September 16, 2013

City of Bozeman
Attn: Mr. Brian Heaston, PE
PO Box 1230
Bozeman, MT 59771

RE: Integrated Water Resources Plan

Dear Brian:

Attached please find three (3) copies of the Integrated Water Resources Plan (IWRP) report document, which reflects input and comments from City staff and the revisions requested by the Technical Advisory Committee (TAC). The recommendations provided by the TAC and corresponding appendices are provided as an attachment to this letter and serve as an integral component of the final deliverable for the IWRP.

On behalf of CH2MHill, AE2S sincerely appreciates the opportunity to work with the City of Bozeman on this very important planning effort. It was also a pleasure working with your water rights consultants and members of the TAC to generate a work product that serves as the foundation for meeting the City's water supply capacity requirements well into the future.

Please do not hesitate to contact me at (406) 268-0626 or nate.weisenburger@ae2s.com if our team can be of further assistance.

In the Spirit of Service,

AE2S

R. Nathan Weisenburger, PE
Operations Manager

Attachments

cc: Gretchen Rupp, TAC Chairperson
Mark Anderson, PE, CH2MHill
Court Harris, PE, CH2MHill

Integrated Water Resources Plan

Recommendations of the Technical Advisory Committee to the Bozeman City Commission

September 30, 2013

Executive Summary
In 2012-2013 the City of Bozeman developed an *Integrated Water Resources Plan* to guide its water supply and water use policy and practices for the next 50 years. As part of the planning process a Technical Advisory Committee (TAC) of local water experts was engaged. The TAC participated in evaluating a broad range of possible water-supply and water-use alternatives. The TAC concurs with the recommendations set forth in the *Plan* and recommends additional measures. A vigorous water conservation program should be the cornerstone of Bozeman's water management. In this regard, the city should take the following steps: continue to make the distribution system more efficient, enact policies to encourage landscape irrigation using non-potable water, institute code revisions and otherwise encourage water-use efficiency in new development. Bozeman should work to acquire additional water rights in Hyalite Reservoir and senior rights in Hyalite and Sourdough Creeks. Over the next 5-10 years, the city should conduct detailed studies to define the costs, legal requirements, and engineering feasibility of optimizing the Lyman Creek water source, creating one or more impoundments in Sourdough Canyon, raising Hyalite Dam a second time, developing a new well field in the Gallatin Valley, and acquiring new water from the Salar Project near Gallatin Gateway. These new water supplies should be phased-in as needed, in the order established by a multiple-criteria screening exercise such as that conducted in this planning project. It is also essential that the city periodically review and update the water resources plan, and commit the funds necessary to better understand its water sources and to mitigate water-system operational difficulties.

Background
These recommendations are part of an integrated planning process for water resources that was undertaken in Spring, 2012. This process is the latest in a series of actions taken by our growing community to balance water supply and demand. Notably, in the past 15 years the city has substantially upgraded and enlarged both its water and wastewater handling facilities, examined water conservation as a way to harmonize supply and demand, initiated an aggressive program to repair leaks and replace old water-distribution lines, and studied the potential for constructing a new impoundment in the canyon of Sourdough Creek.

The planning process that was just completed is well-described in the *Integrated Water Resources Plan*, dated August 2013, prepared by the firms AE2S and CH2MHill under contract to the city. Its broad purpose has been to project the city's water demand decades into the future, examine an exhaustive array of means to meet the demand - both sources of supply and water-use practices - and recommend the most promising measures for further study and potentially for implementation. The planning process has been carried out by city staff and contractors with expertise in hydrology, climate science, water-supply engineering and Montana water law (hereinafter referred to as "the consultants"). This "Technical Advisory Committee," chartered in April 2012 by the City Commission, has participated in every stage of the process. As described in the resolution creating it (Appendix A), the twofold role of the TAC has been to bring local expertise into the planning process and to incorporate interests of key stakeholder groups. To do this, the Commission named to the TAC local experts in water resources, water use, and water law, as well as key agency personnel (Appendix B).

The TAC convened in eight public meetings between June 2012 and August 2013, including six meetings with the city's consultants (see table below). There are two products of its work: specific measures and approaches that were incorporated into the technical analysis reported in the *Water Resources Plan,* and several additional recommendations to the Bozeman City Commission, described below.

Technical Advisory Committee Meetings	
Date	**Major Topics**
June 6, 2012	Procedural actions; review background information; review general types of alternatives and authorize alternatives screening approach
July 5, 2012	Finalize TAC mission statement and process; define alternatives screening criteria and weights; discuss background assumptions
August 3, 2013	Adoption of ranking criteria; discussion of water conservation
December 6, 2012	Conservation planning; water rights management; alternatives refinement
January 11, 2013	Contents and evaluation of conservation alternatives; integrated utilities alternatives situation
March 1, 2013	Alternatives ranking and selection for portfolio analysis
May 23, 2013	Consultant presentation and TAC discussion of portfolio results
August 16, 2013	Review of city public-involvement plan; formulation of recommendations to Commission

TAC Perspective

The TAC strongly commends the Bozeman City Commission and city staff for undertaking this comprehensive planning process before a crisis impends, taking stakeholder concerns into account. We are satisfied that a full range of potential water sources has been examined and the best available science has been applied. We have seen the TAC's input incorporated into the plan at every stage, including the shaping of the alternatives-analysis procedure. This long-term, large-scale planning exercise has set the stage for the detailed future examination of specific measures to secure the city's water. Should the *Water Resources Plan* and the TAC's supplementary recommendations be adopted, the Commission and the citizens of Bozeman can be confident that its water-management policies and practices will serve the city well for decades to come.

Early in the planning process the consultants, in consultation with the TAC, developed twenty-five potential measures ("alternatives") that could be applied to reconcile Bozeman's water supply and demand (see Table 5-1 of the *Water Resources Plan*). The alternatives ranged from aggressive water conservation by residents, to re-use of reclaimed wastewater, to importing water from distant locations. A vital role of the TAC was to rank the alternatives with regard to their priority for further analysis (and hence, potential implementation). We did this by elaborating a set of evaluation criteria first developed by the consultants. The 30 criteria and the relative weights assigned to them by the TAC are attached as Appendix C; the criteria descriptors comprise Appendix D.

CATEGORIES OF EVALUATION CRITERIA	WEIGHT (%)
Technical criteria	18
Environmental criteria	28
Social criteria	13
Economic criteria	19
Water supply criteria	22
TOTAL	**100**

The ranking criteria and their relative weights were the lens that focused this planning process according to our community's values. Among the five types of criteria, environmental factors collectively were scored highest by the TAC. These included factors like energy use (conveying water to the treatment plant via gravity vs pumping using fossil fuels), disruption to aquatic environments, and resilience to climate change. Water-supply factors - the reliability and proximity of the source, its vulnerability to contamination, its quality - were judged next-most-important by the TAC. Alternatives were evaluated on the basis of five economic criteria and six social criteria such as quality-of-life impacts, maintenance of irrigated agriculture, and likely customer satisfaction. Alternatives were also assessed according to technical criteria such as compatibility with existing infrastructure and ability to meet water-supply targets. "Redundancy" was judged an important consideration. A redundant water supply has multiple sources, such that it is resilient to catastrophe. For example, an earthquake that renders Bozeman's Hyalite water source unusable would also likely deprive the city of its Sourdough Creek supply - but possibly not the Lyman Creek supply, which thus provides some degree of redundancy. The criteria are in conflict, to a degree. The same measure cannot both "maximize use of existing infrastructure" and bolster water supply redundancy. This shows how each alternative has both advantages and drawbacks.

Recommendations

To meet its 50-year water needs, the TAC recommends that the Bozeman City Commission formally adopt the *Integrated Water Resources Plan*. In particular, the TAC favors the plan's "Portfolio 14," augmented with additional measures. Beginning this year, the city should take the following actions:

- Initiate a water-conservation program, as specified in the FY 2014 budget recently adopted by the Commission. This should include conventional measures such as a consumer-education program and incentives for change-out of water-wasting fixtures, but also plans for piloting and monitoring less-conventional water-saving measures. Water conservation and water-use efficiency should be the bedrock of the city's water-resource management. These measures are cost-effective relative to developing new sources of supply, and hold important ancillary benefits such as environmental preservation and securing water for agriculture in the Gallatin Valley.

- Implement an ongoing effort to acquire additional shares in the Hyalite Reservoir from willing-seller shareholders. As they become available, the city should also seek to acquire flow rights in Hyalite and Sourdough Creeks with older priority dates. This water can be conveyed by gravity to the new water treatment plant, optimizing the city's very substantial investment there.

- Continue to take the legal actions needed to define, consolidate and make the best use of currently-held water rights.

- Continue and intensify current work to cut unaccounted-for water in the distribution system. The TAC recommends adopting an aggressive goal: less than 10% of produced water. Re-visiting past decisions regarding distribution-system pressure, which is very high by national standards, is recommended. This high pressure exacerbates all leaks, from the largest water mains to the smallest customer tap. Both the "moderate" and "high" conservation alternatives described in the *Water Resources Plan* rely on further cutting water losses from the distribution system.

In the intermediate term, the city should:

- Conduct a cost/engineering/legal feasibility study to define how it can optimize water production from the Lyman Creek source. The city holds a much larger water right there than it is currently able to use. This source could not, alone, make up the water shortfalls projected for the 30- and 50-year planning horizons.

- Work with developers to implement non-potable irrigation in new developments, as possible and appropriate. When lands annexed to the city come with appurtenant irrigation rights, those rights should be accepted and the water used for landscape irrigation, sparing capacity at Bozeman's advanced water treatment plant.

- Expand the conservation program to include the commercial and institutional sectors. The program should emphasize water-use efficiency in new developments, where significant savings may be realized. It should deploy an array of tools, ranging from educational campaigns, to incentive programs, to municipal-code updates.

In the longer term, the city should conduct the appropriate studies and then phase in, as needed, the measures below:

- Construct one or more impoundments on Sourdough Creek above the treatment plant. This would take advantage of the city's water rights and water reservation there, and conveyance to the treatment plant would be by gravity. Alternatively, it may be possible to slightly raise Hyalite Dam, or to raise the maximum-pool elevation behind the existing dam by changes to the intake structure. The city should explore these latter possibilities with water-project engineers and water-rights specialists from the Montana Department of Natural Resources & Conservation.

- Site and develop a new well field to supply the city. The Gallatin Valley has abundant groundwater (the use of which would have to be mitigated with existing water rights). Groundwater has major advantages: it is resilient to drought and impervious to wildfire, and requires less treatment than surface water.

- Work with the owners of the "Salar Project" to develop, on their property near Gallatin Gateway, either a well field or an impoundment drawing from two irrigation canals that originate in the West Gallatin River. These waters would principally be used untreated, for landscape irrigation within the western part of the city.

The TAC recommends against importing water from outside the Gallatin watershed, or far downstream, unless extraordinary circumstances render the approaches above inadequate. Cost, legal hurdles and environmental drawbacks would all be high for such long-range water transport. The only circumstance we can envision that might make this approach worth Bozeman's consideration would be high population growth throughout the Gallatin Valley, sustained for a long period (>5% for more than 10 years).

An important question arising from the development of the *Water Resources Plan* is the implementation schedule for the various recommended water-supply alternatives. An essential aspect of the recently-completed work was comprehensiveness: all measures that were even remotely feasible were screened. Consequently, the cost and engineering data developed for the many alternatives were necessarily very rough. Selecting which measures to undertake, when and in what order, hinges on developing much more detailed information. Therefore, the TAC urges the city to adopt the following practices:

- For the next 5-10 years, as needed, program into the city's capital budget funds for detailed definition of the costs, legal requirements and engineering feasibility of the major water-supply alternatives listed above: Lyman, Sourdough impoundment(s), Hyalite dam raise, a new well field, and the Salar project.

- When these alternatives are well-understood, devise the implementation schedule using the screening matrix developed for the *Water Resources Plan*, or update it with the assistance of a new TAC. This is a comprehensive and robust tool that applies the community's values to capital planning. Among the possible capital-construction projects, the TAC looks most favorably on optimizing the Lyman Creek water source.

While the City is pursuing the above measures, it also needs to conduct several ancillary activities:

- Engage the public in active review and comment on this process and the water-resource possibilities open to Bozeman.

- Develop a plan to address the "shrink factor" or "conveyance loss" of Hyalite Reservoir water. More water may be available to the city than is currently assumed.

- Instrument and monitor Lyman and Sourdough Creeks so that their hydrographs - and the reliable water yields of the watersheds - are better understood.

- Continue to work to mitigate operational difficulties, which were outside the scope of this exercise. TAC members have come to appreciate that having an adequate water supply on paper does not mean it is straightforward for operations staff to get that water into the water plant and the distribution network. If the challenges are clearly defined, Bozeman ratepayers will accept modest added water fees to, for example, update the cumbersome and wasteful operational protocol for the Hyalite dam.

- Assist MSU in its continuing work to optimize water-use efficiency on campus. For example, it may be possible for the city to convey unused water rights to MSU's Family & Graduate Housing, allowing it to cease irrigating its grounds with treated city water.

- Re-visit and update the *Water Resources Plan* every five years. This is especially critical in light of the extreme sensitivity of its analysis to the population growth rate. If growth turns out to be slower than the "moderate-growth" scenario from the plan, the city can delay some actions and save money. On the other hand, rapid growth must be accommodated by accelerating the acquisition of new water and intensifying conservation efforts. An effective conservation program will steadily bring down per-capita water demand over time, allowing the city to postpone major expenditures on new water supplies.

Concluding Observations
This initial effort has been comprehensive and robust, but water-resource activities must be ongoing. Assuring water security into the future will require sustained commitment from future commissions. This must involve not just directing city staff to re-visit plans and assumptions periodically, but committing adequate funds to engage technical consultants and to initiate new demand-side or supply-side water projects. Only a serious level of commitment over a long term will allow the *Water Resources Plan* to be brought to fruition.

Collectively and individually, the members of the TAC thank the Bozeman City Commission for the opportunity to participate in this interesting and vital process. We look forward to following the city's water-resource management in coming years. We are confident it can take place in a manner that provides adequate water for a vigorously-growing city while protecting resident quality of life and the wonderful natural environment we so cherish here.

Appendices
A. City Commission resolution creating the TAC
B. List of TAC members and affiliations
C. TAC criteria scoring matrix
D. Criteria descriptors

APPENDIX A

COMMISSION RESOLUTION NO. 4373

A RESOLUTION OF THE CITY COMMISSION OF THE CITY OF BOZEMAN, MONTANA, CREATING AND DEFINING THE PURPOSE AND STRUCTURE OF A TECHNICAL ADVISORY COMMITTEE CONVENING FOR THE CITY'S INTEGRATED WATER RESOURCES PLAN.

WHEREAS, the purpose of the Integrated Water Resources Plan is to explore, evaluate, prioritize, and document the range of alternatives available to address anticipated water supply challenges for the City of Bozeman; and

WHEREAS, on February 6, 2012 the Bozeman City Commission authorized the City Manager to sign a Professional Services Agreement (PSA) with the firm of Advanced Engineering and Environmental Services Inc (AE2S) to complete an Integrated Water Resources Plan (IWRP) for the City of Bozeman; and

WHEREAS, Task 9 of the IWRP PSA scope of services provides that three Technical Advisory Committee (TAC) meetings will be completed, however, additional TAC meetings may be held if directed or approved by the Bozeman City Commission; and

WHEREAS, on February 6, 2012 the Bozeman City Commission directed interested individuals with a technical background or understanding of water supply planning and water rights to apply for TAC positions; and

WHEREAS, the Bozeman City Commission shall appoint members to the IWRP TAC from applicants that have applied for the IWRP TAC.

NOW THEREFORE, BE IT RESOLVED BY THE CITY COMMISSION OF THE CITY OF BOZEMAN, MONTANA:

<u>Section 1</u>

The Technical Advisory Committee (TAC) of the Integrated Water Resources Plan (IWRP) will assist in reviewing and preparing plan components described in Section 2 of this Commission

Resolution. The professional experience and technical background of TAC members will provide a means of broadening the basis of scrutiny and collective knowledge utilized in review and preparation of the IWRP beyond City Staff and its professional contractors.

Section 2

The TAC will be asked to assist City Staff and its professional contractors in:

1. Water conservation planning.
2. Selecting and weighting alternatives ranking criteria.
3. Developing water supply alternatives.
4. Reviewing modeling efforts, cost estimates and plan results.

Section 3

The structure and oversight of the TAC shall be organized according to the following:

1. The Bozeman City Commission shall appoint members to the TAC from individuals with a technical background or understanding of water supply planning and water rights. TAC is considered temporary in nature. If the Committee is still constituted two years after the date of this Resolution, members will need to be reappointed to the Committee by the City Commission. Vacancies shall be filled in the same matter as original appointments.
2. A Commission liaison is required for the TAC for consultation and information, but the liaison is not required to attend each meeting. At least one Staff member shall attend each TAC meeting.
3. The TAC, at its first scheduled meeting, will elect from amongst its appointed membership a committee Chairperson.
4. Three TAC meetings will be held unless additional meetings are directed and/or approved by the Bozeman City Commission.
5. TAC schedules and agendas shall be prepared by Staff and AE2S with input provided by the committee Chairperson. Agendas will then be provided to the City Clerk for public display at least 72 hours prior to the meeting. Materials for TAC review and deliberation shall be provided by AE2S.
6. TAC minutes will be recorded by AE2S and will be made available to the public.
7. The TAC may, at its discretion, forward an independent formal recommendation to the Bozeman City Commission regarding its work and deliberations on the IWRP.
8. TAC meetings will be open to the public and conducted in accordance with all applicable rules and regulations of the State and the City of Bozeman.
9. The actions of the board shall be advisory only and shall not constitute policy of the City and shall not be binding upon the City Commission or upon the City.
10. Meetings shall be conducted according to Robert's Rules of Order, Eleventh Edition and the model Advisory Board Rules of Procedure.
11. Compliance with the City Code of Ethics. All members are required to follow State ethics laws regarding appointed officials and the city of Bozeman Code of Ethics. Members will receive the City of Bozeman ethics handbook and must sign a form

acknowledging receipt of the handbook and take a written oath they will uphold the state and city ethics codes. Members are also required to take an online or paper ethics training shortly after appointment. Non-compliance with the City Code of Ethics and training requirements may result in removal of a Committee member.

PASSED AND APPROVED by the City Commission of the City of Bozeman, Montana, at a regular session held on the 9th day of April, 2012.

SEAN A. BECKER, Mayor

ATTEST:

STACY ULMEN, CMC
City Clerk

APPROVED AS TO FORM:

GREG SULLIVAN
City Attorney

APPENDIX B
Members of the Technical Advisory Committee

Gretchen Rupp (Chair) has practiced water engineering in Bozeman for more than 25 years, in both the private and public sectors; she currently chairs the Gallatin County Board of Health and the Board of the Gallatin Local Water Quality District.

Kerri Strasheim is the Deputy Regional Manager of the Montana Department of Natural Resources & Conservation, heading the Bozeman Water Resources Regional Office.

Frank Cifala was the US Forest Service Lands and Uses Specialist regarding permits and processes on the Gallatin National Forest.

Laura Ziemer is a Trout Unlimited water law attorney and Director of TU's Montana Water Project; she is a 15 year resident of the Bozeman area.

Walt Sales is a Rancher/Farmer and President of the Association of Gallatin Agricultural Irrigators (AGAI); he is a fourth generation rancher in the Gallatin Valley.

Alan English is a hydrogeologist who served for 12 years as Manager of the Gallatin Local Water Quality District.

Peter Skidmore is a hydrologist and owner of Skidmore Restoration Consulting, LLC; Chair (former) of Greater Gallatin Watershed Council; Chair (former) of the Lands Committee of the Gallatin Valley Land Trust; President (incoming) of the Board of River Restoration Northwest; founding board member of Montana Aquatic Resources Services, Inc.

Tammy Crone is Acting Manager of the Gallatin Local Water Quality District. She has served on the Gallatin Water Resource Task Force, as President of Montana Section of the American Water Resources Association and as an advisory committee member for the Bozeman Source Water Protection Plan.

Rick Moroney is Bozeman's Water Treatment Plant Superintendent.

Rick Hixson is the Bozeman City Engineer.

Carson Taylor is an attorney and mediator who currently serves as a Bozeman City Commissioner.

APPENDIX C
TAC CRITERIA SCORING MATRIX

Categories of Evaluation Criteria	Weight (%)
Technical Criteria	18
Environmental Criteria	28
Social Criteria	13
Economic Criteria	19
Water Supply Criteria Criteria	22
Total (Weight must equal 100%)	**100%**

Technical Criteria	Weight (%)
Constructability	13
Regulations and Drinking Water Quality Impacts	17
Existing Infrastructure Compatibility	15
Water Re-use	9
Water Supply Redundancy	14
Meets 30-Year Planning Horizon Targets	19
Meets 50-Year Planning Horizon Targets	13
Total (Weight must equal 100%)	**100%**
Environmental Criteria	**Weight (%)**
Clean Water Act Compliance (TMDLs)	15
In-stream Flow Maintenance	21
Permitting, Environmental Impact Statements, and Easements	16
Energy Generation and Carbon Footprint	18
Climate Impacts Resiliency	15
General Environmental Impacts (Wildlife, Forested Areas)	15
Total (Weight must equal 100%)	**100%**
Social Criteria	**Weight (%)**
Customer Service Satisfaction	18
Public Health and Safety	21
Quality of Life Impacts	15
Overall Public Support	24
Economic Development and Growth	10
Water Marketing and Leasing – Maintain Ag Rights	12
Total (Weight must equal 100%)	**100%**
Economic Criteria	**Weight (%)**
Magnitude of Capital Investment per Acre-ft of Developable Water Supply	26
Relative Operation and Maintenance Costs	27
Eligibility for Outside Funding	13
Economy of Scale Impacts	11
Delay of Infrastructure to Encourage Growth to Pay for Growth	23
Total (Weight must equal 100%)	**100%**
Water Supply Criteria	**Weight (%)**
Reliability and Control of Water Supply (degree of certainty)	21
Initial Water Quality of Water Supply	13
Risk of Water Supply to Contamination/Sabotage	15
Proximity of Water Supply	18
Storage Volume Potential	14
Potential Impacts to the Water Resources	19
Total (Weight must equal 100%)	**100%**

APPENDIX D
TAC SCREENING CRITERIA DESCRIPTIONS

SCORING APPROACH:

The TAC and Technical Team will independently apply points to each of the ranking categories noted above so that a project that receives full points in every category for each heading (Technical, Social, Environmental, Economic, and Water Supply) would receive 100 points. The TAC and Technical Team will develop two scoring approaches independent of the other. To facilitate this process, the Technical Team has already developed a draft of its scoring approach and will work with the TAC during TAC Meeting #1 to verify the scoring categories and moderate the development of the TAC scoring approach. The Technical Team scoring approach will be finalized with the finalization of the ranking criteria to meet the objectives of the scoring process.

Once the scoring approach is established, each of the alternatives to be considered will have ***up to*** the score for each category applied based on each individual evaluator's best judgment. The individual scores will then go into a spreadsheet and be totaled to identify the projects that have the highest qualitative score of the alternatives considered. This process has successfully been applied in other Integrated Water Resources Planning efforts to capture the intrinsic differences between the experiences, exposure, and priorities of a broad spectrum of professionals tasked with long-range, big picture, planning efforts.

The following descriptions of each scoring category are provided to assist in standardizing the interpretations of each of the categories listed above. Note that alternatives should be scored as they relate to each other. In cases where alternatives qualitatively address the ranking category in the same way, the same scores can be applied. However, every attempt should be made to do a comparative analysis of the alternatives to be considered.

Constructability

To receive points for constructability, the evaluator should consider the process of physically constructing an alternative. For example:

- Would the construction site for the project have accessibility issues?
- Are the site conditions where the alternative will be located unknown, challenging, or dangerous?
- Does the alternative require specialized and unique construction strategies that may be difficult and costly to bring to Montana?
- Are there barriers to construction, such as natural features (mountains, rivers, lakes, wetlands, etc.)
- Would there be any timing/seasonal issues that could make constructing an alternative more challenging?
- Will alternative construction involve construction related inconveniences to the public?
- Can the alternative be constructed to withstand catastrophic events?

Any of the above types of considerations, or others that are similar in nature to the construction of an alternative should result in a reduction in total allowable points for this category.

Regulations and Drinking Water Quality Impacts

To receive points for this category, the evaluator should consider the following:

- Is the proposed water supply consistent with current water supplies for which treatment processes are already in place to treat the water to existing potable drinking water regulations?
- Can treatment processes be constructed to treat the proposed water source to existing potable drinking water regulations?
- Are there regulatory issues with the water supply that will result in regulatory issues in the future and may have public health impacts if implemented prior to regulations being put into place (endocrine disruptors, human health standards for nitrates, cytotoxins (algae) by-products, high organic carbon or organic matter, requiring unique disinfection strategies with byproducts that could be regulated more stringently in the future, etc.).

Higher points should be given to alternatives where water quality is known and regulations can thoroughly be addressed now, with the flexibility to address them into the future as they change.

Existing Infrastructure Compatibility

This category will require that that evaluator consider whether the proposed alternative optimizes use of existing infrastructure. For example:

- Does the proposed solution allow for full utilization of the City of Bozeman WTP that is under construction? The facility is being constructed to a peak capacity of 22 mgd and consists of membrane treatment technologies designed to water quality standards associated with Bozeman Creek, Middle Creek, and Hyalite Reservoir.
- Is there infrastructure already in place to deliver water to the distribution system and serve the different zones of the system effectively?
- Can new infrastructure be constructed to complement the existing infrastructure? If so, rank the alternatives in term of general feasibility of the infrastructure necessary as they compare to each other.

Water Reuse

Does the proposed solution involve a water reuse component, particularly one associated with effluent from the Bozeman Water Reclamation Facility?

- Does the proposed project assist in compliance with the City's Wastewater Permit?
- Is the proposed solution acceptable to the general public?
- Does the solution provide a non-potable water supply to another water rights hold that could then contract its water right to the City for drinking water purposes?

Water Supply Redundancy

A redundant water supply should not only be considered in terms of overall quantity of water from one source (i.e. the source has twice the water in reserve than necessary to serve the community in dry year), but more appropriately:

- Are the supplies developed in two (or more) distinct water sources that have different responses to climate conditions, different delivery mechanisms to the system, different treatment needs, and can effectively replace the other in the event of an emergency (i.e. fire in the Bozeman Creek/Hyalite Watershed, contamination of the water supply, slope failure in Bozeman Creek resulting in temporary loss of the stream, failure of the treatment process equipment, prolonged drought, etc.)?

Meets 30-Year Planning Horizon Targets

Does this Alternative provide enough water supply to meet water demand and population targets that have been established for this study effort in the 30-Year Planning Horizon? If not, could it be combined with other alternatives to accomplish this objective?

Meets 50-Year Planning Horizon Targets

Does this Alternative provide enough water supply to meet water demand and population targets that have been established for this study effort in the 30-Year Planning Horizon? If not, could it be combined with other alternatives to accomplish this objective?

Clean Water Act Compliance (TMDLs)

Does this alternative have components that can assist in watershed water quality improvements, particularly as they relate to various TMDLs (Nutrient, Sediment, and E.Coli) in the Lower Gallatin Watershed? Examples include:

- Wastewater Reuse to prevent discharge of wastewater into the East Gallatin River during Seasonal Permitted Conditions
- Application of reuse water in a manner that reduces the use of chemical fertilizer applications
- Reduction of direct stormwater discharge to local streams
- Provision of augmentation flows to increase low flow conditions in areas of the watershed where water quality impairments could be a challenge (i.e. an out-of-basin import project or impoundment constructed with additional capacity to maintain minimum stream flows at a healthy level could be an example. While this would not offset water supplies, it may be possible to put existing or new water supplies to use under different conditions either on a temporary or permanent basis to achieve this type of compliance objective in the future).

In-Stream Flows

Does the proposed project have the potential to compromise in-stream flows during low flow conditions? Does the proposed project have the potential to add flexibility in mitigating instream flow issues during low flow conditions?

Permitting, Environmental Impact Statements, and Easements

Does the proposed alternative require an extensive permitting, environmental clearance, and easement development process? If so, does the extent of this effort carry risk that the alternative may not be viable or carry with it, the possibility of legal action against the City? If a permit or easement cannot be developed for an alternative, or environmental issues result in a need to modify the alternative, can the alternative be modified to address the concern?

Energy Generation and Carbon Footprint

Does the proposed alternative have the ability to generate energy to offset the gross energy requirement of the alternative, in turn reducing the net carbon footprint of the alternative? Carbon footprint considerations include energy to construct the alternative as well as operate and maintain the alternative.

Climate Resiliency

Is the proposed alternative capable of sustaining reasonable service levels with regard to the potential range of long-term climate impacts? If so, can it also withstand temporary and harsher climate conditions such as drought? Is the water supply able to return to normal conditions relatively quickly after drought events?

General Environmental Impacts (Forests, Wildlife, Water Quality, etc.)

Does the project have the potential to have a significant impact on local forested areas, fish and wildlife, historical and cultural resources, and water quality? Does the alternative have potential to harm or impact endangered species recognized for protection under the Endangered Species Act? Are environmental impacts associated with the alternative reversible in the event the alternative is removed in the future? Does the alternative have long-term applicability in sustaining activities employed to mitigate impacts to forests, wildlife, water quality, etc.?

Customer Service Satisfaction

Will the proposed solution result in acceptable levels of customer satisfaction with regard to aesthetics, water quality and quantity, and cost? How will it compare to the service levels that customers are accustomed to, today?

Public Health and Safety

Outside of regulatory requirements and potable drinking water quality (which were addressed in previous categories), does the proposed alternative present any public health and safety concerns? For example, a reservoir above the City could pose some flood risk if a breach were to occur. Operator safety in maintaining and managing an alternative could be considered in this category as well.

Quality of Life Impacts

Would the water supply alternative carry any impacts that could increase or decrease the quality of life for the City of Bozeman. In the case of an impoundment, could it be used for recreational activities, or does it limit or eliminate recreational activities? Could it be used to sustain a recreational activity that may use large amounts of water (i.e. golf course or park irrigation)? Does developing a large, imported water supply encourage growth that impairs quality of life in Bozeman, or does it allow for structured growth that will continue to attract people to the area that will enhance the quality of life of those in Bozeman? While there are many ways that this category could be scored, it should be scored relative to the other alternatives evaluated, to the greatest extent possible.

Overall Public Support

Does the proposed alternative seem consistent with public sentiment from past water supply planning efforts in regards to what a final project should consider? Does it feel like a project that the City of Bozeman community would generally support, fund, and advocate for in the future.

Economic Development and Growth

Does the proposed alternative include components that will hinder Economic Development and Growth in any way? For example, would the proposed alternative improve or sustain recreational opportunities based on use of our local water supply resources? Would the alternative allow for flexible and appropriate Economic Development and Growth in the City of Bozeman? Would moratoriums on certain types of service sectors be a possibility under certain conditions? If the baseline planning conditions set forth in this study effort are no longer applicable due to unanticipated growth, increased water use, climate, or natural disaster, does the proposed alternative provide flexibility to adapt? Is the alternative easily expandable to allow for large water using industries to locate to the Bozeman area, if desired? Can it accommodate unpredictable swings in growth, both through expansion to serve new growth and overall cost considerations to minimize the pressures of building large infrastructure projects for future populations that don't develop as planned? Can it be combined with other solutions to delay the project until constructing the project is necessary without sacrificing service levels?

Water Marketing and Leasing – Maintain Ag Rights

If a new water supply is using water formerly used for irrigated agriculture, does the use of agricultural water rely on short-term, drought-year, or other temporary leases so that agricultural land remains in production? Such approaches could use rotational fallowing, split-season leases, drought-year leases or dry-land pasture, in contrast to "buy and dry" approaches that would take land out of agricultural production altogether for its associated water rights.

Magnitude of Capital Investment per Acre-ft of Developable Water Supply

Although cost information is not available for all alternatives at this level of the alternatives evaluation, the goal of this category is to provide relative consideration for each alternative as they compare to each other. In general, ranges of developable acre-ft for each alternative are provided in the alternative information. The goal of this category is to consider levels of investment versus the amount of water and flexibility that could be developed. For example, the Sourdough Creek Reservoir Project has included cost estimates of $50 to $70 million dollars for a possible 6,000 ac-ft of water supply. While the alternative evaluation will place some risk on the potential for 6,000 ac-ft (there is some concern regarding the potential of securing the full amount, or any of the 6,000 ac-ft due to water rights law in Montana), in the event that this project could be completed, this results in a range of $8,333/ac-ft to $11,666/ac-ft. Likewise, the current cash in-lieu program charges developers $6,000/ac-ft or the relinquishment of water rights equal to what is necessary to serve the development so that new water rights could be purchased. Likewise, a large development project, such as an import project, may run well over $100 million (perhaps even $200 million) dollars, but result in the development of 30,000 acre-ft, for a relative cost per ac-ft of much less than the alternatives.

Relative Operation and Maintenance (O&M) Costs

While detailed O&M costs have not been developed at this time, the evaluator should consider whether extensive O&M will be required for various alternatives. Will additional staff be required? Does the raw water supply delivery system associated with the proposed alternative require extensive pumping and energy requirements? Will new treatment processes be required that could involve increased mechanical treatment and energy requirements to meet drinking water regulatory requirements?

Eligibility for Outside Funding

Would the proposed alternative be eligible for funding assistance to offset the rate impacts of the project to the City of Bozeman rate payers? Projects that involve regional approaches and address water issues across service sectors (service sectors being municipal, industrial, agricultural, and natural) could be projects that would be eligible for federal and possibly even special State grant funding. The Red River Valley Water Supply Project in North Dakota imports water from the Missouri River to the Red River and is funded through a cost share of 1/3rd federal, 1/3rd state, and 1/3rd local funding. The local portion is allocated based on water reserved from the project by each community participating. Other examples of regional funding programs could be discussed, such as the Rocky Boy's/North Central Montana Regional Water System Project, the Lewis and Clark Regional Water System Project (South Dakota), the Western Area Water Supply Project (WAWSP), in Northwestern North Dakota, etc. While some of these projects have unique circumstances that may not make their strategies directly applicable to a regional project in the Gallatin Valley, these projects are coordinated with the Bureau of Reclamation and funding for both collaborative planning efforts and future projects has been available in the past, is available now, and could be developed in the future. The extent of outside funding would need to be further explored, but some alternatives considered as part of this study effort could be eligible for funding, where others will primarily be the City of Bozeman's responsibility to fund.

Economy of Scale Impacts

A project that can be constructed to serve a larger population base now and in the future will result in economy of scale benefits. The evaluator should consider the population that could be served by each alternative in relationship to the cost of constructing and operating the system. Although one project may be more expensive up front, if it can serve a larger population over the long-term, a cost/benefit analysis may result in the more costly alternative in the future.

Delay of Infrastructure to Encourage Growth to Pay for Growth

This ranking category will mostly be associated with alternatives that involve phasing, organizational mechanisms, or temporary solutions that allow for the delay of infrastructure construction until the population is in place to support the project. Not all alternatives will receive scores in this category.

Reliability and Control of the Water Supply (degree of certainty)

How much does the source fluctuate based on weather patterns and other user demands? Does the development option include senior water rights or ownership in a storage control structure? If storage is involved and a private or other government entity controls the structure, what are the associated risks, such as long-term operation, timing issues, maintenance issues, etc? This allows analysis for whether a source is available continuously, seasonally, or only during periodic events, such as a large storm event or a high-water year.

Initial Water Quality of the Water Supply

Water quality components includes: microbial, nutrient, temperature, metals, etc. Cleaner water in a source leads to reduced treatment costs, saving significant energy and monetary resources. Some components found in water are easier to treat for drinking water than others. This ranking category would include analysis of existing water quality, vulnerability of source to contamination, and water quality compatibility with other supplies.

Risk of Water Supply to Contamination/Sabotage

Is the water supply and/or development protectable? Is the location vulnerable to tampering? This would include the source and any conveyance or storage structures. Potential contamination/sabotage could either be regarding physical supply or quality of the supply.

Proximity of Water Supply

This ranking category helps to promote developing closer water supplies, minimizing conveyance length and loss potential. This ranking criteria could also include analysis of whether conveyance can be by gravity flow or would involve higher energy transport.

Storage Volume Potential

Storage is a critical element in a city water supply, so this category allows analysis for the potential to add storage up front or to develop storage sometime in the future to aid in water supply security. If aquifer storage project, this would allow analysis for whether the aquifer has available capacity for recharge water storage in the aquifer. For other projects, this would allow analysis for the potential to develop storage concurrently or in the future with the water supply development.

Potential Impacts to the Water Resource

Some water supply developments impact a source more than others. Developing groundwater springs can permanently impact the spring flow down development. Also, aquifer storage projects can create gaining reaches of streams and ditches that didn't exist previously. Along with physical water quantity impacts, water quality impacts and other riparian ecosystem impacts could occur. The local community has shown that water source health is an important value. This takes those local values into consideration when analyzing alternatives.

INTEGRATED WATER RESOURCES PLAN

City of Bozeman
Bozeman, MT

August 2013

I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of Montana.

R. Nathan Weisenburger, PE

Date: 9-16-2013 Reg. No. 17751

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EXECUTIVE SUMMARY

The City of Bozeman (City) has experienced varied population growth and anticipates that growth will continue in the future. The future growth trend of Bozeman is uncertain; however, the City recognizes that it possesses a finite supply of water that could potentially be surpassed as the demand for water increases with community growth. The City is located in a closed basin with respect to water rights, and existing water supplies relied upon by the City are susceptible to the impacts of drought and climate change, which could limit the availability of water on a seasonal or annual basis. Based on these concerns, the City retained Advanced Engineering and Environmental Services, Inc. (AE2S) and CH2M Hill to complete an Integrated Water Resources Plan (IWRP) that could conceivably address the water supply requirements over the next 30 to 50 years corresponding to planning horizons of 2042 and 2062.

The work completed for the IWRP consisted of identifying the existing water rights of the City and comparing them to future water demands that could be experienced in relation to community growth, climate change, and other factors. The comparison resulted in the ability to estimate the water balance gap that may occur in the future, which could also be defined as the amount of water needed to meet increasing demands. Based on a range of possible population growth trends, which are presented in Table EX-1, the estimated water balance gap for the planning horizons varies from approximately 2,000 to 18,000 acre-feet, and is presented in Table EX-2. Depending on population growth and the corresponding use of water, estimates indicate that the City could experience a water balance gap under a timeline of 2025 to 2030, as the population approaches approximately 57,000, if new water supply capacity development and/or water demand reductions are not implemented. The range of possibilities prompted the development of the IWRP under an approach that is relatively flexible and capable of being adapted as the City monitors the validity of assumptions and planning values used in the IWRP and updates the information to address actual future conditions.

Table EX-1: Moderate and High Growth Population Projections

Item Description	2012	2042	2062
Moderate Population Projection (2%/yr for 30-years, 1%/yr for next 20-yrs)	38,786	70,256	85,725
High Population Projection (3%/yr for 30-years, 2%/yr for next 20-yrs)	38,786	94,144	139,900

Table EX-2: Estimated Climate Adjusted Annual Water Balance Gap

Item Description	2042	2062	2042	2062
	Moderate Growth		High Growth	
Annual Water Demand (acre-feet/year)	13,500	17,790	17,900	28,700
Annual Firm Yield Supply (acre-feet/year)	11,237	10,948	11,237	10,948
Water Balance Gap (acre-feet/year)	**2,263**	**6,842**	**6,663**	**17,752**

Alternatives involving water conservation measures and concepts to increase the available water supply capacity were identified to meet the estimated water balance gap. Water conservation was given substantial consideration and credibility in the development of the IWRP as a strategic near-term initiative to be implemented by the City to reduce the rate of demand for water by its user classes. Monthly water demands, which serve as the basis for estimating the effectiveness of various water conservation measures, are presented in Table EX-3. The monthly water demand information also indicates the potential viability of other alternatives, such as non-potable irrigation, to meet seasonal (outdoor) demands.

The alternatives were initially screened with respect to a water rights legal assessment and qualitative criteria that were developed with assistance from the Technical Advisory Committee (TAC), which was created by the City to review documentation and provide stakeholder perspective at critical milestones. The alternatives selected through the water rights and

Table EX-3: Historical Indoor and Outdoor Water Use by Month

Month	Indoor Water Use	Outdoor Water Use	Total Water Use
January	106	0	106
February	112	0	112
March	109	0	109
April	109	0	109
May	116	50	166
June	117	87	204
July	118	190	308
August	122	176	298
September	115	107	222
October	129	0	129
November	110	0	110
December	106	0	106
Average Annual Water Demand			**165**

Note: Values presented in units of gallons per capita per day (gpcd) qualitative screening processes were then combined in strategic ways to create 13 different portfolios. A life-cycle cost analysis was completed using the VOYAGE™ model and specific information developed for each of the portfolios. Cost estimates generally included capital and operating cost elements over the 50-year planning horizon. Resulting life-cycle costs reported are comparative and provided at a conceptual level, and estimates may not include all necessary costs for implementation.

The individual portfolios, which included varying levels of demand reduction via water conservation program implementation, were developed to meet the estimated water demands related to the moderate growth projections or the high growth projections. The alternatives comprising the portfolios were prioritized for implementation to achieve a balance between the demand and the available supply of water, such that the timing of alternatives could be completed to meet short-term and long-term demand requirements.

Upon review of draft life-cycle cost analysis results, the TAC expressed interest in the development of an additional portfolio comprised of a more comprehensive list of alternatives to meet the high population growth scenario. Given the conceptual level of effort to generate the portfolios, City representatives also introduced the possibility of initiating parallel efforts that would build on the results of the IWRP and provide more precise information to better define the implementation requirements for the alternatives. Consequently, an additional portfolio (Portfolio 14) was created and evaluated using the VOYAGE™ model.

The estimated comparative net present value of Portfolio 14 is approximately $148 million, compared to a range of $113 million to $296 million for high growth scenarios, and is constructed to meet high growth demands on a monthly basis. Despite a modestly higher cost per unit of annual water volume provided, Portfolio 14 offers increased value as compared to the other portfolios developed to meet the high population growth scenario, based on several criteria developed by the TAC, staff, and the consultant team collaboratively. Portfolio 14 also represents a more diverse range of scalable options and provides increased flexibility and resiliency to the City with respect to changing conditions and uncertainty in the future. Based on this refined input, Portfolio 14 was tested as the basis for an IWRP strategy to be implemented by the City to meet a range of future growth scenarios through the 2042 and 2062 planning horizons:

- Initiating a water conservation program that considers the success of various conservation measures, public acceptance, and a comparison of cost with respect to water supply capacity development with the goal of meeting low to medium water demand reduction targets.
- Adding storage in Sourdough Canyon or Hyalite Reservoir via an infrastructure project to improve current withdrawals and treatment plant operations.
- Developing groundwater system capacity in the Gallatin Gateway area or other appropriate location to meet demand on an as-needed basis.
- Strategically purchasing shares from Hyalite Reservoir and senior surface water rights from Hyalite Creek and Sourdough Creek to obtain water in the near-term.

- Developing non-potable irrigation for new developments on an incremental basis.
- Optimizing the capacity of the Lyman Creek water source.

The future water needs of the City of Bozeman will depend on future conditions, such as the rate of population growth, impacts of climate change, success of the City's water conservation program, availability of useful water rights, and other conditions that are not completely predictable. The IWRP was developed in recognition that future decisions by the City will be made in the context of these conditions as they evolve, and the IWRP is intended to be flexible enough to account for the conditions and contingencies created by these evolving conditions. The following recommendations were developed to represent a logistical strategy for the City to proceed in fulfilling the objectives of the IWRP:

Near-Term

- Implementation of Portfolio 14 should proceed with a robust economic and engineering feasibility analysis for each of the portfolio components, followed by a comparative analysis of the components based on the screening assessment framework established by the IWRP. These steps provide a sound basis for prioritized decision-making by the City of Bozeman regarding its water resource management.
- Incorporate the implementation of Portfolio 14 into the City of Bozeman Capital Improvement Planning budget such that anticipated costs are budgeted well into the future.
- A water conservation plan should be prioritized for implementation to reduce the rate of demand for water as a substantial contribution toward addressing the water balance gap identified for the 2042 and 2062 planning horizons.
- The installation of stream flow monitoring equipment in the watersheds should be implemented to provide useful information to the City for the purpose of assessing climate change impacts and better manage its water resources moving forward.
- Implementation of strategies to improve the capture efficiency of water requested and released from Hyalite Reservoir, such as reducing or potentially eliminating the conveyance efficiency factor and providing increased raw water and/or finished water storage.
- The formal application process with the DNRC should be initiated to secure water rights that are currently available to the City totaling approximately 6,750 acre-feet of water an annual basis. This value does not reflect a historical use analysis that will be conducted for any change applications, and should be noted to avoid any mistaken expectations about the amount of water that is potentially available.
- Shares from Hyalite Reservoir and senior surface water rights from Hyalite Creek and Sourdough Creek should be purchased to the extent possible.

Long-Term

- Water supply and demand trends should be monitored to assess the need for additional water supply capacity development.

- Revisit population growth trends every 5 years, or on a more frequent interval if necessary.
- Additional water supply capacity should be developed by the City in accordance with the outcome of subsequent efforts to evaluate alternatives in more detail and planning objectives that will evolve with actual population growth and water demand trends.

Chapter 1 INTRODUCTION

The City of Bozeman (City) has experienced varied population growth since year 2000, ranging from over 5 percent per year to no growth in population associated with the recent recession. As the economy appears to be recovering, the City and surrounding area is once again experiencing an increase in development activity and positive growth. The future growth trend of Bozeman is uncertain; however, the City recognizes that it possesses a finite supply of water that could potentially be surpassed as the demand for water increases with community growth. Prior to the recent recession and based on a relatively aggressive rate of growth, the 2005 Water Facility Plan estimated that a water supply shortage could be experienced as soon as 2015.

The City is located in a closed basin with respect to water rights, which prevents the City from filing applications for new water rights from the State of Montana without mitigation. Existing water rights held by the City are subject to restriction with respect to senior water rights, stipulated periods of use during the year, and rates of withdrawal. Operational concerns include cold weather and reduced flow impacts that limit the ability to withdraw water from Bozeman Creek (Sourdough Creek). Cold temperatures cause ice formation on Bozeman Creek, which has interfered with intake operations when low flow conditions persist. Hyalite Creek (Middle Creek) can also experience reduced flows, which are supplemented by the release of stored water from Hyalite Reservoir. Calls for the release of water from Hyalite Reservoir must be made 24 hours in advance based on estimates by operators. Operators typically estimate conservatively in order to ensure an adequate release of from Hyalite Reservoir is available to meet demands, which often results in the incomplete capture of the releases by the intake system. The City also recognizes that water supplies are susceptible to the impacts of drought and climate change, which could limit the availability of water on a seasonal or annual basis.

The anticipation of future community growth and limited water supply availability prompted the City to complete an Integrated Water Resources Plan (IWRP) that could conceivably address the water supply requirements over the next 30 to 50 years. Specific components of the IWRP, as envisioned by the City, include:

- Completing an inventory of existing water rights currently held by the Bozeman;
- Conducting a hydrologic firm yield analysis assessing the sensitivity of existing sources to drought and climate change impacts;
- Characterizing existing water use patterns;
- Developing a water demand model, using population projections and water use patterns;
- Developing a preliminary water conservation plan with considerations for drought contingency;
- Identifying and assessing alternatives available to the Bozeman to enhance the availability of existing water supplies and/or develop new water supplies;

- Coordinating work efforts with Water Rights Solutions, Inc. (WRSI), the specialized firm retained by the City to provide consulting on water rights issues, and Peter Scott, legal counsel; and
- Conducting a series of meetings with a Technical Advisory Committee (TAC) to provide local input and perspective on the technical information prepared for the IWRP.

