gap Year	17,700	21,100	17,700	20,100	21,700	25,800
	Gap in Maximum Gap Year	-	3,400	-	2,400	4,000	8,100
	Percent Gap in Maximum Gap Year	-	16%	-	12%	18%	31%

The following are observations on the M&I diversion demands and gaps:

- Average annual M&I gap in the Rio Grande Basin ranges from 0 AF to more than 8,100 AF.
- Municipal diversion demand and SSI diversion demand contribute nearly evenly to total M&I diversion demand, with municipal accounting for just a little more than half. This is unique among Colorado's river basins.
- Population growth is the main driver for the modest increases in M&I demands in the planning scenarios, as per capita water use decreased for every scenario except *Hot Growth*.
- For *Hot Growth*, the M&I gap is much larger than other scenarios, at 31 percent of demand.

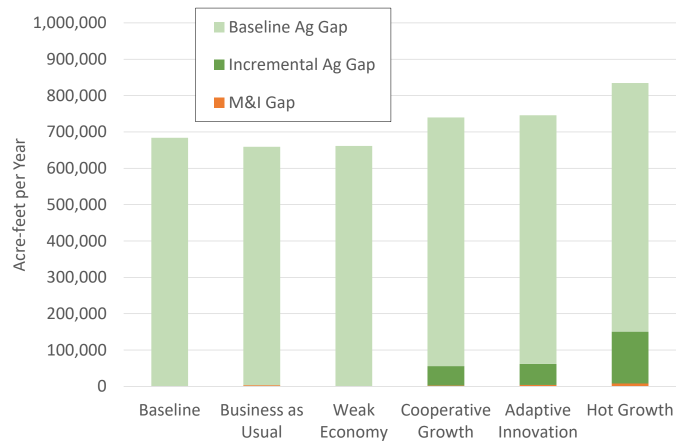
Figure 4.7.12 Projected Maximum Annual M&I Demand Met and Gaps in the Rio Grande Basin



Total Gap

Figure 4.7.13 illustrates the total combined agricultural and M&I diversion demand gap in the Rio Grande Basin. The figure combines the average annual baseline and incremental agricultural gap and the maximum M&I gap. In *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*, gaps were driven by agricultural demands, which increase in the "Hot and Dry" climate conditions.

Figure 4.7.13 Projected Average Annual Agricultural Gaps and Maximum M&I Diversion Demand Gaps in the Rio Grande Basin



Supplies from Urbanized Lands

By 2050, irrigated acreage in the Rio Grande Basin is projected to decrease by 4,000 acres due to urbanization. Irrigation supplies for these lands could potentially be used for M&I needs in the future (subject to a variety of unknowns such as seniority and type of water supply, willingness to change the use of water through water court, etc.). The average annual historical consumptive use associated with potentially urbanized acreage for each scenario is reflected in Table 4.7.11. The data in the table represent planning-level estimates of this potential supply and has not been applied to the M&I gaps.

Table 4.7.11 Estimated Consumptive Use from Lands Projected to be Urbanized by 2050 in the Rio Grande Basin

	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Urbanized Acreage (acres)	4,000	-	4,000	4,000	4,000
Estimated Consumptive Use (AFY)	5,300	-	5,400	4,600	5,100

4.7.7 Available Supply

For the purposes of the Technical Update, it was assumed that due to compact constraints, there are no available water supplies now or in the future that can meet new demands.

4.7.8 Environment and Recreation

A surface water allocation model is not currently available in the Rio Grande Basin. As a result, hydrologic datasets in the Flow Tool include only naturalized flows and naturalized flows as impacted by climate change. A total of four water allocation model nodes, all in the mountains and foothills west of the San Luis Valley, were selected for the Flow Tool within the Rio Grande Basin (see list below and Figure 4.7.14). Figure 4.7.14 also shows subwatersheds (at the 12-digit HUC level) and the relative number of E&R attributes located in each subwatershed.

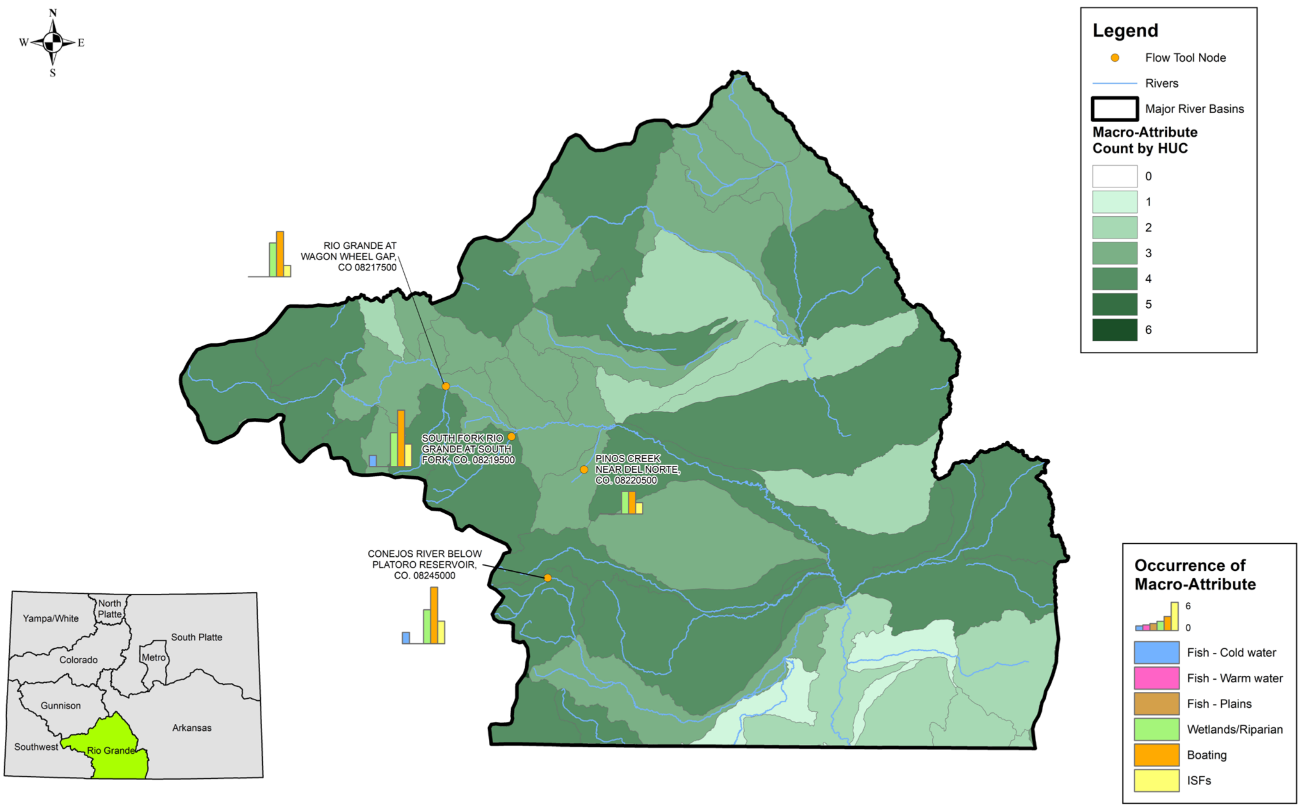
- Rio Grande at Wagon Wheel Gap, Colorado (08217500)
- South Fork Rio Grande at South Fork, Colorado (08219500)
- Pinos Creek near Del Norte, Colorado (08220500)
- Conejos River below Platoro Reservoir, Colorado (08245000)

These sites were selected because they are above major supply and demand drivers where future flow changes would likely be associated with only climate change factors. Management drivers impact river flows in areas downstream of mountainous areas in the Rio Grande and Conejos basins. Because a water allocation model that incorporates management is not available, the Flow Tool results for the Rio Grande Basin include only naturalized conditions and naturalized conditions as impacted by climate drivers ("In-Between" and "Hot and Dry" climate change projections) to illustrate a representative potential change in flow due to climate. These data do not represent changes in flow due to irrigation, transmountain imports, and/or storage.

NATURALIZED FLOW

Naturalized flows reflect conditions that would occur in the absence of human activities. Baseline flows reflect current conditions as influenced by existing infrastructure and river operations. While observations regarding naturalized flows may be informative, baseline flows reflect actual conditions and the diverse operations of a river's many users.

Figure 4.7.14 Flow Tool Nodes Selected in the Rio Grande Basin



Results and observations from Flow Tool analyses using flow data developed in the water supply and gap analyses for baseline conditions and the planning scenarios are described below in Table 4.7.11.

Table 4.7.12 Summary of Flow Tool Results in the Rio Grande Basin

Category	Observation
Projected Flows	For the selected locations, overall peak flow magnitude is not projected to change substantially under climate change projections; however, the timing of peak flow may shift to earlier in the year, with April and May flow magnitudes rising and June flows decreasing under the "In-Between" and "Hot and Dry" climate change projections.
	Mid- and late-summer flow may be reduced in all locations under the "In-Between" and "Hot and Dry" climate change projections, with July streamflow decreasing by roughly half on the Rio Grande and tributaries and even more on the Conejos River.
Ecological Risk	Peak flow related risk for riparian/wetland and fish habitat is projected to remain low or moderate in most cases, although there are some indications that risk could increase in smaller streams.
	Risk to trout due to decreasing mid- and late-summer streamflow may remain moderate in most years but could be higher in July and/or during dry years.
E&R Attributes	Because future flows under the five scenarios have not been modeled in the Rio Grande Basin, projected changes to flow and associated changes in risk to E&R attributes within the Flow Tool are attributable only to projected changes in climate. These climate-induced changes—earlier peak flow and reduced mid- and late-summer flows—are similar to the general pattern seen in many parts of Colorado.

The South Platte Basin is the most populous basin in the state. Approximately 85 percent of Colorado's population resides in the South Platte Basin, and the Front Range area of the basin is Colorado's economic and social engine. The basin also has the greatest concentration of irrigated agricultural lands in Colorado.

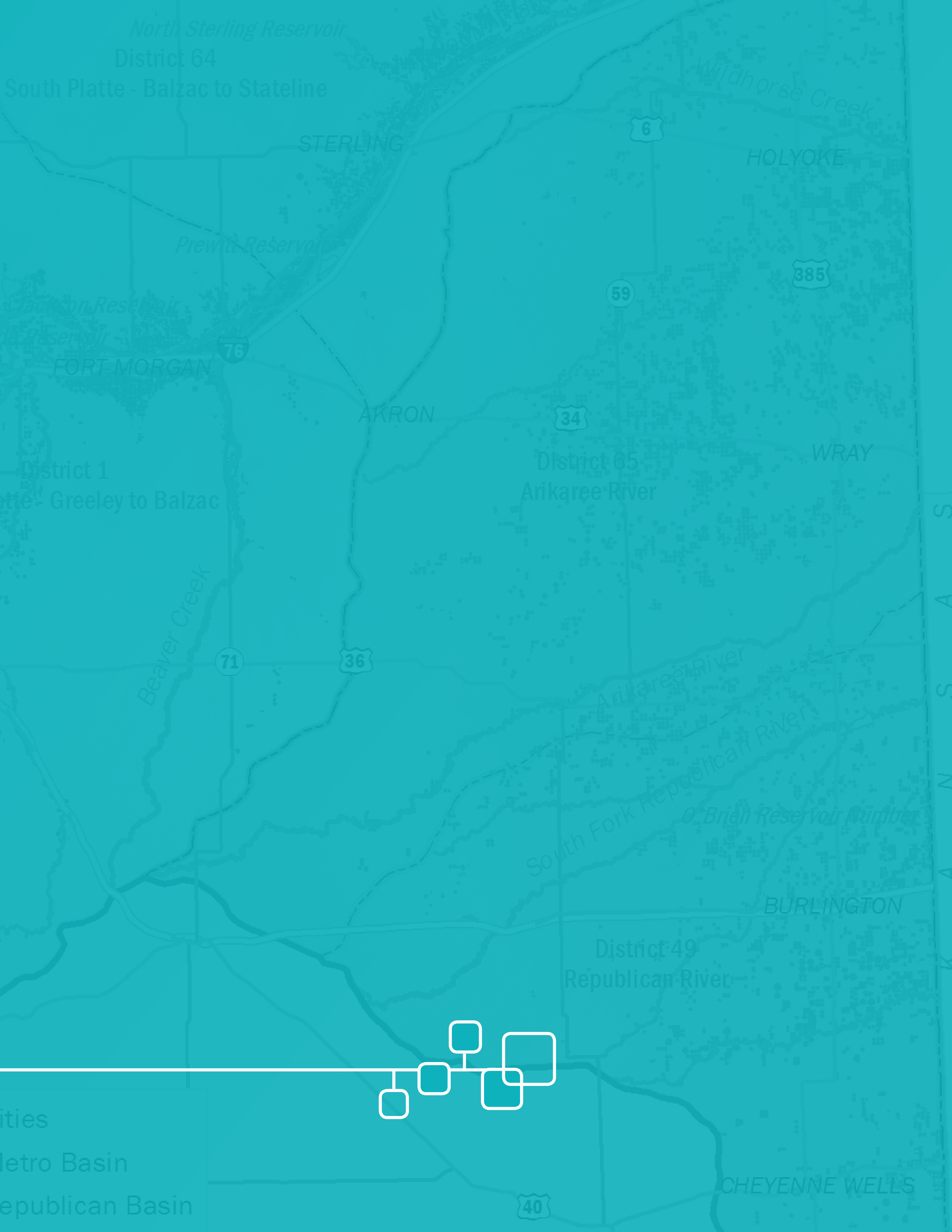
The topographic characteristics of the South Platte Basin are diverse. The western portions of the basin and its mountainous and subalpine areas are mostly forested, while the High Plains region is mainly grassland and planted or cultivated land.

The hydrology of the South Platte Basin is highly variable, with an approximate average annual native flow volume of 1.4 million AF About 400,000 AF of transmountain imports and 30,000 AF from nontributary groundwater aquifers supplement the water supply in the South Platte Basin. Yet, surface-water diversions in the South Platte Basin average about 4 million AF annually, with groundwater withdrawals totaling an additional annual 500,000 AF on average. The amount of diversion in excess of native flow highlights the return flow-dependent nature of the basin's hydrology, and the basinwide efficient use and reuse of water supplies.

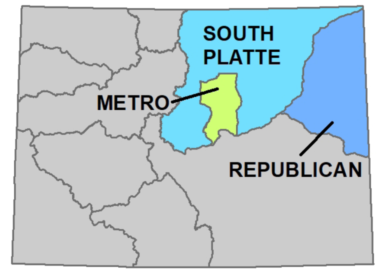
The Republican Basin in Colorado is located on the Northeastern High Plains. Land uses in the basin are primarily agricultural. The topographic characteristics of the Republican Basin, which are similar to the High Plains region of the South Platte Basin, consist mainly of grassland and planted or cultivated land. The Republican Basin in Colorado is underlain by the High Plains or Ogallala aquifer, which is one of the largest aquifer systems in the United States, extending from South Dakota to Texas.

The Technical Update largely keeps the analysis at the basin scale. There are some exceptions where subbasin (river basin) analysis of major waterways was more straightforward. To that end, both the South Platte, Metro and Republican basins were explicitly analyzed where possible. Those results are shown in the following sections. In other sections, of this report where statewide analysis is shown, the entire South Platte Basin (with values from the South Platte, Metro and Republican combined) are shown.

SOUTH PLATTE / METRO


North Sterling Reservoir
District 64
South Platte - Balzac to Stateline
STERLING
HOLYOKE
Wildhorse Creek
6
Prewitt Reservoir
385
59
76
FORT MORGAN
AKRON
34
WRAY
District 65
Arikaree River
District 1
tte - Greeley to Balzac
Beaver Creek
71
36
Arikaree River
South Fork Republican River
O Brien Reservoir Number
BURLINGTON
District 49
Republican River
ities
letro Basin
epublican Basin
CHEYENNE WELLS
40

4.8 SOUTH PLATTE BASIN RESULTS



4.8.1 BASIN CHALLENGES

Key future water management issues in this basin will be focused on meeting future water supply demands for a variety of sectors while complying with interstate compacts and maintaining Coloradans' quality of life. These challenges are described in the Colorado Water Plan and are summarized below.

Table 4.8.1 Key Future Water Management Issues in the South Platte Basin

Agriculture	Environment and Recreation	Municipal and Industrial	Compacts and Administration
• Agriculture is the dominant water use in the basin, but agricultural water transfers are likely to have negative effects on rural communities and the environment. • Depletions to the Ogallala Aquifer and long-term impacts to water supplies are a concern to agricultural viability.	• Environmental and recreational features in the basin are important to Colorado's quality of life and tourism economy.	• Competition for additional M&I supplies is substantial and increases costs to customers. • Lack of new storage projects has led to reliance on non-renewable groundwater supplies in quickly-urbanizing areas of the South Metro region. • Value judgements regarding irrigated landscaping complicate discussions about water development.	• A significant amount of the South Platte Basin's supply originates in the Colorado Basin and is subject to compact compliance. • Aquifer storage, while promising, poses control and administrative issues. • Republican River Compact compliance. • Coordination among water authorities in the Republican Basin is a challenge.
• Water quality will continue to be a challenge for all segments of water use. • Increases in M&I water use efficiency is critical but will reduce the quantity of water available for agriculture and the environment.			

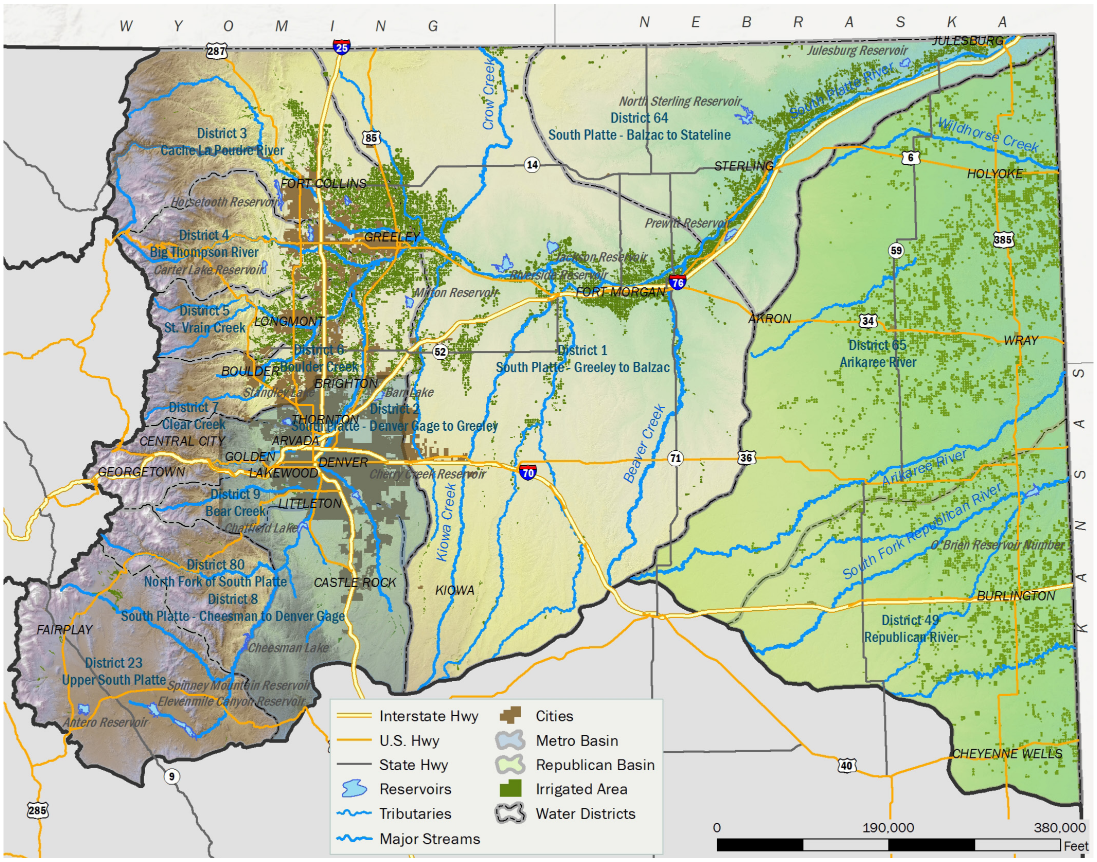


Figure 4.8.1 Map of the South Platte Basin

4.8.2 SUMMARY OF TECHNICAL UPDATE RESULTS

Key results and findings of the Technical Update pertaining to agricultural and M&I demands and gaps as well as findings related to environment and recreation attributes and future conditions are summarized below in Table 4.8.2.

Table 4.8.2 Summary of Key Results in the South Platte and Republican Basins

Agriculture	Environment and Recreation	Municipal and Industrial
• Future agricultural demands in the South Platte Basin are projected to decrease due to loss of irrigated lands from lack of groundwater sustainability. • Future agricultural demands in the South Platte Basin are projected to decrease due to loss of irrigated lands from urbanization and agricultural water transfers. • Agricultural gaps as a percentage of total demand in the South Platte Basin are not projected to greatly increase.	• In several locations in the mountains and foothills, climate-impacted scenarios show variable responses in peak flows. • On the plains, especially east of Interstate 25, flow conditions are projected to be poor for all aspects of ecosystem health. • In the mountains and foothills, climate-impacted scenarios show diminished mid- and late-summer flows.	• M&I demands in Adaptive Innovation are projected to be very similar to Business as Usual despite higher population and hotter/drier climate assumptions in Adaptive Innovation. This result demonstrates the value of higher levels of conservation. • Significant future gaps are estimated for each planning scenario, and they could be exacerbated by reductions in West Slope supplies.

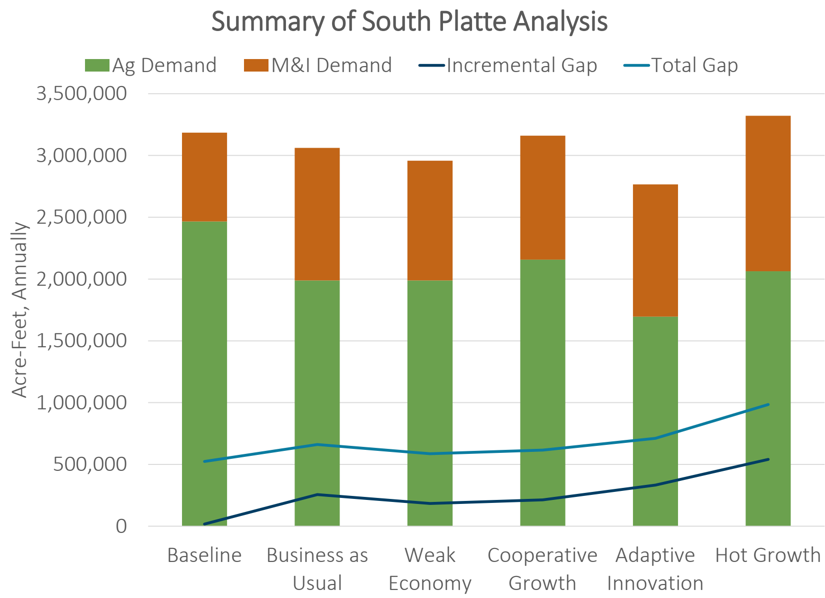
Results describing current and potential future M&I and agricultural demands and gaps are summarized in Table 4.8.3 and Figure 4.8.2.

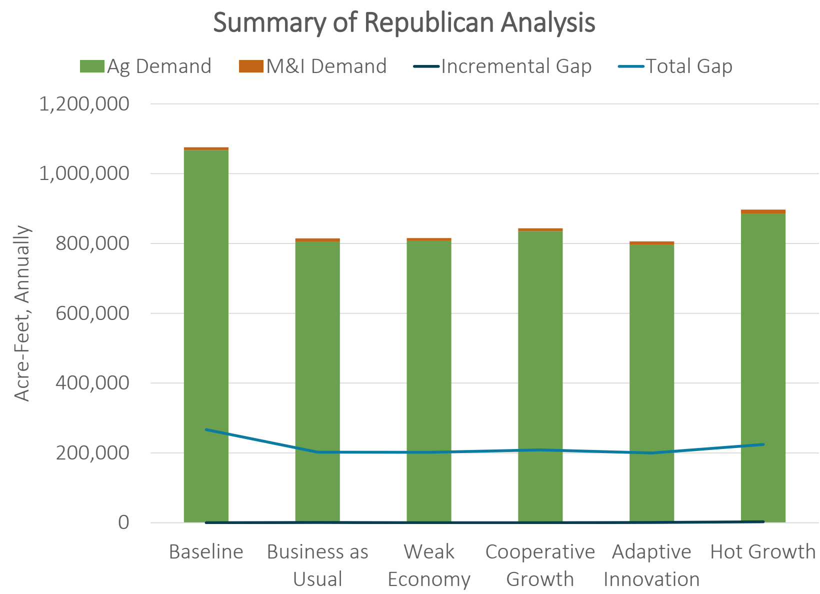
Table 4.8.3 Summary of Diversion Demand and Gap Results in the South Platte and Republican Basins

		Current (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
South Platte	**Average Annual Demand**						
	Agricultural (AFY)	2,465,800	1,988,700	1,988,700	2,157,400	1,696,500	2,063,100
	M&I (AFY)	718,700	1,073,000	968,900	1,002,800	1,070,100	1,257,700
	Gaps						
	Ag (avg %)	21%	20%	20%	19%	22%	22%
	Ag (incremental-AFY)	-	-	-	-	-	-
	Ag (incremental gap as % of current demand)	-	-	-	-	-	-
	M&I (max %)	0%	24%	19%	21%	31%	43%
	M&I (max-AF)	0*	256,300	184,500	213,300	333,200	540,700
Republican	**Average Annual Demand**						
	Agricultural (AFY)	1,067,200	805,500	807,500	835,300	797,200	885,800
	M&I (AFY)	8,400	9,200	7,900	8,100	8,900	11,200
	Gaps						
	Ag (avg %)	25%	25%	25%	25%	25%	25%
	Ag (incremental-AFY)	-	-	-	-	-	-
	Ag (incremental gap as % of current demand)	-	-	-	-	-	-
	M&I (max %)	0%	8%	0%	0%	6%	25%
	M&I (max-AF)	-	700	-	-	500	2,800
Total	**Average Annual Demand**						
	Agricultural (AFY)	3,533,000	2,794,200	2,796,100	2,992,700	2,493,700	2,948,900
	M&I (AFY)	727,100	1,082,200	976,800	1,010,900	1,079,100	1,268,900
	Gaps						
	Ag (avg %)	22%	22%	22%	20%	23%	23%
	Ag (incremental-AFY)	-	-	-	-	-	-
	Ag (incremental gap as % of current demand)	-	-	-	-	-	-
	M&I (max %)	0%	24%	19%	21%	31%	43%
	M&I (max-AF)	0*	257,100	184,500	213,300	333,700	543,500

**CDSS water allocation model in this basin calculates small baseline M&I gaps, but they are either due to calibration issues or they are reflective of infrequent, dry-year shortages that are typically managed with temporary demand reductions, such as watering restrictions.*

Figure 4.8.2 Summary of Diversion Demand and Gap Results in the South Platte and Republican Basins





Summary of Environment and Recreation Findings

- In several locations in the mountains and foothills, *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth* project variable responses to peak flows, in some cases increasing peak flow (thus improving or maintaining risk to plants and fish habitat) and in other cases diminishing peak flows and increasing risk to riparian/wetlands and fish habitat to high or very high.
- In the mountains and foothills, *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth* project diminished mid- and late-summer flows, increasing risk to fish. This risk may remain moderate; however, the metric used to assess risk for fish does not include the month of July because historically July flows are sufficient. Under *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*, July flows may drop substantially, increasing risk for fish.
- On the plains, especially east of Interstate 25, flow conditions are projected to be poor for all aspects of ecosystem health. Peak flows for riparian/wetlands are high risk under baseline conditions and are projected to remain so under all scenarios. Mid- and late-summer flows are very high risk for plains fishes and risk is projected to increase under all future scenarios.
- The recreational in-channel diversions may be met less often in the future.

4.8.3 NOTABLE BASIN CONSIDERATIONS

Section 4.1 described several analysis assumptions and limitations that apply to all basins and should be considered when reviewing and interpreting analysis results. Additional considerations specific to the South Platte Basin are listed below:

- Imports from transmountain diversion projects were set at historical levels and reflect historical operations. In climate-impacted scenarios, transmountain imports are projected to decrease, which could increase agricultural and M&I gaps. Gaps in the South Platte Basin would likely increase more than the reduction in transmountain imports because return flows from transmountain imports are used to extinction within the South Platte Basin by either the importing entity or by downstream agricultural and M&I water users.
- Stakeholders in the South Platte Basin suggested that purchase and transfer of senior irrigation water rights resulting in permanent reductions in irrigated acreage to municipal uses will continue through 2050 even though alternative water transfers have the potential to reduce reliance on transfers resulting in permanent dry up. Stakeholder estimates of acreage associated with these transfers were accounted for in the agricultural diversion demand and the modeling effort the same way urbanized lands were considered. Acreage purchased, transferred, and/or urbanized was quantified, but was not modeled as a future water supply strategy in this effort as it was unknown what municipal entity may benefit from resulting supply.
- Aquifer sustainability will be a primary focus of future water management strategies and activities in the Republican Basin.
- Due to on-going permitting efforts in the basin, the Cache La Poudre basin (Water District 3) was excluded from the CDSS surface water allocation model. Shortages to agriculture and M&I demands within the basin were informed by the results from nearby basins with similar characteristics (e.g. storage, C-BT supplies) to reflect the impact of climate adjustments on hydrology.
- No groundwater modeling was performed in either the South Platte or Republican basin. Groundwater pumping in the planning scenarios was estimated based on the premise that current groundwater pumping would either stay the same or be reduced in the future based on sustainability of groundwater supplies. Groundwater pumping was effectively reduced to account for sustainability concerns by removing acreage served by groundwater supplies.

4.8.4 AGRICULTURAL DIVERSION DEMANDS

Agricultural Setting

South Platte Basin

Approximately 854,000 acres are irrigated in the South Platte Basin. It is the highest producing basin in the state in terms of the value of agricultural products sold. Irrigated lands are located along and adjacent to the South Platte River and its tributaries and stretch to the state line.

Farmers divert surface water and pump groundwater. In many cases, both sources of supply are available to irrigate South Platte Basin farms. Much of the surface water supply in the basin is generated via return flows as an upstream irrigators' inefficiencies become the water supply for downstream irrigators.

The amount of irrigated land in the basin is anticipated to decrease in the future. Urbanization will impact irrigated lands in and around the basin's municipalities by 2050. The majority of urbanization of irrigated land (60 percent) is projected to occur in the St. Vrain River, Big Thompson River, and Cache La Poudre River basins. These basins have some of the highest concentrations of irrigated land adjacent to municipalities that are projected to increase in population. Although large population increases are also anticipated in and around the Denver Metropolitan area, the concentration of irrigated land that could be urbanized is less. Acquisition of senior water rights by "buy and dry" methods is also expected to reduce the amount of irrigated land in the basin.

Republican Basin

The Republican Basin has nearly 580,000 irrigated acres, making it one of the highest producing basins of irrigated crops in the state. The basin has very limited surface water supplies. As a result, irrigators rely on groundwater supplies from the High Plains Aquifer (also known as the Ogallala Aquifer). Approximately 10 percent of total pumping is subject to the Republican River Compact, with the remaining 90 percent pumped from "storage" in the High Plains Aquifer. Groundwater pumping is managed by several groundwater management districts in the basin.

The current amount of irrigated land in the basin is expected to decline in the future. Absent the development of an alternative means to reduce consumptive use, irrigated lands will need to be retired to maintain compliance with the Republican River Compact. In addition, declining saturated thickness in the High Plains Aquifer will also lead to the retirement of groundwater-irrigated lands.

Planning Scenario Adjustments

South Platte Basin

The South Platte Basin is expected to experience the largest municipal growth in the state by 2050, straining already limited water supplies and increasing competition among municipal, industrial, agricultural, environmental and recreation users in the basin. The planning scenarios contemplate various pressures that may affect basin agriculture and consider increased urbanization of irrigated lands, increased municipal conversions of agricultural water supplies, limited augmentation supplies, and higher irrigation demands due to a warmer climate.

Adjustments to agricultural diversion demands were made to reflect the above considerations. Stakeholder outreach was conducted to estimate the amount of irrigated land that could be lost from transfers of water from agriculture to municipal providers and the loss of groundwater-irrigated land due to insufficient augmentation supplies. In addition, the Agricultural Technical Advisory Group provided input on the level of future increases in irrigation efficiency and reductions in future IWR due to advances in agronomic technologies. Table 4.8.4 summarizes the adjustments that were made in each of the planning scenarios to reflect assumed future conditions in agriculture.

Republican Basin

The sustainability of groundwater supplies will be the primary source of future pressure to irrigated agriculture in the Republican Basin. As described previously, irrigated lands are likely going to be retired to comply with the Republican River Compact and also as a result of declining water levels in the High Plains Aquifer. Stakeholder outreach informed the assumptions that were used to reduce irrigated acreage under each of the planning scenarios. Table 4.8.4 summarizes the planning scenario adjustments used to reflect these conditions and other adjustments that impact agricultural diversion demands basin

Table 4.8.4 Planning Scenario Adjustments for Agricultural Demands in the South Platte and Republican Basins

Sub-basin	Adjustment Factor*	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Inno-vation	Hot Growth
South Platte	Change in Irrigated Land due to Urbanization & Municipal Transfers	105,900 Acre Reduction	105,900 Acre Reduction 20% SW Acre Reduction (WD 1 & 64)	105,900 Acre Reduction 20% SW Acre Reduction (WD 1 & 64)	105,900 Acre Reduction 20% SW Acre Reduction (WD 1 & 64)	105,900 Acre Reduction 20% SW Acre Reduction (WD 1 & 64)
	Groundwater Acreage Sustainability	20% GW-Only Acre Reduc-tion (Central)	20% GW-Only Acre Reduc-tion (Central)	20% GW-Only Acre Reduc-tion (Central)	20% GW-Only Acre Reduction (Central)	20% GW-Only Acre Reduc-tion (Central)
	IWR Climate Factor	-	-	15%	24%	24%
	Emerging Technologies	85% GW Only Acreage in Sprinkler	85% GW Only Acreage in Sprinkler	90% GW Only Acreage in Sprinkler	90% GW Only Acreage in Sprinkler 10% IWR Reduction 10% System Efficiency Increase	90% GW Only Acreage in Sprinkler
Republican	Change in Irrigated Land due to Urbanization	1,410 Acre Reduction	-	1,410 Acre Reduction	1,410 Acre Reduction	1,410 Acre Reduction
	Groundwater Acreage Sustainability	135,420 Acre Reduction	135,420 Acre Reduction	135,420 Acre Reduction	135,420 Acre Reduction	135,420 Acre Reduction
	IWR Climate Factor	-	-	4%	11%	11%
	Emerging Technologies	-	-	-	10% IWR Reduction	-

**See section 2.2.3 for descriptions of adjustment methodologies and assumptions*

Agricultural Diversion Demand Results

Table 4.8.5 and Figures 4.8.3 and 4.8.4 summarize the acreage, IWR, and agricultural diversion demand in both the South Platte and Republican basins for current conditions and the five planning scenarios. Note that in the South Platte Basin, surface water and groundwater sources are used for irrigation, and a breakout of diversion demand for these sources is included in the technical memorandum *Current and Projected Planning Scenario Agricultural Diversion Demands* (see Volume 2). All agricultural diversion demands in the Republican Basin were from groundwater sources.

SYSTEM EFFICIENCY

In some cases, diversion demands surface water can be higher in wet years because system efficiency decreases due to the relative abundance of supply.

Future agricultural diversion demands in both the South Platte and Republican Basins are anticipated to be lower in the future due primarily to the loss of irrigated land. While assumptions of a warmer climate increase IWR in *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*, the loss of irrigated land may offset the additional IWR demand, resulting in lower future demands. Projected increases in IWR due to a warmer climate are the same in *Adaptive Innovation* and *Hot Growth*, but the agricultural diversion demand is lower in *Adaptive Innovation* due to the assumed 10 percent reduction in IWR from emerging technologies and a 10 percent increase in system efficiency. Agricultural diversion demands in the South Platte are relatively consistent in wet, average, and dry years due to surface water irrigation system efficiencies that fluctuate in differing hydrologic conditions. Republican Basin irrigation is provided from groundwater, and system efficiencies of wells do not fluctuate. As a result, agricultural diversion demands in the Republican Basin change to a greater degree in response to hydrologic conditions.

