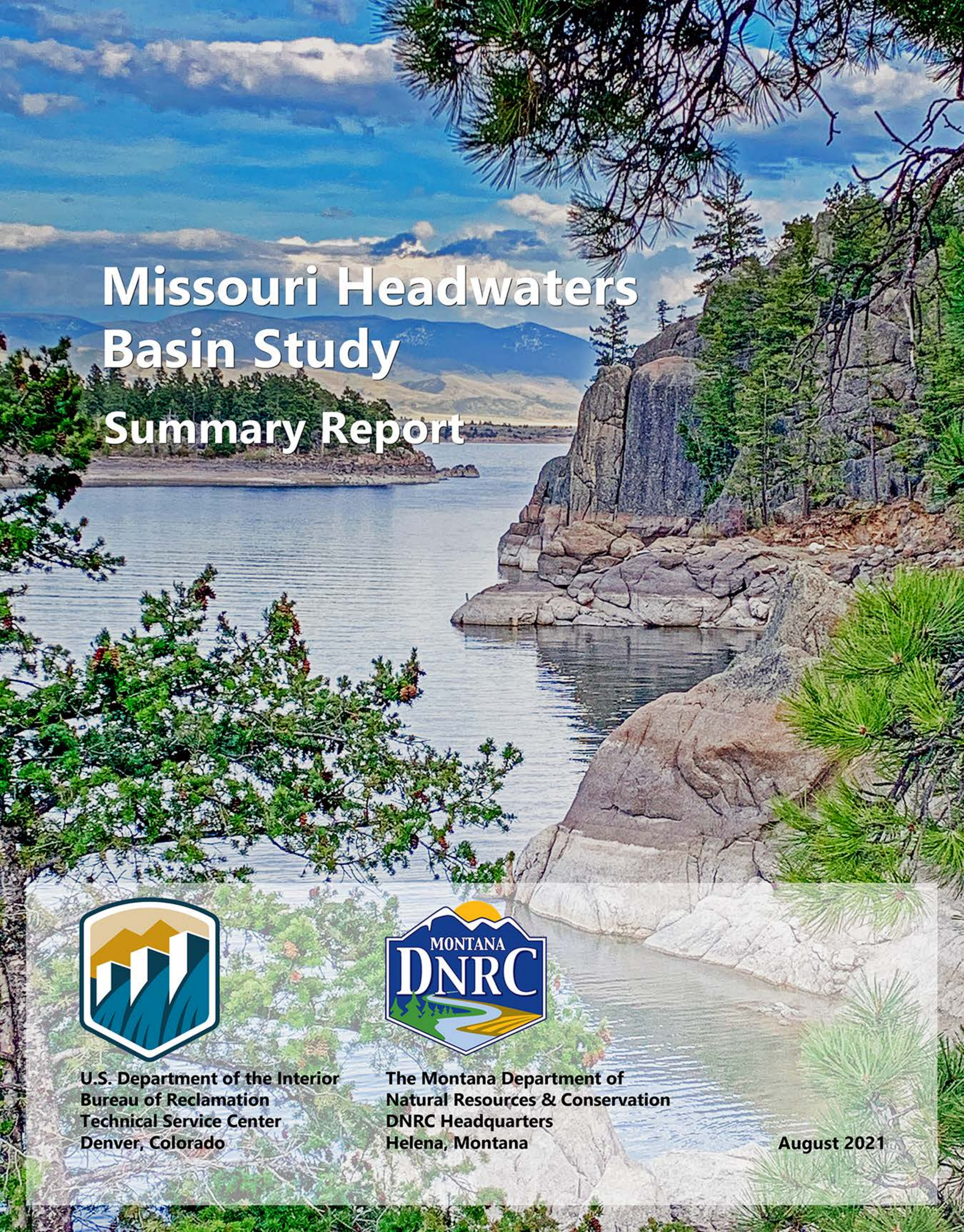

Missouri Headwaters Basin Study

Summary Report

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

The Montana Department of
Natural Resources & Conservation
DNRC Headquarters
Helena, Montana

August 2021

Mission Statements

The **U.S. Department of the Interior** protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

The mission of the **Bureau of Reclamation is** to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Montana Department of Natural Resources and Conservation's mission is to help ensure that Montana's land and water resources provide benefits for present and future generations.

Acronyms and Abbreviations

Basin Study	Missouri Headwaters Basin Study
CT	Central tendency future scenario
ESA	Endangered Species Act
FSID	Fort Shaw Irrigation District
GCM	global climate models
GID	Greensfield Irrigation District
HD	Hot-dry future scenario.
HW	Hot-wet future scenario
Impacts Assessment	Upper Missouri Basin Impacts Assessment
LD	Longest Drought
LP	Longest Pluvial
MID	Most Intense Drought
Montana DNRC	Montana Department of Natural Resources and Conservation
MIP	Most Intense Pluvial
Reclamation	Bureau of Reclamation
USGS	U.S. Geological Survey
WD	Warm-dry future scenario
WW	Warm-wet future scenario
WaterSMART	Water Sustain and Manage America's Resources for Tomorrow

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Introduction

The Missouri Headwaters Basin Study (Basin Study) describes strategies to address water resource challenges in the Missouri River and Musselshell River basins upstream of Fork Peck Reservoir.

These watersheds provide habitat for numerous fish and wildlife species and supply water for agriculture, hydropower, recreation, and tribal, municipal, industrial, and domestic uses. Within this study area, the Missouri River and its tributaries are the primary water source for 320,000 people and about 1.1 million acres of irrigated land.

