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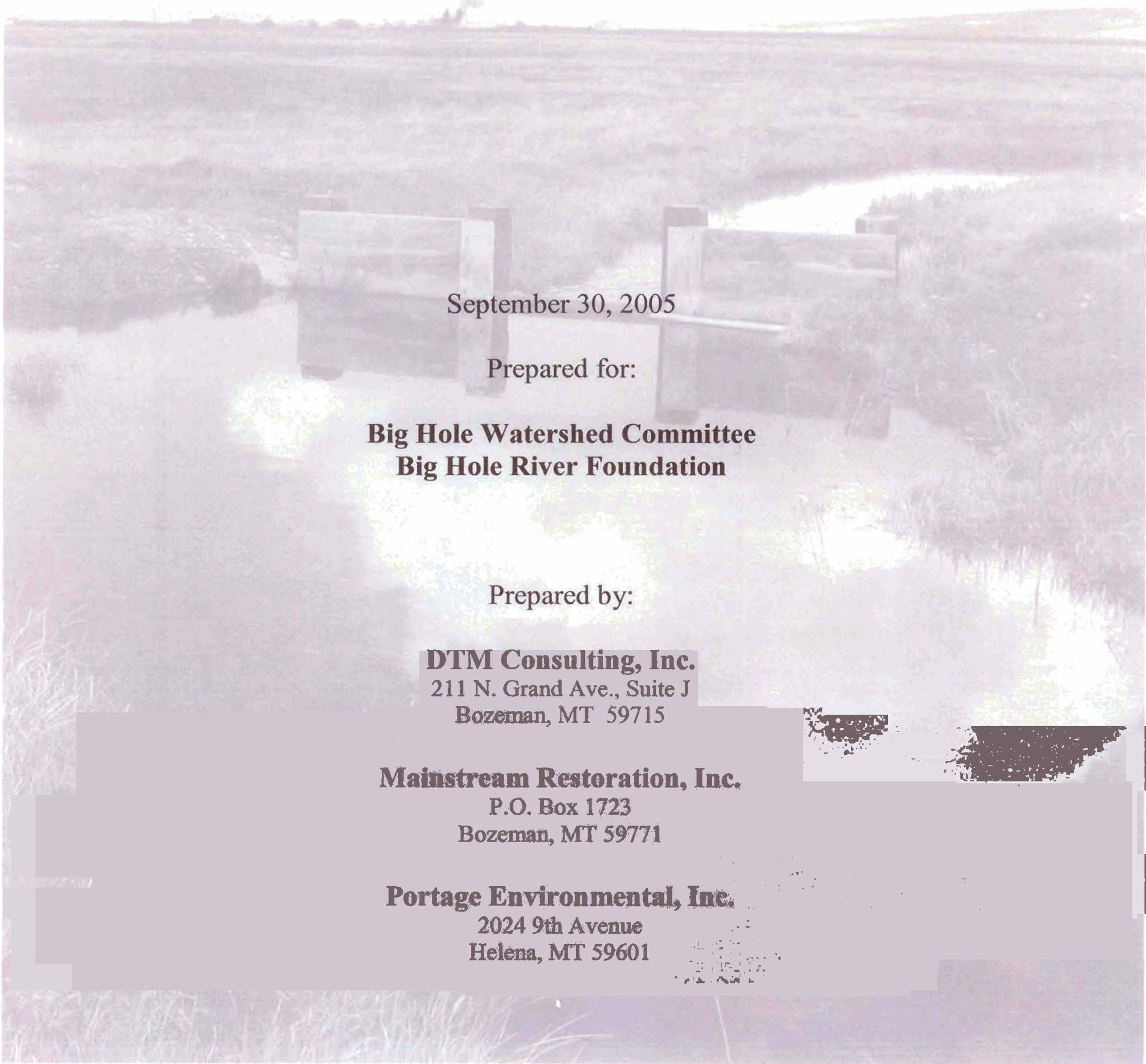
Big Hole Water Storage Scoping Project and Water Management Review

Final Report

Water Management Alternatives



September 30, 2005

Prepared for:

Big Hole Watershed Committee
Big Hole River Foundation

Prepared by:

DTM Consulting, Inc.
211 N. Grand Ave., Suite J
Bozeman, MT 59715

Mainstream Restoration, Inc.
P.O. Box 1723
Bozeman, MT 59771

Portage Environmental, Inc.
2024 9th Avenue
Helena, MT 59601

Forward

This report presents the results of the water management alternatives portion of the Big Hole Water Storage Scoping Project and Water Management Review commissioned by the Big Hole Watershed Committee (BHWC) and the Big Hole River Foundation (BHRF) in the spring of 2004. The project objective was to identify means of improving in-stream flows in the upper Big Hole River to sustain the fluvial artic grayling while maintaining irrigation and stock-water rights and traditional uses. To fulfill the project goals, the Portage Inc., DTM Consulting, Inc., and Mainstream Restoration, Inc. project team evaluated a diverse range of alternatives including:

- Small reservoir development, deep aquifer production wells, ditch lining and other engineered concepts.
- Increasing grass production while decreasing growth of water consumptive, wetland grass species by reducing irrigated pasture in unproductive low-lying areas, eliminating irrigation of unproductive soils, and other modifications to agricultural practices.
- Purchasing water through conservation agreements, land purchase or other financial instruments.
- Re-creating some of the watershed's natural storage capacity through beaver reintroduction and other ecology based alternatives.

The project team evaluated each alternative through an assessment of technical and social criteria including: land ownership and other site suitability issues; local and regional geology; hydrological conditions; land use issues; environmental issues including wetlands and threatened and endangered species; and, social and economic issues. Cost was evaluated for each alternative by estimating the capital cost of implementation and then the operating cost. Where appropriate, costs were calculated over an amortized period representing a typical bank loan. For all alternatives costs presented are a bottom line estimate of the cost per acre-foot of water conserved. A worksheet displaying all of the alternatives analyzed and the estimated cost of each alternative may be found in Appendix A of this document.

Once preliminary alternative evaluations were complete, the project team met with Technical Advisory Committee members to present preliminary results and to identify alternatives not considered viable due to site specific considerations. This report represents the results of our evaluation and includes modifications made in our analysis of alternatives based on valuable input from the Big Hole Watershed Committee and its technical advisory members.

Executive Summary

Water shortages in the upper Big Hole River watershed manifest as low summer stream flows in the mainstem Big Hole River in a reach immediately upstream of Wisdom. Causes of this water shortage include gradual climatic shifts to drier winters and warmer spring temperatures, gradual shifts towards land use practices that use more water than historically, an unintended shift toward cultivation of more water consumptive vegetation, persisting short-term drought conditions, and an irrigation system that locally conveys water around a critical reach for fisheries. The probable listing of the fluvial arctic grayling as an endangered species makes addressing this water shortage imperative.

This study identifies and examines 19 water management alternatives conceptualized to reduce water consumption through gains in irrigation efficiency or reduced irrigation, utilizing groundwater resources, delaying runoff, or purchasing land or water. Identification of the alternatives involved meeting with landowners, a technical advisory committee (TAC), and an open forum where interested parties could suggest alternatives. Evaluation of the alternatives involved developing a spreadsheet-based series of cost worksheets with input data derived from meetings with landowners and the TAC, as well as published data. Evaluation also included assessment of potential locations to implement the alternatives, and expected water savings.

Evaluation of these 19 alternatives eliminated eight, leaving 11 for further consideration. Four alternatives involve reducing irrigation in various areas through compensation of landowners with alternative pastures or forage. However, it is anticipated that careful planning and modification of irrigation practices in these areas can result in no net loss or possibly gains in forage production. Two alternatives involve improving irrigation efficiency by reducing ditch loss or converting flood irrigation to sprinkler. Sprinkler irrigation is an alternative that is only applicable in a few select locations under certain conditions. Two alternatives involve delaying runoff through creation of additional natural storage capacity. One is beaver re-introduction, initially in headwater tributary streams on US Forest Service land, creating storage through beaver dam complexes and associated bank storage. The second involves implementing channel morphology and riparian re-vegetation habitat improvements, which create more storage capacity in soils and groundwater. These projects are also encouraged and funded by two ongoing processes, CCAA and TMDL. Finally, the last two alternatives are water leasing, which can provide a temporary solution to water shortages, and land purchase. Land purchase not only includes purchasing water rights, but it also creates the potential for managing purchased land as a hay or grass bank, which can facilitate providing alternative forage or pasture to implement the first four alternatives.