Table 4.8.5 Summary of Agricultural Diversion Demand Results in the South Platte and Republican Basins

		Current	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
South Platte	Irrigated Acreage (acres)	854,300	701,100	701,100	722,400	722,400	679,900
	Average IWR (AFY)	1,500,000	1,225,000	1,225,000	1,341,000	1,264,000	1,323,000
	Total Surface Water and Groundwater Diversion Demand						
	Average Year (AFY)	2,589,000	2,081,000	2,081,000	2,268,000	1,771,000	2,202,000
	Wet Yr. Change	-6%	-6%	-6%	-4%	-4%	-4%
	Dry Yr Change	2%	2%	2%	1%	2%	-1%
Republican	Irrigated Acreage (acres)	578,800	442,000	443,400	442,000	442,000	442,000
	Average IWR (AFY)	837,000	635,000	636,000	661,000	649,000	721,000
	Groundwater Diversion Demand						
	Average Year (AFY)	1,056,000	800,000	802,000	833,000	799,000	888,000
	Wet Yr. Change	-14%	-15%	-15%	-14%	-13%	-13%
	Dry Yr Change	20%	21%	21%	18%	14%	14%

Figure 4.8.3 Agricultural Diversion Demands and IWR Results in the South Platte Basin

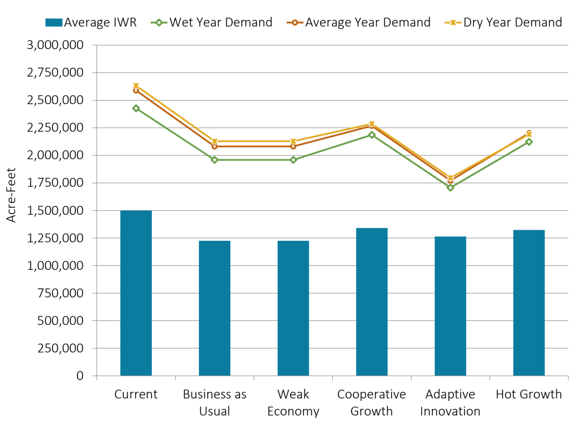
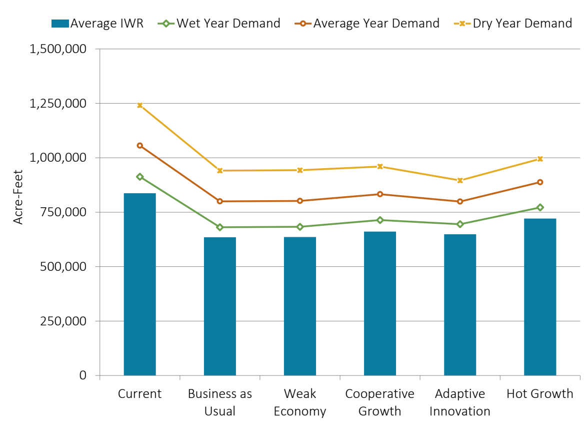


Figure 4.8.4 Agricultural Diversion Demands and IWR Results in the Republican Basin



4.8.5 Municipal and Self-Supplied Industrial Diversion Demands

For purposes of the M&I demand reporting, the South Platte Basin includes three sub-basins—the Metro Region as defined by the basin roundtables, the Republican Basin, and the remainder of the South Platte Basin. SWSI 2010 included the Republican Basin demands in the reporting of the South Platte Basin demands, but separately reported M&I demands for the Metro Region. The Republican Basin was evaluated separately in the water supply and gap analysis in the Technical Update, and the Metro Region demands were analyzed in the South Platte Basin modeling of water supplies and gaps. The three sub-basins are each summarized in the following subsections, along with the combined South Platte Basin.

Population Projections

The South Platte Basin as a whole is currently the most populous basin and includes about 70 percent of the statewide population. The Metro Region holds the majority of the population at 51 percent of the statewide total. The remaining portion of the South Platte Basin has 19 percent of the statewide population, and the Republican Basin has less than 1 percent.

Between the years 2015 and 2050, the South Platte Basin as a whole is projected to grow from approximately 3.8 million people to between 5.4 million and 6.5 million people in the low and high growth scenarios, respectively, which represents an increase in population of 42 to 70 percent. Table 4.8.6 shows how population growth is projected to vary across the planning scenarios for the South Platte Basin.

Table 4.8.6 South Platte Basin 2015 and Projected Populations

Sub-basin	Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Metro Region	2,768,000	4,062,000	3,817,000	3,922,000	4,162,000	4,318,000
Republican Basin	32,000	35,000	30,000	34,000	38,000	41,000
Remaining South Platte Basin	1,030,000	1,857,000	1,586,000	1,929,000	2,292,000	2,149,000
Total South Platte Basin	3,830,000	5,954,000	5,433,000	5,884,000	6,492,000	6,508,000

Current Municipal Demands

The Metro Region baseline water demands were largely based on water provider-reported data and had the highest representation of 1051 data for any basin or region in the state. The Republican Basin baseline water demands were largely estimated, and the remaining South Platte Basin baseline demands were largely based on water provider-reported data (see figures below).

Figure 4.8.5 Sources of Water Demand Data in the Metro Region

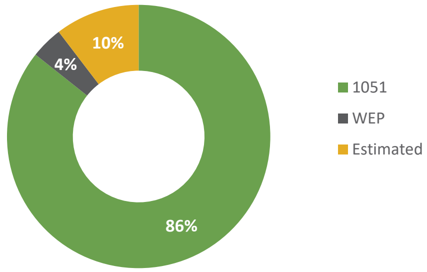


Figure 4.8.6 Sources of Water Demand Data in the Republican Basin

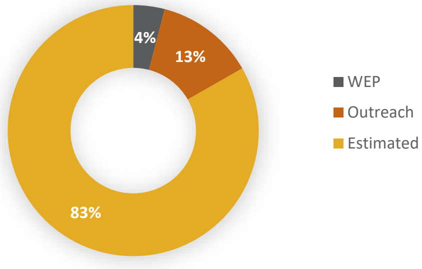


Figure 4.8.7 Sources of Water Demand Data in the Remaining South Platte Basin

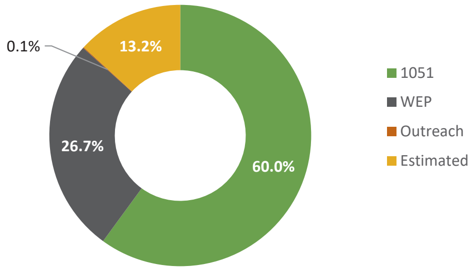
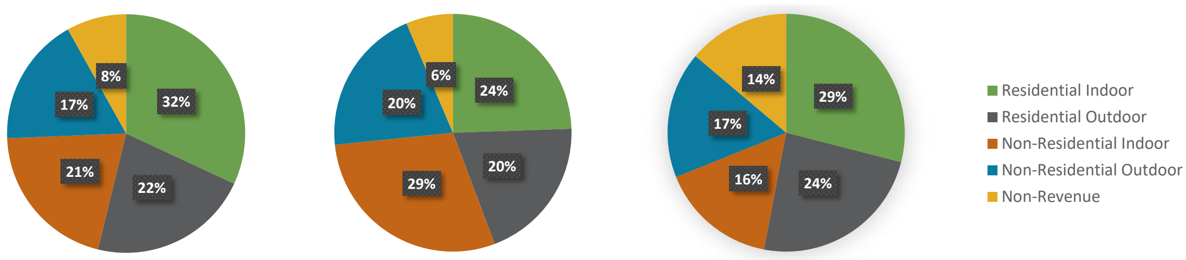


Figure 4.8.8 summarizes the categories of municipal, baseline water usage in the Metro Region, Republican Basin, and the remaining South Platte Basin. In the Metro Region and Republican Basin, non-revenue water as a percentage of systemwide demands is among the lowest in the state (with the Republican Basin being the lowest). Usage percentages in the Metro Region have a significant impact on statewide average, because a significant portion of the state population is located in the Metro Region.

Figure 4.8.8 Categories of Water Usage in the South Platte Basin



Projected Municipal Demands

Figures 4.8.9 through 4.8.11 provide summaries of per capita baseline and projected water demands for the Metro Region, Republican Basin, and the remaining South Platte Basin, respectively. In each basin, systemwide projected per capita demands decrease relative to the baseline except for *Hot Growth*. Additionally, the assumption of a hot and dry climate in *Hot Growth* is projected to cause a significant increase in outdoor demands in each region. Additional observations regarding the demand categories specific to each region are described below:

Metro Region

Consistently across all scenarios, residential indoor demand is the greatest individual demand category; non-revenue water is the lowest.

Republican Basin

Non-residential indoor demand is the greatest individual demand category; non-revenue water is the lowest in all of the scenarios.

Remaining South Platte Basin

The residential indoor demand is the greatest demand category in the baseline, but the residential outdoor demand is projected to exceed the residential indoor demand in *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*.

DECREASING GPCD

The Metro Region average baseline per capita systemwide demand has decreased from 155 gpcd in SWSI 2010 to approximately 141 gpcd. Other areas of the South Platte cannot be directly compared because of differences in reporting.

Figure 4.8.9 Metro Region Municipal Baseline and Projected Per Capita Demands by Water Demand Category

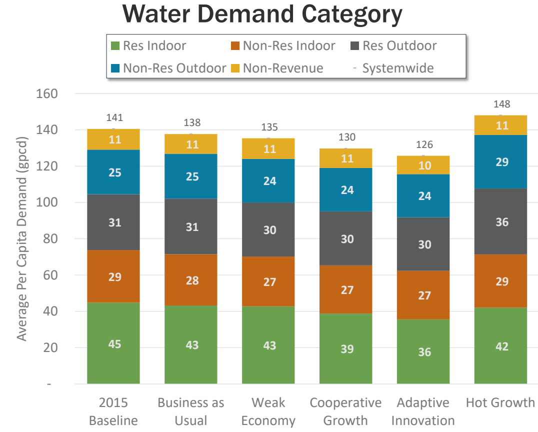


Figure 4.8.10 Republican Basin Municipal Baseline and Projected Per Capita Demands by Water Demand Category

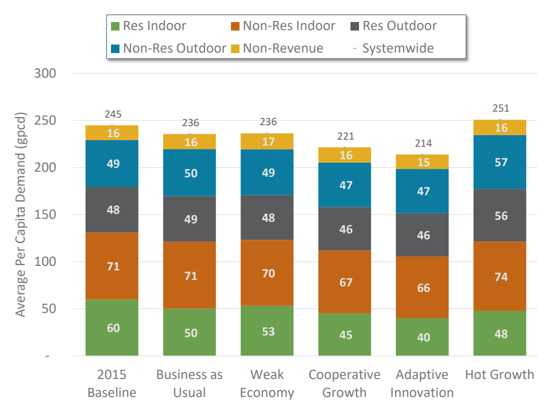
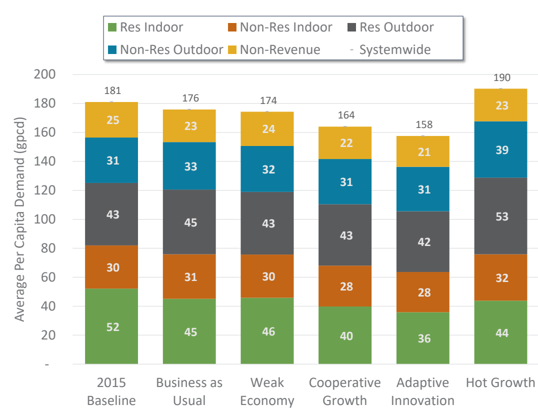


Figure 4.8.11 Remaining South Platte Basin Municipal Baseline and Projected Per Capita Demands by Water Demand Category



The South Platte Basin municipal baseline and projected demands are provided in Table 4.8.7, which shows the combined effect of population and per capita demands. Municipal demands are projected to grow from approximately 653,000 AFY in 2015 to between 897,000 and 1,185,000 AFY in 2050.

Table 4.8.7 South Platte Basin Municipal Baseline and Projected Demands (AFY)

Sub-basin	Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Metro Region	436,000	627,000	579,000	570,000	586,000	716,000
Republican Basin	9,000	9,000	8,000	8,000	9,000	12,000
Remaining South Platte Basin	209,000	366,000	310,000	354,000	405,000	458,000
Total South Platte Basin	653,000	1,002,000	897,000	933,000	1,000,000	1,185,000

The baseline and projected demand distributions for each region and for the South Platte Basin as a whole are shown in Figures 4.8.12 through 4.8.15.

Figure 4.8.12 Metro Region Baseline and Projected Population and Municipal Demands

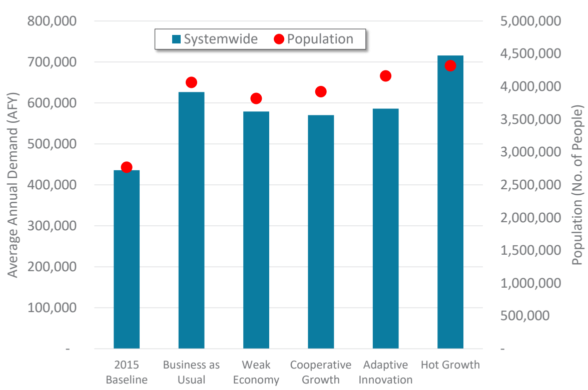


Figure 4.8.13 Republican Baseline and Projected Population and Municipal Demands

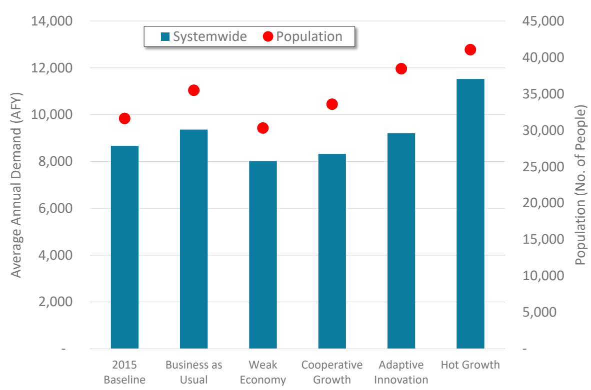


Figure 4.8.14 Remaining South Platte Baseline and Projected Population and Municipal Demands

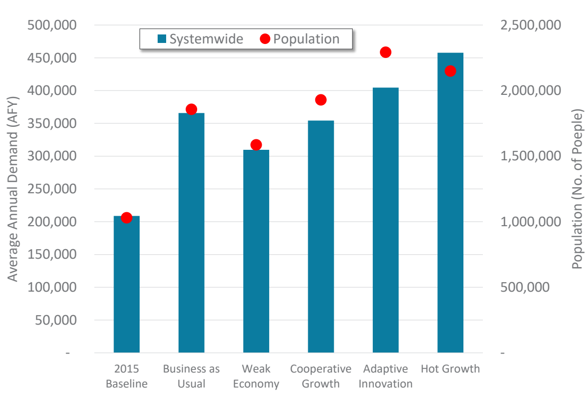
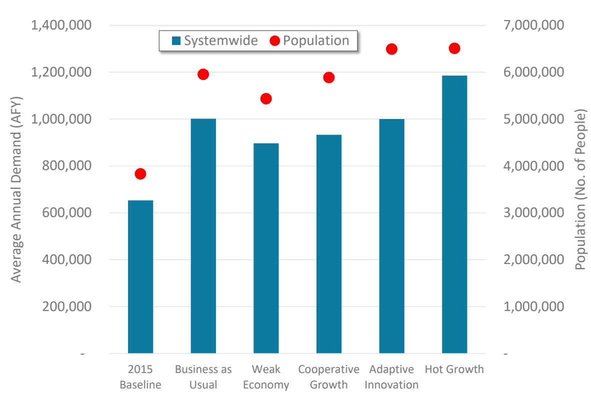


Figure 4.8.15 Total South Platte Basin Baseline and Projected Population and Municipal Demands



Below are some observations on the projected demands and population projections:

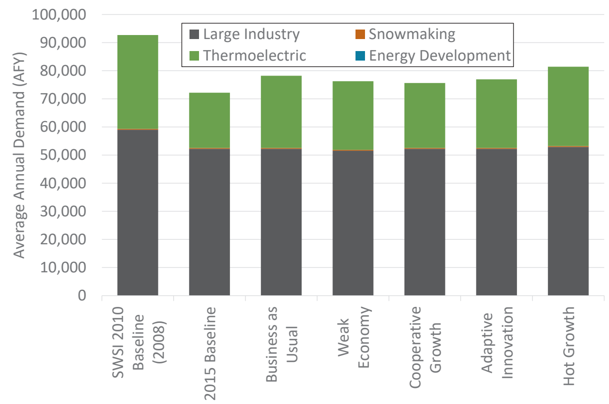
Table 4.8.8 Observations on South Platte Basin M&I Demands

Metro Region	Republican Basin	Remaining South Platte Basin	South Platte Basin/Basin-wide
• All of the planning scenarios result in an increase relative to the baseline. • Projected demand for *Weak Economy, Cooperative Growth, and Adaptive Innovation* are all within 3% of each other, even though each scenario has a different population projection.	• Demands are projected to decrease relative to the baseline in *Weak Economy and Cooperative Growth*.	• All of the planning scenarios result in an increase relative to the baseline. • Projected demands tend to follow population trends, except for *Adaptive Innovation* in which the population exceeds *Hot Growth* but the systemwide demand projection is lower, which shows the influence of projected per capita demands for this basin.	• All of the projection scenarios result in an increase relative to the baseline. • Projected demands in *Business as Usual* and *Adaptive Innovation* are similar, although population projected for *Adaptive Innovation* is about 10% higher.

Self-Supplied Industrial Demands

The South Platte Basin includes about 40 percent of the statewide SSI demand. Approximately 67 percent of the baseline SSI demands are in the Metro Region and 33 percent are in the remaining South Platte Basin. There are no SSI demands in the Republican Basin. SSI demands in the South Platte Basin are associated with the Large Industry, Snowmaking, and Thermoelectric sub-sectors. No demands were projected for the Energy Development sub-sector because no reliable data were available. Basin-scale SSI demands are shown on Figure 4.8.16 and Table 4.8.9.

Figure 4.8.16 Total South Platte Basin Self-Supplied Industrial Demands



Large Industry demands in this basin are located in three counties. Baseline demands in Jefferson County were based on data from an existing hydrologic model, and projected demands were not varied by scenario at the direction of the water user. Large Industry demands in Morgan and Weld counties were based on SWSI 2010. The baseline demand has decreased relative to SWSI 2010 due to reductions in Jefferson County.

The baseline snowmaking demand is 300 AFY (slightly less than in SWSI 2010 due to a reduction in snowmaking acres). Projected demands are 320 AFY and were not varied by scenario.

Thermoelectric demands are related to eight facilities in seven counties. Baseline demands for seven of the eight facilities were updated based on information from Xcel Energy.

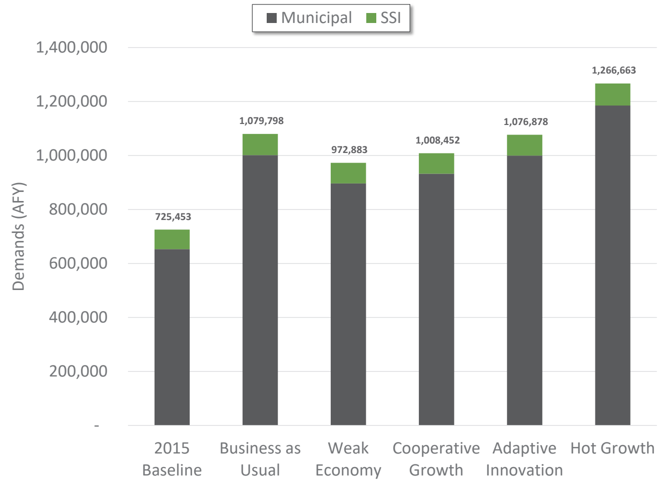
Table 4.8.9 Total South Platte Basin SSI Baseline and Projected Demands (AFY)

	Sub-sector	Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Metro Region	Large Industry	45,630	45,630	45,630	45,630	45,630	45,630
	Snowmaking	0	0	0	0	0	0
	Thermoelectric	3,040	3,040	2,890	2,740	2,890	3,350
	Energy Development	0	0	0	0	0	0
	Sub-Basin Total	48,670	48,670	48,520	48,370	48,520	48,980
Remaining South Platte Basin	Large Industry	6,600	6,600	5,940	6,600	6,600	7,260
	Snowmaking	300	320	320	320	320	320
	Thermoelectric	16,630	22,630	21,500	20,370	21,500	24,890
	Energy Development	0	0	0	0	0	0
	Sub-Basin Total	23,530	29,550	27,760	27,290	28,420	32,470
	Basin Total	**72,200**	**78,220**	**76,280**	**75,660**	**76,940**	**81,450**

Total M&I Diversion Demands

South Platte Basin combined M&I demand projections for 2050 range from approximately 970,000 AFY in *Weak Economy* to 1.27 million AFY in *Hot Growth*, as shown in Figure 4.8.17. SSI demands account for 6 to 10 percent of the M&I demands. On a basin scale, the demand projections do not follow the statewide sequence of the scenario rankings described in the CWP, with *Adaptive Innovation* falling out of sequence.

Figure 4.8.17 South Platte Basin Municipal and Self-Supplied Industrial Demands



4.8.6 Water Supply Gaps

Water supply gap estimates for the five planning scenarios were calculated differently for the South Platte and Republican basins as described in Section 2 and are, therefore, presented separately. In addition, while the CDSS water allocation models used for the water supply gap analysis in the South Platte Basin are able to generate a rich set of demand, supply, and gap data, it is difficult to parse results according to the boundaries of the Metro Region and remaining South Platte Basin. As a result, water supply gaps are described for the combined Metro Region and remaining South Platte Basin.

The agricultural and M&I diversion demands were compared against available water supply modeled for current conditions and the five planning scenarios. Gaps were calculated when water supply was insufficient to meet demands.

South Platte Basin Gaps

Agricultural

The South Platte Basin agricultural diversion demands, demand gaps, and consumptive use gaps for the baseline and planning scenarios are presented in Table 4.8.10 and illustrated in Figure 4.8.18. An annual time series of gaps in terms of percent of demand that was unmet is shown in Figure 4.8.19.

Table 4.8.10 South Platte Basin Agricultural Gap Results (AFY)

		Scenario					
		Scenario	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average	Average Annual Demand	2,465,800	1,988,700	1,988,700	2,157,400	1,696,500	2,063,100
	Average Annual Gap	506,700	404,900	402,100	402,100	378,300	444,000
	Average Annual Gap Increase from Baseline	-	-	-	-	-	-
	Average Annual Percent Gap	21%	20%	20%	19%	22%	22%
	Average Annual CU Gap	278,000	220,400	218,700	220,300	237,800	247,600
Maximum	Demand in Maximum Gap Year	2,982,300	2,411,200	2,411,200	2,419,700	2,006,200	2,360,900
	Gap in Maximum Gap Year	1,206,100	978,400	960,700	901,900	824,800	1,064,000
	Percent Gap in Maximum Gap Year	-	-	-	-	-	-
	Increase from Baseline Gap	40%	41%	40%	37%	41%	45%

Study period for Water Supply Analysis is 1975-2013, reflecting different baseline demand than described in Agricultural Diversion Demands section.

Figure 4.8.18 Projected Average Annual Agricultural Diversion Demand, Demand Met, and Gaps in the South Platte Basin

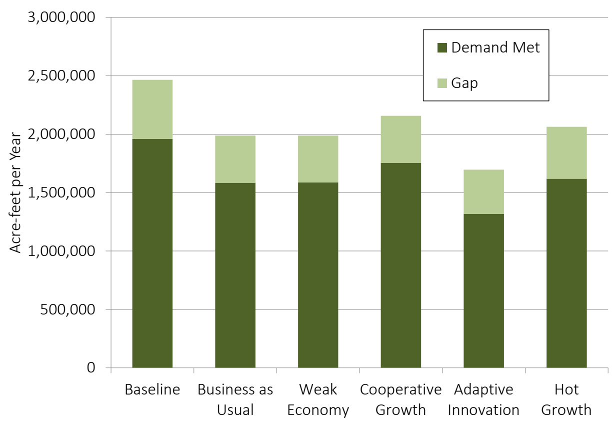
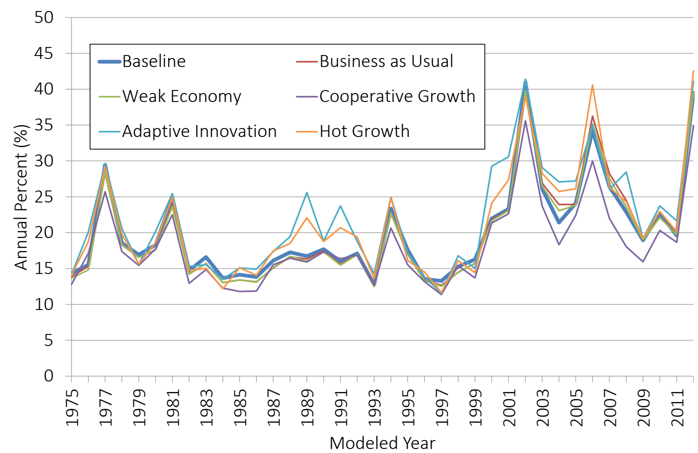


Figure 4.8.19 Annual Agricultural Gaps (expressed as a percentage of demand) for Each Planning Scenario



The following are observations on the agricultural diversion demand and gap results:

- In the South Platte Basin, the current agricultural gap is significant but is not projected to increase greatly in the future as a percentage of demand.
- On a volumetric basis, gaps are projected to decrease as agricultural diversion demands decrease, primarily from urbanization and potential conversion of agricultural water rights to municipal use.
- As shown in Figure 4.8.18, current and future agricultural gap simulation results hovered at around 15 percent of total demand in normal to wetter periods but increased during dry periods.
- In many years, the agricultural gaps in *Adaptive Innovation* and *Hot Growth* are projected to be higher than in other scenarios because of higher irrigation demands and lower supplies associated with the hot and dry future climate assumption. Overall, however, gaps in *Adaptive Innovation* are lower than *Hot Growth* because of the adoption of emerging technologies that lower demand.

M&I

The diversion demand and gap results for M&I uses in the South Platte Basin are summarized in Table 4.8.11 and illustrated in Figure 4.8.20. An annual time series of gaps in terms of percent of demand that was unmet is shown in Figure 4.8.21.

Table 4.8.11 South Platte Basin M&I Gap Results (AFY)

		Scenario					
		Scenario	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average	Average Annual Demand	718,700	1,073,000	968,900	1,002,800	1,070,100	1,257,700
	Average Annual Gap	0*	192,800	136,600	159,800	221,400	390,600
	Average Annual Percent Gap	0%	18%	14%	16%	21%	31%
Maximum	Demand in Maximum Gap Year	720,000	1,074,300	970,200	1,004,100	1,070,200	1,257,700
	Gap in Maximum Gap Year	0*	256,300	184,500	213,300	333,200	540,700
	Percent Gap in Maximum Gap Year	0%	24%	19%	21%	31%	43%

**CDSS water allocation model in this basin calculates small baseline M&I gaps, but they are either due to calibration issues or they are reflective of infrequent, dry-year shortages that are typically managed with temporary demand reductions, such as watering restrictions.*

Study period for Water Supply Analysis is 1975-2013, which reflects a different baseline demand than described in M&I Demand section. Baseline demand also may vary slightly from previous section due to differences in geographic distribution of demand for counties that lie in multiple basins.

Figure 4.8.20 Projected Maximum Annual M&I Diversion Demand, Demand Met, and Gaps in the South Platte Basin

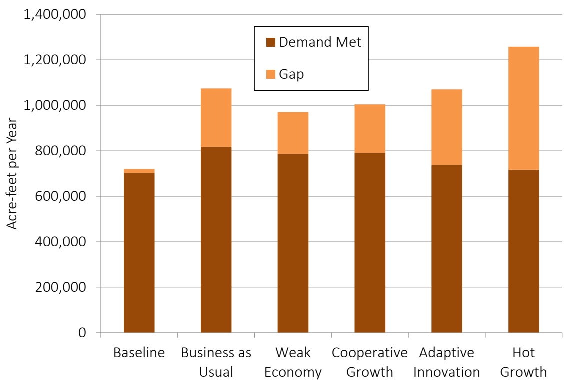
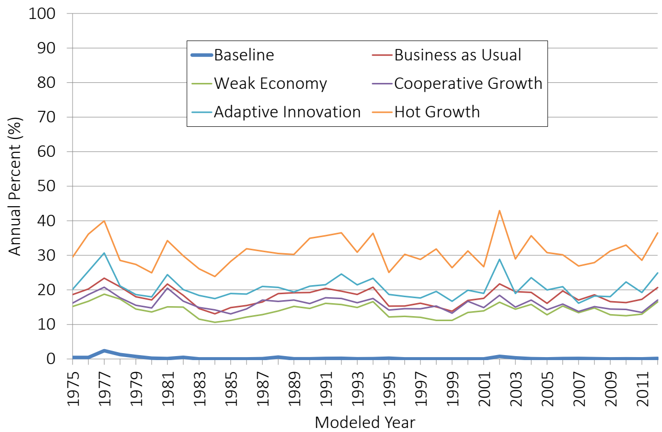


Figure 4.8.21 Annual M&I Gaps (expressed as a percentage of demand) for Each Planning Scenario



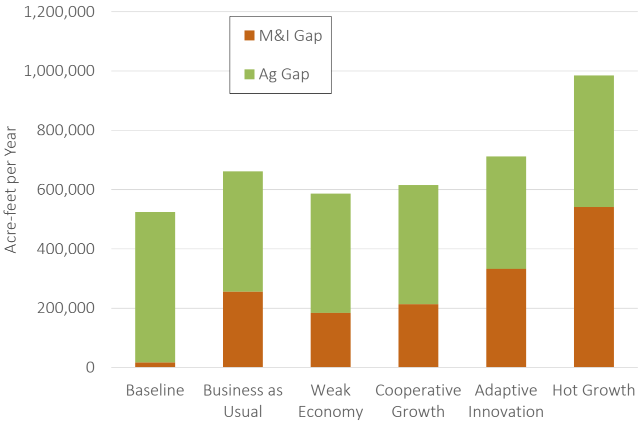
The following are observations on the M&I diversion demand and gap results:

- Gaps under *Hot Growth* are projected to be significantly higher than in other scenarios.
- *Adaptive Innovation* includes similar assumptions to *Hot Growth* in terms of future climate conditions and population projections; however, annual gaps and maximum gaps (as shown in Figure 4.8.19) are projected to be much less, which demonstrates the value of conservation. In addition, the gaps for *Business as Usual* and *Adaptive Innovation* are projected to be very similar even though *Adaptive Innovation* incorporates high population growth and a hot and dry future climate condition. The similarity in gaps suggests that additional conservation on a basinwide scale will help offset additional demands from population growth and climate change. Nonetheless, gaps in *Adaptive Innovation* are projected to be significant and point to the need for developing additional water supplies.
- The persistent nature of the time series of gaps in Figure 4.8.20 points to the need for projects that will provide firm yield.
- Figure 4.8.20 also shows that gaps can increase significantly during dry periods, especially in *Adaptive Management* and *Hot Growth* (the scenarios most severely impacted by future climate assumptions). Projects and water management strategies will be needed to meet periodic maximum M&I gaps.

Total Gap

Figure 4.8.22 illustrates the total combined agricultural and M&I diversion demand gap in the South Platte Basin. The figure combines the average annual agricultural gaps and the maximum M&I gap. Note that agricultural gaps are projected to decrease in the future, and therefore an incremental gap is not shown in the figure.

Figure 4.8.22 Projected Average Annual Agricultural Gaps and Maximum M&I Diversion Demand Gaps in the South Platte Basin.



Supplies from Urbanized Lands and Planned Transfers

The planning scenarios assumed between 127,100 and 169,600 acres of irrigated agricultural land will be urbanized or no longer irrigated because of planned water right transfers from agricultural to municipal use in the South Platte Basin. Irrigation supplies for urbanized lands could potentially be used for M&I needs in the future (subject to a variety of unknowns such as seniority and type of water supply, willingness to change the use of water through water court, etc.). Acreage associated with planned transfers was derived based on stakeholder input.

The average annual historical consumptive use associated with potentially urbanized acreage and planned water right transfers for each scenario is reflected in Table 4.8.12. The data in Table 4.8.12 represents planning-level estimates of this potential supply and has not been applied to the M&I gaps. The data in the table do not represent supplies from permanent water transfers that may be considered by a basin roundtable as a future strategy to meet gaps (note that SWSI 2010 included estimates of permanent transfers beyond those currently planned as a strategy for meeting potential future M&I gaps).

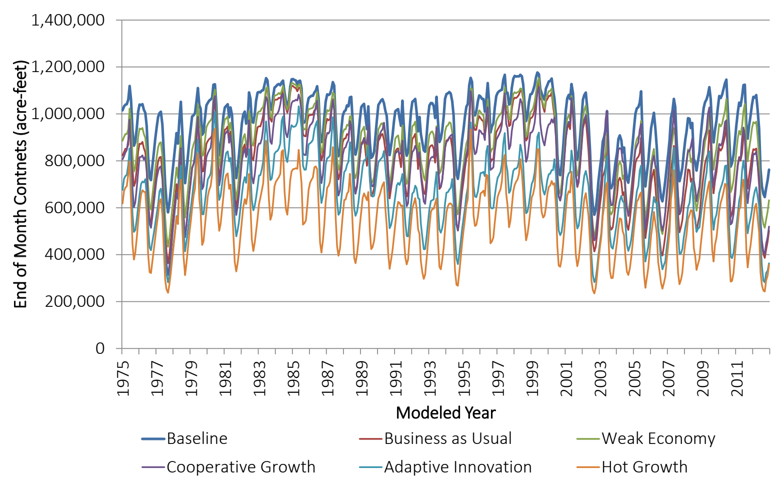
Table 4.8.12 Estimated Consumptive Use from Lands Projected to be Urbanized by 2050 and Planned Transfers in the South Platte Basin

	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Urbanized Acreage and Lands Subject to Planned Transfers (acres)	148,400	148,400	127,100	127,100	169,600
Estimated Consumptive Use (AFY)	209,800	210,200	179,400	172,700	238,600

Storage

Total reservoir storage output from the South Platte water allocation model is shown on Figure 4.8.23. Baseline conditions show the highest levels of water in storage (in general) and the lowest is in *Hot Growth*. *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth* show lower amounts of water in storage than the two scenarios that do not include the impacts of a drier climate. The results indicate that, without new projects, higher demands will draw storage down to lower levels. Concurrent drier conditions will impede full recovery of reservoirs. Lower demands in *Adaptive Innovation* help reservoir levels stay somewhat higher than in *Hot Growth*. It should be noted that the water allocation model allows reservoirs to be drawn down to the full extent water rights and storage amounts allow. Water providers would likely not be comfortable operating with chronically lower amounts of water in storage and would seek to acquire additional supplies or build new projects to boost reserves.

Figure 4.8.23 South Platte Basin Total Reservoir Storage (not including Water District 3)



Republican Basin Gaps

Agricultural

The Republican Basin agricultural diversion demands, demand gaps, and consumptive use gaps for the baseline and planning scenarios are presented in Table 4.8.13 and illustrated in Figure 4.8.24.

Table 4.8.13 Republican Basin Agricultural Gap Results (AFY)

		Scenario					
		Scenario	**Business as Usual**	**Weak Economy**	**Cooperative Growth**	**Adaptive Innovation**	**Hot Growth**
Average	Average Annual Demand	1,067,200	805,500	807,500	835,300	797,200	885,800
	Average Annual Gap	266,800	201,400	201,900	208,800	199,300	221,400
	Average Annual Gap Increase from Baseline	-	-	-	-	-	-
	Average Annual Percent Gap	25%	25%	25%	25%	25%	25%
	Average Annual CU Gap	211,400	159,800	160,200	165,700	161,600	179,600
Maximum	Demand in Maximum Gap Year	1,445,200	1,113,000	1,114,700	1,113,200	1,014,400	1,127,100
	Gap in Maximum Gap Year	361,300	278,300	278,700	278,300	253,600	281,800
	Increase from Baseline Gap	-	-	-	-	-	-
	Percent Gap in Maximum Gap Year	25%	25%	25%	25%	25%	25%

Study period for Water Supply Analysis is 1975-2013, reflecting different baseline demand than described in Agricultural Diversion Demands section.

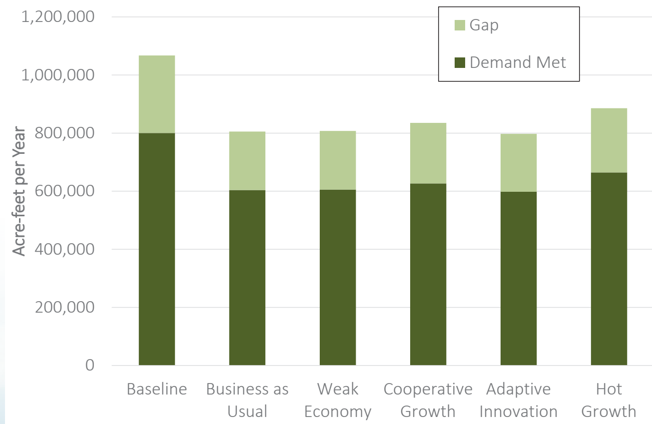
The following are observations on agricultural diversion demands and gaps:

- Both diversion demands and gaps will likely decrease in the future due to reduction of irrigated lands in order to comply with the Republican River Compact and also as a result of declining water levels in the High Plains Aquifer.
- Even with reduced demand, reduced supplies will result in a fairly consistent gap in the future of approximately 25 percent of demand.

INCREMENTAL GAP

The incremental agricultural gap quantifies the degree to which the gap could increase beyond what agriculture has historically experienced under water shortage conditions.

Figure 4.8.24 Projected Average Annual Agricultural Diversion Demand, Demand Met, and Gaps in the Republican Basin



M&I

The diversion demand and gap results for M&I uses in the Republican Basin are summarized Table 4.8.14 and illustrated in Figure 4.8.25.

Table 4.8.14 Republican Basin M&I Gap Results (AFY)

		Scenario					
		Scenario	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average	Average Annual Demand	8,400	9,200	7,900	8,100	8,900	11,200
	Average Annual Gap	-	1,300	-	-	1,100	3,300
	Average Annual Percent Gap	0%	14%	0%	0%	12%	30%
Maximum	Demand in Maximum Gap Year	8,400	9,200	7,900	8,100	8,900	11,200
	Gap in Maximum Gap Year	-	1,300	-	-	1,100	3,300
	Percent Gap in Maximum Gap Year	0%	14%	0%	0%	12%	30%

Total Gap

Figure 4.8.26 illustrates the total combined agricultural and M&I diversion demand gap in the Republican Basin. The figure combines the average annual agricultural gaps and the maximum M&I gap. Note that agricultural gaps are projected to decrease in the future, and therefore an incremental gap is not shown in the figure.

Supplies from Urbanized Lands

The planning scenarios assumed 1,400 acres of irrigated agricultural land will be urbanized in the Republican Basin. Irrigation supplies for these lands could potentially be used for M&I needs in the future (subject to a variety of unknowns such as seniority and type of water supply, willingness to change the use of water through water court, etc.). The average annual historical consumptive use associated with potentially urbanized acreage for each scenario is reflected in Table 4.8.15. The data in Table 4.8.15 represents planning-level estimates of this potential supply and has not been applied to the M&I gaps.