Missouri Headwaters Setting

State: Montana

Major Cities: Bozeman, Helena, Great Falls

Mean Annual Flow: 6.7 million acre-feet

Basin Study Area: 50,000 square miles

Major Water Uses: Municipal, agriculture, hydropower, recreation, flood control, navigation, fish and wildlife

Notable Reclamation Facilities: Pick-Sloan Missouri Basin Program, including East Bench Unit, Crow Creek Pump Unit, Canyon Ferry Unit, Helena Valley Unit, Lower Marias Unit, Sun River Project

Study Area and Existing Challenges

The Basin Study area encompasses the Missouri River and Musselshell River basins upstream of Fort Peck Reservoir, covering about 50,000 square miles (Figure 1). The Jefferson, Madison, and Gallatin Rivers, which originate in southwestern Montana in the Rocky Mountains, join to become the Missouri River near the town of Three Forks. Further north, the Sun River joins the Missouri River in the city of Great Falls, while the Teton, and Marias Rivers join the Missouri River near Fort Benton. The study area also encompasses central Montana watersheds, including the Smith and Judith River basins, which drain to the Missouri River downstream of Great Falls. The study area also includes the extensive tributary drainage of the Musselshell River basin, which drains directly into Fort Peck Reservoir. The combined watersheds have an annual average outflow of about 6.7 million acre-feet.

Figure 1.—Missouri Headwaters Basin Study overview map.

The study area stakeholders face challenges similar to those in other watersheds in the western United States where finite water supplies serve increasing demands. The greatest demand in the study area is for irrigation, comprising about 87 percent of the total consumptive water demand. Reservoir evaporation accounts for about 12 percent and all other uses about 1 percent (Montana Department of Natural Resources and Conservation [Montana DNRC] 2014). In the study area, most of the water has already been appropriated for irrigation, hydropower generation, municipal water supply, and instream flows to support fisheries and recreation.

To illustrate the effects of limited water supply in the region, the Missouri River basin upstream of Great Falls has been closed to new water appropriations since 1993, with some exceptions for groundwater and water storage. Irrigators in this region, and in the Musselshell, Sun, and Teton River basins have already experienced water shortages. Rapid population growth in the study area over the past 20 years is expected to continue and will require additional water for municipal water supplies mostly concentrated in Gallatin, Madison, and Lewis and Clark Counties in southwestern Montana. For example, annual water demand in Gallatin County is expected to at least double by 2080. Currently, unallocated stored water that the Bureau of Reclamation (Reclamation) manages remains in Canyon Ferry Reservoir and Lake Elwell (Tiber Dam)—offering the potential for mitigation against future hydrologic change and for meeting demand for additional water to support both expanded irrigation and population growth.

Another challenge in the region is that hydropower producing facilities on the Missouri River have relatively senior water rights. On top of that, rivers throughout the study area hold instream flow rights to support Endangered Species Act (ESA) listed species such as the Pallid sturgeon, and species of special concern such as the fluvial Arctic grayling and west-slope cutthroat trout, as well as renowned trout fisheries of the Big Hole, Gallatin, Beaverhead, Jefferson, Madison, Smith, and Missouri Rivers. Use by senior water rights holders and instream flow needs leave little flexibility for junior water rights holders to divert water in many parts of the study area. Rivers and reservoirs in the Missouri Headwaters, such as the Missouri and Madison Rivers and Canyon Ferry Reservoir, provide some of the highest value recreation areas in Montana.

Basin Study Purpose and Development

Reclamation and the Montana DNRC undertook this Basin Study. The purposes of this collaborative planning study are to inform stakeholders of current and future water supply challenges and to identify and evaluate strategies for improving resiliency to these challenges and for improving water supply reliability. Strategies include actions like changing current management practices, changing operations, and modifying or developing new infrastructure.

Uncertainty

The information presented in this report was developed in collaboration with basin stakeholders and was peer reviewed in accordance with Reclamation's and Department of the Interior's polices. This report is intended to inform and support planning for the future by identifying potential future scenarios. The analyses provided in this report reflect the use of best available datasets and methodologies at the time of the study.

Water resources studies are developed in collaboration with basin stakeholders to evaluate potential future scenarios to assess risks and potential actions that can be taken to minimize impacts, including supply and demand imbalances. These types of studies support a proactive approach to water resources management, using the best available science and information to develop scenarios of future conditions within the watershed. This positions communities to take steps now to mitigate the impacts of future water supply management issues, including water shortages, impacts of droughts and floods, variations in water supply, and changing water demands for water for new or different uses.

Because every water resources planning study requires the study partners to make assumptions about future conditions, addressing the uncertainties in those assumptions is an essential component of the planning process. For example, there are uncertainties associated with the characterization of future water supply and demand, demographics, environmental and other policies, economic projections, climate conditions, and land use, to name a few. Moreover, projections are often developed using modeling techniques that themselves are only potential representations of a particular process or variable, and therefore, introduce additional uncertainties into characterizations of the future. The cumulative, interacting uncertainties are not well known in the scientific community and, therefore, are not presented within this study. By recognizing this at each process step, uncertainties are adjusted for and reduced when possible, to allow Reclamation and its stakeholders to use the best available science to create a range of possible future risks that can be used to help identify appropriate adaptation strategies, which is fundamental to the planning process. Importantly, scenarios of future conditions should not be interpreted as a prediction of the future, nor is the goal of any water resources planning study to focus on a singular future. Rather the goal is to plan for a range of possible conditions, thereby providing decision support tools for water managers.

The Basin Study builds upon the Upper Missouri Basin Impacts Assessment (Impacts Assessment) (Reclamation 2019c), which summarizes current and future water resource challenges identified through modeling of the managed river system under a range of water supply and demand scenarios. Unlike many completed basin studies, the foundational Impacts Assessment is summarized in a separate report completed by Reclamation, in cooperation with the Montana DNRC. In the Impacts Assessment, Reclamation developed a scenario approach for modeling water supply and demand. These scenarios include: future climate projections at the watershed scale based on global climate model (GCM) output, paleohydrology scenarios generated from tree rings that provide information from the distant past (Martin and Pederson 2019), and a historical scenario that encompasses the observed historical record. Information from this range of scenarios facilitates comparisons between the past and future projections of water supply and demand and can provide information as to whether future water supply and demand are likely to be significantly different from the past. In addition to assessing water supply and demand, Reclamation and the Montana DNRC also collaborated to develop the Upper Missouri RiverWare planning model (Reclamation 2019b), which is the tool used to simulate the river system and quantify impacts to metrics for water delivery, water quality, flood control, threatened and endangered species, flow-dependent ecological resiliency, and recreation.