1.1 Planning Approach

Several variables affect the supply and demand for water in the Bozeman area. The range of possibilities regarding such variables that ultimately contribute to the development of the IWRP for the City is infinite. An abbreviated list of such variables include assumptions regarding population projections; the effectiveness of specific water conservation measures on future water demands; the potential impacts of climate change; and the accuracy of conceptual opinions of cost developed for water supply alternatives. Furthermore, the City recognizes the difficulty of predicting the impact that these and other pertinent factors may have through the identified 30-year and 50-year planning horizons corresponding to year 2032 and year 2062, respectively. To address the range of possibilities, AE2S/CH2M Hill developed the IWRP under a planning approach that is relatively flexible and capable of being adapted as the City monitors the validity of assumptions and planning values used in the IWRP and updates the information to address actual future conditions.

1.2 Project Contact Information

The primary contact person for the City with respect to the administration of the IWRP is:

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The work completed by AE2S/CH2M Hill for the IWRP is presented in this report document and related appendices. It should be noted that not all of the work products used to generate this document are provided for reference; however, additional support documentation, if needed, is available upon request. The primary contact persons regarding the contents of the report and supporting documentation are as follows:

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Chapter 2 WATER RIGHTS CONSIDERATIONS

2.1 Existing Water Rights

The City holds several water rights in various watersheds located in the vicinity of Bozeman. The existing water rights available to the City on an annual basis are summarized in Table 2-1. When considering the volume of water available, it is important to recognize that water demand varies throughout the year. The City typically experiences increased rates of water demand during late spring, throughout the summer, and into the early fall months when outdoor use is prevalent. Similarly, the amount of water available on a daily or monthly basis varies with withdrawal provisions, inadequate flow or production from the source, and infrastructure limitations. For these reasons, the development of the water demand model included in the scope of work for the IWRP considered the comparison of projected water demands to the available supply of water rights on a monthly time step and on an annual total volumetric basis. As indicated in Table 2-1, some of the water rights are not available for use at the existing site of the Sourdough Water Treatment Plant (WTP).

Table 2-1: Summary of Existing Water Rights

Water Source	Documented Water Right (acre-feet/year)
Sourdough Creek (Bozeman Creek)	4,800
Hyalite Creek (Middle Creek)	1,631
Hyalite Reservoir	5,652
Total Water Rights Available at Existing WTP	**12,083**
Sourdough Storage Reservation*	609
Lyman Creek	4,346
Total with Sourdough Storage Reservation	**17,038**
Total without Sourdough Storage Reservation	**16,429**

* Requires action by the City with respect to the construction of appropriate infrastructure.

2.2 Firm Yield of Existing Rights

As stated above, portions of the existing water rights listed in Table 2-1 are not currently available to the City for various reasons. The City has commissioned previous efforts to assess the firm yield of its existing water rights. The basis for this study stems from the 1997 Water Facility Plan. Firm yield values from that study were reviewed and revised, where applicable, based on future climate projections. The estimated firm yield of the existing water rights, as compared to the documented water right, is presented in Table 2-2.

2.3 Climate Change Impacts

Long-term water supply planning must consider whether historic, documented climate trends and projected future conditions may affect proposed strategies. Climate change models have been developed to assess the long-term impact of carbon emissions and are being used to predict the response of a given watershed to changes in the temperature of the atmosphere and the timing and intensity of precipitation, including reduced levels of precipitation that would contribute to drought conditions. Climate change impacts were estimated using SimCLIM, which is a proprietary model developed by ClimSystems. A technical memorandum was prepared by CH2M Hill to explain how SimCLIM was used to estimate the impact of climate change on the firm yield of water sources used by the City. The technical memorandum is provided in Appendix A for reference.

Table 2-2: Estimated Firm Yield of Existing Water Sources[1]

Water Source	Documented Water Right (acre-feet/year)	Estimated Firm Yield (acre-feet/year)
Sourdough Creek (Bozeman Creek)	4,800	3,734
Hyalite Creek (Middle Creek)	1,631	1,526
Hyalite Reservoir	5,652	4,295
Total Water Rights Available at Existing WTP	**12,083**	**9,555**
Sourdough Storage Reservation	609	609
Lyman Creek	4,346	1,280
Total with Sourdough Storage Reservation	**17,038**	**11,444**
Total without Sourdough Storage Reservation	**16,429**	**10,835**

[1] Data Source: 1997 Water Facility Plan

The results of the SimCLIM model with respect to sources of water used by the City are summarized in Table 2-3 and are reported for 2012 and the year 2042 and year 2062 planning horizons. Generally, the firm yield of water sources that are not associated with impoundments or reservoirs to provide storage, such as that for Sourdough Creek and Hyalite Creek, is estimated to decline in the future. The estimated firm yield for water from Hyalite Reservoir and Lyman Creek, which is classified as groundwater from a natural spring, are assumed to remain relatively stable for the analysis, but also may be influenced by changing climate patterns.

Releases of water from Hyalite Reservoir, as requested by WTP staff, are subject to adjustment based on an 80 percent conveyance efficiency factor. The results presented in Table 2-3 for Hyalite Reservoir assume that the adjustment factor could be removed from releases requested by the City to maximize the capture efficiency of the total amount available based on the increased number shares owned by the City and the relative proximity of the City's intake facility as compared to the withdrawal points of other shareholders. The City has also evaluated potential strategies to minimize the amount of released water that is not captured by the intake facility. Possible improvements include raw water storage and/or increased distribution system storage to provide increased operational flexibility in regards to accurately predicting water demands and the corresponding requests for the release of water from Hyalite Reservoir.

The increased amount of water reported for Lyman Creek, as compared to that presented in Table 2-2, reflect relatively recent capital improvements to the spring intake collection system and Lyman Treatment Plant piping system that have increased the firm production capacity.

Table 2-3: Climate Change Impact on Firm Yield of Existing Water Sources

Water Source	2012 Firm Yield (acre-feet/year)	2042 Firm Yield (acre-feet/year)	2062 Firm Yield (acre-feet/year)
Sourdough Creek (Bozeman Creek)	3,633	3,491	3,277
Hyalite Creek (Middle Creek)	1,489	1,436	1,360
Hyalite Reservoir	4,521	4,521	4,521
Total Water Rights Available at Existing WTP	**9,643**	**9,447**	**9,158**
Sourdough Storage Reservation	609	609	609
Lyman Creek	1,790	1,790	1,790
Total with Sourdough Storage Reservation	**12,042**	**11,846**	**11,557**
Total without Sourdough Storage Reservation	**11,433**	**11,237**	**10,948**

2.4 Watershed Monitoring

During the initial meeting with the TAC, the lack of monitoring equipment to measure stream flow in area watersheds was discussed and identified as a limitation to accurately determine the firm yield of existing water sources. The installation of monitoring equipment, such as gauging stations, would facilitate the development of trending assessments in the watersheds. The ability to trend information could assist in understanding the impacts, if any, associated with climate change and potentially provide opportunities to better manage water resources available to the City moving forward.

2.5 Additional Water Rights Available to the City via Formal Application

In addition to the water rights listed in Table 2-1, the City has the ability to secure additional water supply from water rights claims not presently used. A summary of such water rights is presented in Table 2-4. Water rights acquired through annexation are obtained as prescribed by City ordinance as additional development occurs. Developers are required to provide the City with a water right that is capable of meeting the water demand of the subject development or provide payment to the City for the purpose of purchasing water rights. The Mystic Lake water rights pertain to water that was stored behind a dam in the Sourdough Creek watershed. The Mystic Lake water rights have not been available to the City since 1985, when the dam was intentionally breached due to safety concerns experienced in 1984. The water rights presented in Table 2-4 require formal action by the City via preparation and submittal of appropriate change applications to the Montana Department of Natural Resources and Conservation (DNRC). Based on the water supply development objectives of the City and the results of the IWRP, the City will continue to consult with WRSI and its legal counsel to make use of these water rights.

Table 2-4: Water Rights Currently Available Via Formal Application

Water Source/Right	Available Water Right (acre-feet/year)
Mandeville/Tracy Rights	~500
Water Rights Acquired via Annexation	~250
Mystic Lake Water Rights	6,000
Total	**6,750***

* The values do not reflect a historical use analysis that will be conducted for any change applications and should be noted to avoid any mistaken expectations about the amount of water that is potentially available.

Chapter 3 WATER DEMAND MODEL DEVELOPMENT

A primary component of the IWRP consisted of developing a water demand model. The water demand model serves as the basis for projecting future water demands, comparing the projected water demands to the amount of water available from existing sources, and quantifying the amount and at what point in time the City will need to acquire additional sources of water. The development of the water demand model for the IWRP involved several steps, including:

- Characterizing existing water use patterns
- Identifying a service level objective and corresponding water demand
- Establishing a defensible method for population projections
- Estimating water demands for planning horizons

3.1 Water Demand Pattern Characterization

Historical water demand data from 2000 to 2010 was provided by the City for review, interpretation, and statistical manipulation purposes. The data provided by the City included a categorization of the water demand between user classes, such as residential, commercial, industrial, and Montana State University (MSU). It should be noted that a portion of the work effort consisted of working with the City's Geographical Information System (GIS) department to develop reports that link water meter data to specific zones, user class, seasonal periods, etc., to facilitate trending and additional statistical analyses to conduct continued evaluations of water demand patterns, as needed, in the future.

The characterized water use by user class based on the set of water demand data provided by the City is presented in Figure 3-1. Given the format in which the data was provided, it is also possible to present similar characterizations of the water demand information by indoor use and outdoor use trends, which are presented in Figure 3-2 and Figure 3-3, respectively. The ability to review water demand information in the amount of detail afforded by the data presents a substantial amount of increased perspective regarding the use of water and how water use may change or be adjusted moving forward.

The historical water demand data was also manipulated such that seasonal water demands could be reviewed and assessed. Water demands typically vary considerably in communities such as Bozeman that experience a wide range of temperature variation associated with the change of seasons. Water demand trends typically increase during the months associated with late spring, summer, and early fall when outdoor water use is more prevalent. A monthly breakdown of the seasonal demand for Bozeman is provided in Table 3-1 to indicate how the water demand changes over the course of the year. As shown, Bozeman currently experiences a substantial increase in water demand during the summer months.

Figure 3-1: Characterization of Total Water Demand by User Class

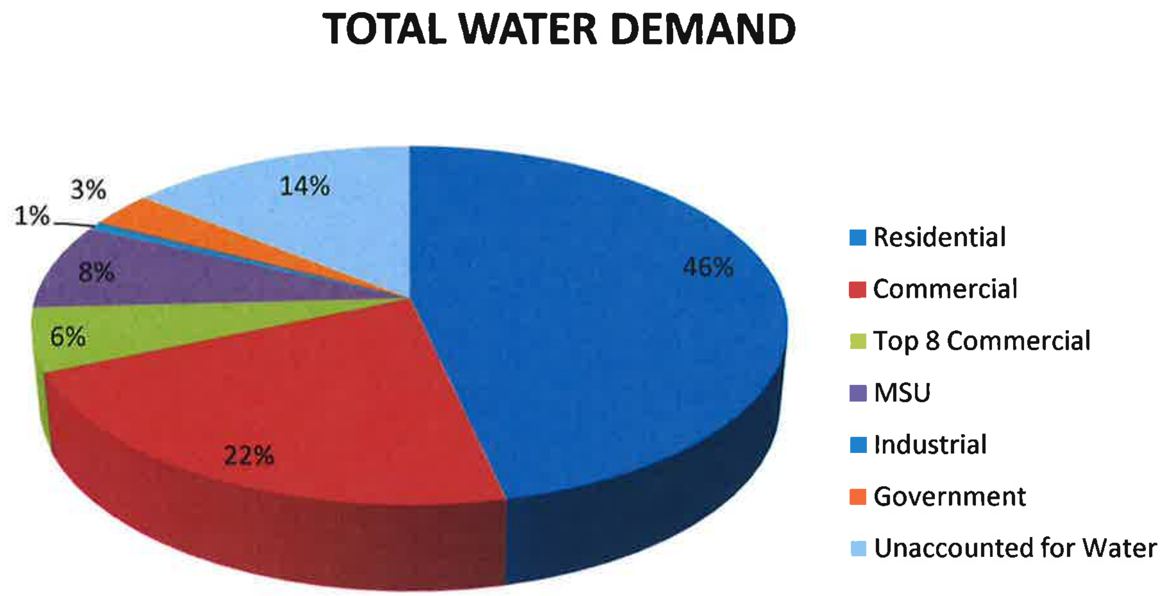


Figure 3-2: Characterization of Indoor Water Demand by User Class

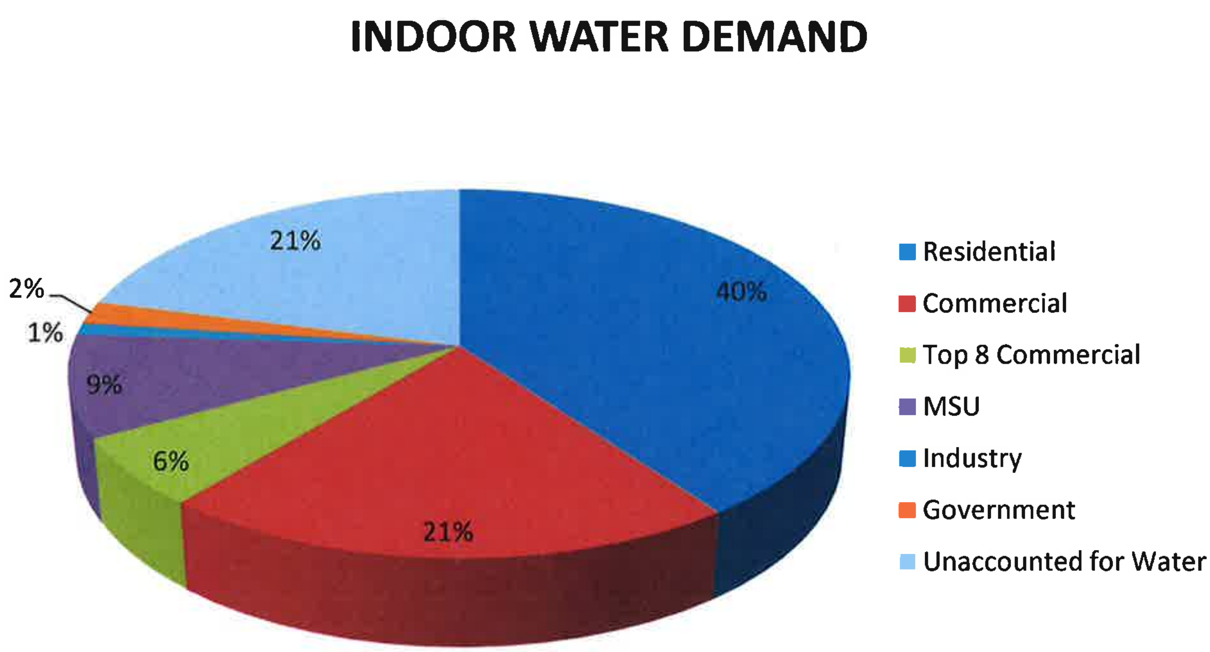


Figure 3-3: Characterization of Outdoor Water Demand by User Class

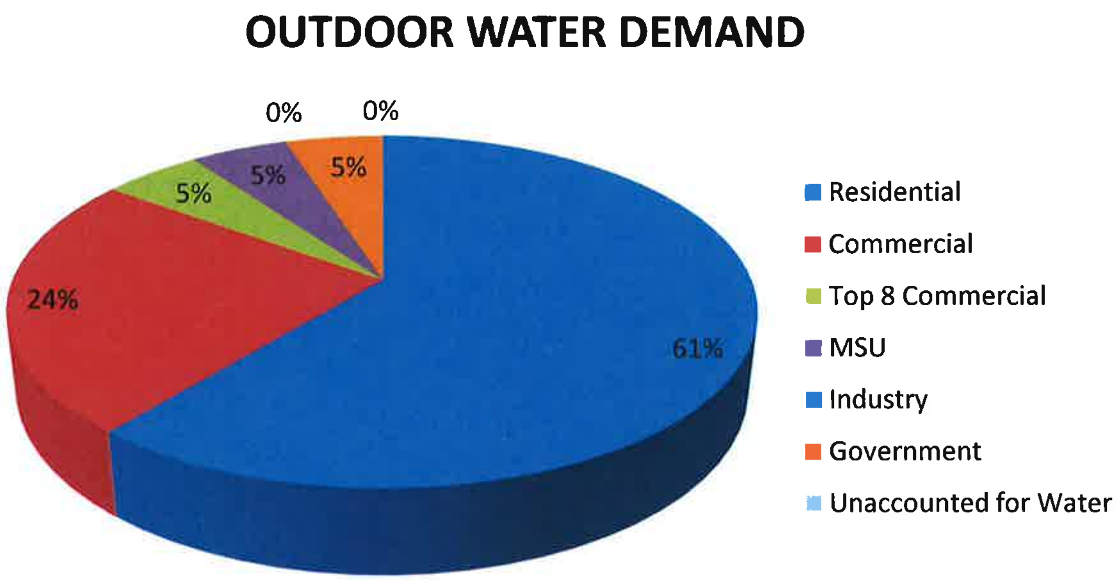


Table 3-1: Historical Indoor and Outdoor Water Use by Month

Month	Indoor Water Use	Outdoor Water Use	Total Water Use
January	106	0	106
February	112	0	112
March	109	0	109
April	109	0	109
May	116	50	166
June	117	87	204
July	118	190	308
August	122	176	298
September	115	107	222
October	129	0	129
November	110	0	110
December	106	0	106
Average Annual Water Demand			**165**

Note: Values presented in units of gallons per capita per day (gpcd)

The seasonal water demand data in Table 3-1 served as the basis for several efforts completed as part of the IWRP. For instance, the data provided a benchmark for the purpose of estimating the effectiveness of various water conservation measures, which are a prominent component of the IWRP moving forward. The monthly water demand information also indicates that the potential viability of other alternatives, such as those that are consistent with the use of non-potable irrigation water, could be implemented to meet increased seasonal demands that do not necessarily require water treated to drinking water standards.

3.2 Service Level Analysis

Most water utilities are willing to accept an operational philosophy that it will not be able to meet the demand for water 100 percent of the time, as this requirement results in additional costs for infrastructure capacity that is rarely used. For this reason, a discussion regarding the identification of an acceptable service level factor was facilitated with the City and members of the TAC. A service level analysis involves statistically evaluating historical water demand data to identify a water demand value that serves as the basis for the implementation of future improvements.

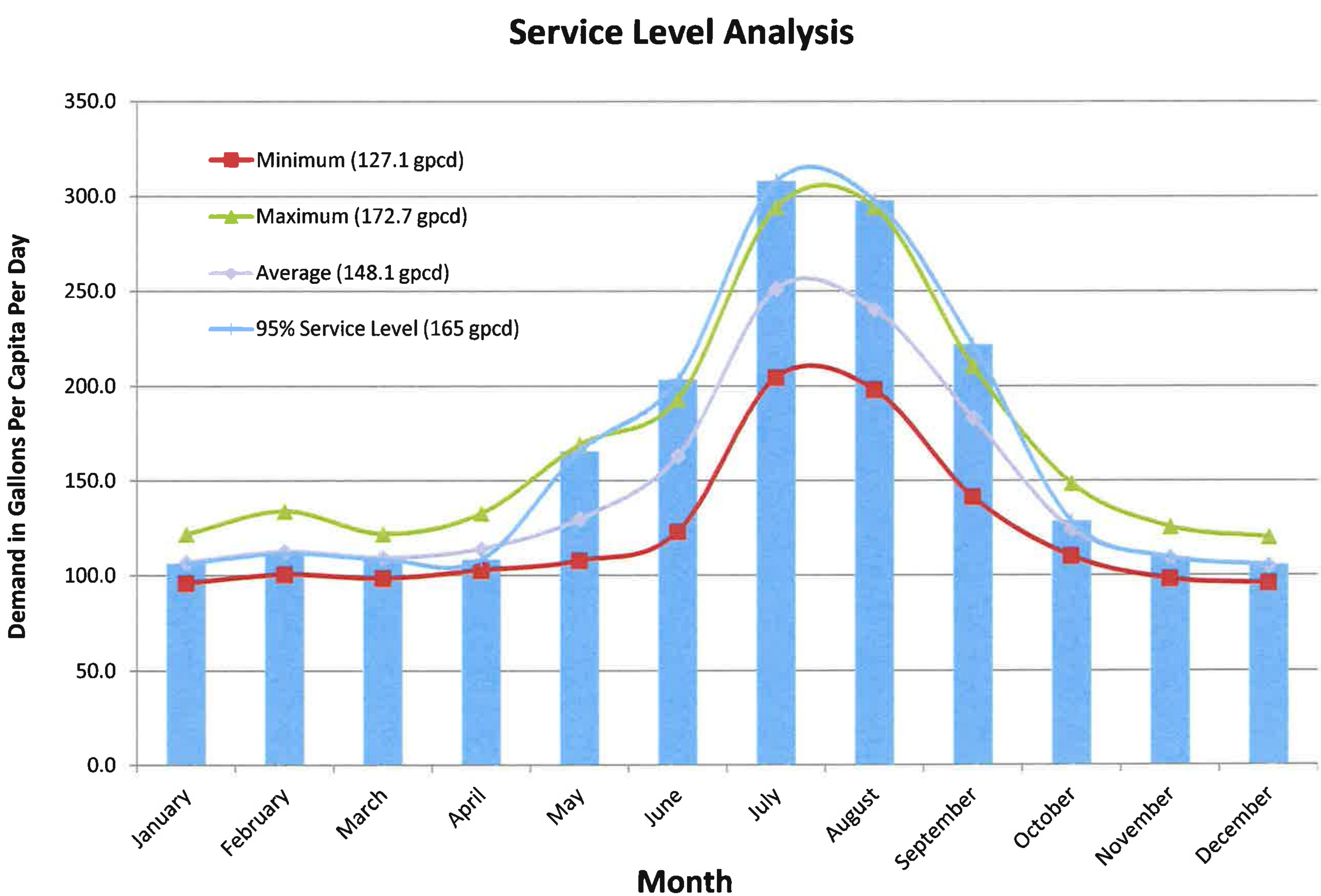
The service level analysis for the City of Bozeman was based on the average of monthly water demand data sets. Historical water demand information from 2000 through 2010 was used to identify planning values for summer months because the data set over this period of time varied considerably with climate conditions. The planning values for the summer months were based on historical water demand information from 2005 through 2010, which have been relatively stable since declining somewhat steadily from 2000 through 2005.

Based on input from the TAC, the City approved the recommendation to base the IWRP on meeting a service level objective of 95 percent. Therefore, the IWRP has been developed to provide enough water supply capacity to theoretically meet 95 percent of the possible average month water demand values that could be experienced by the City. The annual water demand corresponding to a 95 percent service level establishes a reasonable planning value of 165 gallons per capita per day (gpcd). A graphical representation of the statistical analysis used to identify an acceptable service level is presented in Figure 3-4. Water demands that exceed the water supply capacity in the future are anticipated to be managed via the implementation of drought contingency measures. More detailed discussion regarding the service level analysis and drought contingency planning is provided in the Water Conservation Plan technical memorandum, which is located in Appendix B.

3.3 Population Projections

Population growth has varied considerably in the Bozeman area over the past few decades. Previous planning documents, such as the 2005 Water Facility Plan, estimated a population growth rate of 5 percent from 2005 through 2025 based on the amount of development that was occurring in the Bozeman area at that point in time. The Sourdough Creek Reservoir

Figure 3-4: Service Level Objective Statistical Analysis



Development Plan completed in April 2011 estimated that the firm yield of existing water supplies could become inadequate by 2015 to 2020 based on the 2005 Water Facility Plan water demand analysis. Due to the negative impact of the recent economic recession, the City has experienced substantially less growth over the past three to four years, resulting in an opportunity to plan for a range of growth possibilities moving forward.

Using a flexible planning approach, the future population of Bozeman was estimated based on two possibilities consisting of a moderate population projection and a high population projection. The moderate population projection increases the estimated 2012 population by 2 percent per year for 30 years through the 2042 planning horizon, and increases the population by 1 percent per year for a consecutive 20-year period through the 2062 planning horizon. The high population projection increases the estimated 2012 population by 3 percent per year for 30 years through 2042, and increases the population by 2 percent per year for a consecutive 20-year period through the 2062 planning horizon. The results of the population projections are shown in Table 3-2. Actual population projections will most likely differ from the two scenarios documented herein, and the City should monitor the rate of population growth periodically to assess whether adjustments to the recommendations and related implementation timelines are necessary.

3.4 Water Demand Projections

Water demand projections were estimated using historical water demand data, the 95 percent service level analysis, and the inclusion of an adjustment factor to address potential climate impacts on water use. A discussion of the impacts on water demands related to climate change is included in the technical memorandum provided in Appendix A. The annual water demand is calculated by multiplying the climate adjusted water demand value by the projected population corresponding to a given planning horizon. The product of that calculation is converted to units of acre-feet/year by applying a factor of 365 to convert from a daily value to an annual value, and dividing by approximately 325,850 to convert gallons to acre-feet.

Table 3-2: Moderate and High Growth Population Projections

Item Description	2012	2042	2062
Moderate Population Projection (2%/yr for 30-years, 1%/yr for next 20-yrs)	38,786	70,256	85,725
High Population Projection (3%/yr for 30-years, 2%/yr for next 20-yrs)	38,786	94,144	139,900

As presented in Figures 3-1, 3-2, and 3-3, the water demand projections are indicative of the anticipated requirements for each user class and seasonal variation associated with indoor and outdoor water use trends. Specific water demand values associated with the various user classes and seasonal trends that contribute to the overall annual demand calculation is provided in the Water Conservation Plan technical memorandum in Appendix B.

The projected annual water demands for 2042 and 2062, with provisions for growth by Montana State University (MSU), are provided in Table 3-3 for the moderate growth and high growth population projections. The similarity in projected water demands for the 2042 high growth projection and the 2062 moderate growth projection is notable, differing only by 110 acre-feet.

The projected water supply shortage, or water balance gap, is calculated by subtracting the amount of water that is currently available from existing supplies used by the City from the projected water supply demand presented in Table 3-3. The amount of water that is available from existing supplies, as determined from the climate adjusted firm yield analysis, is presented in Table 2-3. Using the data without including the Sourdough Storage Reservation, the projected water balance gap ranges from about 2000 acre-feet to nearly 18,000 acre feet, as presented in Table 3-4.

The projected water balance gap for the 2042 high growth projection and the 2062 moderate growth projection are relatively similar, only differing by approximately 180 acre-feet. The water balance gap determined by the water demand model serves as the foundation for reducing water demand via water conservation or developing additional water supply capacity.

Table 3-3: Estimated Climate Adjusted Annual Water Demand Projections without Water Conservation

Item Description	2042	2062	2042	2062
Climate Adjusted Water Demand (gpcd)	Moderate Growth		High Growth	
	165	180	165	180
Population Projection	70,256	85,725	94,144	139,900
Bozeman Water Demand (acre-feet/year)	13,000	17,290	17,400	28,200
MSU Growth (acre-feet/year)	500	500	500	500
Total Annual Water Demand (acre-feet)	**13,500**	**17,790**	**17,900**	**28,700**

Table 3-4: Estimated Climate Adjusted Annual Water Balance Gap without Water Conservation

Item Description	2042	2062	2042	2062
	Moderate Growth		High Growth	
Annual Water Demand (acre-feet/year)	13,500	17,790	17,900	28,700
Annual Firm Yield Supply (acre-feet/year)	11,237	10,948	11,237	10,948
Water Balance Gap (acre-feet/year)	**2,263**	**6,842**	**6,663**	**17,752**

Chapter 4 WATER CONSERVATION PLAN

The scope of work for the IWRP included an update to the 2002 Water Conservation Plan for the City. Water conservation was a prominent discussion topic during several of the meetings conducted with the City and the TAC, and the approach taken to develop the Water Conservation Plan was tailored in accordance with the input and direction that was received. A detailed explanation of the work completed for the Water Conservation Plan is provided as a technical memorandum in Appendix B.

To meet the objectives established by the City and TAC, three levels of water conservation were developed to estimate the potential reduction in the future demand for water. The three levels of water conservation were developed to reflect low, medium, and high degrees of effort that could be put forth by the City to reduce the overall rate of water consumption. The cost associated with implementing the identified water conservation measures were estimated such that the three levels of water conservation could be included as potential alternatives to assist in meeting the future water supply needs of the City. The estimated volume of water demand reduction achievable by the three water conservation levels at the 2042 and 2062 planning horizons are provided in the top portion of Table 4-1 for the moderate population growth projection. The estimated volume of water demand reduction achievable by the three water conservation levels at the 2042 and 2062 planning horizons are provided in the bottom portion of Table 4-1 for the high population growth projection.

The amount of water required from alternatives other than water conservation measures to meet future demands is equal to the difference between the water balance gap values presented in Table 3-3 and the estimated water reduction for the three levels of water conservation, as presented in Table 4-1. The resulting values of this calculation for the corresponding planning horizon and projected growth scenario are provided in Table 4-2.

Table 4-1: Water Conservation Reduction Summary

Item Description	2042	2062
Moderate Population Growth		
Estimated Low Conservation Reduction (acre-feet/year)	2,013	2,770
Estimated Medium Conservation Reduction (acre-feet/year)	4,282	5,908
Estimated High Conservation Reduction (acre-feet/year)	6,369	8,218
High Population Growth		
Estimated Low Conservation Reduction (acre-feet/year)	2,838	4,806
Estimated Medium Conservation Reduction (acre-feet/year)	5,921	10,108
Estimated High Conservation Reduction (acre-feet/year)	8,240	12,991

Table 4-2: Climate Adjusted Water Balance Gap Including Water Conservation

Item Description	2042	2062	2042	2062
	Moderate Growth		High Growth	
Water Balance Gap - Low Conservation (acre-ft)	250	4,072	3,825	12,946
Water Balance Gap - Medium Conservation (acre-ft)	-2,019	934	742	7,644
Water Balance Gap - High Conservation (acre-ft)	-4,106	-1,376	-1,577	4,761

As shown in Table 4-2, the estimated water balance gap could potentially be addressed through water conversation measures, depending on the amount of growth experienced by the City and extent of water conservation achieved. The estimated water balance gap could approach 13,000 acre-feet by 2062 under the high growth scenario and low water conservation. The water balance gap that remains after the consideration of the water conservation alternatives needs to be met with alternatives that increase the amount of water available to the City. Negative values suggest that water conservation measures could potentially be adequate to address increasing water demand associated with population growth, provided that the increased levels are less expensive than the cost of developing additional water supply. As identified in Table 4-2, high water conservation does not adequately address the water balance gap over the 50-year planning horizon and high growth conditions, indicating that water supply capacity development would be required.

Chapter 5 ALTERNATIVE DEVELOPMENT & SCREENING PROCESS

5.1 Summary of Alternatives

Alternatives were developed to increase the amount of water supply capacity available to the City to meet the water balance gap calculated in the previous section of this report (Table 4-2). The alternatives were generated at a conceptual level with representatives of the City, the TAC, and AE2S/CH2M Hill. The alternatives developed for the IWRP were split into the following general categories:

Integrated Utility (IU) Alternatives: The IU alternatives consist of several concepts to leverage water that could be made available from other utilities operated by the City, primarily treated effluent from the Bozeman Water Reclamation Facility (BWRF).

Water Supply Development (WSD) Alternatives: The WSD alternatives consist of targeting a specific source that could provide additional water supply capacity to the City.

Other Supply (OS) Alternatives: The OS alternatives consist of miscellaneous concepts to increase the available supply of water to the City, either via optimization or strategies to offset the current use of water, such as water conservation.

The list of the alternatives developed for the IWRP is provided in Table 5-1. Summaries of the alternatives were prepared to convey technical information to the City and TAC to facilitate the alternative screening process. The technical summaries for each of the alternatives are provided in Appendix C for reference.

5.2 Alternative Screening Process

The alternatives were screened using a methodical process to eliminate the need for detailed engineering and cost analysis for alternatives that may not be legally or technically feasible or were viewed less favorable as compared to more viable alternatives. The screening process consisted of the following three levels of evaluation:

Screening Level 1:	Water Rights Legal Assessment
Screening Level 2:	Qualitative Criteria
Screening Level 3:	Quantitative Criteria - VOYAGE™ Model Alternative Analysis

Screening Level 1: Water Rights Legal Assessment
As an initial screening effort, the alternatives were reviewed by the City's water rights consultant and special legal counsel with respect to Montana Water Law. Based on the input received, the alternatives were classified into one of three rankings:

Table 5-1: IWRP Alternatives

Alternative Number	Alternative Name
IU Alternatives	
IU1	Northside Non-Potable Water Reuse
IU2	Northside and Southside Non-Potable Water Reuse
IU3	Northside Non-Potable and Potable Water Reuse
IU4	Northside and Southside Non-Potable and Potable Water Reuse
IU5	Agricultural irrigation Water Use
IU6	Industrial Water Reuse
IU7	Groundwater Recharge – Water Reuse
WSD Alternatives	
WSD1	Sourdough Reservoir
WSD2A	Canyon Ferry Import Reservoir Delivery
WSD2B	Canyon Ferry Import Confluence Delivery
WSD3A	Madison Aquifer Groundwater
WSD3B	Belgrade Subarea Groundwater
WSD3C	Gallatin Gateway Subarea Groundwater
WSD4	Yellowstone River Import
WSD5	Adjacent Drainage Development
WSD6	Canal Company Impoundment
WSD7	Sourdough Pond Storage
WSD8	Hyalite Share Purchasing
WSD9	Hyalite Reservoir Dam Raise
WSD10	Brackett Creek Import
OS Alternatives	
OS1	Non-Potable Groundwater Supply
OS2	Lyman Creek Expansion
OS3	Low Water Conservation Approach
OS4	Medium Water Conservation Approach
OS5	High Water Conservation Approach

Green: The alternative is consistent with existing provisions of Montana Water Law, and could likely yield the anticipated results if pursued for implementation by the City.
Yellow: The alternative may or may not be consistent with provisions of Montana Water Law, and the actual outcome may differ from the anticipated results if pursued for implementation by the City.
Red: The alternative is not consistent with Montana Water Law and should not be pursued for implementation by the City unless changes to Montana Water Law are possible.

Alternatives that were classified as green or yellow in accordance with their respective consistency with Montana Water Law proceeded to the second level of the screening process. Alternatives that were classified as red were dismissed from further evaluation.

Screening Level 2: Qualitative Criteria
The alternatives that were deemed possible from a water rights legal assessment perspective were subjected to an evaluation based on wide range of qualitative criteria. The qualitative criteria were developed by AE2S/CH2M Hill and presented to the City and TAC for review, input, and revision. Once the list of criteria was established, each of the criteria was placed into one of the following categories: Technical Criteria; Environmental Criteria; Social Criteria; Economic Criteria; and Water Supply Criteria.

The criteria comprising each of the categories were assigned weighting factors, with the sum of the weighting criteria factors for each category being equal to 100. Similarly, each of the categories was assigned a weighting factor such that the total sum of the weighting factors for the categories resulted in a sum of 100. Based on the identified criteria and categories, which were determined through consensus with the TAC, each member of the TAC was asked to assign weighting factors. The weighting factors assigned to the criteria and categories for the ranking process were determined based on the average of the factors provided by the TAC. The categories and respective weighting factors used to evaluate the alternatives are presented in Table 5-2. The qualitative criteria comprising each category and respective weighting factors are presented in Table 5-3, and detailed descriptions of the criteria pertaining to the evaluation of the alternatives are provided in Appendix C.

Table 5-2: Qualitative Evaluation Categories and Weighting Factors

Categories of Evaluation Criteria	Weight (%)	Score
Technical Criteria	18	
Environmental Criteria	28	
Social Criteria	13	
Economic Criteria	19	
Water Supply Criteria	22	
Total (Weight must equal 100%)	**100%**	

Table 5-3: Qualitative Ranking Criteria and Weighting Factors

Technical Criteria	Weight (%)	Score
Constructability	13	
Regulations and Drinking Water Quality Impacts	17	
Existing Infrastructure Compatibility	15	
Water Re-use	9	
Water Supply Redundancy	14	
Meets 30-Year Planning Horizon Targets	19	
Meets 50-Year Planning Horizon Targets	13	
Total (Weight must equal 100%)	**100%**	
Environmental Criteria	**Weight (%)**	**Score**
Clean Water Act Compliance (TMDLs)	15	
In-stream Flow Maintenance	21	
Permitting, Environmental Impact Statements, and Easements	16	
Energy Generation and Carbon Footprint	18	
Climate Impacts Resiliency	15	
General Environmental Impacts (Wildlife, Forested Areas)	15	
Total (Weight must equal 100%)	**100%**	
Social Criteria	**Weight (%)**	**Score**
Customer Service Satisfaction	18	
Public Health and Safety	21	
Quality of Life Impacts	15	
Overall Public Support	24	
Economic Development and Growth	10	
Water Marketing and Leasing – Maintain Ag Rights	12	
Total (Weight must equal 100%)	**100%**	
Economic Criteria	**Weight (%)**	**Score**
Magnitude of Capital Investment per Acre-ft of Developable Water Supply	26	
Relative Operation and Maintenance Costs	27	
Eligibility for Outside Funding	13	
Economy of Scale Impacts	11	
Delay of Infrastructure to Encourage Growth to Pay for Growth	23	
Total (Weight must equal 100%)	**100%**	
Water Supply Criteria	**Weight (%)**	**Score**
Reliability and Control of Water Supply (degree of certainty)	21	
Initial Water Quality of Water Supply	13	
Risk of Water Supply to Contamination/Sabotage	15	
Proximity of Water Supply	18	
Storage Volume Potential	14	
Potential Impacts to the Water Resources	19	
Total (Weight must equal 100%)	**100%**	

Members of the TAC were tasked with scoring each of the alternatives with respect to the qualitative criteria using a scale of 0 to 3, with 0 being the least favorable score possible and 3 being the most favorable score possible. The average scores for the TAC are presented in Table 5-4. Table 5-4 also includes the TAC rankings presented as ordinal sum values. The scores and ordinal sum values represent data sets from eight of the TAC members. Three members of the TAC abstained from completing the qualitative ranking exercise.

The results of the ranking process were presented to the City and TAC for review and consideration with respect to the development of water supply portfolios, which consist of a combination of alternatives to meet the projected water needs of the City. The scoring and subsequent ranking process prompted vigorous discussion of the alternatives and the possible combinations thereof to create the limited number of IWRP portfolios to be further evaluated using the VOYAGE™ model. Representatives of AE2S/CH2M Hill completed the qualitative scoring and ranking process. This information, along with technical guidance and perspective, contributed to the selection of alternatives and the development of portfolios.

The IU alternatives generally involve the use of effluent from the BWRF as a potential strategy to simultaneously meet a portion of the water demand and achieve compliance with increasingly stringent wastewater discharge regulations. The IU alternatives generated substantial discussion regarding potential conflicts between Montana water law and current and potential wastewater discharge regulations enforced by the Montana Department of Environmental Quality. As Montana municipalities consider alternatives to reduce or eliminate the need to discharge wastewater, it was recognized that mitigation would likely be necessary for BWRF effluent reuse to be considered as an approved strategy to circumvent wastewater discharge permit requirements. Due to the identified water law constraints and uncertainty regarding feasibility, all of the IU alternatives involving the use of effluent from the BWRF were excluded from further consideration.

The possibilities of obtaining water from the Yellowstone River (WSD4), adjacent drainage basins (WSD5), and Brackett Creek (WSD10) were also excluded based on the relatively low qualitative scores and rankings as compared to other alternatives.

The decision was made to use cost information from the Sourdough Creek Reservoir Development Plan prepared in April 2011 as a placeholder for the potential construction of an impoundment or series of impoundments in the Sourdough Creek watershed or the concept of raising Hyalite Dam to gain additional water storage. Therefore, alternatives WSD1, WSD7, and WSD9 were indirectly identified for inclusion in the portfolio modeling process.

The development of groundwater was supported by the City and TAC. Several unanswered questions surround the concept of obtaining water from Madison Aquifer, whereas the ability to obtain groundwater of acceptable quantity and quality in the Belgrade and Gallatin Gateway areas is generally accepted as a feasible option. With respect to the application process, it is recognized that both alternatives would need to satisfy mitigation requirements. As compared

Table 5-4: TAC Qualitative Criteria Ranking Results

Alternative Number/Name		Average Score	Ordinal Sum
IU Alternatives			
IU5	Agricultural irrigation Water Use	1.69	0.83
IU1	Northside Non-Potable Water Reuse	1.61	0.81
IU7	Groundwater Recharge – Water Reuse	1.61	0.76
IU2	Northside/Southside Non-Potable Water Reuse	1.53	0.71
IU3	Northside Non-Potable and Potable Water Reuse	1.49	0.68
IU4	Northside/Southside Non-Potable/Potable Water Reuse	1.47	0.67
IU6	Industrial Water Reuse	1.33	0.60
WSD Alternatives			
WSD8	Hyalite Share Purchasing	2.55	6.67
WSD3A	Madison Aquifer Groundwater	2.05	1.35
WSD3C	Gallatin Gateway Subarea Groundwater	2.03	1.54
WSD7	Sourdough Pond Storage	1.97	1.11
WSD9	Hyalite Reservoir Dam Raise	1.95	1.32
WSD3B	Belgrade Subarea Groundwater	1.92	1.23
WSD6	Canal Company Impoundment	1.88	0.98
WSD1	Sourdough Reservoir	1.84	1.05
WSD2B	Canyon Ferry Import Confluence Delivery	1.70	0.79
WSD2A	Canyon Ferry Import Reservoir Delivery	1.70	0.81
WSD5	Adjacent Drainage Development	1.65	0.83
WSD4	Yellowstone River Import	1.52	0.68
WSD10	Brackett Creek Import	1.38	0.57
OS Alternatives			
OS2	Lyman Creek Expansion	2.25	2.13
OS4	Medium Water Conservation Approach	2.19	2.00
OS3	Low Water Conservation Approach	2.14	1.47
OS5	High Water Conservation Approach	2.13	1.69
OS1	Non-Potable Groundwater Supply	2.05	1.54

to the Belgrade area, the Gallatin Gateway area offers inherent advantages regarding its relative elevation with respect to the City of Bozeman and the possibility of competing interests from the City of Belgrade. Therefore, the Gallatin Gateway area (WSD3A) was selected as the best representative involving the development of a groundwater supply in the Bozeman area. The alternatives involving groundwater development from the Madison Aquifer (WSD3A) and in the Belgrade area (WSD3B) were subsequently excluded from the portfolio modeling process.

The Canyon Ferry import alternative was included in a portfolio as a concept to meet high growth projections with limited efforts expended toward water conservation program implementation. Because of anticipated cost impacts, the confluence option (WSD2B) was selected as a more credible alternative than extending the pipeline from Canyon Ferry Reservoir near Townsend, MT, which eliminated alternative WSD2A from consideration.

The remaining alternatives, including the three water conservation levels, received relatively high scores and were identified for inclusion in the portfolio modeling process. A summary of the alternatives selected for further evaluation is presented in Table 5-5.

Screening Level 3: Quantitative Criteria - VOYAGE™ Model Alternative Analysis

The third level of the screening process consists of completing a life-cycle cost analyses for the identified portfolios based on conceptual capital costs and conceptual operations and maintenance costs. A total of thirteen portfolios, which are listed in Table 5-6, were created using different combinations of the alternatives identified for additional evaluation through the

Table 5-5: Alternatives Considered for Portfolio Development

Alternative Description
WSD1/WSD7/WSD9: Sourdough Impoundment(s)/Hyalite Dam Raise
WSD2B: Canyon Ferry Import Confluence Delivery
WSD3C: Gallatin Gateway Subarea Groundwater
WSD6: Canal Company Impoundment (i.e. SALAR)
WSD9: Hyalite Shares Purchasing
OS1: Non-Potable Groundwater Supply
OS2: Lyman Creek Expansion
OS3: Low Water Conservation Approach
OS4: Medium Water Conservation Approach
OS5: High Water Conservation Approach

qualitative screening process. The portfolios were also developed based on the moderate and high growth projections. Costs for the various alternatives comprising the individual portfolios were optimized and adapted in accordance with requirements to balance the water supply capacity gap, which result in deviations in cost values used for the same alternatives. A discussion of the detailed cost analysis involving the development and quantitative evaluation of the portfolios is provided as a technical memorandum in Appendix D.

Table 5-6: Summary of Portfolios Evaluated Using VOYAGE™ Model

Portfolio Description	
Portfolio 1	WSD9 – Hyalite Shares Purchasing; OS2 – Lyman Creek Expansion; OS3 – Low Water Conservation Approach
Portfolio 2:	WSD9 – Hyalite Shares Purchasing; OS4 – Medium Water Conservation Approach
Portfolio 3	WSD9 – Hyalite Shares Purchasing; OS5 – High Water Conservation Approach
Portfolio 4	WSD2B – Canyon Ferry Import Confluence Delivery; WSD9 – Hyalite Shares Purchasing; OS3 – Low Water Conservation Approach
Portfolio 5	WSD3C: Gallatin Gateway Subarea Groundwater; WSD9 – Hyalite Shares Purchasing; OS3 Low Water Conservation Approach
Portfolio 6	WSD3C: Gallatin Gateway Subarea Groundwater; OS4 Medium Water Conservation Approach
Portfolio 7	WSD3C: Gallatin Gateway Subarea Groundwater; OS5 High Water Conservation Approach
Portfolio 8	WSD1/WSD7/WSD9: Sourdough Impoundment(s)/Hyalite Dam Raise; WSD9 – Hyalite Shares Purchasing; OS2 – Lyman Creek Expansion; OS4 – Medium Water Conservation Approach
Portfolio 9	WSD9 – Hyalite Shares Purchasing; OS1: Non-Potable Groundwater Supply; OS4 – Medium Water Conservation Approach
Portfolio 10	WSD6: Canal Company Impoundment; WSD9 – Hyalite Shares Purchasing; OS4 – Medium Water Conservation Approach
Portfolio 11	WSD9 – Hyalite Shares Purchasing; OS2 – Lyman Creek Expansion; OS4 – Medium Water Conservation Approach
Portfolio 12	WSD9 – Hyalite Shares Purchasing; OS1: Non-Potable Groundwater Supply; OS2 – Lyman Creek Expansion
Portfolio 13	WSD6: Canal Company Impoundment; WSD9 – Hyalite Shares Purchasing; OS2 – Lyman Creek Expansion; OS3 – Low Water Conservation Approach

Note: Shading denotes that the portfolio was developed to meet the water demands associated with the high population growth scenario.

5.3 Summary of Portfolio Modeling Results

The life-cycle analyses were completed with the VOYAGE™ model using data consisting of the conceptual cost information developed for the portfolios and the qualitative rankings from the screening process. The model results, which are provided in Appendix D as a technical memorandum, were subsequently normalized using the total annual volume of water provided in year 2062 to facilitate a basis of comparison between the moderate growth portfolios and the high growth portfolios.

Draft model results were presented during the last meeting with the City and the TAC to provide perspective and gain preliminary input. A comment received from a member of the TAC consisted of the development of an additional portfolio comprised of a more comprehensive list of alternatives to meet the high population growth scenario, particularly incorporating scalable supply development options. City representatives also introduced the possibility of initiating parallel efforts that would build on the results of the IWRP and provide information to better define the implementation requirements for the alternatives. For these reasons, Portfolio 14, as described in Table 5-7, was created and evaluated using the VOYAGE™ model.