Figure 4.8.25 Projected Maximum Annual M&I Demand Met and Gaps in the Republican Basin

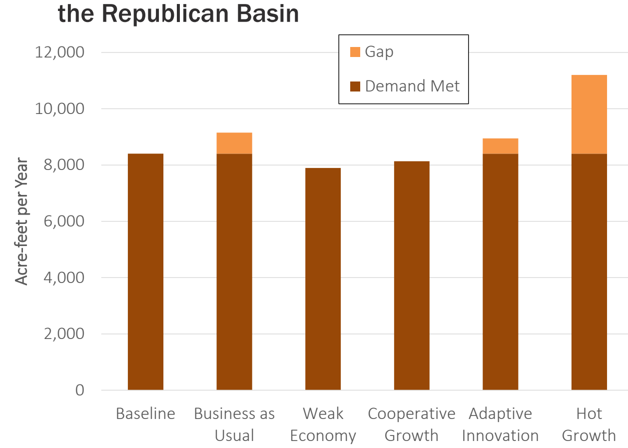


Figure 4.8.26 Projected Average Annual Agricultural Gaps and Maximum M&I Diversion Demand Gaps in the Republican Basin.

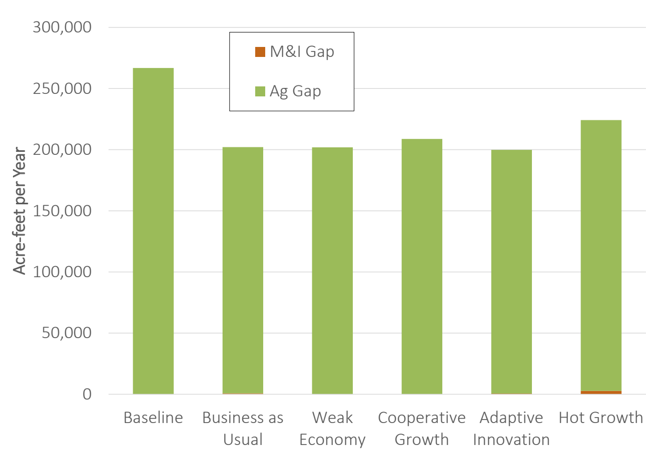


Table 4.8.15 Estimated Consumptive Use from Lands Projected to be Urbanized by 2050 in the Republican Basin

	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Urbanized Acreage (acres)	1,400	-	1,400	1,400	1,400
Estimated Consumptive Use (AFY)	1,500	-	1,600	1,600	1,700

Combined South Platte and Republican Basin Gaps

Table 4.8.16 summarizes the total M&I and agricultural demands in the South Platte and Republican Basins along with a summary of gaps. It should be noted that the South Platte and Republican basins were assessed independently; some of the results from each basin may not be wholly additive in some circumstances. For example, the maximum M&I gap may not occur in the same year in each sub-basin. As a result, the basin as a whole may not experience a year in the future when the total maximum M&I gap corresponds to the sum of the maximum gaps in both sub-basins; however, the sum of the maximum sub-basin gaps does describe the total amount of water that would be needed to fully satisfy all M&I demands in each individual sub-basin, even if the gaps do not simultaneously occur in the sub-basins.

Table 4.8.16 Summary of Total South Platte and Republican Basin Demands and Gaps

	Current (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average Annual Diversion Demand						
Agricultural (AFY)	3,533,000	2,794,200	2,796,100	2,992,700	2,493,700	2,948,900
M&I (AFY)	727,100	1,082,200	976,800	1,010,900	1,079,100	1,268,900
Gaps						
Ag (avg %)	22%	22%	22%	20%	23%	23%
Ag (incremental-AFY)	-	-	-	-	-	-
Ag (incremental gap as % of current demand)	-	-	-	-	-	-
M&I (max %)	0%	24%	19%	21%	31%	43%
M&I (max-AF)	0*	257,100	184,500	213,300	333,700	543,500

**CDSS water allocation model in this basin calculates small baseline M&I gaps, but they are either due to calibration issues or they are reflective of infrequent, dry-year shortages that are typically managed with temporary demand reductions, such as watering restrictions.*

4.8.7 Available Supply

Figures 4.8.27 through 4.8.30 show simulated available at two locations on the South Platte River, the South Platte River at Denver and South Platte River at Kersey. The Denver location, upstream of the Burlington Ditch, is the primary calling right on the mainstem of the Upper South Platte River. The Kersey gage reflects the impact to available flow downstream of the confluence, with the Cache La Poudre River and the Lower South Platte River calling rights for storage and irrigation. Available flow at both locations is generally only available during high flow years and for relatively short periods of time. In scenarios with impacts of climate change, available flows are projected to diminish, and peak flows are projected to occur earlier in the runoff season.

Figure 4.8.27 Simulated Hydrographs of Available Flow at South Platte River at Denver

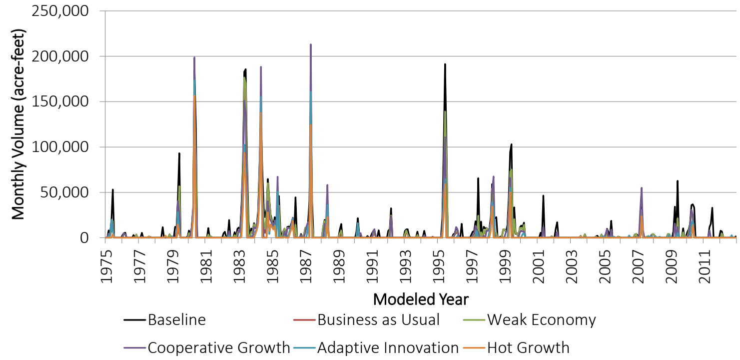


Figure 4.8.28 Average Monthly Simulated Hydrographs of Available Flow at South Platte River at Denver

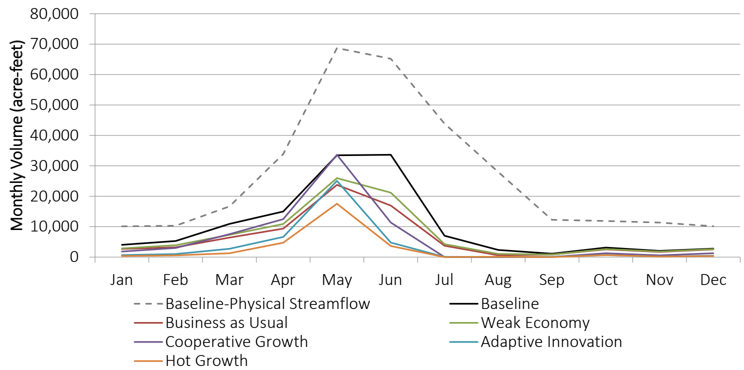


Figure 4.8.29 Simulated Hydrographs of Available Flow at South Platte River at Kersey, CO

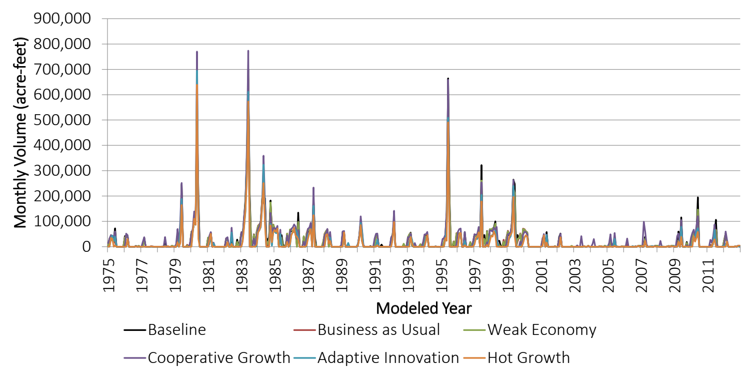
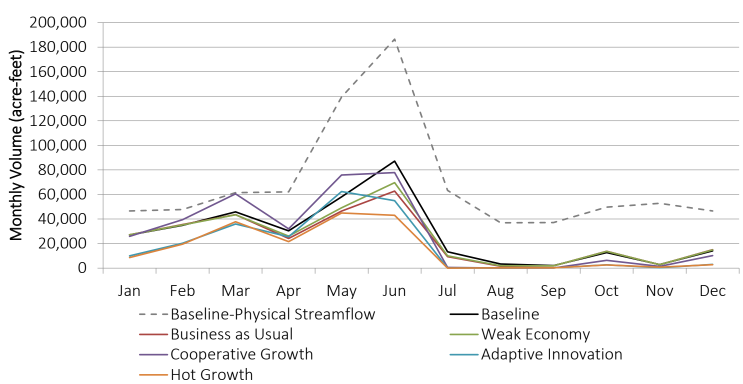


Figure 4.8.30 Average Monthly Simulated Hydrographs of Available Flow at South Platte River at Kersey, CO



4.8.8 Environment and Recreation

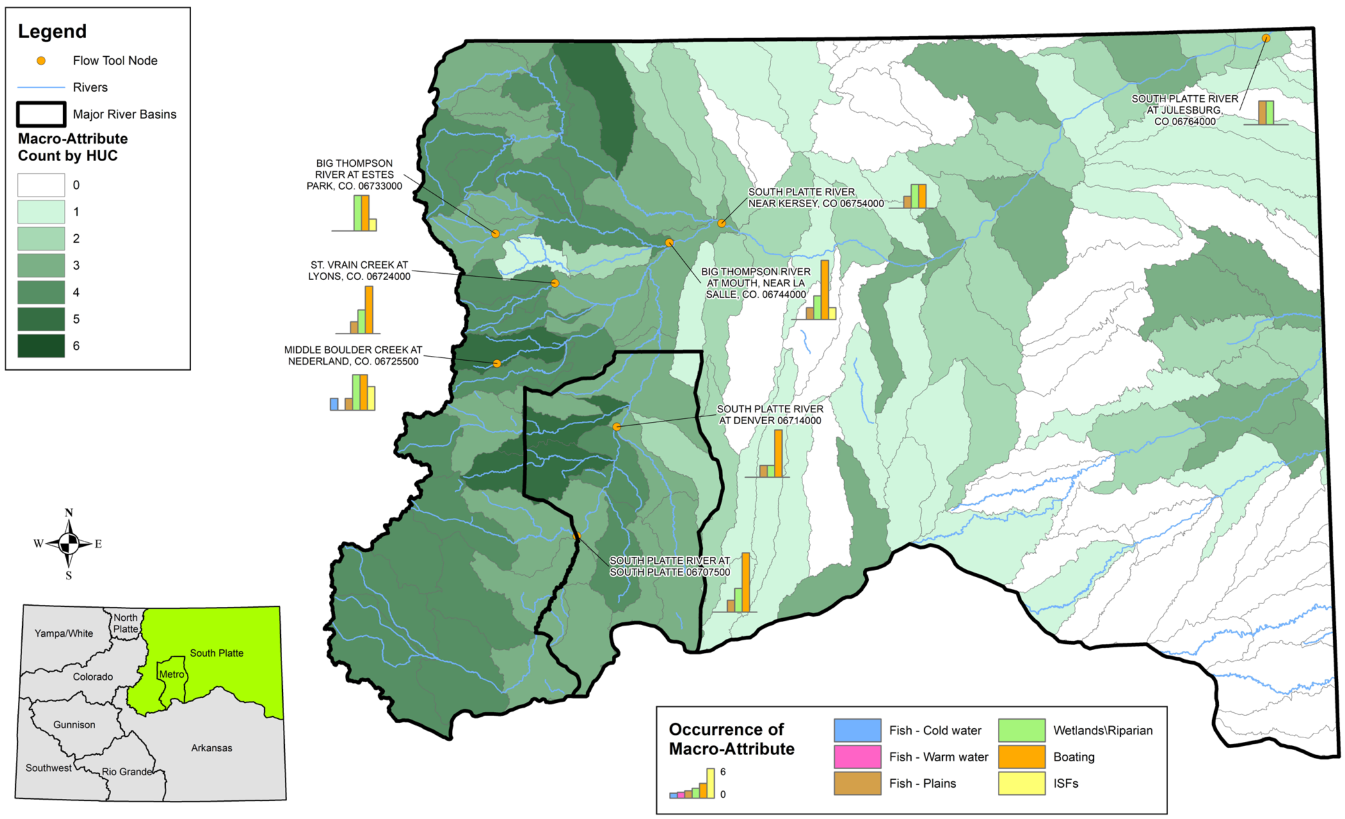
A total of eight water allocation model nodes were selected for the Flow Tool within the South Platte Basin (see list below and Figure 4.8.31). Figure 4.8.31 also shows subwatersheds (at the 12-digit HUC level) and the relative number of E&R attributes located in each subwatershed.

- South Platte River at South Platte (06707500)
- South Platte River at Denver (06714000)
- St Vrain Creek at Lyons, Colorado (06724000)
- Middle Boulder Creek at Nederland, Colorado (06725500)
- Big Thompson River at Estes Park, Colorado (06733000)
- Big Thompson River at Mouth, near La Salle, Colorado (06744000)
- South Platte River near Kersey, Colorado (06754000)
- South Platte River at Julesburg, Colorado (06764000)

■ NATURALIZED FLOW

Naturalized flows reflect conditions that would occur in the absence of human activities. Baseline flows reflect current conditions as influenced by existing infrastructure and river operations. While observations regarding naturalized flows may be informative, baseline flows reflect actual conditions and the diverse operations of a river's many users.

Figure 4.8.31 Flow Tool Nodes Selected for the South Platte Basin



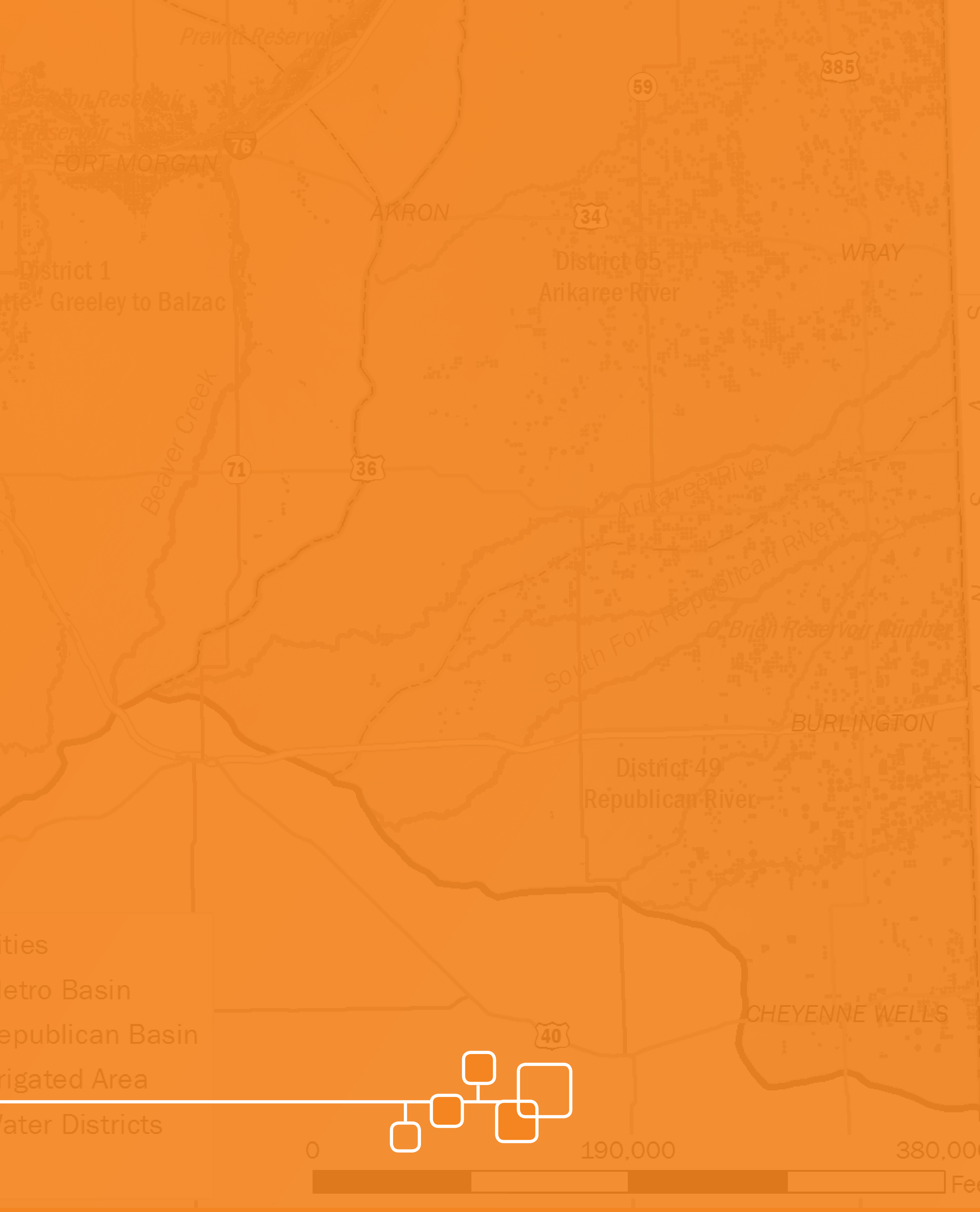
Results and observations from Flow Tool analyses using flow data developed in the water supply and gap analyses for baseline conditions and the planning scenarios are described in Table 4.8.17 below.

Table 4.8.17 Summary of Flow Tool Results in the South Platte Basin

Category	Observation
Projected Flows	Patterns of peak flows are highly variable across locations in the basin.
	Baseline flow patterns diverge the most from naturalized conditions in the Foothills and on the Plains.
	The magnitude of flows on the South Platte in Denver in May and June (historically the months of peak runoff) under baseline conditions are reduced from naturalized conditions, and the divergence from naturalized conditions increases as the South Platte flows through Julesburg. In these locations, peak flow magnitude under the various future scenarios is projected to increase, stay the same, or decrease further depending on location.
	In the mountains (e.g., South Platte River at South Platte, Middle Boulder Creek at Nederland), baseline peak flow magnitudes are only minimally below naturalized peak flow magnitude. Projected changes to peak flow magnitude in these mountain locations also vary depending on location, with minimal changes to peak flow magnitude in some locations and larger declines elsewhere.
	Mountain locations demonstrate a projected pattern under the climate change scenarios where the timing of peak flows shifts earlier in the year, from June to May. The change in timing for peak flows may result in mismatches between peak flow timing and species' needs.
	Mid- and late-summer flows are also highly variable across locations in the basin. On the plains, baseline low flows vary in range below naturalized conditions.
	Under future scenarios, this range is expected to further departed from naturalized conditions in climate-impacted scenarios (*Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*) causing the greatest decline in flows.
	In the mountains, climate change scenarios may cause a decline in low flows (e.g., Middle Boulder Creek at Nederland), while in other areas (e.g., South Platte River at South Platte) declines may be less pronounced due to transbasin imports and releases of stored water.
Ecological Risk	In the Foothills and on the Plains, especially east of Interstate 25, decreased peak flow magnitudes under baseline conditions and all future scenarios may put many aspects of ecosystem function (e.g., over-bank flooding to support riparian plants, sediment transport to maintain fish habitat) at risk. Projected changes to mid- and late-summer flows may also create risk for plains fishes.
	In the mountains, peak flow and low flows generally create low to moderate risk for riparian plants and fish, although these risks may increase under climate change scenarios.
ISFs and RICDs	There are numerous ISF reaches in the mountains and foothills, and several RICDs in the South Platte Basin. The location of modeled flow points does not allow specific insight into what future scenarios imply for these locations, but the general pattern of diminished flows, especially diminished flows under climate change scenarios, suggests that the flow targets for ISFs and RICDs may be met less often.
E&R Attributes	Increasing risk to E&R attributes arise from several sources. Changes in flow timing through water management (e.g., storage of peak flows) can reduce ecosystem functions that are dependent on high flows (e.g., sediment transport) and can reduce boating opportunities. Changes in timing under climate change scenarios (early peak flow) can also increase risk for ecosystems and species.
	Under all scenarios in most locations, ecological and recreational risk may be increased by depletions from increasing human water consumption and decreasing supply under a changing climate. Water management (e.g., reservoir releases) has the potential to mitigate negative impacts.

The San Juan River, Dolores River, and San Miguel River Basins are located in the southwest corner of Colorado and cover an area of approximately 10,169 square miles. The Upper San Juan River and its tributaries flow through two Native American reservations in the southern portion of the basin—the Ute Mountain Ute Reservation and the Southern Ute Indian Reservation. The Southwest Basin is a series of nine sub-basins, eight of which flow out of state before they join the San Juan River in New Mexico or the Colorado River in Utah. The Colorado River Compact, the Colorado Ute Indian Water Rights Settlement, and several Bureau of Reclamation storage projects have shaped the water history of the Southwest Basin.

SOUTHWEST


Prewitt Reservoir
FORT MORGAN
AKRON
WRAY
District 1
Greeley to Balzac
District 65
Arikaree River
Beaver Creek
Arikaree River
South Fork Republican River
O'Brian Reservoir Number
BURLINGTON
District 49
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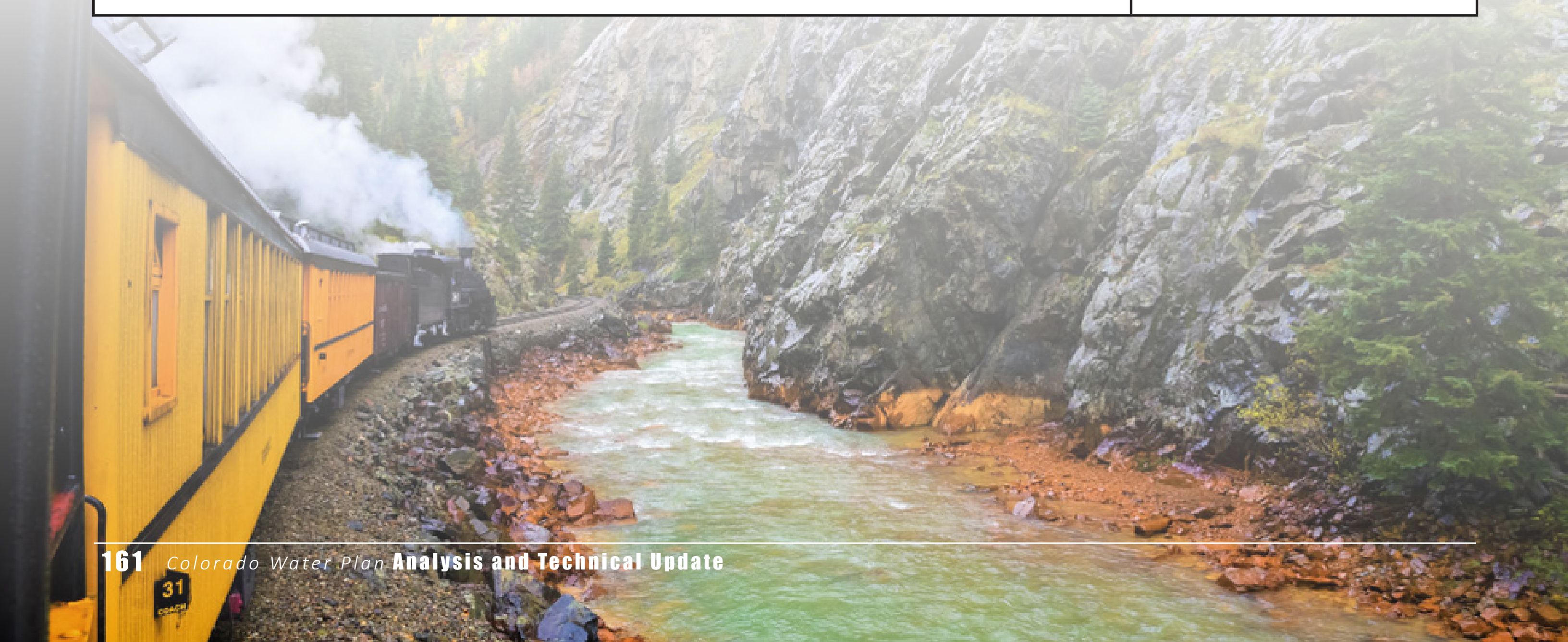
4.9 SOUTHWEST BASIN RESULTS

4.9.1 BASIN CHALLENGES

The Southwest Basin will face several key issues and challenges to balance valued agricultural uses with instream water to support recreational and environmental values, all of which combine to support the economic and aesthetic values that drive settlement and commerce in the Southwest Basin. In addition, water quality is a significant concern in the Southwest Basin. These issues were described in the Colorado Water Plan and are summarized below.

Table 4.9.1 Key Future Water Management Issues in the Southwest Basin

Agriculture	Environment and Recreation	Municipal and Industrial	Compacts and Administration
• The Cortez and Dove Creek area remains strongly agricultural, supplemented by energy production. It is also seeing growth through an increase in retirees moving to the area.	• US Forest Service and Bureau of Land Management have worked with the CWCB Instream Flow Program to secure substantial flow protection at high elevations throughout the basin. As stream-flow protections have increasingly focused on lower elevation streams that are below stored water and communities, instream flow appropriations have become more complex and challenging.	• The Pagosa Springs-Bayfield-Durango corridor is rapidly growing while experiencing areas of localized water shortages. This area is transitioning from oil and gas, mining, and agricultural use to tourism and recreation use, and to a retirement or second-home area. • Another challenge is the development of sufficient infrastructure to deliver M&I water where it is needed. There is also discussion regarding new storage to meet long-term supply requirements in the Pagosa Springs area, as well as in Montrose County.	• In addition to the three compacts governing water use across the broader Colorado Basin, other compacts, settlements, and species-related issues are specific to the San Juan/ Dolores/San Miguel region.
• The San Miguel area shows a mix of recreation and tourism activities, along with a strong desire to maintain agriculture in the western part of the county.			



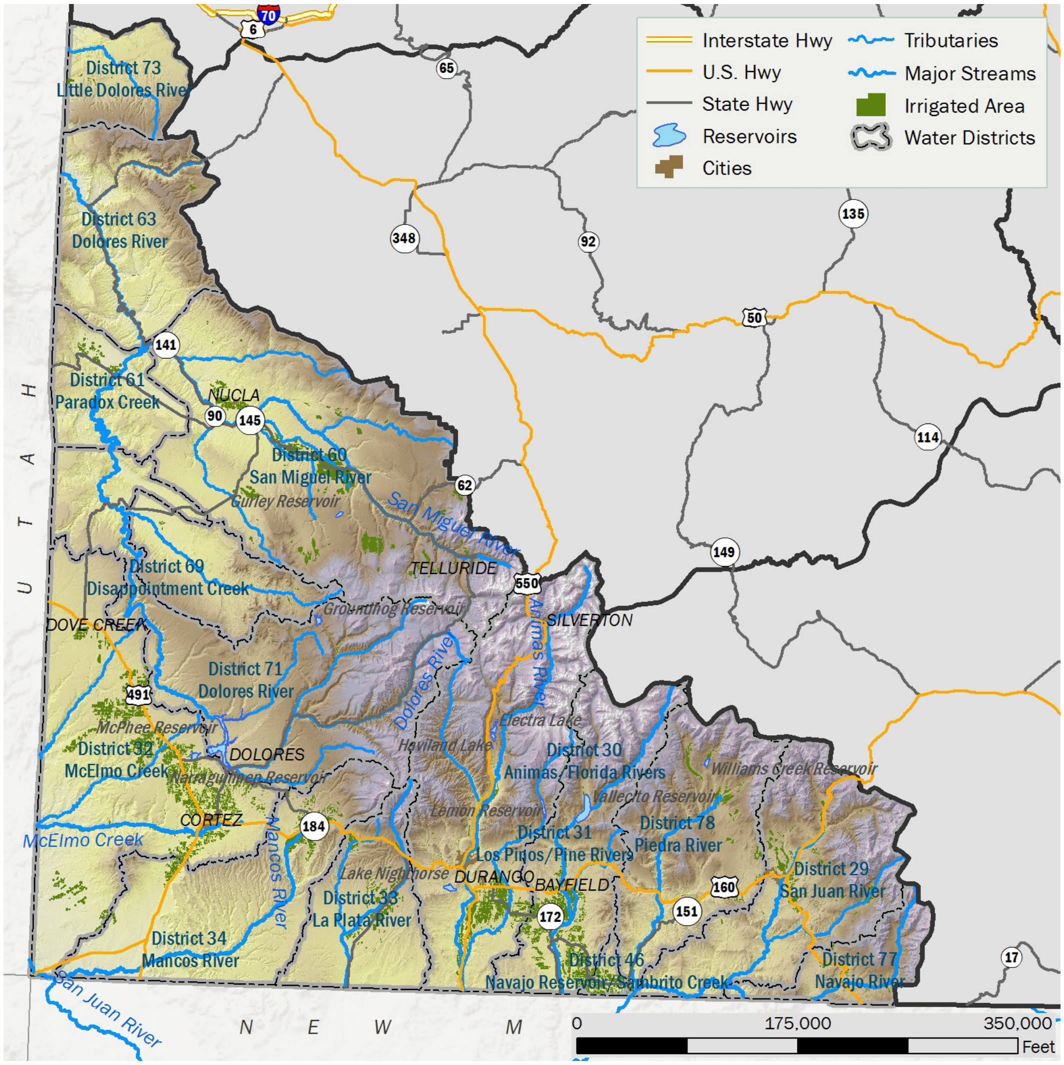


Figure 4.9.1 Map of the Southwest Basin

4.9.2 SUMMARY OF TECHNICAL UPDATE RESULTS

Key results and findings of the Technical Update pertaining to agricultural and M&I demands and gaps as well as findings related to environmental and recreational attributes and future conditions are summarized below.

Table 4.9.2 Summary of Key Results in the Southwest Basin

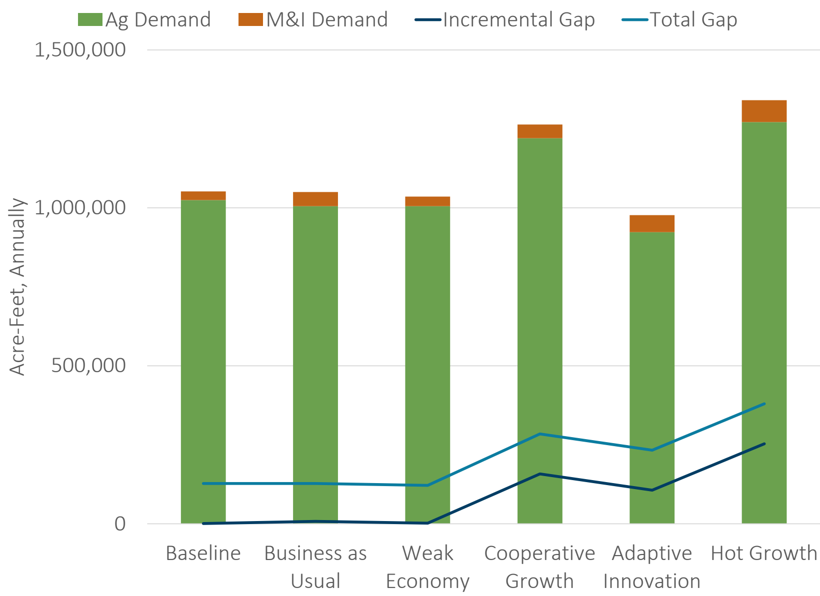
Agriculture	Environment and Recreation	Municipal and Industrial
• Warmer and drier climate conditions in Cooperative Growth, Adaptive Innovation and *Hot Growth* will lead to higher IWR and gaps. • Incorporation of emerging technologies in Adaptive Innovation are projected to help maintain demands and gaps at lower levels than *Hot Growth* despite similar assumptions regarding future climate conditions.	• In locations that are minimally depleted under baseline conditions, peak flows may remain adequate for riparian/ wetlands and fish habitat, but timing mis-matches may occur. • In all locations, mid- and late-summer flows may be substantially reduced, creating high risk for coldwater and warmwater fish.	• Relatively large increases in population could create higher M&I demands and gaps in Adaptive Innovation and *Hot Growth*. • Thermoelectric demands drive a modest increase in SSI demand. • Future per capita demands are projected to decrease in all but *Hot Growth*.

Table 4.9.3 Summary of Diversion Demand and Gap Results in the Southwest River Basin

	Current (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average Annual Demand						
Agricultural (AFY)	1,024,800	1,005,400	1,005,400	1,220,500	923,100	1,271,700
M&I (AFY)	27,200	44,800	30,200	43,300	54,000	69,500
Gaps						
Ag (avg %)	12%	12%	12%	23%	24%	28%
Ag (incremental-AFY)	-	-	-	150,100	92,400	228,400
Ag (incremental gap as % of current demand)	-	-	-	15%	9%	22%
M&I (max %)	0%	17%	6%	18%	26%	36%
M&I (max-AF)	0*	7,500	1,800	7,700	13,800	24,800

* *CDSS water allocation model in this basin calculates small baseline M&I gaps, but they are either due to calibration issues or they are reflective of infrequent, dry-year shortages that are typically managed with temporary demand reductions such as watering restrictions.*

Figure 4.9.2 Summary of Diversion Demand and Gap Results in the Southwest Basin



Summary of Environment and Recreation Findings

- In locations that are minimally depleted under baseline conditions (e.g., the San Miguel River), peak flows may remain adequate for riparian/wetlands and fish habitat, with March-May flows increasing substantially while June flows decrease; possible mis-matches between peak flow timing and species needs may occur.
- In some locations peak flows under baseline conditions indicate high risk to riparian/wetlands and fish habitat, and risk may increase in *Cooperative Growth, Adaptive Innovation*, and *Hot Growth*.
- In all locations, mid- and late-summer flows are projected to be substantially reduced (50 to 80 percent) under *Cooperative Growth, Adaptive Innovation*, and *Hot Growth*, creating high risk for coldwater and warmwater fish. Even on rivers where the baseline condition is low-risk for summer flows, future scenarios may see risks increase substantially. The risk expressed in the coldwater and warmwater fish metrics does not include July because historically July flows are sufficient; however, in some locations, July flows may be reduced (e.g., July flows on the Piedra River near Arboles could be by reduced 84 percent), which could result in much-reduced habitat and high stream temperatures.
- Instream Flow water rights in the Southwest and the Recreational In-Channel Diversion on the Animas River often will likely not be fully met under *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*.

4.9.3 NOTABLE BASIN CONSIDERATIONS

Section 4.1 described several analysis assumptions and limitations that apply to all basins and should be considered when reviewing and interpreting analysis results. Additional considerations specific to the Southwest Basin are listed below:

- The full development of tribal reserved water rights is not represented in the models for several reasons. The Tribal Water Study was completed in December of 2018, which was after the agricultural and M&I demands for the Technical Update were completed. In addition, full use of the reserved rights are not projected to occur by 2050, which is the planning time period contemplated in the current Technical Update. It should be noted that Tribal water use through 2050 is included in the M&I projections in each planning scenario; however, similar to other future M&I demands, it has been grouped with other M&I demands and included in the water allocation model at representative locations in each water district. Basin roundtables can take a different look at how tribal rights are used when they update their BIP.
- Water availability in the various sub-basins in the Southwest Basin can be drastically different. The differences in sub-basin water availability and gaps may not be evident at a basinwide scale due to the aggregated reporting of results in the Technical Update; however, models developed for the Technical Update reflect the variation in sub-basin results and are available for sub-basin specific evaluations that could be conducted in the Basin Implementation Plan update.

4.9.4 AGRICULTURAL DIVERSION DEMANDS

Agricultural Setting

The Southwest Basin is made up of a series of nine sub-basins, each with their own unique hydrology and demands. The basin is home to a diverse set of demands; several small towns founded primarily due to either mining or agricultural interests, two Native American reservations (Southern Ute Indian Tribe and Ute Mountain Ute Tribe), one major transbasin diversion (San Juan–Chama Project)[13], and four major Reclamation projects (Pine River, Dolores, Florida and Mancos) that both brought new irrigated acreage under production and provided supplemental supplies to existing lands. For areas outside of the Reclamation rojects, producers generally irrigate grass meadows for cattle operations aligned along the rivers and tributaries and rely on supplies available during the runoff season. Producers under the Reclamation Projects irrigate a wider variety of crops, such as alfalfa and row crops, due to lower elevations, warmer temperatures, and supplemental storage supplies during the later irrigation season.

Planning Scenario Adjustments

Urbanization in the basin will likely have a limited impact on agriculture in the future. Only 4,080 acres of irrigated land basin-wide were estimated to be urbanized by 2050. The larger towns of Durango, Cortez, and Pagosa Springs do not have significant areas of irrigated acreage located within or directly adjacent to the current municipal boundaries, and urbanization of acreage in these areas is projected to be low in the future. Smaller towns in the basin, such as Norwood, Nucla, Bayfield, and Mancos are surrounded by irrigated agriculture, which may lead to some urbanization of irrigated lands by 2050.

Table 4.9.4 summarizes the planning scenario adjustments described above and other adjustments that impact agricultural diversion demands in the various scenarios.

Table 4.9.4 Planning Scenario Adjustments for Agricultural Demands in the Southwest Basin

Adjustment Factor*	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Change in Irrigated Land due to Urbanization	3,800 Acre Reduction	3,800 Acre Reduction	3,800 Acre Reduction	3,800 Acre Reduction	3,800 Acre Reduction
IWR Climate Factor	-	-	26%	34%	34%
Emerging Technologies	-	-	-	10% IWR Reduction 10% System Efficiency Increase	-

** See section 2.2.3 for descriptions of adjustment methodologies and assumptions*

Agricultural Diversion Demand Results

Table 4.9.5 and Figure 4.9.3 summarize the acreage, IWR, and the agricultural diversion demand for surface water supplies in the Southwest Basin for current conditions and the five planning scenarios. Increased demands were projected for *Cooperative Growth* and *Hot Growth*, reflecting the impacts of climate change, without the benefit of increased efficiencies reflected in *Adaptive Innovation*.