This Basin Study summarizes an analysis of how management and infrastructure changes may alleviate any identified water resources challenges moving forward. With stakeholder input, Reclamation and Montana DNRC developed strategies to mitigate water supply and demand challenges and evaluated them based on their ability to meet the same metrics described above. Further, the Basin Study provides information that can support managing available water resources in the basin, considering existing challenges, growth, and projected future changes to water supplies and demands.

Figure 2 illustrates the components of the Basin Study (shaded beige) and their connections with components of the Impacts Assessment (shaded blue). It illustrates the concept that the Basin Study builds on information developed through the Impacts Assessment and focuses on strategies for addressing projected changes in water supply and demand.

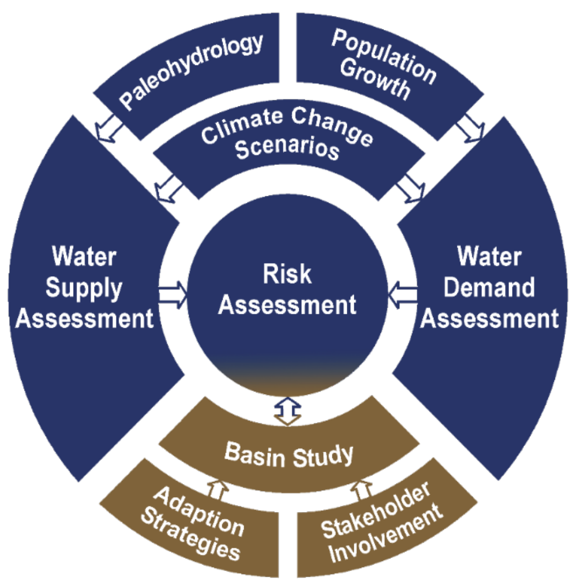


Figure 2.—Overview of the Missouri Headwaters Basin Study and complementary Upper Missouri Basin Impacts Assessment.

Collaboration and Outreach

Basin Studies costs are equally shared between Reclamation and non-Federal partners. Reclamation and Montana DNRC were partners in this Basin Study. In addition, Reclamation contracted with the U.S. Geological Survey (USGS) Northern Rocky Mountain Science Center and Montana State University, Bozeman to develop paleohydrology scenarios (Martin and Pederson 2019) for the Impacts Assessment and Basin Study and provide guidance for their application (Figure 3). In addition, collaboration and outreach with stakeholders and tribes are key components of these studies.

Reclamation and Montana DNRC engaged with stakeholders in the study area to develop management strategies. Stakeholders included members of local watershed groups and conservation districts who are knowledgeable and active in local water resource issues. These groups include: Sun River Watershed Group, Musselshell Watershed Coalition, Beaverhead Watershed Committee, Ruby Watershed Committee, Liberty County Conservation District, Montana DNRC State Water Projects Bureau, East Bench Irrigation District, Helena Valley Irrigation District, and Great Northern Landscape Conservation Cooperative.

Stakeholder involvement was critical in developing strategies and assessing the strategy benefits.

Study Partners

BUREAU OF RECLAMATION

The Montana Department of Natural Resources & Conservation

Guidance and Technical Support

USGS science for a changing world

Figure 3.—Partnerships for the Missouri Headwaters Basin Study.

Additionally, the study team contacted the Blackfeet Tribe Water Resources Director by personal communication at the start of the study to identify possible strategies related to tribal water rights and their use. The Blackfeet Tribe was in the process of finalizing their water right settlement by holding a Tribal referendum to approve the settlement. During this time, the Tribe identified no strategies, but one evaluated strategy in the study explored additional water use from Lake Elwell in the Marias River basin—which may be beneficial to the

Tribe's Lake Elwell allocation per their water rights settlement with the Federal government.
Another important component of each basin study is collaboration with other ongoing efforts in the study area. The study team collaborated with efforts including the National Drought Resilience Partnership Montana Pilot Project and the Missouri Headwaters WaterSMART[1] drought contingency planning process.

Scenarios and Analysis

The Basin Study and the foundational Impacts Assessment incorporate newly developed data and tools to quantify water supply and demand and for evaluating strategies. Reclamation and Montana DNRC used a scenario approach, which is described in detail in the Impacts Assessment, to develop water supply and demand data for a range of plausible conditions. These data were then input into the developed Upper Missouri RiverWare planning model for simulation and analysis.

Water supply scenarios may be described as scenarios of streamflow, reservoir inflows, and local inflows that are simulated by hydrologic and statistical models. Groundwater and surface water interactions were modeled by altering surface water flows based on aquifer characteristics.

Water demand scenarios may be described as scenarios of evaporative demands from reservoirs and agricultural demands via crop evapotranspiration; they also incorporate population estimates for municipal and industrial water use.

Scenarios of water supply and demand encompass three types: paleohydrology (spanning years 1100 to 1998), historical baseline (encompassing years 1950 to 1999), and projected future scenarios under three planning horizons: the 2020s (which encompasses years 2010 - 2039), the 2050s (which encompasses years 2040 - 2069), and the 2080s (which encompasses years 2070 - 2099).

Figure 4 illustrates the scenarios developed for the Basin Study showing the variability in streamflow under different scenarios.

[1] WaterSMART stands for Sustain and Manage America's Resources for Tomorrow.