Recommendations include some proposed methods and requirements for implementing the selected conceptual alternatives, often involving pilot projects to demonstrate the effectiveness of the alternative. Also included are basin wide alternatives such as land management education and monitoring of water application.

1. Introduction

Water in the upper Big Hole River is in short supply during the summer irrigation season, after peak runoff. Demands for water can exceed supply, resulting in very low flows (less than 20 cfs) at the stream gauging station at Wisdom. Populations of fluvial arctic grayling, which historically inhabit this river, have dropped significantly since 2002 (Montana FWP, 2004). The status of the grayling may lead to its listing as an endangered species under the Endangered Species Act. Listing of the grayling would likely bring enforced actions to increase instream flows, which would undoubtedly have a serious impact to the local agricultural industry.

Two stakeholder groups are active in efforts to find solutions to current water supply issues. The Big Hole River Watershed Committee provides an open, consensus-based forum for resolving issues in the 1.8 million-acre Big Hole River watershed. Formed in 1995, its mission is to develop understanding of the river's function and use and achieve agreement among individuals and groups with diverse viewpoints in order best manage the watershed's limited water resources. The Big Hole River Foundation, founded in 1988, is a nonprofit conservation organization dedicated to defending and conserving the natural and cultural resources of the Big Hole watershed. The mission of the Foundation is "to understand, preserve, and enhance the free-flowing character of the Big Hole River, and to protect its watershed, culture, community and excellent wild trout fishery."

1.1. Goals and Objectives

The goals of this study are to assess water management opportunities in the upper Big Hole River watershed to increase in-stream flows. This document covers water management alternatives not associated with reservoir storage. The objectives to meet the goals of this assessment are to:

- Identify viable means by which instream flows in critically dewatered sections of the Big Hole River can be increased,
- Determine approximate costs of implementing the various alternatives,
- Determine the approximate amount of water that could be provided by these alternatives, and
- Create a recommended list of alternatives based on cost and amount of water provided.

The highest water demands typically occur in the months of July and August, coincident with reduced flow after early June peak runoff. The goal of this study is to identify water management alternatives or combinations of alternatives that can significantly reduce water demands during this time. Identified potential water savings will assist with maintaining flow levels as identified in the Big Hole River drought management plan.

1.2. Project Location

The geographic focus of this analysis is primarily the watershed area above the Highway 43 bridge at Wisdom, approximately 590 square miles (377,500 acres). Figure 1-1 below shows the upper Big Hole River watershed and the watershed area above the Wisdom Bridge. Although areas downstream are also important to the life history of fluvial arctic grayling, gauged flow at the Wisdom Bridge is considered an indicator of instream flows throughout the grayling habitat and is within the reach that most often approaches critically low flows and high temperatures. Advocacy groups currently seeking listing of fluvial artic grayling as an Endangered Species also monitor stream flows at the Wisdom gage.

1.3. Causes of Water Shortages

Historic climate records (1946 to present) indicate a gradual shift from wetter to drier winters and from colder to warmer spring temperatures. The average annual precipitation appears to be much the same as it was 50 years ago, while average annual temperatures have risen slightly. Both the lower winter snow pack and warmer spring temperatures reduce the amount of spring and summer runoff for both fisheries and agriculture. In addition, six consecutive drought years have compounded the long-term climate trends.

Land use practices have also gradually changed in the upper Big Hole River watershed over the last 20-30 years. In some areas, a shift from hay production to irrigated pastures results in more water consumed in the late summer months, when hay was traditionally cut and irrigation ditches closed. In addition, the increased use of excavators and other mechanized equipment has allowed irrigators to gradually enlarge and expand irrigation systems. This also contributes to increased water consumption during the late summer months.

The gradual changes in land use and irrigation practices, combined with gradual climate changes contribute toward a critical situation for instream flows in the upper Big Hole River watershed. In addition, several irrigation diversions convey water from the Big Hole River out of the watershed area above the Wisdom Bridge, exacerbating dewatering in this reach. The following section describes this in more detail.

1.4. Irrigation Pattern

The following series of figures illustrates the pattern of irrigation in the upper Big Hole River watershed. The upper Big Hole River watershed can be broken into three distinct physiographic areas: forested uplands, an expansive valley foothill area, and a valley bottom area. Irrigation patterns and water use differs between the three areas. Figure 1-2 illustrates the general pattern of water movement throughout the basin and shows the location of the subsequent figures, which show examples of the significant irrigation patterns. Note the unusual shape of the watershed area above the Wisdom Bridge. East of the Big Hole River, Steel Creek and its tributaries do not reach the Big Hole until several miles downstream of Wisdom. The same occurs west of the Big Hole River where Swamp Creek reaches the Big Hole downstream of Wisdom. The arrows on

Figure 1-1: Map of the upper Big Hole River watershed.

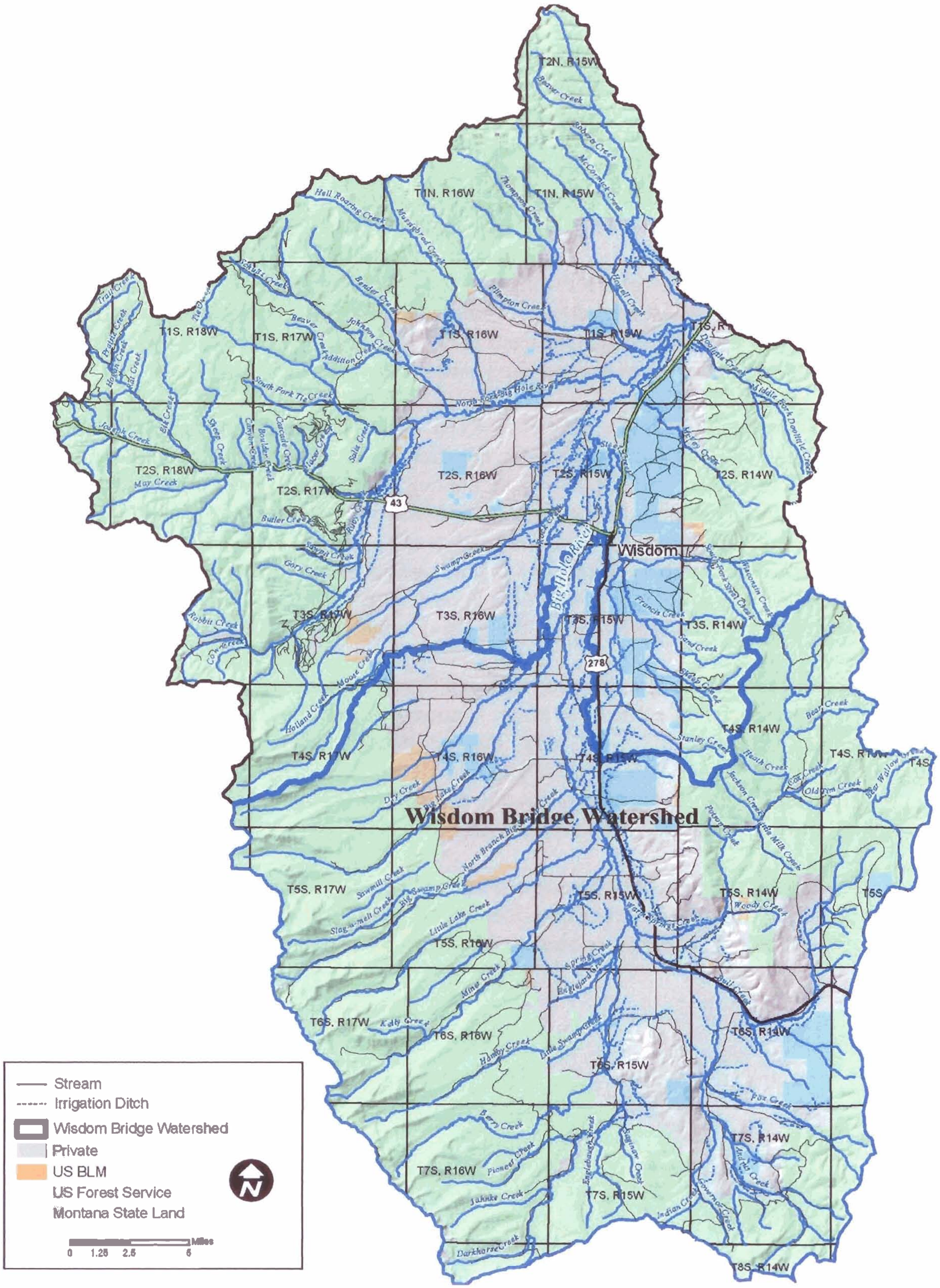


Figure 1-2 show the general pattern of diversion and flow around the dewatered section above Wisdom.