Despite a modestly higher cost per unit of annual water volume provided, as indicated in Table 14 of technical memorandum in Appendix D, Portfolio 14 offers increased value as compared to the other portfolios that were developed to meet the high population growth scenario, based on several criteria developed by the TAC, staff, and the consultant collaboratively. Portfolio 14 also represents a more diverse range of scalable options and provides increased flexibility and resiliency to the City with respect to changing conditions and uncertainty in the future. After testing the portfolio to address comments and concerns expressed by the TAC and the City, Portfolio 14 was identified as the most advantageous option for implementation by the City. Key findings related to the model results for Portfolio 14 are as follows:

Table 5-7: Description of Portfolio 14

Alternatives Comprising Portfolio 14
WSD1/WSD7/WSD9: Sourdough Impoundment(s)/Hyalite Dam Raise
WSD3C: Gallatin Gateway Subarea Groundwater
WSD9: Hyalite Shares Purchasing
OS1: Non-Potable Groundwater Supply
OS2: Lyman Creek Expansion
OS3: Low Water Conservation Approach

- Sensitivity analysis confirmed that the purchase of additional shares from Hyalite Reservoir is a relatively cost effective strategy to obtain additional water supply capacity, especially in the near future. The purchase of senior in-stream rights in Sourdough Creek and Hyalite Creek is also an option available to the City for consideration.
- Conventional water conservation measures could be implemented in the near-term with the possibility to consider more aggressive water conservation strategies depending on the actual amount of water supply capacity obtained from other alternatives comprising Portfolio 14, public acceptance, and the measured success of water conservation efforts on reducing the rate of demand for water. Higher levels of water conservation could be pursued by the City to further reduce water demand if such measures are achievable at a comparable cost to other available alternatives.
- Due to water right withdrawal and seasonal constraints, the portfolio analysis, which is presented in Appendix D, concluded that the City is currently at risk of an intermittent shortage of water during the month of May and should implement an alternative that delivers a new water supply as triggered by the demand for water. A demand trigger of approximately 600 acre-feet during the month of May is suggested as an initial benchmark for the City to proceed with its monitoring efforts.
- Securing approximately 900 acre-feet of water storage via an impoundment or series of smaller impoundments in the Sourdough Creek drainage basin deserves a more detailed investigation, with a secondary objective of improving the operational reliability of the intake system. A series of smaller impoundments above the City's existing water intake is anticipated to be more feasible than building a large reservoir in the Sourdough Creek basin. Raising the level of Hyalite Reservoir via modifications to the dam could also be considered in lieu of or in conjunction with the Sourdough impoundment(s) alternative.
- Non-potable irrigation for new developments could be assessed on an incremental basis, with actual results prompting the need for water from other water sources, which may include irrigation surface water, such as that provided via the Canal Company Impoundment alternative.
- Groundwater development in the Gallatin Gateway subarea was identified as a relatively flexible alternative to serve as a "relief valve" to balance the amount of water supply needed to meet increased water demands related to future growth. Variations to this alternative are possible and include alternate sites for groundwater development or potentially leveraging the property associated with the Canal Company Impoundment alternative.
- The actual costs associated with acquiring new water rights may deviate from that assumed for the life-cycle cost analysis and need to be considered as the implementation of alternatives moves forward.

Chapter 6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The following conclusions were identified based on the work product completed for the IWRP:

- The planning approach used to develop the IWRP offers the City much needed flexibility with respect to meeting future growth and the associated increase in water demand.
- The City possesses a finite supply of water with an estimated 2012 annual firm yield ranging from 11,433 acre-feet to 12,042 acre-feet, depending on the inclusion of 609 acre-feet associated with the Sourdough Storage Reservation.
- The existing water supplies are currently capable of meeting the annual demand for water; however, operational constraints have been encountered due to seasonal impacts that limit the availability of existing water supplies on an intermittent basis.
- Changing climate conditions could potentially reduce the estimated annual firm yield of existing water supplies that are not regulated with storage, resulting in a decline in the annual firm yield of approximately 200 acre-feet by 2042 and approximately 500 acre-feet by 2062.
- The installation of stream flow monitoring equipment in the watersheds would provide useful information to the City for the purpose of assessing climate change impacts and better managing its water resources moving forward.
- Strategies to improve the capture efficiency of water requested and released from Hyalite Reservoir should be considered; such strategies consist of reducing or potentially eliminating the conveyance efficiency factor and providing increased raw water and/or finished water storage.
- Up to 6,750 acre-feet of water on an annual basis, which is subject to a historical use analysis, could be available to the City via the formal application process with the DNRC.
- A water demand of 165 gpcd, which is subjected to adjustments with respect to climate change and likely reduction via water conservation program implementation, represents a reasonable value for planning purposes based on characterization of historical water demand data and the objective of achieving a service level of 95 percent.
- In anticipation of future growth, and the relative uncertainty thereof, population projections for the City were developed to represent moderate and high growth scenarios for the 2042 and 2062 planning horizons.
- The population projections for the 2042 and 2062 planning horizons under the moderate growth scenario are 70,256 and 94,144, respectively.
- The population projections for the 2042 and 2062 planning horizons under the high growth scenario are 85,725 and 139,900, respectively.
- The climate adjusted annual water demand projections for the 2042 and 2062 planning horizons under the moderate growth scenario are estimated to be 13,500 acre-feet and 17,790 acre-feet, respectively.

- The climate adjusted annual water demand projections for the 2042 and 2062 planning horizons under the high growth scenario are estimated to be 17,900 acre-feet and 28,700 acre-feet, respectively.
- The climate adjusted annual water balance gap for the 2042 and 2062 planning horizons under the moderate growth scenario are estimated to 2,263 acre-feet and 6,842 acre-feet, respectively.
- The climate adjusted annual water balance gap for the 2042 and 2062 planning horizons under the high growth scenario are estimated to 6,663 acre-feet and 17,752 acre-feet, respectively.
- A suggested trigger regarding the need for additional water supply capacity is a demand of approximately 600 acre-feet during the month of May.
- The implementation of a more formal water conservation plan is a strategy available to the City to reduce the rate of demand for water and could be used to meet a portion of the water balance gap identified for 2042 and 2062 planning horizons.
- Several alternatives are available to the Bozeman to increase the annual water supply capacity to meet future water demands, and the combination of various alternatives to comprise a comprehensive portfolio is consistent with the planning approach of the IWRP.
- The net present value of portfolios developed to meet the moderate population growth scenario ranged from approximately $85 million to $118 million.
- The net present value of portfolios developed to meet the high population growth scenario ranged from approximately $113 million to $296 million.
- Despite marginally higher life-cycle costs, Portfolio 14, consisting of the implementation of the following alternatives, offers the City increased value as compared to other portfolios and a higher degree of flexibility and resiliency to meet a range of future growth scenarios through the 2042 and 2062 planning horizons:
    - Initiating a water conservation program that considers the success of various conservation measures, public acceptance, and a comparison of cost with respect to water supply capacity development with the goal of meeting low to medium water demand reduction targets.
    - Adding storage in Sourdough Canyon or Hyalite Reservoir via an infrastructure project to improve current withdrawals and operational efficiency.
    - Developing groundwater system capacity in the Gallatin Gateway area or other appropriate location to meet demand on an as needed basis.
    - Strategically purchasing shares from Hyalite Reservoir and senior surface water rights from Hyalite Creek and Sourdough Creek to obtain water in the near-term.
    - Developing non-potable irrigation for new developments on an incremental basis.
    - Optimizing the capacity of the Lyman Creek water source.
- The estimated net present value of Portfolio 14 is approximately $148 million, and is intended to provide an annual volume of water equivalent to 16,240 acre-feet through a planning horizon of 2062.

6.2 Recommendations

The future water needs of the City of Bozeman will depend on future conditions, such as the rate of population growth, impacts of climate change, success of the City's water conservation program, availability of useful water rights, and other conditions that are not completely predictable. The IWRP was developed in recognition that future decisions by the City will be made in the context of these conditions as they evolve, and the IWRP is intended to be flexible enough to account for the conditions and contingencies created by these evolving conditions. The following recommendations were developed based on the conclusions outlined above and a logistical strategy for the City to proceed in fulfilling the objectives of the IWRP:

Near-Term

- Implementation of Portfolio 14 should proceed with a robust economic and engineering feasibility analysis for each of the portfolio components, followed by a comparative analysis of the components based on the screening assessment framework established by the IWRP. These steps provide a sound basis for prioritized decision-making by the City of Bozeman regarding its water resource management.
- Incorporate the implementation of Portfolio 14 into the City of Bozeman Capital Improvement Planning budget such that anticipated costs are budgeted well into the future.
- A water conservation plan should be prioritized for implementation to reduce the rate of demand for water as a substantial contribution toward addressing the water balance gap identified for the 2042 and 2062 planning horizons.
- The installation of stream flow monitoring equipment in the watersheds should be implemented to provide useful information to the City for the purpose of assessing climate change impacts and better manage its water resources moving forward.
- Implementation of strategies to improve the capture efficiency of water requested and released from Hyalite Reservoir, such as reducing or potentially eliminating the conveyance efficiency factor and providing increased raw water and/or finished water storage.
- The formal application process with the DNRC should be initiated to secure water rights that are currently available to the City totaling approximately 6,750 acre-feet of water an annual basis. This value does not reflect a historical use analysis that will be conducted for any change applications, and should be noted to avoid any mistaken expectations about the amount of water that is potentially available.
- Shares from Hyalite Reservoir and senior surface water rights from Hyalite Creek and Sourdough Creek should be purchased to the extent possible.

Long-Term

- Water supply and demand trends should be monitored to assess the need for additional water supply capacity development.
- Revisit population growth trends every 5 years, or on a more frequent interval if necessary.

- Additional water supply capacity should be developed by the City in accordance with the outcome of subsequent efforts to evaluate alternatives in more detail and planning objectives that will evolve with actual population growth and water demand trends.

APPENDIX A

Climate Change Adjustments to Firm Yield and Demand for Bozeman, MT

Climate Change Adjustments to Firm Yield and Demand for Bozeman, MT

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DATE: July 25, 2013

PROJECT NUMBER: 435325.03.35.25.05

This technical memorandum documents the methods, results and analysis involved in the development of climate change adjusted firm yield and demand values for the Bozeman Integrated Water Resources Plan. The adjusted firm yield and demand values will be used in the water balance and scenario modeling efforts conducted under separate tasks of the Bozeman Integrated Water Plan.

Executive Summary

Analysis of global climate models (GCMs), downscaled to the Bozeman region, and local hydrologic and climatic data were used to develop adjustment factors for firm yield and water demand values. The analysis indicates a predicted general trend of warming earlier in the year and overall lower precipitation, resulting in lower peak stream flows that occur earlier in the year than historical peaks. These trends also result in an extension to the period of time in which irrigation is needed to sustain crops and landscape plants, and increasing the amount of irrigation water required during historical irrigation months to make up for the lack of precipitation.

Methodology

Overview

The goal of this task was to establish an estimate of climate-change impacts to the four water sources included in the Bozeman IWRP: Sourdough, Middle, Lyman, and Hyalite, and adjust the firm yield values used in other IWRP tasks accordingly. This adjustment projects existing firm yield to the 30-year and 50-year planning horizon: 2042 and 2062. City of Bozeman Water Facility Plan firm yield values were used as the basis for this analysis. Facility Plan firm yield values for Hyalite Reservoir, Lyman Creek, and Middle Creek represent the reliable yield from existing water rights, which are related to hydrologic conditions, but not necessarily directly proportional because of priority, volume, and seasonal limitations. Details of the original development of the existing firm yield values are not available except that Sourdough Creek (also called Bozeman Creek) firm yield was developed from historic dry year flow data. Reported values for Lyman and Middle Creek were used with no further adjustments. Monthly distribution of firm yield values for Hyalite Reservoir were adjusted to reflect current withdrawal operations, based on conversations with city staff.

Firm yield of Middle Creek was adjusted by the same climate-change based scaling factor established for Sourdough Creek through the process described in this memorandum, equal to the change in projected dry year stream flow in Sourdough Creek. Hyalite Reservoir and Lyman Creek were not adjusted for climate-change effects based on perceived supply resiliency of Hyalite Reservoir and operator feedback that Lyman Creek is not presently being used at a level above its firm yield.

In order to generate climate change adjusted stream flows (and thus firm yield scaling factors), a simple monthly water balance hydrologic model was created and calibrated. The USGS's Thornthwaite Monthly Water Balance Program was used because it generates results on a monthly scale, only requires inputs of monthly temperature and precipitation, and because calibration is relatively simple due to limited calibration parameters. The USGS Thornthwaite Model program uses an accounting procedure to analyze the allocation of water among various components of the hydrologic system; this procedure is generally known as the Thornthwaite water balance and is used in both academia and industry for hydrologic evaluations. Climate change adjustments for temperature and precipitation were developed for 2042 and 2062 using SimCLIM, a climate change analysis software package developed by CLIM Systems. Climate change adjusted temperature and precipitation time series were used as inputs to the hydrologic model to develop adjusted stream flow time series, which were used to develop firm yield scaling factors.

Data Sources

Numerous data sources were used to calibrate and validate the hydrologic model. Climate data sources are summarized in Table 1. It was important to understand the geography of the basin tributary to the USGS Sourdough Creek gage. Geographic Information System (GIS) data sources used to develop Sourdough Creek basins statistics are summarized in Table 2. A map of the three gages, as well as the Sourdough Creek basin is shown in Figure 1.

TABLE 1
Summary of Hydroclimate Data Sources

Name	Source	Location	Date Range	Notes
Sourdough Creek Monthly Average Flow	USGS; obtained as PDF file from the City of Bozeman. Not available electronically on USGS NWIS website. Gage number 06047500.	Long: -111.020833 Lat: 45.577778 Elev: 5,351	October 1937 to September 1986 (see Notes)	PDF is of poor quality fax of data. Some values, particularly those before 1947, were not readable. The reliable period of record from this data was limited to October 1947 to September 1986
Lick Creek Daily Precipitation and Temperature	SNOTEL; Lick Creek. Site No. 578.	Long: -110° 58' Lat: 45° 30' Elev: 6,860	October 1982 to September 2011 (precipitation record started in 1978)	
Bozeman, MT Precipitation and Temperature	NOAA;Bozeman MT., 59715.	Long: -111.05 Lat: 45.67 Elev: 4,900	January 1892 to December 1997	

TABLE 2
Summary of GIS Data Sources

Name	Publisher	Website
National Hydrography Dataset; Prestaged Subregion NHDM1002_92v200	USGS;	nhd.usgs.gov; accessed 5/4/2012
National Hydrography Dataset Plus; Prestaged Region 10UV01_01	Horizon Systems (with EPA and USGS)	http://www.horizon-systems.com/nhdplus/; accessed 5/4/2012
National Elevation Dataset;	USGS	ned.usgs.gov; accessed 5/4/2012

Figure 1. Map showing location of climate and stream flow gages, and of Sourdough Creek basin outline (mean elevation 7051 ft).

Hydroclimate Summary

The Sourdough Creek watershed is located between 5 and 15 miles south of the City of Bozeman, Montana. Its hydroclimate, as characterized by the nearby Lick Creek SNOTEL gage, has mean summer temperatures between 50 and 60 degrees Fahrenheit(F) (10 and 15 degrees Celsius (C)), and mean winter temperatures around 20 degrees F (-5 degrees C). Extreme summer temperatures of 97 degrees F (36 degrees C) and winter temperatures of -50 degrees F (-46 degrees C) have been recorded at the Lick Creek gage. Mean annual precipitation is 3.28 ft (1.00 meter), with approximately 40 percent of the total falling during the wettest three months from April to June. The remaining months receive between 2-3 inches (50-75 millimeters (mm)) per month on average. Flows in Sourdough Creek, as measured by a USGS stream gage, range between a winter base flow of 5 -15 cubic feet per second (cfs), and a spring peak runoff that ranges between 50 and 160 cfs. The peak runoff typically occurs in June, and occasionally in May. The mean June flow is 76 cfs; the mean January flow 10 cfs, and the mean annual flow 26 cfs. Given a 28.2 square mile watershed, approximately 32 percent of the annual precipitation is seen as stream runoff on an annual basis.

Dry year hydrologic firm yield from Sourdough Creek is reported to be 3.23 million gallons per day (MGD) for every month of the year except for May and June. The May firm yield is 4.04 MGD and the June firm yield is 3.64 MGD. The resulting total annual dry year hydrologic firm yield volume is 1,217 million gallons.

Hydrologic Model

The USGS Thornthwaite Monthly Water Balance model (McCabe and Markstrom, 2007) was used as the hydrologic model for this project. Inputs to the Thornthwaite model are monthly temperature and precipitation in degrees C and mm. Outputs include potential evapotranspiration, total runoff, actual evapotranspiration, snow storage and snow melt. USGS Sourdough Creek gage data from 1960 to 1970 were used to calibrate the model. Because the existing firm yield is known to be developed from dry year hydrology, and because the 1960s includes many low flow years, this time period was selected as the calibration period. The Thornthwaite model tracks soil moisture storage which can carry over from year to year, thus it is important to run the model for multiple years at a time.

GIS analysis of the tributary basin to the USGS Sourdough Creek gage shows that the mean elevation of the basin is 7,051 feet. Although the Lick Creek gage is not in the Sourdough Creek basin, its elevation (6,860 feet) is much closer to that of the basin, and is more likely to represent the temperature and precipitation patterns observed in the basin. Unfortunately, the date ranges for the Lick Creek climate gage full record (precipitation and temperature) and the Sourdough Creek flow gage only overlap 4 years (1982 to 1986). Thus, NOAA Bozeman temperature and precipitation gage data was used as a substitute for Lick Creek data to calibrate to a full decade of flow gage data, and to validate model performance. To use this data, a correlation between the Lick Creek climate gage and the NOAA Bozeman climate gage was developed, and the NOAA Bozeman climate gage transformed to the Lick Creek gage site. In addition to this transformation, the temperature was decreased by 0.7 degrees F (0.4 degrees C) , the temperature lapse for the 190 feet difference between the Lick Creek gage and mean Sourdough Creek basin elevation. The correlation between the Lick Creek (SNOTEL gage) and Bozeman (NOAA gage) for temperature and precipitation is shown in Figures 2 and 3.

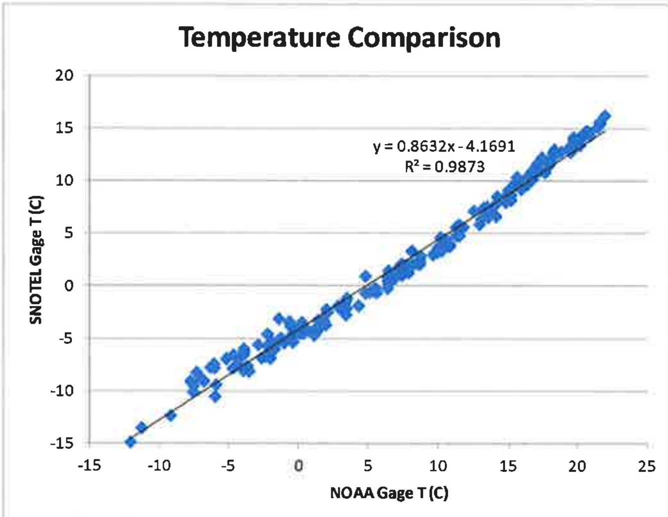


Figure 2: Lick Creek (SNOTEL) and Bozeman (NOAA) gage temperature correlation. Transformed NOAA Bozeman data was used for model calibration and validation.

The adjusted precipitation and temperature data were used to calibrate the Thornthwaite model. Calibrated Thornthwaite parameters are listed in Table 3. For a full description of how these parameters are used, see the Thornthwaite model documentation (McCabe and Markstrom, 2007).

TABLE 3
Calibrated Thornthwaite Monthly Water Balance Parameter Values

Parameter Name	Parameter Value
Runoff Factor	16%
Direct Runoff Factor	5%
Soil-Moisture Storage Capacity	47 mm (1.85 inches)
Latitude of Location	46 Degrees of Latitude
Rain Temperature Threshold	3.3 Degrees Celsius (37.9 degrees F)
Snow Temperature Threshold	-1.0 Degrees Celsius (30.2 degrees F)
Maximum Melt Rate	90%

Calibration of the Thornthwaite model focused on low flow years, especially on the maximum and minimum flow values for those years. The declining limb of the Sourdough Creek hydrograph, as measured by the USGS gage. was especially difficult to match during model calibration. Flow rates in the Thornthwaite model tended to move from peak spring runoff to minimum summer/fall flows much more slowly than recorded at the USGS gage. This could possibly be due to the changing soil-moisture storage capacity resulting from the freezing and thawing of the ground. The Thornthwaite model is only able to account for a single value for the soil-moisture storage capacity. In order to account for the timing difference between model outputs and gage data, a modification factor was developed for each month based on the average ratio between USGS and Thornthwaite flow rates for the entire period of stream gage record (October 1947 to September 1986; see Table 1).

Use of unmodified Thornthwaite flow rates resulted in a modeled volume 134 percent of the USGS measured volume (for entire period of overlapping record), and a standardized root mean square error (a measure of calibration, where 1.0 is perfect) of 0.71. The use of the monthly modification factor resulted in a 100 percent volume match, and a standardized root mean square error of 0.58. The monthly adjustment factors used are listed in Table 4.

TABLE 4
Thornthwaite Model Monthly Flow Rate Modification Factors

Month	Monthly Average Flow Rate Scaling Factor
October	0.47
November	0.50
December	0.50
January	0.53
February	0.71
March	0.77
April	1.00
May	1.00
June	1.00
July	1.00
August	0.53
September	0.47

Calibration to the low flow years resulted in a good match between model outputs and gage data in years with low peak flows. This calibration approach, however, also resulted in a mismatch between model outputs and gage data in years with high peak flows. This was deemed acceptable because the firm yield values were developed using only low flow years, and thus the firm yield climate change adjustment factors would also be developed using only low flow years. Therefore, it is more important to match model outputs to low flow years than to high flow years.

Thornthwaite model calibration results for the calibration period 1960-1970 are shown in Figure 3. This figure illustrates how the modification factors were used to get a better match between the gage data (shown in blue) and the model outputs (unmodified outputs are shown in red; modified outputs are shown in green). The figure also shows how the modified model matches the lower peaks (for example the peaks in 1960-1963), but does not match the higher peaks (1964-1968)

The entire validation period, 1947 to 1986, is shown in Figure 4. This figure demonstrates that the modification factors and matching trend established for the ten-year calibration period are relevant throughout the entire period of record.

A scatter graph comparing gage and both modeled and the modified model flow is shown in Figure 5. The distribution of data shows that modified model outputs are closer to a perfect match to gage flows for flows up to about 25 cfs.

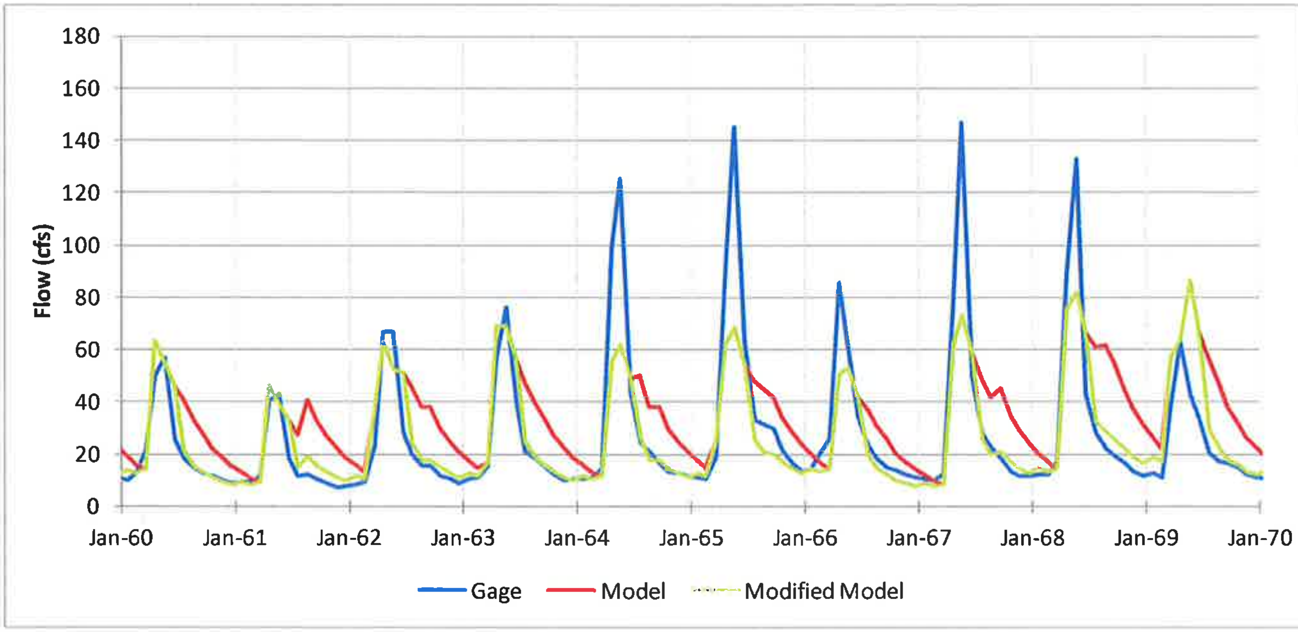


Figure 3. Thornthwaite Monthly Water Balance Hydrologic Model Calibration

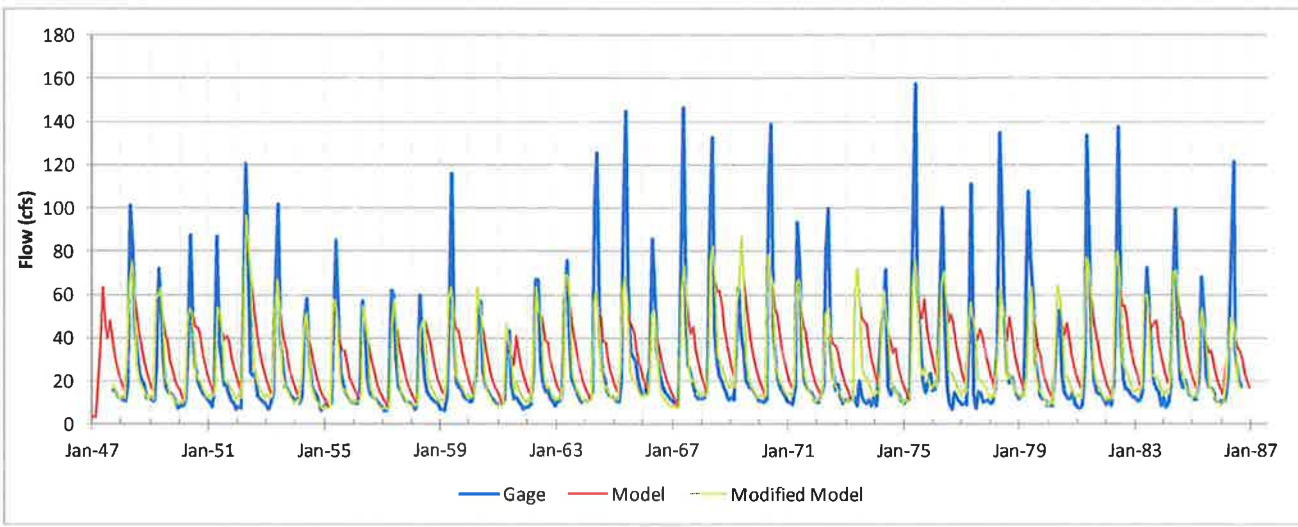


Figure 4. Thornthwaite Monthly Water Balance Hydrologic Model Validation

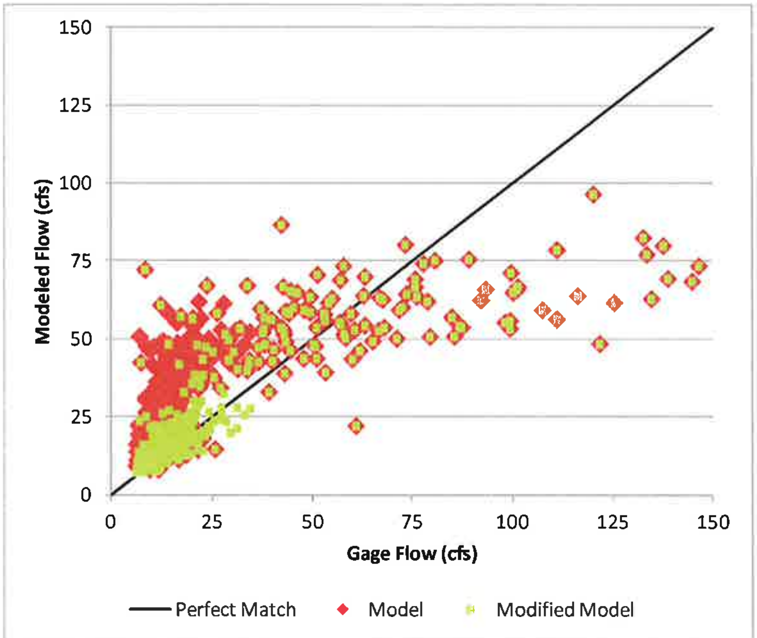


Figure 5. Model Calibration Scattergraph

Projections of Future Temperature and Precipitation

The SimCLIM tool was used to develop monthly adjustments to temperature and precipitation reflecting projected changes in 2042 and 2062 as compared to the baseline year of 1990. The SimCLIM tool incorporates the results from 21 global climate models (GCMs) simulated for multiple global greenhouse gas emission scenarios developed by the Intergovernmental Panel on Climate Change (IPCC). Results from SimCLIM reflect a broad range of global projections and are downscaled by the software to the 1-km resolution in this region. As such there are many possible climate futures that result from global climate change modeling. This analysis considered the full range of Global Climate Model (GCM) and climate emissions scenario combinations included in the IPCC Fourth Assessment Report (AR4), and selected a representative range of projections for use for use in this project. Additional information on climate change, GCMs and climate scenarios can be found in CH2M HILL (2011).

Figures 6a and 6b show the projected monthly change in temperature between 1990 and 2042, and 1990 and 2062 for several emission scenarios. Unless noted otherwise, the median (50th percentile) GCM result from an ensemble of 21 GCMs is reported for each emissions scenario (e.g. graph series A1B, A1F1, etc). These values were generated using a medium climate sensitivity for the location of the Bozeman NOAA climate gage. Figures 7a and 7b show the percent change in monthly precipitation between 1990 and 2042, and 1990 and 2062. These results show an increase in temperature between 1 and 3 degrees C during the summer by 2042, and between 2 and 5 degrees by 2062. The temperature increase is less extreme during the peak runoff season of May and June, with an increase of between 0.5 and 1.5 degrees C by 2042 and between 1 and 3 degrees C by 2062. This overall increase in temperature will cause an earlier snow runoff than previously experienced. While change in annual precipitation is only expected to be a small decrease (between 0.5 and 0.6 percent decrease by 2042 and a 0.8 to 1.1 percent decrease by 2062), the seasonality of this precipitation is expected to change. In general, decreases of summer and fall precipitation as high as 13 percent by 2042 and 20 percent by 2062 could be experienced. Conversely, winter and spring precipitation could increase as much as 10 percent by 2042 and 20 percent by 2062.

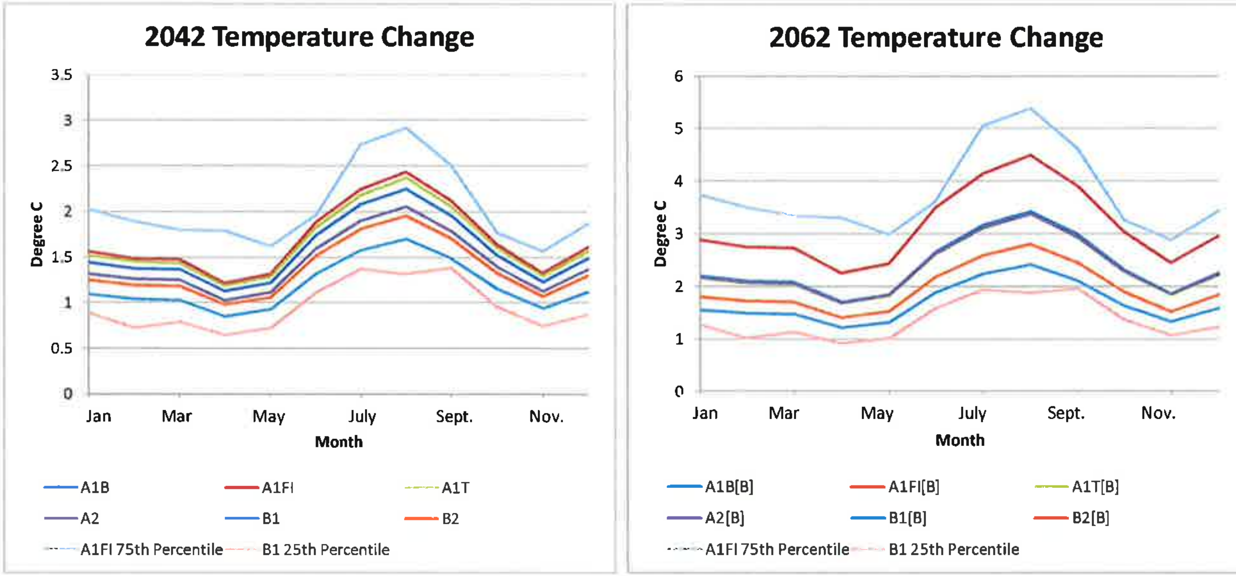


Figure 6a and 6b: Change in monthly temperature (degrees centigrade) between (a) 1990 and 2042 and (b) 1990 and 2062. Unless noted otherwise, the median value of an ensemble of 21 GCMs is reported for each emissions scenario (A1B, A1FI etc.).

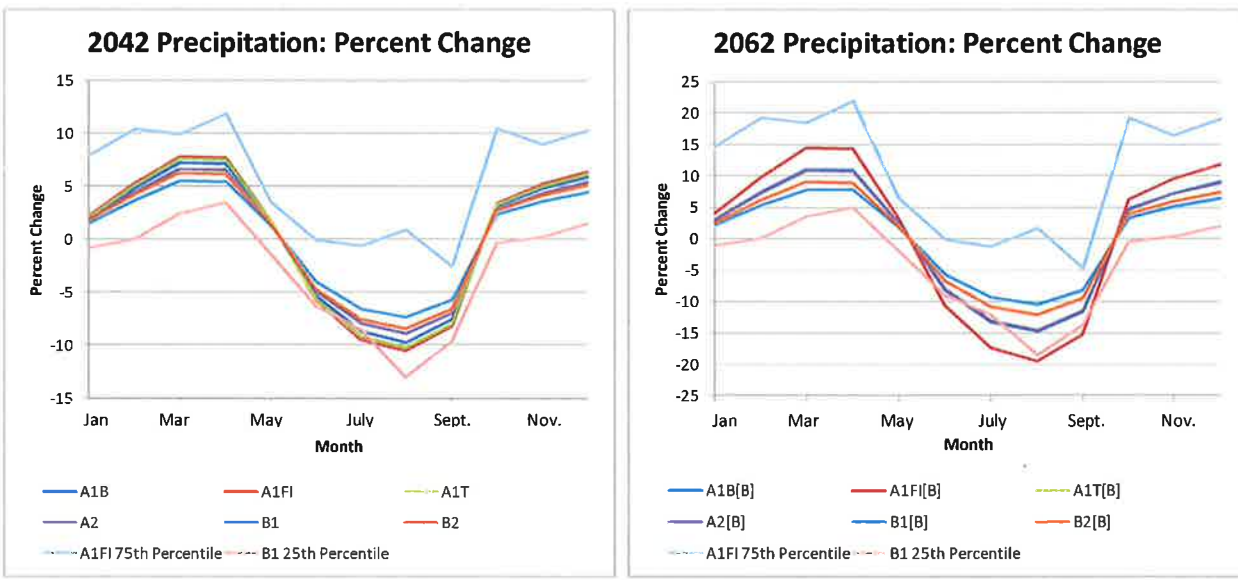


Figure 7a and 7b: Percent change in monthly precipitation between (a) 1990 and 2042 and (b) 1990 and 2062. Unless noted otherwise, the median value of an ensemble of 21 GCMs is reported for each emissions scenario (A1B, A1FI etc.).

The results from the A1FI 50th percentile were selected as a conservative estimate of climate change for both 2042 and 2062, and were used for Firm Yield and Voyage model analysis. The A1FI 50th percentile results are similar to the A2 75th percentile results, which are often used in climate change analyses. The A1FI 75th percentile was selected as an upper bound and the B1 25th percentile was selected as a lower bound to represent climate change uncertainty; both of these scenarios were used to develop changes in monthly stream flow values shown in Figure 11, but were not carried through full Firm Yield and Voyage model analysis.

Monthly and annual adjustments for the A1FI 50th percentile and the bounding A1FI 75th percentile and B1 25th percentile are presented for Temperature and Precipitation in Table 5 and Table 6.

TABLE 5

Monthly and Annual Temperature Adjustments for Selected GCMs

	Temperature (increase, degree C)					
	2042			2062		
Month	B1 25th	A1FI 50th	A1FI 75th	B1 25th	A1FI 50th	A1FI 75th
October	1.0	1.6	1.8	1.4	3.0	3.2
November	0.8	1.3	1.6	1.1	2.5	2.9
December	0.9	1.6	1.9	1.2	3.0	3.4
January	0.9	1.6	2.0	1.3	2.9	3.7
February	0.7	1.5	1.9	1.0	2.7	3.5
March	0.8	1.5	1.8	1.1	2.7	3.3
April	0.6	1.2	1.8	0.9	2.2	3.3
May	0.7	1.3	1.6	1.0	2.4	3.0
June	1.1	1.9	2.0	1.6	3.5	3.6
July	1.4	2.2	2.7	1.9	4.1	5.0
August	1.3	2.4	2.9	1.9	4.5	5.4
September	1.4	2.1	2.5	2.0	3.9	4.6
Annual	**1.1**	**1.7**	**1.9**	**1.5**	**3.1**	**3.5**

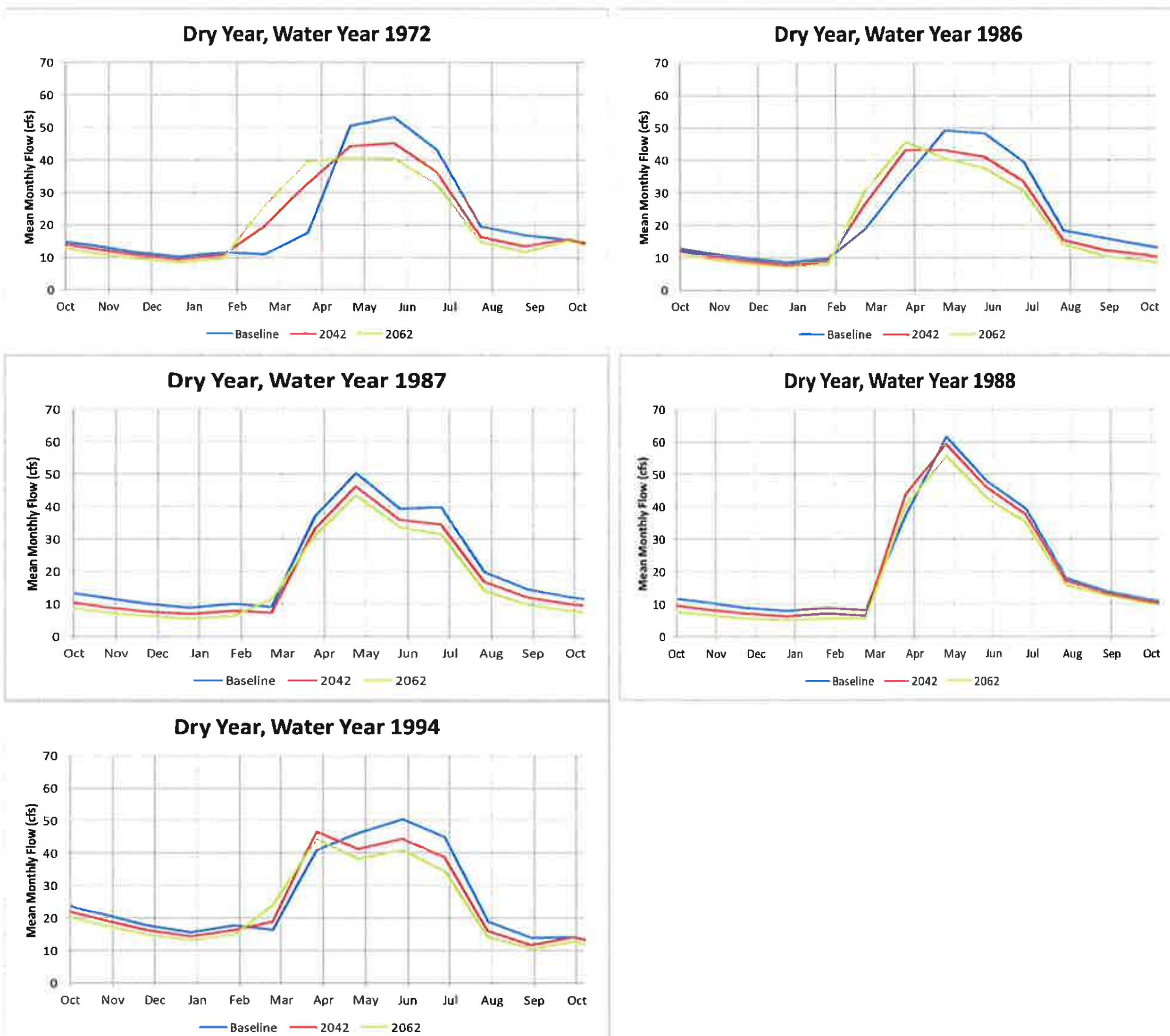
TABLE 6

Monthly and Annual Precipitation Adjustments for Selected GCMs

	Precipitation (percent change)					
	2042			2062		
Month	B1 25th	A1FI 50th	A1FI 75th	B1 25th	A1FI 50th	A1FI 75th
October	-0.4	3.4	10.4	-0.4	3.4	10.4
November	0.3	5.2	8.9	0.3	5.2	8.9
December	1.4	6.4	10.3	1.4	6.4	10.3
January	-0.8	2.1	7.9	-0.8	2.1	7.9
February	0.0	5.2	10.4	0.0	5.2	10.4
March	2.4	7.8	9.9	2.4	7.8	9.9
April	3.5	7.7	11.8	3.5	7.7	11.8
May	-1.4	1.8	3.4	-1.4	1.8	3.4
June	-6.3	-5.8	-0.1	-6.3	-5.8	-0.1
July	-8.6	-9.4	-0.7	-8.6	-9.4	-0.7
August	-13.0	-10.5	0.9	-13.0	-10.5	0.9
September	-9.6	-8.2	-2.5	-9.6	-8.2	-2.5
Annual	**-1.2**	**-0.6**	**2.2**	**-1.2**	**-0.6**	**2.2**

Climate Change Adjustments to Firm Yield

Because the baseline for the SimCLIM climate change calculations is 1990, a 30-year period from 1967 to 1997 was selected for analysis of change in stream flow due to climate change. Of this 30-year period, low flow water years of 1972, 1986, 1987, 1988, and 1994 were selected for scaling firm yield. Based on Thornthwaite model results for 1967 to 1997, the three water years with lowest total annual flow were 1972, 1987, and 1988. The three water years with lowest peak monthly flow were 1986, 1987, and 1994. The combination of these two data sets results in the selected set for firm yield scaling. Figures 8a through 8e show baseline and A1FI – 50% climate change adjusted model results for the five selected dry years. These figures illustrate the general reduction in peak stream flows as well as the trend of higher than baseline flows occurring earlier in the year.



Figures 8a-e. Thornthwaite modeled stream flow for the baseline, and with climate adjusted to 2042 and 2062 using the SimCLIM A1FI 50th percentile results. Analysis completed for five dry years nearest the 1990 climate baseline: 1972, 1986, 1987, 1988, and 1994.

Monthly stream flow was averaged for each of the dry years to create a year-long hydrograph from which to evaluate change in firm yield. This synthetic dry-year hydrograph was created for the baseline condition (representing a dry year flow with climate from 1990) and for three model scenarios (B1 – 25th percentile, A1FI – 50th percentile, and A1FI – 75th percentile) representing bounds of uncertainty for each of the study years of 2042 and 2062. Figure 9 shows the baseline synthetic dry-year hydrograph, the A1FI 50th percentile dry year hydrograph for both 2042 and 2062, and the range of streamflows in 2062 bounded by the B1 25th percentile and A1FI 75th percentile climate scenarios.

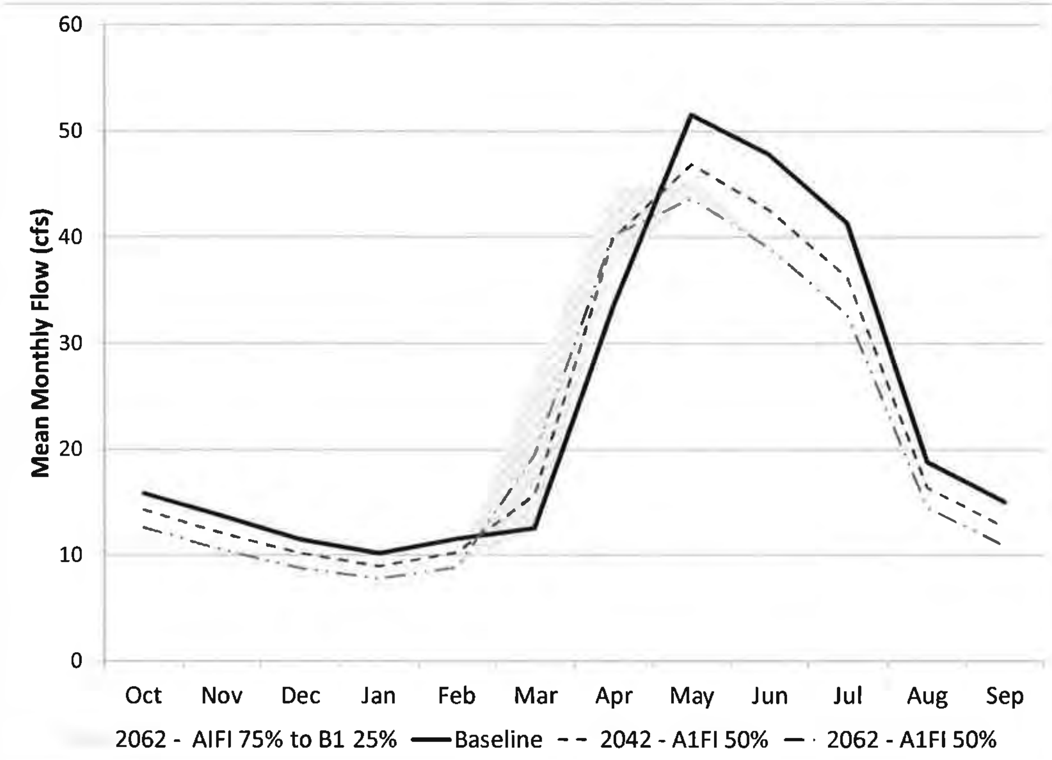


Figure 9. Modeled dry year hydrographs for various climate change scenarios, using projected flow data from modeled dry years: 1972, 1986, 1987, 1988 and 1994.

Firm Yield Results

The ratio of monthly streamflow between 1990 and 2042, and 1990 and 2062 using the A1FI 50th percentile scenario, as shown in Figure 11, was used as the basis for scaling the existing firm yield to the 2042 firm yield and 2062 firm yield. Linear interpolation was used between the 1990 baseline and 2042 to determine an incremental increase up to the 2042 percent change. Linear interpolation was also used to increase from the 2042 percent change up to the 2062 percent change. Table 7 shows the results of the linear interpolation, divided into three periods: SimCLIM Baseline (1990) to 2012, 2012 to 2042, and 2042 to 2062. The value in each column represents the projected percent change for that period.

The values shown in Table 7 were applied to Bozeman Creek and Middle Creek, the two river sources considered in the Bozeman Integrated Water Resources Plan to create climate-adjusted firm yields for 2012, the beginning of the planning period for the Bozeman Integrated Water Resources Plan, as well as the 30-year and 50-year planning horizon. The resulting adjusted values are shown in Table 8.. Analysis of the overall climate-adjusted water supply portfolio indicates that the supply is limited by water rights or Hyalite Reservoir operations rather than hydrology for all months except March - June. Therefore the total available volume of water during these months does not reflect the projected hydrologic supply.