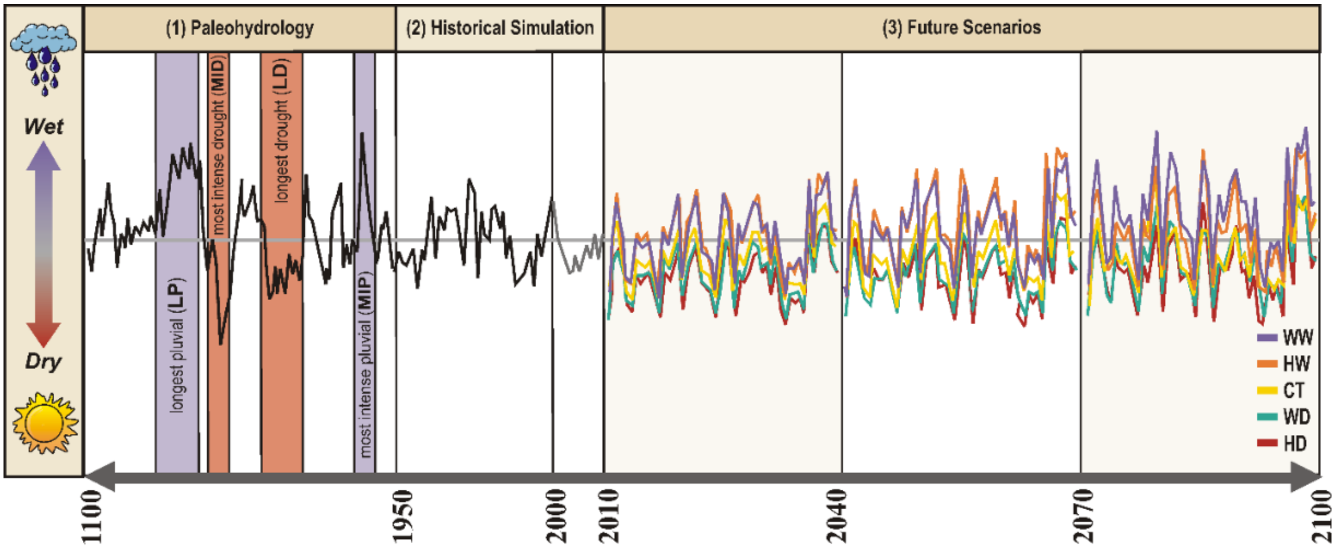


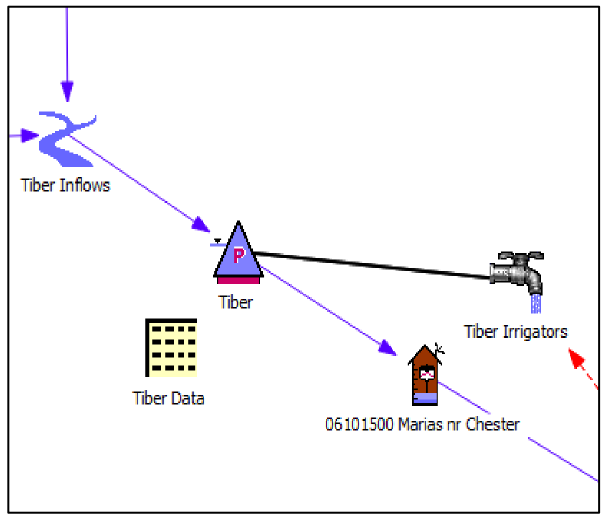
Figure 4.—Illustration of scenario approach for Missouri Headwaters Basin Study.

Details of the different scenario types are provided below.

- **Paleohydrology.** Paleohydrology was developed from tree-rings to provide a record of hydrologic conditions over the past 900 years, from about 1100 to 1998 (Martin and Pederson 2019). The study team developed daily streamflow timeseries over 50-year periods that encompass either extreme drought periods or extreme wet periods (also called pluvial periods), identified from tree rings-collectively. These daily streamflow timeseries were used in two unique ways:
    - By identifying the longest wet period (termed longest pluvial [LP]), the period with the most intense wet period (termed most intense pluvial ([MIP]), the period with the most intense drought (MID), and the longest drought (LD) in the paleohydrology record and used these as paleohydrology scenarios—collectively, these are called "extreme paleo events."
    - By combining the streamflow sequences and event durations from the extreme scenarios described above with projected streamflow from future scenarios (described below)—these are called "future scenarios combined with paleohydrology."
- **Historical simulations.** The Basin Study simulated the historical baseline period from 1950 to 1999 (water years 1951 - 1999) to represent historical hydrologic conditions over that period.

- **Future scenarios**. Future scenarios based on GCM projections were developed and provide our best estimate of what could occur over the coming century with respect to climate dynamics and warming. For this study, each scenario for a particular time horizon is considered an equally likely future planning scenario. These scenarios include five climate timeseries developed for the region that represent the range of projected changes in temperature (less warming to more warming) and precipitation (from decreases to increases) for three future time horizons, the 2020s, the 2050s, and the 2080s and these are called warm-wet (WW), hot-wet (HW), a middle range central tendency (CT), warm-dry (WD), and hot-dry (HD).

For these scenario types, the study team used the Upper Missouri RiverWare planning model to simulate river and reservoir operations, with and without strategies in place, and assuming 2017 operating policies. Model results provide information on agricultural water deliveries, managed river flows, and reservoir levels. The study team compared results from future scenarios to both historical baseline simulations and to paleohydrology scenario simulations to answer whether projected future conditions may be outside the range of conditions seen over the last 900 years.



Upper Missouri RiverWare Planning Model excerpt.

The analyses provided in this report reflect the use of best available datasets and data development methodologies at the time of the study. It is important to acknowledge the uncertainties inherent within projecting future planning conditions for water supply and demand. For example, projections of future climate, population, water demand, and land use contain uncertainties that vary geographically and temporally depending on the model and methodology used. Trying to identify an exact impact at a particular place and time remains difficult, despite advances in modeling efforts over the past half-century. Accounting for these uncertainties, Reclamation and its stakeholders used a scenario planning approach that encompasses the estimated range of future planning conditions. More detailed information about uncertainties related to each part of the study is available in the Missouri Headwaters Basin Study full report.

Findings from the Impacts Assessment

The Impacts Assessment summarizes how water supply and demand under paleohydrology scenarios and projected future scenarios may be different from recent historical conditions. It also summarizes how various categories of water use (water deliveries, hydroelectric power resources, flood control operations, ecological resources, and recreation) may change under these scenarios compared with recent historical conditions. These water use categories were examined through simulations of the Upper Missouri RiverWare planning model. This assessment also provides valuable context about whether managed resources under future scenarios face conditions never experienced in the recent or distant past. Key findings from the Impacts Assessment are summarized in this section to provide an understanding of impacts to water resources under various scenarios, without implementing any changes to operational policies or infrastructure. This information may serve as a foundation for later discussion of whether explored strategies may alleviate those impacts.

Water Supply

Flooding in the Sun River.