Table 4.9.5 Summary of Agricultural Diversion Demand Results in the Southwest Basin

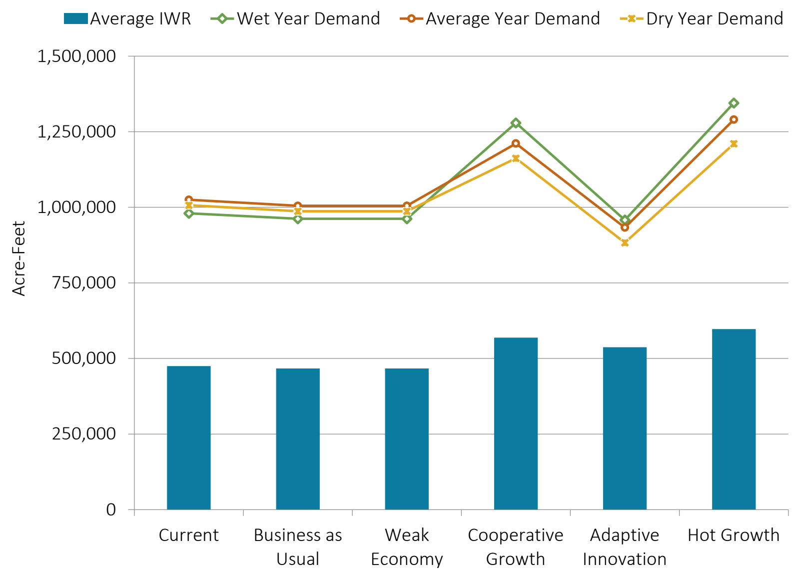
	Current (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Irrigated Acreage (acres)	222,500	218,800	218,800	218,800	218,800	218,800
Average IWR (AFY)	474,900	467,000	467,000	569,000	537,000	597,000
Total Surface and Groundwater Diversion Demand						
Average Year (AFY)	1,025,000	1,005,000	1,005,000	1,211,000	933,000	1,290,000
Wet Yr. Change	-4%	-4%	-4%	6%	3%	4%
Dry Yr Change	-2%	-2%	-2%	-4%	-5%	-6%

Average agricultural diversion demand was calculated using the average hydrologic years (i.e., years classified as neither wet or dry) from 1950-2013

SYSTEM EFFICIENCY

In some cases, diversion demands can be higher in wet years because system efficiency decreases due to the relative abundance of supply.

Figure 4.9.3 Agricultural Diversion Demands and IWR Results in the Southwest Basin



4.9.5 Municipal and Self-Supplied Industrial Diversion Demands

Population Projections

The Southwest Region currently includes about 2 percent of the statewide population. Between the years 2015 and 2050, it is projected to grow from approximately 110,000 to between 130,000 and 280,000 people in the low and high growth projections, respectively, which is an increase in population of 16 to 161 percent. On a percentage basis, the Southwest Basin has the largest projected increase of all basins throughout the state. Table 4.9.6 shows how population growth is projected to vary across the planning scenarios for the Southwest Basin.

Table 4.9.6 Southwest Basin Baseline and Projected Populations

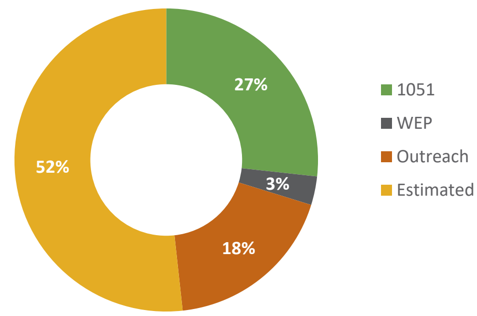
Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
107,999	195,837	125,814	201,010	264,189	282,144

Current Municipal Demands

Sources of water demand data such as 1051 or WEP data made up less than half of the available information in the Southwest Basin, and baseline water demands were largely estimated as shown in Figure 4.9.4.

Figure 4.9.5 summarizes the categories of municipal, baseline water usage in the Southwest Basin. On a basin scale, the non-residential outdoor demand as a percentage of the systemwide demand is one of the lowest reported throughout the state, at approximately 9 percent. Conversely, the baseline non-revenue water demand is one of the highest statewide, at approximately 15 percent of the systemwide demands.

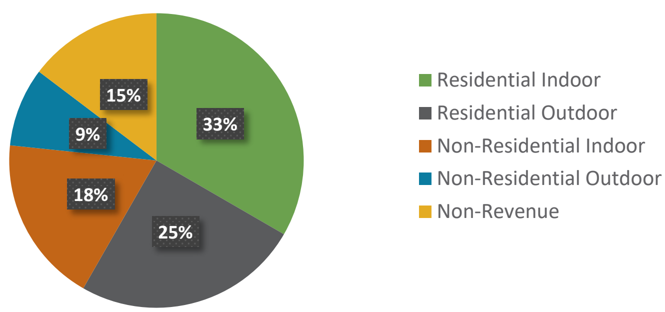
Figure 4.9.4 Sources of Water Demand Data in the Southwest Basin



DECREASING GPCD

The Southwest Region average baseline per capita systemwide demand has increased from 183 gpcd in SWSI 2010 to approximately 198 gpcd.

Figure 4.9.5 Categories of Water Usage in the Southwest Basin



Projected Municipal Demands

Figure 4.9.6 provides a summary of per capita baseline and projected water demands for the Southwest Basin. Systemwide, the projected per capita demands decrease relative to the baseline except for *Hot Growth,* which has a similar systemwide per capita demand as the baseline, but the demand category distributions are different. The residential indoor demand is the greatest demand category in the baseline, but the residential outdoor demand exceeds the residential indoor demand in the all of the projections except for *Weak Economy*. Outdoor demands increased significantly for *Hot Growth* due to an increase in outdoor demands driven by the "Hot and Dry" climate factor (described in Section 2).

The Southwest Basin municipal baseline and projected demands are provided in Table 4.9.7, showing the combined effect of population and per capita demands. Municipal demands are projected to grow from approximately 24,000 AFY in 2015 to between 26,000 and 63,000 AFY in 2050. La Plata County accounts for nearly half of the baseline demand, followed by Montezuma County at just under one-third of the basin demand.

The baseline and projected demand distributions shown in Figure

Figure 4.9.6 Southwest Basin Municipal Baseline and Projected Per Capita Demands by Water Demand Category (gpcd)

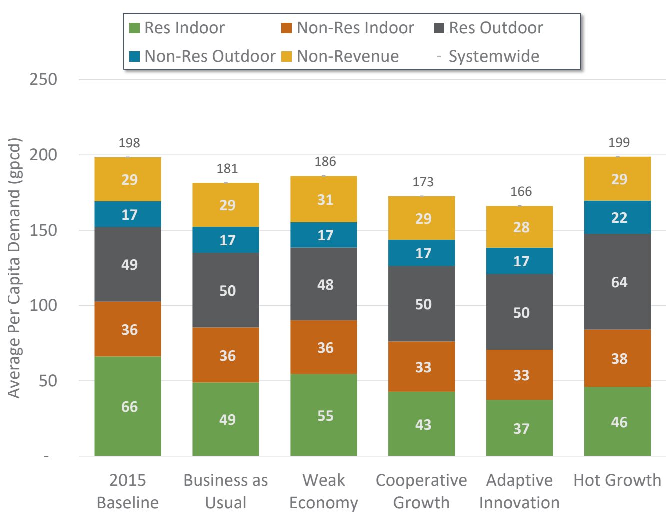
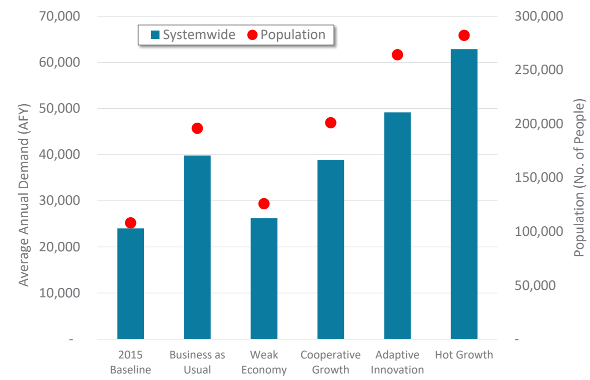


Table 4.9.7 Southwest Basin Municipal Baseline and Projected Demands (AFY)

Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
24,009	39,810	26,214	38,864	49,164	62,851

4.9.7 also show how the population varies between the scenarios. All of the planning scenarios except for *Weak Economy* result in a significant increase relative to the baseline. Demands generally follow the population patterns, however increased outdoor demands for the "Hot and Dry" climate condition have a greater impact on gpcd, resulting in higher demands for *Hot Growth*.

Figure 4.9.7 Southwest Basin Baseline and Projected Population and Municipal Demands



Self-Supplied Industrial Demands

The Southwest Basin currently includes about 1 percent of the statewide SSI demand. SSI demands in this basin are associated with the snowmaking and thermoelectric sub-sectors, with no demands projected for large industry or energy development sub-sectors. Southwest region total SSI demands are shown in Figure 4.9.8 and summarized in Table 4.9.8.

The baseline snowmaking demand is 430 AFY as compared to 410 AFY in SWSI 2010. Projected demands remain at 430 AFY because there is no planned expansion of snowmaking acreage. Projected demands were not varied by scenario.

Thermoelectric demands are related to one facility located in Montrose County and were based on information in SWSI 2010. The baseline demand remains 1,850 AFY as represented in SWSI 2010. Projected thermoelectric demands range from 3,510 AFY to 4,290 AFY.

Figure 4.9.8 Southwest Basin Self-Supplied Industrial Demands

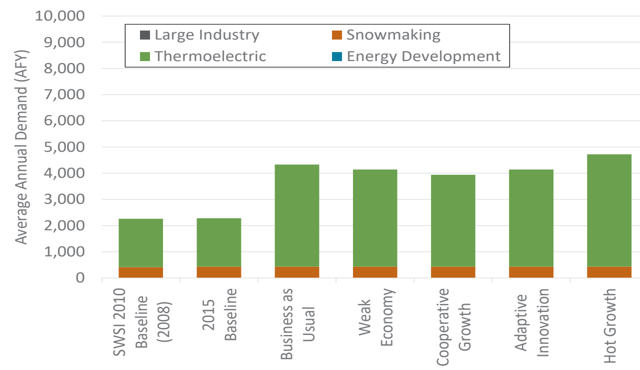


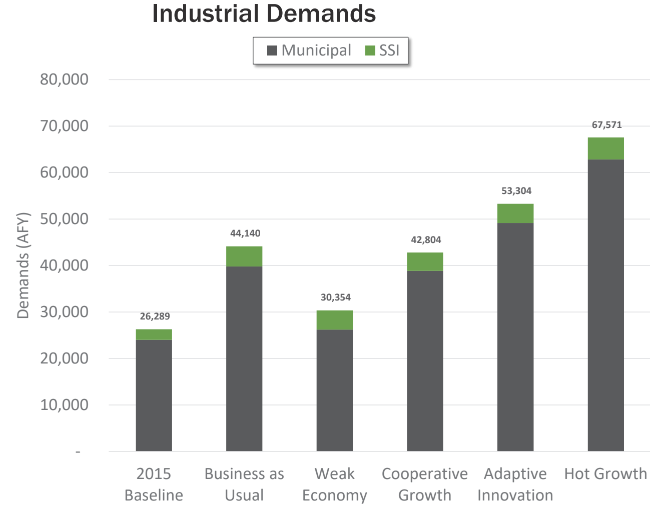
Table 4.9.8 Southwest Basin SSI Baseline and Projected Demands (AFY)

Sub-sector	Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Large Industry	-	-	-	-	-	-
Snowmaking	430	430	430	430	430	430
Thermoelectric	1,850	3,900	3,710	3,510	3,710	4,290
Energy Development	-	-	-	-	-	-
Sub-Basin Total	2,280	4,330	4,140	3,940	4,140	4,720

Total M&I Diversion Demands

Southwest Basin combined M&I demand projections for 2050 range from approximately 30,000 AFY in the *Weak Economy* to 68,000 AFY in *Hot Growth*, as shown in Figure 4.9.9. SSI demands account for around 7 to 14 percent of the M&I demands in the Southwest Basin. On a basin scale, the demand projections follow the statewide sequence of the scenario rankings described in the CWP.

Figure 4.9.9 Southwest Basin Municipal and Self-Supplied Industrial Demands



4.9.6 Water Supply Gaps

The agricultural and M&I diversion demands were compared against available water supply modeled for current conditions and the five planning scenarios. Gaps were calculated when water supply was insufficient to meet demands.

Agricultural

The Southwest Basin agricultural diversion demands, demand gaps, and consumptive use gaps for the baseline and planning scenarios are presented in Table 4.9.9 and illustrated in Figure 4.9.10. An annual time series of gaps in terms of percent of demand that was unmet is shown in Figure 4.9.11.

> **INCREMENTAL GAP**
>
> The incremental agricultural gap quantifies the degree to which the gap could increase beyond what agriculture has historically experienced under water shortage conditions.

Table 4.9.9 Southwest Basin Agricultural Gap Results (AFY)

		Scenario					
		Scenario	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average	Average Annual Demand	1,024,800	1,005,400	1,005,400	1,220,500	923,100	1,271,700
	Average Annual Gap	126,600	120,300	119,800	276,700	219,000	355,100
	Average Annual Gap Increase from Baseline	-	-	-	150,100	92,400	228,400
	Average Annual Percent Gap	12%	12%	12%	23%	24%	28%
	Average Annual CU Gap	72,300	68,700	68,400	158,500	147,200	206,400
Maximum	Demand in Maximum Gap Year	1,153,000	1,131,100	1,131,100	1,215,200	899,300	1,238,200
	Gap in Maximum Gap Year	517,600	507,400	504,900	679,500	474,000	738,100
	Increase from Baseline Gap	-	-	-	161,900	-	220,500
	Percent Gap in Maximum Gap Year	45%	45%	45%	56%	53%	60%

Study period for Water Supply Analysis is 1975-2013, reflecting different baseline demand than described in Agricultural Diversion Demands section.

Figure 4.9.10 Projected Average Annual Agricultural Diversion Demand, Demand Met, and Gaps in the Southwest Basin

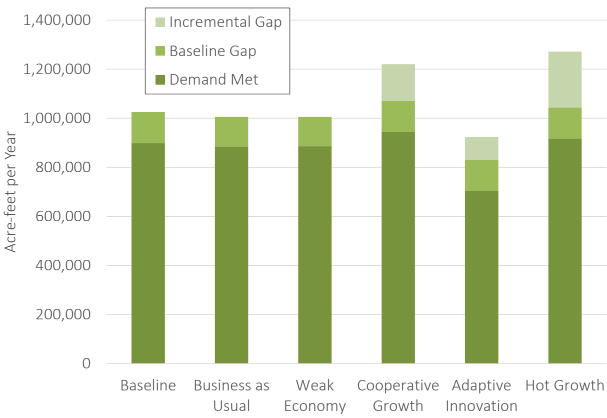
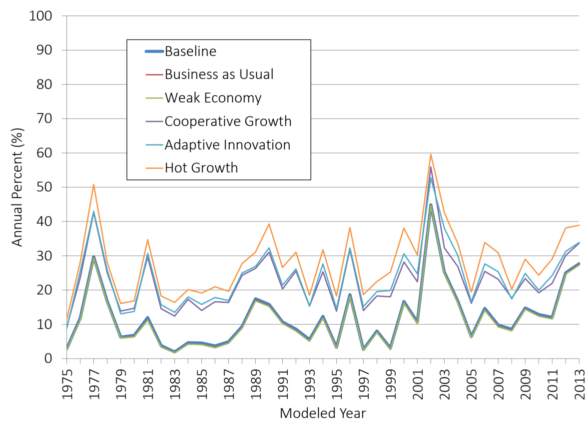


Figure 4.9.11 Annual Agricultural Gaps (expressed as a percentage of demand) for Each Planning Scenario



The following are observations on agricultural demands and gaps:

- Agricultural diversion demands are reduced in three of the five planning scenarios due to urbanization and reduction of irrigated acres.
- Agricultural diversion demand is projected to increase by 11 to 16 percent in *Cooperative Growth* and *Hot Growth* due to climate impacts. The increased demand in these scenarios is exacerbated by reduced water supply, resulting in an increased gap.
- Although *Adaptive Innovation* estimates reduced demand, the reduction in water supply due to climate change could result in an increased gap over baseline.

M&I

The diversion demand and gap results for M&I in the Southwest Basin are summarized in Table 4.9.10 and illustrated in Figure 4.9.12. An annual time series of gaps in terms of percent of demand that was unmet is shown in Figure 4.9.13.

Table 4.9.10 Southwest Basin M&I Gap Results (AFY)

		Scenario					
		Scenario	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average	Average Annual Demand	27,200	44,800	30,200	43,300	54,000	69,500
	Average Annual Gap	0[1]	3,300	400	4,100	7,800	13,400
	Average Annual Percent Gap	0%	7%	1%	9%	14%	19%
Maximum	Demand in Maximum Gap Year	27,200	44,800	30,200	43,300	54,000	69,500
	Gap in Maximum Gap Year	0*	7,500	1,800	7,700	13,800	24,800
	Percent Gap in Maximum Gap Year	0%	17%	6%	18%	26%	36%

** CDSS water allocation model in this basin calculates small baseline M&I gaps, but they are either due to calibration issues or they are reflective of infrequent, dry-year shortages that are typically managed with temporary demand reductions, such as watering restrictions.*

Study period for Water Supply Analysis is 1975-2013, reflecting different baseline demand than described in M&I Demand section. Baseline demand also may vary slightly from previous section due to differences in geographic distribution of demand for counties that lie in multiple basins.

Figure 4.9.12 Projected Maximum Annual M&I Demand Met and Gaps in the Southwest Basin

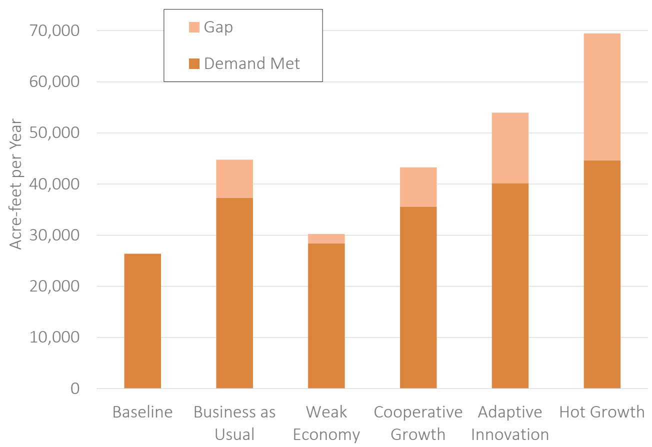
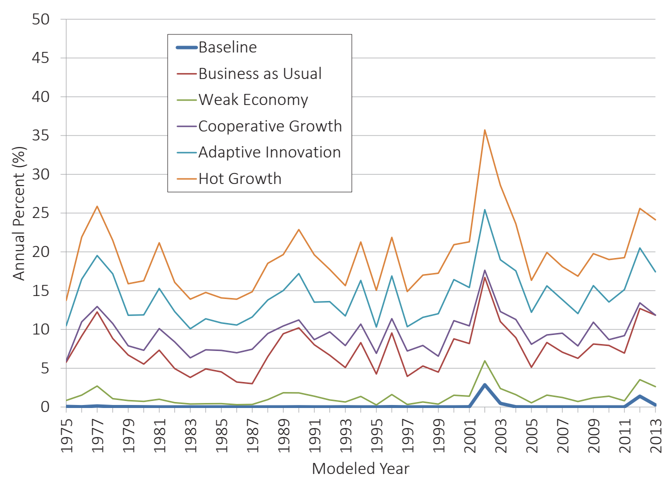


Figure 4.9.13 Annual M&I Gaps (expressed as a percentage of demand) for Each Planning Scenario



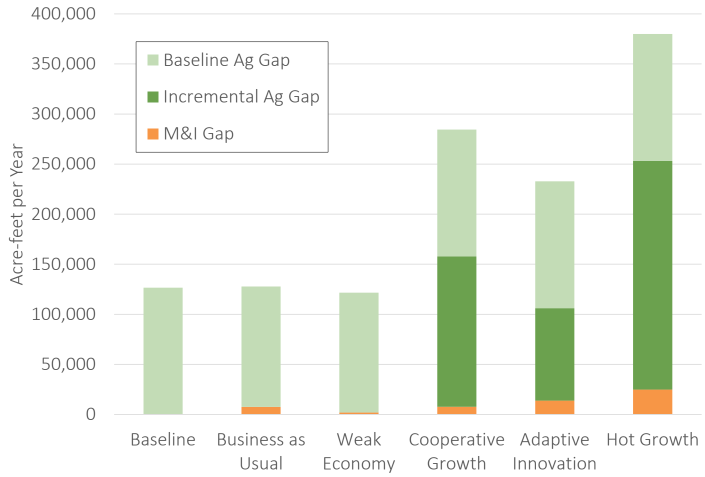
The following are observations on M&I diversion demands and gaps:

- The Southwest Basin is projecting the largest percentage increase in population in the state, which results in increased municipal demand for all future scenarios.
- Thermoelectric demands drive a modest increase in SSI demand.
- Water supply gaps for the planning scenarios range from 1 to 20 percent of demand. The largest gap is projected for *Hot Growth*, which is 36 percent of demand in the maximum gap year.

Total Gap

Figure 4.9.14 illustrates the total combined agricultural and M&I diversion demand gap in the Southwest Basin. The figure combines the average annual baseline and incremental agricultural gaps and the maximum M&I gap. In *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*, gaps were driven by agricultural demands, which increase in the "Hot and Dry" climate conditions.

Figure 4.9.14 Projected Average Annual Agricultural Gaps and Maximum M&I Diversion Demand Gaps in the Southwest Basin



Supplies from Urbanized Lands

By 2050, irrigated acreage in the Southwest Basin is projected to decrease by 3,800 acres due to urbanization. Irrigation supplies for these lands could potentially be used for M&I needs in the future (subject to a variety of unknowns such as seniority and type of water supply, willingness to change the use of water through water court, etc.). The average annual historical consumptive use associated with potentially urbanized acreage for each scenario is reflected in Table 4.9.11. The data in the table represent planning-level estimates of this potential supply and has not been applied to the M&I gaps.

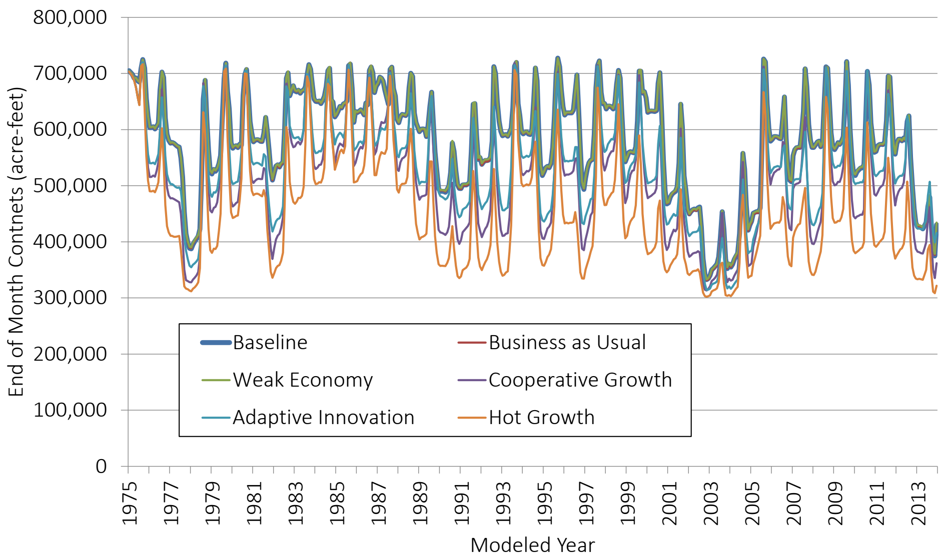
Table 4.9.11 Estimated Consumptive Use from Lands Projected to be Urbanized by 2050 in the Southwest Basin

	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Urbanized Acreage (acres)	3,800	3,800	3,800	3,800	3,800
Estimated Consumptive Use (AFY)	6,900	6,900	7,100	6,800	6,800

Storage

Total simulated reservoir storage from the Southwest Basin water allocation model is shown on Figure 4.9.15. Baseline and *Weak Economy* conditions show the highest levels of water in storage (in general) and the lowest is in *Hot Growth*. A significant spread between storage levels is shown for the various planning scenarios, with as much as 200,000 AF storage difference between *Weak Economy* and *Hot Growth*.

Figure 4.9.15 Southwest Basin Total Simulated Storage



4.9.7 Available Supply

Figures 4.9.16 through 4.9.19 show simulated available flow for the Southwest Basin at two locations to illustrate the difference in hydrology and water availability across the multiple sub-basins. The Animas River at Durango gage is located just upstream of the Durango Boating Park, which is a recreational instream flow demand of 1,400 cfs. Available flow greatly increases downstream of the Boating Park reach.

The La Plata River produces very little runoff and demands on the river chronically experience shortages due to physical flow limitations and curtailment due to the La Plata Compact. At both of the locations, available flows are projected to diminish and peak flows could occur earlier in the runoff season under planning scenarios with climate change impacts.

Figure 4.9.16 Simulated Hydrographs of Available Flow at Animas River at Durango, CO

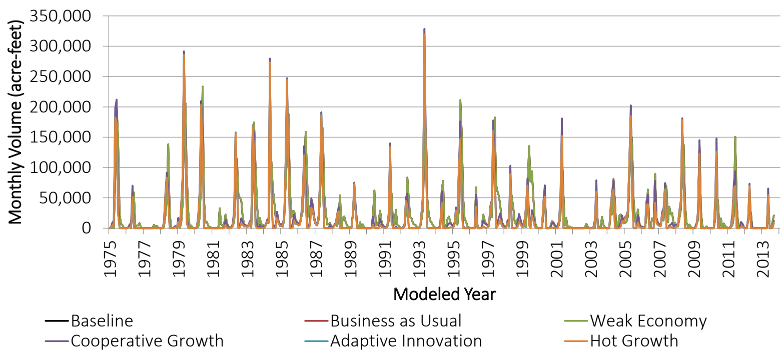


Figure 4.9.17 Average Monthly Simulated Hydrographs of Available Flow at Animas River at Durango, CO

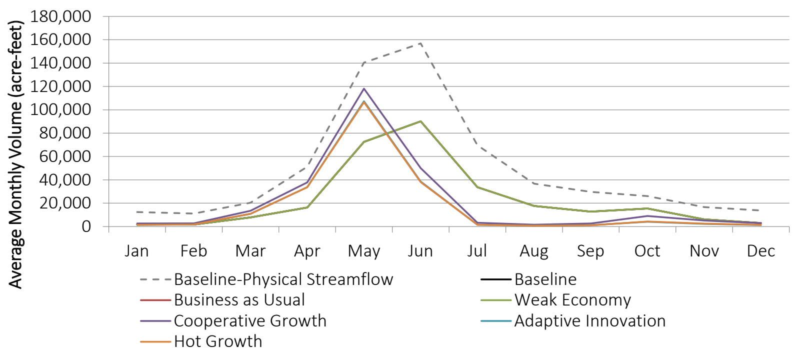


Figure 4.9.18 Simulated Hydrographs of Available Flow at La Plata River at Hesperus, CO

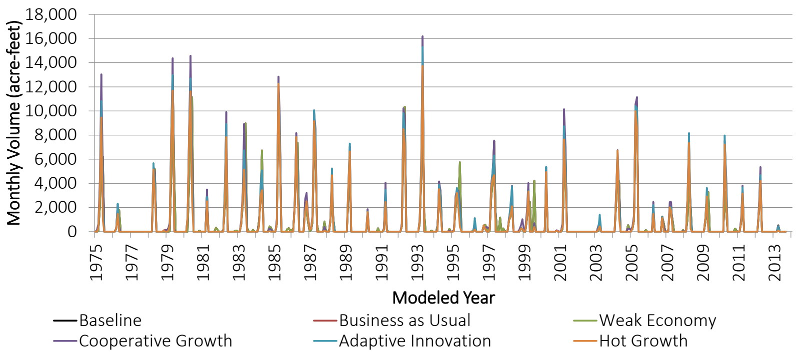
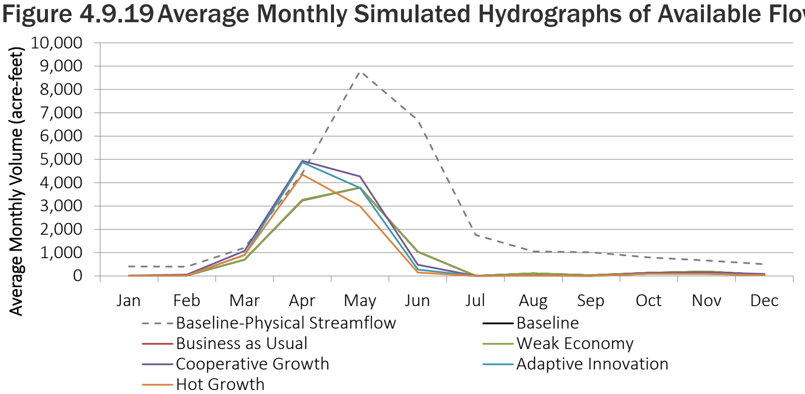


Figure 4.9.19 Average Monthly Simulated Hydrographs of Available Flow at La Plata River at Hesperus, CO



4.9.8 Environment and Recreation

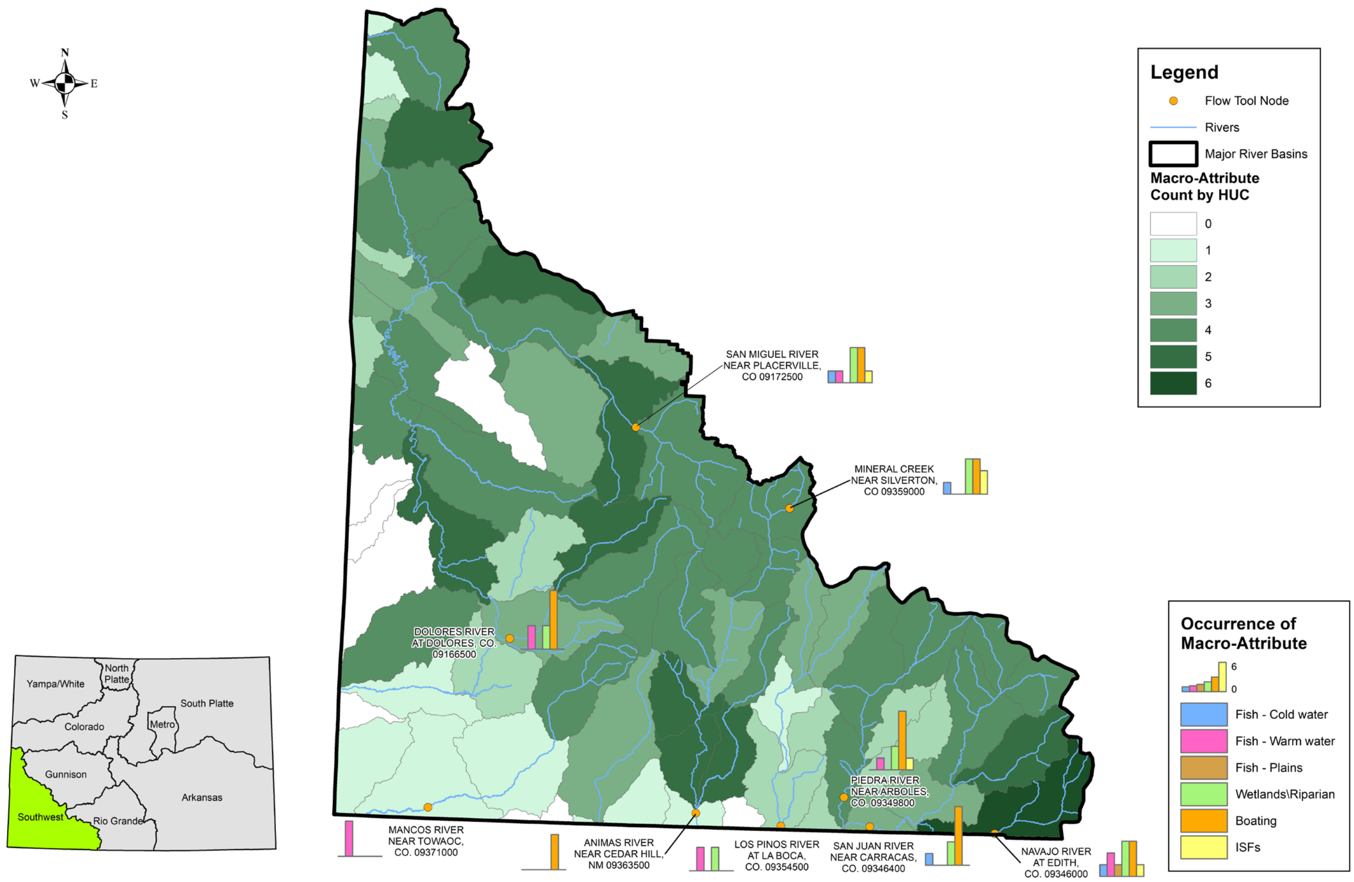
A total of nine water allocation model nodes were selected for the Flow Tool within the Southwest Basin (see list below and Figure 4.9.20). Figure 4.9.20 also shows subwatersheds (at the 12-digit HUC level) and the relative number of E&R attributes located in each subwatershed.

- Dolores River at Dolores, Colorado (09166500)
- San Miguel River near Placerville, Colorado (09172500)
- Navajo River at Edith, Colorado (09346000)
- San Juan River near Carracas, Colorado (09346400)
- Piedra River near Arboles, Colorado (09349800)
- Los Pinos River at La Boca, Colorado (09354500)
- Animas River at Howardsville, Colorado (09357500)
- Animas River near Cedar Hill, New Mexico (09363500)
- Mancos River near Towaoc, Colorado (09371000)

NATURALIZED FLOW

Naturalized flows reflect conditions that would occur in the absence of human activities. Baseline flows reflect current conditions as influenced by existing infrastructure and river operations. While observations regarding naturalized flows may be informative, baseline flows reflect actual conditions and the diverse operations of a river's many users.

Figure 4.9.20 Flow Tool Nodes Selected for the Southwest Basin



Results and observations regarding Flow Tool analyses using flow data developed in the water supply and gap analyses for baseline conditions and the planning scenarios are described below in Table 4.9.12.

Table 4.9.12 Summary of Flow Tool Results in the Southwest Basin

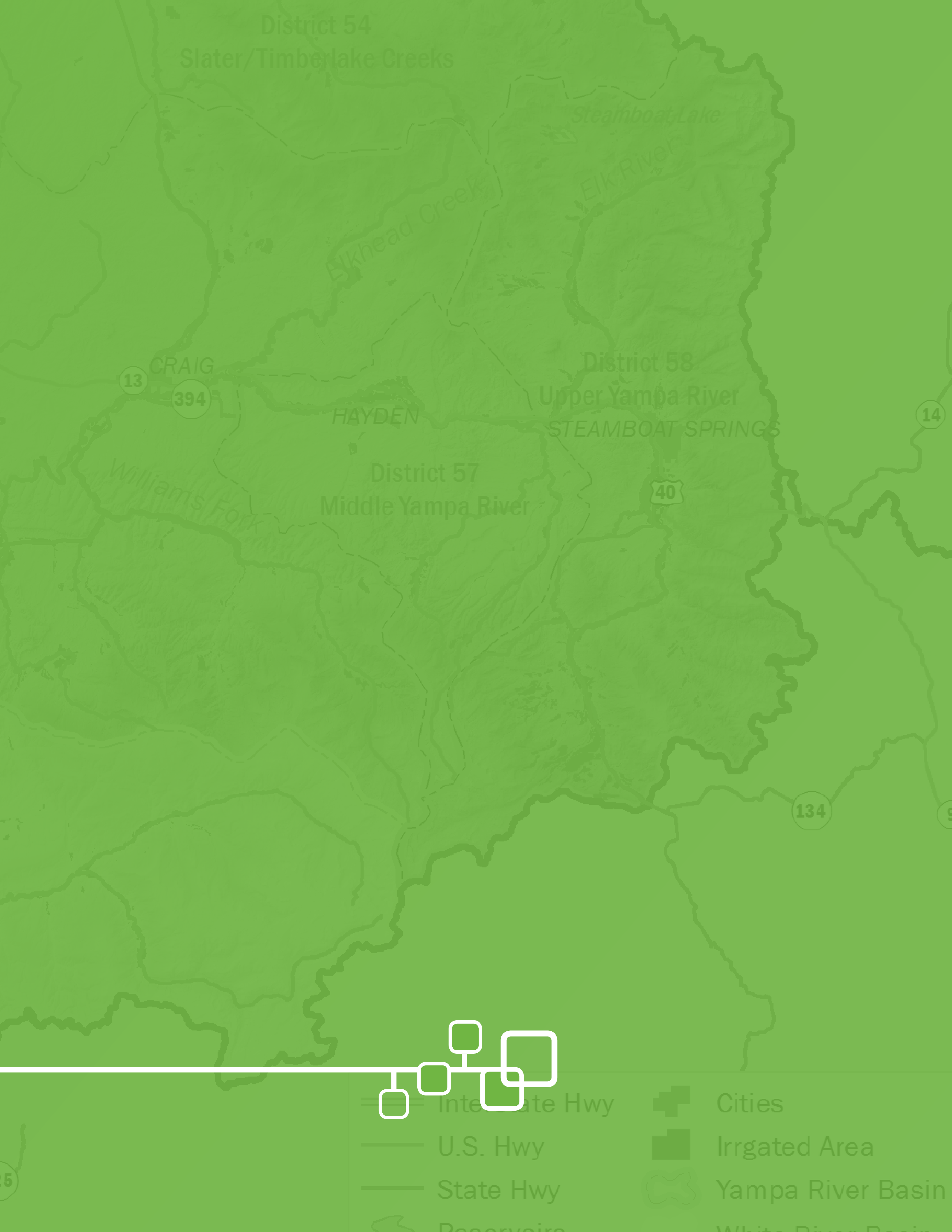
Category	Observation
Projected Flows	In locations where baseline conditions are minimally depleted from naturalized conditions (e.g., the San Miguel River), peak flow magnitude under *Business as Usual* and *Weak Economy* are projected to decline only slightly below baseline. Under climate change scenarios, declines in peak flow magnitude are projected to be further below baseline.
	At all locations, the timing of peak flow is projected to move earlier in the year for all climate change projections (Cooperative Growth, Adaptive Innovation, and Hot and Dry). Under these climate change projections, June flows may decrease the most (e.g., Dolores River at Dolores). Under these same scenarios, April flow may increase, but the increase in April flow magnitude may not offset the decline in June flow magnitude.
Ecological Risk	In all locations, mid- and late-summer flows are projected to decline under *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth* scenarios, increasing risks for coldwater and warmwater fish.
	In locations where naturalized and baseline conditions are similar, peak flow-related risk to riparian/wetland plants and fish are projected to remain low to moderate under *Business as Usual*, *Weak Economy*, and *Cooperative Growth* scenarios. Under *Adaptive Innovation* and *Hot Growth*, this risk may increase.
	In locations where peak flows under baseline are already substantially less than naturalized conditions, peak flow-related risk to riparian/wetland plants and fish is already high and may increase under climate change scenarios.
	Under all climate change scenarios, runoff and peak flows occur earlier, and possible mis-matches between peak flow timing and species' needs may occur.
	In locations where naturalized and baseline conditions are similar, risk to coldwater fish (mainly trout) may increase under the various planning scenarios because of declines in mid- and late-summer flow. However, the risk remains moderate in most years.
	In locations that experience low summer flows, risk to fish may increase. Note that the Flow Tool risk assessment using coldwater and warmwater fish metrics does not include July because historically July flows are sufficient. In some locations, July flows may be significantly reduced under climate change scenarios (e.g., July flows under *Hot Growth* on the Piedra River near Arboles). The projected reduction will likely result in reduced habitat and increased stream temperatures.
ISFs and RICDs	ISFs throughout the Southwest and the RICD on the Animas River may not be met in many years under *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*. For example, flows on the San Miguel River near Placerville are projected to fall short of the 93 cfs summer ISF regularly during mid- and late-summer. In August, this ISF is projected to be unmet during 1 out of 3 years under *Cooperative Growth* and during two out of three years under *Adaptive Innovation* and *Hot Growth*.
	On the Animas River, the 25 cfs RICD near Howardsville is projected to not be met in numerous years during late summer (August) through October, and again in January and February (when the minimum flow is 13 cfs) under the three climate change scenarios.
E&R Attributes	Under baseline, *Business as Usual*, and *Weak Economy*, current flow issues related to E&R attributes arise primarily because of depletions that increase moving downstream.
	In some locations, transbasin diversions reduce and change the timing of flow in the basin of origin while augmenting flows in the receiving basin.
	Under climate change scenarios, the shift in the timing of peak flow, reductions in total runoff, and increasing consumptive demands may contribute to reductions in mid- and late-summer flows.