Table 7

Firm Yield Adjustment Factors

	Percent Change		
Month	**SimCLIM Baseline (1990) to 2012**	**2012 to 2042**	**2042 to 2062**
January	-5%	-8%	-12%
February	-5%	-8%	-12%
March	8%	11%	29%
April	11%	15%	5%
May	-4%	-5%	-7%
June	-5%	-6%	-7%
July	-5%	-7%	-9%
August	-6%	-7%	-9%
September	-7%	-9%	-11%
October	-4%	-6%	-12%
November	-6%	-8%	-12%
December	-6%	-8%	-12%

Table 8

Climate Adjusted Firm Yield

	Un-Adjusted Hydrologic Firm Yield (AC-FT)		Climate Adjusted Flow at Beginning of Planning Period (2012) (AC-FT)		30-Year Planning Horizon (2042) Flow (AC-FT)		50-Year Planning Horizon (2062) Flow (AC-FT)	
Basin	**S**	**M**	**S**	**M**	**S**	**M**	**S**	**M**
Jan	307	20	19	18	17	16	13	12
Feb	278	20	20	19	17	16	13	12
Mar	307	20	22	24	26	29	36	45
Apr	297	10	11	13	14	16	17	18
May	384	7	7	6	6	6	5	5
Jun	335	11	10	10	9	8	8	7
Jul	307	2	2	2	2	1	1	1
Aug	307	2	2	2	2	1	1	1
Sep	297	11	10	9	9	8	7	6
Oct	307	20	20	19	17	16	14	13
Nov	297	20	19	18	17	16	13	12
Dec	307	20	19	18	17	16	13	12
Total Annual Volume (MG)	**3733**	**165**	**161**	**158**	**153**	**149**	**144**	**142**
S = Sourdough; M = Middle								

Climate Change Adjustments to Demand

The Thornthwaite hydrologic model calculates potential evapotranspiration (PET) as an intermediary step in calculating runoff and provides monthly values for each timestep of the model period. PET results from the calibrated Thornthwaite model were used to estimate climate change effects on baseline demand rates. Climate change effects were limited to effects on irrigation demand. Other behavioral changes in response to increased temperature and decreased precipitation (such as increased use of air conditioners or more frequent filling of private pools) were not considered.

The Thornthwaite model results indicate an increase in PET for every month of the year. However, urban irrigation demands are only expected to increase during the active growing season after freezes have stopped occurring, and are not expected to exactly mimic water demands in the natural environment. The Montana State University (MSU) agricultural extension service provides a climatological data summary which states that the average growing season for the City of Bozeman is 120 days, based on the average number of frost-free days per year for the period 1991-2000. According to frost freeze data provided by the extension service, spring freezes end in late May and fall freezes begin in mid-September.

Monthly baseline demand rates were provided by AE2S based on analysis of historical records provided by the City of Bozeman. Increases in temperature and decreases in precipitation in the spring and fall months as projected in the GCM simulations can reasonably be expected to extend the growing season into April and October. The percent change in PET between 1990 and 2042 was used to adjust the baseline demand for each month. Linear interpolation was used between the 1990 baseline and 2042 to determine an incremental annual increase up to the 2042 percent change. Linear interpolation was also used to determine an incremental annual increase from 2042 to 2062.

Half of the projected 2042 percent change was applied to baseline demand rates to estimate increased demand in April and October in 2042; the total projected 2042 percent change was used to increase May-September demands. The total projected 2062 percent change was used for all months (April – October) to estimate increased demands in 2062.

Baseline demand rates, adjustment factors through 2042 and 2062, and the resulting increased demand rates for each month of the extended growing season in 2042 and 2062 are summarized in Table 9.

TABLE 9.
Climate Adjusted Demand based on PET

Month	Baseline Demand Rate (gpcd)	Demand Increase through 2042	Demand Increase 2042-2062	Adjusted Demand Rate 2042 (gpcd)	Adjusted Demand Rate 2062 (gpcd)
April	109	2%	11%	112	124
May	166	5%	8%	174	188
June	204	7%	12%	218	244
July	308	9%	14%	335	382
August	298	9%	16%	326	378
September	222	8%	13%	240	271
October	129	3%	16%	133	154

Assumptions, Limitations and Recommendations

The following assumptions and limitations should be considered when using the data presented in this memorandum. The analysis summarized in this memorandum is high level and based on simplified methods. Recommendations for more robust analysis are included below.

- Climate Change
    - A medium climate response was assumed for all climate change analysis
    - Other than A1FI and B1, only the median set of monthly results from an ensemble of 21-GCMs was considered. For A1FI and B1, the 75th percentile and 25th percentile (respectively) of the 21-GCM ensemble were also considered. Using this limited set of GCM simulations tends to exclude outliers. Use of the median emphasizes the central tendency of the 21-GCM ensemble.

      Additional consideration of a fuller range of possible futures is recommended. This would include the use of data in the hydrologic model of more than the three scenarios included here (A1FI 75th percentile, A1FI 50th percentile, and B1 25th percentile)
    - The change in temperature and precipitation considered is that for the City of Bozeman. Actual changes may vary spatially across the Sourdough Creek basin.
    - Future analysis should include a representation of changes to temperature and precipitation spatially distributed across the entire Sourdough Creek basin. Downscaled GCM results in SimCLIM are available at a 1-km grid cell resolution. Use of spatially distributed climate will require a spatially distributed hydrologic model.
    - Linear interpolation was used to develop an estimate of incremental annual change between the SimCLIM baseline and each of the planning horizons. In the absence of a recent-year complete set

of stream gage data, temperature and precipitation data, the correlation between the three cannot be verified.

- Verification of the climate change predictions could be achieved in the future with a thorough monitoring program for each of the four sources of water considered.

- Thornthwaite Model
  - The Thornthwaite Model is a very simple hydrologic model, and does not account for many of the complex hydrologic processes- especially those present in snowmelt-dominated watersheds.

    Additional analysis should consider using a more robust hydrologic model that better accounts for the complex physical processes that affect snowmelt and runoff in the Sourdough Creek basin. Such a model should account for changes in infiltration rates due to the freeze and thaw of soils, effects of soil type on infiltration, effect of vegetation type on evapotranspiration, spatially distributed differences in precipitation, temperature and snowmelt, the effect of hill aspect on snow melt, and other more complex processes.
  - Calibration of the Thornthwaite Model is limited to the 10-year calibration period, and is imperfect. As noted above, relationships between snow, snowmelt, and streamflow are complex, and may be sensitive to the rough model calibration parameters. Future analysis should consider calibration to a longer period of time, and focus on more than just dry year hydrology.
  - Because the climate change analysis focuses on the change in hydrology affecting firm yield, and not the gross magnitude of flows in Sourdough Creek, we believe the use of a simple hydrologic model is appropriate for high level discussion of effects of climate change. Model bias that creates consistently high or low flows is present in both the base and climate change scenarios, and should not affect the difference between scenarios.
- Firm Yield
  - The specific method used to develop the original Firm Yield is unknown. It is assumed that monthly values were developed using dry year hydrology for Sourdough Creek and summer reductions in Middle Creek; the specific "dry" years are not known.
  - The hydrology of each of the four basins may not be representative of Sourdough Creek dry years (1972, 1986, 1987, 1988, 1994).
  - That the firm yield is adjusted by the same ratio as that between the average dry year flows and the average dry year flows projected using climate adjusted precipitation and temperature is a gross assumption.
  - Firm yield for Lyman Creek and Hyalite Reservoir would require a more thorough hydrologic dataset extending multiple years. At the present time, only operational usage is available, which has never been limited due to hydrologic conditions of both sources. To assess true firm yield conditions, hydrologic flow monitoring is recommended.
  - Future analysis should confirm the methods used to develop the original firm yield, and consider using the same and/or an improved method using adjusted climate inputs.

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APPENDIX B

City of Bozeman 2012 Water Conservation Plan

TECHNICAL MEMORANDUM

To: Brian Heaston, PE, City of Bozeman

From: Judel Buls, PE AE2S, Inc.
Mark Anderson, PE, CH2M HILL

Re: **City of Bozeman 2012 Water Conservation Plan**

Date: July 18, 2013

BACKGROUND

The City of Bozeman secured Advanced Engineering and Environmental Services, Inc. (AE2S) to complete an Integrated Water Resources Plan (IWRP), Task 4 of which consists of an update to the City of Bozeman Water Conservation Plan, completed in 2002. The purpose of the IWRP is to explore, evaluate, and prioritize the range of alternatives available to address anticipated water supply challenges for the City of Bozeman. The IWRP will focus on four categories of water demand and supply projects, including water conservation, water rights management, water reuse, and new water supply development.

The scope of the 2012 Water Conservation Plan includes:

- Identification of water conservation measures (including those in the 2002 Water Conservation Plan and others that may be appropriate for consideration as well) that could have an impact on the City of Bozeman water usage patterns. Areas that will be explored include:
  - Public Education Programs
  - System Efficiency (Unaccounted for Water Reduction/Leak Reduction Programs)
  - Residential Water Conservation Measures
  - Commercial Water Conservation Measures
  - Large User/Industrial Water Conservation Measures
  - Government/City Water Conservation Measures

- Conducting a screening level evaluation of water conservation measures with a Commission appointed Technical Advisory Committee (TAC) for the City of Bozeman to pursue in the future.

- Use of a water demand and supply model (developed as an outcome of other Task efforts associated with the IWRP) to determine viable ranges of achievable water conservation reductions over time. These achievable levels will be associated with monthly water usages.

- Development of a matrix of water conservation measure impacts based on 5 gpcd increments of reduction and the impact this would have on supply management, revenue generation, and an anticipated cost of accomplishing these reductions in $/acre-feet. Due to a modification of the original scope that involves the use of a computer model to calculate measure impacts and cost, this information is presented as an estimate of potential reductions that could be achieved given the level of water conservation targeted for implementation.

- Prioritization of water conservation measures with a City commission appointed Technical Advisory Committee (TAC) that are most likely to accomplish water demand reductions for the City.

- Proposal of a series of water conservation measure pilot studies that can be used to measure achievable water conservation in the Bozeman Community over time.

- Proposal of a threshold where water conservation would cross into drought contingency planning (voluntary measures versus mandatory restrictions, respectively).
  - A table of possible drought contingency levels will be proposed, including a 3-tiered, 4-tiered, and 5-tiered drought contingency plan.
  - A review of drought contingency plans from other communities similar in size to the City of Bozeman will be completed.
  - A summary of information regarding trigger conditions, enforceability, and structure of the plans will be provided.

This technical memorandum will summarize the outcomes of the Water Conservation Plan, including recommendations for implementing the plan, updating the plan, considering drought contingency planning, and incorporating water conservation as a long-term system management strategy for the City of Bozeman.

2002 Water Conservation Plan

The City of Bozeman completed its first Water Conservation Plan in 2002 with Aquacraft, Inc. Water Engineering and Management, Boulder, Colorado. The original plan included an overview of the existing Bozeman water system, a review of water demands (based on year 2000), and development of a number of different possible conservation approaches, with a recommendation of Scenario B, involving:

- Reduction of Single Family Home Water Use from an estimated 70 gpcd to 40 gpcd and Multi-Family Home Water Use from 45 gpcd to 40 gpcd through the implementation of indoor technology installation (faucets, toilets, showers, and washing machines).
- Upgrading of 5 percent of existing homes per year to new technologies.
- 25 percent reduction in bathroom uses in commercial and public accounts, with all new customers and 5 percent of existing customers complying per year with requirements, including waterless urinals, dual flush toilets, and metered faucets being considered.

The success of the proposed Scenario B was based on the following assumptions:

- No change in baseline for Montana State University beyond compliance with Energy Policy Act requirements and basic new plumbing fixture installation.
- An assumption of a planning population of 46,600 people in 2020.

The results of the proposed plan were:

- Savings of 948 acre-ft, 11.9 percent of the baseline water demands (30-years).
- A conservation scenario that considered both indoor and outdoor conservation measures and incorporated more aggressive conservation at Montana State University (MSU) was proposed, which increased savings up to 1,424 acre-ft after full implementation (30-years), or 16 percent reduction in demands.
- A cost-benefit analysis was completed that considered only the cost of implementing building codes and policy, including staff time to administer the program. No rebate incentives were included in the analysis. All but the residential only indoor and outdoor conservation program showed a cost benefit (more money was saved by the City in terms of not operating treatment facilities than would be required to implement a conservation program based on the previously noted assumptions).

- It was recommended that the City initiate a residential only indoor conservation program as the lowest cost program for the highest value of return.
- The plan suggested that water supply challenges were not an issue in the City of Bozeman and the incentive to complete a water conservation program were purely economical.

Water Conservation in the City of Bozeman since the 2002 Water Conservation Plan

Since the completion of the plan, the following water conservation practices and policy changes have been implemented in the City of Bozeman, none of which were directly related to the recommendations of the 2002 Water Conservation Plan, but have likely impacted water use in the City of Bozeman (the degree of which has not been directly measured):

1) The City of Bozeman experienced considerable growth, some of which came through annexation and much of which was associated with the construction of new development. That new development was required to meet Uniform Building Code standards, which, over time, have incorporated more water efficient requirements for indoor water use.
2) The planning department implemented an outdoor landscaping policy requiring that developers meet a minimum number of points for their landscaping plan before approval of the development by the City. Higher points are awarded for drought tolerant and water efficient plantings, making it easier for developers to achieve approval.
3) In 2008, the City of Bozeman initiated a toilet rebate program. The rebate program presently provides $125 for pre-1996 toilets and $50 for post- 1996 toilet replacements with a maximum of two rebates per household. As of December 2012, 1,455 toilets have been replaced by the program, with 91% being for pre-1996 toilets. The program requires toilets with a rating of 1.28 gallons per flush (gpf) or better be installed. The total replacement above, equates to approximately 981 households. Although the 2002 Water Conservation Plan recommended indoor conservation, the mechanism for accomplishing this was through mandatory policy changes as opposed to incentivized rebate programs. This water conservation plan will provide information on the advantages and disadvantages of each. A table providing details of the current program's estimated impact on water use to date is provided at the end of this section.
4) In 2008, the City of Bozeman implemented an inclining rate structure for its water utility. The modified rate structure looks as follows:
   a. The City's 2012 base rate for water is $19.42, which includes up to 200 CF.
   b. From 200 to 700 CF, the rate is $2.38 per HCF.
   c. From 800 to 1,500 CF, the rate is $2.56 HCF.
   d. Over 1,500 CF, the rate is $3.02 per HCF.
5) The City of Bozeman has had a "cash-in-lieu" program since 1984 that requires a developer to relinquish water rights equivalent to the amount necessary to serve a developed area of land via the City of Bozeman water supply. If water rights cannot be supplied (or the developer does not want to relinquish them), a payment in a pre-determined amount can be paid to the City so that the City may purchase the water rights, as appropriate. In 2008, the "cash-in-lieu" program was modified to significantly increase the cost per acre-ft to $6,000. While this program does not directly result in a decrease in water demand, it is anticipated that it will have implications and could be the driver behind several water conservation approaches and efforts in the future.
6) Montana State has been actively reducing water demands, primarily related to its irrigation needs, but also associated with technology upgrades on heating and cooling systems, residence halls and food courts, and installation of efficient water fixtures with new and remodeled construction.

Table 1: Existing Toilet Rebate Program Estimated Reductions in Water Use

ASSUMPTIONS AND INPUTS	
2.11	Ppl Per Household (2010 Census)
1455	# Toilets Replaced (December 2012 Program Review)
1330	# Rebate Toilets Pre 1996
125	# Rebate Toilets Post 1996
981	Households Participating In Rebate Program
$ 2.38	$/Hcf (2012 Water Rate ~ Residential)
748	Gal/HCF
31	Days in Month
$ 160.00	Cost Per HE Unit + Installation
$ 125.00	Rebate Toilets Pre 1996
$ 50.00	Rebate Toilets Post 1996
4	Average Uses Per Capita Per Day
1.28	HE gpf
3.5	Old_Gallons
PROGRAM ESTIMATED IMPACTS ON WATER USE	
2.06	Gal/Day Savings for Each Flush (Average of All Replaced Toilets)
17,023	Gal/Day Savings for All Toilets
0.439	Residential gpcd (Spread Across Entire Community) Savings Based on Toilets Replaced
11.70	Gal/Day/Toilet
527.7	Monthly Gallons Saved/Household
0.7	Monthly HCF Saved/Household
$ 1.68	Monthly Savings Per SF Residential Account
$ 20.15	Annual Savings Per SF Residential Account
7.9	Customer Estimated Payback in Years without Rebate
1.7	Customer Estimated Payback in Years with Rebate
6,213,458	Gallons Saved Per Year Based on Toilets Replaced To Date
19.07	Acre Feet Saved Based On Toilets Replaced
$ 172,500	Cost of Rebate Program To Date
$ 9,046	Cost Per Acre-Foot

The information in Table 1 is highly dependent on the number of average uses per capita per day of the installed toilet. For planning purposes, this value was selected as 4 average uses per capita per day due to the following reasons:

1) The toilets were only replaced in single family residential homes and as a result are only used when those residents are home. This community comprises a higher percentage of working residents with children in school, which shifts a portion of the resident's water use out of the home for long hours in a day.
2) The number of toilets replaced would be commensurate with a maximum rebate value of $250.

3) Average values ranged from 4 to 13 flushes per day per person in various study efforts. The table was calculated at a range of possible conditions within this range. However, without verification, City Staff felt most comfortable assuming a lower savings. Most estimates ranged from 4 to 7 flushes per day per person in a literature search. Some variability in projecting the success of the program forward was built into development of planning targets later in this report to acknowledge the possibility of doing better. However, 4 flushes per day per person seemed the most justifiable and conservative value given that no data has been collected to suggest otherwise.

City of Bozeman Water Use 2000 to 2010

Task 6 of the IWRP encompasses a comprehensive characterization of water use across the City of Bozeman for the period of 2000 to 2010. A more detailed discussion of the outcome of this effort is provided as an appendix to the deliverable document for the IWRP. Pertinent information to water conservation planning is summarized herein, including:

- Water demand baseline planning criteria
- Water demand baseline planning criteria broken down by month, by seasonal requirements, and by indoor and outdoor use:
    - System-wide Water Use
    - System-wide Water Use without MSU
    - By Service Sector
- Water demand baseline planning criteria broken down by the following service sectors:
    - Residential (Single Family and Multi Family are combined for this evaluation) Indoor
    - Residential (Single Family and Multi Family are combined for this evaluation) Outdoor
    - Commercial Indoor
    - Commercial Outdoor
    - Largest 8 Commercial (Note that the accounts change on an annual basis, but this general reflects the largest hotels and Bozeman Deaconess Hospital)
    - Montana State University (MSU)
    - Industrial
    - Government
    - Unaccounted for Water
    - Water Treatment Plant Efficiency Factor

Baseline Planning Criteria

System-wide Water Use

The IWRP process involved a statistical analysis of the water use from 2000 to 2010 to determine whether there were trends in water use that are occurring. The analysis involved fitting the data to a bell curve, identifying average monthly water use information, and then determining a standard deviation at various "service levels". A service level can best be explained as a measure of the variability in the data set that will capture a prescribed percentage of possible water demands that could be experienced. For datasets where there is more variability, a larger standard deviation results and a more conservative planning value is selected.

Service levels ranging from one standard deviation to 3 standard deviations (68% to 99.8%) were considered. The period of 2000 to 2010 demonstrated a steady decline in indoor water use, followed by a leveling off from 2005 to 2010. As a result, data from 2005 to 2010 was used as the basis for water supply planning associated with indoor water uses. Outdoor water use, however, did not demonstrate any discernible trends during the study period. As a result, the entire dataset was used for outdoor months and standard deviations were greater.

The result of the baseline planning effort was the selection of a 95 percent service level for planning purposes. Per capita average annual use rates varied between 165 and 180 gpcd in the planning analysis, depending on what period was considered of the 50-year planning horizon. Monthly values varied between 106 and308 gpcd due to seasonal fluctuations in water use. The City has two separate water supply sources with different factors of efficiency since one system has treatment and the other does not. A factor of 95 percent, which is consistent with the design criteria for the new membrane treatment facility on the Sourdough/Middle Creek Supply was used for the entire water supply. A water loss factor associated with the raw water delivery system for the Lyman Creek system has never been calculated. The 95 percent efficiency factor should more than account for any water losses in the raw water pipeline, storage tank, and transmission pipeline of disinfected water supply from this source.

For conservation planning purposes, the planning demand was also broken down to consider winter versus summer water use and also indoor versus outdoor water use. Figure 1 provides a pie chart of the breakdown in total gallons per year and overall percentage of winter versus summer water use (winter months include October to April). Table 2 provides an overall breakdown of indoor and outdoor water use by month.

For conservation planning purposes, the above information was then broken down by service sector. Special consideration was given to MSU as the University has worked diligently over the study period to reduce water demands for both indoor and outdoor uses, with particular regard to the development of a dedicated landscape irrigation system and updates to institutional heating and cooling systems.

Figure 1: Overall Breakdown of Annual Water Use based on Indoor and Outdoor Water Use

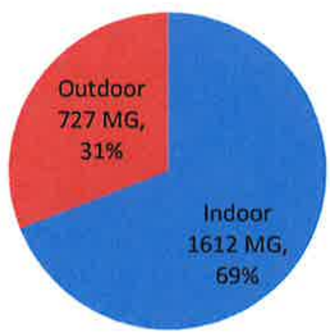


Table 2: Overall Breakdown of Indoor and Outdoor Water Use by Month

MONTH	Indoor Water Use (MG)	Indoor Water Use (gpcd)*	Outdoor Water Use (MG)	Outdoor Water Use (gpcd)*
January	128	106		
February	121	112		
March	131	109		
April	126	109		
May	139	116	60	50
June	136	117	101	87
July	142	118	229	190
August	146	122	212	176
September	134	115	125	107
October	155	129		
November	128	110		
December	127	106		
TOTAL	1612		727	
AVERAGE		114		122

*Note: The indoor and outdoor water use (gpcd) values are calculated by dividing the total volume of water delivered from the sources to the community by the estimated population for that given time period.

MSU

A historical review of MSU water demands demonstrates a downward trend for both indoor and outdoor water use over the study period. During this same timeframe, enrollment at the University was relatively consistent at around 14,000 students a year. The following three figures demonstrate:

- Figure 2: Annual MSU Water Use from 2000 to 2010.
- Figure 3: Monthly Outdoor Water Use from May through September from 2000 to 2010.
- Figure 4: Winter and Summer Water Use Trends (gpcd) from 2000 to 2010.

The information in Figure 3 was normalized to the 2000 population of 27,800 people. The reason for this is that MSU enrollment has been somewhat steady during the last decade while the population of the City of Bozeman has grown considerably. The get a true representation of how the gallons per capita per day were impacted by MSU improvements, normalizing the data to a set population was necessary. Note that when applying true population data over that time, the per capita demands required for MSU are even less than shown because there is more people in the City of Bozeman to share essentially the same population of water use for the University. Growth in the City of Bozeman without growth at the University results in a natural reduction in per capita demands over time that is significant.

Figure 2: Annual MSU Water Use from 2000 to 2010

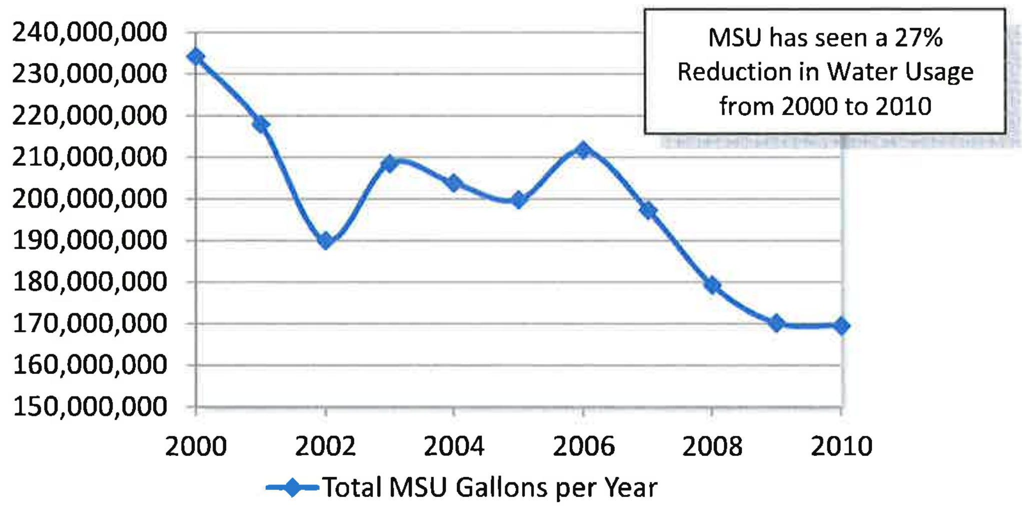


Figure 3: Monthly Outdoor Water Use from May through September from 2000 to 2010

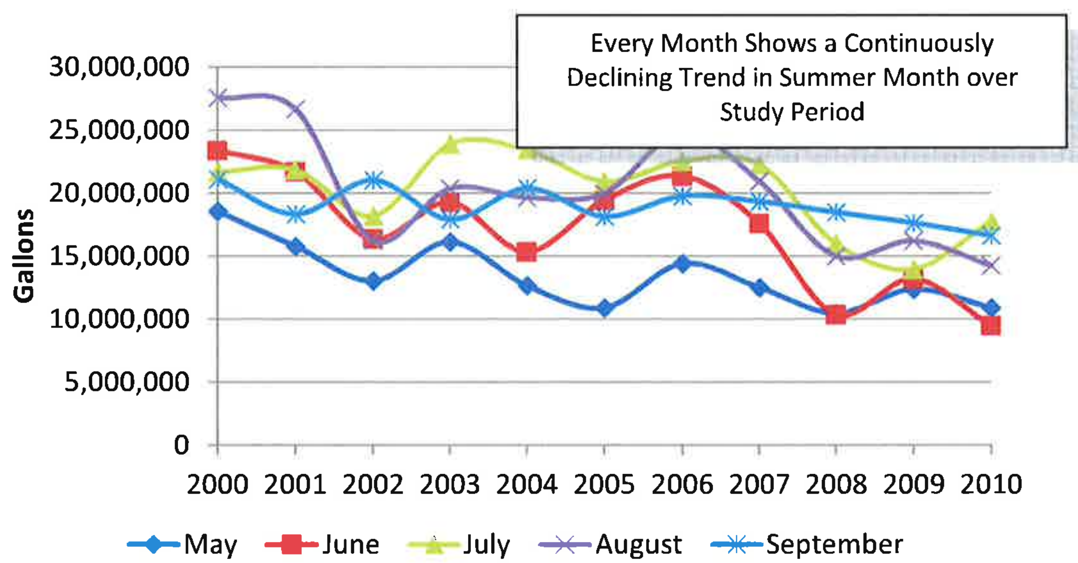
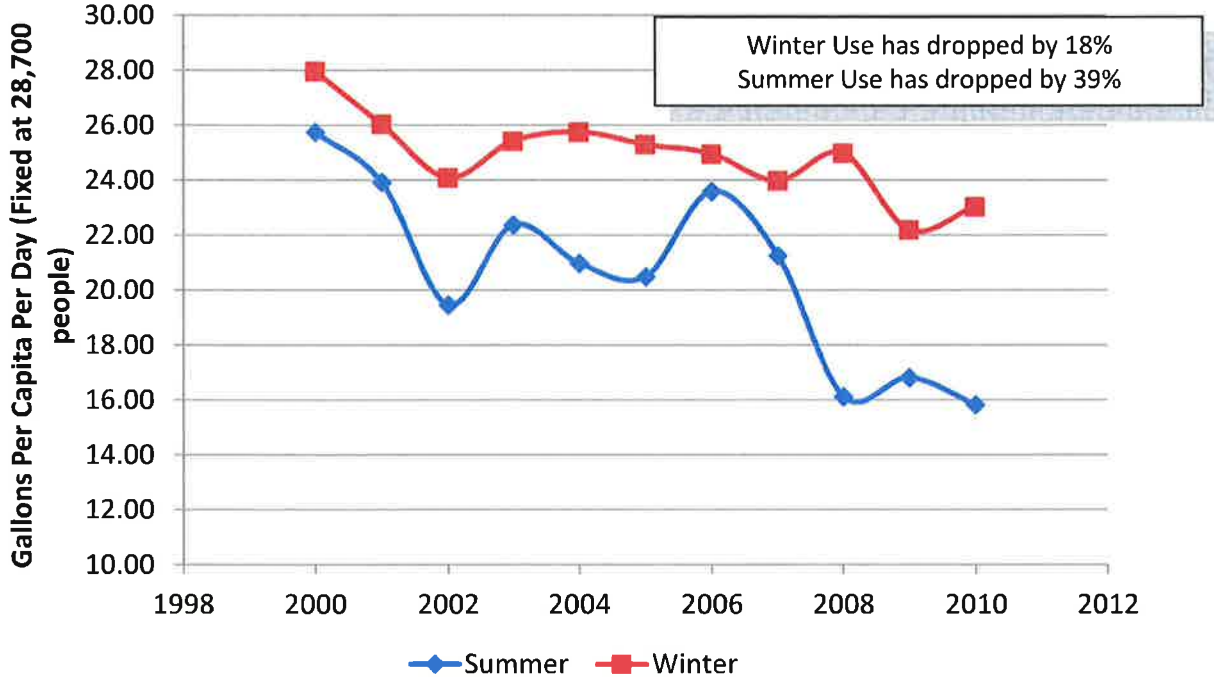


Figure 4: Winter and Summer Water Use Trends (gpcd) from 2000 to 2010



In addition to a review of historical data, correspondence with MSU personnel in August of 2012 indicated the following:

- MSU is releasing a Strategic Plan (September 2012) Targeting growth to 16,000 Students by 2019 (a 2 percent per year growth in University Enrollment)
- MSU is working with Family Housing to move Outdoor Irrigation Demands at the Family Housing complex to the nonpotable irrigation system; however, an additional 100 ac-ft of water rights to be incorporated into the University irrigation pond will likely need to be acquired.
- MSU continues to upgrade heating and cooling systems across the campus.
- MSU is working with an energy efficiency consultant to put updates in place that will have impacts on water use and has also initiated work on a residence hall and food court water reduction plan. This effort needs more work, but is evidence of a continued commitment to reducing water use campus wide.
- Facility personnel believe that sustaining a net zero footprint for water provided by the City of Bozeman, despite growth projections, could be achieved through the 2019 campus planning period. If growth continues at this rate beyond that, additional water may be required.
- While irrigation water to serve family housing would still be necessary from somewhere in the Gallatin Basin, it would not necessarily need to be purchased from the City of Bozeman and be treated by the City's water treatment plant in the future.
- Sustainable university growth at a rate of 2 percent per year through the planning horizon was utilized as an upper level of growth potential for MSU. Comparative water use at a gpcd consistent with today's water use by MSU was calculated. The outcome resulted in approximately 500 acre-ft additional water needs for MSU through the planning horizon.

While MSU may be able to further reduce water demands on campus despite the targeted enrollment goals, an assumption was made for the City's conservation planning effort that MSU water use could increase by up to 500 acre-ft throughout the planning period.

Service Sectors

A historical analysis of the other service sectors also resulted in the following planning assumptions:

1) Unaccounted for water was fairly consistent across a typical year and could not be attributed to any specific seasonal condition. As a result, it was assumed that Unaccounted for Water is a part of Indoor Water Use.
2) Industrial water use was an extremely small portion of the City of Bozeman water use and is also consistent throughout the year. Industrial water use was therefore considered Indoor Water Use.

Table 3 provides a breakdown of water demands on a monthly basis for each service sector, using a planning value of 173 gpcd. Table 3 does not provide a breakdown of outdoor water use for Government and Top 8 commercial users as they are a very small fraction of the overall water use across the system. Later sections of the conservation plan consider these fractions in more detail and apply a fractional responsibility to these areas for water reduction goals. MSU also has an outdoor water use component, but due to reasons noted above, it was not broken out separately for this analysis. This analysis also considers the fraction of water use related to water losses at the treatment plant, which will drop proportionally as water use across the City decreases. Table 3 provides the foundation for applying water reduction goals to each service sector for planning purposes of the IWRP. Figures 5 and 6 provide an annual snapshot of water use by sector for planning purposes.

A summary of the current conditions for the City of Bozeman based on the historical analysis and other considerations that may impact water use in the future include:

- In 1989, the City of Bozeman Average Annual Demand was 191 gpcd.
- In 1993, the City of Bozeman Average Annual Demand was 211 gpcd, the 20-year peak annual demand.
- In the year 2000, the City of Bozeman Average Annual Demand was 163 gpcd.
- In the year 2010, the City of Bozeman Average Annual demand was 134 gpcd.
- The 20-year minimum annual demand happened in 2009, at 127 gpcd.
- A 30 percent reduction in water use has occurred from 1989 to 2010.

Table 3: Service Sector Breakdown of Monthly Planning Demand for the City of Bozeman

Month	Supply Based Demand (173 gpcd)	WTP Efficiency Losses (gpcd)	MSU (gpcd)	Unacc. for Water (gpcd)	Ind. (gpcd)	Top 8 Comm. (Hotels) (gpcd)	Govt. (gpcd)	Res. Indoor (gpcd)	Res. Outdoor (gpcd)	Comm. Indoor (gpcd)	Comm. Outdoor (gpcd)
January	112	6	10	21	1	6	3	43		22	
February	118	6	10	23	1	7	2	45		23	
March	114	6	10	22	1	7	3	43		23	
April	114	6	10	23	1	7	2	43		23	
May	174	9	13	23	1	9	6	45	31	24	12
June	214	11	15	25	1	11	7	47	53	25	21
July	324	16	20	24	1	17	13	47	116	25	46
August	314	16	20	26	1	16	11	49	108	26	42
September	234	12	16	23	1	12	9	46	65	24	26
October	135	7	12	27	1	8	3	51		27	
November	116	6	10	22	1	7	3	44		23	
December	111	6	10	22	1	6	2	42		22	
Average	173	9	13	23	1	9	5	45	75	24	29
% Total	100%	5%	8%	14%	1%	5%	4%	25%	18%	14%	7%

Figure 5: Indoor Planning Demand Breakdown by Service Sector

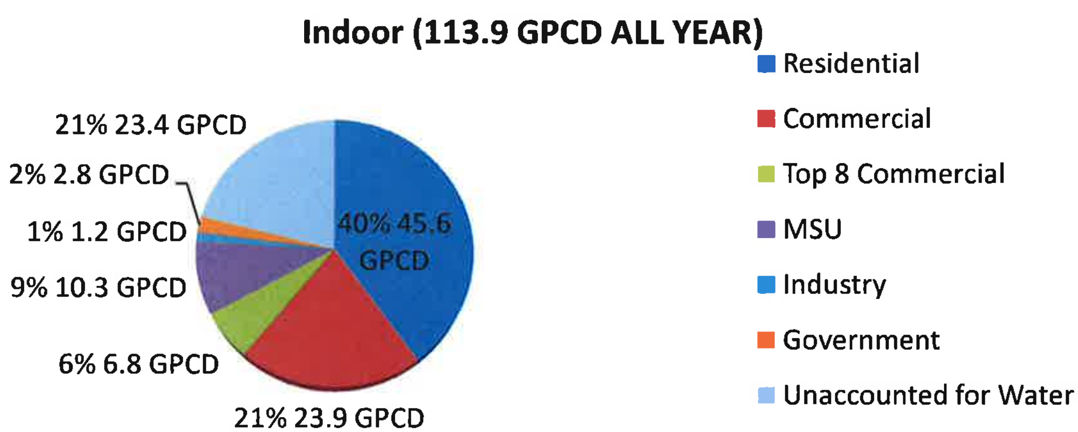
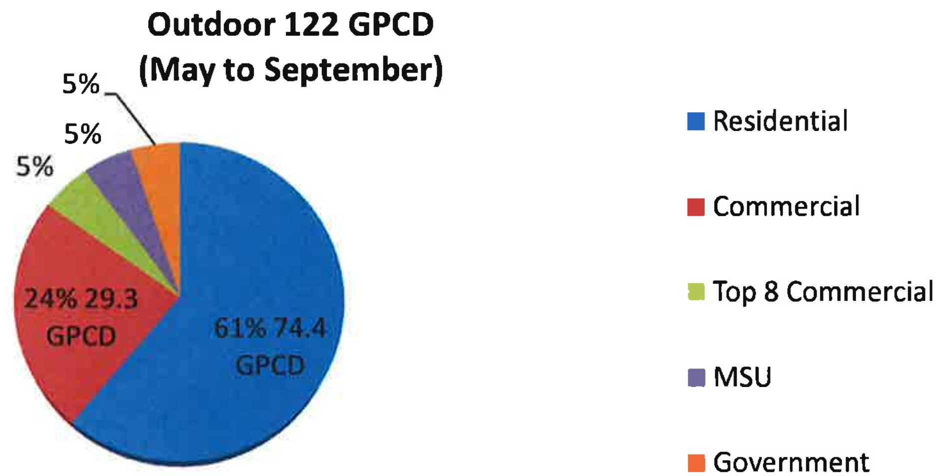


Figure 6: Outdoor Planning Demand Breakdown by Service Sector



- An 18 percent reduction in water use has occurred from 2000 to 2010.
- A 40 percent reduction in water use has occurred from 1993 to 2009 (max. year to min. year).
- Summer variability in water use caused planning values to be significantly higher than the water use that has occurred in the last five years. This suggests that external conditions (climate, economy, etc.) may be impacting water use and a harsher climate year or a better economy may result in increases in water use that the City of Bozeman should be prepared for whether a conservation program is in place or not.
- A conservation plan was completed in 2002 that was largely unimplemented.
- A toilet rebate program was implemented in 2008.
- The existing WTP is highly inefficient, but a new facility is being constructed that will be significantly more efficient, particularly during high water quality periods throughout the year. Although the system was designed with a 95 percent efficiency factor, some times of the year may be less efficient while others times of the year will be more efficient. Highly turbid periods (spring runoff and summer storm events) will be the most difficult to treat with the new membrane system, resulting in lower plant efficiencies.
- Utility rates have increased significantly in the City of Bozeman since 2000 due to the need for constructing a new WWTP and also a need for a new WTP. These rate increases may have had some impact on the reduction of water use over the last 10 and 20-year periods.
- There has been tremendous development and annexation occurring over the last 10-years. These have impacted the way that water is used by implementing new technologies and also sharing water associated with larger users over a larger population base.
- Montana State is making a concerted effort to reduce water use of the City's potable water supply.
- Outdoor water use only accounts for around 31 percent of the total use.
- Unaccounted for water may account for around 11 to 12 percent of the water demand on an annual basis. However, monthly swings in the data were significant and from a planning perspective, this variability in the data set resulted in a planning value for unaccounted for water of 14 percent. System information to target unaccounted for water in the City of Bozeman water distribution system is not available.
- The City of Bozeman is very active in pursuing system leaks and diligently maintains a robust metering system, which is continuing to improve with the installation of Automatic Meter Reading technology that reports through a telemetry system every 4-hours. Full implementation of this system will take some time and may not capture the entire Bozeman water distribution system in the future. However, it will provide much better monitoring throughout much of the City when complete.
- The City of Bozeman Water Department is preparing to hire a Water Conservation Specialist.

Water Supply

The IWRP Report provides a comprehensive discussion of the City of Bozeman Water Supply, including a review of sources, an update to the City's firm yield, and the application of climate change impacts through the year 2062 (a 50-year planning horizon). The IWRP concluded:

- Within the 30-year and 50-year planning horizons, the City of Bozeman will exceed its water supply at current baseline planning demands.
- At a baseline planning demand of 173 gpcd (Supply) and 165 gpcd (Treated Water), the climate adjusted supply can serve up to a population of approximately 57,600 people.
- Climate impacts will reduce firm yield and increase demand over the 50-year planning period.
- Population projections have been established for planning purposes at two different thresholds as part of the IWRP Study effort:
    - 85,725 people through 2062 using a growth factor of 2 percent per year through 2042, followed by 1 percent per year through 2062.
    - 139,900 people through 2062 using a growth factor of 3 percent per year through 2042, followed by 2 percent per year through 2062.

The 2005 Water Facility Plan considered a growth rate of 5 percent per year based on the significant development activity experienced by the City of Bozeman at that time. The recent economic recession and reduction in development activity suggests that the population projections included in the 2005 Water Facility Plan could potentially overestimate future community growth for Bozeman, and revised projections were necessary to complete the IWRP. As an alternative projection methodology, it was assumed that periods of growth could vary substantially in the future, with periods of high growth followed by periods of relatively low growth. Ultimately, the actual rate of growth will reflect the compounded average of community development activity when applied over an extended planning horizon of 30 to 50 years.

As a reasonable alternative, a range of relatively modest growth rates, as defined above, were presented to the City for consideration. The City approved the range of population projections based on past historical data indicating that the City of Bozeman has experienced an average population growth rate of approximately 2.07 percent over the 50-year period of time from 1960 through 2010. The use of growth rates that are more consistent with what has been experienced over the past 50 years was generally accepted as reasonable scenarios of growth that the City could experience over an extended period and more accurately reflect a cyclical pattern of community growth moving forward.

Based on the above information, a range of conditions termed a water balance gap have been identified. By 2042, the City of Bozeman may need to develop anywhere from 2,260 to 6,660 acre-ft. By 2062, the City of Bozeman may need to develop anywhere from 6,840 to 17,750 acre-ft. Closing this gap could be accomplished either by developing or purchasing new water supplies or through demand reduction. This information is summarized in Table 4.

BENCHMARKING EVALUATION

A considerable benchmarking effort was completed by both AE2S and CH2M HILL of communities across the US. Water conservation programs and successful achievement of water demand reductions were evaluated with the goal of determining reasonable planning goals for the City of Bozeman. Identifying demand reduction strategies most likely to help the City accomplish these goals was also a priority of the survey.

Table 4: Range of Water Supply Planning Targets for Various Planning Conditions

	2042	2062
Climate Adjusted Firm Yield Supply	11,240 acre-ft	10,950 acre-ft
Climate Adjusted Water Demand (gpcd)	165 gpcd	180 gpcd
MSU Demand Reservation (acre-ft)	500 ac-ft	500 ac-ft
Moderate Population Projection	70,256	85,725
Climate Adjusted Water Demand (acre-ft)	13,500 acre-ft	17,790 acre-ft
Water Balance Gap (Supply versus Demand)	2,260 acre-ft	6,840 acre-ft
Corresponding Demand Reduction	22 gpcd	71 gpcd
High Population Projection	94,144	139,900
Climate Adjusted Water Demand (acre-ft)	17,900 acre-ft	28,700 acre-ft
Water Balance Gap (Supply versus Demand)	6,660 acre-ft	17,750 acre-ft
Corresponding Demand Reduction	63 gpcd	113 gpcd

Water providers and communities initiate programs to increase water use efficiency (water conservation) for a variety of reasons. For example, programs may be a result of regulatory requirements, water supply shortages, and infrastructure with limited peaking capacity or as part of a community ethic to incorporate sustainable water resource approaches into their utility management systems. Publically available data were used from water providers the project team deemed similar to the City of Bozeman based on demographics, location, and data availability. The project team discovered few "aggressive" conservation programs in Montana and the surrounding states; therefore, communities of similar size that were not in water-scarce regions were selected. Some of which are in the early stages and some of which have been actively investing in conservation programs for decades.

Where information was available, the drivers and goals for water conservation are provided, conservation measures implemented in the community were listed, and information on water use and gallons per capita per day (gpcd) is provided. For conservation planning purposes, it is estimated that Bozeman's water use is 173 gpcd of supply. The American Water Works Association conducted a survey of various utilities across the country. The range of overall per capita water use in the survey was 97 to 274 gallons per capita per day (gpcd); the national average per capita water use is 160 gpcd (AWWA), 2001). At the planning level, Bozeman is slightly above the national average. Actual recent usage is below the national average.

While gpcd is one way to measure water use intensity and efficiency within a system and useful as a measure to track efficient use of water with a growing population, it is not the only standard. For example, in Georgia's Water Conservation Plan, water use intensity for commercial and industrial users is evaluated based on water used per unit of production or activity (e.g., gallons per square foot of carpet or per hotel bed) (Georgia, 2010). Another way to gauge water use efficiency is to look at average use versus peak use, especially in situations in which peak use results from discretionary uses such as outdoor watering. Evaluating peak to average water use ratios is another way to assess water usage. Generally, peak usage represents discretionary outdoor water use that could present an opportunity for water demand reductions. As with gpcd comparisons, however, other factors could contribute to a water system's peak use such as large seasonal populations relative to the permanent population or seasonal variation in manufacturing outputs. Whatever metric is selected to measure water use efficiency, it tends to be most useful when used to track an individual water system's changing water consumption over time with consideration given to changes in external forces (e.g., weather or general economic conditions) as well as changes to the customer base such as gains or losses of high-water using industries (BBC, 2012).

Conservation efforts that were studied as comparable communities to the City of Bozeman for planning purposes spanned the Arid Western US with highlighted communities including the following list and Table 5:

- The State of Utah
    - St. George, UT
    - Park City, UT
- The State of California
    - 20 x 20 Conservation Plan
    - California Urban Conservation Council
- The State of Colorado
    - Colorado Water Conservation Board
    - Colorado Springs, CO
- The State of Oregon – Bend
- The State of Montana
    - Helena, MT
    - Billings, MT
- The State of Texas – San Antonio

Table 5: Water Customer And Utility Profile For Benchmarked Water Providers

City/ Water Provider	2010 Population (estimated annual growth rate) [1]	Annual Water Use MG (Acre-feet)	Peak to Average Ratio	Residential Customers			Comments
				Percent of total customer base	gpcd	Outdoor Use (% of annual)	
Bozeman, MT	**37, 285 (2%)**	**2339 MG (7,178 af)**	**2.25**	**87%**	**77**	**31%**	**Residential gpcd includes residential indoor and outdoor water use**
Boise, ID	205,671 (2.2 %) 240,000 (total served by United Water)	14,000 MG (42,965 af)		Not available			United Water serves Boise and surrounding area.
Town of Cary, NC	135,249 (3.2 %)	5,146 MG	1.53	65%	58	30%	
Claremont, CA	34,926 (0.6%)	Not available	Not available	Not available	143	50 %	Gpcd calculated using aver cons of 11,100 per residence & 2.58 people/household
Denver, CO	600,008 (3.3%) (1.3 million – total served)	(234,000 af)	Not available	48%	80.6		Residential gpcd derived from 168 total gpcd
Longmont, CO[3]	86,270 (1.7%)	5,909 MG (18,134 af)	Not available	54%	104.5		gpcd based on rolling average 2000- 2007; raw water canal system provides outdoor water
Waukesha, WI	70,718 (0.2%)		1.28	58.3 %	40	31%	Residential use includes single-family and multi-family
Wichita, KS	382,368 (0.05 %) 430,000 (total served)	18,158 MG (55,725 af)	1.26	85	65	35%	Data derived from Cost of Service Study; gpcd for inside city limits customers only

Many of the water providers identified have adopted detailed integrated water supply plans or water conservation plans. For other providers, such plans were not identified. To some degree, the reasons, or drivers, contributing to the providers' conservation efforts provide a foundation for understanding the level of investment in the program. For example, a city that is water-short or investing in expensive additional supplies or infrastructure to meet peak demands has an incentive to invest in water conservation, which can be a lower cost option to meet demands. Other cities responded to permit requirements or court mandates specifying water use or water efficiency requirements. Still others have implemented conservation programs for a variety of reasons, such as part of sustainability plans, environmental awareness programs or because it is the "right thing" to do. Where possible, the conservation drivers for the benchmarked cities are presented in Table 6.

Table 6: Drivers For Water Conservation In Benchmarked Cities

City/ Water Provider	Conservation Goal	Planning Year	Driver for Conservation Program	Comments
Bozeman, MT		**2002**	**Growing population, need for additional water supply, makes good business sense at certain levels.**	**2002 plan suggests conservation of 1,400 acre-feet per year**
Boise, ID	None Identified			
Town of Cary, NC	No numeric goal, but they are focused on reducing peak and overall gpcd	On-going	Reduce operating costs; delay infrastructure expansion and need for new supplies	
Claremont, CA	20% by 2020		State law	
Denver, CO	22% from pre-drought levels by 2016 (165 gpcd)	2006	Growing population; costs of alternative supplies; permit/court requirement in 1980's	
Longmont, CO	10% by 2025	2008	Part of integrated water supply portfolio	
Waukesha, WI	1% per year	2012	Right thing to do; Future infrastructure needs; Great Lakes Permit	2012 Conservation Plan outlines numerous new conservation measures over next 5 years
Wichita, KS	15%	1993	Part of integrated water supply portfolio	

Just as the reasons for implementing a water conservation programs vary among utilities and cities, the measures to increase water use efficiency also vary. Across the country most conservation programs begin with a foundation of information and education provided through a website, speaker's bureau, newsletters, social media such as Twitter and similar methods. Financial incentives including rate structures and rebates for fixture, appliance and landscape replacements or retrofits are often implemented. A third strategy often incorporated into conservation programs includes ordinances establishing standards for water-using fixtures or activities such as irrigation systems, water times or frequency, standards for new construction and other policies or regulations. Table 7 provides an overview of conservation measures in place at the benchmarked communities.