Across the study area, **annual water supply is projected to increase under most future scenarios compared to recent history**. Projections generally show decreases in snowpack (especially in high elevation parts of the Rocky Mountains), a shift to earlier peak snowpack, and thus earlier snowmelt driven runoff. **Projected changes in the seasonality of water supply may leave areas more vulnerable to flooding during winter and spring seasons and water supply shortages late in the irrigation season.** Projected future warming will shift spring snowmelt toward earlier in the year, causing a shift in the timing of peak streamflow with increasing winter and early spring runoff and decreasing runoff later in the spring and summer. **The shift in seasonal runoff will be most pronounced along the Rocky Mountains**. The shift is not projected in lower elevation watersheds, such as the Judith River basin. During the late summer season, a critical period for irrigation, water supply is projected to decrease on many streams under most scenarios. However, there are exceptions to this projection in some regions. For example, the watersheds along the Rocky Mountains, the Beaverhead River basin, and Musselshell River basin may experience little change or even an increase in summer streamflow.

Looking back over the reconstructed paleohydrology record, analysis showed that the range of annual streamflow over the last 900 years is greater than the range over the historical scenario period (1950 - 1999). This is to be expected in part because of the larger number of years contributing to the range in addition to the known major drought and pluvial events not captured in the timeframe of the more recent historical period. Droughts and wet periods (pluvial events) spanning 2 to 8 years are fairly common in the study area. **Longer drought events lasting 10 to 30 years do occur. For example, the Dust Bowl (15 years) spanned from 1929 - 1943 and the Millennium drought (11 years) spanned from 2000 - 2010, and longer duration droughts have occurred in the paleohydrology record.**

Water Demand

Analysis of historical and projected future demand shows that **future warming in the study area will cause overall increases in water demand, on top of increases in demand from expanded irrigation and population growth.** In fast growing regions, particularly the Gallatin Valley, there remains little unallocated water left to support increased water demand associated with population growth.

Helena Valley irrigation.

Also, water demands associated with crop water consumption are projected to increase with warming temperatures particularly in summer months. **Increases in water demands, along with increases in reservoir evaporation, generally result in decreased reservoir storage by the end of the irrigation season.** Seasonal shifts in water supply availability could affect current irrigation practices for both agriculture and municipal lawn watering.

Projected increases in precipitation that are expected at other times of the year may offset some of these projected demands, but precipitation is projected to decrease in summer months, which will increase reliance on reservoir storage.

Risk Assessment

The Impacts Assessment follows a modeling framework for evaluating water supply and demand conditions in a changing climate (Reclamation 2019a). That framework is used to evaluate risks to water management in the future and to evaluate the ability to meet the needs of the many users in the study area. As part of that framework, the Upper Missouri RiverWare planning model was developed to simulate current river and reservoir operations in the Upper Missouri River and Musselshell River and allow for easy simulation of water supply and demand scenarios. From these model simulations, the study team performed an assessment of water management risks. The RiverWare model was used to compute risk assessment measures related to agricultural water deliveries, managed river flows, and reservoir levels, among other things, throughout the study area. Quantitative measures are used to help bring to light certain imbalances in water supply and demand under current management policies. Measures also allow for exploration of strategies that may reduce those imbalances. These measures were identified based on input from study partners, stakeholders, and resource managers in the basin. Examples of measures are summarized in Table 1.

Table 1.—Risk Assessment Measures

Measure Category	Measure Description
Basin-wide Responses	Change in the days of centroid of flow timing
	Change in end of month reservoir storage
	Change in annual reservoir inflow volume
	Change in April-October reservoir inflow volume
	Change in November-March reservoir inflow volume
Water Deliveries	Change in end of water year reservoir storage
	Change in irrigation supply shortages
Hydroelectric Power Resources	Change in annual hydropower production at State, Federal, and private facilities
Flood Control Operations	Change in days per month exceeding reservoir flood pool (Canyon Ferry, Clark Canyon, Tiber)
Ecological Resources*	Change in monthly streamflow
	Change in the annual maximum 7-day streamflow
	Change in the annual minimum 7-day streamflow
	Change in streamflow percentiles (5^{th}, median, 95^{th})
Recreation	Change in median number of unusable days at boat ramps

*The ecological resources category includes: fish and wildlife habitat; species listed as an endangered, threatened, or candidate species under the ESA; flow and water dependent ecological resiliency; and water quality.

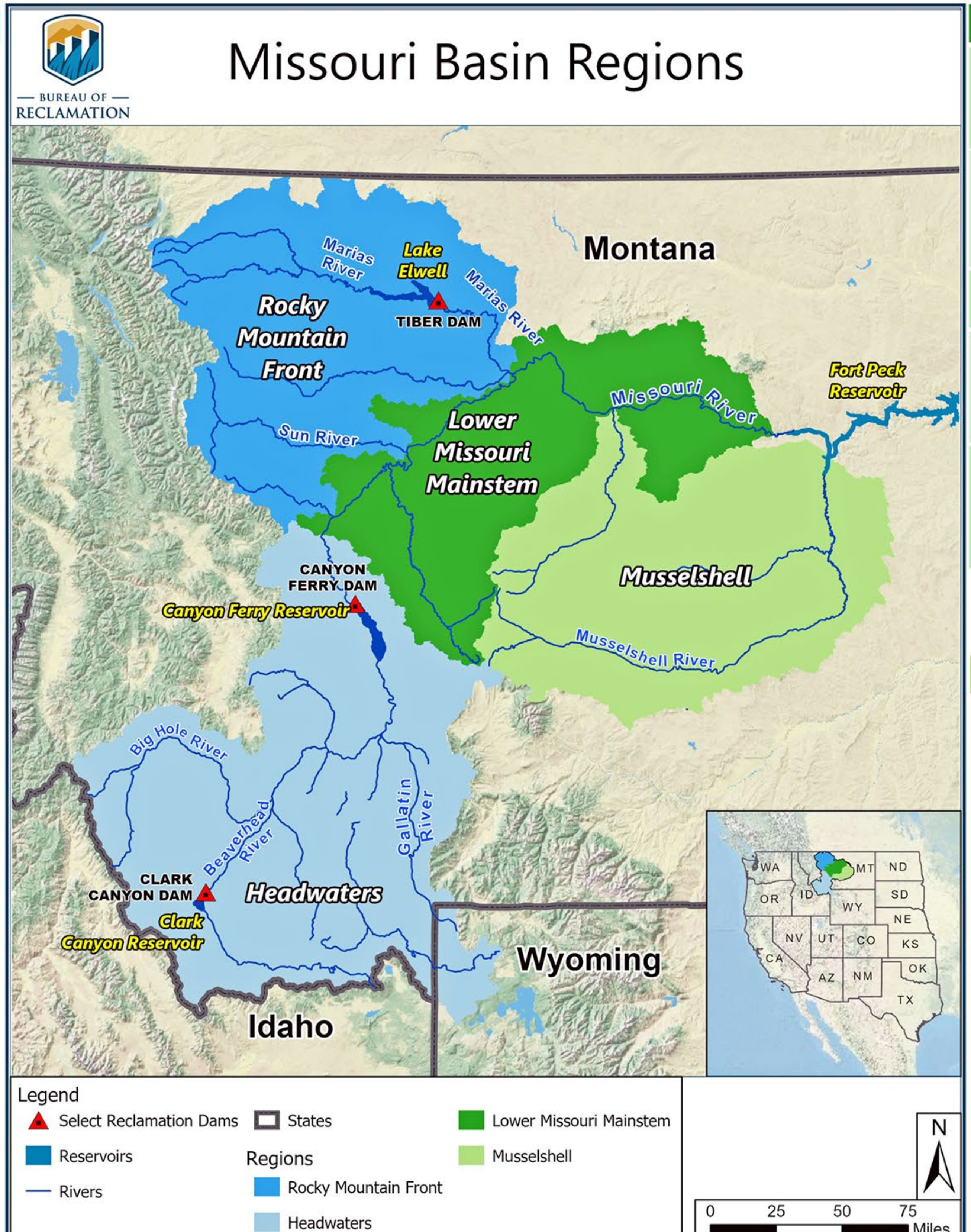
A summary of impacts related to the water use categories, and these measures, is provided in Figure 5. These impacts highlight the need for strategies to address potential impacts to system performance..