Some of the water withdrawn for irrigation from the mainstem of the Big Hole River flows through ditches out of the Wisdom Bridge watershed and into the Steel Creek and Swamp Creek watersheds. In addition, tributary streams to the Big Hole River, which historically flowed into the mainstem above Wisdom, are also diverted out of the Wisdom Bridge watershed. Warm Springs Creek east of the Big Hole and Rock Creek, west of the Big Hole, are examples of large tributary streams partially diverted out of the Wisdom Bridge watershed. The following figures illustrate some of these withdrawals.

Irrigators utilize flood irrigation throughout the upper Big Hole River watershed. Diversion from tributary streams begins where these streams leave forested uplands and enter the valley foothills. Irrigation from these tributary streams occurs on both low gradient valley bottom areas and perched bench areas (Figure 1-3).

Further downstream, mainstem Big Hole River valley bottom and adjacent areas are also irrigated with water withdrawn from the Big Hole River. A series of generally northeast oriented ditches convey water away from the Big Hole River. Examples are the Helming, Huntley, Miller, Dishnow, Chickenhouse, and Maverick ditches (Figure 1-4). Water leaves these ditches through a series of headgates to irrigate the areas between the ditches. The result of these diversions is the removal of a significant amount of flow from the Big Hole River mainstem to the Steel Creek watershed. Unused portions of this water can return to the Big Hole, but not until downstream of Wisdom.

On the west side of the Big Hole River, Rock Creek is modified from its historic configuration such that some of its water is conveyed into the Swamp Creek watershed immediately to the north (Figure 1-5). This removes a significant portion of the flow contribution of Rock Creek from the Big Hole River. Since Swamp Creek does not reach the Big Hole River until several miles downstream of Wisdom, this water essentially bypasses the dewatered reach above Wisdom.

Finally, Figure 1-6 shows the Spokane Dich and Hirschy Diversion, two of the larger points of diversion on the upper Big Hole River. Both of these diversions convey water out of the Wisdom Bridge watershed and into the Swamp Creek watershed.

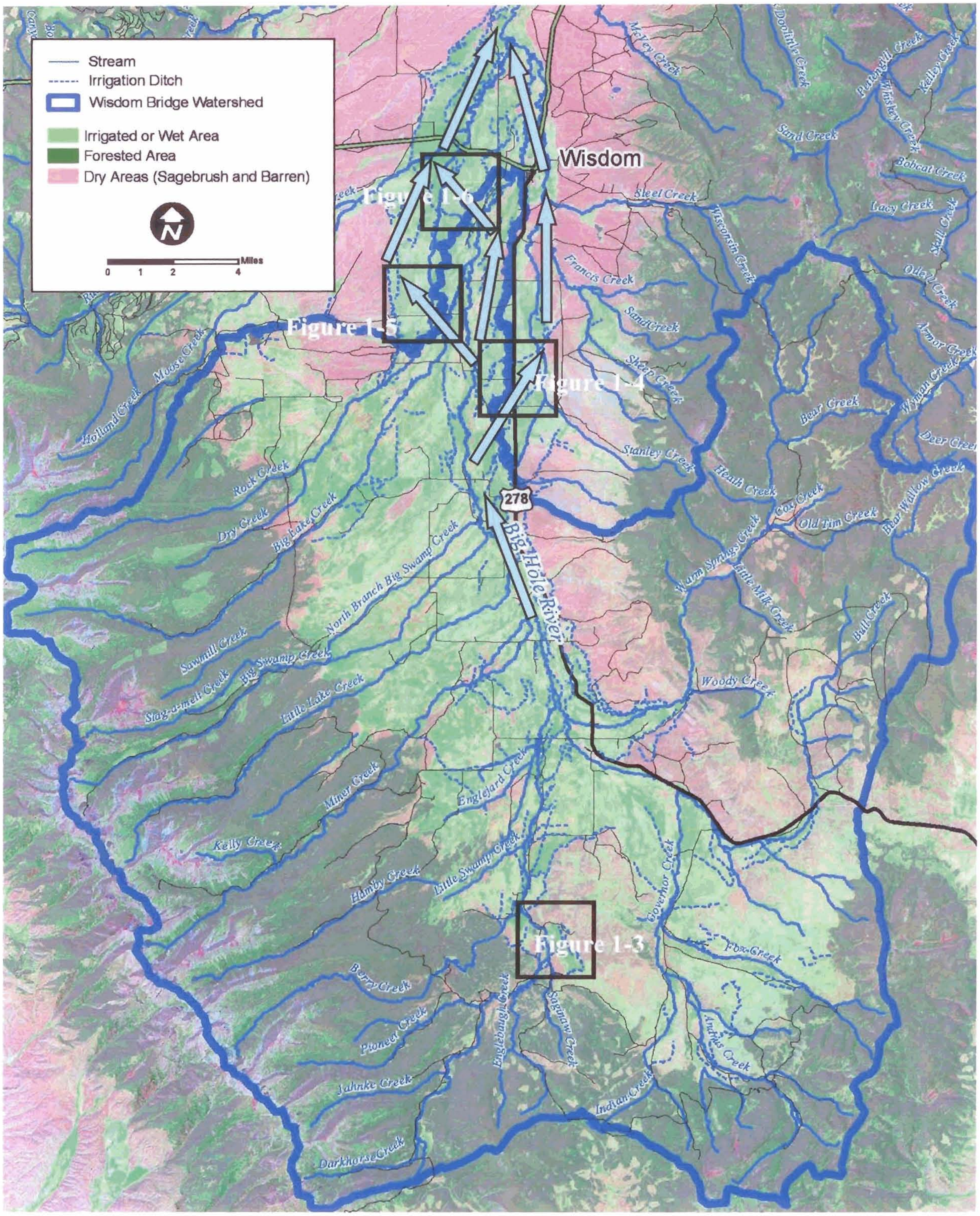


Figure 1-2: Irrigation overview of the upper Big Hole River with locations of subsequent figures. Arrows indicate the movement of water around the dewatered reach above Wisdom.

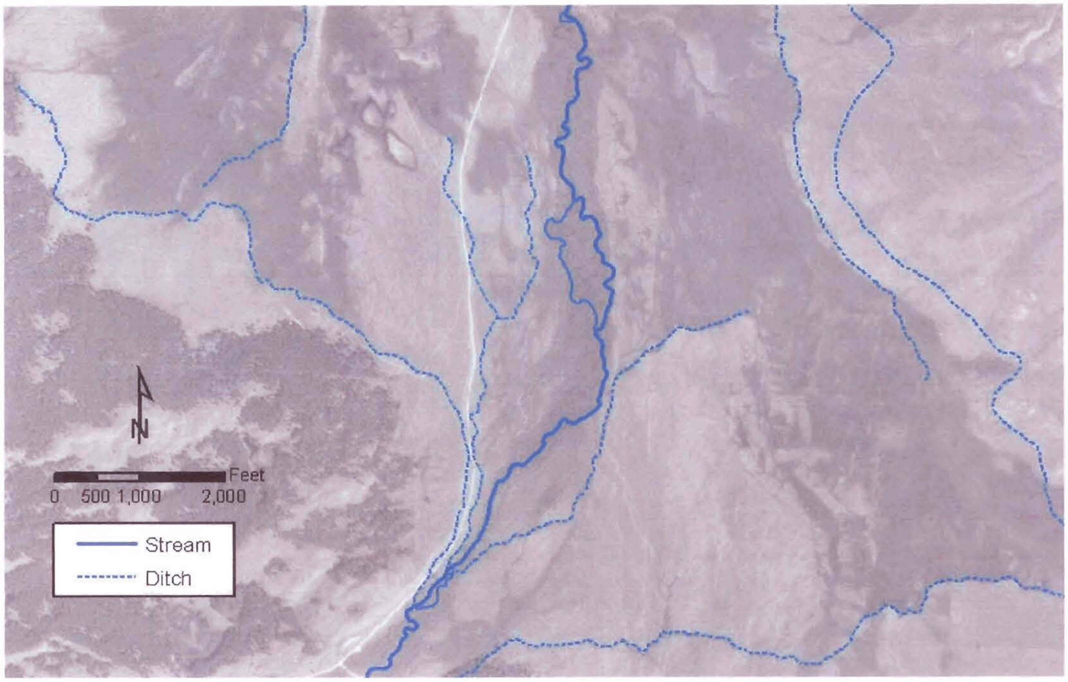


Figure 1-3: Irrigation from diversions near forested headwaters.