A presentation was provided summarizing relevant information at the Technical Advisory Committee meeting #2, in August of 2012 for systems and programs listed above. Conclusions drawn from this benchmarking effort pertaining to conservation planning for the City of Bozeman include:

- In general, water demands are going down nationally due to water conservation practices related to updated plumbing codes, new development, and conservation education and program development.
- In general, the cost of implementing conservation programs is perceived to be less than developing new water supplies, particularly when water supplies are scarce.
- Water conservation programs have been accused of reducing revenue, with an unintended consequence of requiring rate increases.
- State legislation and regional water supply development tend to drive Conservation Program development.
- Program development and management can be more costly than originally intended with fewer impacts than predicted. Selecting measurable water reduction strategies has become a goal of many conservation programs that have been completed in recent years.
- Program outcomes are still primarily predictive. Relatively few programs have implemented measurable programs or effective monitoring approaches.
- A programmatic shift towards measuring outcomes of conservation programs is happening. This is necessary to know the true impact and cost of these programs as the reported information varies considerably based on cost inputs, who's paying for what, and the overall imposition using less water has on the community as a whole.
- It is generally reasonable to plan for around 1 to 2 percent per year water conservation.
- Water conservation could be inevitable whether concerted programs are established or not. As homes and commercial entities update plumbing fixtures and address high energy uses, water conservation typically follows. As utility bills increase, consumers become more aware of their uses and find ways to be more efficient. Balancing these inevitable conditions against conditions that are intentionally impacted may only serve to achieve water use reduction faster with the same overall future outcome regardless of program implementation.
- A Conservation program needs to be continually reviewed and updated. The most successful programs appear to be based on establishment of goals for a 10-year timeframe, with a 5-year review of progress towards goal achievement.
- Pilot study programs, public education, and retaining a Conservation Program Coordinator are critical to implementing a successful conservation program.

Table 7: Conservation Measures For Benchmarked Communities

City/ Water Provider	Residential Indoor	Outdoor (Residential & Commercial)	Industrial, Commercial and Institutional	Youth Education and Public Information	System Management	Other Conservation Measures
Bozeman, MT	Rebate for High Efficiency Toilets	Incentive for new development	None found	Web site information	Universal metering, leak repair, monthly billing	Increasing block rates
Boise, ID	None found	None found	None found	Information and tips on the website	None found	
Town of Cary, NC	High Efficiency Toilet Rebates; showerhead, rain gauge aerator give-away	Turf buy-back program; rain barrel distribution program; alternate day watering schedule; irrigation plan review; new development ordinance; separate irrigation meters required	Reclaimed water; new programs under consideration with 2012 plan update.	School program, Website, newsletter, block leader program; media	Leak detection; main replacement; reuse system	Increasing block rates; water waste prevention ordinance
Claremont, CA	High Efficiency Toilets and clothes washers	Turf removal program; free sprinklers & nozzles; irrigation controller and nozzles rebates (commercial)	High Efficiency Toilets and urinals, cooling tower improvements; dry vacuum pump, food steamer, ice maker, flow restrictor	Website and other information; demonstration garden; workshops; festivals;	None found	Year round ordinance with watering schedule and prohibiting waste (no car washing on hard surfaces), restaurants serve water only upon request, hotels must allow guests to refuse daily laundering; no once-thru cooling system; Increasing block rate structure
Denver, CO	Clothes washer, High Efficiency Toilet	Rotary nozzle & smart controller rebates; soil amendment requirements; landscape requirements; watering schedules; water use audits	Rebates for high efficiency toilets, urinals, flushometers, coin operated laundry machines, cooling tower retrofits, sub-metering, and ware-washing equipment;	Extensive school curricula (changes over time); workshops; outreach; media	Leak detection; reuse system; other system management	Standards for new construction; water waste prevention ordinances. Dynamic program

Table 7: Conservation Measures For Benchmarked Communities

City/ Water Provider	Residential Indoor	Outdoor (Residential & Commercial)	Industrial, Commercial and Institutional	Youth Education and Public Information	System Management	Other Conservation Measures
			"customer defined" conservation incentives; water use audits; public housing retrofits; retrofit of city facilities and landscapes;			
Longmont, CO	Fixture and appliance rebates	Irrigation audits; xeriscape in a box kits; rebates; Landscaping Ordinance/Rebate for New Construction Voluntary Watering Restrictions	Dishwashing faucet replacements	Water festivals, website and other media, workshops	Meter replacement; city facility and irrigation retrofits	Leak Detection and Repair; Meter Testing, Repair and Replacement; Water Waste Ordinance /Hotline; Plumbing Fixture requirements
Waukesha, WI	High-Efficiency toilet rebate	Sprinkling ban;	High-Efficiency toilet rebate; other rebates planned	Tours; classroom tours; newsletters; events; website	Leak detection & repair; pressure management; system water audits;	
Wichita, KS		Conservation rates (base/excess use tiered rates)				
Longmont, CO	Clothes washer, toilet, and dishwasher rebates; fixture replacement to received cert of occupancy (C of O)	Landscape requirements & low fixtures required for new construction and C of O; soil amendments required for new construction	Municipal facilities retrofits;	Extensive outreach	System water audit;	Waste prevention ordinance; demonstration garden; Increasing block rate structure
Boise, ID	Information to customers about water audits and finding leaks	Free rain sensors and hose timers; landscape workshops and demonstration garden	No information available	Tours, information and conservation tips	No information available	None identified

CONSERVATION SCENARIO PLANNING

Upon finalization of the historical data analysis and benchmarking approach, the project team acquired the Alliance for Water Efficiency (AWE) Conservation Tracking Tool (version 2.0) and populated the tool to develop a hypothetical portfolio of potential conservation measures the City could implement over the next 10 years for three potential water conservation scenarios, including a Low, Medium, and High. Numerous assumptions were made to develop the portfolio at this stage of planning, so the tool is able to provide planning level/order of magnitude costs and water savings estimates.

For each scenario, assumptions were made with respect to participation rates, number of retrofits, etc. The assumptions led to "inputs" for various measures into the tool. For each scenario, the assumptions and variables are presented. Also for each scenario, a table is provided to show assumptions or savings factors in the tool for various measures. For the "behavior based" savings, CH2M HILL developed some savings estimates. Note that system efficiency (City-wide infrastructure projects that could decrease the rate of water loss) were added to the results of the AWE Modeling Tool and CH2M HILL effort in a later step. The following tables outline the inputs and assumptions used to generate the results of the AWE Modeling Tool conservation development effort.

Table 8 provides the inputs to the tool that were used throughout all of the scenarios to estimate savings. It also summarizes some basic financial assumptions used to project the cost of implementing the various conservation measures that were evaluated through the 10-year conservation planning horizon.

Tables 9 through 24 provide the additional assumptions, mathematical translations, and outcomes that were made under each of the low, medium, and high scenarios. The first table in each set of tables provides a summary of the assumptions that the project team made regarding the participation in each of the conservation measures that were considered. The next table includes a translation into the number of accounts that have begun using the measure. And the final table provides the results of each measure.

It should be noted that the proposed Conservation Program assumes a 10-year program implementation timeline. However, the planning horizon for this project extends to 30- or 50-years. The methodology used to project the impacts of a low, medium, or high conservation plan through the complete planning horizon is discussed in subsequent sections of this technical document.

Table 8: General Bozeman Assumptions Input into AWE Tracking Tool

Analysis Start Year	2013	2020	2030	2040	2050
Service Area Population	38,786	45,444	55,396	67,528	76,077
Service Area Population in 1990	22,660	**2.66%**	**2.10%**	**1.73%**	**1.16%**
Peak-Season Start Date ('month/day')	1-May				
Peak-Season End Date ('month/day')	30-Sep				
Nominal Interest Rate	4.00%				
Inflation Rate	3.00%				
Year in which to Denominate Costs & Benefits	2012				
Persons Per Household – SF (2010 Census)	2.3				
Persons Per Household – MF (2010 Census)	1.9				
Full Bathrooms Per Household – SF	1.70				
Half Bathrooms Per Household – SF	0.60				
Full Bathrooms Per Household – MF	1.80				
Half Bathrooms Per Household – MF	0.20				
SF Housing Units Built *before 1992* *(City of Bozeman Records)*	3,880				
MF Housing Units Built *before 1992* *(City of Bozeman Records)*	7,198				
Reference ET (inches/yr)	40.75				
Avg. Annual Rainfall (inches/yr)	19.30				

Table 9: Low Scenario – Assumptions (Inputs)

Measure/Activity	Participation/ Market Penetration Assumptions
Residential HE Toilets, SF	Assumed replacement of toilets in 10% of single family homes, divided evenly across 10 years.

Table 10: Estimated Accounts that are Using Measure by Year ~ Low Scenario

Measure/Activity	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Residential HE Toilets, SF	80	90	90	90	90	90	90	90	90	90

Table 11: AWE Tool or CH2M HILL Water Savings Estimate ~ Low Scenario

Measure/Activity	Savings Factor
Residential HE Toilets, SF	Water saved: 4,072 gallons/year/unit
Increased Education*	Assumed a 3% decrease in use based on an increased education/public outreach program.
Passive Conservation	Includes water savings from activity implementation that is not attributable solely to the program action because it would have occurred anyway due to code requirements or program free-riders.

*Savings for this measure was defined by CH2M HILL based on literature and/or best professional judgment

Table 12: Medium Scenario – Assumptions (Inputs) ~ Medium Scenario

Measure/Activity	Participation/ Market Penetration Assumptions
Residential HE Toilets, SF	Assumed replacement in approximately 70% of homes built prior to 1992 that had not previously participated in toilet retrofit program
Residential HE Toilets, MF	Assumed replacement in 35% of homes built prior to 1992
Residential Surveys, SF	Assumed two per month.
Residential Surveys, MF	Assumed approximately one per month, as these are more involved.
Residential LF Showerhead, SF	Assumed these would be given to residents or installed at the time a survey is conducted.
Residential LF Showerhead, MF	Assumed these would be given to residents or installed at the time a survey is conducted.
Residential HE Washer, SF	Assumed a total replacement in 50% of homes.
Residential HE Washer, MF	Assumed approximately 2 facilities per year, 5 machines per facility.
Residential Turf Replacement	Assumed replacement in approximately 2% of households per year, with a 2 year "ramp up" time period. This was assumed to be a combination of turf replacement, irrigation system replacement, or similar measures.
CII 1/2 Gallon Urinal	Assumed 5 urinals per property, 10 properties per year, with a 1 year "ramp up" time period.
CII Tank-Type HE Toilet	Assumed 15 toilets per property, 10 properties per year, with a 1 year "ramp up" time period.
CII Laundromat	Assumed a total of 15 washing machines would be replaced.
CII Dishwasher	Assumed replacement in a total of 2 facilities per year beginning in year 4.
CII Spray Rinse Valve	Assumed replacement in a total of 2 facilities per year beginning in year 4.

Table 13: Estimated Accounts that are Using Measure by Year ~ Medium Scenario

Measure/ Activity	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Residential HE Toilets, SF	200	200	200	200	200	200	200	200	200	200
Residential HE Toilets, MF	250	250	250	250	250	250	250	250	250	250
Residential Surveys, SF	24	24	24	24	24	24	24	24	24	24
Residential Surveys, MF	10	10	10	10	10	10	10	10	10	10
Residential LF Showerhead SF	30	30	30	30	30	30	30	30	30	30
Residential LF Showerhead MF	10	10	10	10	10	10	10	10	10	10
Residential HE Washer, SF		50	50	50	50	50	50	50	50	50
Residential HE Washer, MF		10	10	10	10	10	10	10	10	10
Residential Turf Replacement			5	50	100	100	100	100	100	100
CII 1/2 Gallon Urinal			30	50	50	50	50	50	50	50
CII Tank-Type HE Toilet			90	150	150	150	150	150	150	150
CII Laundromat			3	3	3	3	3			
CII Dishwasher				2	2	2	2	2	2	2
CII Spray Rinse Valve				2	2	2	2	2	2	2

Table 14: AWE Tool or CH2M HILL Water Savings Estimate ~ Medium Scenario

Measure/Activity	Savings Factor
Residential HE Toilets, SF	Water saved: 4072 gal/year/unit
Residential HE Toilets, MF	Water saved: 4,613 gal/year/unit.
Residential Surveys, SF	Water saved: 12,373.0 gallons/year/household
Residential Surveys, MF	Water saved: 4,015.0 gallons/year/household
Residential LF Showerhead, SF	Water saved: 2,062.3 gallons/year/unit
Residential LF Showerhead, MF	Water saved: 1,898.0 gallons/year/unit
Residential HE Washer, SF	Water saved: 7,043.3 gallons/year/household
Residential HE Washer, MF	Water saved: 25,310.0 gallons/year/household
Residential Turf Replacement	Water saved: 40,261.2 gallons/year/household
CII 1/2 Gallon Urinal	Water saved: 6,206.0 gallons/year/unit
CII Tank-Type HE Toilet	Water saved: 11,426.1 gallons/year/unit
CII Laundromat	Water saved: 50,000.0 gallons/year/unit
CII Dishwasher	Water saved: 57,757.0 gallons/year/unit
CII Spray Rinse Valve	Water saved: 28,285.0 gallons/year/unit
Public Information*	Assumed a 3% decrease in use based on increased ed./public outreach.
Pricing Mods/ Water Budgets*	Assumed a 3% decrease in use due to inverted pricing structure.
Watering restrictions (≤twice/week)*	Assumed a 3% decrease in use based on implementation of a sprinkling ordinance that limits days a facility may be watered to no more than 2.
Passive Conservation	Includes water savings from activity implementation not attributable solely to the program action because it would have occurred anyway due to code requirements or program free-riders.

*Savings for these measures were defined by CH2M HILL based on literature and/or best professional judgment

Table 15: High Scenario – Assumptions (Inputs)

Measure/Activity	Participation/ Market Penetration Assumptions
Residential HE Toilets, SF	Assumed a total replacement of 67% (2/3) more than the medium scenario (would include home built post-1992), evenly dispersed over 10 years.
Residential HE Toilets, MF	Assumed replacement in 70% of homes built prior to 1992. 10% would receive rebates (this activity), 50% would benefit from direct installation (below).
Residential Surveys, SF	Assumed approximately 10 per month conducted.
Residential Surveys, MF	Assumed 5 per month conducted.
Residential LF Showerhead, SF	Assumed these would be distributed or installed alongside HE toilet rebates.
Residential LF Showerhead, MF	Assumed these would be distributed or installed alongside HE toilet rebates.
Residential HE Washer, SF	Assumed replacement in 50% of homes.
Residential HE Washer, MF	Assumed replacement in 50% of homes.
Residential Turf Replacement	Assumed replacement in approximately 25% of homes.
CII 1/2 Gallon Urinal	Assumed replacement in 50% of commercial entities.
CII Tank-Type HE Toilet	Assumed replacement in 50% of commercial entities.
CII Laundromat	Based on literature, assumed a 40% water savings over traditional units and 225 washing machines available to be replaced. Assumed 100% replacement.
CII Dishwasher	Based on literature, assumed a 30% water savings over traditional units, which equated to 130 units.
CII Spray Rinse Valve	Based on literature, assumed a 30% water savings over traditional units, which equated to 130 units.
Large Land. Turf Replacement	Assumed 20% of commercial accounts would be considered large landscapes that could be replaced.
Residential HE Toilet Direct Install, MF	Assumed replacement in 70% of homes built prior to 1992. 10% would receive rebates (above), 50% would benefit from direct installation (this activity).
Hotel HE Toilet Direct Install	Assumed 22 hotels with an average of 75 rooms each, replacement in 3 hotels per month starting in 4th quarter of 2015, ending in 2016.

Table 16: Estimated Accounts that are Using Measure by Year ~ High Scenario

Measure/Activity	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Residential HE Toilets, SF	332	332	332	332	332	332	332	332	332	332
Residential HE Toilets, MF	540	540								
Residential Surveys, SF	100	100	100	100	100	100	100	100	100	100
Residential Surveys, MF	60	60	60	60	60	60	60	60	60	60
Residential LF Showerhead, SF	592	592	592	592	592	592	592	592	592	592
Residential LF Showerhead, MF	385	385								
Residential HE Washer, SF		400	500	500	500	500	500	500	500	500
Residential HE Washer, MF		300	400	400	450	450	450	450	450	450
Residential Turf Replacement			100	300	300	300	300	300	300	300
CII 1/2 Gallon Urinal			50	50	50	50	75	75	75	75
CII Tank-Type HE Toilet			50	50	50	50	75	75	75	75
CII Laundromat				50	150	25				
CII Dishwasher						30	50	50		
CII Spray Rinse Valve						30	50	50		
Large Land. Turf Replacement					30	30	30	30	40	40
Residential HE Toilet Direct Install, MF			990	990	990	990				
Hotel HE Toilet Direct Install			675	975						

Table 17: AWE Tool or CH2M HILL Savings Estimate ~ High Scenario

Measure/Activity	Savings Factor
Residential HE Toilets, SF	Water saved: 9,541.2 gallons/year/unit
Residential HE Toilets, MF	Water saved: 14,363.4 gallons/year/unit
Residential Surveys, SF	Water saved: 12,373.0 gallons/year/household
Residential Surveys, MF	Water saved: 4,015.0 gallons/year/household
Residential LF Showerhead, SF	Water saved: 2,062.3 gallons/year/unit
Residential LF Showerhead, MF	Water saved: 1,898.0 gallons/year/unit
Residential HE Washer, SF	Water saved: 7,043.3 gallons/year/household
Residential HE Washer, MF	Water saved: 25,310.0 gallons/year/household
Residential Turf Replacement	Water saved: 40,261.2 gallons/year/household
CII 1/2 Gallon Urinal	Water saved: 6,206.0 gallons/year/unit
CII Tank-Type HE Toilet	Water saved: 11,426.1 gallons/year/unit
CII Laundromat	Water saved: 50,000.0 gallons/year/unit
CII Dishwasher	Water saved: 57,757.0 gallons/year/unit
CII Spray Rinse Valve	Water saved: 28,285.0 gallons/year/unit
Large Land. Turf Replacement	Water saved: 811,933.2 gallons/year/facility
Residential HE Toilet Direct Install, MF	Water saved: 14,363.4 gallons/year/unit
Hotel HE Toilet Direct Install	Water saved: 14,363.4 gallons/year/unit
Public Information*	Assumed a 3% decrease in use based on an increased education/public outreach program.
Pricing Modifications/ Water Budgets*	Assumed a 3% decrease in use based on an inverted pricing structure.
Watering restrictions (≤twice/week)*	Assumed a 3% decrease in use based on implementation of a sprinkling ordinance that limits days a facility may be watered to no more than 2.
Passive Conservation	Includes water savings from activity implementation that is not attributable solely to the program action because it would have occurred anyway due to code requirements or program free-riders.

*Savings for these measures were defined by CH2M HILL based on literature and/or best professional judgment

Table 18: Low Conservation Scenario Results (Values presented in units of acre-feet)

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Measure	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Residential HE Toilets, SF[1]	1.00	2.12	3.25	4.37	5.50	6.62	7.75	8.87	10.00	11.12
Increased Education[2]	132.99	135.73	138.77	141.92	145.19	148.57	152.07	155.69	159.27	162.87
Passive Conservation		58.86	103.82	147.72	190.46	232.12	272.78	312.52	293.85	278.99
Total	133.99	196.71	245.84	294.02	341.15	387.31	432.60	477.09	463.12	452.98

1. Assumed a replacement of 10% of single family homes.
2. Assumed a 3% decrease in use based on an increased education/public outreach program; it is difficult to correlate public awareness campaigns with reduced water use.

Table 19: Estimated Annual Cost[1] for Low Conservation Scenario

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Measure	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Residential HE Toilets, SF	$10,300	$11,935	$12,293	$12,662	$13,042	$13,433	$13,836	$14,251	$14,679	$15,119
Public Information[2]	$19,000	$19,500	$20,000	$20,500	$21,000	$21,500	$22,000	$22,500	$23,500	$23,500
FTEs required ($100k per person per year)[3]	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000
Total	$54,300	$56,435	$57,293	$58,162	$59,042	$59,933	$60,836	$61,751	$63,179	$63,619
TOTAL PROGRAM COST										$594,550

1. Cost estimate includes direct costs for the Bozeman utility system for a particular program. Expected savings (e.g., reduce treatment and power costs) have not been deducted.
2. Assumed value based on best professional judgment; this assumes approx $.50 per capita
3. Assumed quarter-time FTE

Notes:
Estimated water savings per conservation measure were calculated using the AWE Tracking Tool, unless noted.
Conservation values are presented as cumulative values (including the previous year outcome)
Cost are annual and must be totaled for each year to determine total program cost.
Potential impact to revenues resulting from reduced consumption has not been evaluated for this study.

Table 20: Medium Conservation Scenario Results (Values presented in units of acre-feet)

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Measure	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Residential HE Toilets, SF	2.50	5.00	7.50	10.00	12.50	15.00	17.50	19.99	22.49	24.99
Residential HE Toilets, MF	3.54	7.08	10.62	14.16	17.70	21.24	24.77	28.31	31.85	35.39
Residential Surveys, SF	0.91	1.64	2.22	2.69	3.06	3.06	3.06	3.06	3.06	3.06
Residential Surveys, MF	0.12	0.22	0.30	0.36	0.41	0.41	0.41	0.41	0.41	0.41
Residential LF Showerhead, SF	0.19	0.38	0.57	0.76	0.95	1.14	1.33	1.52	1.71	1.90
Residential LF Showerhead, MF	0.06	0.12	0.17	0.23	0.29	0.35	0.41	0.47	0.52	0.58
Residential HE Washer, SF	0.00	1.08	2.16	3.24	4.32	5.40	6.48	7.56	8.65	9.73
Residential HE Washer, MF	0.00	0.78	1.55	2.33	3.11	3.88	4.66	5.44	6.21	6.21
Residential Turf Replacement	0.00	0.00	0.62	6.80	19.15	31.51	43.86	56.22	68.57	80.93
CII 1/2 Gallon Urinal	0.00	0.00	0.57	1.52	2.48	3.43	4.38	5.33	6.29	7.24
CII Tank-Type HE Toilet	0.00	0.00	3.16	8.42	13.68	18.94	24.20	29.45	34.71	39.97
CII Laundromat	0.00	0.00	0.29	0.58	0.87	1.16	1.45	1.45	1.45	1.45
CII Dishwasher	0.00	0.00	0.00	0.35	0.71	1.06	1.42	1.77	2.13	2.48
CII Spray Rinse Valve	0.00	0.00	0.00	0.17	0.35	0.52	0.69	0.87	1.04	1.22
Public Information	132.99	135.73	138.77	141.92	145.19	148.57	152.07	155.69	159.27	162.87
Pricing Modifications/ Water Budgets	265.98	271.45	277.54	283.84	290.38	297.15	304.15	311.39	318.54	325.74
Watering restrictions (≤twice/week)	265.98	271.45	277.54	283.84	290.38	297.15	304.15	311.39	318.54	325.74
Passive Conservation		58.9	103.8	147.7	190.5	232.1	272.8	312.5	293.8	279.0
Total	672.27	753.78	827.40	908.95	995.97	1,082.08	1,167.77	1,252.86	1,279.30	1,308.90

Notes: Consistent with those from Low Scenario

Table 21: Estimated Annual Cost for Medium Conservation Scenario

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Measure	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Residential HE Toilets, SF	$25,750	$26,523	$27,318	$28,138	$28,982	$29,851	$30,747	$31,669	$32,619	$33,598
Residential HE Toilets, MF	$32,188	$33,153	$34,148	$35,172	$36,227	$37,314	$38,434	$39,587	$40,774	$41,997
Residential Surveys, SF	$2,348	$2,419	$2,491	$2,566	$2,643	$2,722	$2,804	$2,888	$2,975	$3,064
Residential Surveys, MF	$515	$530	$546	$563	$580	$597	$615	$633	$652	$672
Residential LF Showerhead, SF	$155	$159	$164	$169	$174	$179	$184	$190	$196	$202
Residential LF Showerhead, MF	$52	$53	$55	$56	$58	$60	$61	$63	$65	$67
Residential HE Washer, SF	$0	$10,609	$10,927	$11,255	$11,593	$11,941	$12,299	$12,668	$13,048	$13,439
Residential HE Washer, MF	$0	$3,925	$4,043	$4,164	$4,289	$4,418	$4,551	$4,687	$4,828	$4,972
Residential Turf Replacement	$0	$0	$5,311	$54,700	$112,681	$116,062	$119,544	$123,130	$126,824	$130,629
CII 1/2 Gallon Urinal	$0	$0	$14,752	$25,324	$26,084	$26,866	$27,672	$28,502	$29,357	$30,238
CII Tank-Type HE Toilet	$0	$0	$19,669	$33,765	$34,778	$35,822	$36,896	$38,003	$39,143	$40,317
CII Laundromat	$0	$0	$1,213	$1,249	$1,287	$1,325	$1,365	$0	$0	$0
CII Dishwasher	$0	$0	$0	$2,251	$2,319	$2,388	$2,460	$2,534	$2,610	$2,688
CII Spray Rinse Valve	$0	$0	$0	$338	$348	$358	$369	$380	$391	$403
Public Information	$19,000	$19,500	$20,000	$20,500	$21,000	$21,500	$22,000	$22,500	$23,500	$23,500
Pricing Modifications/ Water Budgets										
Watering restrictions (≤twice/week)										
Passive Conservation										
FTEs required ($100k per person per year)	$100,000	$125,000	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000
Total	$180,007	$221,871	$340,637	$420,210	$483,042	$491,404	$500,001	$507,435	$516,983	$525,787
Total Program Cost										$4,187,377

Table 22: High Conservation Scenario Results (Values presented in units of acre-feet)

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Measure	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Residential HE Toilets, SF	9.72	19.44	29.16	38.88	48.61	58.33	68.05	77.77	87.49	97.21
Residential HE Toilets, MF	23.80	47.61	47.61	47.61	47.61	47.61	47.61	47.61	47.61	47.61
Residential Surveys, SF	3.80	6.83	9.27	11.21	12.76	12.76	12.76	12.76	12.76	12.76
Residential Surveys, MF	0.74	1.33	1.80	2.18	2.49	2.49	2.49	2.49	2.49	2.49
Residential LF Showerhead, SF	2.10	4.20	6.30	8.40	10.51	12.61	14.71	16.81	18.91	21.01
Residential LF Showerhead, MF	3.15	6.29	6.29	6.29	6.29	6.29	6.29	6.29	6.29	6.29
Residential HE Washer, SF	0.00	8.65	19.45	30.26	41.07	51.87	62.68	73.49	84.30	95.10
Residential HE Washer, MF	0.00	23.30	54.37	85.44	120.39	155.35	190.30	225.25	260.21	271.86
Residential Turf Replacement	0.00	0.00	12.36	49.42	86.49	123.56	160.62	197.69	234.76	271.83
CII 1/2 Gallon Urinal	0.00	0.00	0.95	1.90	2.86	3.81	5.24	6.67	8.09	9.52
CII Tank-Type HE Toilet	0.00	0.00	1.75	3.51	5.26	7.01	9.64	12.27	14.90	17.53
CII Laundromat	0.00	0.00	0.00	7.67	30.69	34.52	34.52	34.52	34.52	34.52
CII Dishwasher	0.00	0.00	0.00	0.00	0.00	5.32	14.18	23.04	23.04	23.04
CII Spray Rinse Valve	0.00	0.00	0.00	0.00	0.00	2.60	6.94	11.28	11.28	11.28
Large Land. Turf Replacement	0.00	0.00	0.00	0.00	74.75	149.50	224.26	299.01	373.76	448.51
Residential HE Toilet Direct Install, MF	0.00	0.00	43.64	87.28	130.92	174.55	174.55	174.55	174.55	174.55
Hotel HE Toilet Direct Install	0.00	0.00	29.75	72.73	72.73	72.73	72.73	72.73	72.73	72.73
Public Information	132.99	135.73	138.77	141.92	145.19	148.57	152.07	155.69	159.27	162.87
Pricing Modifications/ Water Budgets	265.98	271.45	277.54	283.84	290.38	297.15	304.15	311.39	318.54	325.74
Watering restrictions (≤twice/week)	265.98	271.45	277.54	283.84	290.38	297.15	304.15	311.39	318.54	325.74
Passive Conservation		58.9	103.8	147.7	190.5	232.1	272.8	312.5	293.8	279.0
Total	708.26	855.14	1,060.38	1,310.12	1,609.82	1,895.90	2,140.73	2,385.24	2,557.90	2,711.19

Notes: Consistent with those from Low/Medium Scenarios

Table 23: Estimated Annual Cost for High Conservation Scenario

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Measure	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Residential HE Toilets, SF	$42,745	$44,027	$45,348	$46,709	$48,110	$49,553	$51,040	$52,571	$54,148	$55,773
Residential HE Toilets, MF	$69,525	$71,611	$0	$0	$0	$0	$0	$0	$0	$0
Residential Surveys, SF	$9,785	$10,079	$10,381	$10,692	$11,013	$11,343	$11,684	$12,034	$12,395	$12,767
Residential Surveys, MF	$3,090	$3,183	$3,278	$3,377	$3,478	$3,582	$3,690	$3,800	$3,914	$4,032
Residential LF Showerhead, SF	$1,710	$1,761	$1,814	$1,868	$1,924	$1,982	$2,042	$2,103	$2,166	$2,231
Residential LF Showerhead, MF	$2,781	$2,864	$0	$0	$0	$0	$0	$0	$0	$0
Residential HE Washer, SF	$0	$84,872	$109,273	$112,551	$115,927	$119,405	$122,987	$126,677	$130,477	$134,392
Residential HE Washer, MF	$0	$117,760	$161,724	$166,575	$193,019	$198,810	$204,774	$210,917	$217,245	$223,762
Residential Turf Replacement	$0	$0	$106,213	$328,198	$338,044	$348,186	$358,631	$369,390	$380,472	$391,886
CII 1/2 Gallon Urinal	$0	$0	$24,586	$25,324	$26,084	$26,866	$41,508	$42,753	$44,036	$45,357
CII Tank-Type HE Toilet	$0	$0	$10,927	$11,255	$11,593	$11,941	$18,448	$19,002	$19,572	$20,159
CII Laundromat	$0	$0	$0	$20,822	$64,340	$11,045	$0	$0	$0	$0
CII Dishwasher	$0	$0	$0	$0	$0	$35,822	$61,494	$63,339	$0	$0
CII Spray Rinse Valve	$0	$0	$0	$0	$0	$5,373	$9,224	$9,501	$0	$0
Large Land. Turf Replacement	$0	$0	$0	$0	$681,723	$702,174	$723,240	$744,937	$767,285	$790,303
Residential HE Toilet Direct Install, MF	$0	$0	$286,677	$295,277	$304,136	$313,260	$0	$0	$0	$0
Hotel HE Toilet Direct Install	$0	$0	$195,462	$290,803	$0	$0	$0	$0	$0	$0
Public Information [1]	$38,000	$38,700	$40,000	$41,000	$42,000	$43,000	$44,000	$45,000	$46,000	$46,600
Pricing Modifications/Water Budgets										
Watering restrictions (≤twice/week)										
Passive Conservation										
FTEs required ($100k per person per year)	$150,000	$200,000	$300,000	$300,000	$300,000	$300,000	$300,000	$300,000	$300,000	$300,000
Total	$317,636	$574,857	$1,295,683	$1,654,452	$2,141,390	$2,182,342	$1,952,761	$2,002,024	$1,977,710	$2,027,262
Total Program Cost										$16,126,116

Table 24: Comparison of 10 year Conservation Program Scenarios

	Savings (Acre-Feet per Year)[1]	Savings (Total 10-Year Program Savings, Acre-Feet per Year)[2]	Savings (% of planning gpcd/ % of planning gpcd)	Annual Cost (low)[2]	Annual Cost (high)[2]	Total Program Cost[3]
Low	453	3,425		$54,300	$63,619	$594,550
Medium	1,309	10,249		$180,007	$525,787	$4,187,377
High	2,711	17,235		$317,636	$2,182,342	$16,126,116

1. The annual water savings presented is in year 10 of the 10 year program. Annual savings increase as the program is implemented each additional year; this is the maximum reached. Saving continue during the following years.

2. Savings will continue for most measures beyond the ten years included in this planning exercise with minimal to no additional investment.

3. The lowest cost is always in the first year. The year in which the highest cost is achieved depends on the program implementation plan.

4. 10-year program total cost to City. Note this does not account for the reduction in revenue experienced when a utility is selling less water to its customers.

Once the AWE Tracking Tool analysis was complete, the technical team made an effort to break the above information down into the following categories:

1) Retrofits Impacting Existing Accounts
2) Measures Impacting General Water Use Behavior for the Entire Population
3) Additionally, although not included in the above AWE Tracking Tool effort, the technical team considered system efficiency improvements as following:
    a. A reduction from 15.9% to 12% unaccounted for water due to current practices and spending the City has already incorporated into its Capital Plan was assumed as an addition to the Low Scenario.
    b. A reduction from 15.9% to 10% unaccounted for water due to the addition of a hydraulic model calibration and pressure optimization project to the current capital plan was assumed as an addition to the Medium Scenario.
    c. A reduction from 15.9% to 5% unaccounted for water due to the addition of a hydraulic model calibration and pressure optimization project, plus $100,000 per year added budget for system efficiency projects, increasing by $25,000 a year through the 10 year program was assumed as an addition to the High Scenario.

Because the proposed planning horizon for this project is 30-years and 50-years, the proposed conservation program was extrapolated into future years using the following methodology:

1) All new growth associated with the low scenario could be required to develop according to improved development standards for water conservation. It was assumed that as a maximum condition, water demands achieved as part of the medium water conservation scenario could be achieved for new development.
2) All new growth associated with the medium and high scenarios could be required to develop according to improved development standards for water conservation to accomplish demand reduction equivalent to the amount predicted by the high conservation scenario.

Based on the above considerations, Tables 25 through 28 present information associated with Conservation Program accomplishments at Medium and High Growth projections through the planning horizons. Costs have also been developed assuming that infrastructure improvement costs for system efficiency would continue through the planning horizon, staff positions would be retained, and educational budgets would be maintained. Costs estimated beyond the 10-year conservation program horizon were indexed at 3% per year. The costs that are shown are cumulative, according to each planning horizon.

Some considerations to be applied to this analysis include:

- The costs proposed are considered Level 5 cost estimates and as a result, it could be appropriate to apply as much as a 30 to 50 percent contingency factor to the costs for further alternative analysis.
- The City of Bozeman may choose not to impose more stringent standards of water conservation for new construction as suggested herein. In this case, the achievable water demands projected into the future could be significantly less than those proposed in this analysis.
- Due to the length of the planning horizon (50-years), it is not impossible that dramatic improvements to technology could occur during the planning horizon that could have significant impacts on the way that water is used for a community. The technical team recommends that the City of Bozeman extract appropriate planning values from this effort that will provide for a range of planning conditions to consider in the future.

Table 25: Moderate Growth Reductions in Acre Feet Due to Conservation Program Implementation at 2042 and 2062 Planning Horizons

Item Description	2015	2025	2042	2062
Moderate Growth Population Projections	**41,160**	**49,190**	**70,256**	**85,725**
Water Demands (gpcd)	**173**	**173**	**165**	**180**
Annual Water Demands Pre-Conservation No MSU (acre-ft)	**7,977**	**9,533**	**12,986**	**17,286**
Annual MSU Growth Demand (acre-ft)		**167**	**500**	**500**
TOTAL	**7,977**	**9,700**	**13,486**	**17,786**
Low Conservation Retrofit Reduction (acre-ft)		11	11	11
City Efficiency Reduction (15.9% to 12%) (acre-ft)		372	506	674
Low Conservation Non-Retrofit and Future Development Reduction (acre-ft)		442	1,175	1,602
Low Conservation Reduction		**825**	**1,692**	**2,287**
Medium Conservation Retrofit Reduction (acre-ft)		216	216	216
City Efficiency Reduction (15.9% to 10%) (acre-ft)		562	766	1,020
Medium Conservation Non-Retrofit and Future Development Reduction (acre-ft)		1,093	2,965	4,173
Medium Conservation Reduction		**1,871**	**3,947**	**5,408**
High Conservation Retrofit Reduction (acre-ft)		1,618	1,618	1,618
City Efficiency Reduction (15.9% to 5%) (acre-ft)		1,039	1,415	1,884
High Conservation Non-Retrofit and Future Development Reduction (acre-ft)		1,093	2,965	4,172
High Conservation Reduction		**3,750**	**5,999**	**7,674**

Table 26: Estimated Opinion of Probable Cost in $/Acre-ft to Implement Low, Medium, and High Conservation for Moderate Population Growth Projections

MODERATE GROWTH	Total Program Cost Assuming Education, Staff, and Infrastructure Improvement Budgets Continue to Planning Horizons with 3% Inflation per Year			Comparative Cost in $/Acre-ft		
Item Description	2025	2042	2062	2025	2042	2062
Low Conservation Reduction	$594,550	$1,791,438	$4,234,132	$721	$1,059	$1,851
Medium Conservation Retrofit Reduction (acre-ft)						
City Efficiency Reduction (15.9% to 10%) (acre-ft)	$1,500,000	$2,479,271	$4,477,840	$2,667	$3,236	$4,391
Medium Conservation Non-Retrofit and Future Development Reduction (acre-ft)						
Medium Conservation Reduction	$4,187,377	$23,635,805	$42,511,175	$2,238	$5,988	$7,861
High Conservation Retrofit Reduction (acre-ft)						
City Efficiency Reduction (15.9% to 5%) (acre-ft)	$2,375,000	$7,072,516	$23,881,662	$2,286	$4,997	$12,675
High Conservation Non-Retrofit and Future Development Reduction (acre-ft)						
High Conservation Reduction	$16,126,116	$30,815,188	$60,793,716	$4,300	$5,137	$7,922

Table 27: High Growth Reductions in Acre Feet Due to Conservation Program Implementation at 2042 and 2062 Planning Horizons

Item Description	2015	2025	2042	2062
High Growth Population Projections	**42,383**	**55,300**	**94,144**	**139,900**
Water Demands (gpcd)	**173**	**173**	**165**	**180**
Annual Water Demands Pre-Conservation No MSU (acre-ft)	**8,214**	**10,717**	**17,401**	**28,209**
Annual MSU Growth Demand (acre-ft)		**167**	**500**	**500**
TOTAL	**8,214**	**10,884**	**17,901**	**28,709**
Low Conservation Retrofit Reduction (acre-ft)	0.0	11	11	11
City Efficiency Reduction (15.9% to 12%) (acre-ft)		418	679	1,100
Low Conservation Non-Retrofit and Future Development Reduction (acre-ft)		442	1,590	2,657
Low Conservation Reduction		**871**	**2,279**	**3,768**
Medium Conservation Retrofit Reduction (acre-ft)	0.0	216	216	216
City Efficiency Reduction (15.9% to 10%) (acre-ft)		632	1,027	1,664
Medium Conservation Non-Retrofit and Future Development Reduction (acre-ft)		1,093	4,101	7,162
Medium Conservation Reduction		**1,941**	**5,343**	**9,042**
High Conservation Retrofit Reduction (acre-ft)	0.0	1,618	1,618	1,618
City Efficiency Reduction (15.9% to 5%) (acre-ft)		1,168	1,897	3,075
High Conservation Non-Retrofit and Future Development Reduction (acre-ft)		1,093	4,101	7,162
High Conservation Reduction		**3,879**	**7,615**	**11,854**

Table 28: Estimated Opinion of Probable Cost in $/Acre-ft to Implement Low, Medium, and High Conservation for Moderate Population Growth Projections

HIGH GROWTH	Total Program Cost Assuming Education, Staff, and Infrastructure Improvement Budgets Continue to Planning Horizons with 3% Inflation per Year			Comparative Cost in $/Acre-ft		
Item Description	2025	2042	2062	2025	2042	2062
Low Conservation Reduction	$594,550	$1,791,438	$4,234,132	$683	$786	$1,124
Medium Conservation Retrofit Reduction (acre-ft)						
City Efficiency Reduction (15.9% to 10%) (acre-ft)	$1,500,000	$2,479,271	$4,477,840	$2,372	$2,415	$2,690
Medium Conservation Non-Retrofit and Future Development Reduction (acre-feet)						
Medium Conservation Reduction	$4,187,377	$23,635,805	$42,511,175	$2,157	$4,424	$4,702
High Conservation Retrofit Reduction (acre-ft)						
City Efficiency Reduction (15.9% to 5%) (acre-ft)	$2,375,000	$7,072,516	$23,881,662	$2,033	$3,729	$7,767
High Conservation Non-Retrofit and Future Development Reduction (acre-ft)						
High Conservation Reduction	$16,126,116	$30,815,188	$60,793,716	$4,157	$4,047	$5,128

DROUGHT CONTINGENCY PLANNING

The concept of drought contingency planning involves considering water use management approaches that are not applicable on a primarily voluntary daily basis like water conservation, but instead, considers the application of more stringent, mandatory water restrictions when certain triggers are experienced that could impact the sustainability of the City's firm yield water supply. A preliminary effort to consider how development of a drought contingency plan might be considered by the City of Bozeman that aligns with the three proposed conservation scenarios was completed. The following recommendations are proposed:

- A drought management plan for the City of Bozeman should be based on three tiers of triggers, including:
  - **Drought Advisory ~ Tier 1**
    - 80% of Planning Demand at Climate Adjusted and Conservation Adjusted.
    - U.S. Drought Monitor at D1 Drought- Moderate or more intense.
    - Flows in Sourdough and Middle Creek at 120% or less of low monthly for 7 consecutive days. Flows need monitoring, and a flow of 5 cfs will be assumed as low for both.
    - Weather forecast for 2 week period projecting no rain.
    - Goal: Level off at 80% of planning condition based on Climate Adjusted projection and Conservation and maintain condition or improve.
  - **Drought Warning ~ Tier 2**
    - Continued increase in water demands over ensuing 2 week period.
    - Weather forecast for the following 2 weeks with no rain.
    - Continued or worsening of Drought Monitor intensity.
    - OR the following occurs in conjunction with Trigger #1 and separate from #2 and #3
      - Water Supply Flows drop to Firm Yield.
    - Goal: Level off at 80% of planning condition based on Climate Adjusted projection and Conservation and maintain condition or improve. Note: assumed a target of 132.8 gpcd and Firm Yield of 10,950 acre-feet would be sufficient for 73,703 people.
  - **Drought Emergency ~ Tier 3**
    - Continued increase of demands
    - Continued weather forecast with no rain
    - Continued or worsening of Drought Monitor intensity
    - Water Supply Flows drop below Firm Yield
    - Goal: All outdoor use restricted, Water demand goal of 99 gpcd for 73,703 people will require 8,173 acre-feet of supply.

As a comparison to the above drought management plan criteria, the firm yield, as it compares to indoor and outdoor water use is shown in Table 29. Note that without conservation considered, there is only one instance where the available firm yield would adequately cover indoor water needs in the event of a drought emergency, which is in Year 2042 under a moderate growth scenario. In all other cases, indoor water use reduction would be necessary to keep water use under the available firm yield in a drought emergency. As an alternative, indoor water conservation would be necessary to permanently reduce the indoor water use to make it possible for current supplies to cover indoor water use even in a drought emergency, where outdoor water use is completely restricted.

Table 29: Comparison of Disaggregated (Indoor and Outdoor) Climate Adjusted Water Demands without Conservation to Available Water Supplies in a Drought Emergency

Total Available (acre-ft)	Total Needed for Indoor (acre-ft)	Total Left for Outdoor (acre-ft)	Outdoor Total (acre-ft)	Outdoor Gap (acre-ft)
Moderate Growth 2042 Planning Horizon, Population = 70,256 (No Conservation)				
11,240	9,175	2,065	4,699	2,634
Moderate Growth 2062 Planning Horizon, Population = 85,725 (No Conservation)				
10,950	10,963	-13	7,200	7,213
High Growth 2042 Planning Horizon, Population = 94,144 (No Conservation)				
11,240	12,294	-1,054	6,296	7,350
High Growth 2062 Planning Horizon, Population = 139,900 (No Conservation)				
10,950	17,892	-6,942	11,750	18,692

APPENDIX C

Technical Summaries of Alternatives
&
Alternative Screening Criteria

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

IU1 Northside Non-Potable Water Reuse

LEGAL/WATER RIGHTS RANKING

This alternative involves utilization of effluent from the Bozeman Water Reclamation Facility (BWRF) to offset water use by customers of the City of Bozeman and/or by water users in the Gallatin Valley that may have an interest in effluent in exchange for a City lease of water rights held by that entity. Water reuse is a common approach in water resource management and is becoming more popular across the US, including within the State of Montana. In some instances, however, the Montana Department of Natural Resources and Conservation (DNRC) may require an application for a new water right even in a reuse situation, making Water Reuse subject to the same legal conditions as any Water Supply Development Alternative being considered.

BACKGROUND INFORMATION AND REFERENCES

- HB 52 Summary Discussion
- City of Bozeman Effluent Management Plan (EMP) ~ HDR and associated references in this document
- Discussions with Tom Adams, BWRF Superintendent
- Montana DEQ Circular-2
- Various Nutrient Work Group Meeting Minute and reference documents
- Salt Lake City Reuse Feasibility Study Summary
- Golf Course Environmental Profile Measures, ~ Applied Turfgrass Science

WATER SUPPLY PLANNING CRITERIA

- The East Gallatin River Nutrient TMDL cannot be met by current treatment technologies for wastewater.
- The BWRF achieves TN and TP conc. near limits of technology, but ca not comply with new water quality regulations.
- Authorization to continue discharge of wastewater from the BWRF has been granted by Montana DEQ through 2027.
- A permit variance of 20-years to meet more stringent water quality criteria could be obtained to gain compliance time.
- Additional advanced treatment or removal of its discharge from the East Gallatin River are available options for the City.
- The BWRF produces a high quality, reliable effluent that could provide a variety of non-potable uses.
- For the purpose of this analysis, up to 4 million gallons per day (MGD) (which will increase with growth) may be available for reuse that offsets or allows for lease of new supply.
- BWRF effluent would need to be filtered at BWRF, stored, and pumped throughout system.
- Not discharging may have water resource consequences during low flow conditions ~ evaluation needed.

TECHNICAL CRITERIA

- Water Reuse options in this alternative include turf applications at local golf courses and a possible north-side development.
- Supply redundancy is possible on a short-term basis only, as effluent flows are dependent on influent flows.
- Planning for 0.7 MGD per 18-hole golf course is recommended.
- For Bozeman, at least 3,000 homes may be needed to offset residential outdoor water use with 1 MGD of BWRF effluent.
- Riverside Golf Course has 2 MGD irrigation right with pre-1880 priority date from April to October.
- Riverside Water and Sewer District has provisional groundwater rights in excess of its water needs.
- Bridger Creek Golf Course utilizes groundwater for irrigation.
- EMP details other open spaces that may be candidates but may or may not use potable water for irrigation. More evaluation needed.
- Potential to meet 30- and 50-year planning targets should be studied. Golf course use could range from 80K to 1.4M gpd. Lease potential could range from 0 gpd to a seasonal demand of 3
- MGD. Proposed Planning = 1.4 MGD reuse and seasonal 2 MGD
- supply lease (equivalent to 1,200 ac-ft from May to September).
- Potable Surface Water treatment of leased supplies will be required

ENVIRONMENTAL CRITERIA

- Water Reuse is a compliance mechanism for the Clean Water Act.
- Impacts on in-stream flows would need further evaluation.
- Primary permitting issues are associated with approval from both DNRC and Montana DEQ on compliance approach.
- Climate Resiliency impact should be studied further. Dry climate translates to less water and less flows in wastewater utility.
- Treatment process is energy intensive and has a high carbon footprint, which may increase with additional treatment. Reuse impacts, however, could reduce carbon footprint of water treatment by using lower quality water for non-potable needs.
- Environmental Impacts should be evaluated for net positive or negative benefit

SOCIAL CRITERIA

- Water Reuse has historically struggled with public support. However, trends suggest this sentiment may be changing and many non-potable projects have been implemented across the US. Class A Effluent (Food Crop Application Proposed).
- Could be a resource for economic development for industrial users and may be a component of water marketing.
- Riverside Golf Course has indicated it would be willing to receive some water from the City, but only estimated 40,000 gpd, which is significantly less than they use for irrigation.