The Yampa, White, and Green Basins cover approximately 10,500 acres in northwestern Colorado and south-central Wyoming. The basin landscape is diverse and includes steep mountain slopes, high plateaus, canyons, and broad alluvial valleys. Livestock, grazing, and recreation are the predominant land uses. Near the towns of Craig, Hayden, Steamboat Springs, Yampa, and Meeker, much of the land is dedicated to agricultural use, and the mountains are covered by forest. The Steamboat Springs area, featuring a destination ski resort, is likely to experience continued and rapid population growth.

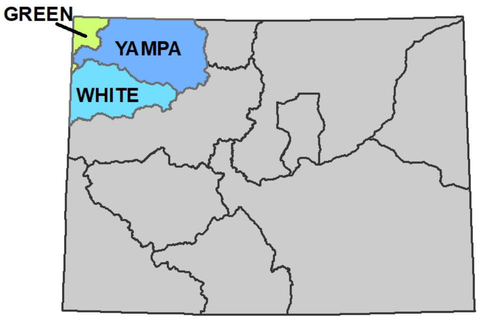
The Technical Update largely keeps the analysis at the basin scale. There are some exceptions where subbasin (river basin) analysis of major waterways was more straightforward. To that end, both the Yampa and the White river basins were explicitly modeled with results that are shown in this section. The combined Yampa-White-Green results are shown where statewide results are described.

Note that tributaries of the Green River have five diversions and one instream flow water right, and these are included in the model for the Yampa Basin. The demands and potential gaps from these structures are included in the Yampa Basin results.

YAMPA WHITE GREEN


District 54
Slater/Timberlake Creeks
Steamboat Lake
Elk River
Elkhead Creek
CRAIG
13
394
HAYDEN
District 58
Upper Yampa River
STEAMBOAT SPRINGS
14
District 57
Middle Yampa River
Williams Fork
40
134
Interstate Hwy
U.S. Hwy
State Hwy
Cities
Irrgated Area
Yampa River Basin

4.10 YAMPA-WHITE-GREEN BASIN RESULTS

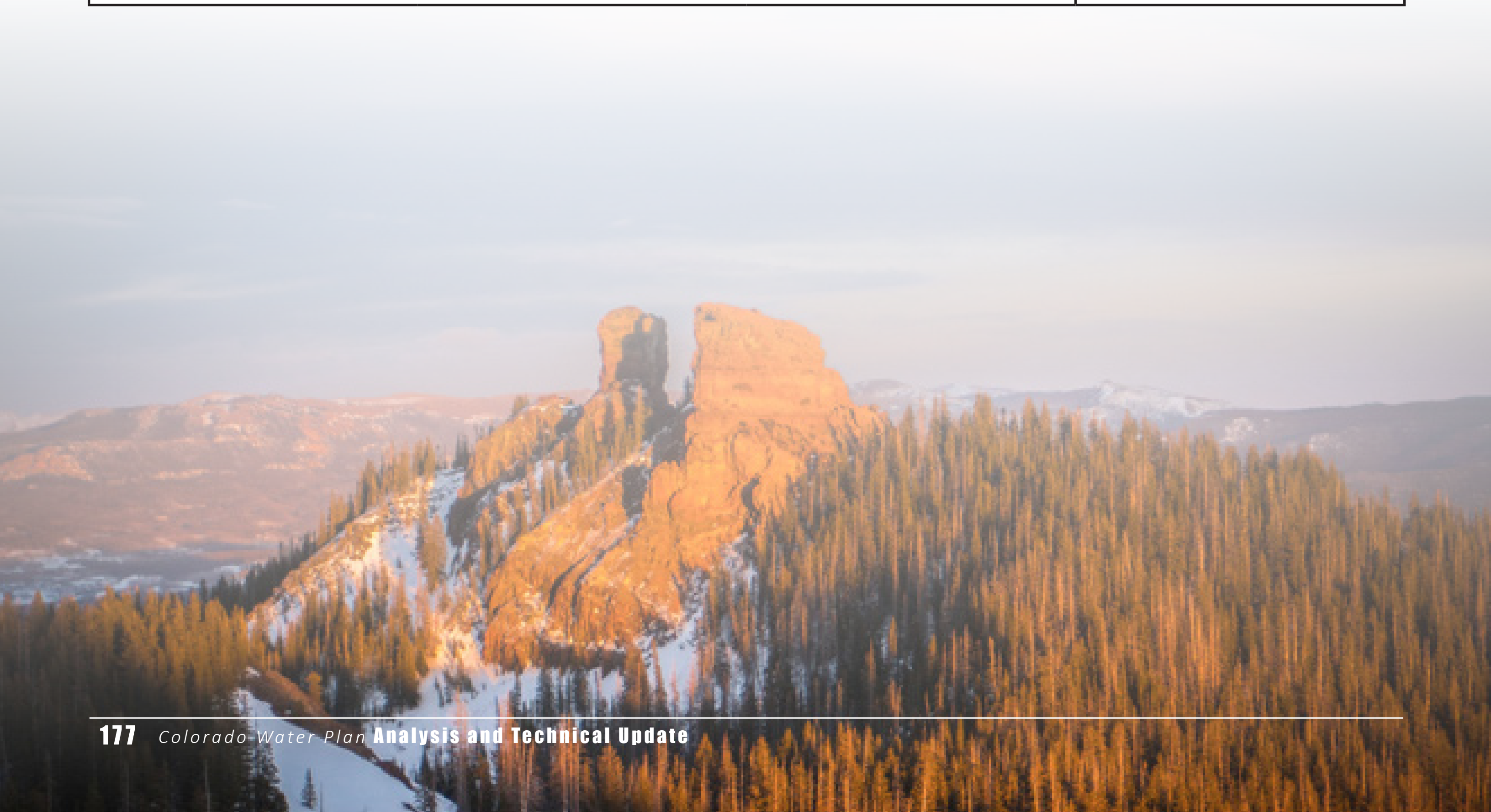


4.10.1 BASIN CHALLENGES

Key future water management issues for this basin include gas and oil shale development and addressing water resources needs for agriculture, tourism and recreation, and protection of endangered species. These challenges are outlined in the Colorado Water Plan and are summarized below.

Table 4.10.1 Key Future Water Management Issues in the Yampa-White-Green Basin

Agriculture	Environment and Recreation	Municipal and Industrial	Compacts and Administration
• Agricultural producers would like to increase irrigated land by 14,000 acres but lack finances to do so.	• Implementation of a successful Upper Colorado River Endangered Fish Recovery Program is vital to ensuring protection of existing and future water uses.	• The emerging development of gas and oil shale resources is affecting water demand, for both direct production and the associated increase in municipal use. • Industrial uses, especially power production, are a major water use. Future energy development is less certain.	• While rapidly growing in the Steamboat Springs area, the basin as a whole is not developing as quickly as other portions of the state. Concerns have arisen that the basin will not get a "fair share" of water under the Colorado River Compact in the event of a compact call.
• Agriculture, tourism, and recreation are vital components of this basin's economy. As the needs of communities and industry grow, competition among sectors could increase.			



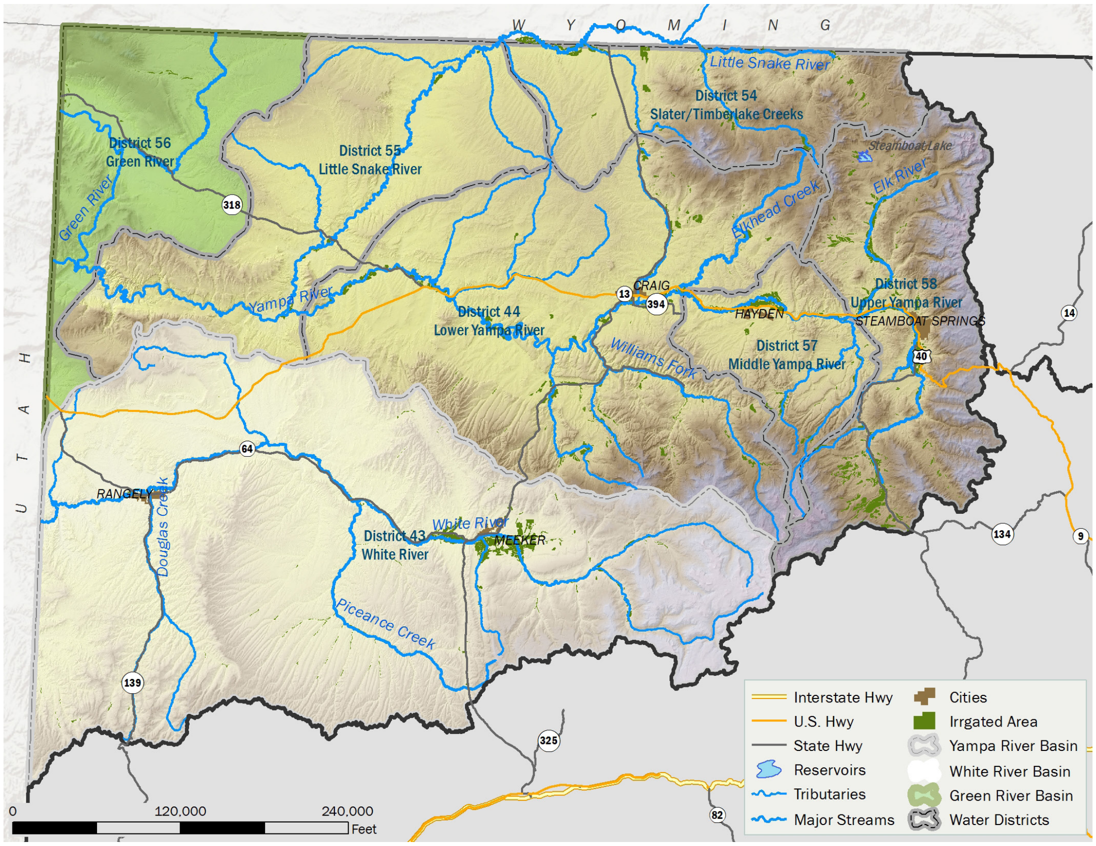


Figure 4.10.1 Map of the Yampa-White-Green Basin

4.10.2 SUMMARY OF TECHNICAL UPDATE RESULTS

Key results and findings of the Technical Update pertaining to agricultural and M&I demands and gaps as well as findings related to environmental and recreational attributes and future conditions are summarized below in Table 4.10.2.

Table 4.10.2 Summary of Key Results in the Yampa-White-Green Basin

Agriculture	Environment and Recreation	Municipal and Industrial
• Agricultural gaps may increase significantly in the Yampa Basin if water demands increase because of new acreage and higher IWR. • Gaps in the Yampa and White basins may also increase if stream flow is diminished via climate change. • Agricultural gaps in the White Basin are not projected to be as significant as in the Yampa	• In most locations, summer flows may be depleted significantly in climate-impacted scenarios, which creates high to very high risk for coldwater and warmwater fish. • Stream flows may be substantially below flow recommendations in some locations under climate-impacted scenarios.	• M&I demand for the combined basin ranges between 6 to 10 percent of agricultural demand. • Water supply gaps in the White Basin show a large increase in *Hot Growth* mainly due to potential increased energy development demand. • Increased population and thermoelectric demand drive increasing M&I gaps in the Yampa Basin.

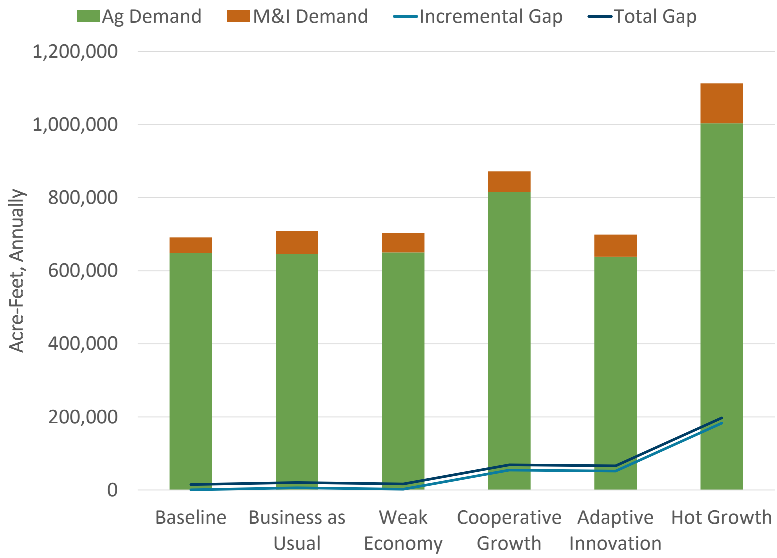
Results describing current and potential future M&I and agricultural demands and gaps are summarized in Table 4.10.3 and in Figure 4.10.2.

Table 4.10.3 Summary of Diversion Demand and Gap Results in the Yampa-White-Green Basin

		Current (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Yampa	**Average Annual Demand**						
	Agricultural (AFY)	402,500	403,600	403,600	522,500	461,000	684,300
	M&I (AFY)	36,900	53,300	46,700	48,900	53,000	68,300
	Gaps						
	Ag (avg %)	3%	3%	3%	12%	13%	22%
	Ag (incremental-AFY)	-	400	300	49,800	45,700	136,800
	Ag (incremental gap as % of current demand)	-	0%	0%	12%	11%	34%
	M&I (max %)	0%	3%	1%	3%	5%	12%
	M&I (max-AF)	0*	1,600	700	1,600	2,500	8,200
White	**Average Annual Demand**						
	Agricultural (AFY)	246,700	242,900	246,700	293,900	177,800	319,700
	M&I (AFY)	5,300	10,000	6,100	6,900	7,700	41,000
	Gaps						
	Ag (avg %)	0%	1%	0%	1%	2%	2%
	Ag (incremental-AFY)	-	-	-	1,900	2,100	4,600
	Ag (incremental gap as % of current demand)	-	0%	0%	1%	1%	2%
	M&I (max %)	0%	39%	15%	13%	17%	82%
	M&I (max-AF)	0	3,900	900	900	1,300	33,500
Total	**Average Annual Demand**						
	Agricultural (AFY)	649,200	646,500	650,400	816,300	638,700	1,004,000
	M&I (AFY)	42,200	63,400	52,800	55,900	60,600	109,300
	Gaps						
	Ag (avg %)	2%	2%	2%	8%	10%	16%
	Ag (incremental-AFY)	-	400	300	51,700	47,800	141,400
	Ag (incremental gap as % of current demand)	-	0%	0%	8%	7%	22%
	M&I (max %)	0%	9%	3%	5%	6%	38%
	M&I (max-AF)	0*	5,600	1,600	2,600	3,800	41,700

** CDSS water allocation model in this basin calculates small baseline M&I gaps, but they are either due to calibration issues or they are reflective of infrequent, dry-year shortages that are typically managed with temporary demand reductions, such as watering restrictions.*

Figure 4.10.2 Summary of Diversion Demand and Gap Results in the Yampa-White-Green Basin



Summary of Environmental and Recreational Findings

- In most stream locations, peak flows may be modestly depleted with low to moderate risk to riparian/wetlands and fish habitat. Peak flows may move earlier in the year, with March, April and May flows increasing substantially and June flows decreasing. Possible mis-matches between peak flow timing and species needs may occur.
- In most stream locations, including those with current low risk during mid- and late-summer, summer flows may be depleted 65 to 90 percent under *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*, which could create high to very high risk for coldwater and warmwater fish.
- The recreational in-channel diversion in Steamboat Springs could be at risk of being unmet often in mid- to late-summer, and Instream Flow water rights in most areas could be at greater risk of not being met, especially under *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*.
- In critical habitat for endangered species, extremely reduced flows in mid- and late-summer (greater than 90 percent reduction in July on the Yampa River near Maybell; greater than 80 percent reduction in July and August on the White River near Watson) may result in the flows in most years being substantially below flow recommendations. On the Yampa, in addition to loss of habitat for endangered fish, extremely low flows favor non-native fish reproduction and survival.

4.10.3 NOTABLE BASIN CONSIDERATIONS

Section 4.1 described several analysis assumptions and limitations that apply to all basins and should be considered when reviewing and interpreting analysis results. Additional considerations specific to the Yampa-White-Green Basin are listed below:

- The Yampa-White-Green has published a follow-on report to their BIP, which has different results based on different modeling objectives, assumptions, and inputs (e.g., climate assumptions around paleohydrology are different than the assumptions in the Technical Update; see section 2.2.1).
- The Technical Update used water allocation models that reflect a strict application of water administration. In the Yampa-White-Green basin, some water users refrain from placing a call to share the benefit of available supplies.
  - As an example, in the White Basin, Kenney Reservoir is used for hydropower production. If future water shortages occur that might impact energy development, it is very possible that hydropower operators would choose to reduce generation as opposed to curtailing energy development uses.
- The Yampa-White-Green SSI demands for energy production could be further researched.
- Projected gaps in several scenarios are low relative to other basins. The result is consistent with expectations because supplies in the Yampa-White-Green have historically met demands. The first mainstem call on the Yampa occurred in 2018.
- Current Elkhead Reservoir operations related to the Yampa Programmatic Biological Opinion (PBO) are included in the Yampa model. The White PBO is in progress and was not included in the model. Future water supply projects and strategies were not included in the analysis.

GREEN RIVER DEMANDS

Tributaries of the Green River have five diversions and one instream flow water right, and these are included in the model for the Yampa Basin. The demands and potential gaps from these structures are included in the Yampa Basin results.

4.10.4 AGRICULTURAL DIVERSION DEMANDS

Agricultural Setting

Yampa Basin

Agriculture is a primary focus in the Yampa Basin. Irrigated acreage in the basin consists primarily of high mountain meadows and cattle ranches in the upper reaches of the basin along Elk Creek and the Yampa River. Irrigated acreage is also located along the Little Snake River as it meanders between Colorado and Wyoming.

White Basin

Approximately 60 percent of the irrigated acres in the White Basin are concentrated along the river near the Town of Meeker. The remaining acreage is located along tributaries and spread along the lower mainstem. Grass pasture is the dominant crop in the basin, and alfalfa is also grown. These forage crops support cattle grazing and ranching operations in the basin, which is a major economic driver. Mining and oil and gas extraction are also important elements of the basin's economy.

Planning Scenario Adjustments

Section 2 described ways in which inputs to agricultural diversion demand estimates were adjusted to reflect the future conditions described in the planning scenarios. Adjustments in the Yampa-White-Green Basin focused on urbanization, potential future climate conditions, and implementation of emerging technologies.

Yampa Basin

The Yampa-White-Green basin roundtable completed an Agricultural Water Needs Study in 2010 that identified 14,805 acres of potentially irrigable land in the Yampa Basin. For the Technical Update effort, the Yampa/White/Green basin roundtable contemplated how the irrigable land could be developed under the planning scenarios, recognizing that growth could vary depending on the future demand and economics for hay crops and cattle production. The stakeholders in the basin provided a varying amount of acreage and crops types for planned agricultural projects in each planning scenario in the Yampa Basin as reflected in Table 4.10.4.

Population projections anticipate significant growth in the Yampa Basin. The impact to irrigated areas, however, will be limited because the three largest municipal centers in the basin (Steamboat Springs, Hayden, and Craig) are not surrounded by irrigated agricultural areas.

White Basin

Future urbanization of irrigated lands is expected to be relatively limited in the basin, with 360 acres total in and around the towns of Meeker and Rangely projected to be urbanized. Population projections in Rio Blanco County are expected to decline in *Weak Economy*, and urbanization in this scenario was set to zero. Table 4.10.4 provides a summary of the adjustments to agricultural diversion demand drivers based for each planning scenario.

Table 4.10.4 summarizes the planning scenario adjustments described above and other adjustments that impact agricultural diversion demands in the various scenarios.

SYSTEM EFFICIENCY

In some cases, diversion demands surface water can be higher in wet years because system efficiency decreases due to the relative abundance of supply

Table 4.10.4 Planning Scenario Adjustments for Agricultural Demands in the Yampa and White Basins

Sub-basin	Adjustment Factor*	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Yampa	Change in Irrigated Land due to Urbanization	1,500 Acre Reduction	1,500 Acre Reduction	1,500 Acre Reduction	1,500 Acre Reduction	1,500 Acre Reduction
	Planned Agricultural Development Projects	1,000 Acre Increase 100% Alfalfa	1,000 Acre Increase 100% Alfalfa	5,000 Acre Increase 50/50 Grass Pasture/Alfalfa	14,805 Acre Increase 50/50 Grass Pasture/Alfalfa	14,805 Acre Increase 50/50 Grass Pasture/Alfalfa
	IWR Climate Factor	-	-	19%	34%	34%
	Emerging Technologies	-	-	-	10% IWR Reduction 10% System Efficiency Increase	-
White	Change in Irrigated Land due to Urbanization	360 Acre Reduction	-	360 Acre Reduction	360 Acre Reduction	360 Acre Reduction
	IWR Climate Factor	-	-	22%	37%	37%
	Emerging Technologies	-	-	-	10% IWR Reduction 10% System Efficiency Increase	-

** See section 2.2.3 for descriptions of adjustment methodologies and assumptions*

Agricultural Diversion Demand Results

Table 4.10.5 and Figures 4.10.3 and 4.10.4 summarize the acreage, IWR, and the agricultural diversion demand for surface water supplies in both the White and Yampa Basins for current conditions and the five planning scenarios. The largest variation in the White Basin occurred in *Adaptive Innovation* due to 10 percent reduction in IWR and 10 percent increase to system efficiency. In this basin, the combined impact of *Adaptive Innovation* adjustments resulted in an agricultural diversion demand that is lower than the current demand. The Yampa Basin saw the greatest increase in demand for *Hot Growth*, which assumed a large increase in irrigated acres.

Table 4.10.5 Summary of Agricultural Diversion Demand Results in the Yampa and White Basins

		Current	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Yampa	Irrigated Acreage (acres)	78,900	78,400	78,400	82,400	92,300	92,300
	Average IWR (AFY)	150,600	150,000	150,000	188,000	209,000	232,000
	Diversion Demand						
	Average Year (AFY)	402,000	403,000	403,000	518,000	456,000	679,000
	Wet Yr. Change	-4%	-3%	-3%	0%	1%	2%
	Dry Yr Change	0%	0%	0%	-1%	-2%	-3%
White	Irrigated Acreage (acres)	28,100	27,700	28,000	27,700	27,700	27,700
	Average IWR (AFY)	46,400	45,800	46,400	55,700	55,900	62,100
	Diversion Demand						
	Average Year (AFY)	243,000	239,000	243,000	293,000	180,000	324,000
	Wet Yr. Change	3%	3%	3%	4%	3%	6%
	Dry Yr Change	0%	0%	0%	-5%	-4%	-6%

Average agricultural diversion demand was calculated using the average hydrologic years (i.e., years classified as neither wet or dry) from 1950-2013

Figure 4.10.3 Agricultural Diversion Demands and IWR Results in the Yampa Basin

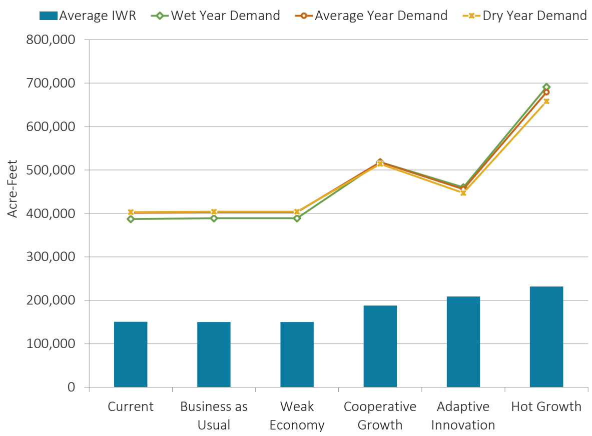
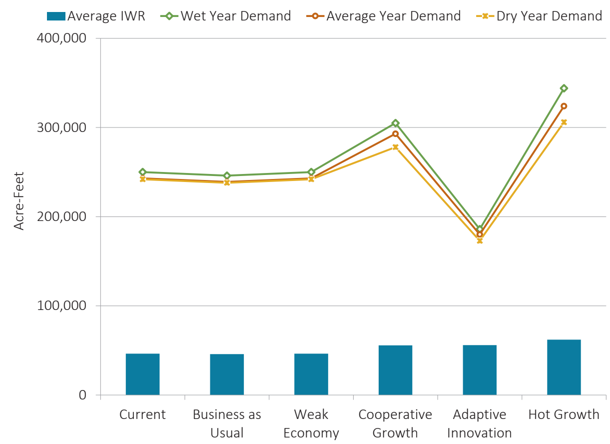


Figure 4.10.4 Agricultural Diversion Demands and IWR Results in the White Basin



4.10.5 Municipal and Self-Supplied Industrial Diversion Demands

Population Projections

The combined Yampa-White Basin currently includes less than 1 percent of the statewide population. Between the years 2015 and 2050, it is projected to change from approximately 44,000 to between 39,000 and 103,000 people in the low and high growth projections, respectively. Table 4.10.6 shows how population growth is projected to vary across the planning scenarios for White and Yampa basins.

Table 4.10.6 Yampa-White Basin 2015 and Projected Populations

Sub-basin	Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Yampa	37,200	59,900	34,400	63,500	86,000	91,900
White	6,500	7,400	4,200	7,000	10,600	11,300
Yampa-White Total	43,700	67,200	38,600	70,400	96,600	103,200

Current Municipal Demands

Sources of water demand data such as 1051 or WEP data were scarce in the Yampa and White Basins, and baseline water demands were largely estimated as shown on Figure 4.10.5.

Figure 4.10.6 summarizes the categories of municipal, baseline water usage in the Yampa and White Basins. In the Yampa Basin, and on a basin-scale, the residential indoor demand as a percentage of the systemwide demands is the highest reported throughout the state, at more than 50 percent. Conversely, the baseline residential outdoor water demand is the lowest statewide, at approximately 15 percent of the systemwide demands.

Figure 4.10.5 Sources of Water Demand Data in the Yampa-White Basin

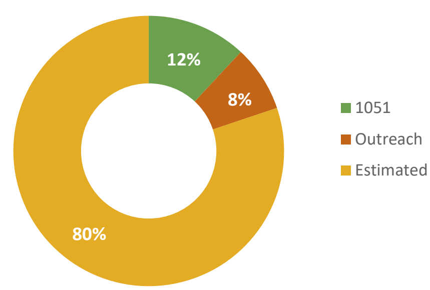
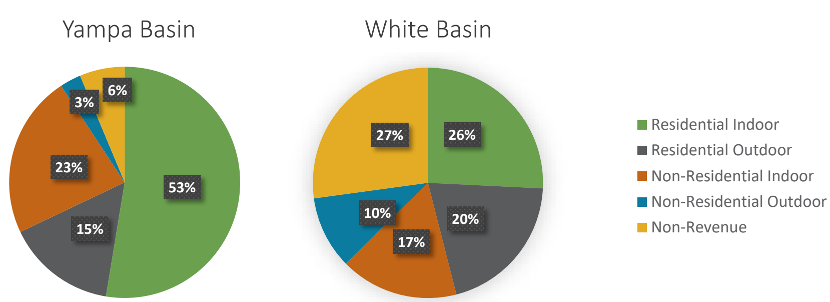


Figure 4.10.6 Categories of Water Usage in the Yampa-White Basin



Projected Municipal Demands

Figure 4.10.7 provides a summary of per capita baseline and projected water demands for the Yampa Basin. Systemwide, the projected per capita demands decrease relative to the baseline under all scenarios.

Figure 4.10.8 shows a summary of per capita baseline and projected water demands for the White Basin. Systemwide, the estimated per capita demands are projected to decrease relative to the baseline except in *Weak Economy* and *Hot Growth*. Consistently across all scenarios, the non-revenue water is the greatest demand category.

DECREASING GPCD

The Yampa-White Basin average baseline per capita systemwide demand has decreased slightly from 230 gpcd in SWSI 2010 to approximately 228 gpcd.

The relative proportions of various demand categories were estimated to be somewhat different in the White and Yampa Basins. Much of the difference is related to lack of representative data. In the White Basin, some usage data was derived from targeted outreach, but most of the data was filled (based on the outreach). In the Yampa Basin, some data were available via 1051 reporting, water efficiency plans, and targeted outreach, but much of the data was filled based on results from the available sources. Basin roundtables could work to acquire better data during the BIP update process.

Figure 4.10.7 Yampa Basin Municipal Baseline and Projected per Capita Demands by Water Demand Category

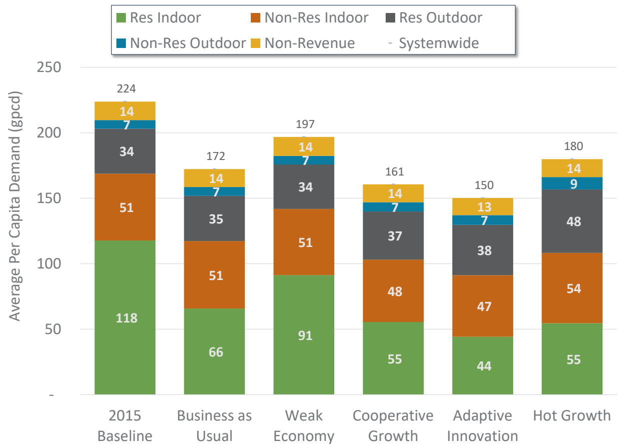


Figure 4.10.8 White Basin Municipal Baseline and Projected per Capita Demands by Water Demand Category

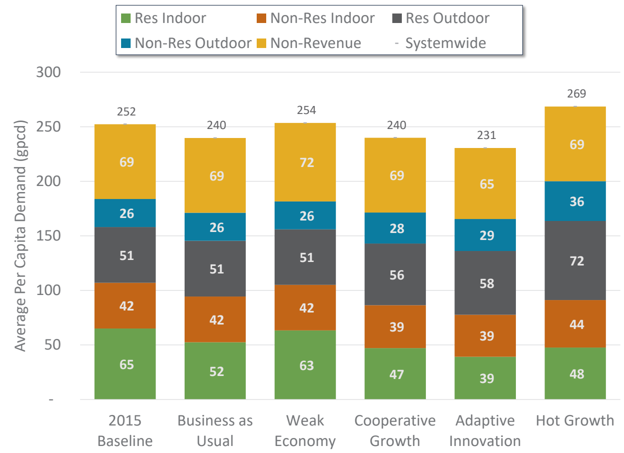


Table 4.10.7 Yampa-White Basin Municipal Baseline and Projected Demands (AFY)

Sub-basin	Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Yampa Basin	9,300	11,600	7,600	11,400	14,500	18,500
White Basin	1,800	2,000	1,200	1,900	2,700	3,400
Yampa-White Basin Total	11,200	13,500	8,800	13,300	17,200	21,900

Figure 4.10.9 Combined Yampa-White Basin Baseline and Projected Population and Municipal Demands

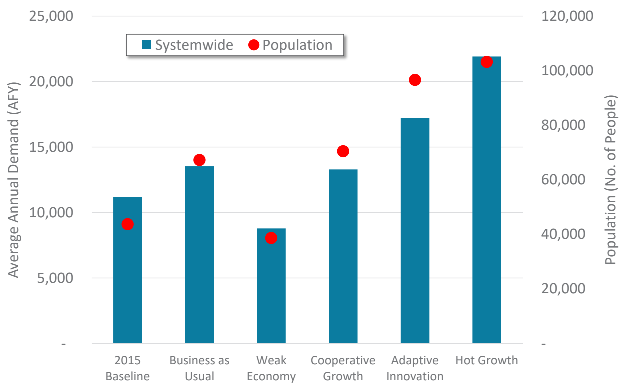
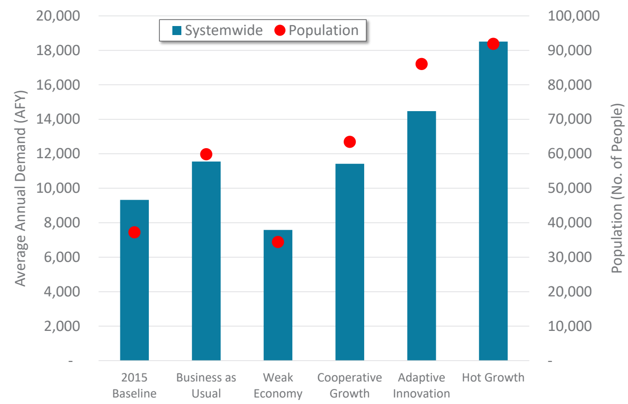


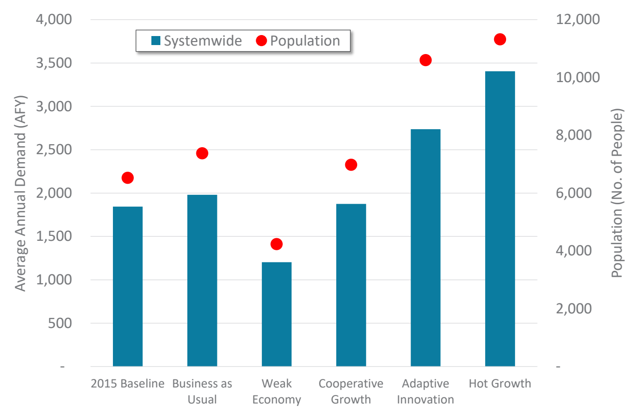
Figure 4.10.10 Yampa Basin Baseline and Projected Population and Municipal Demands



The Yampa-White Basin municipal baseline and projected demands are provided in Table 4.10.7, showing the combined effect of population and per capita demands. Municipal demands are projected to grow from approximately 11,000 AFY in 2015 to between 9,000 and 22,000 AFY in 2050.

The baseline and projected demand distributions are shown on Figures 4.10.9 through 4.10.11. Projected demands in *Business as Usual* and *Cooperative Growth* are nearly identical. All of the projection scenarios except for *Weak Economy* result in an increase relative to the baseline. Demands generally follow the population patterns, which shows the influence that population has within this region. *Adaptive Innovation* demands are an exception to this in that they are lower than *Hot Growth*. *Adaptive Innovation* demands include higher levels of water conservation, which keep demands lower despite similar assumptions of high population growth used in *Hot Growth*. Projected demands and populations in *Business as Usual* and *Cooperative Growth* are similar, with a slightly more noticeable distinction with the White Basin.

Figure 4.10.11 White Basin Baseline and Projected Population and Municipal Demands

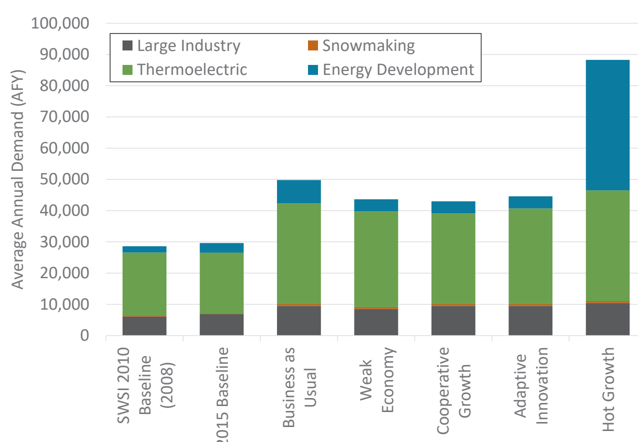


Self-Supplied Industrial Demands

The Yampa-White Basin includes about 17 percent of the statewide SSI demand. Approximately 93 percent of the baseline SSI demands are in the Yampa Basin and 7 percent are in the White Basin. SSI demands in the Yampa-White Basin are associated with all four sub-sectors. Basin-scale SSI demands are shown on Figure 4.10.12 and are summarized in Table 4.10.8.

Large Industry demands in this basin are located in Moffat and Routt counties. All baseline demands were based on SWSI 2010 and are related to mining in Moffat County and mining and golf courses in Routt County.