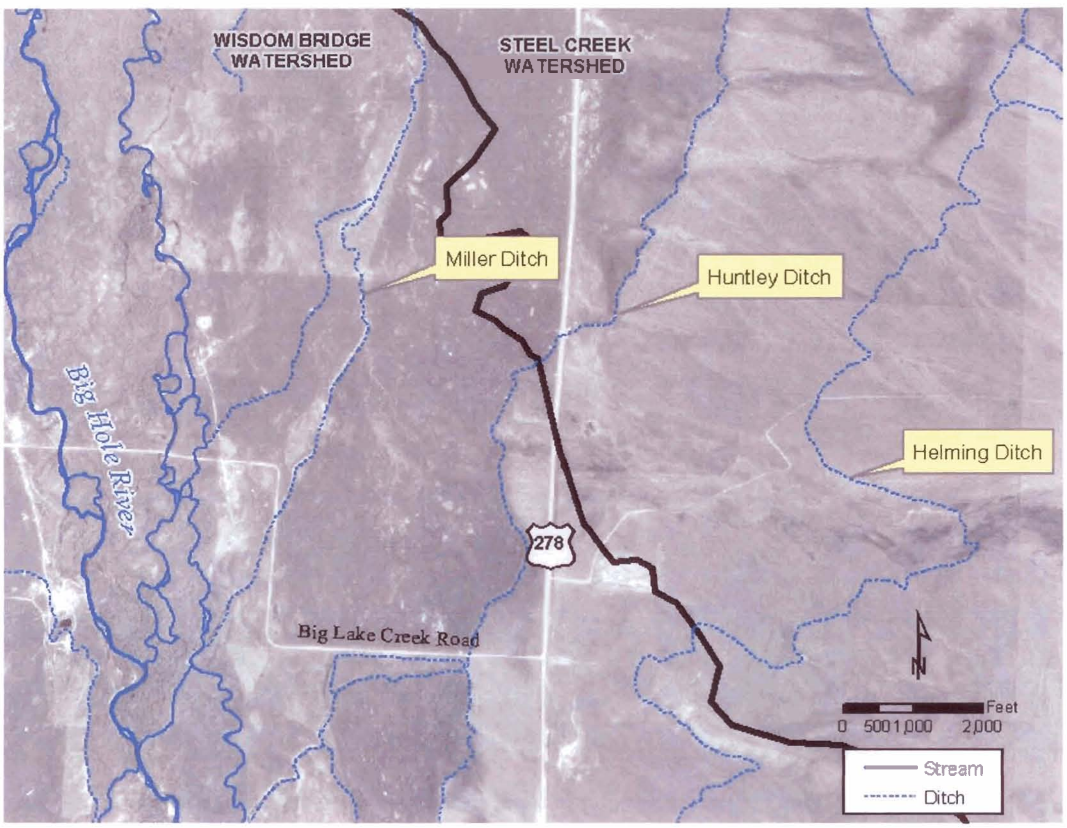


Figure 1-4: Significant ditches on the east side of the upper Big Hole River.

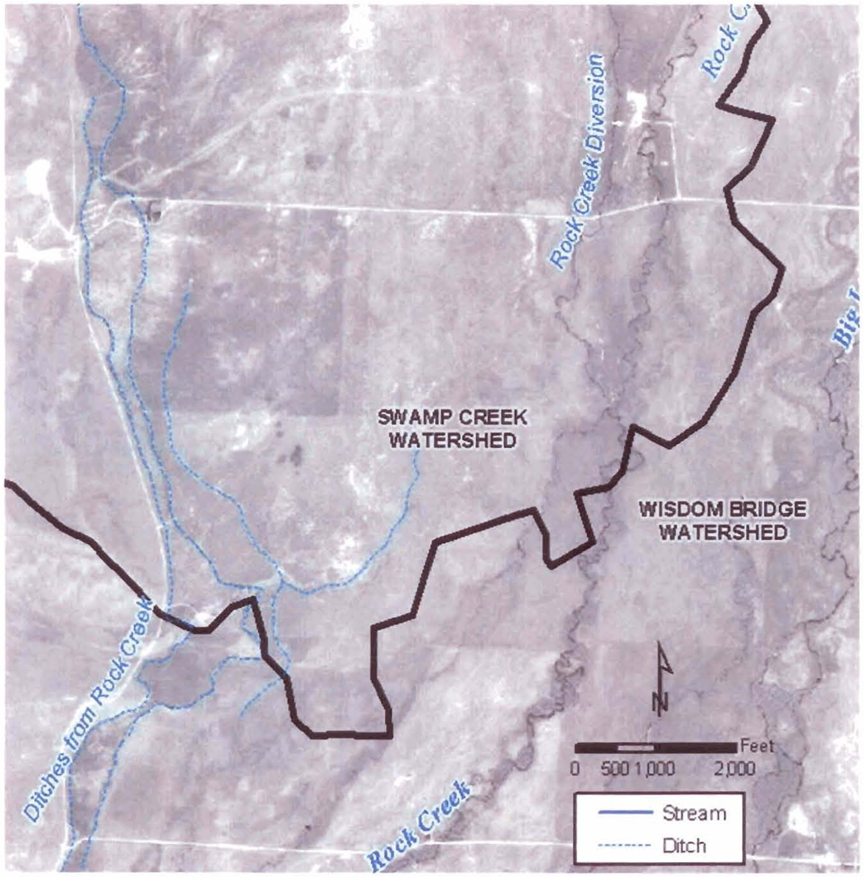


Figure 1-5: Significant diversions on the west side of the upper Big Hole River.

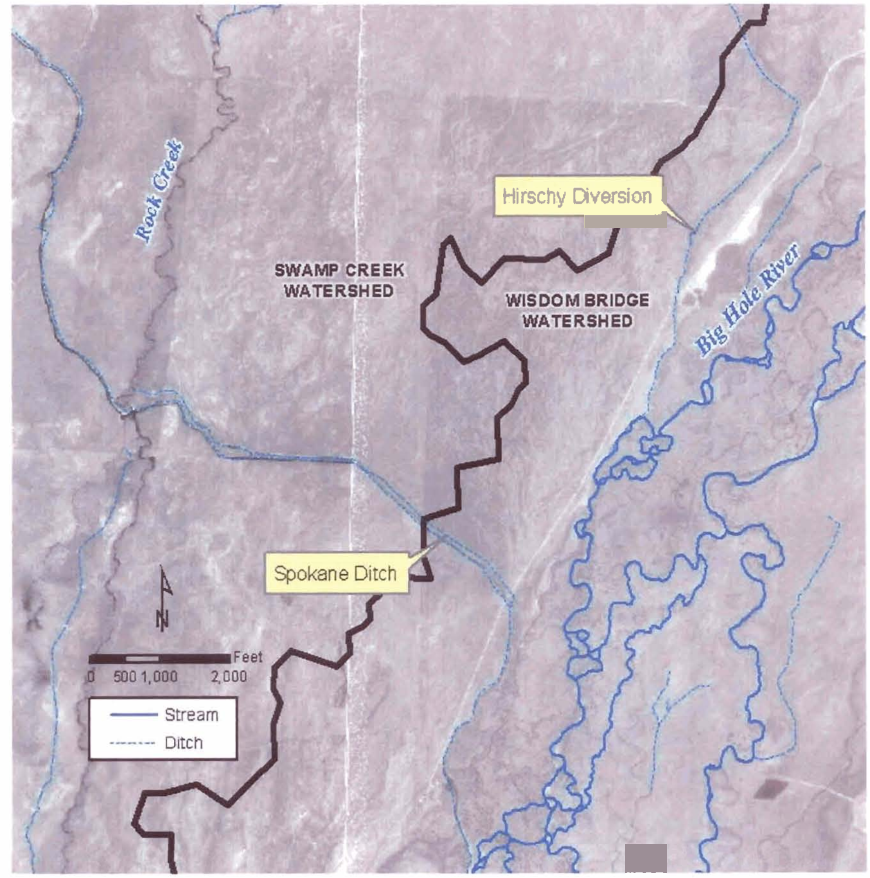


Figure 1-6: The Spokane Ditch and Hirschy Diversion.