ECONOMIC CRITERIA

- May eliminate need for purchasing water rights.
- EMP Estimates (2007 dollars):
  - $2.5M for effluent filters and disinfection for Class A effluent
  - $500K for effluent storage ponds
  - $2M for pumping system (designed for City-wide service)
  - $1.3 to 1.9M for trunk line infrastructure.
  - Dual pipe system for residential reuse not calculated.
  - O&M Estimated at $60K/yr
- Saves money in reducing treatment of non-potable water and delays expansion of WTP
- Leasing of water rights owned by partners may be necessary.
- Likely not a regional solution
- Costs may be as much as $9M with inflation + O&M + Water
- Treatment of leased surface water supplies to potable standards.

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

IU2 Northside and Southside Non-Potable Water Reuse

LEGAL/WATER RIGHTS RANKING

This alternative involves utilization of effluent from the Bozeman Water Reclamation Facility (BWRF) to offset water use by customers of the City of Bozeman and/or by water users in the Gallatin Valley that may have an interest in effluent in exchange for a City lease of water rights held by that entity. Water reuse is a common approach in water resource management and is becoming more popular across the US, including within the State of Montana. In some instances, however, the Montana Department of Natural Resources and Conservation (DNRC) may require an application for a new water right even in a reuse situation, making Water Reuse subject to the same legal conditions as any Water Supply Development Alternative being considered.

BACKGROUND INFORMATION AND REFERENCES

- HB 52 Summary Discussion
- City of Bozeman Effluent Management Plan (EMP) ~ HDR and associated references in this document
- Discussions with Tom Adams, BWRF Superintendent
- Montana DEQ Circular-2
- Various Nutrient Work Group Meeting Minutes and reference documents
- Salt Lake City Reuse Feasibility Study
- Golf Course Environmental Profile Measures ~ Applied Turfgrass Science

WATER SUPPLY PLANNING CRITERIA

- Reference IU1 ~ Northside Non-Potable Water Reuse for appropriate Water Supply Planning Criteria.
- The only difference in this alternative is the amount of non-potable water reuse infrastructure that would be installed and the extent it would be made available.

TECHNICAL CRITERIA

Includes all reuse technical criteria provided with IU1 Technical Handout in addition to the following:

- Water Reuse options include turf applications at 1 additional local golf course (Valley View), at MSU family housing and to offset MSU irrigation use on campus and on potential research crops with a lease of Hyalite shares owned by MSU, extends into the downtown area and to the southeast, near Deaconess Hospital, and to several park areas in the City
- Complicated operation and maintenance (O&M) program
- Will be planning intensive due to type of infrastructure needs
- Develops another underground infrastructure system in the community("purple pipes")
- Increased potential for cross-connections.

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TECHNICAL CRITERIA

- Additional water rights that could be leased/acquired include:
  - MSU Irrigation Shares (~0.5 MGD for Planning Purposes).
  - Valley View Golf Course (EMP Reported Groundwater right of 675 gpm, likely seasonal, but reuse need of only 186,000 gpd).
  - Local parks already irrigated with groundwater rights owned by City, which could go through change of use to municipal right.
  - Irrigation with potable water by proposed recipients of reuse water has not been evaluated in detail. Potential water supply needs in EMP estimated at 1.5 MGD. Estimate could underestimate golf course potential and MSU potential with diligent and attractive cooperation. Another 1 MGD may be possible.
  - EMP estimates a potential future use of 1.2 MGD.
  - Further study evaluation ofEMP study to better quantify opportunities and optimize to increase water supplies is necessary. Residential reuse should be evaluated as well.

ENVIRONMENTAL CRITERIA

- Environmental Criteria is the same as those noted for IU1

SOCIAL CRITERIA

- Water Reuse has historically struggled with public support. However, trends suggest this sentiment may be changing. More collaboration with public is recommended.
- Could be a resource for economic development for industrial users and may be a component of water marketing.
- This alternative requires construction of 86,000 feet of effluent reuse pipeline throughout the key corridors of the City of Bozeman. In some cases, this construction could cause temporary inconveniences and unforeseen construction costs.
- Establishes precedence for using the "right" quality of water for the "right" water need.
- Depending on how strategic a "purple pipe" system is developed and embraced by a community, growth could be served with outdoor use coming from reuse water supplies, allowing for some relief for growing areas in terms of the potable water treatment capacity needed to serve them.

ECONOMIC CRITERIA

- May eliminate need for purchasing water rights.
- EMP Estimates (2007 dollars):
  - $5M for filters and disinfection for Class A effluent and effluent storage ponds
  - $2M for pumping system
  - $9.9M for trunk line infrastructure.
  - Dual pipe system for residential reuse not calculated.
  - O&M Estimated at $750K/yr
- Saves money in reducing water treatment capacity; delays expansion of WTP
- Leasing of water rights owned by partners may be necessary.
- Likely not a regional solution.
- Costs may be as much as $22.3M with inflation + O&M +

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

IU3 Northside Non-Potable and Potable Water Reuse

LEGAL/WATER RIGHTS RANKING

This alternative involves utilization of effluent from the Bozeman Water Reclamation Facility (BWRF) to offset water use by customers of the City of Bozeman and/or by water users in the Gallatin Valley that may have an interest in effluent in exchange for a City lease of water rights held by that entity. Water reuse is a common approach in water resource management and is becoming more popular across the US, including within the State of Montana. In some instances, however, the Montana Department of Natural Resources and Conservation (DNRC) may require an application for a new water right even in a reuse situation, making Water Reuse subject to the same legal conditions as any Water Supply Development Alternative being considered. Potable reuse of reclaimed water would also face considerable scrutiny by the public and by the Montana Department of Environmental Quality.

BACKGROUND INFORMATION AND REFERENCES

- HB 52 Summary Discussion
- City of Bozeman Effluent Management Plan (EMP) ~ HDR and associated references in this document
- Discussions with Tom Adams, BWRF Superintendent
- Montana DEQ Circular-2
- Various Nutrient Work Group Meeting Minutes and reference documents
- Salt Lake City Reuse Feasibility Study Summary
- Golf Course Environmental Profile Measures, ~ Applied Turfgrass Science

WATER SUPPLY PLANNING CRITERIA

- Reference IU1 ~ Northside Non-Potable Water Reuse for appropriate Water Supply Planning Criteria.
- The only difference in this alternative is that any excess reuse water would be blended with other water supply resources on the northside of the City to provide a more robust potable water supply.

TECHNICAL CRITERIA

Includes all reuse technical criteria provided with IU1 Technical Handout in addition to the following:

- Treatment of the water supply may require special advanced treatment processes beyond typical surface water treatment process due to addition of BRWF effluent.
- A blended supply could include multiple sources of groundwater and surface water combined at one location.
- Blending could happen upstream of a proposed new WTP or within a groundwater supply (ASR) to add an extra barrier between BWRF effluent and treatment.

TECHNICAL CRITERIA

- Blending could occur in a pretreatment facility where all the sources are brought together at a specified blending ratio to satisfy public health and safety concerns and regulatory requirements.
- Reuse for potable supply may be less costly than reuse for non-potable supply due to the ability to use more of the water in close proximity to the BWRF without constructing pipeline infrastructure.
- Water treatment could be located on the north side of the City and enter the distribution system via the Pear Street Pump House.
- Pumping system improvements may be necessary.
- Will likely increase the amount of water from the BWRF that could be used to directly influence water supply and reduce the number of leases of water rights from others that receive non-potable water.
- A potable reuse option enables at least some portion of the effluent to be used year round if necessary. Although this may not be necessary to meet TMDL requirements, it could address potential water supply shortages during dry years and identified winter season impacts. Non-potable reuse only allows water to be used and offset during seasonal conditions.

ENVIRONMENTAL CRITERIA

- Environmental Criteria is the same as those noted for IU1

SOCIAL CRITERIA

- Social Criteria is the same as IU1, with the following considerations:
  - The public may not be ready to accept the concept of potable water reuse when other options are available, no matter what the cost savings.

ECONOMIC CRITERIA

- May eliminate need for purchasing water rights.
- The costs proposed in IU1 would change dramatically, depending on what percentage of BWRF flows are used for potable treatment and what percentage is used for non-potable supplies.
- A cost analysis would need to be completed to compare the economic impacts of potable versus non-potable treatment requirement.

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

IU4 Northside and Southside Non-Potable and Potable Water Reuse

LEGAL/WATER RIGHTS RANKING

This alternative involves utilization of effluent from the Bozeman Water Reclamation Facility (BWRF) to offset water use by customers of the City of Bozeman and/or by water users in the Gallatin Valley that may have an interest in effluent in exchange for a City lease of water rights held by that entity. Water reuse is a common approach in water resource management and is becoming more popular across the US, including within the State of Montana. In some instances, however, the Montana Department of Natural Resources and Conservation (DNRC) may require an application for a new water right even in a reuse situation, making Water Reuse subject to the same legal conditions as any Water Supply Development Alternative being considered. Potable reuse of reclaimed water would also face considerable scrutiny by the public and by the Montana Department of Environmental Quality.

BACKGROUND INFORMATION AND REFERENCES

- HB 52 Summary Discussion
- City of Bozeman Effluent Management Plan (EMP) ~ HDR and associated references in this document
- Discussions with Tom Adams, BWRF Superintendent
- Montana DEQ Circular-2
- Various Nutrient Work Group Meeting Minutes and reference documents
- Salt Lake City Reuse Feasibility Study
- Golf Course Environmental Profile Measures ~ Applied Turfgrass Science

WATER SUPPLY PLANNING CRITERIA

- Reference IU2 ~ Northside and Southside Non-Potable Water Reuse for appropriate Water Supply Planning Criteria.
- The only difference in this alternative is that any excess reuse water would be blended with other water supply resources on the northside of the City to provide a more robust potable water supply.

TECHNICAL CRITERIA

Includes all reuse technical criteria provided with IU2 Technical Handout in addition to the following:

- Treatment of the water supply may require special advanced treatment processes beyond typical surface water treatment processes due to addition of BRWF effluent.
- A blended supply could include multiple sources of groundwater and surface water combined at one location to accomplish treatment.
- Blending could happen upstream of a proposed new WTP or within a groundwater supply (ASR) to add an extra barrier between BRWF effluent and treatment.

TECHNICAL CRITERIA

- Blending could occur in a pretreatment facility where all the sources are brought together at a specified blending ratio to satisfy public health and safety concerns and regulatory requirements.
- Reuse for potable supply may be less costly than reuse for non-potable supply due to the ability to use more of the water in close proximity to the BWRF via constructing pipeline infrastructure.
- Water treatment could be located on the north side of the City and enter the distribution system through the Pear Street Pump House.
- Pumping system improvements may be necessary.
- Will likely increase the amount of water from the BWRF that could be used to directly influence water supply and reduce the number of leases of water rights from others that receive non-potable water.
- A potable reuse option enables at least some portion of the effluent to be used year round if necessary. Although this may not be necessary to meet TMDL requirements, it could address potential water supply shortages during dry years and identified winter season impacts. Non-potable reuse only allows water to be used and offset during seasonal conditions.

ENVIRONMENTAL CRITERIA

- Environmental Criteria is the same as those noted for IU2

SOCIAL CRITERIA

- Social Criteria is the same as IU2, with the following considerations:
    - The public may not be ready to accept the concept of potable water reuse when other options are available, no matter what the cost savings.

ECONOMIC CRITERIA

- May eliminate need for purchasing water rights.
- The costs proposed in IU2 would change dramatically, depending on what percentage of BWRF flows are used for potable treatment and what percentage is used for non-potable supplies.
- A cost analysis would need to be completed to compare the economic impacts of potable versus non-potable treatment requirement.

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

IU5 Agricultural Irrigation Water Use

LEGAL/WATER RIGHTS RANKING

This alternative involves utilization of effluent from the Bozeman Water Reclamation Facility (BWRF) to offset water use by customers of the City of Bozeman and/or by water users in the Gallatin Valley that may have an interest is effluent in exchange for a lease of water rights held by that entity that could be used by the City. While water reuse is a common approach in water resource management and is becoming more popular across the US, the State of Montana may require that the City of Bozeman apply for a water right to reuse the water supply, making Water Reuse subject to the same legal conditions as any Water Supply Development Alternative being considered.

BACKGROUND INFORMATION AND REFERENCES

- HB 52 Summary Discussion
- City of Bozeman Effluent Management Plan (EMP) ~ HDR and associated references in this document
- Discussions with Tom Adams, BWRF Superintendent
- Montana DEQ Circular-2
- Various Nutrient Work Group Meeting Minutes and reference documents

WATER SUPPLY PLANNING CRITERIA

- The East Gallatin River Nutrient TMDL cannot be met by current treatment technologies for wastewater.
- The BWRF achieves TN and TP conc. near limits of technology, but can not comply with new water quality regulations.
- Authorization to continue discharge of wastewater has been granted by Montana DEQ through 2027.
- A permit variance of 20-years to meet more stringent water quality criteria could be obtained to gain compliance time.
- Additional advanced treatment or removal of its discharge from the East Gallatin River available option for the City.
- The BWRF produces a high quality, reliable effluent that could provide a variety of nonpotable uses.
- Not discharging will likely have consequences on the overall water resource during low flow conditions.
- The Beck-Jones Canal intersects the BWRF property, and the canal company has a water right from the East Gallatin totaling 2.23 MGD (likely seasonal).
- The Springhill Sod Farm is located north of the BWRF. The water right is unknown, but irrigation needs are 632,000gpd
- Other agricultural users and water rights holders exist, but have not been evaluated as potential reuse partners.

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TECHNICAL CRITERIA

- Many of the same technical criteria for IU1 apply to this alternative.
- Beck-Jones Canal water users have a 3 MGD water right. The canal would provide low cost, effective transmission of reclaimed water to agricultural users and also potentially allow for transport of water supplies across the Interstate to areas where it could be used by developers for turf irrigation.
- To date, the Beck-Jones Canal water users have not been approached to determine interest in participating in a water supply partnership.
- Springhill Sod Farm responded to EMP stating it was happy with current water supply approach.
- Concerns with water losses along the canal delivery system may need to be addressed in terms of groundwater impacts.

ENVIRONMENTAL CRITERIA

- Environmental criteria are consistent with IU1.

SOCIAL CRITERIA

- Water Reuse has historically struggled with public support. However, trends suggest this sentiment may be changing. More collaboration with public is recommended.
- Could be a resource for economic development for industrial users and may be a component of water marketing.
- Current potential recipients of reuse water have not been contacted or participated in discussions to gauge real interest.
- At this time, other alternatives appear to have more public interest and support.
- Social criteria for IU1 are applicable here.

ECONOMIC CRITERIA

- May eliminate need for purchasing water rights.
- If only these two users were contacted, the capital costs would include the following (from EMP ~ 2007$):
    - $5 million at BWRF
    - Around $700K to connect to both users.
- O&M would be around $60K
- A WTP facility on the north side of the City would need to be constructed to treat the surface water supply that could be leased by the City for drinking water purposes.
- Improvements to the Pear Street Pump Station and other possible distribution system improvements would need to be completed to treated water into the distribution system.

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

IU6 Industrial Water Reuse

LEGAL/WATER RIGHTS RANKING

This alternative involves utilization of effluent from the Bozeman Water Reclamation Facility (BWRF) to offset water use by customers of the City of Bozeman and/or by water users in the Gallatin Valley that may have an interest is effluent in exchange for a lease of water rights held by that entity that could be used by the City. While water reuse is a common approach in water resource management and is becoming more popular across the US, the State of Montana may require that the City of Bozeman apply for a water right to reuse the water supply, making Water Reuse subject to the same legal conditions as any Water Supply Development Alternative being considered.

BACKGROUND INFORMATION AND REFERENCES

- HB 52 Summary Discussion
- City of Bozeman Effluent Management Plan (EMP) ~ HDR and associated references in this document
- Discussions with Tom Adams, BWRF Superintendent
- Montana DEQ Circular-2
- Various Nutrient Work Group Meeting Minute and reference documents

WATER SUPPLY PLANNING CRITERIA

- Water Supply Planning Criteria outlined in IU1 applies to this alternative. However:
  - There is presently not an industry located in the City of Bozeman, nor any industry actively seeking to locate to the City of Bozeman that may need a significant volume of water supply for industrial purposes.
  - Even if an industry relocated to the Gallatin Valley, it would likely not have water rights that could be shared with the City with attractive volumes, priority dates, and within a water supply that is consistent with the City's other potential resources.

TECHNICAL CRITERIA

- At this time, this alternative has no basis for technical determination as there are no industrial water users that fit the parameters to provide a sufficient water supply resource for the City of Bozeman through reuse water and leasing of existing water rights.

ENVIRONMENTAL CRITERIA

- Environmental criteria are consistent with IU1.
- Depending on the type of industry, there could be other environmental impacts

SOCIAL CRITERIA

- The social criteria of this alternative are unknown due to lack of an identified industrial entity at this point in time.

ECONOMIC CRITERIA

- An Industrial partner would need to be identified to provide an economic evaluation of this alternative.

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Integrated Water Resources Plan Alternatives

IU7 Groundwater Recharge ~ Water Reuse

LEGAL/WATER RIGHTS RANKING

This alternative involves utilization of effluent from the Bozeman Water Reclamation Facility (BWRF) to mitigate groundwater use by the City of Bozeman in exchange for a City lease of water rights held by that entity. It falls under the "reuse category" due to the fact that the alternative would require that the City discharge to groundwater, then withdraw groundwater nearby for its drinking water supply. The aquifer would serve as "storage", provide some natural treatment of the effluent, and allow mixing with existing groundwater supplies. The point at which effluent becomes part of the watershed again would need to be more thoroughly defined to determine the feasibility and legal basis of this alternative. The Montana Department of Natural Resources and Conservation (DNRC) may require an application for a new water right, making this alternative subject to the same legal conditions as any Water Supply Development Alternative being considered.

BACKGROUND INFORMATION AND REFERENCES

- HB 52 Summary Discussion
- City of Bozeman Effluent Management Plan (EMP) ~ HDR and associated references in this document
- Discussions with Tom Adams, BWRF Superintendent
- Montana DEQ Circular-2
- Various Nutrient Work Group Meeting Minutes and reference documents

WATER SUPPLY PLANNING CRITERIA

- Water Supply Planning Criteria outlined in IU1 Apply to this alternative.
- The discharge would likely be subject to groundwater discharge permit limits.
- Infiltration/Percolation (IP) Beds already have been constructed to the west of the BWRF, but they are in poor condition and would need considerable work to be rehabilitated.
- Groundwater injection wells could be considered as an alternative technology, with approval from MDEQ.
- The EMP suggests that the groundwater in this area may not be hydraulically connected to surface water, but no verifiable reference was provided and more study would need to be done to evaluate this potential.
- Without a confined aquifer, it would be difficult to defend the concept of this water being temporarily held for additional treatment/reuse purposes, which may be the basis by which DNRC and MDEQ approve such an approach.
- Whether discharged to surface water or discharged to groundwater, the overall net volume of water discharged to the environment would not change.

TECHNICAL CRITERIA

- Many technical criteria have already been outlined in IU1.
- The BWRF operators have been challenged by the current IP bed design. Other options are available, but groundwater permitting rules in Montana makes these costly alternatives for meeting compliance.
- The groundwater aquifer essentially acts purely as a storage reservoir that is likely not very capable of securely storing a reliable volume of water. The current IP bed design is also not large enough to handle the full flows of the BWRF, so additional capacity would need to be added.
- As with all the reuse options, no water is added to the overall watershed. The benefit comes from reuse water offsetting water that would need to otherwise come from somewhere else as the community grows. More people could be served with the same amount of water.
- More detailed evaluation is necessary to establish volumes of water that could be stored through this approach, infrastructure costs, regulatory requirements, and legal implications.
- This approach may be the cheapest way to get the water into the system if Class A requirements do not need to be met (EMP proposes Class A), a piping network does not need to be constructed, and water from another location in the aquifer could be directly pumped to a strategically located WTP. Other reuse concepts, such as irrigating local agricultural land, golf courses, and other nearby open spaces could continue to be explored, with lease options for water rights held by the appropriate entities.

ENVIRONMENTAL CRITERIA

- Environmental Criteria outlined in IU1 are largely applicable to this alternative.
- While surface water flows could decrease as much as 33 percent during dry conditions (at current discharge volumes), the groundwater supply would receive this as a supplement and the water would likely stay in the local watershed longer. Use of the reuse supply would eventually result in a zero net benefit of water to the watershed. This impact should be evaluated in more detail.

SOCIAL CRITERIA

- Water Reuse has historically struggled with public support. However, trends suggest this sentiment may be changing and many non-potable projects have been implemented across the US.
- Could be a resource for economic development for industrial users and may be a component of water marketing.

ECONOMIC CRITERIA

- May eliminate need for purchasing water rights.
- EMP Estimates IP Bed Reconstruction to be (2007 dollars):
  - $2.5M for effluent filters and disinfection for Class A effluent
  - $500K for effluent storage ponds
  - $2M for pumping system (designed for City-wide service)
  - ~ $7M to reconstruct IP Beds
  - O&M $270K
- May be more cost effective than a nonpotable delivery system.
- Leasing of water rights owned by partners may be necessary if some nonpotable uses still want to be considered.
- Likely not a regional solution
- Costs may be as much as $14.3M (2012$) + O&M + Water Treatment of groundwater supplies to potable standards.

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

WSD1 Sourdough Reservoir

LEGAL/WATER RIGHTS RANKING

The City of Bozeman holds municipal shares in the Bozeman Creek Reservoir Company at a flowrate of 25 cfs and a volume of 6,000 ac-ft for year round use. This water was originally stored in the Mystic Lake Dam, which was breached in the mid-1980s. The City has studied the construction of a reservoir in the Sourdough drainage to provide storage of these shares since that time. Various legal issues surround this water supply alternative that must be resolved prior to moving forward, including: 1) Verification that the City of Bozeman has shown no intent to abandon this water supply, 2) Establishment of the historical use of the water supply, and 3) Consideration for a change of use to allow the water supply to be more strategically used as a component of another alternative.

BACKGROUND INFORMATION AND REFERENCES

1999 Feasibility Study Sourdough Creek Dam Project (URS)
2004 Sourdough Creek Watershed Assessment (Bozeman Watershed Council)
2011 Sourdough Creek Reservoir Development Plan (Great West)
1986 Memorandum on City of Bozeman's Water Rights (Moon)
1978 BznCk Watershed Engineering File (CCS)
1980 BznCk Watershed Preli Investigation Rpt (SCS)
1974 BznCk Field Examination Rpt (SCS)

WATER SUPPLY PLANNING CRITERIA

- Current Planning Documents Propose a 6,000 ac-ft Dam
  - 6000 acre-feet BCRC Share tied to Mystic Lake Dam
  - Spring Runoff Exemption Potential (New Rights Could be Developed)
  - Other Rights in Basin Could be Moved to Reservoir
  - Legal Issues (Noted Above)
- High Quality Headwaters Supply, out of same watershed as current treatment plant is designed to treat
- Reservoir Construction Results in Stored Rights, Improving Reliability of Supply
- Public Accessibility remains to be determined
- Susceptible to Forest Fires
- Gravitational Delivery through Sourdough Creek directly to the existing WTP Intake
- Could be Designed and Constructed at greater volume
- Would store water currently utilized in watershed in other ways.

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TECHNICAL CRITERIA

- Access to the proposed site presents construction challenges.
- Slope and Seismic Studies completed, Reported high seismicity and unstable slopes; In vicinity of two potentially active faults. Despite this, study identified stable construction sites.
- Poses flood risk if dam breaches
- Consistent with current utility infrastructure
- Limited chance of upstream contamination
- Provides second storage reservoir, but may be susceptible to same environmental catastrophes (forest fires)
- Some question of available water rights

ENVIRONMENTAL CRITERIA

- Feasibility Level Engineering Screening Completed for Sites 1 and 3 in the 1999 Feasibility Study:
  - It is believed no "fatal flaws" existing environmentally to prevent construction.
  - *agapetus caddisfly* concerns.
  - Field surveys necessary of populace of variety of mammals and plant species.
  - Class III Inventory will be required.
  - Willow habitat impacts (moose winter range).
- Environmental Compliance Plan completed for 2011 Study
- In-stream flows would become managed via Dam Operations.
- USFS Special Use Permit Required for Sites 1 and 3
- Delivery to WTP will not require energy and could create energy (hydropower evaluated)
- Permitting, EIS, and Easement processes have not started.
- Climate impact predictions suggest wetter spring runoff, drier fall. Storage capable of capturing spring runoff could help provide a more resilient supply to climate impacts for Bozeman

SOCIAL CRITERIA

- Storage generally improves customer service satisfaction in the quality of water delivered
- Some risk of flooding due to a dam breach
- High quality water supply
- 6,000 ac-ft serves approx. 90,000 people, with no new large industrial water users
- Public Involvement has been extensive with a strong sentiment towards conservation and continued evaluation of other resources. Recreational value of the Sourdough creek canyon is extremely high.

ECONOMIC CRITERIA

- Capital costs in 2009 are ~ $37 million at Site #1.
- The 2011 Report Suggests a range of $50 to $70M for 6,000 acre-ft (Capital)
- 1999 Feasibility Study Estimated O&M at $10K/yr
- 1999 Feasibility Study Estimated Site 3 as higher cost
- City of Bozeman only Financial Contributor through reserves and low interest loan programs.

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

WSD2A Canyon Ferry Import Reservoir Delivery

LEGAL/WATER RIGHTS RANKING

The Canyon Ferry Reservoir has a volume of ~ 300,000 ac-ft available annually for leasing from the Bureau of Reclamation. A contractual process for acquiring rights out of the Reservoir is anticipated to take less than one year and will secure the right to use water from the Reservoir for a period of 40-years, at which point renewal of the contract is necessary. Municipal and Industrial uses are a priority for the reservoir in the Upper Missouri River Basin.

BACKGROUND INFORMATION AND REFERENCES

- http://www.usbr.gov/gp/mtao/canyonferry/
- http://www.usbr.gov/gp/mtao/canyonferry/contract_renewals/fea.pdf
- 83,156 AF/yr estimated to Helena Valley Irrigation District
- 7,496 AF/yr estimated to Toston Valley Irrigation District (Taken upstream of Reservoir 16 miles)
- 11,300 AF/yr allocated to City of Helena for Municipal Needs

WATER SUPPLY PLANNING CRITERIA

- Water Quality issues include typical surface water quality concerns.
- Natural Background Arsenic concentration due to influence from Yellowstone area.
- Firm Yield of Reservoir could supply City of Bozeman water needs for many years
- Resilient supply to catastrophic events outside of a dam failure.
- Would require pumping and piping infrastructure to deliver to the Gallatin Valley.
- Could be a full replacement option of water supply if developed strategically.

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TECHNICAL CRITERIA

- Pipeline and Pump Stations Through Open Corridor and Constructrable Terrain (60 miles to Reservoir).
- Arsenic Concentrations in Reservoir of 22 to 31 ppb. Upstream concentrations vary.
- Helena Missouri WTP Treats Arsenic acceptably to drinking water standards.
- Membrane treatment processes would need to be evaluated and optimized for source water change.
- Provides total replacement supply
- Available volume meets and exceeds 30- and 50-year planning criteria.

ENVIRONMENTAL CRITERIA

- May Provide Low Flow Augmentation Opportunity
- Full Replacement of Supply in Dry Years could leave natural flows in local creeks and streams and rivers.
- Could recharge local groundwater supplies
- EA was completed for Helena Water Supply and Irrigation District Water Contracts.
- Permitting and Easements with land owners and water crossings, MDOT/ other agencies.
- Supply must be pumped from source.
- Very Climate Resilient Supply.
- Construction along developed corridors, no forested areas, possibly waterfowl habitats/fisheries crossings, with ultimate project underground.

SOCIAL CRITERIA

- Customer Service for Water Supply Met.
- Water Supply can be treated to meet public health and safety.
- Large water supply will allow for minimal water supply impacts on quality of life.
- Will not limit future economic development or growth.
- Water Marketing could be a component of project.
- Regional initiative could provide water for a broad context of issues impacting entire Gallatin Valley

ECONOMIC CRITERIA

- $1/ac-ft/year of reserved supply for O&M of reservoir.
- $28/ac-ft/year for actual diversions (minimum contract of ~500 ac-ft/year).
- ~$40,000/yr for full 26,000 ac-ft base, $28/ac-ft/yr use.
- 36-inch Pipeline and Appurtenances $1.5 million/mile.
- Pumping Infrastructure and Raw Water Intake.
- Annual O&M on Pipeline and Pumping Costs.
- Bureau of Reclamation Rural Water Supply Program.
- State/Federal/Local Cost Share Opportunities.
- Phasing Strategies.
- Regional Partnerships and Economies of Scale.
- Could solve water supply issues for well beyond planning period with proposed infrastructure.

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

WSD2B Canyon Ferry Import Confluence Delivery

LEGAL/WATER RIGHTS RANKING

The Canyon Ferry Reservoir has a volume of ~ 300,000 ac-ft available annually for leasing from the Bureau of Reclamation. A contractual process for acquiring rights out of the Reservoir is anticipated to take less than one year and will secure the right to use water from the Reservoir for a period of 40-years, at which point renewal of the contract is necessary. Municipal and Industrial uses are a priority for the reservoir in the Upper Missouri River Basin. The Bureau already contracts water to Toston Valley Irrigation District (TVID) upstream of the reservoir 16-miles. Confluence withdrawals have been proposed as a possibility. Mitigation of water for users between confluence and reservoir may be necessary with various options available

BACKGROUND INFORMATION AND REFERENCES

- http://www.usbr.gov/gp/mtao/canyonferry/
- http://www.usbr.gov/gp/mtao/canyonferry/contract_renewals/fea.pdf
- 83,156 AF/yr estimated to Helena Valley Irrigation District
- 7,496 AF/yr estimated diverted to Toston Valley Irrigation District (upstream of Reservoir 16 miles)
- 11,300 AF/yr allocated to City of Helena for Municipal Needs

WATER SUPPLY PLANNING CRITERIA

- Water Quality issues include typical surface water quality concerns.
- Natural Background Arsenic concentration due to influent from Yellowstone area.
- Firm Yield of Reservoir could supply City of Bozeman water needs for many years
- Resilient supply to catastrophic events outside of a dam failure.
- Would require pumping and piping infrastructure to deliver to the Gallatin Valley.
- Could be a full replacement option of water supply if developed strategically.

TECHNICAL CRITERIA

- Pipeline and Pump Stations Through Open Corridor and Constructable Terrain (30 miles to Confluence).
- Arsenic Concentrations should be evaluated.
- Helena Missouri WTP Treats Arsenic acceptably to drinking water standards with Reservoir water.
- Membrane treatment processes would need to be evaluated and optimized for source water change.
- Provides total replacement supply.
- Available volume meets and exceeds 30- and 50-year planning criteria.
- TVID divertswater 16 miles upstream of reservoir.

ENVIRONMENTAL CRITERIA

- May Provide Low Flow Augmentation Opportunity
- Full Replacement of Supply in Dry Years could leave natural flows in local creeks and streams and rivers.
- Could recharge local groundwater supplies
- EA was completed for Helena Water Supply and Irrigation District Water Contracts.
- Permitting and Easements with land owners and water crossings, MDOT/ other agencies.
- Supply must be pumped from source.
- Very Climate Resilient Supply.
- Construction along developed corridors, no forested areas, possibly waterfowl habitats/fisheries crossings, with ultimate project underground.

SOCIAL CRITERIA

- Customer Service for Water Supply Met.
- Water Supply can be treated to meet public health and safety.
- Large water supply will allow for minimal water supply impacts on quality of life.
- Will not limit future economic development or growth.
- Water Marketing could be a component of project.
- Regional initiative could provide water for a broad context of issues impacting entire Gallatin Valley

ECONOMIC CRITERIA

- $1/ac-ft/year of reserved supply for O&M of reservoir.
- $28/ac-ft/year for actual diversions (minimum contract of ~500 ac-ft/year).
- ~$40,000/yr for full 26,000 ac-ft base, $28/ac-ft/yr use.
- 36-inch Pipeline and Appurtenances $1.5 million/mile.
- Pumping Infrastructure and Raw Water Intake.
- Annual O&M on Pipeline and Pumping Costs.
- Bureau of Reclamation Rural Water Supply Program.
- State/Federal/Local Cost Share Opportunities.
- Phasing Strategies.
- Regional Partnerships and Economies of Scale.
- Could solve water supply issues for well beyond planning period with proposed infrastructure.

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Integrated Water Resources Plan Alternatives

WSD3A Madison Aquifer Groundwater

LEGAL/WATER RIGHTS RANKING

Withdrawal of water from the Madison Aquifer may be possible above the existing Bozeman Water Treatment Plant (WTP) in the Sourdough Canyon. The determination of supply interconnectivity to the surface water system is one that has not been determined. If the source were ultimately deemed "unconnected", it could be considered a new supply and new rights could be developed. Loss of watershed runoff to the aquifer has been documented. Springs have been identified that supply water to watershed, but the source has not been definitively qualified as the Madison Aquifer. Low cost solutions may exist to capture some portion of needed water rights at this source, but not enough work has been completed to determine true feasibility.

BACKGROUND INFORMATION AND REFERENCES

- Madison Aquifer Study ~ Karin Kirk Thesis, MSU

WATER SUPPLY PLANNING CRITERIA

- Sourdough Creek Estimated to Lose 2,600 ac-ft/year to the Madison Aquifer out of the Sourdough Creek Drainage
- Two Springs exist in the Sourdough Drainage, but it was unable to be determined if these were truly Madison Aquifer fed springs.
- An attempt to identify Aquifer recharge points in the Hyalite, Sourdough, and Bear Creek watersheds was made. Hyalite has three springs, but not enough information is known about them to determine their source.
- Well drilling was recommended at a minimum depth of 460 ft to over 2000 feet near Mystic Lake to determine the extents of the Madison Aquifer
- Water quality was measured at Two Springs, which met water quality standards, excluding Total Coliforms.
- Drilling locations in Hyalite and Bear Creek Watersheds were also noted with advantages and disadvantages of each.
- Depth to the water suggested energy costs to pump water could be significant.
- An alternate solution to drilling, involving piping across the areas where Sourdough Creek is losing 2,600 ac-ft/yr was proposed.

TECHNICAL CRITERIA

- Study Area located above WTP and within watersheds that deliver water to existing system already.
- Accessibility to various drilling sites noted as a challenge in reporting documents.
- Water quality samples have been collected, but how representative of desired aquifer should be studied further.
- Madison Aquifer Extends beneath 8 States and is a very deep and active aquifer. Depth to solid water supply would need to be studied further.
- Concept of bridging water losses to aquifer may result in 2,600 ac-ft/year of new water.

ENVIRONMENTAL CRITERIA

- Interconnectivity issue not well defined.
- Wells have limited impact on land and wildlife.
- Deep, expansive aquifer likely robust when considering climate impacts.
- Pumping, possibly from great depths could be required to extract adequate groundwater supplies to be delivered into surface water delivery system.

SOCIAL CRITERIA

- Small infrastructure footprint within existing delivery system with limited impacts to recreational and environmental characteristics of watershed.
- Without more information on water supply characteristics, it is uncertain of whether the quality and volume of water is available to meet the social criteria identified.

ECONOMIC CRITERIA

- Without more information on quality, volume of water, and physical characteristics of water supply, financial implications are difficult to predict.

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

WSD3B Belgrade Subarea Groundwater

LEGAL/WATER RIGHTS RANKING

The Gallatin Valley is a closed basin with requirements that new groundwater rights must demonstrate that there is no interconnectivity with surface water. The burden of proof is on the applicant and a successful application demonstrating that a specific groundwater source is not connected to surface water has not been completed to date. Studies completed by the Bureau of Mines have suggested that a "disconnected" aquifer does not exist. Mitigation of groundwater use through surface water recharge is a possible approach. Utility Solutions, a private water utility serving the Four Corners area of the Gallatin Valley has successfully used this approach to provide a drinking water supply to its customers.

BACKGROUND INFORMATION AND REFERENCES

Tom Michalek References

WATER SUPPLY PLANNING CRITERIA

- Groundwater in the Belgrade subarea is presently utilized for water supply by the City of Belgrade, the Town of Manhattan, and also several rural developments.
- The water in this area is primarily shallow aquifer and interconnected to the surface water system.
- Crop irrigation has a significant impact on late season recharge and changing land use will negatively impact shallow aquifer characteristics.
- Water quality information suggests water generally meets current groundwater standards.
- Degraded water quality due to septic system impacts has been noted as a concern, but not thoroughly documented.
- The City of Belgrade currently holds a groundwater discharge permit for its lagoon treated wastewater facility.
- The impacts of a significant, new withdrawal in the Belgrade Subarea has not been studied to the extent necessary to draw quantitative conclusions on viability of this water supply to meet the ranking criteria for this category.
- Interconnectivity suggests that water cannot be stored with certainty in this area of the aquifer. To have no impact, water may need to be pumped into the groundwater supply reasonably close to the withdrawal site making recharge infrastructure a component of this alternative.

TECHNICAL CRITERIA

- Construction of a well field in the Gallatin Valley is technically feasible from a constructability standpoint.
- Septic and permitted groundwater discharges for municipal wastewater facilities may have a negative impact on water quality in the Belgrade Subarea, particular contaminants of concern include elevated nitrates and endocrine disruptors (not regulated, but on the EPA target list).
- The Belgrade Subarea is a farther distance from the existing WTP. However, the water supply may not need to be treated pending blending analysis.
- Water could be delivered to the Bozeman distribution system through the Lyman Creek infrastructure, which would require some pump station and distribution system optimization.
- Provided that water rights and a mitigation approach acceptable to DNRC can be developed for the desired water supply, this alternative could meet the 30- and 50-year planning criteria.

ENVIRONMENTAL CRITERIA

- A well field would likely have very limited direct impacts on wildlife and the natural surrounding environment.
- Mitigating the withdrawals with water from other areas of the watershed could have consequences on in-stream flows, water quality, and the environment.
- The interconnected nature suggests that this groundwater resource would be impacted by climate but not to the extent of a surface water supply.
- A well field does require pumping, which can be optimized through design. In some cases, pumping is less energy intensive than treatment. A more indepth evaluation would be needed to establish this relationship.

SOCIAL CRITERIA

- In general, a well field and groundwater source would likely be supported by the community of Bozeman, but may not be supported by other communities or water rights holders that already use these resources.
- Water marketing/leasing could be a mechanism for sustaining water resources in this alternative, instead of purchasing and changing the use of existing rights. It could allow this alternative to be expanded beyond the rights the City may be able to move to a well field that are presently owned by the City.

ECONOMIC CRITERIA

- This could be an interim solution strategically planned to be part of a regional approach. Other groundwater users may be interested in collaborating on this solution.
- Additional study is needed to establish viability of this alternative, but the closed basin nature and economic importance to Montana of the Gallatin Valley could drive State assistance in evaluating this alternative further.

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

WSD3C Gallatin Gateway Subarea Groundwater

LEGAL/WATER RIGHTS RANKING

The Gallatin Valley is a closed basin with requirements that new groundwater rights must demonstrate that there is no interconnectivity with surface water. The burden of proof is on the applicant and a successful application demonstrating that a specific groundwater source is not connected to surface water has not been completed to date. Studies completed by the Bureau of Mines have suggested that a "disconnected" aquifer does not exist. Mitigation of groundwater use through surface water recharge is a possible approach. Utility Solutions, a private water utility serving the Four Corners area of the Gallatin Valley has successfully used this approach to provide a drinking water supply to its customers.

BACKGROUND INFORMATION AND REFERENCES

Tom Michalek References

WATER SUPPLY PLANNING CRITERIA

- Groundwater in the Gallatin Gateway subarea is presently utilized for water supply by Utility Solutions and may serve as a supply for other rural developments and water districts in the future.
- Two aquifers exist, including the shallow aquifer and a deep aquifer, but evidence of interconnectivity for both to surface water is available.
- Crop irrigation has a significant impact on late season recharge and changing land use will negatively impact aquifer characteristics.
- Water quality information suggests water generally meets current groundwater standards.
- While this subarea is not as well developed as the Belgrade subarea, significant growth has occurred since the 1999 study and degraded water quality due to septic system impacts is possible, but not thoroughly documented.
- The impacts of a significant, new withdrawal in the Gallatin Gateway Subarea has not been studied to the extent necessary to draw quantitative conclusions on viability of this water supply to meet the water supply planning ranking criteria.
- Aquifer storage may be better in this subarea as part of the deep aquifer system, but more study would be necessary to determine this.

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TECHNICAL CRITERIA

- Construction of a well field in the Gallatin Valley is technically feasible from a constructability standpoint.
- Septic and permitted groundwater discharges for municipal wastewater facilities may have a negative impact on water quality. Particular contaminants of concern include elevated nitrates and endocrine disruptors (not regulated, but on the EPA target list).
- While closer to the existing WTP and water supply delivery system than the Belgrade Subarea, this system is farther from Manhattan and Belgrade. The water supply may not need to be treated pending blending analysis.
- Provided water rights and a mitigation approach acceptable to DNRC can be developed for the desired water supply, this alternative could meet the 30- and 50-year planning criteria.

ENVIRONMENTAL CRITERIA

- A well field would likely have very limited direct impacts on wildlife and the natural surrounding environment.
- Mitigating the withdrawals with water from other areas of the watershed could have consequences on in-stream flows, water quality, and the environment.
- The interconnected nature suggests that a groundwater resource would by impacted by climate, although probably not to the extent of a surface water supply.
- A well field does require pumping, which can be optimized through design. In some cases, pumping is less energy intensive than treatment. A more indepth evaluation would be needed to establish this relationship.

SOCIAL CRITERIA

- In general, a well field and groundwater source would likely be supported by the community of Bozeman, but may not be supported by other communities or water rights holders that already use these resources.
- Water marketing/leasing could be a mechanism for sustaining water resources in this alternative, instead of purchasing and changing the use of existing rights. It could allow this alternative to be expanded beyond the rights the City may be able to move to a well field that are presently owned by the City.

ECONOMIC CRITERIA

- This could be an interim solution strategically planned to be part of a regional approach. Other groundwater users may be interested in collaborating on this solution.
- Additional study is needed to establish viability of this alternative, but the closed basin nature and economic importance to Montana of the Gallatin Valley could drive State assistance in evaluating this alternative further.

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

WSD4 Yellowstone River Import

LEGAL/WATER RIGHTS RANKING

The Yellowstone River is an open basin and as such, new water right applications can be made. Although a detailed analysis of water rights in the Yellowstone River Basin has not been done previous to this effort and would need to be completed, the amount of water the City of Bozeman is seeking is not anticipated to be so great that the Yellowstone River could not support it. This supply serves as the municipal drinking water supply for the City of Livingston, approximately 30 miles to the East and over the Bozeman Pass from the City of Bozeman. Objections may be expressed by current water right holders and the City's right would be the most junior on the river. The need for legislative approval should be evaluated.

BACKGROUND INFORMATION AND REFERENCES

Previous to this study effort, the Yellowstone River has not been considered or studied as a potential water supply for the City of Bozeman. Limited information is available and it is beyond the scope of this preliminary study effort to complete an extensive technical evaluation of this alternative.

WATER SUPPLY PLANNING CRITERIA

- The use of this supply for municipal drinking water is not a new idea. It can be treated to municipal drinking water standards via typical surface water treatment technologies.
- The water supply is an open basin and the Yellowstone River has large flows even during drought conditions.
- A study has not been completed to evaluate the available water rights on the Yellowstone River.
- This supply would provide a redundant source and although storage on the river is not available upstream, flows are so great that it may not matter. Additional study effort is necessary to confirm.

TECHNICAL CRITERIA

- The Yellowstone River is already used as a water supply for municipal service.
- Surface water treatment technologies would be necessary.
- A raw water intake, pipeline, and pumping infrastructure would need to be constructed over Bozeman Pass.
- Significant elevation impacts would present design and operational challenges.
- An evaluation of available water rights and water supply yields would need to be conducted to confirm adequate supplies through planning horizons.
- Provides redundancy.
- Difficult Digging Conditions Could be Encountered.

ENVIRONMENTAL CRITERIA

- The anticipated infrastructure for this project will have limited impacts on the environment.
- Instream flows and TMDLs on the Yellowstone River are unlikely to be significantly impacted due to the City's needs.
- Pumping and energy costs of this alternative could be considerable given the elevation that must be overcome.
- The potential for climate impacts that would compromise supply is limited based on available volume.
- Permitting and easements could likely be attained over time and the piping route, while terrain challenged, is relatively open.
- More study is needed.
- Potential for classification as intrabasin transfer.

SOCIAL CRITERIA

- Public support for this alternative has not been tested.
- Public support would also need to consider water users in the Yellowstone River Watershed.
- It is anticipated a project, if constructed would satisfy public health and safety and customer satisfaction criteria.
- Dual pipelines may be warranted to provide redundancy and limit supply interruption.
- More study is needed to determine the potential for growth and expanding this right for future needs.

ECONOMIC CRITERIA

- Other Gallatin Valley water users could be interested in participating in a project. However, given the terrain issues and need to apply for a water right in the Yellowstone, the appeal of this project regionally may be less desirable than other import alternatives.
- Infrastructure costs would likely be greater than an import option from the head of the Missouri River due to cost of construction over the Bozeman Pass. O&M would also be more significant due to pumping costs over the pass.

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

WSD5 Adjacent Drainage Development

LEGAL/WATER RIGHTS RANKING

Adjacent Drainage Development would involve identifying a drainage (Bear Creek, Bridger Creek, Cottonwood Creek, etc) where water rights could be purchased and transferred to the City of Bozeman water utility infrastructure in some manner (pipeline, canals, etc.). There are technically many options that could be evaluated as part of this alternative, but because these drainages are all included in the Closed Basin area, they would be subject to the same legal and water rights development scrutiny as other in-basin options. Factors that could impact the viability of these rights include historical use, irrigation versus municipal rights, unknown firm yield information, system leakage losses (if transferred via canal), etc.

BACKGROUND INFORMATION AND REFERENCES

- City of Bozeman Integrated Water Resources Plan ~ Water Rights Report ~ Water Rights Solutions, Inc

WATER SUPPLY PLANNING CRITERIA

- Storage in the Adjacent Drainages is not available.
- Flows are similar to Bozeman Creek and Middle Creek and could face firm yield issues without storage.
- Water quality is anticipated to be similar to Bozeman Creek and Middle Creek.
- Estimated available water based on paper rights by drainage:

Drainage	Pre 1880 (Ac-ft)	Total (Ac-ft)	At Firm Yield?
Bear Creek	244	758	?
Big Bear Creek	1,963	10,741	?
Bridger Creek	309	1,089	?
Hyalite Creek	8,926	31,109	Likely
Limestone Creek	124	247	?
Little Bear Creek	-	123	?
Little Bridger Creek	-	107	?
Sourdough Creek	2,347	5,346	Yes
TOTAL (Ac-ft)	**13,913**	**49,520**	

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TECHNICAL CRITERIA

- Depending on which drainage and where in the drainage the rights are available, the technical challenges vary considerably.
- In general, pumping infrastructure will likely be necessary
- The potential for available rights to meet planning criteria at 30- and 50-years depends on the availability of willing sellers. The total pre-1880 rights from all of the drainages doesn't meet the 15,500 ac-ft planning criteria established.
- The only drainage with enough potential rights to meet 5,000 ac-ft needs is Hyalite Creek meaning water from multiple drainages would need to be obtained.