Figure 4.10.12 Total Yampa-White Basin SSI Baseline and Projected Demands



The baseline snowmaking demand is 290 AFY, which is the same as in SWSI 2010 because there has been no increase in snowmaking acreage. Projected demands are 570 AFY and were not varied by scenario.

Thermoelectric demands are related to two facilities. Baseline demands for the facility on Routt County were updated based on information from Xcel. Baseline demands for the facility in Moffat County were updated based on the BIP.

Table 4.10.8 Yampa-White SSI Baseline and Projected Demands (AFY)

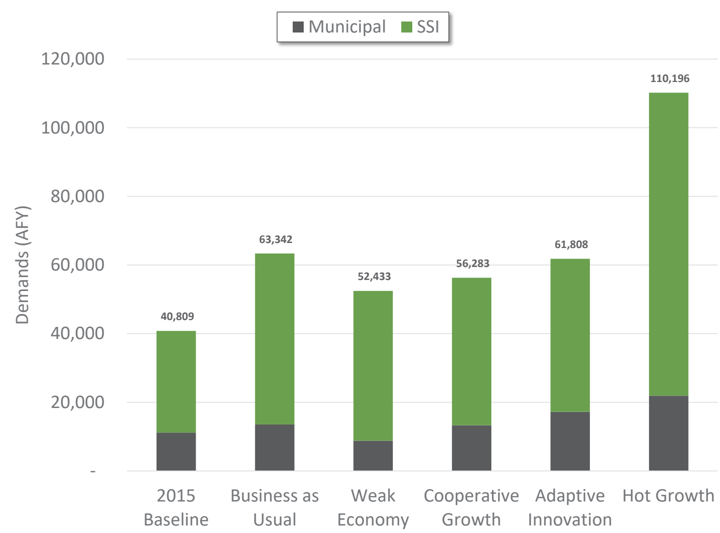
	Sub-sector	Baseline (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Yampa Basin	Large Industry	6,900	9,500	8,550	9,500	9,500	10,450
	Snowmaking	290	570	570	570	570	570
	Thermoelectric	19,350	32,240	30,630	29,020	30,630	35,460
	Energy Development	1,500	1,700	900	900	900	3,900
	Sub-Basin Total	28,040	44,010	40,650	39,990	41,600	50,380
White Basin	Large Industry	-	-	-	-	-	-
	Snowmaking	-	-	-	-	-	-
	Thermoelectric	-	-	-	-	-	-
	Energy Development	1,600	5,800	3,000	3,000	3,000	37,900
	Sub-Basin Total	1,600	5,800	3,000	3,000	3,000	37,900
	Basin Total	**29,640**	**49,810**	**43,650**	**42,990**	**44,600**	**88,280**

Energy development demands are located in Moffat, Rio Blanco, and Routt counties. Energy development demands in the White Basin for *Hot Growth* are much higher than for other scenarios but are consistent with high estimates of demands in Rio Blanco County used in SWSI 2010.

Total M&I Diversion Demands

Yampa-White Basin combined M&I demand projections for 2050 range from approximately 52,000 AFY in the *Weak Economy* to 110,000 AFY in *Hot Growth*, as shown on Figure 4.10.13. Under every planning scenario, SSI demands exceed the municipal. This is influenced by SSI use in the Yampa Basin and is the only basin in the state in which SSI demands exceed municipal. Self-supplied industrial demands make up approximately 70 percent to 80 percent of the total M&I demands in the Yampa-White Basin, depending on planning scenario. On a basin scale, the demand projections do not follow the statewide sequence of the scenario rankings described in the CWP, with the *Adaptive Innovation* falling out of sequence.

Figure 4.10.13 Yampa-White Basin Municipal and Self-Supplied Industrial Demands



4.10.6 Water Supply Gaps

The agricultural and M&I diversion demands were compared against available water supply modeled for current conditions and the five planning scenarios. Gaps were calculated when water supply was insufficient to meet demands.

In general, agricultural diversion demands gaps in the Yampa Basin are projected to be relatively low on an average annual basis in *Business as Usual* and *Weak Economy*, but gaps may be more significant in climate-impacted scenarios. Additional observations on the modeling results are summarized below.

Yampa Basin Gaps

Agricultural

The Yampa Basin agricultural diversion demands, demand gaps, and consumptive use gaps for the baseline and planning scenarios are presented in Table 4.10.9 and illustrated on Figure 4.10.14. An annual time series of gaps in terms of percent of demand that was unmet is shown in Figure 4.10.15. Agricultural diversion demand and consumptive use gap estimates were influenced by a number of drivers including climate, urbanization, planned agricultural projects, and emerging technologies.

Table 4.10.9 Yampa Basin Agricultural Gap Results (AFY)

		Scenario					
		Scenario	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average	Average Annual Demand	402,500	403,600	403,600	522,500	461,000	684,300
	Average Annual Gap	13,300	13,600	13,600	63,100	58,900	150,000
	Average Annual Gap Increase from Baseline	-	400	300	49,800	45,700	136,800
	Average Annual Percent Gap	3%	3%	3%	12%	13%	22%
	Average Annual CU Gap	7,400	7,600	7,600	34,400	37,800	81,500
Maximum	Demand in Maximum Gap Year	448,900	450,500	450,500	533,000	463,800	667,500
	Gap in maximum Gap Year	55,600	55,400	55,200	123,400	97,700	246,500
	Increase From Baseline Gap	-	-	-	67,900	42,200	191,000
	Percent Gap in Maximum Gap Year	12%	12%	12%	23%	21%	37%

Study period for Water Supply Analysis is 1975-2013, reflecting different baseline demand than described in Agricultural Diversion Demands section

Figure 4.10.14 Projected Average Annual Agricultural Diversion Demand Met, Baseline Gaps, and Incremental Gaps in the Yampa Basin

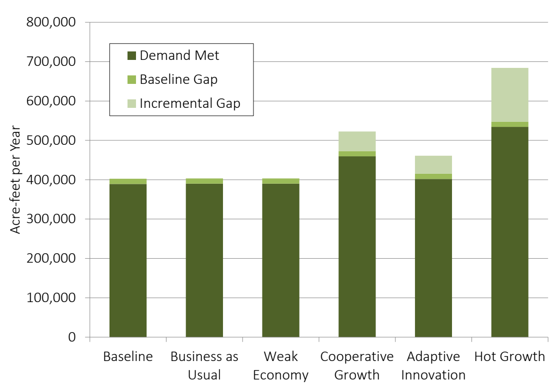
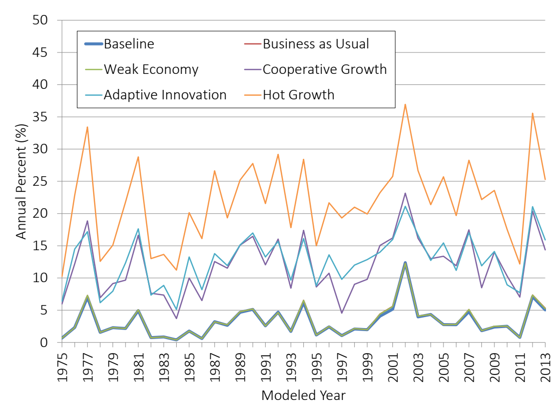


Figure 4.10.15 Annual Agricultural Gaps for Each Planning Scenario



- The Yampa Basin currently experiences an agricultural diversion demand gap, but the gap was not projected to significantly increase under the *Business as Usual* or *Weak Economy* scenarios.
- Agricultural diversion demand gaps increased in *Cooperative Growth*, *Adaptive Innovation* and *Hot Growth* due to additional demand from planned agricultural projects with junior water rights and higher IWR with concurrent lower water supply due to a drier and warmer climate.
- Climate conditions in *Adaptive Innovation* were hotter and drier than the *Cooperative Growth* scenario, but gaps were projected to be similar. Strategies associated with higher system efficiencies and the adoption of emerging technologies such as irrigation schedulings tended to offset climatic and hydrologic drivers that would have otherwise increased gaps in the *Adaptive Innovation* scenario.
- Agricultural water users do not have access to significant reservoir storage in the Yampa Basin. Gaps in *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth* were impacted by earlier runoff seasons and lower water availability during the latter part of the growing season.

INCREMENTAL GAP

The incremental agricultural gap quantifies the degree to which the gap could increase beyond what agriculture has historically experienced under water shortage conditions.

M&I

The water supply and gap results for M&I in the Yampa Basin are summarized Table 4.10.10 and illustrated on Figure 4.10.16. An annual time series of gaps in terms of percent of demand that was unmet is shown on Figure 4.10.17.

The following are observations on the M&I diversion demands and gaps:

- The modeling suggests M&I gaps occur under baseline conditions, but this result is due to minor model calibration issues and does not currently occur.
- M&I providers and systems with more robust water rights portfolios and access to storage (i.e. systems that were explicitly modeled) will likely have lower gaps than other providers without access to supplemental supplies.
- In general, projected M&I gaps under the scenarios are projected to be relatively modest with the exception of *Hot Growth*.
- Higher M&I diversion demands along with lower water availability due to climate impacts drive higher estimated gaps in the *Hot Growth* scenario

Table 4.10.10 Yampa Basin M&I Gap Results (AFY)

		Scenario					
		Scenario	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average	Average Annual Demand	36,900	53,300	46,700	48,900	53,000	68,300
	Average Annual Gap	0*	600	200	800	1,400	4,800
	Average Annual Percent Gap	0%	1%	0%	2%	3%	7%
Maximum	Demand in Maximum Gap Year	36,900	53,300	46,700	48,900	53,000	68,300
	Gap in Maximum Gap Year	0*	1,600	700	1,600	2,500	8,200
	Percent Gap in Maximum Gap Year	0%	3%	1%	3%	5%	12%

** CDSS water allocation model in this basin calculates small baseline M&I gaps, but they are either due to calibration issues or they are reflective of infrequent, dry-year shortages that are typically managed with temporary demand reductions, such as watering restrictions.*

Study period for Water Supply Analysis is 1975-2013, reflecting different baseline demand than described in M&I Demand section. Baseline demand also may vary slightly from previous section due to differences in geographic distribution of demand for Counties that lie in multiple basins.

Figure 4.10.16 Projected Maximum Annual M&I Diversion Demand, Demand Met, and Gaps in the Yampa Basin

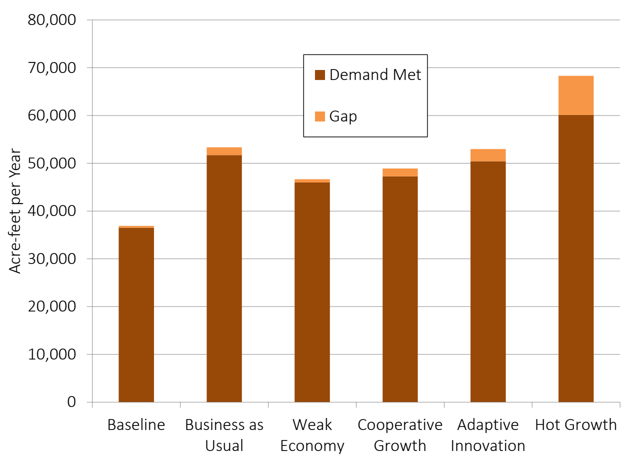
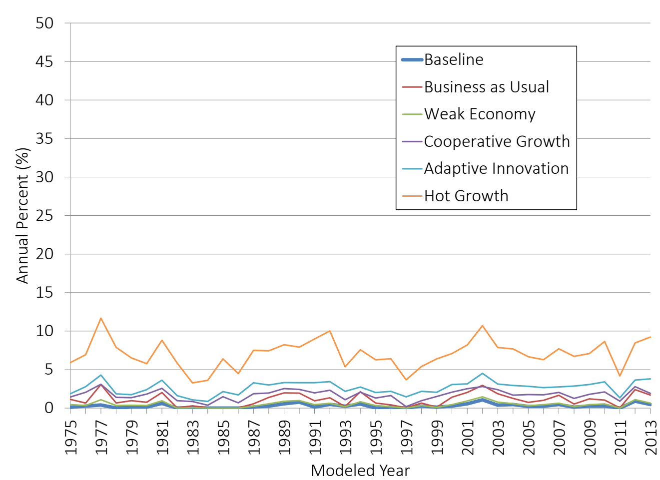


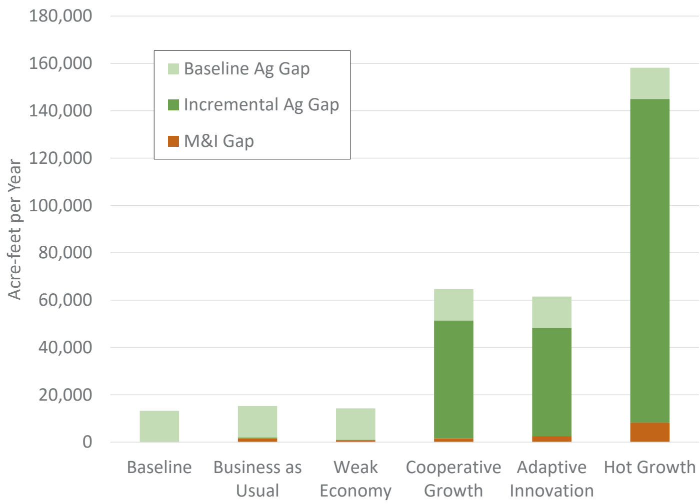
Figure 4.10.17 Annual M&I Gaps for Each Planning Scenario



Total Gap

Figure 4.10.18 illustrates the total combined agricultural and M&I diversion demand gap in the Yampa Basin. The figure combines the average annual baseline and incremental agricultural gap and the maximum M&I gap. Total gaps were driven by agriculture and were projected to be the highest in *Hot Growth*, which includes the highest amount of additional demand from planned agricultural projects and the most severe climate impacts.

Figure 4.10.18 Projected Average Annual Agricultural Gaps and Maximum M&I Diversion Demand Gaps in the Yampa Basin



Supplies from Urbanized Lands

By 2050, irrigated acreage in the Yampa Basin is projected to decrease by 1,500 acres due to urbanization. Irrigation supplies for these lands could potentially be used for M&I needs in the future (subject to a variety of unknowns such as seniority and type of water supply, willingness to change the use of water through water court, etc.). The average annual historical consumptive use associated with potentially urbanized acreage for each scenario is reflected in Table 4.10.11. The data in the table represent planning-level estimates of this potential supply and has not been applied to the M&I gaps.

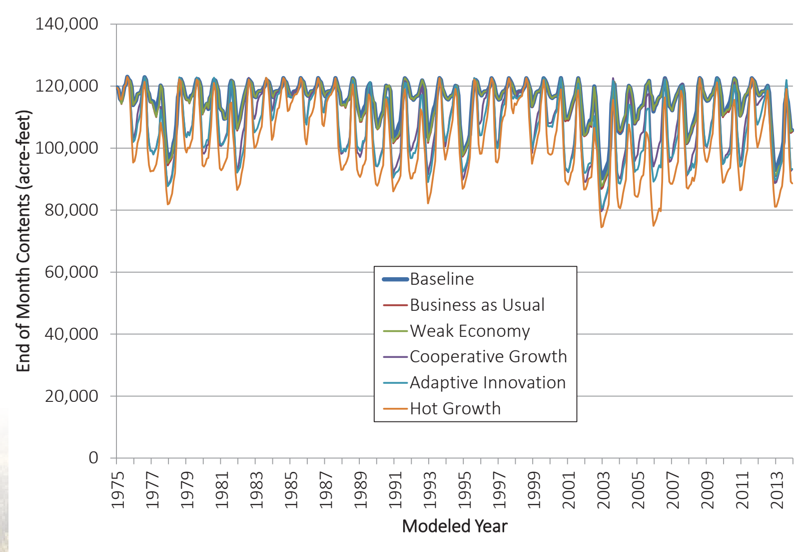
Table 4.10.11 Estimated Consumptive Use from Lands Projected to be Urbanized in the Yampa Basin

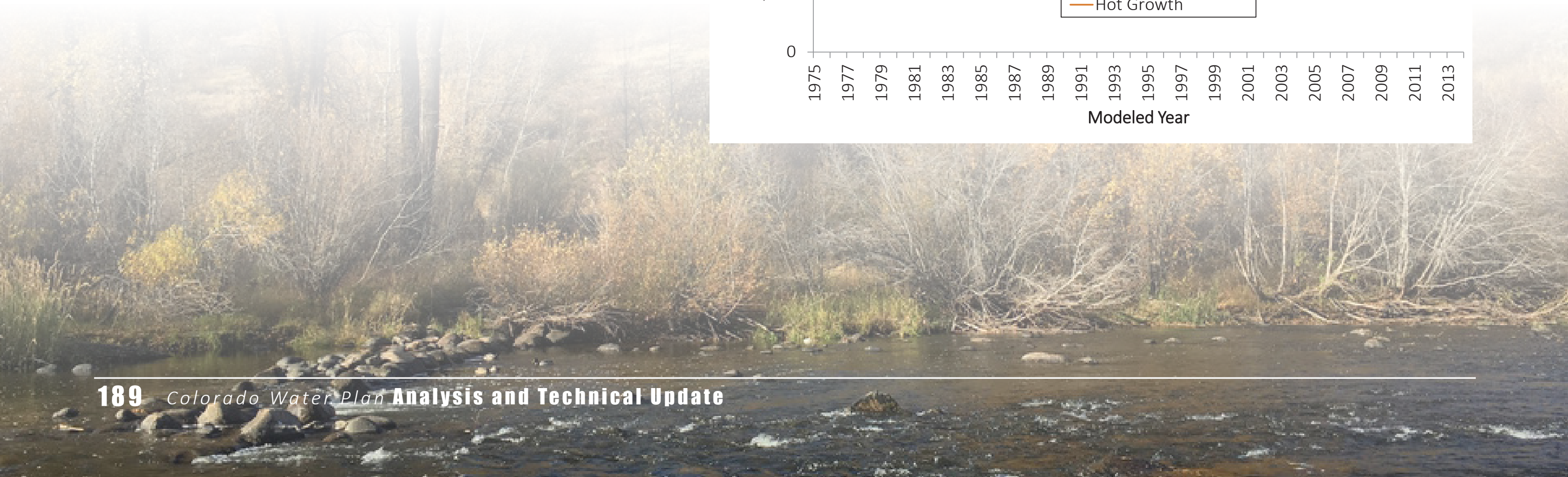
	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Urbanized Acreage (acres)	1,500	1,500	1,500	1,500	1,500
Estimated Consumptive Use (AFY)	2,700	2,700	2,800	2,800	2,400

Storage

Total simulated reservoir storage from the Yampa River water allocation model is shown on Figure 4.10.19. Baseline conditions show the highest levels of water in storage (in general), and the lowest is in *Hot Growth*. *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth* show lower amounts of water in storage during dry periods than the two scenarios that do not include the impacts of a drier climate; however, storage levels generally recover back to baseline levels after dry periods.

Figure 4.10.19 Total Simulated Reservoir Storage in the Yampa Basin





White Basin Gaps

Agricultural

The White Basin agricultural diversion demands, demand gaps, and consumptive use gaps for the baseline and planning scenarios are presented in Table 4.10.12 and illustrated on Figure 4.10.20. An annual time series of gaps in terms of percent of demand that was unmet is shown on Figure 4.10.21.

Table 4.10.12 White Basin Agricultural Gap Results (AFY)

		Scenario					
		Scenario	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average	Average Annual Demand	246,700	242,900	246,700	293,900	177,800	319,700
	Average Annual Gap	1,200	1,200	1,200	3,200	3,400	5,800
	Average Annual Gap Increase from Baseline	-	-	-	1,900	2,100	4,600
	Average Annual Percent Gap	0%	0%	0%	1%	2%	2%
	Average Annual CU Gap	700	700	700	1,700	2,200	3,200
Maximum	Demand in Maximum Gap Year	242,300	238,500	242,300	281,400	174,300	307,600
	Gap in maximum Gap Year	6,000	6,000	6,000	9,500	8,500	12,200
	Increase from Baseline Gap	-	-	-	3,500	2,500	6,200
	Percent Gap in Maximum Gap Year	2%	3%	2%	3%	5%	4%

Study period for Water Supply Analysis is 1975-2013, reflecting different baseline demand than described in Agricultural Diversion Demands section

Figure 4.10.20 Projected Average Annual Agricultural Diversion Demand, Demand Met, and Gaps in the White Basin

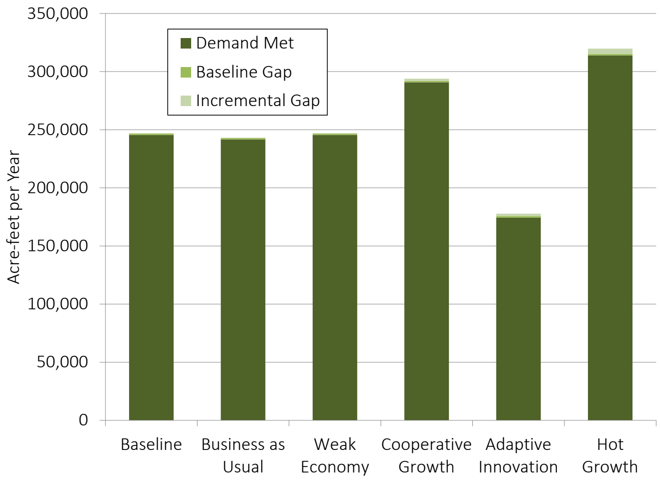
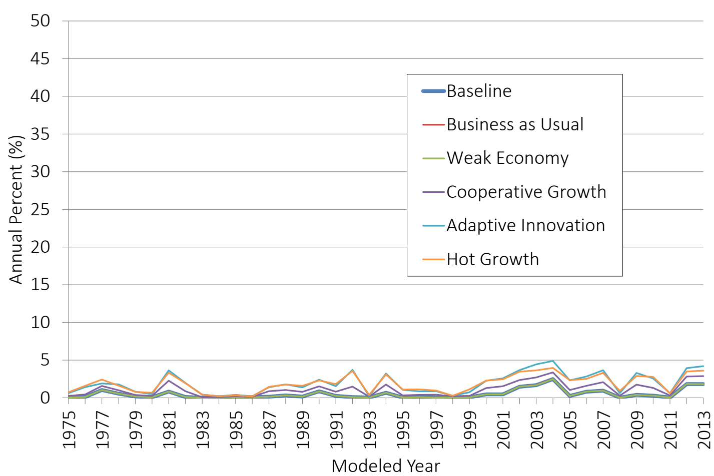


Figure 4.10.21 Annual Agricultural Gaps for Each Planning Scenario



In the White Basin, the current agricultural gap is small, and gaps are not projected to increase greatly in the planning scenarios. Agricultural gaps are greater in dry years. The largest annual, modeled gap occurred in *Hot Growth*, but it was small relative to demands at approximately 4 percent.

M&I

The diversion demand and gap results for M&I uses in the White Basin are summarized Table 4.10.13 and illustrated on Figure 4.10.22. An annual time series of gaps in terms of percent of demand that was unmet is shown in Figure 4.10.23.

Table 4.10.13 White Basin M&I Gap Results (AFY)

		Scenario					
		Scenario	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average	Average Annual Demand	5,300	10,000	6,100	6,900	7,700	41,000
	Average Annual Gap	0	3,000	700	700	800	27,500
	Average Annual Percent Gap	0%	30%	12%	10%	10%	67%
Maximum	Demand in Maximum Gap Year	5,300	10,000	6,100	6,900	7,700	41,000
	Gap in Maximum Gap Year	0	3,900	900	900	1,300	33,500
	Percent Gap in Maximum Gap Year	0%	39%	15%	13%	17%	82%

Figure 4.10.22 Projected Maximum Annual M&I Demand Met and Gaps in the White Basin

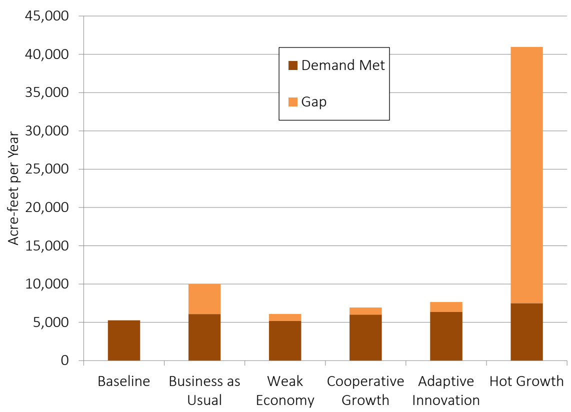
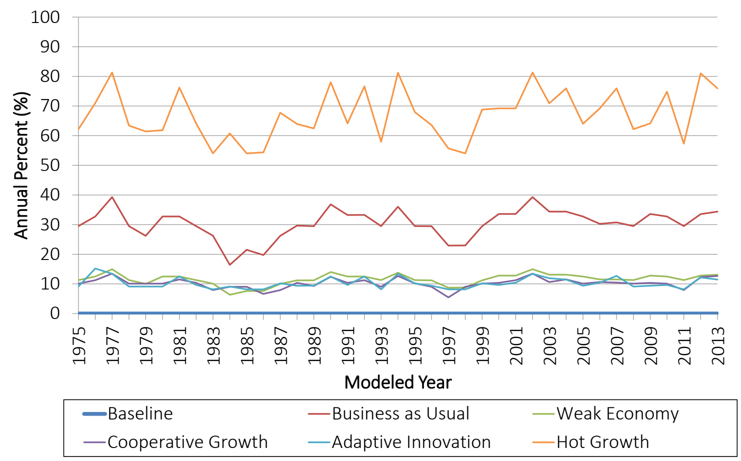


Figure 4.10.23 Annual M&I Gaps for Each Planning Scenario



The following are observations on the M&I diversion demands and gaps:

- The average annual M&I gap in the White Basin is greater than the agricultural gap, ranging from about 700 AF for *Weak Economy*, *Cooperative Growth*, and *Adaptive Innovation* up to 27,500 AF for *Hot Growth*.
- The maximum M&I gap for the five planning scenarios ranges from 900 AF to more than 33,000 AF.
- The M&I gaps were modeled to be largest in the *Business as Usual* and *Hot Growth* scenarios and were driven by relatively large energy development demands (especially in *Hot Growth*).

Total Gap

Figure 4.10.24 illustrates the total combined agricultural and M&I diversion demand gap in the White Basin. The figure combines the average annual baseline and incremental agricultural gaps and the maximum M&I gap. In *Business as Usual* and *Hot Growth*, gaps were driven by relatively high SSI demands. In *Weak Economy*, *Cooperative Growth*, and *Adaptive Management*, agricultural gaps were greater than M&I gaps.

Supplies from Urbanized Lands

By 2050, irrigated acreage in the White Basin is projected to decrease by 360 acres due to urbanization. Irrigation supplies for these lands could potentially be used for M&I needs in the future (subject to a variety of unknowns such as seniority and type of water supply, willingness to change the use of water through water court, etc.). The average annual historical consumptive use associated with potentially urbanized acreage for each scenario is reflected in Table 4.10.14. The data in the table represent planning-level estimates of this potential supply and has not been applied to the M&I gaps.

Figure 4.10.24 Projected Average Annual Agricultural Gaps and Maximum M&SSI Diversion Demand Gaps in the White Basin

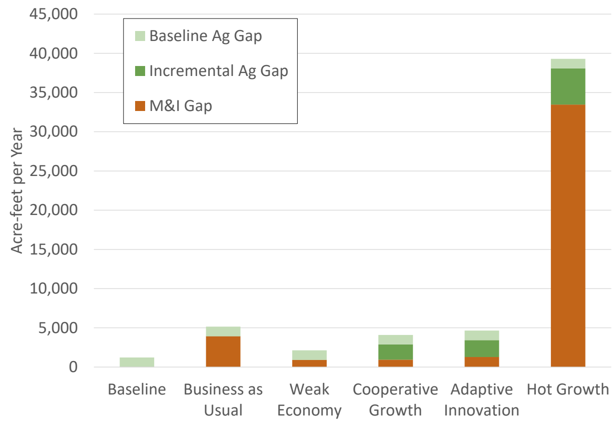


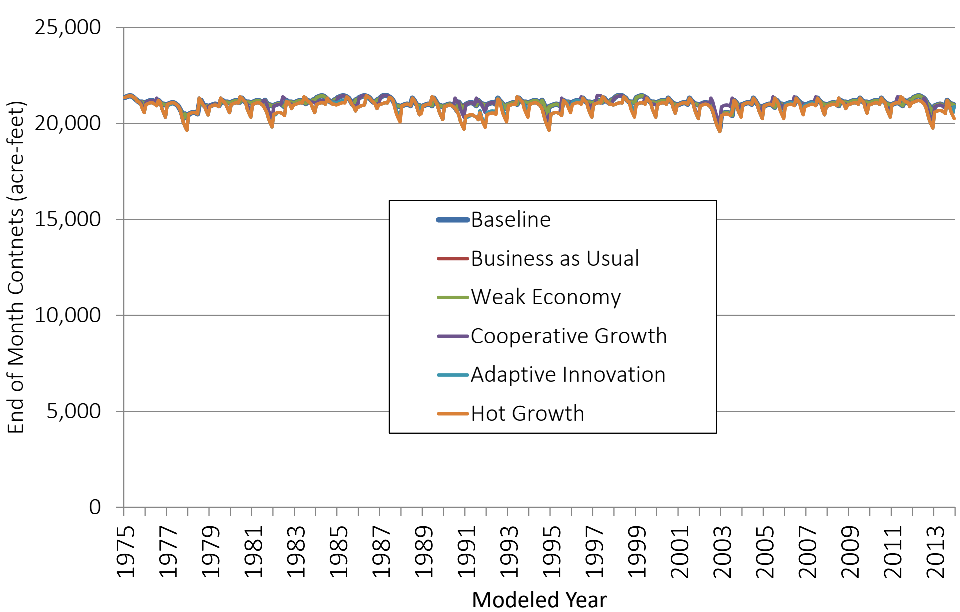
Table 4.10.14 Estimated Consumptive Use from Lands Projected to be Urbanized in the White Basin

	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Urbanized Acreage (acres)	360	-	360	360	360
Estimated Consumptive Use (AFY)	600	-	700	700	800

Storage

Total simulated reservoir storage from the White River water allocation model is shown on Figure 4.10.25. Basinwide storage levels do not significantly change in any of the planning scenarios, because agricultural and municipal water users in the basin do not typically use storage.

Figure 4.10.25 Total Simulated Reservoir Storage in the White Basin



Combined Yampa-White Basin Gaps

Table 4.10.15 summarizes the total M&I and agricultural demands in the Yampa-White Basin along with a summary of gaps. It should be noted that the Yampa and White Basins were modeled independently, and some of the results from each basin may not be wholly additive in some circumstances. For example, the maximum M&I gap may not occur in the same year in each sub-basin. As a result, the Yampa-White Basin as a whole may not experience a year in the future when the total maximum M&I gap corresponds to the sum of the maximum gaps in both sub-basins; however, the sum of the maximum sub-basin gaps does describe the total amount of water that would be needed to fully satisfy all M&I demands in each individual sub-basin, even if the gaps do not simultaneously occur in the sub-basins.

Table 4.10.15 Summary of Total Yampa-White Basin Demands and Gaps

	Current (2015)	Business as Usual	Weak Economy	Cooperative Growth	Adaptive Innovation	Hot Growth
Average Annual Demand						
Agricultural (AFY)	649,200	646,500	650,400	816,300	638,700	1,004,000
M&I (AFY)	42,200	63,400	52,800	55,900	60,600	109,300
Gaps						
Ag (avg %)	2%	2%	2%	8%	10%	16%
Ag (incremental-AFY)	-	400	300	51,700	47,800	141,400
Ag (incremental gap as % of current demand)	-	0%	0%	8%	7%	22%
M&I (max %)	0%	9%	3%	5%	6%	38%
M&I (max-AF)	01	5,600	1,600	2,600	3,800	41,700

CDSS water allocation model in this basin calculates small baseline M&I gaps, but they are either due to calibration issues or they are reflective of infrequent, dry-year shortages that are typically managed with temporary demand reductions such as watering restrictions.

4.10.7 Available Supply

Figures 4.10.26 and 4.10.27 show simulated monthly available flow for the Yampa Basin near the Maybell Canal, which is typically the senior calling right in the basin. Available flow at this location is very near to the physical flow in the stream, meaning that the Maybell Canal does not have a large impact on the available flow upstream. The figures show that flows are projected to be available each year, though the amounts will vary annually and across scenarios (available flows under the scenarios impacted by climate change are less than in other scenarios). Peak flows are projected to occur earlier in the year under scenarios impacted by climate change.

Figure 4.10.26 Simulated Hydrographs of Available Flow at Yampa River Near Maybell

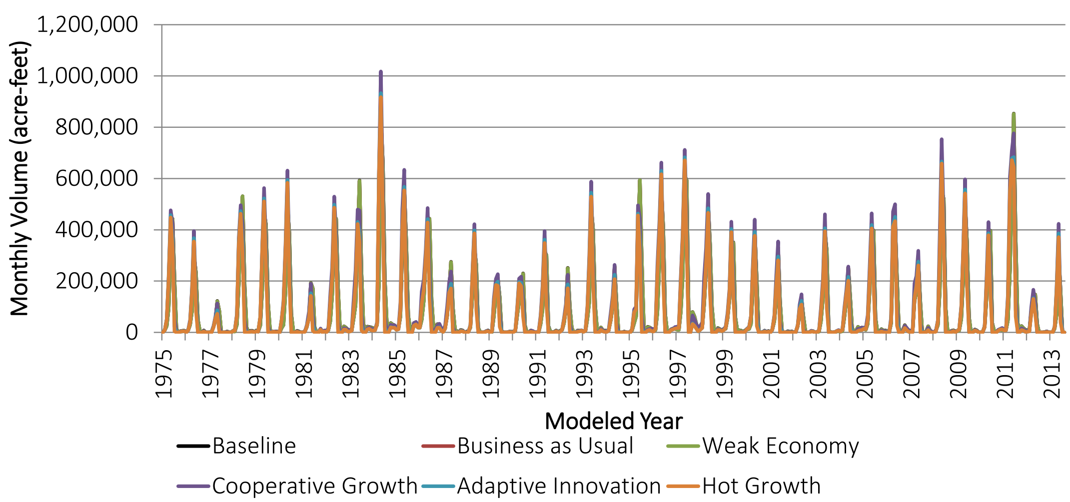
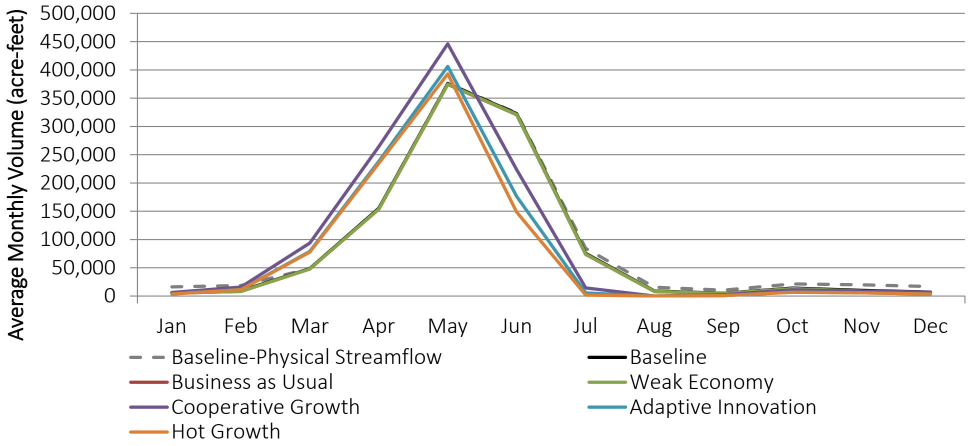


Figure 4.10.27 Average Monthly Simulated Hydrographs of Available Flow at Yampa River near Maybell



Figures 4.10.28 and 4.10.29 show simulated monthly available flow on the White River below Boise Creek, which is just above Kenney Reservoir. The reservoir has a hydropower water right that is not fully satisfied and serves as the calling right in the model. The figures show that flows are projected to be available in most years, though the amounts will vary annually and across scenarios (available flows under the scenarios impacted by climate change are less than in other scenarios). In some years, very little to no flow is available under current and future conditions at this location. Peak flows are projected to occur earlier in the year under scenarios impacted by climate change.