Rocky Mountain Front

Water Deliveries	Irrigation water shortage in the Sun River basin and in the upper Marias River basin are projected to increase because reservoirs will fill earlier, deliveries will begin earlier, and overall irrigation demands are expected to increase.
Hydropower	Annual hydropower production is projected to decrease at Tiber Dam; however, for February through April the wetter future scenarios project a modest increase in projection.
Flood Control	Lake Elwell is projected to have an increase in the average number of days in the flood pool.
Ecological Resources	Winter streamflow may increase while summer flows may increase or decrease depending on the scenario. Any decreases in summer streamflow would negatively affect ecological resources.
Recreation	Usable days for boat ramps from April to October are projected to decrease for Lake Elwell.

Headwaters

Water Deliveries	Irrigation water shortage may increase for most irrigators except for Clark Canyon water users where shortages may decrease.
Hydropower	Canyon Ferry annual hydropower production may increase in wetter future scenarios and decrease in drier future scenarios.
Flood Control	Canyon Ferry Reservoir is projected to have more days in the flood pool. Clark Canyon reservoir is projected to have more days in the flood pool in wetter future scenarios, and fewer in drier future scenarios.
Ecological Resources	Winter streamflow may increase, while summer streamflow may decrease under most future scenarios, except in the Beaverhead watershed where summer flows are projected to increase under most future scenarios. Lower summer streamflow could further stress ecological systems.
Recreation	Boat ramps will have fewer accessible days from April through October at Clark Canyon under all but the wettest future scenario. Boat ramps will have more usable days at Canyon Ferry under wetter future scenarios and fewer under drier future scenarios.



Lower Missouri Mainstem

Water Deliveries	Risk factors such as drought and climate change may have a smaller impact at these facilities because the reservoirs are maintained at constant pool elevations.
Hydropower	Future scenarios suggest greater annual hydropower production under wetter scenarios and reduced hydropower production under drier scenarios, and may experience shifts in production timing.
Flood Control	Reservoirs in this region are not formally operated for flood control.
Ecological Resources	Potential increases in high flows may indicate greater opportunities for bank full streamflow release events that may improve ecological resources in the Upper Missouri Wild and Scenic River.
Recreation	The Smith River's popular recreational boating season may shift toward earlier in the year, corresponding with higher peak flows from December to May and lower peak flows during the rest of the year.

Musselshell

Water Deliveries	Irrigation water shortages may remain about the same or even decrease on average for those users in the Musselshell River and Judith River basins. At the same time, crop water consumption will increase. Shortages are about 45 percent of demand in the Musselshell River historically. Any additional projected shortages would compound existing shortage issues.
Hydropower	NA
Flood Control	NA
Ecological Resources	All future scenarios indicate a higher maximum peak streamflow in the lower Musselshell River basin. Minimum streamflow is likely to decrease under most future scenarios in the Judith River basin, while it will decrease under drier future scenarios and increase under wetter future scenarios in the upper Musselshell River basin.
Recreation	Average monthly reservoir levels may increase for wetter scenarios and decrease for drier scenarios, which may impact recreation access.

Figure 5.—Summary of Impacts Assessment results by region.

Strategies and Key Findings

In the Basin Study, study partners developed and evaluated strategies to address challenges identified in the Impacts Assessment and to address issues identified by study partners and through stakeholder outreach. This section contains a brief description of the strategies selected for analysis.

Because the Missouri Headwaters is such a large basin, not all adaptation strategies affect the entire basin. Many of the adaptation strategies included here are specific to the larger Missouri River tributaries. Figure 6 lists the strategies by location. It is possible that strategies in different subregions may be implemented simultaneously without impacting each other. Each group of strategies is further described below. The strategies' key findings are then summarized in Table 2 at the end of this section.

Strategies were developed to address future water needs and to adjust future water infrastructure operations to changing hydrologic conditions. The adaptation strategies also address major issues identified by the project partners and various stakeholders.