1.5. Return Flow

Return flow from irrigation is an important consideration when evaluating water management alternatives that alter irrigation practices. Literature reviewed on irrigation return flows from both within and outside of the Big Hole River watershed indicates that there are three important aspects of return flows that should be considered. These are:

- Irrigation return flows typically have degraded water quality compared to the diverted water,
- Surface irrigation return flows may have significant thermal loads, and
- Subsurface return flows may contribute to late season base flows.

Due to higher elevations in the upper Big Hole River watershed, the irrigation season typically starts later than other areas in southwest Montana. Irrigation usually begins in May, with some variation between landowners and different parts of the valley. May irrigation is typically heavy; with landowners rushing to get moisture into soils and groundwater aquifers before spring runoff subsides. Peak runoff usually occurs in the first week in June. Typically, this leads to saturation of soils and associated surface runoff. The very rapid hydrologic response to rainfall events illustrates this process. For example, a 1.25 inch rainfall on June 12-13, 2005 resulted in an increase in flow at the Wisdom bridge gage from 200 to 900 cfs on June 13. Ensuing warm weather caused flows to drop back to 200 cfs on June 16. Brief review of historic precipitation and stream gage data indicate a reduced hydrologic response magnitude to rainfall later in the summer season.

This heavy early season irrigation, although beneficial for getting moisture into the soil and groundwater, has unintended negative impacts including:

- Thermal loading due to abundant standing surface water,
- Nutrient loading from surface runoff through pastures and corrals,
- Reduced flows in the Big Hole River during grayling emergence, and
- Enhanced growth of water consumptive vegetation (wetland species).

During late summer, return flows from groundwater could augment base flows. However, Marvin and Voeller (2000), in their groundwater study, concluded that plant evapotranspiration consumes most groundwater during July and August. It was not until September, where cool temperatures stop plant growth and groundwater return flows augment stream flows. Overall, Marvin and Voeller (2000) concluded that the yearly upper Big Hole basin water yield is approximately 1.7 million acre feet but that evapotranspiration consumes 70% of this water. If water conservation measures could reduce this by 1% by growing more grass and less sedge and water consumptive species, this would amount to 17,000 acre feet of water.

Return flow is a complicated subject that has many variables and can change drastically from place to place. Irrigation is very effective at removing water from streams. Vegetation is very effective at consuming that water. However, the process of putting water back into streams, especially during July and August, is much less certain.

1.6. Additional Considerations

Both water storage and non-storage alternatives face similar obstacles to success. The most important is getting additional water to the dewatered section of the Big Hole River during the hottest and one of the driest parts of the year, July and August.

1.6.1. Water Rights

All water management alternatives implemented in the upper Big Hole River watershed face a similar challenge; ensuring that any water saved or stored reaches the critically dewatered reach above the Wisdom Bridge. Until water rights in the basin are adjudicated, this may be difficult. The coordinated efforts of DNRC personnel, ditch riders, and landowners will be required to ensure these efforts are successful.

The Montana DNRC water rights database identifies 167 water right points of diversion on the mainstem Big Hole River upstream of the Wisdom Bridge (Montana DNRC, 2005). Mapping irrigation infrastructure and related habitat features as part of a Conservation Planning Initiative (CPI) grant identified 86 distinct water diversion points along the same stretch of the Big Hole River (DTM and AGI, 2005). Water saved or stored through implementation of water management efforts will need to bypass many of these diversions to positively impact instream flow in the reach above Wisdom. Careful monitoring and agreements with irrigators to allow additional water to flow through the dewatered section are critical to the success of any water management efforts.

1.6.2. Coordination with Existing Efforts

Several other efforts are under way in the upper Big Hole River watershed which will have significant implications for water management and maintaining adequate instream flows. These include:

- The current CCAA (Candidate Conservation Agreement with Assurances) efforts underway by Montana FWP and NRCS,
- TMDL (Total Maximum Daily Load) development overseen by Montana DEQ,
- The CPI (Conservation Planning Inititative) grant which is providing education, outreach, and development of land use planning data, and
- Additional restoration planning studies and restoration projects spearheaded by the Big Hole River Watershed Committee and Big Hole River Foundation.

Coordination of these efforts with water management planning and alternative implementation to follow up this project should be pursued. Of particular importance to water conservation efforts are the water management actions that CCAA plans will require of landowners and habitat improvements implemented through this program and implementation of TMDLs.

2. Initial Alternative Identification

The sections that follow describe the identification and grouping of water management alternatives by type. Each alternative is described in detail. The following descriptions are conceptual ways to conserve or redirect water in the upper Big Hole River watershed, with only generalized locations where these alternatives are applicable. Subsequent sections describe implementation of these alternatives and combinations of alternatives in specific areas.

2.1. Contribution by Stakeholders

The identification of water management alternatives involved a collaborative process with members of the Big Hole Watershed Committee, area ranchers, state and federal resource agencies and the consultants responsible for conducting the analysis. Beginning in May of 2004, these participants contributed to the formation of a list of alternatives. During subsequent discussions at the next few monthly Big Hole Watershed Committee and Big Hole River Foundation meetings, this list evolved and was eventually refined to consist of nineteen alternatives. In order to characterize and group the alternatives, we divided them into nine categories of differing types. The following sections describe the categories and alternatives.

2.2. Alternatives Identified

The identified water management alternatives fit into nine categories based on a broad overview of the alternative purpose. The groupings are as follows:

- Reduce pasture irrigation in valley bottom areas;
- Reduce pasture irrigation in wet meadow areas;
- Reduce pasture irrigation on low productivity soils;
- Purchase water;
- Purchase land;
- Increase water yield;
- Improve irrigation efficiency;
- Develop groundwater resources; and
- Delay runoff.

Within each grouping are one or more specific alternatives that represent means of accomplishing the goal of the category. The descriptions of each alternative also contain additional information on implementation, including coordination with ongoing conservation efforts in the basin.

2.2.1. Reduce Pasture Irrigation in Valley Bottom Areas

Within the last few decades, there has been a shift in agricultural land use in the upper Big Hole River basin from the traditional practice of growing and harvesting hay to feed cattle to the more common practice of pasturing livestock within grass-producing fields. The irrigation patterns associated with these two methods of raising cattle differ significantly. Ranchers typically irrigate hay ground until early to mid-July, after which time they discontinue irrigation for the remainder of the season. Conversely, ranchers typically irrigate pasture throughout the entire growing season (beginning in the spring and continuing through the fall) as long as irrigation water is available. While limited water availability tends to reduce the rate of late-season irrigation, pasture irrigation nonetheless uses water from mid-June until into September. This is the critical period when flows in the river are lowest and grayling most threatened. The following three alternatives address possible ways to reduce the use of irrigation water during July and August by altering land use patterns.

Alternative 1. Convert Pasture to Hay Production

This alternative involves converting land currently used for pasture into land where ranchers would grow, cut and bale hay. Land used for pasture often supports grasses that are less suitable for hay production, and may not lend itself to efficient irrigation and cutting of hay (for example, due to uneven ground). While little effort might be required to convert some pasture into hay producing land, other pasture land may require a variety of actions, including flood irrigation ditch improvement, reseeding and weed treatment. In more extreme cases, conversion may require land leveling and tilling of existing grasses, followed by reseeding and weed treatment.

Location and Availability

Approximately 90,000 acres of the Big Hole River watershed upstream of the Wisdom Bridge are irrigated (Roberts, 2004). Much of this area has traditionally been irrigated pasture. Examination of current (1996 and 2001) and historic (1942 and 1955) aerial photography indicates that numerous areas adjacent to the Big Hole River have been converted from hay production to pasture. Discussions with landowners indicate that much of this change occurred in the last 25 years. Figure 2-1 illustrates the distribution of irrigated areas in the Wisdom Bridge watershed. Light green areas in the valley foothill portions of this map are primarily irrigated (although some are naturally wet), dark green areas are forested, and pale red areas are dry or barren, and often dominated by sagebrush. This alternative involving conversion of pasture land to hay production could be applied to irrigated areas near the Big Hole River that were once used primarily for hay production.