ENVIRONMENTAL CRITERIA

- Energy required to get water to the City of Bozeman would vary with alternative approach and drainage.
- Climate impacts are anticipated to be consistent with Sourdough drainage at present, without construction of storage component.
- Storage approaches could impact environment similar to other storage options.
- Instream flows and TMDL impacts should be further evaluated as municipal use would vary from irrigation use and could impact overall Gallatin watershed.

SOCIAL CRITERIA

- Public Support for these options may echo sentiments associated with Sourdough Reservoir project.
- Irrigation water rights holders would need to be consulted to determine support for this type of project due to impacts on irrigation water sources.
- Water marketing could be an option if focused on one specific drainage such as Hyalite Creek.
- Overall lack of excessive rights to sustain all uses in the Gallatin Valley via these drainages may result in water supplies limiting growth.

ECONOMIC CRITERIA

- Since alternatives within this alternative could vary significantly, costs could vary significantly as well.
- Seeking water rights in multiple drainages will likely result in significantly higher costs, overall.
- It is unlikely this solution could support a regional project, at least on its own.
- Water rights attained via this type of alternative could be a component of a solution if they could be used as mitigation water for groundwater alternatives.

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

WSD6 Canal Company Impoundment

LEGAL/WATER RIGHTS RANKING

At present, the most likely solution to a Canal Company Impoundment involves the Salar Project, located in the Gallatin Gateway area, which involves construction of a reservoir on property that has two separate canal systems within its boundaries. The current approach proposed by the Salar project involves canal company leasing of water rights estimated at around 2,700 ac-ft. In this type of arrangement, the City would negotiate directly with other water rights holders and avoid the need to apply to the DNRC for changes to existing or purchased water rights. Viability hinges on canal company willingness to participate and acceptable negotiations with the City with respect to capital and O&M costs. The Salar project is presently held by a private entity and could be purchased by the City if desired.

BACKGROUND INFORMATION AND REFERENCES

- Salar Project Files and Presentations
- Site Visit and Personal Communications with Project Representatives

WATER SUPPLY PLANNING CRITERIA

- Extensive study and planning has been completed to confirm the constructability of an impoundment at this location.
- The impoundment could be used in a variety of ways.
- A well field could also be constructed and additional water supplies from the canal could be used for recharge similar to the Utility Solutions approach.
- Water quality from the canal would be worse quality than current source, but treatable to drinking water standards.
- The canal system is relatively open to contamination points, but water treatment would be required to meet drinking water standards anyway. The type of treatment or impacts to treatment cost could increase.
- The water could be used as mitigation water for other sources.
- Like others, there are several alternatives within this one alternative. This alternative, however, has been very well studied and documented, including various sub-alternatives and many of the conversations and coordination has already been initiated by Salar Project representatives.
- Other impoundments could be possible with other canal companies, but interest has not been expressed.

TECHNICAL CRITERIA

- Extensive technical evaluation of this alternative has been completed to demonstrate technical feasibility, provided successful negotiations with canal companies could take place.
- There is some concern that the existing project would not be able to meet the full planning needs of the City of Bozeman (5,000 ac-ft). It is unlikely the project could meet 15,500 ac-ft.
- Various approaches could allow this project to be part of an overall solution to water supply challenges.

ENVIRONMENTAL CRITERIA

- Depending on how the property and water supply system is developed, energy needs could vary. Utilization of the canal system to deliver the water to various locations across the Valley would be relatively low cost.
- The canal systems likely lose a considerable amount of water, and determination of carrying losses would need to be completed.
- Stored water is more resilient to climate impacts, and if spring runoff is stored, the climate study predicts spring runoff should increase making storage a good climate resiliency solution.
- The agricultural land has been previously disturbed. Project will likely have limited environmental impacts.
- Instream flows and TMDLs could be impacted positively if water is used to mitigate other withdrawals, but this will depend on how this alternative is ultimately developed.

SOCIAL CRITERIA

- Provided successful canal company negotiations can take place, this project is likely to be viewed favorably by the public.
- The project may not provide enough water to allow for progressive development, and high customer satisfaction by itself.
- Project would require municipal and agricultural users to work collaboratively and fit the concept of water marketing. Other organizational and managerial approaches to the currently proposed strategy could be explored.

ECONOMIC CRITERIA

- Considerable cost information has been developed on this alternative for both capital and operation and maintenance.
- Ownership of infrastructure and cost sharing has yet to be developed.
- Regional collaboration could be possible; however, the quantity of available water may not make this strategic.
- Outside funding development would be a challenge.
- Public/private partnership could be explored.
- $16,500 NPV/Ac-ft stored, for fully treated and conveyed water supply based on current assumptions, which could be modified/revised.

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

WSD7 Sourdough Pond Storage

LEGAL/WATER RIGHTS RANKING

The City of Bozeman holds municipal shares in the Bozeman Creek Reservoir Company at a flowrate of 25 cfs and a volume of 6,000 ac-ft for year round use. This water was originally stored in the Mystic Lake Dam, which was breached in the mid-1980s. The City has studied the construction of a reservoir in the Sourdough drainage to provide storage of these shares since that time. Various legal issues surround this water supply alternative that must be resolved prior to moving forward, including: 1) Verification that the City of Bozeman has shown no intent to abandon this water supply, 2) Establishment of the historical use of the water supply, and 3) Consideration for a change of use to allow the water supply to be more strategically used as a component of another alternative.

BACKGROUND INFORMATION AND REFERENCES

Similar to WSD1, but not studied in detail in past. Involves construction of small ponds throughout Sourdough Creek Drainage to store smaller quantities of water in multiple locations. This option was proposed as it may be more cost effective to construct, more supported by the public, and have less impacts on the environment. However, no studies have been completed to verify this potential.

WATER SUPPLY PLANNING CRITERIA

- Current Planning Documents Propose a 6,000 ac-ft Dam
  - 6000 acre-feet BCRC Share tied to Mystic Lake Dam
  - Spring Runoff Exemption Potential (New Rights Could be Developed)
  - Other Rights in Basin Could be Moved to Drainage
  - Total could be split between small storage ponds throughout Drainage.
- High Quality Headwaters Supply, out of same watershed as current treatment plant is designed to treat
- Small ponds provide some storage, improving reliability of supply
- Susceptible to Forest Fires
- Gravitational Delivery through Sourdough Creek directly to the existing WTP Intake
- Would store water currently utilized in watershed in other ways.

TECHNICAL CRITERIA

- Access to the proposed site presents construction challenges.
- Small pond construction sites have not been identified and potential for enough sites to properly design holding ponds and appropriate control structures to serve City is unknown
- Consistent with current utility infrastructure
- Limited chance of upstream contamination
- Provides secondary storage to Hyalite Reservoir, but may be susceptible to same environmental catastrophes (forest fires)
- Some question of available water rights
- Operating plan for multiple smaller ponds could be challenging.

ENVIRONMENTAL CRITERIA

- Similar Environmental Issues to the Sourdough Reservoir could be associated with this alternative as well.
- Smaller ponds may have fewer impacts on the impacted land area.
- Smaller ponds may be able to take advantage of natural topography and be less susceptible to failure.
- Smaller ponds could impact more distance of the drainage than one large reservoir.
- USFS Special Use Permit(s) would be required for sites on USFS land
- Delivery to WTP will not require energy
- Permitting, EIS, and Easement processes have not started.
- Climate impact predictions suggest wetter spring runoff, drier fall. Storage capable of capturing spring runoff could help provide a more resilient supply to climate impacts for Bozeman

SOCIAL CRITERIA

- More evaluation of the feasibility of this option in providing a reliable water supply is needed.
- Would likely not be capable of serving high growth scenario without other alternatives.
- Public support may be stronger as existing recreational uses may be more sustainable. However, additional study is needed to determine the accuracy of this statement.

ECONOMIC CRITERIA

- Costs are unknown at this time for both capital and O&M.
- City of Bozeman only Financial Contributor through reserves and low interest loan programs.

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

WSD8 Hyalite Share Purchasing

LEGAL/WATER RIGHTS RANKING

The City of Bozeman owns 5,652 ac-ft of shares in Hyalite Reservoir which is reduced to 4,521 ac-ft due to a 20% shrinkage factor applied across the system. Total shares in the reservoir are 10,184 ac-ft, (applying the shrinkage factor, the available water supply is 8,147 ac-ft, leaving **3,626** ac-ft of supply the City does not own). It may be possible to reduce the shrinkage factor or eliminate it entirely if the City were to acquire all of the rights in the reservoir or shift its municipal uses to outside the irrigation season. Potential concerns with this alternative include the willingness of present share holders to sell shares from the reservoir, the potential for modifying the shrinkage factor, and establishment of the strategic volume of water the City should seek from the reservoir.

BACKGROUND INFORMATION AND REFERENCES

http://dnrc.mt.gov/wrd/water_proj/factsheets/middlecreek_factsheet.pdf

WATER SUPPLY PLANNING CRITERIA

- Due to the fact that this water resource is the current resource for the City, purchase of shares from the existing reservoir provides water that is reliable, stable, high quality, and will have minimal impacts on the overall watershed given that the delivery system is consistent.
- An analysis of water needed to meet peak day demands at the existing WTP suggests that if this alternative serves as only part of a portfolio, purchase of water shares may be strategically limited to be consistent with the peak month capacity of the new WTP. That analysis suggests the City may want to limit water right purchase from Hyalite Reservoir to 650 ac-ft until it is determined how the remainder of the portfolio will be constructed and whether new water supplies would be delivered to the existing facility or delivered to another location.
- The primary “unknown” associated with this alternative is how the City would coordinate with other shareholders to obtain shares in the future, what those shares are valued at, and how many shares would actually be available.

TECHNICAL CRITERIA

- This alternative does not provide a redundant water supply.
- Unless the shrinkage factor can be eliminated, this alternative does not meet the 50-year water supply planning criteria of 5,000 additional ac-ft.
- No or minimal construction is necessary to utilize the water. Purchase of the rights will make it immediately available to the City.

ENVIRONMENTAL CRITERIA

- Utilization of purchased shares requires no additional energy.
- The canal systems used by the irrigation share holders likely lose a considerable amount of water. Additionally irrigation water is a significant late season source of recharge for the groundwater supply. Using these water supplies for municipal use could have some environmental consequences, accordingly.
- Stored water is more resilient to climate impacts than free flowing supplies.
- Use of the water for municipal purpose could change the operations of the dam due to use on an annual basis instead of seasonal, and the potential for more continuous fluctuations in reservoir level.
- The impacts to TMDLs and Instream Flows of modified reservoir use have not been evaluated.

SOCIAL CRITERIA

- This alternative would be well supported by the users of the water system of the City of Bozeman.
- Public support from other share holders may present a challenge.
- This alternative, by itself, may limit large industrial water users from considering Bozeman as a potential location for establishing business.
- This alternative, by itself, would make it difficult to allow growth to happen independent of the need for adequate water supplies.

ECONOMIC CRITERIA

- The City is currently assessing a fee of $6,000 per ac-ft to developers in lieu of providing water rights necessary to serve new developments via City services.
- The cost of purchasing shares from Hyalite Reservoir is a cost that must be negotiated between the purchaser and seller.

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

WSD9 Hyalite Reservoir Dam Raise

LEGAL/WATER RIGHTS RANKING

The City of Bozeman has coordinated with Montana DNRC in the past to increase the dam height of Hyalite Reservoir and obtain an additional 2,784 ac-ft of water for municipal uses (early 1990s). This alternative would involve increasing the height of the dam again. Water rights to fill the dam raise would need to come from either a transfer of rights from some other location in the basin, or through application for runoff storage from snowmelt, which could be exempt from closed basin restrictions. There is some concern that increasing the dam structure again would not be approved by Montana DNRC, would come with objections by other water users in the Gallatin Valley, and require considerable environmental evaluation before the project would be approved.

BACKGROUND INFORMATION AND REFERENCES

http://dnrc.mt.gov/wrd/water_proj/factsheets/middlecreek_factsheet.pdf
Kevin Smith Correspondence

WATER SUPPLY PLANNING CRITERIA

- Due to the fact that this water resource is a current resource for the City, purchase of shares from the existing reservoir provides water that is reliable, stable, high quality, and will have minimal impacts on the overall watershed given that the delivery system is consistent.

- This alternative has not been studied to date and comes with a number of issues that would need to be evaluated. However, many of these are similar in nature and scope to a dam in the Sourdough drainage making this alternative one the City may want to consider.

- Storing additional spring runoff could be a viable option given climate predictions that available water are anticipated to increase considerable, during spring runoff in the future due to climate impacts. While these are predictions at this point based on a limited dataset, a more robust study could be completed to confirm this potential. If this water is not stored in Hyalite, it will eventually be stored in Canyon Ferry Reservoir.

TECHNICAL CRITERIA

- This alternative does not provide a redundant water supply.
- The dam has not been evaluated to determine whether raising it again is technically feasible. Or reconstructing the entire dam would be necessary.
- Dam improvements may be necessary in the future. The raise could be coordinated with improvements work.
- Capacity of a new dam has not been evaluated, but this alternative would likely be constructed to the greatest capacity possible.

ENVIRONMENTAL CRITERIA

- Considerable environmental assessment would be necessary for this type of a project, similar to what could be expected for a Sourdough Reservoir project.
- Arctic Grayling has been identified as a species to be listed as a High Priority for listing on the Endangered Species Act and any negative impacts would need to be addressed.
- Due to the fact that a dam is already there, a dam raise could have less environmental impacts than constructing a new dam in an alternate drainage. More study would be required to determine this.

SOCIAL CRITERIA

- Public Support for this alternative has not been measured at this point.
- As with other mountain reservoirs, failure of this reservoir could have public safety concerns associated with a flood event.
- The reservoir does not provide a redundant supply, so in the event that the water quality is compromised or the dam fails, the City would immediately lose a major component of its water supply.
- If a project of this magnitude is completed, it is likely that it would be constructed with consideration for future growth needs. Likewise, acquisition of existing shares could increase the total available water supply from this one source.

ECONOMIC CRITERIA

- The cost to raise Hyalite Reservoir in the early 1990s was over $5 million dollars in capital costs. This project would require at least double the height increase of the 1990s project and perhaps complete replacement of the dam.
- If new water supply cannot be acquired through runoff increases, this alternative may also require the purchase of some amount of water rights, which is currently established at $6,000 per ac-ft for planning purposes. *(Is City OK with this??)*
- O&M of the Hyalite Reservoir would likely not change significantly with a dam raise.
- Raising HyaliteDam may or may not be a project eligible for outside funding and may or may not be a viable solution for a regional project. More study would be necessary to determine project feasibility.

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

WSD10 Brackett Creek Import

LEGAL/WATER RIGHTS RANKING

Brackett Creek is located in the Bridger Mountain Range and flows to the Yellowstone River Drainage. The legal/water rights issues in Brackett creek are similar to the Yellowstone River, with one distinct difference. Brackett Creek is a much smaller drainage and little is known about the true physical availability of water under this alternative. Delivery of this water supply would involve piping the water from Brackett Creek into Bridger Creek. It may require legislative approval and come with objections to current water rights owners. At this point in time, it does not appear to be closed, but there are a number of water rights already existing for agricultural activities, local residences, and stock water.

BACKGROUND INFORMATION AND REFERENCES

Previous to this study effort, this alternative has not been considered or studied as a potential water supply for the City of Bozeman. Limited information is available and it is beyond the scope of this preliminary study effort to complete an extensive technical evaluation of this alternative.

WATER SUPPLY PLANNING CRITERIA

- It is anticipated that Brackett Creek could be treated to acceptable drinking water standards.
- The water quality is anticipated to be good quality and there are a couple noted springs that are used by the Bureau of Land Management for stock and wildlife watering purposes.
- The susceptibility of the water supply to contamination would be primarily due to forest fire potential, but is does provide redundancy to the sourdough/hyalite drainage from this perspective.
- There is not enough information to determine the resiliency of the supply or the stability of the supply.
- USGS flow gauge information is not available to determine minimum flow information.
- A study has not been completed to evaluate the available water rights on the Yellowstone River.
- Raw water storage may still be needed to assure a stable and reliable supply.
- Seniority in water rights may be an issue. Additional study effort is necessary to confirm.

TECHNICAL CRITERIA

- Surface water treatment technologies would be necessary.
- The intake could be located in a way to minimize the raw water delivery infrastructure. Some pumping would be necessary, but the majority of delivery could occur naturally, via Bridger Creek.
- An evaluation of available water rights and water supply yields would need to be conducted to confirm adequate supplies through planning horizons.
- Provides redundancy.
- Difficult Digging Conditions Could be Encountered.
- Would Require Approximately 5 miles of Pipeline to Connect Brackett Creek to Bridger Creek along Bridger Canyon Road.

ENVIRONMENTAL CRITERIA

- The anticipated infrastructure for this project will have limited impacts on the environment.
- Instream flows impacts on Brackett and Bridger Creeks would need to be evaluated.
- Pumping and energy costs of this alternative will exist, but would need to be studied to determine the true impacts.
- Climate impacts could impact this supply in a similar manner to predictions for Sourdough and Hyalite Drainages.
- More study is needed.
- Potential for classification as intrabasin transfer.

SOCIAL CRITERIA

- Public support for this alternative has not been tested.
- Public support would also need to consider water users in the Yellowstone River Watershed.
- It is anticipated a project, if constructed would satisfy public health and safety and customer satisfaction criteria.
- More study is needed to determine the potential for growth and expanding this right for future needs.

ECONOMIC CRITERIA

- Given the need to apply for a water right in the Yellowstone, the appeal of this project regionally may be less desirable than other import alternatives.
- Infrastructure costs are not known, but may not be the limiting factor in this alternative. Infrastructure and O&M may be within reasonable thresholds. However, the physical availability of enough supply to meet the City's needs, along with providing a flexible supply into the future are concerns with this alternative.

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

OS1 Non-Potable Groundwater Supply

DOMESTIC/PERMITTED WATER RIGHTS RANKING

This alternative involves utilization of localized groundwater wells that would provide a water supply of untreated groundwater for irrigation purposes to a small community, neighborhood, subdivision, or development property. This concept would require the use of either exempt wells or larger wells that would be constructed with an associated water right. The acquisition of a water right under this scenario may include the transfer of existing water rights to these locations or purchase of water rights from others that would need to go through the permitting process. It is also possible that future developers would be left responsible for the development of their own water rights and irrigation system to be managed by a homeowner's utility. At the present time, the available rights to support this concept have not been well defined.

BACKGROUND INFORMATION AND REFERENCES

- This concept has not been studied in the past and is a new concept in water resources planning for the City of Bozeman.

WATER SUPPLY PLANNING CRITERIA

- This alternative would involve drilling several small localized wells, primarily to serve new development.
- The goal would be to develop wells for domestic irrigation that would be used from April/May to October of each year.
- This alternative could serve existing areas if new piping infrastructure were constructed. However, it is most likely appropriate for new development.
- Outdoor water demands are estimated at about 31% of the City's current total water demand.
- Groundwater supplies are connected to surface water and are considered undevelopable in a closed basin.
- Rights could be purchased or transferred from existing or unused rights to support this alternative.
- Since the water will be used for non-potable uses, the risk of contamination and sabotage is not a substantial factor.
- The quality of the water is appropriate for the application. Using potable water for non-potable applications can be considered inefficient because high quality water is not necessary for irrigation purposes.
- The water supply would be in close proximity due to the fact that it would be developed locally without any additional treatment.
- There may be some risk that more water could be used under this alternative due to the fact that the cost structure would be different. Cost controls may need to be considered to encourage moderate usage.

TECHNICAL CRITERIA

- This alternative would require an additional network of pipeline infrastructure for new development.
- As a non-potable application, the alternative is not subject to drinking water quality regulations
- This alternative would require new infrastructure consisting of localized wells and piping infrastructure.
- This alternative does not provide water supply redundancy as it is available for irrigation purposes only.
- 2042 Available Water Supply = 11,204 ac-ft
- 2062 Available Water Supply = 10,950 ac-ft.
- Could reduce 2042 Growth Demands with 100% future outdoor use supplied through groundwater as follows:
  - Moderate Growth Demand: From 12,041 ac-ft to 10,754 ac-ft.
  - High Growth Demand: From 16,136 ac-ft to 13,780 ac-ft.
- Could reduce 2062 Growth Demands with 100% future outdoor use supplied through groundwater as follows:
  - Moderate Growth Demand: From 15,941 ac-ft to 13,300 ac-ft.
  - High Growth Demands from 26,015 ac-ft to 20,400 ac-ft.

ENVIRONMENTAL CRITERIA

- This alternative will not impact TMDLs directly, but if flows are removed from connected groundwater, there could be indirect impact.
- This alternative will not address in-stream flow maintenance requirements.
- Other than water rights permitting, it is not anticipated that this alternative would present major permitting challenges.
- Groundwater supplies are not typically as susceptible to climate change, but due to connectivity to surface water, the impact of climate change should be considered.
- Reduced carbon footprint would need to be studied. This alternative involves pumping costs, but would not require treatment of the supply.
- Limited impacts on the environment are anticipated due to the urban location of the well.

SOCIAL CRITERIA

- This alternative may have mixed public support depending on customer preference for using potable water for irrigation purposes.
- Public support may depend on who provides the well, the water right, and the increased cost of infrastructure development.
- Could be a concept to incorporate into a conservation program as a mechanism for conservation marketing. Developers may choose this approach in lieu of a portion of water rights payment.

ECONOMIC CRITERIA

- Cost estimates for this alternative have not been completed. However, compared to groundwater supply development, it is anticipated that the cost of developing one large well field and incorporating this water into the potable supply after disinfection could potentially be a much more efficient investment of dollars for potential developable acre-ft.
- O&M, of decentralized systems such as this is typically higher than O&M of one major utility.
- This alternative could serve as a mechanism for delaying larger infrastructure.

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

OS2 Lyman Creek Expansion

LEGAL WATER RIGHTS RANKING

This alternative involves utilization of existing rights held by the City of Bozeman on Lyman Creek. The current system withdraws water from a spring that is hydraulically limited during times of the year to prevent the City from utilizing the full water right associated with Lyman Creek. The City's current supply on paper for the Lyman system is 4,346 ac-ft. The existing infrastructure appears to be able to provide 1,790 ac-ft per year. If new infrastructure is constructed, it could achieve the additional 2,556 ac-ft. It may also be possible that the City could apply for a change of use associated with this right to transfer it to a location where it could be consolidated with other rights the City owns to optimize the manner in which infrastructure is constructed for future water supplies. The amount of water left after a change of use application is likely to be less than the currently held right.

BACKGROUND INFORMATION AND REFERENCES

- Various studies have been completed by the City of Bozeman involving the measurement of flows on Lyman Creek and are included on the City's ftp site.

WATER SUPPLY PLANNING CRITERIA

- The Lyman Supply has demonstrated reliable and sustainable water supply over time in terms of quantity and also demonstrated historical use for the full right of 4,346 ac-ft.
- The City has already protected the watershed from public use.
- The SWTR required updates to this supply that included the construction of a spring, a raw water transmission pipeline, and upgrades to the reservoir. The full right of 4,346 ac-ft cannot be accessed with the current treatment system due to gravitational issues, water tables, and other operational intricacies.
- The new WTP will be constructed in a manner that will allow the City to push the Lyman creek system to find its true limits of operations, which may be beyond 1,790 ac-ft, but less than the full 4,346 ac-ft.
- Flow data is presently collected off the weir at the spring box (the overflow) and at the reservoir. The combined flow equals the total production of the water supply. Measurements at the weir box are a challenge to collect in the winter due to accessibility issues. Telemetry and a robust metering system could improve data collection.
- Additional withdrawal points in the City's water right would allow access to creek flows, but surface water treatment would be required.
- Installation of a pumping system at the spring or another ground water location or relocating the reservoir lower in the watershed may also increase access to available supply.

TECHNICAL CRITERIA

- All of the possible solutions at Lyman Creek are technically feasible, compatible with existing infrastructure, can be constructed to comply with drinking water regulations, and provides a redundant water supply to the City of Bozeman.
- Increased flows from the Lyman system can be conveyed to the City through the existing transmission main. However, improvements to the Pear Street Pump Station are recommended for long-term operations. Optimization of the hydraulic operations of the distribution system should also be evaluated if this supply becomes a greater part of the City's water supply portfolio.
- The redundancy is not a full replacement and is presently less than half of the City's water needs during summer months.
- The 2,550 ac-ft could meet the 30-year, medium growth water gap of 801 ac-ft. However, it is not enough water to meet the 50-year, high growth water gap of almost 5,000 ac-ft.
- The 2,550 ac-ft does not meet either of the high growth water gap values.
- If a change of use for the 2,550 ac-ft was pursued, some amount of this water could be moved and strategically combined with other water resources and supplies in the system to take advantage of shared infrastructure.

ENVIRONMENTAL CRITERIA

- This alternative may have a limited impact on TMDLs only due to the fact that using more water in Lyman creek translates to less water flowing into the East Gallatin River.
- East Gallatin River in-stream flows could be impacted.
- Permitting challenges are minor.
- Operational experience suggests this right is less than the firm yield of the supply. More robust flow monitoring is recommended to verify and address future climate impacts.
- Evidence suggests it does demonstrate decreased flows during dry years.
- The spring is currently a very low carbon footprint supply and is a natural delivery system with very high quality water.
- Limited impacts on the environment are anticipated due to the existing system being in place already.

SOCIAL CRITERIA

- Public Support and Satisfaction of this alternative are anticipated to be high.
- Alternative does not allow for a lot of flexibility in the water supply to allow for water intensive community growth as a standalone alternative. However, it could be a part of an overall portfolio that could provide this flexibility.
- There is not a strong water marketing component to this alternative unless the flows are used to mitigate use from a downstream location. This is already occurring, so no new water would be added to the supply.

ECONOMIC CRITERIA

- Cost estimates for this alternative have not been completed and are highly dependent on how the water rights are incorporated into an overall portfolio.
- Developing infrastructure at this location without considering other pieces of a portfolio may result in a much higher cost per ac-ft to develop this water.
- If the infrastructure used to treat, store, and convey this water was the same infrastructure used for other supplies, the costs could become more palatable.

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

OS3 Low Water Conservation Approach

LEGAL WATER RIGHTS RANKING

This alternative involves encouraging the City of Bozeman community to reduce water use. The Low Water Conservation Approach encourages the continuation of the Toilet Rebate program, assuming an additional 10% of accounts could be switched to high efficiency toilets, the City adds to its education program budget and begins doing some basic promotion of water saving efforts in the community, and relies on a one of its current staff members to take on the role of part-time conservation specialist (estimated at about 25% of its time). Note that this option was developed using the Alliance for Water Efficiency Conservation Tracking Tool. It should be noted that from a legal perspective, there are no implications of water conservation as it pertains to water rights. It is also intended to be a sustainable practice and carries wide-spread benefits that could impact the City utility wide.

BACKGROUND INFORMATION AND REFERENCES

- 2002 Water Conservation Plan
- Water Conservation Plan Technical Memorandum developed as part of this IWRP (note that additional references are outlined in this document of other utilities and programs used as a basis for developing a water conservation approach for the City of Bozeman.

WATER SUPPLY PLANNING CRITERIA

- Because this alternative is not a tangible supply, but a reduction in water use on a per capita basis, many of the criteria identified for this ranking category are not applicable.
- Reliability may be the most appropriate to discuss as most conservation programs to date have been developed primarily on assumptions and not well tracked in accordance with related successes. Shifts in the industry to address this issue are happening and have been proposed for the City of Bozeman as it pursues conservation. The predictions that have been made at this high level of planning are based on a broad set of assumptions that may or may not be directly applicable to the City of Bozeman, itself.
- Pilot study efforts and water use monitoring are recommended with any conservation program the City pursues in the future to make sure that goals are being achieved.
- The low range water conservation scenario is based on 10-years of implementation and results in 235 ac-ft per year, by the end of the 10-year period. At a 2025 population (assuming the program begins in 2015), this reduces water demands by 3% and drops the climate adjusted baseline planning demand to 169 gpcd.

TECHNICAL CRITERIA

- This alternative is technically feasible
- It does not meet 30-year and 50-year planning criteria
- While it does not serve as a redundant supply, it translates into supply that is never needed and as such, acts similar to a redundant supply in overall application.

ENVIRONMENTAL CRITERIA

- Environmental Benefits of Conservation are significant. If more water is left in the watershed, water quality of the East Gallatin is likely to improve due to increased dilution.
- No infrastructure must be constructed to account for increased water.
- No permitting is required for reducing water use.
- In-stream flows are impacted positively as more water is left in the watershed.
- Natural systems are maintained at their current status and the likelihood of having to impact them in the future is less.
- The carbon footprint of conservation is reduced. Less water is treated, less energy is needed to convey the water to customers, new infrastructure is delayed, and less energy is needed to treat the water at the City's wastewater treatment plant.
- For this particular alternative, the comparative acre-ft reduction is likely to have limited environmental impacts due to its relatively small amount when compared to the water that will be necessary to continue to serve a growing population.

SOCIAL CRITERIA

- Public support for conservation measures can be mixed. In some cases, not enough effort is placed on conservation to obtain support for the concept as a benefit to the community. In others, so much pressure can be placed on the community to take on the responsibility of using less water that the public can be resistant and unsupportive of the efforts.
- For the City of Bozeman, the key will be to finding the correct balance of water conservation goals and public support. The Bozeman community is anticipated to be more supportive of a community due to its makeup than others.
- It is anticipated that the low scenario would be supported, but would not excite the community enough to begin taking conservation to the next level on its own.
- There are no water marketing components to this alternative.
- The reduction in water use is not enough to provide the flexibility necessary for addressing water intensive development in the future on its own. It would need to be combined with other alternatives in a portfolio.

ECONOMIC CRITERIA

- Cost estimates for this alternative have been completed, assuming continued toilet rebates, enhanced education, and use of 25% of a current FTE for the City to manage the conservation program. The associated 10-year cumulative cost (in 2013$) = $594,550.
- A total cost per acre-ft of this conservation program is $2,531 per acre-ft.
- Note that the above cost does not include the impacts of reduced treatment at the water and water reclamation facilities or the reduced cost of conveying the water to the community.
- It also does not consider the one-time costs of having to purchase the comparative rights or evaluate the cost impacts of delayed infrastructure.

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

OS4 Medium Water Conservation Approach

LEGAL WATER RIGHTS RANKING

This alternative involves encouraging the City of Bozeman community to reduce water use. The Medium Water Conservation Approach developed a full list of conservation measures and assumed a typical percentage of households and commercial entities implement the proposed conservation measures. It covered indoor and outdoor conservation, pricing modifications, education, and assumed up to two full time conservation program specialists over the course of the program. Note that this option was developed using the Alliance for Water Efficiency Conservation Tracking Tool. It should be noted that from a legal perspective, there are no implications of water conservation as it pertains to water rights. It is also intended to be a sustainable practice and carries wide-spread benefits that could impact the City utility wide.

BACKGROUND INFORMATION AND REFERENCES

- 2002 Water Conservation Plan
- Water Conservation Plan Technical Memorandum developed as part of this IWRP (note that additional references are outlined in this document of other utilities and programs used as a basis for developing a water conservation approach for the City of Bozeman.

WATER SUPPLY PLANNING CRITERIA

- Because this alternative is not a tangible supply, but a reduction in water use on a per capita basis, many of the criteria identified for this ranking category are not applicable.
- Reliability may be the most appropriate to discuss as most conservation programs to date have been developed primarily on assumptions and not well tracked in accordance with related successes. Shifts in the industry to address this issue are happening and have been proposed for the City of Bozeman as it pursues conservation. The predictions that have been made at this high level of planning are based on a broad set of assumptions that may or may not be directly applicable to the City of Bozeman, itself.
- Pilot study efforts and water use monitoring are recommended with any conservation program the City pursues in the future to make sure that goals are being achieved.
- The medium range water conservation scenario is based on 10-years of implementation and results in 1,264 ac-ft per year, by the end of the 10-year period. At a 2025 population (assuming the program begins in 2015), this reduces water demands by 14% and drops the climate adjusted baseline planning demand to 149 gpcd.

TECHNICAL CRITERIA

- This alternative is technically feasible and leaves some options in the technical approach that encourage flexibility. If one approach doesn't work, another could be developed.
- It meets the 30-year, but not 50-year planning criteria
- Although not redundant, it translates into supply that is never needed.

ENVIRONMENTAL CRITERIA

- Environmental Benefits of Conservation are significant. If more water is left in the watershed, water quality of the East Gallatin is likely to improve due to increased dilution.
- No infrastructure must be constructed.
- No permitting is required for reducing water use.
- In-stream flows are impacted positively as more water is left in the watershed.
- Natural systems are maintained at their current status and the likelihood of having to impact them in the future is less.
- The carbon footprint of conservation is reduced. Less water is treated, less energy is needed to convey the water to customers, new infrastructure is delayed, and less energy is needed to treat the water at the City's wastewater treatment plant.
- For this particular alternative, the comparative acre-ft reduction would have a more appreciable beneficial impact to the environment as it will save over 4 times the water to the low conservation scenario.

SOCIAL CRITERIA

- Public support for conservation measures can be mixed. In some cases, not enough effort is placed on conservation to obtain support for the concept as a benefit to the community. In others, so much pressure can be placed on the community to take on the responsibility of using less water that the public can be resistant and unsupportive of the efforts.
- For the City of Bozeman, the key will be to finding the correct balance of water conservation goals and public support. The Bozeman community is anticipated to be more supportive of a community due to its makeup than others.
- It is anticipated that the medium scenario would be well supported by the community and perhaps inspire some to take it to the next level, allowing for better success than the targeted goal.
- Water conservation marketing components could be incorporated into this alternative.
- Water rates may increase under this alternative.
- There may be some increased flexibility for supporting water intensive development in the future, but not a lot.

ECONOMIC CRITERIA

- Cost estimates for this alternative have been completed. The associated 10-year cumulative cost (in 2013$) = $4.67 Million.
- A total cost per acre-ft of this conservation program is $3,541 per acre-ft.
- Note that the above cost does not include the impacts of reduced treatment at the water and water reclamation facilities or the reduced cost of conveying the water to the community.
- It also does not consider the one-time costs of having to purchase the comparative rights or evaluate the cost impacts of delayed infrastructure.

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City of Bozeman, MT

Integrated Water Resources Plan Alternatives

OS5 High Water Conservation Approach

LEGAL WATER RIGHTS RANKING

This alternative involves encouraging the City of Bozeman community to reduce water use. The High Water Conservation Approach developed a full list of conservation measures and assumed a more aggressive percentage of households and commercial entities implement the proposed conservation measures. It also expanded outdoor conservation to include a large land turf replacement program. It assumes the City of Bozeman would employ up to three full time conservation program specialists over the course of the program. Note that this option was developed using the Alliance for Water Efficiency Conservation Tracking Tool. It should be noted that from a legal perspective, there are no implications of water conservation as it pertains to water rights. It is also intended to be a sustainable practice and carries wide-spread benefits that could impact the City utility wide.

BACKGROUND INFORMATION AND REFERENCES

- 2002 Water Conservation Plan
- Water Conservation Plan Technical Memorandum developed as part of this IWRP (note that additional references are outlined in this document of other utilities and programs used as a basis for developing a water conservation approach for the City of Bozeman.

WATER SUPPLY PLANNING CRITERIA

- Because this alternative is not a tangible supply, but a reduction in water use on a per capita basis, many of the criteria identified for this ranking category are not applicable.
- Reliability may be the most appropriate to discuss as most conservation programs to date have been developed primarily on assumptions and not well tracked in accordance with related successes. Shifts in the industry to address this issue are happening and have been proposed for the City of Bozeman as it pursues conservation. The predictions that have been made at this high level of planning are based on a broad set of assumptions that may or may not be directly applicable to the City of Bozeman, itself.
- Pilot study efforts and water use monitoring are recommended with any conservation program the City pursues in the future to make sure that goals are being achieved.
- The high range water conservation scenario is based on 10-years of implementation and results in 3,185 ac-ft per year, by the end of the 10-year period. At a 2025 population (assuming the program begins in 2015), this reduces water demands by 44% and drops the climate adjusted baseline planning demand to 114 gpcd.

AE2S Think Big. Go Beyond. CH2MHILL Water Right Solutions Inc.

TECHNICAL CRITERIA

- This alternative is technically feasible, but will be technical intensive to make successful.
- It meets the 30-year, but not 50-year planning criteria
- While it does not serve as a redundant supply, it translates into supply that is never needed and as such, acts similar to a redundant supply in overall application.

ENVIRONMENTAL CRITERIA

- Environmental Benefits of Conservation are significant. If more water is left in the watershed, water quality of the East Gallatin is likely to improve due to increased dilution.
- No infrastructure must be constructed.
- No permitting is required for reducing water use.
- In-stream flows are impacted positively as more water is left in the watershed.
- Natural systems are maintained at their current status and the likelihood of having to impact them in the future is less.
- The carbon footprint of conservation is reduced. Less water is treated, less energy is needed to convey the water to customers, new infrastructure is delayed, and less energy is needed to treat the water at the City's wastewater treatment plant.
- For this particular alternative, the comparative acre-ft reduction would have a more appreciable beneficial impact to the environment as it will save over 10 times the water to the low conservation scenario.

SOCIAL CRITERIA

- Public support for conservation measures can be mixed. In some cases, not enough effort is placed on conservation to obtain support for the concept as a benefit to the community. In others, so much pressure can be placed on the community to take on the responsibility of using less water that the public can be resistant and unsupportive of the efforts.
- For the City of Bozeman, the key will be to finding the correct balance of water conservation goals and public support. The Bozeman community is anticipated to be more supportive of a community due to its makeup than others.
- It is anticipated that the high scenario may be supported by some members of the community, but will likely not be supported by all of the community.
- Water conservation marketing components could be incorporated into this alternative.
- Water rates would likely increase under this alternative.
- The increased flexibility may be tempered by restrictive water use policies.

ECONOMIC CRITERIA

- Cost estimates for this alternative have been completed. The associated 10-year cumulative cost (in 2013$) = $16.45 Million.
- A total cost per acre-ft of this conservation program is $5,164 per acre-ft.
- Note that the above cost does not include the impacts of reduced treatment at the water and water reclamation facilities or the reduced cost of conveying the water to the community.
- It also does not consider the one-time costs of having to purchase the comparative rights or evaluate the cost impacts of delayed infrastructure.

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SCREENING LEVEL #1 ~ Water Rights Legal Assessment

Green Project ~ Meets Water Rights Laws, Developable Resource

Yellow Project ~ Does not meet Water Rights Laws, but may be Possible to Change

Red Project ~ Does not meet Water Rights Laws, and is Unlikely or Impossible to Change

Note: Green Projects Move Forward, Yellow Projects May Move Forward, Red Projects Eliminate

SCREENING LEVEL #2 ~ Qualitative Criteria

Note: Criteria Above a Certain Threshold will be Moved into Conceptual Cost Development

	TAC	TECHNICAL TEAM
Categories of Evaluation Criteria	**Weight (%)**	**Score**
Technical Criteria		
Environmental Criteria		
Social Criteria		
Economic Criteria		
Total (must equal 100%)	**100%**	

Technical Criteria	**Weight (%)**	**Score**
Constructability		
Regulations and Drinking Water Quality Impacts		
Existing Infrastructure Compatibility		
Water Ruse		
Water Supply Redundancy		
Meets 30-Year Planning Horizon Targets		
Meets 50-Year Planning Horizon Targets		
Total (must equal 100%)	**100%**	
Environmental Criteria	**Weight (%)**	**Score**
Clean Water Act Compliance (TMDLs)		
In-stream Flow Maintenance		
Permitting, Environmental Impact Statements, and Easements		
Climate Impacts Resiliency		
Energy Requirements		
General Environmental Impacts (Wildlife, Forested Areas)		
Total (must equal 100%)	**100%**	
Social	**Weight (%)**	**Score**
Customer Service Satisfaction		
Public Health and Safety		
Quality of Life Impacts		
Overall Public Support		
Economic Development and Growth		
Total (must equal 100%)	**100%**	
Economic	**Weight (%)**	**Score**
Magnitude of Capital Investment per Acre-ft of Developable Water Supply		
Relative Operation and Maintenance Costs		
Eligibility for Outside Funding		
Economy of Scale Impacts		
Delay of Infrastructure to Encourage Growth to Pay for Growth		
Total (must equal 100%)	**100%**	

SCREENING LEVEL #3 ~ Cost Analysis

Conceptual Capital Costs

Conceptual O&M Costs

Life Cycle Costs

$/Acre-Foot Cost

SCORING APPROACH:

The TAC and Technical Team will independently apply points to each of the ranking categories noted above so that a project that receives full points in every category for each heading (Technical, Social, Environmental, and Economic) would receive 100 points. The TAC and Technical Team will develop two scoring approaches independent of the other. To facilitate this process, the Technical Team has already developed a draft of its scoring approach and will work with the TAC during TAC Meeting #1 to verify the scoring categories and moderate the development of the TAC scoring approach. The Technical Team scoring approach will be finalized with the finalization of the ranking criteria to meet the objectives of the scoring process.

Once the scoring approach is established, each of the alternatives to be considered will have ***up to*** the score for each category applied based on each individual evaluator's best judgment. The individual scores will then go into a spreadsheet and be totaled to identify the projects that have the highest qualitative score of the alternatives considered. This process has successfully been applied in other Integrated Water Resources Planning efforts to capture the intrinsic differences between the experiences, exposure, and priorities of a broad spectrum of professionals tasked with long-range, big picture, planning efforts.

The following descriptions of each scoring category are provided to assist in standardizing the interpretations of each of the categories listed above. Note that alternatives should be scored as they relate to each other. In cases where alternatives qualitatively address the ranking category in the same way, the same scores can be applied. However, every attempt should be made to do a comparative analysis of the alternatives to be considered.

Constructability

To receive points for constructability, the evaluator should consider the process of physically constructing an alternative. For example:

- Would the construction site for the project have accessibility issues?
- Are the site conditions where the alternative will be located unknown, challenging, or dangerous?
- Does the alternative require specialized and unique construction strategies that may be difficult and costly to bring to Montana?
- Are there barriers to construction, such as natural features (mountains, rivers, lakes, wetlands, etc.)
- Would there be any timing/seasonal issues that could make constructing an alternative more challenging?
- Will alternative construction involve construction related inconveniences to the public?

Any of the above types of considerations, or others that are similar in nature to the construction of an alternative should result in a reduction in total allowable points for this category.

Regulations and Drinking Water Quality Impacts

To receive points for this category, the evaluator should consider the following:

- Is the proposed water supply consistent with current water supplies for which treatment processes are already in place to treat the water to existing potable drinking water regulations?
- Can treatment processes be constructed to treat the proposed water source to existing potable drinking water regulations?
- Are there regulatory issues with the water supply that will result in regulatory issues in the future and may have public health impacts if implemented prior to regulations being put into place (endocrine disruptors, human health standards for nitrates, cytotoxins (algae) by-products, high organic carbon or organic matter, requiring unique disinfection strategies with byproducts that could be regulated more stringently in the future, etc.).

Higher points should be given to alternatives where water quality is known and regulations can thoroughly be addressed now, with the flexibility to address them into the future as they change.

Existing Infrastructure Compatibility

This category will require that that evaluator consider whether the proposed alternative optimizes use of existing infrastructure. For example:

- Does the proposed solution allow for full utilization of the City of Bozeman WTP that is under construction? The facility is being constructed to a peak capacity of 22 mgd and consists of membrane treatment technologies designed to water quality standards associated with Bozeman Creek, Middle Creek, and Hyalite Reservoir.
- Is there infrastructure already in place to deliver water to the distribution system and serve the different zones of the system effectively?
- Can new infrastructure be constructed to complement the existing infrastructure? If so, rank the alternatives in term of general feasibility of the infrastructure necessary as they compare to each other.

Water Ruse

Does the proposed solution involve a water reuse component, particularly one associated with effluent from the Bozeman Water Reclamation Facility?

- Does the proposed project assist in compliance with the City's Wastewater Permit?
- Is the proposed solution acceptable to the general public?
- Does the solution provide a non-potable water supply to another water rights hold that could then contract its water right to the City for drinking water purposes?

Water Supply Redundancy

A redundant water supply should not only be considered in terms of overall quantity of water from one source (i.e. the source has twice the water in reserve than necessary to serve the community in dry year), but more appropriately:

- Are the supplies developed in two (or more) distinct water sources that have different responses to climate conditions, different delivery mechanisms to the system, different treatment needs, and can effectively replace the other in the event of an emergency (i.e. fire in the Bozeman Creek/Hyalite Watershed, contamination of the water supply, slope failure in Bozeman Creek resulting in temporary loss of the stream, failure of the treatment process equipment, prolonged drought, etc.)?

Meets 30-Year Planning Horizon Targets

Does this Alternative provide enough water supply to meet water demand and population targets that have been established for this study effort in the 30-Year Planning Horizon? If not, could it be combined with other alternatives to accomplish this objective?

Meets 50-Year Planning Horizon Targets

Does this Alternative provide enough water supply to meet water demand and population targets that have been established for this study effort in the 30-Year Planning Horizon? If not, could it be combined with other alternatives to accomplish this objective?

Clean Water Act Compliance (TMDLs)

Does this alternative have components that can assist in watershed water quality improvements, particularly as they relate to various TMDLs (Nutrient, Sediment, and E.Coli) in the Lower Gallatin Watershed? Examples include:

- Wastewater Reuse to prevent discharge of wastewater into the East Gallatin River during Seasonal Permitted Conditions
- Application of reuse water in a manner that reduces the use of chemical fertilizer applications
- Reduction of direct stormwater discharge to local streams
- Provision of augmentation flows to increase low flow conditions in areas of the watershed where water quality impairments could be a challenge (i.e. an out-of-basin import project or impoundment constructed with additional capacity to maintain minimum stream flows at a healthy level could be an example. While this would not offset water supplies, it may be possible to put existing or new water supplies to use under different conditions either on a temporary or permanent basis to achieve this type of compliance objective in the future).

In-Stream Flows

Does the proposed project have the potential to compromise in-stream flows during low flow conditions? Does the proposed project have the potential to add flexibility in mitigating instream flow issues during low flow conditions?

Permitting, Environmental Impact Statements, and Easements

Does the proposed alternative require an extensive permitting, environmental clearance, and easement development process? If so, does the extent of this effort carry risk that the alternative may not be viable or carry with it, the possibility of legal action against the City? If a permit or easement cannot be developed for an alternative, or environmental issues result in a need to modify the alternative, can the alternative be modified to address the concern?

Climate Resiliency

Is the proposed alternative capable of sustaining reasonable service levels with regard to the potential range of long-term climate impacts? If so, can it also withstand temporary and harsher climate conditions such as drought? Is the water supply able to return to normal conditions relatively quickly after drought events?

Energy Requirements

Does the raw water supply delivery system associated with the proposed alternative require extensive pumping and energy requirements? Will new treatment processes be required that could involve increased mechanical treatment and energy requirements to meet drinking water regulatory requirements? Could the new water supply be used to generate energy?

General Environmental Impacts (Forests, Wildlife, Water Quality, etc.)

Does the project have the potential to have a significant impact on local forested areas, fish and wildlife, historical and cultural resources, and water quality?

Customer Service Satisfaction

Will the proposed solution result in acceptable levels of customer satisfaction with regard to aesthetics, water quality and quantity, and cost? How will it compare to the service levels that customers are accustomed to, today?

Public Health and Safety

Outside of regulatory requirements and potable drinking water quality (which were addressed in previous categories), does the proposed alternative present any public health and safety concerns? For example, a reservoir above the City could pose some flood risk if a breach were to occur. Operator safety in maintaining and managing an alternative could be considered in this category as well.

Quality of Life Impacts

Would the water supply alternative carry any impacts that could increase or decrease the quality of life for the City of Bozeman. In the case of an impoundment, could it be used for recreational activities, or does it limit or eliminate recreational activities? Could it be used to sustain a recreational activity that may use large amounts of water (i.e. golf course or park irrigation)? Does developing a large, imported water supply encourage growth that impairs quality of life in Bozeman, or does it allow for structured growth that will continue to attract people to the area that will enhance the quality of life of those in Bozeman? While there are many ways that this category could be scored, it should be scored relative to the other alternatives evaluated, to the greatest extent possible.