Figure 4.10.28 Simulated Hydrographs of Available Flow at White River Below Boise Creek

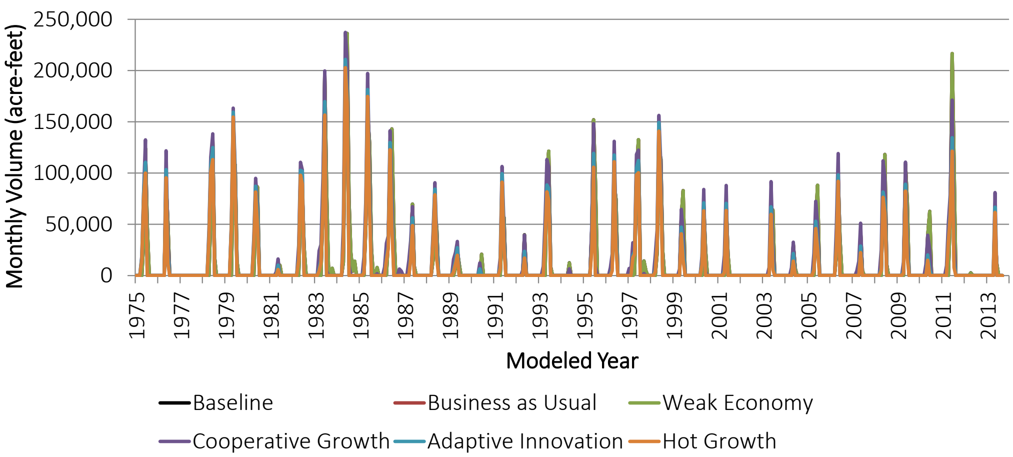
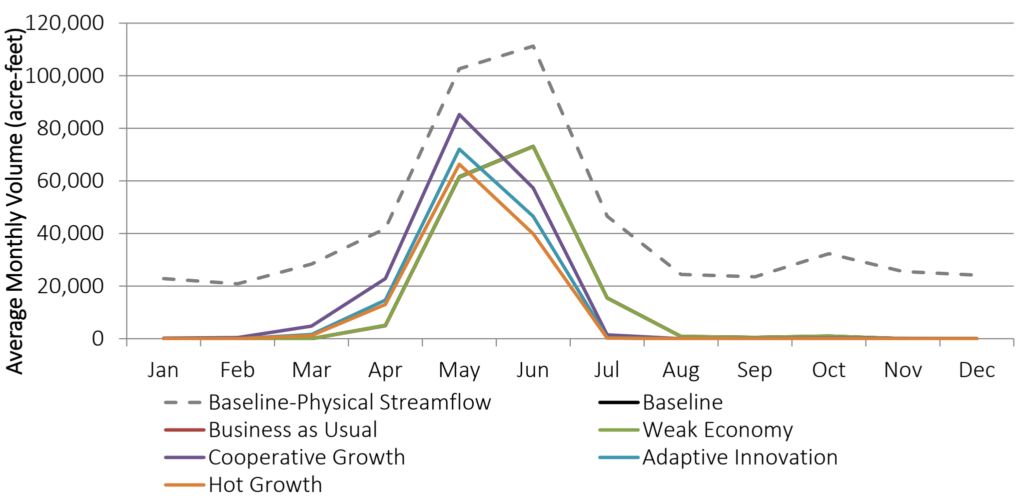


Figure 4.10.29 Average Monthly Simulated Hydrographs of Available Flow at White River Below Boise Creek



4.10.8 Environment and Recreation

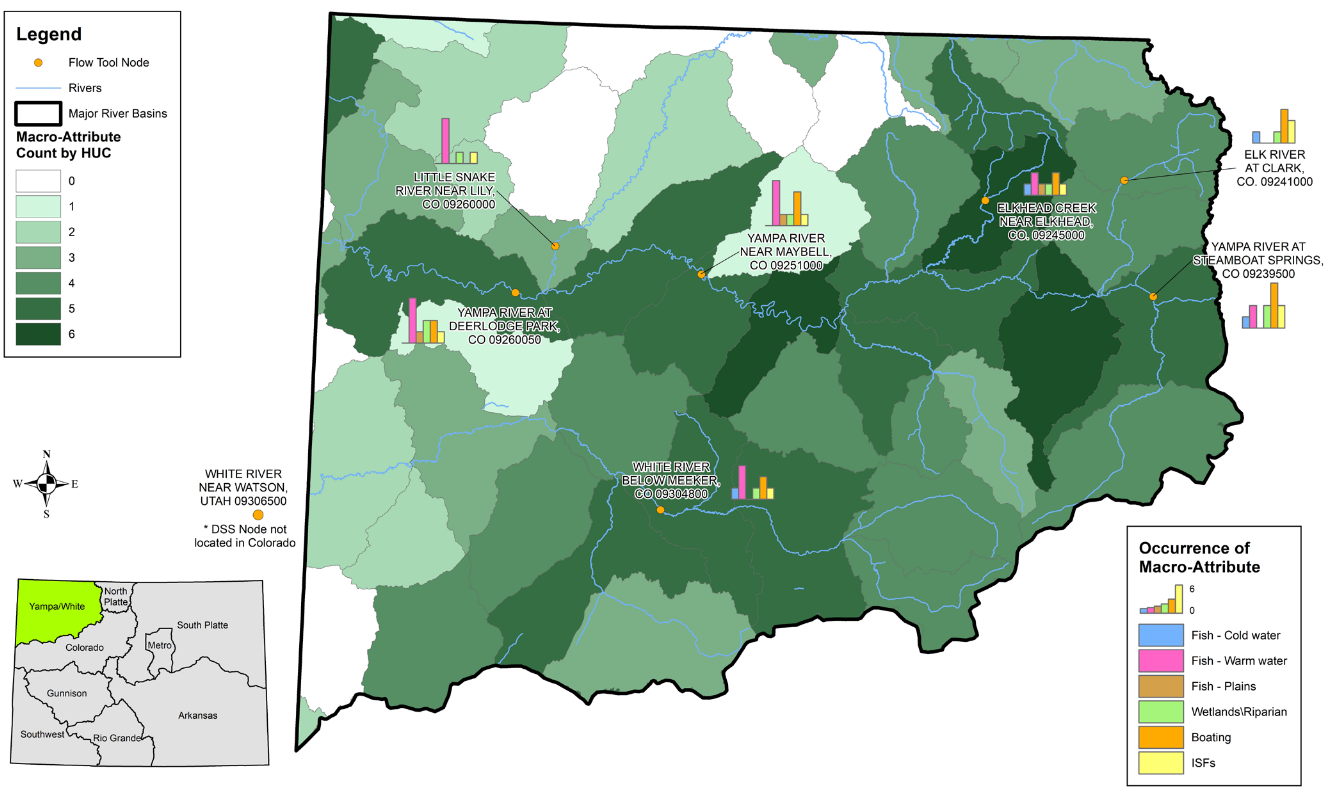
A total of eight water allocation model nodes were selected for the Flow Tool within the Yampa-White-Green Basin (see list below and Figure 4.10.30). Figure 4.10.30 also shows subwatersheds (at the 12-digit HUC level) and the relative number of E&R attributes located in each subwatershed.

- Yampa River at Steamboat Springs, Colorado (09239500)
- Elk River at Clark, Colorado (09241000)
- Elkhead Creek near Elkhead, Colorado (09245000)
- Yampa River near Maybell, Colorado (09251000)
- Little Snake River near Lily, Colorado (09260000)
- Yampa River at Deerlodge Park, Colorado (09260050)
- White River below Meeker, Colorado (09304800)
- White River near Watson, Utah (09306500)

NATURALIZED FLOW

Naturalized flows reflect conditions that would occur in the absence of human activities. Baseline flows reflect current conditions as influenced by existing infrastructure and river operations. While observations regarding naturalized flows may be informative, baseline flows reflect actual conditions and the diverse operations of a river's many users.

Figure 4.10.30 Flow Tool Nodes Selected for the Yampa/White Basin



Results and observations regarding Flow Tool analyses using flow data developed in the water supply and gap analyses for baseline conditions and the planning scenarios are described in Table 4.10.16 below.

Table 4.10.16 Summary of Flow Tool Results in the Yampa-White-Green Basin

Category	Observation
Projected Flows	On the Yampa and White Rivers, peak flow magnitudes under baseline conditions are only slightly reduced (10 percent) from naturalized conditions. A similar status holds for *Business as Usual* and *Weak Economy*. Under *Hot Growth*, total peak flows decline approximately 10 percent.
	At all locations, the timing of peak flow is projected to move earlier in the year under all climate change impacted scenarios (*Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*). Under these scenarios, June flow may decrease approximately 30 percent at higher elevations (e.g., Elk River at Clark) and continue to decrease more at lower elevations (e.g., Yampa River at Deerlodge Park). Under these same scenarios, April flows may increase at a similar rate. May flows may increase or decrease depending on location and scenario.
	Under baseline conditions, mid- and late-summer flows are minimally depleted at higher elevations under naturalized conditions, are reduced further through mid-elevations (e.g., Steamboat Springs), and continue to decline through low-elevations (e.g., White River below Meeker and Yampa River at Deerlodge Park). Under all climate change scenarios, in most locations, mid- and late-summer flows are projected to have a wide departure from naturalized conditions.
Ecological Risk	Despite declines in peak flow magnitude, flow-related risk to riparian/wetland plants remains low to moderate across the basin. However, flow-related risk to warmwater fish is projected to increase, with the most risk occurring under *Hot Growth*. The change in timing for peak flows may result in mismatches between peak flow timing and species' needs.
	Projected reductions in mid- and late-summer flows may result in increased risks for trout at high and mid-elevations and for warmwater fish at low elevations. Increased risk would be caused by reduction in habitat under reduced flows.
	For trout, increased stream temperatures under low-flow conditions also increases risks, as has been the case in some recent years in Steamboat Springs. Additionally, the projected reductions in flows in mid- and late-summer may result in flows that are below the recommendations for endangered fish. For comparison, flows in August and September of 2018 were among the lowest flows on record and resulted in the first ever call on the Yampa River.
	September flows are projected to be similarly low in nearly one-quarter of all years under *Cooperative Growth* and nearly one-third of all years under *Adaptive Innovation* and *Hot Growth*. These low flows lead to a loss of habitat for endangered fish and favor reproduction and survival of non-native fish that prey upon endangered fish.
ISFs and RICDs	ISFs and RICDs are at risk of being met less often in mid- to late-summer under all future scenarios that include climate change (*Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth*). An example of an ISF at risk is the 65 cfs ISF on the Elk River. This ISF is met in July in every year under the baseline scenario; however, under *Cooperative Growth*, average July flow is projected to drop below 65 cfs in approximately one-third of years and is unmet in approximately half of the modeled years under *Adaptive Innovation* and *Hot Growth*. In August, the Elk River ISF is projected to be unmet in nearly every year under all climate change scenarios.
	The total amount of boating flows during runoff may not change significantly if peak flow magnitude does not decline substantially, but the timing of boating opportunities will shift to earlier in the year under all climate change scenarios. An example of a RICD at risk is for the whitewater park in Steamboat Springs. The August RICD decreed flow of 95 cfs is often not met under baseline conditions. Under *Adaptive Innovation* and *Hot Growth*, the August RICD decree is almost never met.
E&R Attributes	Under baseline conditions and *Business as Usual*, and *Weak Economy*, current flow risk related to E&R attributes arises primarily because of depletions that increase moving downstream.
	Under climate change scenarios, both the projected shift in the timing of peak flow and reductions in total runoff may contribute to reductions in mid- and late-summer flows.

SECTION 5
INSIGHTS, TOOLS, AND RECOMMENDATIONS

In addition to the core analysis of this report, the Technical Update incorporates a set of topic-specific evaluations (insights), supporting tools, and recommendations. These efforts aim to provide insights, assistance and direction to basin roundtables as they update their BIPs and consider solutions for addressing future gaps. Technical memoranda on each of the insights and existing tools are included in Volume 2 (see Appendix A for a full list). An overview of each of these topics is provided in the following subsections and as summarized below:

Insights: Section 5.1 provides a summary of high-level and conceptual analyses on the following focused topics related to implications of supply/demand gaps and key points to consider when developing potential solutions to solving future gaps. Basin roundtables may choose to expand on these analyses if necessary or desirable when updating their BIPs. The analyses focused on the following water-related areas:

- Public values regarding water issues in Colorado
- Overview and case study descriptions of Alternative Transfer Methods (ATM)
- Overview of water reuse mechanism
- Storage opportunities in Colorado
- Economic impacts of failing to solve future projected supply/demand gaps

Tools: Section 5.2 highlights several tools for basin roundtables to use when updating their BIPs. During the Technical Update, the consistency of data across all the existing BIPs was reviewed. The results of this review pointed to a strong need to improve the completeness and uniformity of information on all water supply projects/strategies and related costs. The tools developed in the Technical Update build on prior efforts in the following areas:

- Costing Tool
- E&R Flow Tool
- E&R database
- Projects database

Recommendations: Section 5.3 outlines several recommendations that primarily focus on how to use, enhance, and integrate findings from the Technical Update into the BIP updates. Recommendations stem from multiple stakeholder interactions and divide into five major update areas:

- BIP
- Project
- Technical
- Outreach
- Strategic

5.1 INSIGHTS

5.1.1 Public Perception Insights

In 2012 and 2013, a survey entitled, *Public Opinions, Attitudes and Awareness Regarding Water in Colorado*, was conducted on behalf of the CWCB. In addition, other survey research was documented relevant to understanding social values in the context of the Technical Update planning scenarios and water supply challenges that Colorado will face. Findings from the survey are documented in the technical memorandum, *Observations Regarding Public Perceptions on Water* (included in Volume 2, Section 12) and summarized below.

- Coloradans have varied levels of knowledge regarding water use in the state. Only one in three residents recognizes that agriculture is the largest water user in Colorado. In 2012 and 2013, a large majority of the state's residents were paying more attention to water issues and their own water use than they had in the past. In part, this was likely due to 2012's dry summer conditions. Repeated surveys in other locations found that water awareness rises during droughts and diminishes after the drought recedes.
- Among eight potential water-related concerns, Coloradans identified protecting home water quality, having enough water for Colorado's farms and ranches, and having enough water for Colorado's cities and towns as the most important issues. These were the top three issues in each region of the state, although the ranking order of the issues varied by region.
- Coloradans most frequently described conservation as their preferred approach to addressing Colorado's water issues, followed by prioritizing environmental needs and building new water supply projects. Conservation was the most frequently recommended strategy in every region, and support for prioritizing environmental needs was consistent across Colorado's regions. Support for developing new water supply projects was more varied.
- Coloradans perceive home water service to be affordable compared to other home services, and they are willing to pay more to address Colorado's water issues. On average, Coloradans are willing to pay between $5 and $10 more per month to address water-related concerns. At $5 per month per household, this willingness to pay would correspond to statewide annual financial support of about $125 million.

5.1.2 ATM Insights

Overview

The Technical Update shows that under multiple planning scenarios a growing population, healthy economy, and climate change will lead to increasing municipal and industrial water demands and subsequently intensify pressure to permanently transfer agricultural water rights. In particular, the South Platte and Arkansas basins face significant reductions in irrigated agricultural land due to increasing demand. Other drivers of permanent reductions in irrigated acreage include urbanization, inadequate augmentation water supplies, declining aquifers, and compact compliance.

Across the state, water stakeholders want to minimize permanent reductions in irrigated agricultural land and support a variety of alternative options, such as water banking and interruptible water supply agreements. Colorado's Water Plan sets a goal of achieving 50,000 acre-feet of water transfers through voluntary ATMs by 2030. The Water Plan also sets a goal that ATMs compete with, if not out-perform, traditional transactions in the water market. Through the long-standing ATM Grant Program and other initiatives, the CWCB continues to facilitate the development and implementation of ATM projects across the state

The technical memorandum, *Review of Successful Alternative Transfer Method Programs and Future Implementation* (included in Volume 2, Section 11) reviews select ATM projects that have been successfully implemented and highlights key characteristics of each ATM that provide insight into how future ATMs might also be successfully structured. Additionally, the study provides perspectives on agricultural to municipal transfers, and includes recommendations for monitoring metrics to track the effectiveness of future ATM programs.

ATM projects provide several general benefits when compared to permanent, buy-and-dry water transfers. For municipalities, ATMs may provide a reliable source of dry-year water supplies and can be more cost effective than permanent transfers and other traditional new supply sources. By maintaining some farm operations as part of the ATM program, rural economies that depend on agricultural activities can be sustained, and agricultural users can have access to new income streams for purchasing new equipment and investing in infrastructure improvements or other operational needs. ATMs can also be useful in preserving ecosystem services associated with working agricultural lands, such as open space and wildlife habitat. Additionally, ATMs can be applied to address multiple water supply challenges, including municipal and industrial needs, compact compliance, groundwater management, and non-consumptive needs.

Challenges to ATM implementation include balancing the municipal and industrial user's desire for certainty and permanence of long-term supply with the supplier's desire to maintain profitable agriculture, and potentially high infrastructure costs needed to implement a viable water transfer (potentially high infrastructure costs are a barrier to implementing a permanent transfer and are not necessarily unique to ATMs). Furthermore, high transaction and administration costs common to nearly all transfers can discourage some parties from pursuing an ATM arrangement. Several efforts have been made to address these challenges over recent years, including the continued financing of ATM projects through the CWCB's ATM Grant Program and development of more flexible, administrative ATM project approvals through the HB13-1248 Fallowing-Leasing Pilot Program and Agricultural Water Protection Water Right.

ATM Case Study Examples **(can this just be Case Studies throughout? case study and examples seems redundant)**

ATMs in Colorado are predominantly used to transfer water from agriculture to municipal, industrial, or environmental uses on a temporary basis, but several long-term ATM projects have been developed based on the needs of the parties involved. Case study examples of recently implemented ATMs in Colorado were developed to better understand methods used to overcome challenges and past barriers to implementing ATMs, unique issues between the parties involved, overall benefits, and key lessons learned that can apply to future ATM implementation. The case studies selected represent different ATMs, and are shown below:

Agricultural to Municipal and Industrial

- Little Thompson Farm
- Catlin Canal

Agricultural to Environmental

- McKinley Ditch

Compact Compliance

- Grand Valley Water Users Association Conserved Consumptive Use Pilot Program

Hypothetical Agricultural to Municipal Transfer Considerations

A hypothetical example ATM program was considered to provide context into how a coordinated, large-scale rotational fallowing program could be developed to meet a significant portion of the M&I gap. The example describes a large-scale fallowing program and concluded that a significant portion of irrigated acreage would need to be enrolled in the program to yield significant amounts of supply. Additionally, several infrastructure components may be required to implement a large-scale ATM program, including augmentation and operational storage, pipelines and pump stations, and water treatment systems. This infrastructure may be needed even if traditional agricultural transfers were implemented from the same geographical areas.

ATM Implementation and Effectiveness Monitoring

Following recommendations in the Water Plan concerning ATM data compilation, future ATM monitoring metrics were identified to help give insight to the effectiveness and operation of a single ATM, or a large-scale ATM program across a larger geographic area to gauge regional or basinwide trends. Obtaining this data for a wide variety of implemented ATMs (both geographically and for different ATMs) will provide more information to decision makers to evaluate the effectiveness of proposed ATMs, identify trends, and evaluate pricing. ATMs provide an opportunity to meet increasing water demands of a growing population while lessening the impacts to Colorado agricultural communities. Next steps to be considered include:

- Developing better guidance as to what types of projects and processes further Water Plan goals related to maintaining or enhancing agricultural viability while meeting potential new demands and addressing other water resource management issues
- Assessing institutional support of ATMs and evaluating progress made on addressing the primary barriers to ATM development and implementation
- Developing additional pilot projects for the varying ATM programs and engaging in thoughtful monitoring of their effectiveness
- Working with basin roundtables to consider how ATMs can play a role in addressing basin needs and priorities
- Pursuing further the collection of recommended monitoring data for ATMs as they are developed and sharing this information through existing platforms such as CDSS or new platforms such as an ATM data clearinghouse.

5.1.3 Water Reuse Insights

The Colorado Water Plan notes that various forms of water reuse will be an important component of closing future supply-demand gaps for municipalities; it also encourages water providers to build on the successes of the many reuse projects already implemented in Colorado. To advance these concepts, high-level comparisons of various water reuse mechanisms were compared and contrasted in a fact-sheet style format that summarized hypothetical mass balances of a municipal water system implementing reuse. Benefits, tradeoffs, unintended consequences, treatment requirements, and regulatory considerations pertaining to a particular reuse mechanism were also evaluated. This information was designed to provide guidance on how to define potential municipal reuse projects in future BIP efforts. Evaluated reuse mechanisms included:

- Reuse via. Exchange
- Non-potable reuse
- Indirect potable reuse
- Direct potable reuse
- Graywater reuse

The results of the comparisons are presented in a technical memorandum *Opportunities and Perspectives on Water Reuse* (see Volume 2, Section 13).

Key Findings

In this analysis, particular attention was paid to quantifying and qualifying the impact of a local reuse project on the greater basin and watershed system. The mass balance exercises noted previously identified the following key takeaways to consider when a municipality is evaluating implementation of a particular reuse mechanism:

- *Reuse of Existing Reusable Return Flows:* If a municipality can reuse existing legally reusable return flows, the amount of new supplies needed to meet future demands can be reduced. Indirect, direct, or reuse via exchange methods have the best opportunity to reduce the need for new supplies due to the ability to reuse water year-round. When a municipality begins to reuse return flows that historically have not been reused, a flow reduction to downstream users can result. Coordination between the water provider and downstream water users could help those users plan for this reduction in downstream water availability.
- *Reuse of New Supplies:* If a municipality cannot reuse existing return flows, reusing future, new, legally reusable supplies will reduce the amount of new supplies needed. Reuse of new supplies using indirect, direct, or reuse by exchange methods can be used year-round, which maximizes the benefit of reuse to the municipality and minimizes the amount of new supplies needed.

5.1.4 Storage Opportunity Insights

The CWP states that Colorado must develop additional storage to manage and share conserved water and manage the challenges of a changing climate. It sets a measurable objective of attaining 400,000 acre-feet of innovative water storage by 2050. The technical memorandum, *Opportunities for Increasing Storage* (see Volume 2, Section 10), investigates concepts related to increasing water storage to assist in meeting current and future water supply challenges throughout Colorado.

Conditional Storage Water Rights

To evaluate future storage opportunities in Colorado, the State's current water right database was queried for potential reservoir sites with conditional storage rights greater than 5,000 acre-feet. As shown in Figure 5.5.1, there are more than 6.5 million acre-feet (MAF) of conditional storage rights at reservoir sites with greater than 5,000 AF on file with the State of Colorado.

The 6.5 MAF of conditional storage rights (if constructed) would nearly double the existing surface water storage in Colorado and is more than 15 times the CWP's measurable objective of 400,000 AF of additional storage by 2050. It is not likely that the 6.5 MAF of new surface water storage will occur by 2050; however, if only a portion of the conditional storage sites were ultimately determined to be technically and environmentally feasible, those new surface water storage facilities could become a critical component to a balanced approach to meeting projected water resources gaps throughout Colorado.

Other Storage Opportunities

In addition to considering conditional storage rights, other opportunities for new storage and increasing operational storage in existing reservoirs were evaluated as a means to help solve Colorado's projected water supply and demand gaps. Table 5.5.1 summarizes the key considerations for each type of potential storage discussed in Volume 2, Section 10 titled *Opportunities for Increasing Storage*.

Figure 5.1.1 Sum of Conditional Storage Right Volumes in Various River Basins

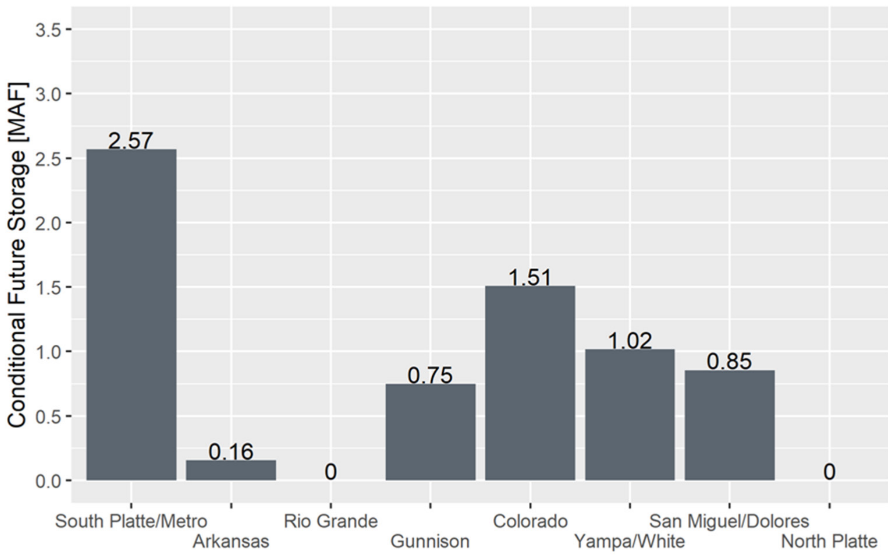
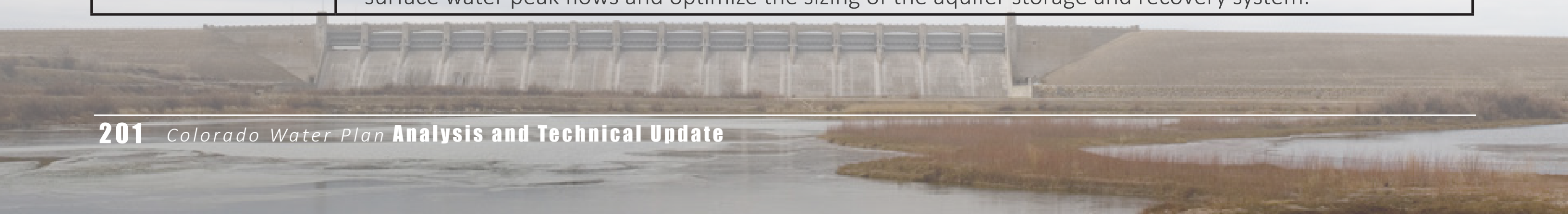


Table 5.1.1 Overview of Water Storage Opportunities

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



5.1.5 Economic Impacts Insights

The technical memorandum *Potential Economic Impacts of Not Meeting Projected Gaps* (see Volume 2, Section 9) provides order-of-magnitude estimates of the economic consequences of failing to meet future supply gaps within Colorado and each of its basins. The study was based on data developed for the medium scenario[14] for 2050 M&I gaps from the previous SWSI effort (SWSI 2010), which anticipated a statewide gap for these uses of approximately 390,000 AF per year by 2050[15], and the projected 2050 shortage in water supplies for irrigated agriculture from the previous SWSI study, which was estimated at more than 1.7 MAF per year[16].

The economic analysis conducted for this study was based on a relatively simplified approach consistent with the goal of identifying the general magnitude of the economic consequences of failing to meet future gaps. The analysis focused on the economic implications of projected future gaps for agricultural and M&I uses. There are also significant economic implications for the state and each of its river basins in failing to meet non-consumptive needs for environmental and recreational purposes; however, quantifying the economic implications of shortfalls with respect to non-consumptive needs was beyond the scope of this study.

Three types of economic costs were included:

- Agricultural costs that are already being incurred
- Original costs of a portion of projected future M&I gaps
- Opportunity costs of foregone future economic development

The projected economic impacts of failing to meet the gaps identified in the specific 2010 SWSI demand conditions analyzed in this study provide a number of general insights regarding the importance of Colorado's water planning efforts.

The lack of sufficient supply to meet the full consumptive use requirements for irrigated crops in Colorado already results in an estimated annual loss in potential production value of more than $3 billion and about 28,000 fewer jobs directly and indirectly supported by irrigated agriculture[17]. In many basins, economic impacts on livestock production due to reduced crop and forage output are larger than the economic impacts on the crop producers. Projected gaps in 2050 irrigation water supplies indicate that these reductions in potential agricultural economic activity will continue into the future.

Economic effects of projected M&I gaps depend on the severity of the projected gap in each basin. In areas with smaller M&I gaps relative to projected 2050 demands (less than 10 or 15 percent of projected demand), the primary effects would likely be a substantial reduction in consumer welfare due to greatly reduced water availability for outdoor use and severe effects on the municipal "green industry," involving sectors such as landscape services, nurseries, and car washes. In areas with more severe M&I gaps (greater than 10 or 15 percent of projected future M&I demand), much larger economic impacts are projected due to the opportunity cost of foregone future residential, commercial, and industrial development.

Overall, the potential economic impacts and opportunity costs of the projected gaps in agricultural and M&I water supplies are substantial in every basin in Colorado. From a statewide perspective, failing to meet the gaps identified in the 2010 SWSI demand condition example analyzed in this case study could lead to between 355,000 and 587,000 fewer jobs in Colorado in 2050; $53 to $90 billion fewer dollars in annual economic output; a reduction in gross state product of between $30 and $51 billion per year; $20 to $33 billion in reduced labor income; and $3 to $6 billion fewer dollars in state and local tax revenues. To put these numbers in perspective, the projected economic impacts are equivalent to approximately 9 to 16 percent of current statewide economic output, gross state product, statewide employment, and statewide labor income.

The economic values associated with agricultural water use are substantial but are generally considerably lower than the economic values associated with M&I use. This reality, combined with the flexibility to move water among different uses and locations under Colorado law, implies that there will be continuing economic pressure to shift water from Colorado's farms to its cities and industrial users. Given the importance that the state's residents place on maintaining agriculture in Colorado, as noted in *Observations Regarding Public Perceptions on Water* (Volume 2, Section 12), these economic pressures highlight the need for strategies to mitigate potential future impacts resulting from water transfers that would negatively affect Colorado's agricultural economy. This fact underscores the importance of developing basin-specific water management and supply strategies, and collaborative BIP updates.

5.2 TOOLBOX FOR BASIN ROUNDTABLES

Several tools were developed during the Technical Update that will be useful for basin roundtables during the BIP update process. The tools will be further refined and upgraded in the future as they are used, additional data are gathered, and on-line portals capable of hosting these tools are developed.

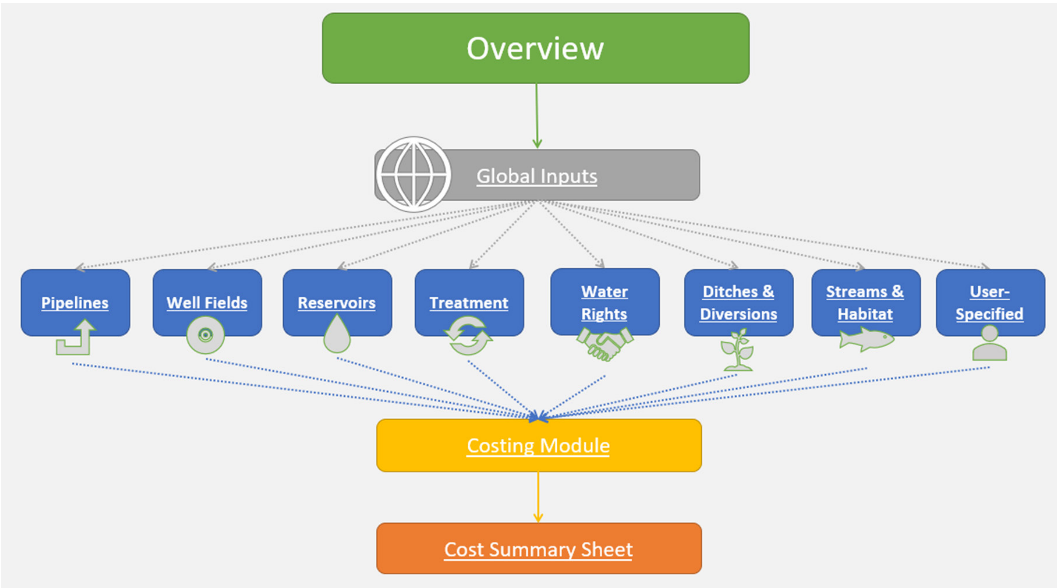
5.2.1 Project Costing Tool

The *Colorado Water Project Cost Estimating Tool* (Cost Estimating Tool) was developed for the Technical Update to provide a common framework for the basin roundtables to develop planning-level project cost estimates. Only 16 percent of the projects and methods listed in previous BIPs included cost estimates. The Cost Estimating Tool provides a baseline cost estimate for use in the planning process and serves as a mechanism to collect useful information for additional planning and tool refinement in future iterations. Its targeted use is for project concepts for which cost estimates have not yet been developed.

Cost Estimating Tool limitations and additional tool functionality recommendations are included in the technical memorandum titled *Colorado Water Project Cost Estimating Tool*, included in Volume 2, Section 5 of the Technical Update.

The Cost Estimating Tool is organized by Project Modules, with each module representing a different type of water supply project. Data from each Project Module is synthesized in the Costing Module and Cost Summary Sheets to develop the overall cost estimate (see Figure 5.2.1).

Figure 5.2.1 Cost Estimating Tool Schematic



Projects Module

The module overview page includes a navigation view of the tool and allows the user to modify global inputs such as project yield, peaking factors, cost indices, and life-cycle and annual costs. Links to each Project Module are also available from the overview page. The Project Modules represent either an entire water project or a component of a large-scale, complex project. The types of projects proposed in BIPs have been pre-loaded into the tool, and users able to customize the parameters associated with their project(s) to reflect a specific design and physical characteristics (see Table 5.2.1). Output from the Project Modules becomes input to the Costing Module.

Table 5.2.1 Project Cost Tool Module Types, Components and Inputs

Project Module	Types	Components	General User Inputs
Pipelines	raw, treated	pipelines, pump stations, storage	project yield and peaking factor, pipeline profile components, pipe size and length, pump type
Well Fields	public supply, aquifer storage and recovery, injection, irrigation wells	wells, booster pumps, pipe network	water table characteristics, project yield and peaking factor, transmission pipeline profile components, number of wells and average production, well depth and capacity, transmission pipe size and length, booster pump capacity
Reservoirs	new reservoir, reservoir expansion, reservoir rehabilitation	reservoir, reservoir rehabilitation, hydropower production	project type, new storage volume, project description, cost of rehabilitation, height of falling water, discharge through hydropower station
Treatment	typical treatment technologies such as direct filtration, conventional, reverse osmosis, etc.	various treatment technologies	average day demand and peaking factor, treatment type
Water Rights	instream flow requirements, recreational in-channel diversion, water supply	cost	total capital cost of water right purchase
Ditches and Diversion	new ditch, ditch rehabilitation	diversion structure, headgate structure, ditch	type of diversion structure, type of headgate structure, maximum diversion discharge/ditch capacity, type of ditch, ditch length
Streams and Habitat	stream restoration, conservation, habitat restoration/species protection, acid mine drainage water treatment	land acquisition, channel improvements, channel structures, channel realignment	stream width range, length of restoration, level of restoration
User-Specified Project	project types not represented by other modules	user-specified	project description, total capital costs, total operations and maintenance costs

Costing Module

The Costing Module brings together information supplied or calculated from the Project Modules to develop planning-level cost estimates. The costs are broken down into construction, project development, and annual costs. Costs are developed based on output from the Project Modules and by applying unit costs or cost curves where available. Unit costs or cost curves are adjustable to account for current market conditions using readily available indices. Other costs are based on industry standard or researched percent values of a direct cost. Values can be adjusted by the user as needed.

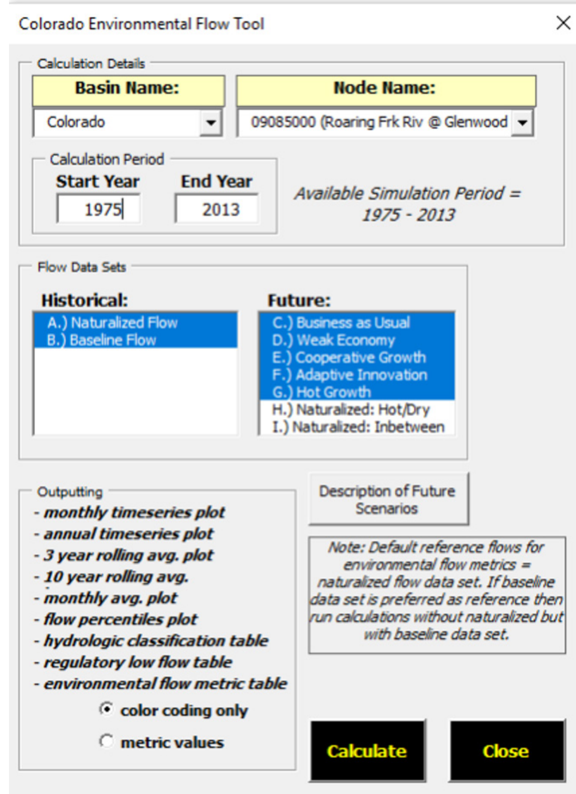
The Costing Module provides a final cost summary sheet that includes a summary outline of project costs by type, present-worth calculations, and a normalized cost that can be used for project comparison.

5.2.2 E&R Flow Tool

The Technical Update included the development of a Flow Tool designed to assess flow conditions in each basin. The Flow Tool was designed to serve as a resource to help basin roundtables refine, categorize, and prioritize their portfolio of E&R projects and methods through an improved understanding of flow needs and potential flow impairments, both existing and projected. The Flow Tool uses hydrologic data from CDSS, additional modeled hydrologic data for various planning scenarios, and established flow-ecology relationships to assess risks to flows and E&R attribute categories at pre-selected gages across the state.

The Flow Tool was constructed in Microsoft Excel by combining components of the Historical Streamflow Analysis Tool and the Watershed Flow Evaluation Tool. The platform provides a familiar and portable working space for the tool user, and offers standard spreadsheet pre- and post-processing capabilities. User inputs specific to the application of the tool are provided via a user-friendly input form (Figure 5.2.2).

Table 5.2.2 Example Input Window from Flow Tool



The flow tool provides the following outputs:

- Monthly and annual time series plots
- Three and ten year rolling average time series plots
- Plot of monthly means
- Monthly flow percentile plots
- A tabular summary of annual hydrologic classifications
- A tabular summary of statistical low flow
- A tabular summary of the calculated environmental flow metrics

The environmental flows table is generated using the flow-ecology relationships described in Section 2. Numeric output is presented as percent departure from reference flows. Reference flows can be specified as either the naturalized flow dataset (default) or the baseline flow dataset. The table is also color coded based on risk category (from low risk to very high risk). Risk categories are pre-defined by subject matter experts according to percent departure threshold values (compared to reference condition). Risk category thresholds differ for each metric. Flow Tool outputs for all 54 nodes across each of the nine basins are available for review and consideration by basin roundtables. Flow statistics under future planning scenarios can be compared to the timing and magnitude of historical peak and low flows. Risk categories identified through analysis of the environmental flow metrics are also available for review and can inform planning discussion in each basin.

The Flow Tool is easy to use and designed for a range of potential end users; however, adding new stream nodes to the tool is not currently an option available to the user and would require additional programming by the tool developers. While the Flow Tool is intended to provide data for use in planning E&R projects and methods, it is not prescriptive.

The Flow Tool does not:

- Designate any gap values
- Provide the basis for any regulatory actions
- Identify areas where ecological change may be associated with factors other than streamflow
- Provide results as detailed or as accurate as a site-specific analysis

The Flow Tool is intended to be a high-level planning tool that:

- Uses the foundations of the HSAT and Watershed Flow Evaluation Tool to scale to a statewide platform
- Post-processes CDSS projections to provide summaries of changes in monthly flow regime at pre-selected locations under different planning horizons
- Identifies potential risks to E&R attribute categories through flow-ecology calculation projections
- Serves as a complementary tool to CDSS to refine, categorize, and prioritize projects
- Provides guidance during Stream Management Plan development and BIP development

5.2.3 E&R Database

The Nonconsumptive Needs Assessment Database (NCNAdb) was developed in 2010 to help manage nonconsumptive data received by basin roundtables and other stakeholders. The database included information related to nonconsumptive attributes, projects, and protections. A significant focus of the Technical Update has been enhancing the NCNAdb (now referred to as the E&Rdb). The E&Rdb includes an enhanced technical foundation, a more engaging and meaningful user interface, and better integration into the Colorado water planning process.