Advantages

Converting areas from irrigated pasture to hay production would benefit instream flows during low flow periods after hay has been harvested (which usually occurs about July 4).

Disadvantages

The conversion from hay to pasture occurred for economic reasons, as pasturing in more cost effective. For that reason, local landowners do not consider this an economically viable alternative. Therefore, we have removed this alternative from further consideration.

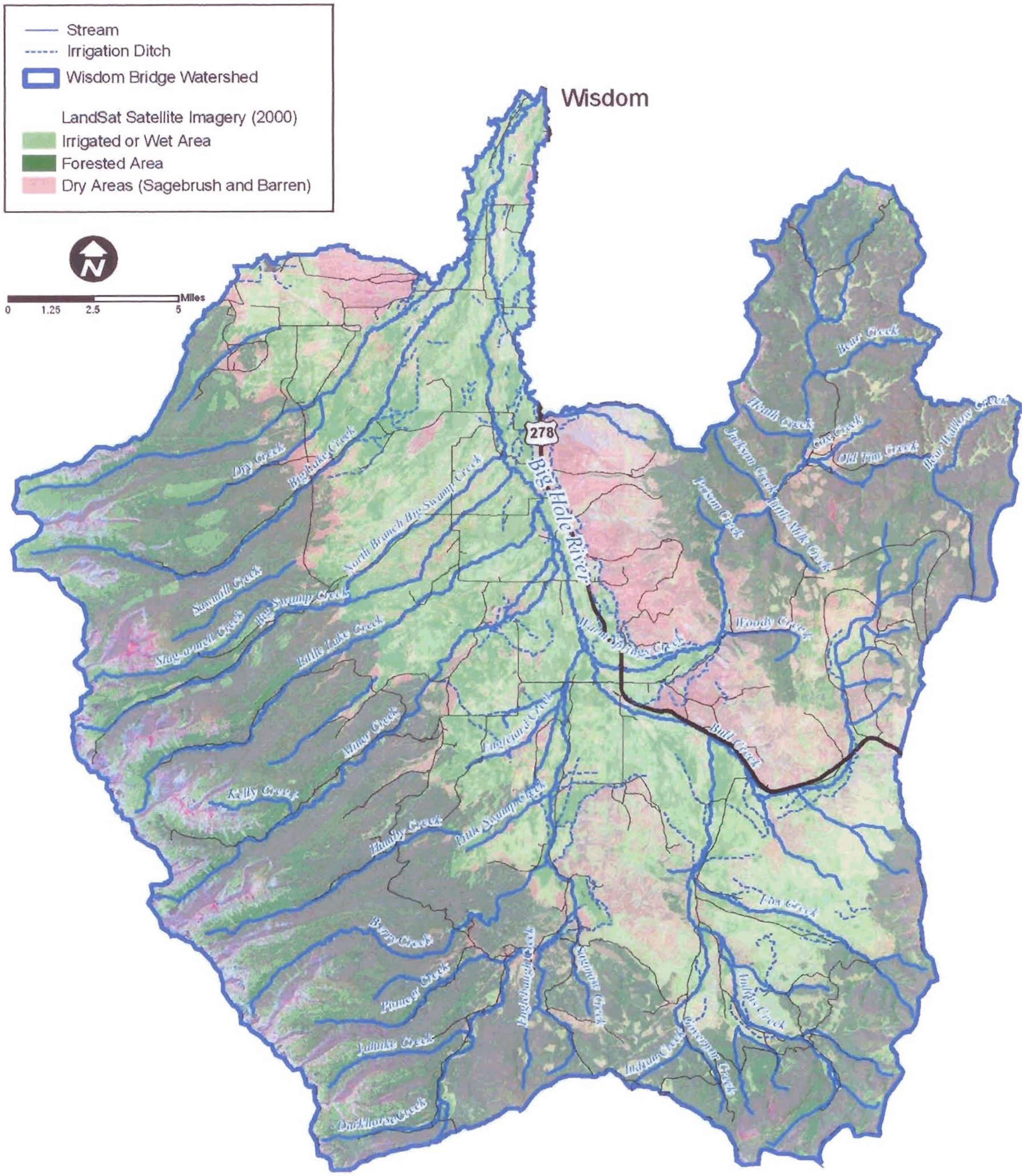


Figure 2-1: Satellite image of the upper Big Hole River watershed (2000).

Alternative 2. Provide Alternative Pastures for Livestock

This alternative involves using alternative grazing land for livestock grazing during July and August. It involves removing the cattle from pastures in early July and transporting them to alternative pastures that would either not require irrigation or would be irrigated with water that would not deplete the critical reach of the river. These pastures would still receive irrigation water during early runoff (May and June), and cattle could graze until grass produced from this irrigation was depleted. In addition to livestock transport to and from alternative pastures, this alternative includes the additional labor required and the monthly lease of land. The alternative does not include potential increased livestock mortality resulting from transport, which we considered negligible for this analysis. Utilizing this alternative could involve voluntary reductions in water use, contracted reductions associated with CCAA agreements, and some compensation from farm bill programs or water leasing.

Implementation of this alternative can be on a temporary, rotating or permanent basis. For example, areas that receive significant sub-irrigation water and have better soils are likely candidates for longer-term implementation. Conversely, grass in typically dry areas (such as bench areas perched above the Big Hole River and tributary streams) may only tolerate an intermittent season of no late-season irrigation without detrimental effects. Conversations with area ranchers following the NRCS compensation program in the summer of 2004 indicate that many landowners learned they could still maintain good grass production without irrigating during the late-season. Conversely, landowners irrigating bench areas indicate that their grass would not sustain consecutive years of no irrigation in late summer. In addition, in some valley bottom areas, sedge and wetland grasses are the dominant vegetation types partially due to gradual conversion from grass. This conversion is due to overwatering (based on conversations with landowners and agency managers). Reducing irrigation in these areas would improve forage quality if grasses were to replace sedges.

Location and Availability

This alternative could be applied to any areas currently used for pasture irrigation where landowners are willing to make this change (Figure 2-1).

Advantages

This alternative can be applied on a rotational basis that allows for recovery of grass from any detrimental effects of reduced late summer irrigation. If conversion of sedges to grasses occurs from implementing this practice, forage quality could improve. In addition, the mainstem Big Hole River valley bottom areas have a higher water table, and would not likely suffer a loss of grass production. A monitoring program should accompany any implementation of this alternative. Monitoring would allow a determination of the true benefits and costs over time. Entering into this type of irrigation management program may help landowners comply with the terms of CCAA agreements and qualify for EQIP funding.

Disadvantages

Determining the frequency of sustainable, late season non-irrigation will require some trial and error. A pilot program with willing landowners can help to determine the best locations and under what conditions this alternative is most appropriate. In addition, since the value of leased pasture may vary from year to year, costs may vary.

Alternative 3. Provide Alternative Forage from Off Site

This alternative involves providing an alternative source of forage to livestock so that cattle would not be dependent on the production of grass in pastures during the latter half of the summer. As with Alternative 2, early season irrigation would proceed until late June or when stream flow rates drop below threshold levels. Ranchers would continue to graze livestock within these pastures; however, they would no longer irrigate this land after mid-July. We have assumed that there would be a reduction in forage production in these pastures with the cessation of irrigation. This reduction in pasture grass production would be offset by off-site forage sources. Ranchers would purchase hay or alfalfa, grown in another location (either within or outside of the basin), which they would transport to their pastures and feed to their cattle. This alternative includes the purchase, transporting and feeding of livestock. Funding for this alternative could potentially come from water leasing or farm bill programs.

Location and Availability

As with Alternative 2, this alternative could be applied to any areas currently used for pasture irrigation where landowners are willing to make this change (Figure 2-1).

Advantages

This alternative can be applied on a rotational basis that allows for recovery of grass from any detrimental effects of reduced late summer irrigation. A monitoring program should accompany any implementation of this alternative. This would allow determining the true benefits and costs over time. Entering into this type of irrigation management program may help landowners comply with the terms of CCAA agreements.

Disadvantages

Determining the frequency of sustainable, late season non-irrigation will require some trial and error. A pilot program with willing landowners can help to determine the best locations and under what conditions this alternative is most appropriate. In addition, since this alternative involves purchasing hay from outside sources, costs may vary from year to year.