Overall Public Support

Does the proposed alternative seem consistent with public sentiment from past water supply planning efforts in regards to what a final project should consider? Does it feel like a project that the City of Bozeman community would generally support, fund, and advocate for in the future.

Economic Development and Growth

Does the proposed alternative include components that will hinder Economic Development and Growth in any way? For example, would the proposed alternative improve or sustain recreational opportunities based on use of our local water supply resources? Would the alternative allow for flexible and appropriate Economic Development and Growth in the City of Bozeman? Would moratoriums on certain types of service sectors be a possibility under certain conditions? If the baseline planning conditions set forth in this study effort are no longer applicable due to unanticipated growth, increased water use, climate, or natural disaster, does the proposed alternative provide flexibility to adapt? Is the alternative easily expandable to allow for large water using industries to locate to the Bozeman area, if desired? Can it accommodate unpredictable swings in growth, both through expansion to serve new growth and overall cost considerations to minimize the pressures of building large infrastructure projects for future populations that don't develop as planned? Can it be combined with other solutions to delay the project until constructing the project is necessary without sacrificing service levels?

Magnitude of Capital Investment per Acre-ft of Developable Water Supply

Although cost information is not available for all alternatives at this level of the alternatives evaluation, the goal of this category is to provide relative consideration for each alternative as they compare to each other. In general, ranges of developable acre-ft for each alternative are provided in the alternative information. The goal of this category is to consider levels of investment versus the amount of water and flexibility that could be developed. For example, the Sourdough Creek Reservoir Project has included cost estimates of $50 to $70 million dollars for a possible 6,000 ac-ft of water supply. While the alternative evaluation will place some risk on the potential for 6,000 ac-ft (there is some concern regarding the potential of securing the full amount, or any of the 6,000 ac-ft due to water rights law in Montana), in the event that this project could be completed, this results in a range of $8,333/ac-ft to $11,666/ac-ft. Likewise, the current cash in-lieu program charges developers $6,000/ac-ft or the relinquishment of water rights equal to what is necessary to serve the development so that new water rights could be purchased. Likewise, a large development project, such as an import project, may run well over $100 million (perhaps even $200 million) dollars, but result in the development of 30,000 acre-ft, for a relative cost per ac-ft of much less than the alternatives.

Relative Operation and Maintenance (O&M) Costs

While detailed O&M costs have not been developed at this time, the evaluator should consider whether extensive O&M will be required for various alternatives. Will new treatment be necessary? Will pumping be necessary? Will additional staff be required?

Eligibility for Outside Funding

Would the proposed alternative be eligible for funding assistance to offset the rate impacts of the project to the City of Bozeman rate payers? Projects that involve regional approaches and address water issues across service sectors (service sectors being municipal, industrial, agricultural, and natural) could be projects that would be eligible for federal and possibly even special State grant funding. The Red River Valley Water Supply Project in North Dakota imports water from the Missouri River to the Red River and is funded through a cost share of 1/3rd federal, 1/3rd state, and 1/3rd local funding. The local portion is allocated based on water reserved from the project by each community participating. Other examples of regional funding programs could be discussed, such as the Rocky Boy's/North Central Montana Regional Water System Project, the Lewis and Clark Regional Water System Project (South Dakota), the Western Area Water Supply Project (WAWSP), in Northwestern North Dakota, etc. While some of these projects have unique circumstances that may not make their strategies directly applicable to a regional project in the Gallatin Valley, these projects are coordinated with the Bureau of Reclamation and funding for both collaborative planning efforts and future projects has been available in the past, is available now, and could be developed in the future. The extent of outside funding would need to be further explored, but some alternatives considered as part of this study effort could be eligible for funding, where others will primarily be the City of Bozeman's responsibility to fund.

Economy of Scale Impacts

A project that can be constructed to serve a larger population base now and in the future will result in economy of scale benefits. The evaluator should consider the population that could be served by each alternative in relationship to the cost of constructing and operating the system. Although one project may be more expensive up front, if it can serve a larger population over the long-term, a cost/benefit analysis may result in the more costly alternative in the future.

Delay of Infrastructure to Encourage Growth to Pay for Growth

This ranking category will mostly be associated with alternatives that involve phasing, organizational mechanisms, or temporary solutions that allow for the delay of infrastructure construction until the population is in place to support the project. Not all alternatives will receive scores in this category.

APPENDIX D

City of Bozeman Integrated Water Resources Plan Portfolio Analysis Model

City of Bozeman Integrated Water Resource Plan – Portfolio Analysis Model

PREPARED FOR: AE2S, City of Bozeman

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DATE: July 18, 2013

Introduction

This technical memorandum describes the portfolio analysis conducted by CH2M HILL in support of the City of Bozeman's Integrated Water Resource Plan.

CH2M HILL's Voyage™ model, a dynamic water balance simulation tool built in the commercial ExtendSim software, was selected as the appropriate mechanism for conducting portfolio analysis. The customized model was built to represent the expected demands, possible conservation programs, current and future supplies for Bozeman. Further description of the demand projections, conservation program options and firm yield from current supplies is provided elsewhere in the project report.

Objectives

There are four objectives for the portfolio modeling exercise:

1. Evaluate supply and demand seasonality to produce a monthly water balance over the planning period;
2. Estimate lifecycle costs for each portfolio
3. Estimate timing of required expansions or new supplies and associated capital costs;
4. Develop recommendations for the best value portfolio to meet Bozeman's long term objectives.

Water Supply Portfolio Analysis

Portfolio Summary

The Technical Advisory Committee (TAC), city staff, and consultant team identified 13 portfolios to be evaluated with the dynamic simulation model. These Portfolios reflect various combinations of demand projections, conservation programs, and water supply alternatives.

Water Supply Alternatives Comprising the Portfolios

Seven new water supply alternatives are included in the portfolios. A brief description of the infrastructure or other requirements included in each alternative is provided in Table 1.

TABLE 1. NEW WATER SUPPLY ALTERNATIVES

Alternative Name	Description
Sourdough Creek Impoundment	Construct new storage impoundment(s) on Sourdough Creek, convey to existing water treatment plant.
Confluence Import from Canyon Ferry	Construct new treatment facility and 42" pipeline to convey treated water to Bozeman distribution system.
Groundwater in Gallatin Gateway subarea	Drill new groundwater wells, pump water to existing treatment plant. Includes some operational storage.

TABLE 1. NEW WATER SUPPLY ALTERNATIVES

Alternative Name	Description
Agricultural impoundment	Construct new impoundment to supply non-potable quality water for agricultural irrigation.
Purchase of Shares from Hyalite	Purchase additional water rights from Hyalite reservoir. Ice protection for withdrawal during winter months included.
Non-Potable Irrigation water	Construct non-potable water distribution system in new developments.
Lyman Creek expansion	Expand treatment capacity of existing Lyman treatment plant by constructing new raw water intake, conveying raw water to a new 10 million gallon concrete storage reservoir, adding a new chlorine and fluoride injection facility, and a new parallel pipeline to connect to the distribution system.

Additional shares from Hyalite, the agricultural impoundment, Gallatin groundwater and Sourdough Creek storage are all new raw water sources that were assumed to be treated at the Sourdough Water Treatment Plant. Portfolios requiring more than 22 mgd of water from the Sourdough Plant will trigger expansion of that facility to the maximum capacity of 36 mgd for which it is designed.

Initial Portfolio Contributions based on Annual Water Balance

New portfolios were initially developed based on an annual water balance designed to meet 2062 demands. The proposed annual volume of water contributed by each new supply and conservation is summarized in Table 2. Shaded columns indicate portfolios to meet high growth demands.

TABLE 2. INITIAL PORTFOLIO CONTRIBUTIONS BASED ON ANNUAL WATER BALANCE (YEAR 2062)

Alternative	1	2	3	4	5	6	7	8	9	10	11	12	13
	Acre-Feet of Water from Each Alternative												
Sourdough Creek Impoundment								6,000					
Import from Canyon Ferry				20,000									
Groundwater in Gallatin Gateway					13,714	9,062	6,179						
Agricultural impoundment										2,700			2,700
Purchase Shares from Hyalite	1,765	1,792	650	650	650			650	650	650	650	650	650
Non-Potable Irrigation water									4,000			4,000	
Lyman Creek expansion	3,165							3,165			3,165	3,165	3,165
Low Conservation	2,770			4,806	4,806								2,770
Medium Conservation		5,908				10,108		10,108	3,058	5,908	5,908		
High Conservation			8,218				12,991						
Total Portfolio	**7,700**	**7,700**	**8,868**	**23,420**	**19,170**	**19,170**	**19,170**	**19,923**	**7,708**	**9,258**	**9,723**	**7,815**	**9,285**

Planning Period and Model Time Step

The modelling exercise evaluates portfolio performance over a 52 year planning period starting in 2010 and terminating in 2062.

The model evaluates supplies, demands, and costs on a monthly time step.

Evaluation Process

The model was first used to check whether each portfolio, as described in Table 2, would work on a monthly basis after seasonality of conservation measures, supplies, and demands were taken into consideration. The model calls on existing supplies to fulfil demands (after accounting for reduced demand due to conservation). Unmet demands are then filled by new supplies according to each portfolio.

The amount of water called for from each new supply was then adjusted to provide adequate water to balance each portfolio on a monthly basis. These adjustments were made based on assumptions about operational constraints and end-uses of water from a given source. Hyalite reservoir, the agricultural impoundment, Sourdough Creek impoundments, and Gallatin Gateway groundwater were all assumed to have full operational flexibility to withdraw as much water as needed in a given month (up to an annual maximum) to meet demands. The Lyman system was assumed to have no operational flexibility due to the presence of ice instead of flowing water in winter and shoulder months, as experienced in recent years.

Net present value lifecycle costs for each balanced portfolio were then determined and used to calculate dollars per acre-foot of new water supply delivered in 2062 for each portfolio. These costs were graphed against the benefit scores determined by the TAC. The cost/benefit graph was used to identify which of the portfolios provide the highest value and to develop a recommendation for a diverse and resilient portfolio that could adapt over time to actual growth, demand, and supply variability.

Lifecycle Cost

Lifecycle costs include capital cost and operating cost for each new supply component of a portfolio, including the water conservation program. Details about specific components of the lifecycle costs included for each new water supply are provided in the Cost Basis section of this memorandum.

Costs for new supplies are not incurred until water from that supply is required to meet demands. Costs for the conservation program were calculated on an annual basis and were assumed to begin in 2013. Annual costs vary over the ten-year program implementation period as the individual conservation measures are implemented, and then continue at a constant rate to reflect the cost of personnel and public information materials through the duration of the planning period. Further detail about the conservation program costs are provided elsewhere in the project report

Lifecycle costs were converted to net present value in 2012 dollars to provide an apples-to-apples basis for comparing the portfolios using a discount rate of 1.5 percent per year.

Benefit Score

Overall benefit scores based on scores provided by individual members of the TAC were used in the portfolio evaluation process. Scores from individual members were combined into one score representing the entire committee. Discussion of the evaluation criteria, weighting, and scoring process is provided elsewhere in this report. The overall benefit score for each Portfolio used in the evaluation process is summarized in the Cost/Benefit comparison section of this memorandum. Aggregate scores for portfolios were water volume-weighted by contributing supply alternative.

Model Inputs and Assumptions

The following sections describe the data inputs and assumptions used in the simulation model.

Existing Supplies

The City of Bozeman currently draws water from four sources: Hyalite Reservoir, Lyman Creek, Sourdough Creek, and Middle Creek (aka Hyalite Creek). For purposes of determining unmet demand which must be supplied by new water sources, each existing source was considered to have a firm yield – a maximum amount of water that could be supplied by that source in a given month. An update to the City's previous Firm Yield analysis provided in its 1997 Water Facility Plan was undertaken as part of the Integrated Water Resource Plan. Part of this update included adjusting expected future firm yield from Middle Creek and Sourdough Creek to account for climate change effects to hydrology. Although the Lyman system may in fact respond to reduced precipitation, it was assumed that Hyalite and Lyman are unaffected by climate change in the future. Discussion of the firm yield update is provided in a previous section of the project report. Climate adjusted values were used in the portfolio analysis.

Firm Yield

Monthly firm yield values used in the model for each individual supply are summarized in Table 3. Total firm yield values for climate-adjusted supplies (Middle and Sourdough Creek) and the total value are reported for the beginning of the model simulation period (2010), the mid-term planning horizon (2042), and at the end of the planning period (2062) to show the decrease in firm yield over time due to climate change adjustment.

TABLE 3. FIRM YIELD OF INDIVIDUAL EXISTING SUPPLIES (AC-FT)

Month	Hyalite Reservoir[1]	Lyman Creek	Middle Creek			Sourdough Creek		
			2010	2042	2062	2010	2042	2062
January	0	91	186	171	150	290	267	235
February	0	87	168	154	136	266	245	216
March	0	83	212	236	304	332	369	475
April	0	72	106	122	128	331	381	400
May	26[1]	106	50	48	45	369	351	326
June	1,200	180	83	78	72	319	299	278
July	1,200	312	18	17	15	291	271	246
August	1,204	313	18	17	15	290	270	246
September	917	226	94	85	76	278	253	225
October	0	142	187	176	155	294	276	243
November	0	95	180	165	145	282	259	228
December	0	83	186	171	150	290	267	235

Notes:

1. May firm yield for Hyalite Reservoir was assumed to equal the demand unmet by other supplies for 2012.

TABLE 4. TOTAL FIRM YIELD EXISTING SUPPLIES (AC-FT)

Month	Total Firm Yield		
	2010	2042	2062
January	567	529	476
February	521	486	438
March	627	687	862

TABLE 4. TOTAL FIRM YIELD EXISTING SUPPLIES (AC-FT)

	Total Firm Yield		
Month	2010	2042	2062
April	509	575	600
May	552	531	503
June	1,781	1,757	1,731
July	1,821	1,800	1,774
August	1,825	1,804	1,778
September	1,515	1,481	1,444
October	623	595	540
November	556	519	468
December	559	521	468

Seasonality

Seasonality of the existing supplies is reflected in the values reported in Table 4. High values in summer reflect current operations of Hyalite Reservoir which is drawn upon to fulfil peak demands.

Demand

The model portfolios reflect either medium or high growth and a 95% service level based on average historical water use. Demands were adjusted from historical trends to account for increases in irrigation demands resulting from global climate model predictions of warmer temperatures in earlier months and reduced precipitation over the course of the year. Climate-adjusted demands used in the model for each growth scenario are summarized in Table 5. Monthly demands are reported for the beginning of the model simulation period (2010), the mid-term planning horizon (2042), and at the end of the planning period (2062).

TABLE 5. TOTAL DEMAND FOR MEDIUM AND HIGH GROWTH SCENARIOS (AC-FT)

	Medium Growth			High Growth		
Month	2010	2042	2062	2010	2042	2062
January	378	667	803	378	877	1,278
February	397	698	840	397	917	1,336
March	386	681	819	386	894	1,304
April	385	689	919	385	904	1,460
May	588	1,121	1,463	588	1,485	2,356
June	722	1,382	1,861	722	1,823	2,981
July	1,093	2,169	2,988	1,093	2,878	4,819
August	1,057	2,093	2,931	1,057	2,774	4,723
September	787	1,540	2,100	787	2,040	3,380
October	456	835	1,165	456	1,099	1,859
November	389	681	818	389	892	1,297
December	375	667	803	375	878	1,283

Seasonality

Seasonality of demands is reflected in the values reported in Table 5, showing higher use in summer months due to irrigation demands, and lower use in winter months when there is no irrigation occurring.

Conservation Reduction

Conservation Scenarios and Gross Conservation Reduction

The City has developed low, medium, and high conservation scenarios as described in a previous section of the project report. Each of the scenarios includes several individual conservation measures that will be phased in over a ten year implementation period. Conservation measures will continue to be practiced over the course of the planning period; therefore the conservation reduction to demand will grow in proportion to population (and the associated demand) growth.

The gross annual conservation reduction for each conservation scenario for both medium and high growth is provided in Table 6. Conservation reduction values are reported in acre-feet for the end of the conservation program implementation period (2023), the mid-term planning horizon (2042), and at the end of the planning period (2062).

TABLE 6. GROSS CONSERVATION REDUCTION (AC-FT)

Conservation Scenario	Medium Growth			High Growth		
	2023	2042	2062	2023	2042	2062
Low	715	2,013	2,770	726	2,838	4,806
Medium	1,622	4,282	5,908	1,618	5,921	10,108
High	3,250	6,369	8,218	3,233	8,240	12,991

Seasonality of Conservation Measures

Three of the conservation measures included in the medium and high conservation scenarios directly impact irrigation uses and will therefore only provide effective conservation during the summer irrigation months. The measures considered to directly impact irrigation uses are turf reduction (residential and commercial), pricing modifications, and watering restrictions. These outdoor measures result in a seasonal fluctuation to the overall conservation reduction, with more water being conserved in summer months. These measures are not included in the low conservation scenario and therefore there is no seasonal difference in conservation reduction for the low scenario.

The proportion of overall conservation made up by the outdoor measures decreases over time as more indoor measures are implemented. For the medium growth scenario, outdoor measures account for approximately 79 percent of the total conservation reduction at the beginning of the conservation program, decreasing to approximately 56 percent toward the end of the implementation period. For the high growth scenario, outdoor measures comprise approximately 75 percent of the conservation reduction at the beginning of the implementation period, decreasing to about 50 percent at the end. The seasonal fraction is assumed to remain constant after the 10-year implementation period. The fraction of the total conservation reduction contributed by outdoor measures is shown in Figure 1.

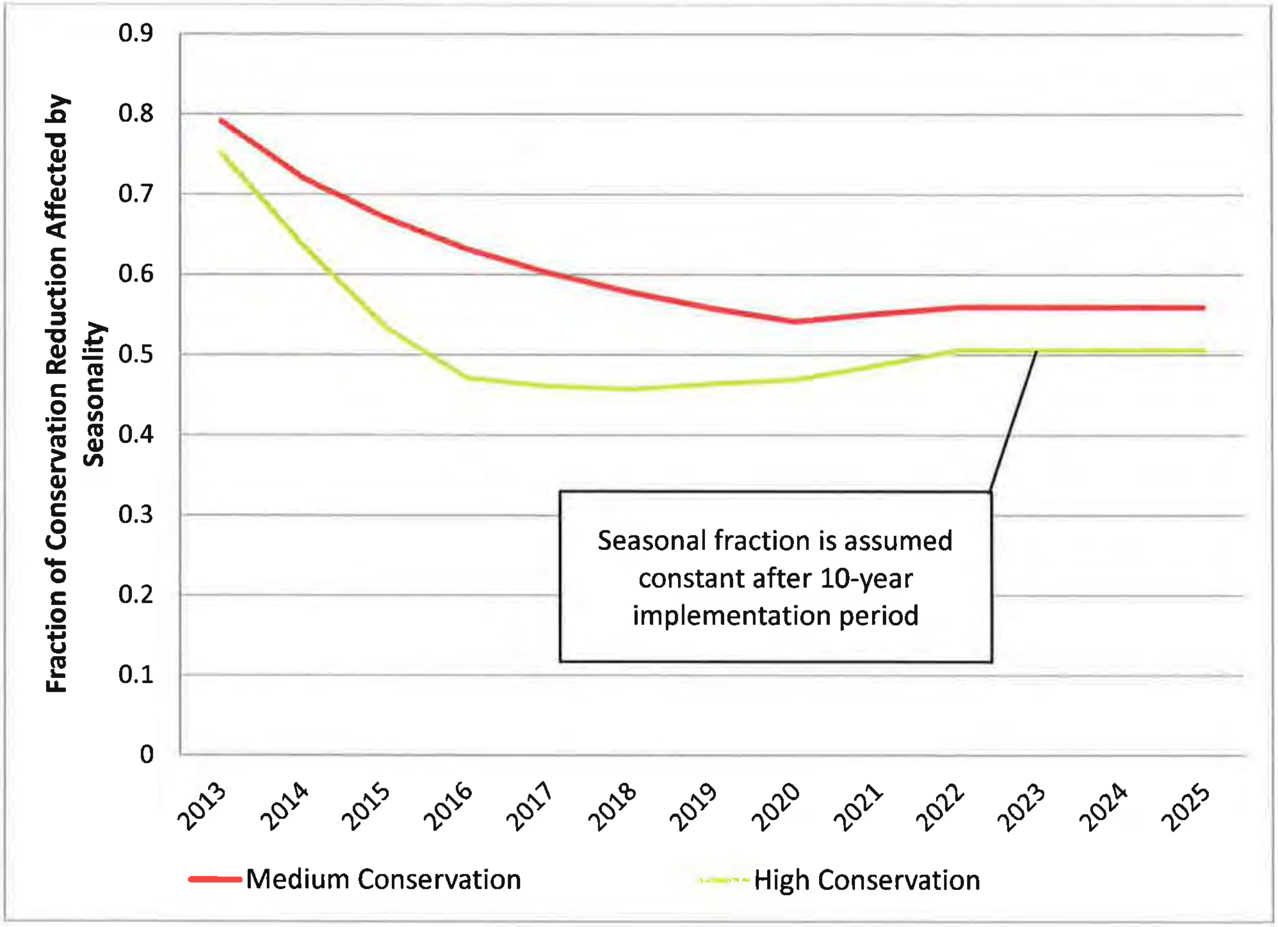

Figure 1. Fraction of Conservation Reduction contributed by Outdoor Measures

Net Conservation Reduction

The net conservation reduction is the amount of water conserved in a given month after accounting for seasonality of the conservation measures. The monthly net conservation reduction for each conservation scenario, for both medium and high growth, is summarized in Table 7. Net conservation reductions are reported for the end of the planning period (2062) and are provided on a monthly basis to illustrate the variability in the medium and high conservation scenarios due to outdoor measures. The low conservation scenario does not include outdoor measures and therefore the monthly values do not vary; each month is assumed to have 1/12th the total annual conservation reduction.

TABLE 7. NET CONSERVATION REDUCTION

	Net Conservation Reduction in 2062 – Medium Growth (ac-ft)			Net Conservation Reduction in 2062 – High Growth (ac-ft)		
Month	Low Conservation	Medium Conservation	High Conservation	Low Conservation	Medium Conservation	High Conservation
January	231	217	338	400	371	535
February	231	217	338	400	371	535
March	231	217	338	400	371	535
April	231	557	766	400	952	1,210
May	231	557	766	400	952	1,210
June	231	705	953	400	1,207	1,506

TABLE 7. NET CONSERVATION REDUCTION

Month	Net Conservation Reduction in 2062 – Medium Growth (ac-ft)			Net Conservation Reduction in 2062 – High Growth (ac-ft)		
	Low Conservation	Medium Conservation	High Conservation	Low Conservation	Medium Conservation	High Conservation
July	231	1,129	1,485	400	1,931	2,348
August	231	1,003	1,328	400	1,717	2,099
September	231	656	891	400	1,123	1,409
October	231	217	338	400	371	535
November	231	217	338	400	371	535
December	231	217	338	400	371	535
TOTAL	2,770	5,908	8,218	4,806	10,108	12,991

Cost Basis

Lifecycle costs over the 50-year planning period for the various portfolios were estimated using the information contained in Tables 8, 9 and 10. Table 8 provides costs for conservation, Table 9 provides detail for the capital cost components and Table 10 provides details about the operations and maintenance costs. Cost information was collected from a number of sources. It was not possible to fully equalize cost assumptions across source data, so certain inconsistencies exist. In some cases, costs developed for a specific project type and size were scaled linearly to a different capacity. It is understood that this is a significant assumption and further refinement of costs for recommended alternatives is strongly advised. In general, cost estimates at a conceptual level have accepted accuracy of -50% to +100% of the stated value. In that context, comparative cost estimates should be interpreted based on general ranking and order-of-magnitude values. Comparative costs only attempt to capture the major differentiating elements between alternatives, rather than the full cost of implementation. Net present value provides comparative data, excluding inflation, material shortages, or other factors that would affect the actual dollar cost at the time of expenditure.

TABLE 8. CONSERVATION COST BASIS

Conservation Scenario	Cost ($/AF saved)
Low	$620
Medium	$1,560
High	$1,750

TABLE 9. CAPITAL COST BASIS

New Supply/Expanded Facility	Total Capital Cost/AF	Engineering/Permitting/ Contingency or Other Allowance Included in Total	Water Rights Purchase Included in Total	Source of Information and Notes
Additional shares from Hyalite Reservoir	$6,000	None	Included	Email communication (April 08, 2013), City of Bozeman Water Treatment Superintendent.
Agricultural Impoundment	$9,900	8% mobilization, taxing, bonding, insurance; 20% contingency	Not included	Construction cost estimated from 3rd party document. Cost/AF based on project cost estimate of $27,695,146 for 2,806 AF capacity.
Gallatin Groundwater	$6,740	25%	Not included	Wellfield cost estimated from 3rd party document. Cost per acre-foot assume that each well operates 12/hr/day at 600 gpm and include $2,760,000 for electricity system expansion and storage (based on 2007 Belgrade Water Facility Plan). Total cost also includes $325,000/mile of collection piping, which varies with the number of wells required..
Lyman Expansion	$9,080	28% allowance for contractor markups on construction cost; 40% engineering/permitting/ legal	Assumed not to be needed	CH2M HILL cost estimating model (CPES), based on database of project costs adapted to specific location using industry standard location factors. Further detail included in City of Bozeman Cost Estimate and Assumptions memorandum included as an attachment to this memorandum.
Canyon Ferry Import	$17,590	28% allowance for contractor markups on construction cost; 18% engineering/permitting/ legal	Not included	CH2M HILL cost estimating model (CPES), based on database of project costs adapted to specific location using industry standard location factors. Further detail included in City of Bozeman Cost Estimate and Assumptions memorandum included as an attachment to this memorandum.
Sourdough Creek Storage	$10,580	Included	Assumed not to be needed	2011 Sourdough Creek Reservoir Development Plan. Cost/AF based on midpoint of cost estimate range ($3.5M Environmental Compliance/NEPA process plus $60M project development) for 6,000 AF capacity.
Non-Potable Irrigation	$8,000	30% engineering/admin/legal	Not included	Total cost for trunkline non-potable water distribution system in Damascus, Oregon (CH2M HILL 2013) scaled to area required to consume 4,000 AF of non-potable water for irrigation in Bozeman (5,045 acres total residential area based on assumed irrigable landscape area per lot)
Sourdough Membrane Expansion	$11,640	21.5% allowance for contractor markups; 19% engineering/admin	Not Required for facility (costs would be associated with source water, not the treatment facility)	Cost reflects facility expansion from 22mgd to 34 mgd only, and apply only to portfolios which require treatment of more than 22 mgd. Costs were scaled from City of Bozeman Hyalite/Sourdough Treatment Plant Replacement Project Cost Estimate (HDR 2010).

TABLE 10. OPERATIONS & MAINTENANCE COST BASIS

New Supply/Expanded Facility	Operations & Maintenance Cost	Source of Information and Notes
Additional shares from Hyalite Reservoir	$35/AF plus $6,715 annual site lease	Email communication (April 08, 2013), City of Bozeman Water Treatment Superintendent.
Agricultural Impoundment	$60/AF	Third party estimate adjusting data from HKM memo Oct 28, 2010 to Nov 2012 dollars.
Gallatin Groundwater	$131/AF	Includes power, general maintenance, and labor costs per third party cost estimate. Assumes that O&M costs vary directly with AF/supplied.
Lyman Expansion	$115-$282/AF	CH2M HILL cost estimating model (CPES), based on database of project costs adapted to specific location using industry standard location factors. Total cost includes power and chemicals, equipment replacement and maintenance, and labor. Further detail included in City of Bozeman Cost Estimate and Assumptions memorandum included as an attachment to this memorandum.
Canyon Ferry Import	$310/AF	CH2M HILL cost estimating model (CPES), based on database of project costs adapted to specific location using industry standard location factors. Total cost includes power and chemicals, equipment replacement and maintenance, and labor. Further detail included in City of Bozeman Cost Estimate and Assumptions memorandum included as an attachment to this memorandum.
Sourdough Creek Storage	$22/AF	Operational costs for earthen storage facility as used in Damascus Integrated Water Resource Plan, converted to appropriate units (CH2M HILL 2011).
Non-Potable Irrigation	$295/AF	Operational costs for non-potable distribution system, assuming no treatment as used in Damascus Integrated Water Resource Plan, converted to appropriate units (CH2M HILL 2011).
Sourdough Membrane Expansion	$1,577,000/year plus $64/AF plus replacement of 22 mgd capacity membranes after 20 years (net present value = $851,161)	Costs include non-flow dependent annual operational costs for things like facility maintenance and staffing, and additional cost per acre-foot treated for power and chemicals. Costs are based on FY14 Operating costs provided by City of Bozeman Water Facility Superintendent, June 14, 2013. Assumes that 80 percent of FY14 operating costs are independent of volume of water treated flow while remaining 20 percent are for power and chemicals which vary with throughput. Operational costs are applied for all flows through the Sourdough plant regardless of

TABLE 10. OPERATIONS & MAINTENANCE COST BASIS

New Supply/Expanded Facility	Operations & Maintenance Cost	Source of Information and Notes
		whether expansion from 22 mgd to 34 mgd is required (refer to Table 9).

Results

Portfolio Contributions based on Monthly Water Balance

Year 2062 contributions to the total portfolio from each new supply, based on a monthly rather than annual water balance, are shown in Table 10. Water conserved is also shown in Table 11, along with the total annual volume for 2062.

TABLE 11. NEW WATER SUPPLY AND CONSERVATION PORTFOLIO CONTRIBUTIONS BASED ON MONTHLY WATER BALANCE (YEAR 2062)

Alternative	1	2	3	4	5	6	7	8	9	10	11	12	13
	Acre-Feet of Water from Each Alternative												
Sourdough Creek Impoundment								3,371					
Import from Canyon Ferry				10,994									
Groundwater in Gallatin Gateway					10,994	6,505	4,282						
Agricultural impoundment										1,025			1,137
Purchase Shares from Hyalite	2,641	1,416	456	643	643			545	2,379	390	428	1,758	543
Non-Potable Irrigation water									1,113			1,689	
Lyman Creek expansion	1,125							2,590			988	2,699	2,086
Low Conservation	2,770			4,806	4,806								2,770
Medium Conservation		5,908				10,108		10,108	3,060	5,908	5,908		
High Conservation			8,218				12,991						
Total Portfolio	6,536	7,324	8,674	16,443	16,443	16,613	17,273	16,613	6,552	7,323	7,323	6,146	6,536

Due to the irrigation-based seasonality affecting water conservation measures and the degree to which non-potable irrigation can offset overall demand, the amount of water actually needed from certain supplies may vary significantly from the amount identified in the original portfolios presented in Table 2 based on the annual water balance.

Cost Summary & Ranking

Results of the cost analysis for each portfolio are provided in Table 12, ranked in order from lowest to highest total lifecycle cost. High growth portfolios are indicated by shaded rows. Individual components of the total lifecycle cost (capital cost, operations and maintenance cost, and cost of the conservation program) are shown in addition to the overall lifecycle cost for each portfolio. All costs are presented in net present value 2012 dollars, expressed in millions.

TABLE 12. NET PRESENT VALUE PORTFOLIO LIFECYCLE COST SUMMARY (MILLIONS OF DOLLARS)

Portfolio	Description	Capital Cost	Operations & Maintenance Cost	Conservation Program Cost	Total Lifecycle Cost
2	Hyalite shares, Medium Conservation	2	77	6	85
3	Hyalite shares, High Conservation	1	74	10	85
9	Hyalite, NP Irrigation, Medium Conservation (3058)	5	81	2	88
10	Ag Impoundment, Hyalite Shares, Medium Conservation	11	77	6	93
11	Hyalite shares, Lyman, Medium Conservation	18	77	6	101
1	Hyalite shares, Lyman, Low Conservation	19	81	2	101
12	Hyalite, Non-potable Irrigation, Lyman, Low Conservation	26	86	0	111
6	Gallatin groundwater, Medium Conservation	12	86	14	113
7	Gallatin groundwater, High Conservation	12	80	23	114
13	Ag Impoundment, Hyalite shares, Lyman, Low Conservation	36	81	2	118
5	Gallatin groundwater, Hyalite shares, Low Conservation	24	95	4	123
8	Sourdough Impoundment, Hyalite, Lyman, Med Conservation	60	82	14	157
4	Canyon Ferry, Hyalite, Low Conservation	188	105	4	296

Notes:

1. Shaded rows indicate high growth scenario

Cost/Benefit Comparison

Benefit scores developed by the TAC for each portfolio are provided in Table 13. These scores reflect weighting of the individual alternatives by the relative contribution each alternative contributes to the portfolio.

TABLE 13. BENEFIT SCORES FOR EACH PORTFOLIO

Portfolio	Description	Score
1	Hyalite shares, Lyman, Low Conservation	2.9
2	Hyalite shares, Medium Conservation	3.1
3	Hyalite shares, High Conservation	2.1
4	Canyon Ferry, Hyalite, Low Conservation	1
5	Gallatin groundwater, Hyalite shares, Low Conservation	1.7
6	Gallatin groundwater, Medium Conservation	1.8
7	Gallatin groundwater, High Conservation	1.6
8	Sourdough Impoundment, Hyalite, Lyman, Med Conservation	1.9
9	Hyalite, NP Irrigation, Medium Conservation (3058)	2.2
10	Ag Impoundment, Hyalite Shares, Medium Conservation	2

TABLE 13. BENEFIT SCORES FOR EACH PORTFOLIO

Portfolio	Description	Score
11	Hyalite shares, Lyman, Medium Conservation	2.4
12	Hyalite, Non-potable Irrigation, Lyman, Low Conservation	2.2
13	Ag Impoundment, Hyalite shares, Lyman, Low Conservation	1.9

Lifecycle costs for each portfolio, as provided in Table 12, were converted to a unit cost per acre-foot of water delivered by the portfolio in 2062. Water conserved through the conservation program was included in the total volume of water delivered. Conversion of the total lifecycle cost to unit cost allows for direct comparison of the portfolios, regardless of growth scenario.

Total lifecycle costs, total annual volume of water delivered in 2062 (including conservation), and the resulting unit cost per acre-foot for each portfolio are provided in Table 14. The portfolios are ranked from lowest unit cost to highest unit cost. Portfolios designed for high growth scenarios are indicated by the shaded rows. Unit costs have been rounded to the nearest $100. In general, economy of scale, especially for water treatment operations, makes the high-growth scenarios cost less on a per unit delivered basis.

TABLE 14. UNIT COST ($/AC-FT) FOR WATER DELIVERED IN 2062

Portfolio	Description	Total Lifecycle Cost ($Millions)	Annual Volume of Water Delivered in 2062 (ac-ft)	Unit Cost ($/ac-ft)
7	Gallatin groundwater, High Conservation	114	17,273	$6,600
6	Gallatin groundwater, Medium Conservation	113	16,613	$6,800
5	Gallatin groundwater, Hyalite shares, Low Conservation	123	16,443	$7,500
8	Sourdough Impoundment, Hyalite, Lyman, Med Conservation	157	16,613	$9,400
3	Hyalite shares, High Conservation	85	8,674	$9,800
2	Hyalite shares, Medium Conservation	85	7,324	$11,600
10	Ag Impoundment, Hyalite Shares, Medium Conservation	93	7,324	$12,700
9	Hyalite, NP Irrigation, Medium Conservation (3058)	88	6,552	$13,400
11	Hyalite shares, Lyman, Medium Conservation	101	7,324	$13,800
1	Hyalite shares, Lyman, Low Conservation	101	6,536	$15,500
4	Canyon Ferry, Hyalite, Low Conservation	296	16,443	$18,000
13	Ag Impoundment, Hyalite shares, Lyman, Low Conservation	118	6,536	$18,100
12	Hyalite, Non-potable Irrigation, Lyman, No Conservation	111	6,146	$18,100

Notes:

1. Shaded rows indicate high growth scenario

Unit costs were plotted against both the TAC benefit score to demonstrate the relative value of each portfolio, where value is defined as achieving the highest benefit for the lowest unit cost. Following this definition, portfolios falling the lowest and furthest to the right of the graph provide the highest value. The cost/benefit graph is shown in Figure 2;shaded ovals indicate high growth.

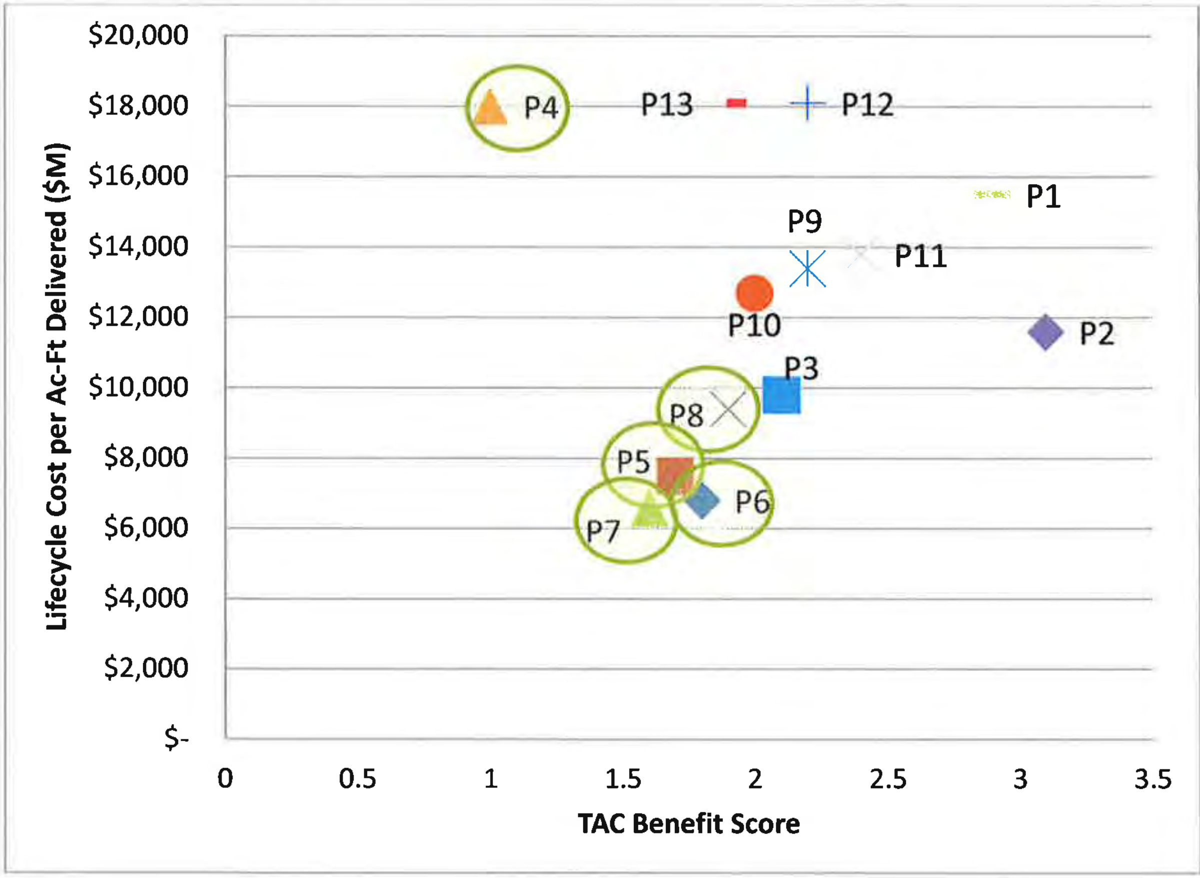

Figure 2. Cost/Benefit Comparison of Portfolios, based on TAC Benefit Scores.

Sensitivity Analysis

Cost Sensitivity

Several of the portfolios rely on new shares from Hyalite reservoir as a key component of new water supply. New shares from Hyalite are a particularly flexible resource as very little infrastructure is required to allow withdrawal of water at time of the year (some ice protection has been recommended by city staff to prevent operational disruptions in winter months). Because very little infrastructure is required, new shares can be implemented relatively quickly to fill near term gaps in the supply/demand balance. Given the importance of new shares from Hyalite to the overall water portfolio, cost sensitivity analysis was conducted to see how the overall value rankings of each of the portfolios would change if both the capital and operating costs of new shares were twice as much as assumed initially. Increasing the capital cost of new shares from $6,000/ac-ft to $12,000/ac-ft and doubling the annual operations and maintenance costs from $35/ac-ft to $70/ac-ft resulted in a 3.7 percent increase in overall lifecycle costs for portfolio 1, the portfolio most heavily dependent on new shares from Hyalite. The relative value ranking of portfolios remained unchanged from the initial analysis. This analysis demonstrated that new shares from Hyalite are a relatively cost-effective means of supplying new water.

Recommendations

Recognizing the uncertainty associated with growth projections and reliance on behaviour change to achieve high levels of water conservation to reduce overall demand, the TAC and technical team developed a fourteenth portfolio recommendation that is flexible enough to allow for realization of either the medium or high growth scenario and a realistically achievable level of conservation.

This recommended portfolio relies on a suite of new supplies that can be implemented in phases as the City evaluates growth and conservation program effectiveness. Contributions to the fourteenth portfolio, based on the high growth scenario, are provided in Table 15. Capacity selected for each contributing element was based on conservative assumptions about the likely contribution of each. In most cases, it may be possible to develop more supply from each individual source.

TABLE 15. RECOMMENDED PORTFOLIO COMPONENTS AND ANNUAL CONTRIBUTIONS BASED ON HIGH GROWTH PROJECTION

Portfolio Component	Contribution to High Growth Annual Water Balance in 2062 (ac-ft)
Conservation	4,500
New shares from Hyalite	650
Lyman system expansion	3,165
Non-potable irrigation	1,200
Sourdough Creek impoundments	915
Groundwater from Gallatin Gateway subarea	5,810
Total Annual Supply	16,240

Costs for Portfolio 14 are summarized in Table 16.

TABLE 16. NET PRESENT VALUE RECOMMENDED PORTFOLIO LIFECYCLE COST SUMMARY (MILLIONS OF DOLLARS)

Portfolio	Description	Capital Cost	Operation & Maint. Cost	Conser-vation Program Cost	Total Lifecycle Cost	Annual Volume of Water in 2062 (ac-ft)	Unit Cost ($/ac-ft)
14	Hyalite shares, Lyman expansion, Non-potable irrigtation, Sourdough Impoundments, Gallatin Gateway groundwater, medium/low conservation	50	93	4	147	16,240	$9,100

Portfolio 14 was scored using the TAC scores for individual portfolio components (as discussed in a previous section of the project report). The composite TAC score for this portfolio is 2.05. The cost-benefit relationship scores for all the portfolios, based on the TAC scores, are shown in Figure 3. As shown on Figure 3, portfolio 14 provides a high value portfolio relative to the other high growth scenarios. While the unit cost is marginally higher than three of the other high-growth portfolios, portfolio 14 offers a more diverse and flexible water supply portfolio; diversity and flexibility make the portfolio more resilient to changing conditions and uncertainty in the future. These positive attributes are reflected in the higher benefit score.

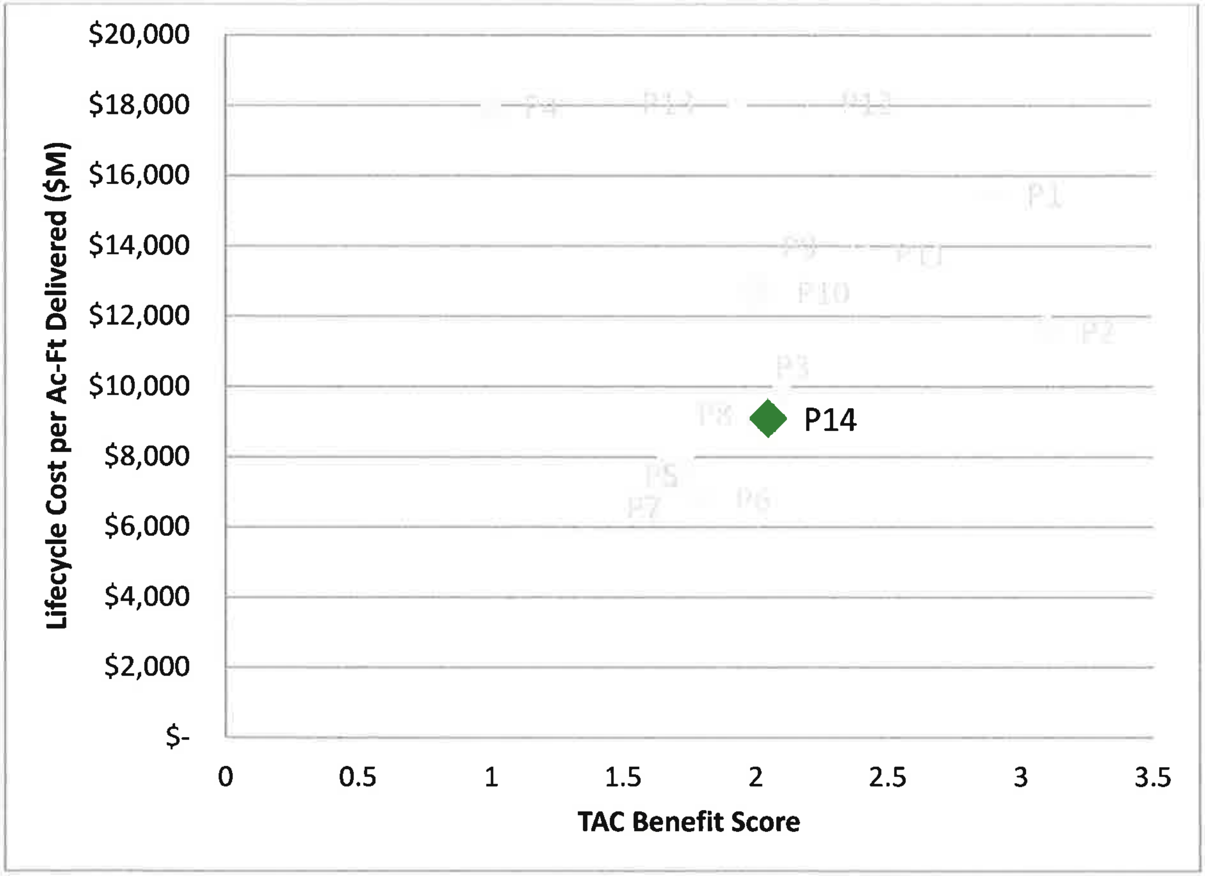

Figure 3. Cost-Benefit Relationship of Recommended Portfolio (Portfolio 14)

Implementation

The recommended portfolio would rely on conservation and new shares from Hyalite in the early years. Based on the assumed monthly availability of each supply, the water balance model indicates that additional water from other new water supplies required when May demands are approximately 610 ac-ft (6.5 mgd).

Based on evaportranspiration rates for grass and assuming that 40 percent of residential areas are landscaped, approximately 1,500 acres of new development will be required to consume the 1,200 AF of water proposed for non-potable irrigation. The amount of water supplied by other sources can be increased if the rate of development in the non-potable irrigation area does not keep pace with growing demands in other areas of the city. Portfolio development assumed that the non-potable system would be brought on-line in 100 ac-ft increments (corresponding to a development of approximately 125 acres).

Groundwater from the Gallatin Gateway subarea was considered a “relief valve” for purposes of balancing the fourteenth portfolio. Gallatin groundwater could be implemented relatively early in order to allow an evaluation period in which reliable groundwater yield could be assessed. If the groundwater yield proves to be less than called for by the portfolio, additional contributions from Hyalite could be added to compensate.

Costs for new water rights purchase were included where those costs were known, but additional costs may be incurred for water rights acquisition from various sources. These costs will need to be taken into consideration as they become clearer and the City decides the order in which to implement new supplies.

Conclusion

The portfolio development and analysis process has resulted in a recommended portfolio that provides the City of Bozeman with a flexible, resilient water resource management strategy. Input from the TAC and technical team

were used to make the analysis as robust as possible given the available information. The cost analysis provides an order of magnitude cost comparison between the portfolios, while the cost/benefit assessment reflects the values of the community for which the strategy is devised. The recommended portfolio is a high-value solution that delivers maximal benefits for a competitive cost. Both the order in which new supplies are implemented and the degree to which each new supply is utilised can be can be adapted by City managers to future conditions as those conditions unfold.