Strategies Evaluated

Providing Water for Future Uses

- Providing Water for Future Consumptive Use through Contract Water from Canyon Ferry Reservoir and Lake Elwell

Providing Water for Future Municipal, Domestic, and Industrial Uses in the Gallatin Valley

Increasing Canal and On-farm Irrigation Efficiencies

Ecological Flow Releases from Canyon Ferry Reservoir and Lake Elwell

Beaverhead River Basin Strategies

- Decreasing Drawdown for Flood Storage and Clark Canyon Reservoir
- Capping Winter Releases from Clark Canyon Reservoir to 100 cfs
- Decreasing Flood Storage and Capping Winter Releases

Sun River Basin Strategies

- Increasing Willow Creek Feeder Canal Capacity
- New Off-stream Storage for Sun River Water
- Increasing Pishkun Supply Canal Capacity
- New Off-stream Storage and Increasing Pishkun Supply Canal Capacity

Musselshell River Basin Strategy

- New Off-stream Storage in Lower Musselshell River Basin

Water Management Strategy for Increased Drought Resilience

Figure 6.—Overview of strategy locations.

Providing Water for Future Consumptive Uses through Contract Water from Canyon Ferry Reservoir and Lake Elwell

Contracting unallocated stored water managed by Reclamation from Canyon Ferry Reservoir and Lake Elwell (on the Marias River) is one of the greatest opportunities in the study area for relieving water resources challenges. Much of the basin is closed to new appropriations and less water in the lower Missouri River at Virgelle and in the Marias River below Tiber Dam/Lake Elwell is expected, potentially reducing Federal and state hydropower production. **Contracting additional Canyon Ferry and Lake Elwell water might provide one of the few opportunities available to meet future consumptive use demands while sustaining other important resources.** Measures associated with this strategy would not be impacted more substantially depending on the type of scenario, future or paleohydrology.

Providing Water for Future Municipal, Domestic, and Industrial Uses in the Gallatin Valley

During most years, water is available for the Lower Gallatin River beyond the senior instream flow rights from April through early July which are set by Montana Department of Fish Wildlife and Parks. However, during the driest years, there is little, if any, water available above these rights. Although substantial regulatory hurdles may exist, **providing additional domestic water to the Gallatin Valley through surface and groundwater conjunctive use or transporting surface water from Canyon Ferry Reservoir, could meet demands without impacting local water conditions**. However, an important consideration for this strategy is that irrigated acres were modeled to be retired to supply the water needs for the municipal and rural domestic growth. This would substantially reduce irrigated acres in the greater Gallatin Valley.

Canyon Ferry Dam.

Increasing Canal and On-farm Irrigation Efficiencies

Over the past 40 years, irrigated areas have been converting from gravity flood systems to sprinkler irrigation systems, and delivery systems have decreased losses, for example, by converting open ditches to pipelines. This strategy investigated the effects of further increasing on-farm irrigation efficiencies and conveyance efficiencies across the study area.

Watersheds in the study area will be impacted to varying degrees by increased irrigation efficiencies. **Although more efficient irrigation systems usually require less water to be diverted, more water generally will be depleted from the system through evapotranspiration, as irrigation water is delivered in a more uniform and timely manner.**

While irrigation water shortages could increase under future scenarios with warming temperatures, increased irrigation efficiencies could lessen the impact, with the largest shortage reductions under hotter future scenarios. Also, as irrigation systems become more efficient, opportunities might open to mitigate potential late-season streamflow reductions through refinements to reservoir and delivery system operations. However, further increasing irrigation efficiency would have some adverse effects too—August flows would decrease in streams across the study area and hydropower production would decrease by a modest amount.

Ecological Flow Releases from Canyon Ferry Reservoir and Lake Elwell

Ecological pulse flow releases from Canyon Ferry and Tiber Dams might improve aquatic habitat in the Missouri and Marias Rivers, and potentially trigger pallid sturgeon spawning in the lower Missouri River. Higher streamflow can mobilize streambed gravel and flush out accumulated sediment, which helps to provide an oxygen rich environment for fish eggs to incubate and provide habitat for aquatic insects which provide food for fish such as trout and whitefish.

Opportunities for ecological flow releases, which may also be thought of as pulse flows to benefit fish and wildlife habitat, will be similar or even greater in the future, since future scenarios suggest it is likely for the region to be wetter overall. The results for this strategy show that scenarios reflecting climate change alone would have a greater impact than the future scenarios combined with paleohydrology in that the projected wet periods would be wetter than those experienced in the distant past.

Beaverhead River Basin Strategies

Irrigation water shortages are common in the Beaverhead River basin. Late summer streamflow in the Beaverhead River between Clark Canyon Reservoir and the Barret's Diversion Dam are projected to decrease under most future scenarios. The following strategies could store more water in Clark Canyon Reservoir to increase irrigation allocations during dry years and possibly improve Beaverhead River instream flow:

Clark Canyon Reservoir.

- Decrease drawdown of Clark Canyon Reservoir maintain higher storage to decrease irrigation water shortages and to improve summer flows
- Provide a more consistent winter instream flow rate downstream of the dam through reducing the maximum winter releases

These strategies together could allow for more carry-over storage in Clark Canyon Reservoir, thus making more water available for instream flow in late summer and resulting in fewer irrigation water shortages for the East Bench Irrigation District and Clark Canyon Water Supply Company users. Sun and Musselshell River basins strategies appear to show only modest ability to meet their goals. Paleohydrology scenarios suggest that a broader range of reservoir inflows is possible, meaning that there could be more substantially decreased allocations if extreme drought conditions were to recur. Under such scenarios, the strategy could alleviate negative impacts.

Sun River Basin Strategies

A system of canals and off-stream reservoirs provide water to Sun River irrigation water users. All future scenarios project that irrigation water shortages will increase, reservoir end of water year storage will decrease, and Sun River August flows will decrease. Strategies considered in the Sun River basin include modifying existing infrastructure associated with the Greenfields Irrigation District (GID) and Fort Shaw Irrigation District (FSID)[2] to reduce irrigation water shortages and improve the ability to meet instream flow requirements. Infrastructure modifications include increased Willow Creek Feeder Canal and Pishkun Supply Canal capacity, as well as new off-stream storage facilities. There would be modest benefits in dry years, reducing irrigation shortages and increasing reservoir end of water year storage. There would not be any appreciable impacts on summer streamflow in the Sun River.

[2] No changes to Broken O Ranch irrigation infrastructure or management were modeled.