2.2.2. Reduce Pasture Irrigation in Wet Meadow Areas

Different grasses require different rates of irrigation and produce different quantities and qualities of forage. Optimal grasses produce large quantities of forage high in nutrient value for a given amount of irrigation. Less optimal grasses produce minimal quantities of forage with only limited nutrient value and require relatively higher amounts of irrigation. Western Timothy grass (*Phleum pratense*), orchardgrass (*Dactylis glomerata*) and tall fescue (*Festuca arundinacea*) are examples of common hay and pasture grasses in Montana with high forage value. Conversely, sedge grass or nut grass (such as *Carex nebrascensis*) is of lower forage value and requires continuous wet conditions to grow. Sedge grows along irrigation ditches, in low areas that tend to remain wet or inundated, and at the end of flood irrigation networks. Irrigators sometimes route excess water (flood irrigation water not consumed by dryland plant species) to low and end-point areas to promote the growth of sedge (Figure 2-2).

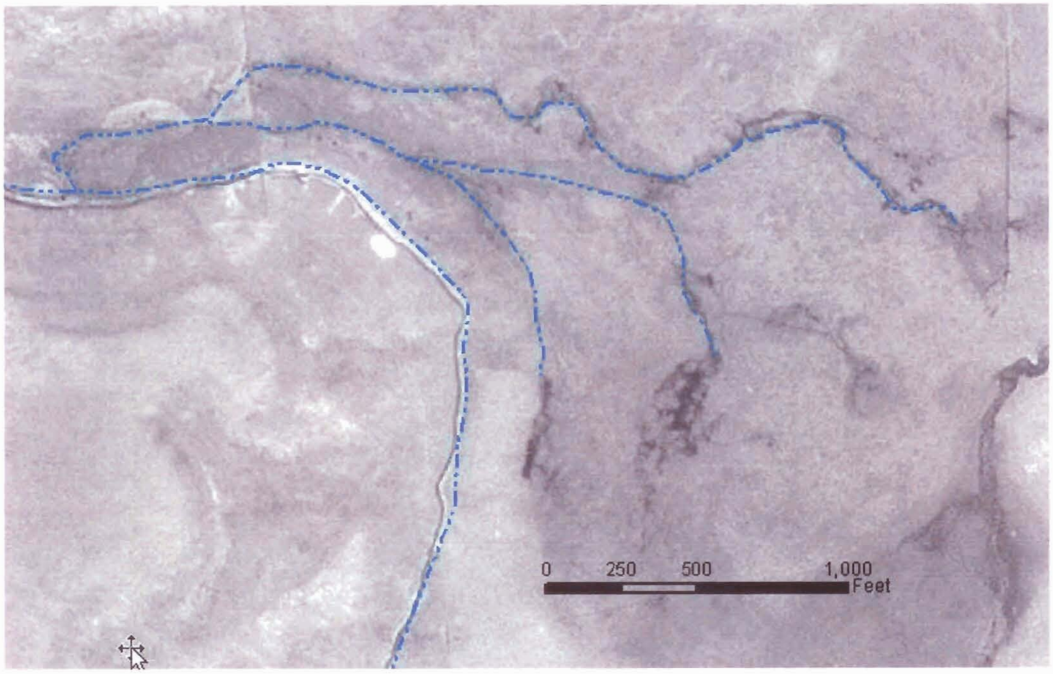


Figure 2-2: Irrigation ditches terminating in wet meadow areas.

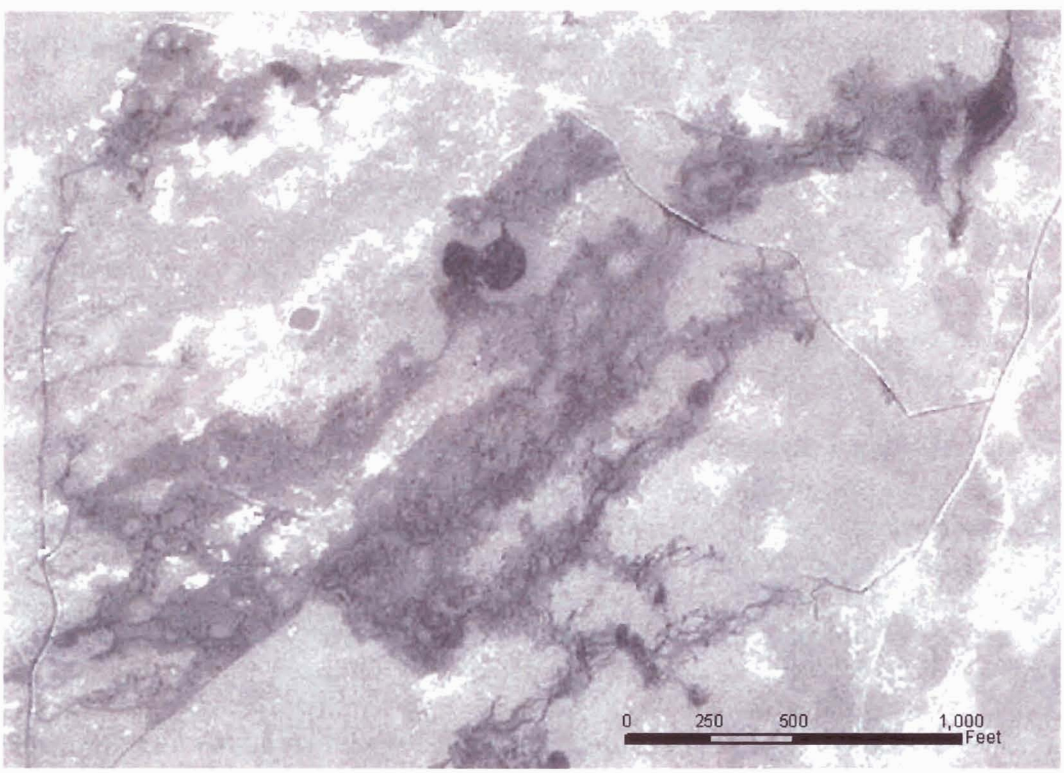


Figure 2-3: Air photo of sedge meadow created by loss from irrigation ditches.

Figure 2-4: Photograph of mixed sedge and wetland grasses in low areas with desirable forage (and cattle) on high spots.

They consider this plant, although not particularly high in nutrient value, a valuable late-season source of livestock forage. Sedge meadows also occur where irrigation ditches run through large flat areas, (Figure 2-3). Alternative 11, reducing ditch loss, may also address these areas. Recent aerial photo analysis has shown an increase over the last few decades of the extent of sedge grass. This increase in sedge is likely a result of shifts in irrigation patterns, particularly where irrigators apply more water to pastures throughout the mid- to late-summer. The following alternative addresses a means to reduce the use of irrigation water during July and August.

Alternative 4. Provide Alternative Fall Forage

This alternative involves providing an alternative source of forage to livestock so that sedge grass would not be a significant source of feed to cattle during the latter half of the summer. Ranchers would no longer manage their irrigation practices to intentionally grow sedge, and in fact, would work to minimize excessive standing water in low areas and release of water past irrigation end-points. Sedge would continue to flourish in some low areas and would continue to provide some late-season livestock forage. However, to augment this reduction in late-season forage, ranchers would utilize forage from off-site sources. Ranchers would purchase hay or alfalfa, grown in another location (either within or outside of the basin), which they would transport to their pastures and fed to their cattle. This alternative includes the purchase, transporting and feeding of livestock. Potential funding sources are water leases and farm bill programs.

Location and Availability

Examination of aerial photography indicates there are numerous areas where ditches terminate in wet meadow areas or flow through flat areas and lose enough water to create wet meadows. Sedges and wetland grasses that serve as fall forage typically transpire three to four times more water than typical pasture grasses (Berger, et al., 2001) but do not provide a higher dry mass of forage. In a December 2004 meeting with upper basin landowners, irrigation rates were determined to be approximately one miners inch per acre (1 cfs per 40 acres) on typical pasture. If irrigation of wet meadow areas was reduced on just 10% (240 acres) of the identified topographic depressions, then savings equivalent to the amount of water applied to three to four times that acreage (720 to 960 acres) could be achieved. The resultant water savings would be between 18 to 24 cfs. This flow rate, over a two-month period, equates to 2,100 to 2,800 acre-feet of water.

Advantages

The advantage with this alternative is that it addresses a relatively inefficient use of water for producing forage. Since sedges and wetland grasses consume three to four times as much water as pasture grass, the potential water savings is quite large. If the areas currently dominated by sedge revert to grass-dominant species, forage production could increase while water consumption goes down. Implementation of these water conservation measures may help landowners comply with CCAA agreements and qualify for EQIP funding.