The E&Rdb is a Microsoft Access database formatted in Microsoft Access 2010 file format. The database contains several tables, queries, and modules. The database uses industry standards such as indexes, keys, referential integrity, normalization, and naming standards for tables and fields.

The core data tables in the E&Rdb are described in Table 5.2.2. A more in-depth data dictionary is provided in the E&Rdb TM included in Volume 2 and is available within the database (tblDataDictionary).

Table 5.2.2 Core Data Tables in the E&Rdb

Table	Description
tblBasin	Contains basin information
tblContact	Contact information such as name, address, phone
tblContactProject	Intermediate table relates contacts to projects
tblDatabaseLog	Used to document modifications to database
tblDataDictionary	Contains all tables/fields and respective attributes within the database
tblProject	Projects
tblProjectProtection	Protections assigned to projects and their attributes
tblSegment	Stream segments
tblSegmentAttributeClass	Attribute classifications for attributes along a given stream segment
tblSegmentProject	List of projects that are related to stream segments, and the length of the segment
tblSegmentIDXRef	Contains cross-reference identification between COMID and GNISID
tblSegmentReach	List of Reaches by COMID

The database contains several tools to help browse, search, and extract data; a project data entry form contains the projects and related information. Predefined reports can be used to view and export data. Querying the database requires experience using Microsoft Access, a solid understanding of the question that is translated to a query, and familiarity with the database design to retrieve the information appropriately. The database includes a Microsoft Excel template that can be used to add or update projects and attributes associated with projects.

5.2.4 Project Database

SWSI 2010 and the BIPs led to the initial development and subsequent revision of project datasets for each basin roundtable. These datasets reflect potential projects and processes identified by stakeholders in each basin that may be developed to meet future water supply needs. Project data across basins are inconsistent in content and format due to the complexity of studies, variation by basin, and number of entities involved. Through the Technical Update, project data were reviewed and formatted to increase the usefulness of data products that can be created and to enhance the consistency of analyses using the data.

Project Dataset Content Standards

After a review of each basin roundtable's project dataset, the principal recommendation for developing a standard project dataset for the Technical Update effort was for the datasets to exist in a Microsoft Excel file (e.g., flat file) format and implement standard dataset fields.

Project Dataset Products

Ultimately, two primary data products were developed through this effort: a consistent standard table reflecting the statewide project dataset and mapping products displaying the project datasets. The original project datasets were inconsistent across each basin, and many of the basins did not provide information that could be represented using standard fields. Original project datasets were converted to the standard project format by interpreting the meaning of project data fields in individual basin's datasets and by using engineering judgement. As reflected in Table 5.2.3, several basins did not have data for all standard fields. In these cases, fields were left blank in the standard project dataset.

Table 5.2.3 Standard Project Data Fields and Presence of Fields in Final Basin Project Datasets

Data Field/Column	Arkansas	Colorado	Gunnison	North Platte	Rio Grande	South Platte / Metro	Southwest	Yampa-White-Green
Project_ID	X	X	X	X	X	X	X	X
Project_Name	X	X	X	X	X	X	X	X
Project_Description	X		X	X			X	X
Project_Keywords								
Status	X	X	X				X	
Lead_Proponent	X	X	X		X	X	X	X
Lead_Contact	X		X	X		X	X	
Municipal_Ind_Need	X	X	X	X	X	X	X	X
Agricultural_Need	X	X	X	X	X		X	X
Envr_Rec_Need	X	X	X	X	X		X	X
Admin_Need					X			
Latitude	X	X	X	X	X	X	X	X
Longitude	X	X	X	X	X	X	X	X
County	X	X	X	X	X	X	X	X
Lat_Long_Flag								
Water_District	X	X	X	X	X	X	X	X
Estimated_Yield	X	X	X			X		
Yield_Units	X	X	X			X		
Estimated_Capacity	X					X		
Capacity_Units	X					X		
Estimated_Cost	X	X	X		X	X		

Uses of Projects Dataset

The availability of required data fields will support several future uses of project datasets:

- **Filtered Lists.** It will be possible to create customized datasets, maps, spreadsheet files, and other formats for use in analysis and visualizations.
- **Maps.** The addition of general location coordinate data for each project allows for all projects to be easily located on maps. A user interested in a particular basin or region can then quickly determine the projects in that area and find more information.

5.3 BIP UPDATES

Recommendations from the Technical Update have been distilled into five "next step" categories: 1) BIP Updates, 2) Project Updates, 3) Technical Updates, 4) Strategic Updates, and 5) Outreach Updates. These recommendations, detailed below, will be used to guide upcoming discussion with Colorado's nine basin roundtables, including future phases of work to update BIPs and the Water Plan.

Each action item is accompanied by a brief background description that provides insight into the history of stakeholder processes and conversations that led to the recommended action. This includes, but is not limited to, input from roundtables; public education, participation and outreach workgroups (known as PEPO); the Interbasin Compact Committee; and the 2018-2019 Implementation Working Group.

The following list of recommendations is intended to provide basin roundtables flexibility in the update process, tailoring approaches to best suit roundtable goals. These recommendations provide a framework for some level of standardization across the BIP updates. This iterative process is meant to support statewide water supply planning, cross-basin dialogue, project funding, enhanced future supply analyses, revised goals, and updated project lists. Integrating Technical Update findings with the BIPs, project lists, and the Colorado Water Plan update ensures state water planning will continue to be informed by the best available data.

5.3.1 BIP Updates

A. Evaluate the scope of BIP updates to integrate Technical Update findings

Basin roundtables will work with the CWCB and their membership to identify how to best update their BIPs. In the first BIP process, the CWCB created a guidance document that each roundtable tailored to suit its own needs. Each roundtable then hired separate contractors to assist with its first plan development. To lighten the level of effort required to update these plans, the CWCB, roundtables, and the IWG reviewed the benefit of hiring a central contractor (selected by the CWCB and roundtable chairs) to support each roundtable and coordinate a path forward. Local expert contractors (selected by each roundtable) will play an important role in supporting the roundtables and the general contractor. A first order of business will be coordinating on the full scope of the BIP update, including an evaluation of core needs (e.g., reviewing project lists) and any additional analysis that may be beneficial to each roundtable.

B. Integrate relevant studies and local plans into BIP updates

Basin roundtables will evaluate which plans and studies should inform and be referenced in their BIPs. As noted by the IWG, several local, regional, and statewide studies are available since the initial BIPs (2015) that may provide important context to basin planning. Examples include stream management plans, conservation plans, forest health studies, climate studies, city/master plans, and resilience plans.

C. Identify opportunities for enhanced data inputs that improve modeling output

Basin roundtables will identify if additional data inputs can support enhanced analysis. In all modeling studies, future projections are only as good as the data that inform the model. In the Technical Update, basin-specific data were limited in certain areas and could likely be refined. For example, municipal irrigated acreage data were not something to which the state had access, which limited the ability to model outdoor municipal water use analysis in more detail; however, municipal providers may have this information, and sharing it could be used to refine the model. Other opportunities exist across municipal, environmental, and agricultural reporting where the Technical Update could likely be enhanced in future iterations with the basin roundtable's help to refine model input data.

5.3.2 Project Updates

A. Enhance planned project data

Basin roundtables will enhance and maintain project data with the help of the contracting team as part of the BIP update. The Technical Update review of basin project lists (previously known as identified projects and processes, or IPPs) recommends 20 data fields to be associated with every project (e.g., project name, location, yield, proponent and cost). The Implementation Working Group reviewed the attribute list and added fields such as water rights and permitting status. While much of the data are not captured in existing project lists, the CWCB is working to develop a project database to assist with consistent data collection and input. This not only helps better support water supply planning needs, but also supports roundtable funding and the refinement of funding needs identified in the Water Plan.

B. Improve project costs in Water Plan

Basin roundtables will update project costs to help confirm Water Plan funding needs. The Water Plan identifies how project cost estimates will be improved upon in the BIP update process. Currently, less than 50 percent of the projects in any BIP have associated costs. To assist in this next step, the Technical Update scope included developing a costing tool to help evaluate project costs. As Water Plan funding is an increasing focus, it is critical to have more accurate cost information to better support how funds would be spent.

C. Assess how to best use project tiers

Basin roundtables will work collectively to help inform simplified and standardized project tiers. To be strategic with limited resources, some level of prioritization is necessary. Three of the eight BIPs already utilize some form of project ranking or tier system. At a minimum, missing data can serve as a de facto tiering system in which projects with clearly listed project proponents, costs, and other data are ranked over those without these data points; however, this needs to be reviewed more carefully as it may not be feasible to have all the data listed based on where a project is in the planning cycle.

To assist with this effort, the IWG reviewed a draft "Project Tier Matrix" that will need to be evaluated further during the BIP updates. The IWG determined that both proof-of-concept and shovel-ready (immediately implementable) projects are equally important to fund. The IWG also saw value in a placeholder category for Projects that may be more conceptual in their current phase but might be fleshed out in the future. This is especially true if the project lists are used establish future funding needs. Similarly, the IWG noted that a tier system should not generate competition in funding between basin roundtables.

5.3.3 Technical Updates

A. Review modeling assumptions + consider refinement

Basin roundtables will review beneficial localized and statewide modeling changes as needed. Every model is based on a set of assumptions. The TAG process reviewed, evaluated, and agreed on baseline model assumptions. However, a number of decision points on additional/refined assumptions arose in later stages of modeling. If roundtables decide additional modeling is desired for their BIP update, roundtables will work with the central contractor to ensure their modeling questions are in-line with baseline model assumptions (to support an "apples-to-apples" analysis). Modeling assumptions cannot be changed in ways that could potentially be used to address sensitive legal issues (local or statewide), conflict with policy, or create divisions across the basins.

B. Consider modeling projects

Basin roundtables will evaluate modeling needs and if/how they choose to model projects. Roundtables may choose to model their own unique variables as appropriate (such as projects). Unlike SWSI 2010, the Technical Update did not include any specific projects (e.g. water savings from planned projects) in the analysis, largely due to insufficient project data. The opportunity remains for roundtables to model their own unique projects to explore offsets to the Technical Update supply gaps. Any modeling would carefully consider potential implications of modeling discrete projects that could conflict with ongoing planning or permitting efforts (or any caveats outlined by the Attorney General's Office).

C. Review sub-basin modeling needs

Basin roundtables will review need and trade-offs of summarizing more granular subbasin data. Each of the original BIPs divided their basins into tributary regions differently, resulting in regional data and planning at different scales; however, it was unclear if each roundtable found their BIP sub-basin breakouts to be helpful, if they would have done them differently, or if they would potentially need them at all. Additionally, modeling at granular scales is intensive, costly, and complex. The CWCB chose to report modeling findings at the basin level only. If higher resolution data are desirable, regional delineations would require roundtable input.

5.3.4 Strategic Updates

A. Continue to focus on adaptive management strategies through scenario planning

Basin roundtables will evaluate how they can be nimble amidst changing conditions. Adaptive management has been a key component of roundtable and IBCC discussions for many years. This discussion directly informed the adoption of using a scenario planning approach to account for key drivers and uncertainties within the planning horizon (2050). How basin projects and plans can be tested against these variant futures (the five scenarios) or could be shifted to respond to future changes is something that needs to be considered. Projects and basin roundtable planning should be reviewed for impact and responsiveness. This is at the heart of the No-and-Low Regrets Action Plan that comprise not only core strategies in the Water Plan but also received 100 percent consensus by the IBCC and CWCB board. These core strategies aim to establish a set of plans having the highest benefit with the least unintended consequences, regardless of the future condition.

B. Develop signposts with CWCB support

Basin roundtables will work with the CWCB to identify and establish signposts as appropriate. Using signposts, or check-in points, is fundamental to scenario planning. There may be triggers or key indicators that help determine if specific actions are needed and/or there should be a set frequency for review to help determine growth trajectories. A signpost may also be seen as the frequency by which the state and/or basin roundtables look for and review key indicators. Roundtables and the CWCB need to collaborate on the best approach for establishing clear signposts that help provide the necessary review and analysis of current conditions.

C. Evaluate climate extremes for greater integration

Basin roundtables should identify how to best integrate climate change into planning. Climate change factors are incorporated into three of the five scenarios. Beyond temperature, other issues with climate extremes and greater variability are a major concern for acute and chronic impacts. For example, earlier runoff can affect agricultural operations in early and late season. Additionally, the scale of climate extremes, like major floods, may not be reflected in all the current modeling (e.g., the floods of 2013). Issues such as flood, forest fires, invasive species, and drought need to be considered in future planning. Evaluating and planning for climate impacts and extreme weather events with adaptive and resilient management strategies should be a focus that helps with planning for any potential future.

5.3.5 Outreach Updates

A. Enhance water plan goals, messaging and stakeholder engagement

Basin roundtables will work to engage new audiences in water planning and outreach. The Water Plan set education and outreach goals through 2020, which are all on track to be met. Roundtables will review and enhance their Education Action Plans while considering the Statewide Education Action Plan, which is still under development by Water Education Colorado, to further improve coordination and continue the effort to reach beyond the traditional roundtable audience. Each roundtables Education Action Plan will be coordinated with the BIP updates in support of the greater Water Plan goals. The CWCB will need to work across these groups to identify what new outreach goals will need to be established in future plans.

B. Rebrand around the Water Plan for consistency

Basin roundtables will support rebranding that integrates BIPs around the Water Plan. The Technical Update, Basin Implementation Plans, and Water Plan update are all intertwined. Each effort builds on the last and, as such, the collective process informs the comprehensive Water Plan update. Basin roundtables will need to help evaluate creative ways to communicate this comprehensive message using new and innovative strategies. This may include improved data visualization, surveys, statewide events, water-related contests, campaigns, or other means of engaging with and focusing on the Water Plan.

SECTION 6
CITATIONS

1 Colorado Water Conservation Board, IBCC Annual Report (CWCB, 2012), 78 .

2 Figure 4.9 in Colorado's Water Plan shows the three composite scenarios selected representing "Hot and Dry", "Between 20th century observed and Hot and Dry" (or "In-Between"), and the current hydrology (or "Baseline Hydrology").

3 Temperature and precipitation were not attributes that were used in estimates of future hydrologies but are extracted from the datasets to help contextualize what the changes in IWR and runoff relate to. See Technical Update Volume 2 technical memo, "Temperature Offsets and Precipitation Change Factors Implicit in the CRWAS-II Planning Scenarios." A temperature offset (°C) quantifies the predicted temperature change from baseline conditions (1970–1999) to future conditions (2050), summarized as (future = historical + offset). A precipitation change factor (unitless) is the ratio of predicted future (2050) to baseline (1970–1999) precipitation totals, summarized as (future = historical x factor)

4 The planning scenarios developed for Colorado's Water Plan and this Technical Update were built upon the foundational work of the multiphase Colorado River Water Availability Study, Phase II (CRWAS-II). Detailed methodology and analysis results can be found in CRWAS-II Task 7: Climate Change Approach and Results.

5 House Bill 2010-1051 requires that the CWCB implement a process for the reporting of water use and conservation data by covered entities. A "covered entity" is defined as each municipality, agency, utility, including any privately owned utility, or other publicly owned entity with a legal obligation to supply, distribute, or otherwise provide water at retail to domestic, commercial, industrial, or public facility customers, and that has a total demand for such customers of two thousand acre-feet or more, per Section 37-60-126(1)(b) of the Colorado Revised Statutes (C.R.S.). 1051 reporting data provided by CWCB for the Technical Update in February 2018.

6 The adoption rate was applied to all demand categories except for non-revenue water.

7 Source: https://www.onthesnow.com/colorado/skireport.html

8 SWSI 2010 did not conduct any surface water modeling but Section 6 of that report provided a cursory review of water availability from existing studies.

9 Colorado Springs Utilities has water supply to meet additional future demands, and the additional supply was accounted for in gap calculations. Pueblo Board of Water Works did not have an estimate additional future demand that could be met with existing supplies, and gaps were not adjusted.

10 Source: Contribution of Agricultural to Colorado's Economy (January 2012, Colorado State University Extension)

11 Source: Rio Grande Basin Implementation Plan (April 2015)

12 RGDSS represents groups of wells with similar hydraulic characteristics as a "response area", and their combined impact to streams is represented as a "response function". Each Subdistrict represents the geographic area reflected in the RGDSS "response area".

13 The San Juan Chama Project delivers water from San Juan tributaries to the Rio Grande basin in New Mexico. The baseline and planning scenario models include the current demand and operations, but the project deliveries are not considered a transbasin export for the Technical Update as the project does not operate under a Colorado water right; cannot call out Colorado water users; and the supply is not delivered to a Colorado entity.

14 Other scenarios examined in the SWSI 2010 analysis projected the 2050 gap in M&I supplies to potentially be as low as 190,000 AFY or as high as 630,000 AFY.

15 See Table ES-6 from SWSI 2010 Executive Summary.

16 See Table ES-4 from SWSI 2010 Executive Summary

17 Based on the estimated existing gap between available water supplies for irrigated agriculture and the full irrigation requirement for current irrigated acres shown in Table ES-3 from SWSI 2010 Executive Summary.

APPENDIX A - *VOLUME II TABLE OF CONTENTS*

CURRENT AND PROJECTED WATER DEMANDS

PROJECTED WATER SUPPLIES AND GAPS

TOOLS FOR BASIN ROUNDTABLES AND WATER STAKEHOLDERS

INSIGHTS FOR BASIN ROUNDTABLES AND WATER STAKEHOLDERS

APPENDIX B - *NARRATIVE TO NUMBERS*

Table 4: Business as Usual Scenario Hydrologic Modeling Inputs

	Relevant Scenario Narrative Language	Key Driver	Water Demand Model Parameter	Input Adjustment (**~no adjustment,** --- large decrease, – moderate **decrease,** - small **decrease,** + small **increase,** ++ moderate **increase,** **+++ large increase)**
M&SSI Demands	By 2050, Colorado's population is close to 9 million people. Single family homes dominate, but there is a slow increase of denser developments in large urban areas. Municipal water conservation efforts slowly increase.	Land Use & Associated Population Growth	Population	~ Per SDO Office Forecast
	The economy goes through regular economic cycles but grows over time.	Economic Growth	Indoor and Outdoor gpcd	~ Economic conditions have similar to historical impact on water use
	The climate is similar to the observed conditions of the 20th century. Municipal water conservation efforts slowly increase.	Climate Conditions	Outdoor gpcd	~ Water use not significantly impacted by climate change
	Social values and regulations remain the same. Regulations are not well coordinated and create increasing uncertainty for local planners and water managers.	Regulations & Technology Change	Indoor and Outdoor gpcd	~ Regulations / technology does not change historic water use
	Social values and regulations remain the same. Willingness to pay for social and environmental mitigation of new water development slowly increases.	Social Values Changes	Indoor and Outdoor gpcd	~ Social values **do not change** historic water use behaviors
Agricultural Demands	Transfer of water from agriculture to urban uses continues. Efforts to mitigate the effects of the transfers slowly increase. Large portions of agricultural land around cities are developed by 2050.	Land Use Changes	Acres of Crops	- - Irrigated agricultural land within and adjacent to city boundaries is converted to housing except in counties with no projected growth
	The climate is similar to the observed conditions of the 20th century.	Climate Conditions	Crop Consumptive Use	~ Similar to recent past
	Agricultural economics continue to be viable, but agricultural water use continues to decline.	Technology Changes	Irrigation Efficiency	~ Similar to recent past
	Social values and regulations remain the same.	Social Values Changes	Crop Types	~ Similar to recent past
Hydrologic	The climate is similar to the observed conditions of the 20th century.	-	Stream Flows	20th century observed
	-	-	Demands	Business as Usual Scenario Demands

APPENDIX B *CONTINUED*

Table 5: Weak Economy Scenario Hydrologic Modeling Inputs

	Relevant Scenario Narrative Language	Key Driver	Water Demand Model Parameter	Input Adjustment (~no adjustment, --- large decrease, -- moderate decrease, - small decrease, + small increase, ++ moderate increase, +++ large increase)
M&SI Demands	Population growth is lower than currently projected, slowing the conversion of agricultural land to housing.	Land Use & Associated Population Growth	Population	- Rural areas have less population decline than SDO forecast & urban areas have less growth than SDO forecast
	The world's economy struggles, and the state's economy is slow to improve. Many sectors of the state's economy, including most water users and water dependent businesses, begin to struggle financially.	Economic Growth	Indoor and Outdoor gpcd	- Poor economy limits water purchases
	Greenhouse gas emissions do not grow as much as currently projected and the climate is similar to the observed conditions of the 20th century.	Climate Conditions	Outdoor gpcd	~ Water use not significantly impact by climate change
	Regulations are not well coordinated and create increasing uncertainty for local planners and water managers. The maintenance of infrastructure, including water facilities, becomes difficult to fund. There is little change in social values, levels of water conservation, urban land use patterns, and environmental regulations.	Regulations & Technology Change	Indoor and Outdoor gpcd	~ Poor economy results in reduced maintenance & increased leakage
	There is little change in social values, levels of water conservation, urban land use patterns, and environmental regulations.	Social Values Changes	Indoor and Outdoor gpcd	~ Social values **do not** change historic water use behaviors
Agricultural Demands	Population growth is lower than currently projected, slowing the conversion of agricultural land to housing. There is little change in social values, levels of water conservation, urban land use patterns, and environmental regulations.	Land Use Changes	Acres of Crops	- Irrigated agricultural land within and adjacent to city boundaries is converted to housing except in counties with no projected growth
	Greenhouse gas emissions do not grow as much as currently projected and the climate is similar to the observed conditions of the 20th century.	Climate Conditions	Crop Consumptive Use	~ Similar to recent past
	There is little change in social values, levels of water conservation, urban land use patterns, and environmental regulations.	Technology Changes	Irrigation Efficiency	~ Similar to recent past
	There is little change in social values, levels of water conservation, urban land use patterns, and environmental regulations.	Social Values Changes	Crop Types	~ Similar to recent past
Hydrologic Modeling Inputs	Greenhouse gas emissions do not grow as much as currently projected and the climate is similar to the observed conditions of the 20th century.	-	Stream Flows	20th century observed
	-	-	Demands	Weak Economy Scenario Demands

Table 6: Cooperative Growth Scenario Hydrologic Modeling Inputs

	Relevant Scenario Narrative Language	Key Driver	Water Demand Model Parameter	Input Adjustment (~no adjustment, --- large decrease, -- moderate decrease, - small decrease, + small increase, ++ moderate increase, +++ large increase)
M&SSI Demands	Population growth is consistent with current forecasts. Mass transportation planning concentrates more development in urban centers and in mountain resort communities, thereby slowing the loss of agricultural land and reducing the strain on natural resources compared to traditional development.	Land Use & Associated Population Growth	Population	~ Overall urban and rural growth per SDO forecast, but more population in urban areas than suburban areas.
M&SSI Demands	Broad alliances form to provide for more integrated and efficient planning and development. Eco-tourism thrives.	Economic Growth	Indoor and Outdoor gpcd	~ Economic conditions have similar to historic impact on water use
M&SSI Demands	There is a moderate warming of the climate, which results in increased water use in all sectors, in turn affecting stream flows and supplies.	Climate Conditions	Outdoor gpcd	+ Moderate warming results in slight increase of outdoor water use
M&SSI Demands	Coloradans embrace water and energy conservation. New water-saving technologies emerge. Water-development controls are more restrictive and require both high water-use efficiency and environmental and recreation benefits. Environmental regulations are more protective, and include efforts to re-operate water supply projects to reduce effects.	Regulations & Technology Change	Indoor and Outdoor gpcd	- - Water saving technology advancements occur and are required
M&SSI Demands	Environmental stewardship becomes the norm. Coloradans embrace water and energy conservation. Demand for more water-efficient foods reduces water use. This dynamic reinforces the social value of widespread water efficiency and increased environmental protection.	Social Values Changes	Indoor and Outdoor gpcd	- - Increased conservation behaviors
Agricultural Demands	Population growth is consistent with current forecasts. Mass transportation planning concentrates more development in urban centers and in mountain resort communities, thereby slowing the loss of agricultural land and reducing the strain on natural resources compared to traditional development.	Land Use Changes	Acres of Crops	- Irrigated agricultural land within and adjacent to city boundaries is converted to housing but less dry-up occurs from agricultural water transfers
Agricultural Demands	There is a moderate warming of the climate, which results in increased water use in all sectors, in turn affecting stream flows and supplies.	Climate Conditions	Crop Consumptive Use	+ Moderate warming
Agricultural Demands	Coloradans embrace water and energy conservation. New water-saving technologies emerge. Water-development controls are more restrictive and require both high water-use efficiency and environmental and recreation benefits.	Technology Changes	Irrigation Efficiency	~ Agriculture maintains current trends in efficiency improvements
Agricultural Demands			Crop Types	-
	Environmental stewardship becomes the norm. Coloradans embrace water and energy conservation. Demand for more water-efficient foods reduces water use. This dynamic reinforces the social value of widespread water efficiency and increased environmental protection.	Social Values Changes		Similar to recent past
Hydrologic Modeling Inputs	There is a moderate warming of the climate, which results in increased water use in all sectors, in turn affecting stream flows and supplies.	-	Stream Flows	In-between 20th century observed and hot and dry
Hydrologic Modeling Inputs		-	Demands	Cooperative Growth Scenario Demands

APPENDIX B *CONTINUED*

Table 7: Adaptive Innovation Scenario Hydrologic Modeling Inputs

	Relevant Scenario Narrative Language	Key Driver	Water Demand Model Parameter	Input Adjustment (~no adjustment, --- large decrease, -- moderate decrease, - small decrease, + small increase, ++ moderate increase, +++ large increase)
M&SSI Demands	The relatively cooler weather in Colorado (due to its higher elevation) and the high-tech job market cause population to grow faster than currently projected. More food is bought locally, increasing local food prices and reducing the loss of agricultural land to urban development. More compact urban development occurs through innovations in mass transit.	Land Use & Associated Population Growth	Population	+
				More population growth than forecasted by SDO with greatest growth in urban areas
	Renewable and clean energy become dominant. Colorado is a research hub and has a strong economy. The warmer climate reduces global food production increasing the market for local agriculture and food imports to Colorado	Economic Growth	Indoor and Outdoor gpcd	~
				Economic conditions have similar to historic impact on water use
	A much warmer climate causes major environmental problems globally and locally.	Climate Conditions	Outdoor gpcd	++
				Significant warming results in increased outdoor water use
	Technological innovation becomes the dominant solution. Strong investments in research lead to breakthrough efficiencies in the use of natural resources, including water. The warmer climate increases demand for irrigation water in agriculture and municipal uses, but innovative technology mitigates the increased demand. The regulations are well defined and permitting outcomes are predictable and expedited.	Regulations & Technology Change	Indoor and Outdoor gpcd	- -
				Water saving technology advancements occur and are required
	Social attitudes shift to a shared responsibility to address problems	Social Values Changes	Indoor and Outdoor gpcd	- -
				Increased conservation behaviors
Agricultural Demands	More food is bought locally, increasing local food prices and reducing the loss of agricultural land to urban development.	Land Use Changes	Acres of Crops	-
				Irrigated agricultural land within and adjacent to city boundaries is converted to housing but less dry-up occurs from agricultural water transfers
	A much warmer climate causes major environmental problems globally and locally.	Climate Conditions	Crop Consumptive Use	++
				Much warmer
	The warmer climate increases demand for irrigation water in agriculture and municipal uses, but innovative technology mitigates the increased demand.	Technology Changes	Irrigation Efficiency	+
				New technologies increase efficiency
	The warmer climate reduces global food production increasing the market for local agriculture and food imports to Colorado. More food is bought locally, increasing local food prices and reducing the loss of agricultural land to urban development.	Social Values Changes	Crop Types	-
				Demand for locally grown foods allows for investment in new irrigation efficiency technologies and crops. Increased temperatures and drier conditions lead to crop hybrids that consume less water.
Hydrologic Modeling Inputs	A much warmer climate causes major environmental problems globally and locally. Droughts and floods become more extreme.	-	Stream Flows	Hot and dry
		-	Demands	Adaptive Innovation Scenario Demands

APPENDIX B *CONTINUED*

Table 8: Hot Growth Scenario Hydrologic Modeling Inputs

	Relevant Scenario Narrative Language	Key Driver	Water Demand Model Parameter	Input Adjustment (~no adjustment, --- large decrease, -- moderate decrease, - small decrease, + small increase, ++ moderate increase, +++ large increase)
M&SSI Demands	A vibrant economy fuels population growth and development throughout the state. Families prefer low-density housing and many seek rural properties, ranchettes, and mountain living. Agricultural and other open lands are rapidly developed. A much warmer global climate brings more people to Colorado with its relatively cooler climate.	Land Use & Associated Population Growth	Population	+ More population growth than forecasted by SDO with growth in both urban and suburban areas
	A vibrant economy fuels population growth and development throughout the state. Worldwide demand for agricultural products rises, greatly increasing food prices. Fossil fuel is the dominant energy source, and there is large production of oil shale, coal, natural gas, and oil in the state.	Economic Growth	Indoor and Outdoor gpcd	++ Increased oil and gas production increases water use
	Hot and dry conditions lead to a decline in stream flows and water supplies. A much warmer global climate brings more people to Colorado with its relatively cooler climate.	Climate Conditions	Outdoor gpcd	++ Significant warming results in increased outdoor water use
	Regulations are relaxed in favor of flexibility to promote and pursue business development.	Regulations & Technology Change	Indoor and Outdoor gpcd	+ Regulations are relaxed in favor of business
	Regulations are relaxed in favor of flexibility to promote and pursue business development.	Social Values Changes	Indoor and Outdoor gpcd	~ Social values do not change historic water use behaviors
Agricultural Demands	Agricultural and other open lands are rapidly developed.	Land Use Changes	Acres of Crops	- - - More agricultural land near cities and in rural areas is converted to housing and more irrigated land is dried up for agricultural water transfers
	Hot and dry conditions lead to a decline in stream flows and water supplies. A much warmer global climate brings more people to Colorado with its relatively cooler climate. A hotter climate decreases global food production. Worldwide demand for agricultural products rises, greatly increasing food prices.	Climate Conditions	Crop Consumptive Use	++ Much warmer
	Regulations are relaxed in favor of flexibility to promote and pursue business development.	Technology Changes	Irrigation Efficiency	~ Similar to recent past
	Agricultural and other open lands are rapidly developed.	Social Values Changes	Crop Types	~ Similar to recent past
Hydrologic Modeling Inputs	Hot and dry conditions lead to a decline in stream flows and water supplies. Droughts and floods become more extreme.	-	Stream Flows	Hot and dry
		-	Demands	Hot Growth Scenario Demands

APPENDIX C - *CONSULTANT TEAM*

Technical Update to the Colorado Water Plan Consultant Teams		
Prime Consultant	**Subconsultants**	**Subconsultant Responsibilities**
Brown and Caldwell	CDR Associates	Facilitation (if needed)
	HDR Engineering, Inc.	Facilitation and public relations assistance (if needed), technical advisors related to general water resources
	Lynker Technologies, Inc.	Technical advisors related to general water resources and climate change
CDM Smith	The Nature Conservancy	Technical advisors related to environmental and recreational needs, gaps, etc.
Jacobs	BBC Research & Consulting	Research and calculations related to population estimates and water-related values
	ELEMENT Water Consulting	Research and calculations related to municipal and self-supplied industrial water demands and water conservation
	The Open Water Foundation	IPP information development
	Southwest Water Resource Consulting	Technical advisors related to planning scenarios
	Wilson Water Group	Research and calculations related to water supplies, projects and methods, and gap analyses

APPENDIX D - *TECHNICAL ADVISORY GROUP (TAG) & IMPLEMENTATION WORKING GROUP (IWG) PARTICIPANTS*

Technical Advisory Group Participant List (July 2017)			
NAME	**BASIN**	**ORGANIZATION**	**TAG**
Laurna Kaatz	Metro	Denver Water	Planning Scenario
Joe Frank	South Platte	Lower South Platte WCD	Planning Scenario
Frank Kugel	Gunnison	Upper Gunnison WCD	Planning Scenario
Steve Harris	Southwest	Harris Water Engineering	Planning Scenario
Cary Denison	Gunnison	Trout Unlimited, Gunnison Basin	Planning Scenario
Jim Hall	South Platte	Northern Water Conservancy District	Planning Scenario
Heather Dutton	Rio Grande	San Luis Valley WCD	Planning Scenario
Kevin McBride	Yampa/White	Upper Yampa WCD	Planning Scenario
Jim Broderick	Arkansas	Southeastern WCD	Planning Scenario
John Currier	Colorado	Colorado River WCD	Planning Scenario
David Graf	Gunnison, CO & SW	Colorado Parks and Wildlife	Planning Scenario
Ken Neubecker	Colorado (Enviro Rep)	American Rivers	Environmental & Recreational
Cary Denison	Gunnison (Enviro Rep)	Trout Unlimited	Environmental & Recreational
David Nickum	Metro (Enviro Rep)	Trout Unlimited	Environmental & Recreational
Barbara Vasquez	North Platte (Enviro Rep)	At-large	Environmental & Recreational
Rio de la Vista	Rio Grande (Enviro Rep)	Rio Grande Headwaters Land Trust	Environmental & Recreational
Jason Roudebush	South Platte	Ducks Unlimited	Environmental & Recreational
SeEtta Moss	Arkansas (Rec Rep)	Arkansas Basin Roundtable	Environmental & Recreational
Tim Hunter	Southwest (Rec Rep)	At-large	Environmental & Recreational
Geoff Blakeslee	Yampa White (Enviro Rep)	The Nature Conservancy	Environmental & Recreational
Kent Vertrees	Yampa White (Rec Rep)	Steamboat Powdercats	Environmental & Recreational
Pete Conovitz	Statewide	Colorado Parks and Wildlife	Environmental & Recreational
Mickey O'Hara	Statewide	Colorado Water Trust	Environmental & Recreational
Laura Belanger	Statewide	Western Resource Advocates	Environmental & Recreational
Tammy Allen	Statewide	CDPHE	Environmental & Recreational
Matt Rice	Statewide	American Rivers	Environmental & Recreational
Nathan Fey	Statewide	American Whitewater	Environmental & Recreational
Greg Fisher	Metro	Denver Water	Municipal & Industrial
Lyle Whitney	Metro	Aurora Water	Municipal & Industrial
Rick Marsicek	Metro	South Metro Water Supply Authority	Municipal & Industrial
Liesl Hans	South Platte	City of Fort Collins	Municipal & Industrial
Katie Melander	South Platte	Northern Water	Municipal & Industrial
Ben Moline	South Platte	Molson Coors	Municipal & Industrial
Scott Winter	Arkansas	Colorado Springs Utilities	Municipal & Industrial
Alan Ward	Arkansas	Pueblo Water	Municipal & Industrial

APPENDIX D *CONTINUED*

Technical Advisory Group Participant List (July 2017), continued			
NAME	**BASIN**	**ORGANIZATION**	**TAG**
Maureen Egan	Colorado	Eagle River Water San. Dist.	Municipal & Industrial
Rick Brinkman	Gunnison & Colorado	City of Grand Junction	Municipal & Industrial
Jackie Brown	Yampa/White	Tri State	Municipal & Industrial
Ann Bunting	Rio Grande	Town of Crestone	Municipal & Industrial
Ed Tolin	Southwest	La Plata Archuleta Water District	Municipal & Industrial
Richard Belt	Statewide	Xcel Energy	Municipal & Industrial
Jorge Figueroa	Statewide	Western Resource Advocates	Municipal & Industrial
Kelley Thompson	Statewide	Colorado DWR	Agriculture
Perry Cabot	Statewide	CSU Extension	Agriculture
Cindy Lair	Statewide	Colorado Dept of Agriculture	Agriculture
Tom Trout	Statewide	USDA	Agriculture
Terry Fankhauser	Statewide	Colorado Cattlemen's Association	Agriculture
Eric Wilkinson	South Platte	Northern Water	Agriculture
Mark Sponslor	South Platte	Colorado Corn	Agriculture
Jim Yahn	South Platte	South Platte Roundtable	Agriculture
Joe Frank	South Platte	South Platte Roundtable	Agriculture
T. Wright Dickinson	Yampa/White	Yampa Roundtable	Agriculture
Mary Brown	Yampa/White	Yampa Roundtable	Agriculture
Ty Wattenberg	North Platte	North Platte Roundtable	Agriculture
Travis Smith	Rio Grande	Rio Grande Roundtable	Agriculture
Ken Curtis	Southwest	Southwest Roundtable	Agriculture
Terry Scanga	Arkansas	Arkansas Roundtable	Agriculture
Jack Goble	Arkansas	Arkansas Roundtable	Agriculture
Paul Bruchez	Colorado	Colorado Roundtable	Agriculture
Frank Kugel	Gunnison	Gunnison Roundtable	Agriculture

APPENDIX D *CONTINUED*

Implementation Working Group Participant List (January 2019)	
NAME	**BASIN**
Terry Scanga	Arkansas
Amber Shanklin	Arkansas
Abby Ortega	Arkansas
Jim Pokrandt	Colorado
Ken Neubecker	Colorado
Mike Wageck	Colorado
Joanne Fagan	Gunnison
Frank Kugel	Gunnison
Cary Denison	Gunnison
Lisa Darling	Metro
Casey Davenhill	Metro
Rick Marsicek	Metro
Curran Trick	North Platte
Kent Crowder	North Platte
Barbara Vasquez	North Platte
Ty Wattenberg	North Platte
Heather Dutton	Rio Grande
Emma Reesor	Rio Grande
Daniel Boyes	Rio Grande
Judy Lopez	Rio Grande
Sean Cronin	South
Lisa McVicker	South
Mike Shimmin	South
Mely Whiting	Southwest
Philip Johnson	Southwest
Karen Guglielmone	Southwest
Kevin McBride	Yampa
Alden Brink	Yampa
Jackie Brown	Yampa
Kelly Romero-Heaney	Yampa

COLLABORATING ON COLORADO’S WATER FUTURE