Musselshell River Basin Strategy

The current severe water shortages in drier years in the lower Musselshell River basin are projected to increase under most future scenarios. A strategy to address these shortages is namely a new off-stream storage reservoir in the lower watershed would be constructed in Horse Creek Coulee with inflow from the Musselshell River through the Delphia-Melstone Canal. The reservoir would have the most significant benefits during moderate flow years when there are enough flows to store in the fall and supplement irrigation in the following spring. In dry years, the reservoir could provide supplemental irrigation water during the first year of a drought.

A new off-stream storage reservoir would generally increase flows in the Musselshell River at Mosby during critical summer months. Flows would decrease during the fall and spring reservoir fill periods, but still meet required instream flow targets. Water shortages to lower Musselshell River irrigators would increase, and summer instream flows decrease in most future scenarios. Although the new reservoir would offer limited benefits on average, it would reduce irrigation shortages and improve instream flows during moderate and low-flow years.


Musselshell River.

Water Management Strategy for Increased Drought Resilience

Several ongoing efforts in the Missouri River basin are investigating the impacts of drought and developing strategies for drought resilience, including the 2015 Montana State Water Plan, National Drought Resilience Partnership Montana Headwaters Drought Resiliency Project, and associated efforts through Reclamation's drought contingency planning.

This strategy investigates the impact of severe drought in the Big Hole River basin and investigates ongoing efforts by the National Drought Resilience Partnership and Reclamation to mitigate its impacts and how effective these efforts might be in the future. The concept is that voluntary instream flow targets for the purpose of water conservation during drought may lessen severe impacts on the range of uses as a whole. Although this is not a system-wide strategy, it is a demonstration strategy for addressing the need for greater drought resilience.

Through the demonstration project for drought resilience in the Big Hole River basin, it appears that **voluntary flexible instream flow targets could provide multiple benefits while at the same time not substantially impacting**

irrigation water users. Especially under the hotter and drier future scenarios, instream flow targets could be more important in maintaining aquatic resources. Future scenarios suggest greater impacts to late summer streamflow than if paleo events were to reoccur.

Next Steps

The Missouri Headwaters Basin Study provides foundational information on the security of water supplies in the region, both historically and looking ahead to the future. The information developed in this study may be used for further analysis and/or in depth study.

For example, one key finding from this study is that future scenarios suggest higher overall streamflow volumes in the future and shifting of the seasonal peak flow in many subbasins toward earlier in the year. Additional strategies may be explored to examine alternative operations specifically to address these changes. This was not identified as a strategy among stakeholder groups but could be analyzed in the future.

In another example, the Upper Missouri RiverWare planning model could be improved and used as an adaptive management tool for existing and potential future water resources problems. Further, the RiverWare model structure and results are already being used to inform and enhance current operational models for Reclamation reservoirs, such as in the Beaverhead River basin. This could be expanded to other parts of the study area.

Table 2.—Key Findings

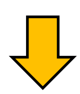
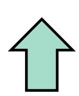
Strategy	Impact	Description
Providing Water for Future Consumptive Uses through Contract Water from Canyon Ferry and Lake Elwell		Additional contracts for stored water in Canyon Ferry Reservoir and Lake Elwell would cause streamflow and hydropower production to decrease downstream (more substantially below Lake Elwell).
		Additional contracts for stored water in Canyon Ferry Reservoir and Lake Elwell would result in increased irrigation and agricultural production.

Table 2.—Key Findings

Strategy	Impact	Description
Providing Water for Future Municipal, Domestic, and Industrial Uses in the Gallatin Valley	↑	Providing additional domestic water to the Gallatin Valley could meet demands without impacting local water conditions.
Increasing Canal and On-farm Irrigation Efficiencies	↑	The Missouri Headwaters region would benefit the most by decreased irrigation water shortages, followed by the Rocky Mountain Front region and the Musselshell region.
	↓	August streamflow in the Missouri River at Toston and the Sun River at Simms would modestly decrease, Big Hole River at Melrose and the Musselshell River at Roundup would see greater decreases. Hydropower production at Canyon Ferry Dam and NorthWestern Energy facilities on the Missouri River would also decrease.
Ecological Flow Releases	↑	Future ecological flow releases would be possible at least as frequently as under historical conditions, and potentially much more frequently under wetter future scenarios.
	↓	Hydropower production would modestly decrease at Tiber Dam but other facilities would see little impact. Also, late summer flows in the Missouri River and Marias Rivers would not be noticeably impacted.
Beaverhead River Basin Strategies	↑	Storing additional water in Clark Canyon reservoir would decrease drawdown for flood storage and increase end of water year storage in dry years. There would be little impact on winter streamflow in the Beaverhead River downstream of Clark Canyon Reservoir, even in dry years.
Sun River Basin Strategies	↑	There would be modest benefits in dry years, reducing irrigation shortages and increasing reservoir end of water year storage. There would not be any appreciable impacts on summer streamflow in the Sun River.
Musselshell River Basin Strategy	↑	A new storage reservoir would have modest benefits in dry years, reducing irrigation shortages and increasing streamflow in moderate to low-flow years. There would not be any appreciable impacts on summer streamflow in the Musselshell River.
Water Management Strategy for Increased Drought Resilience	↑	Agricultural interests will likely be asked to provide more water to maintain instream flows in the future, although these increased contributions are not expected to increase irrigation water shortages.
	↓	Maintaining a minimum instream flow of 60 cfs will become more difficult under most future scenarios.

In addition, Reclamation, Montana DNRC, and other stakeholders could take steps to continue to promote the collaboration and water resources planning in the basin which is key to implementing strategies. Some of these include:

- Consider using the model to facilitate the analysis of water contracting from Reclamation reservoirs, such as at Canyon Ferry Reservoir and Lake Elwell.
- Consider using the model to facilitate the implementation of water rights compacts, such as those for the Blackfeet Tribe and Chippewa Cree Tribe-Montana Compact.
- The project partners developed or enhanced working relationships with many agency staff and groups during this Basin Study. This collaboration could provide future benefits, such as through periodic attendance and presentation at watershed group meetings, and presentations at conferences of professional organizations.
- The project partners could continue to support, when resources allow, the work of watershed groups and conservation districts, especially for adaptive water management activities.

References

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