Disadvantages

Landowners may be reluctant to implement land use practices that are considerably different than those practiced over the last 100 years. Implementation of this type of alternative will require a landowner willing to implement a pilot test of these practices during a monitored trial effort. Documentation of increased or minimally reduced forage from reduced irrigation practices may convince other landowners to participate as well.

2.2.3. Reduce Pasture Irrigation on Low Productivity Soils

The quantity and quality of forage that ranchers can produce on a given acre depends on the productivity of the soils and the amount of irrigation water applied. Within the Big Hole River basin, there are large expanses of soils derived from the Tertiary Bozeman Formation sediments (Figure 2-5). These soils have low clay content, are highly permeable and have low available water capacity to plants. In other words, these soils do not retain moisture and will not support substantial plant growth. Irrigators have typically compensated for the low water holding capacity of these soils by applying relatively heavy rates of water using flood irrigation methods.

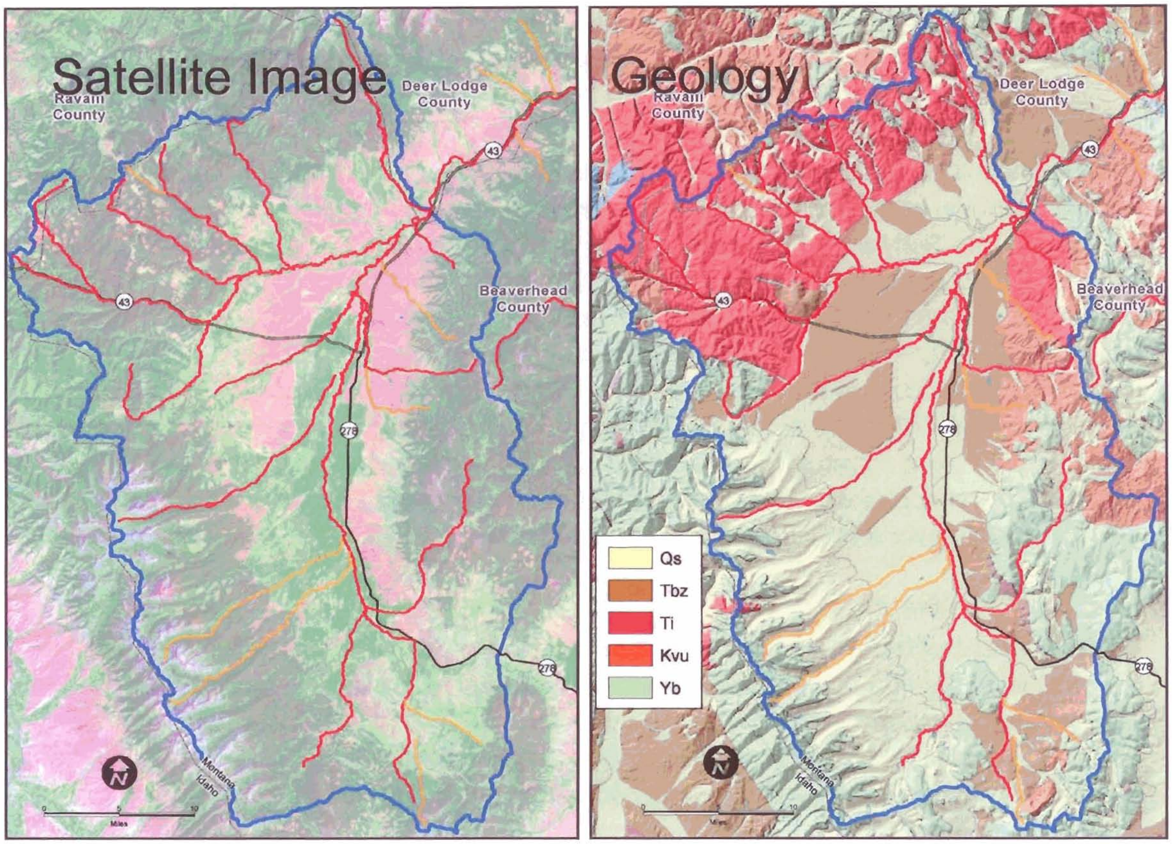


Figure 2-5: Correlation between low productivity soils and Bozeman formation sedimentary rocks.

Despite such applications, the production of forage from these soils is often one half to one third that of more productive bottom land. Figure 2-6 illustrates a typical pattern of irrigation on soils derived from Bozeman Formation sediments. In this aerial photograph, irregular topography and high infiltration rates leads to low lying sedge vegetation in low lying areas with islands of sparse vegetation. Similar irrigation patterns also occur in other areas not derived from Bozeman Formation soils, suggesting that pasture on soils derived from Quaternary glacial deposits may also be suitable for this alternative. The following alternative addresses a means to reduce the use of irrigation water on these low productivity soils.

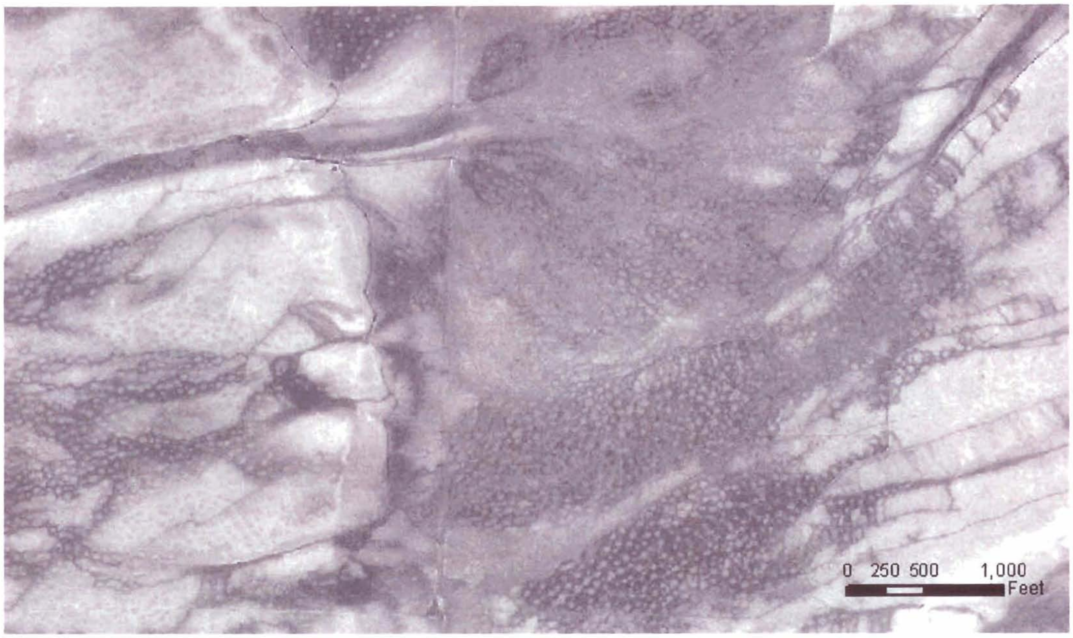


Figure 2-6: Irrigation pattern typical on lower productivity soils.

Alternative 5. Provide Alternative Forage

This alternative involves providing an alternative source of forage to ranchers so that they would not irrigate low productivity soils. Similar to other alternatives that involve alternative sources of forage, ranchers would purchase hay or alfalfa, grown in another location (either within or outside of the basin), which they would transport to their pastures and fed to their cattle. Ranchers would continue to graze livestock within these areas. Forage production on low productivity soils would be greatly reduced with the curtailment of irrigation; this reduction would be offset by off-site forage sources. This alternative includes the purchase, transporting and feeding of livestock.

Location and Availability

Examination of aerial photography and geologic data indicates that landowners currently irrigate approximately 6660 acres of low productivity soils in the watershed area above the Wisdom Bridge (Figure 2-7). Aerial photography indicates that sedge vegetation associated with these areas is extensive. If sedge irrigation in these areas is reduced by a conservative estimate of 100 acres, approximately 5 cfs could be conserved. This estimate uses the pasture irrigation rate of 1 cfs per 40 acre provided by upper basin landowners and a 2:1 ratio of evapotranspiration between sedge and grass. Five cfs during July and August would add almost 600 acre feet of water to instream flows.

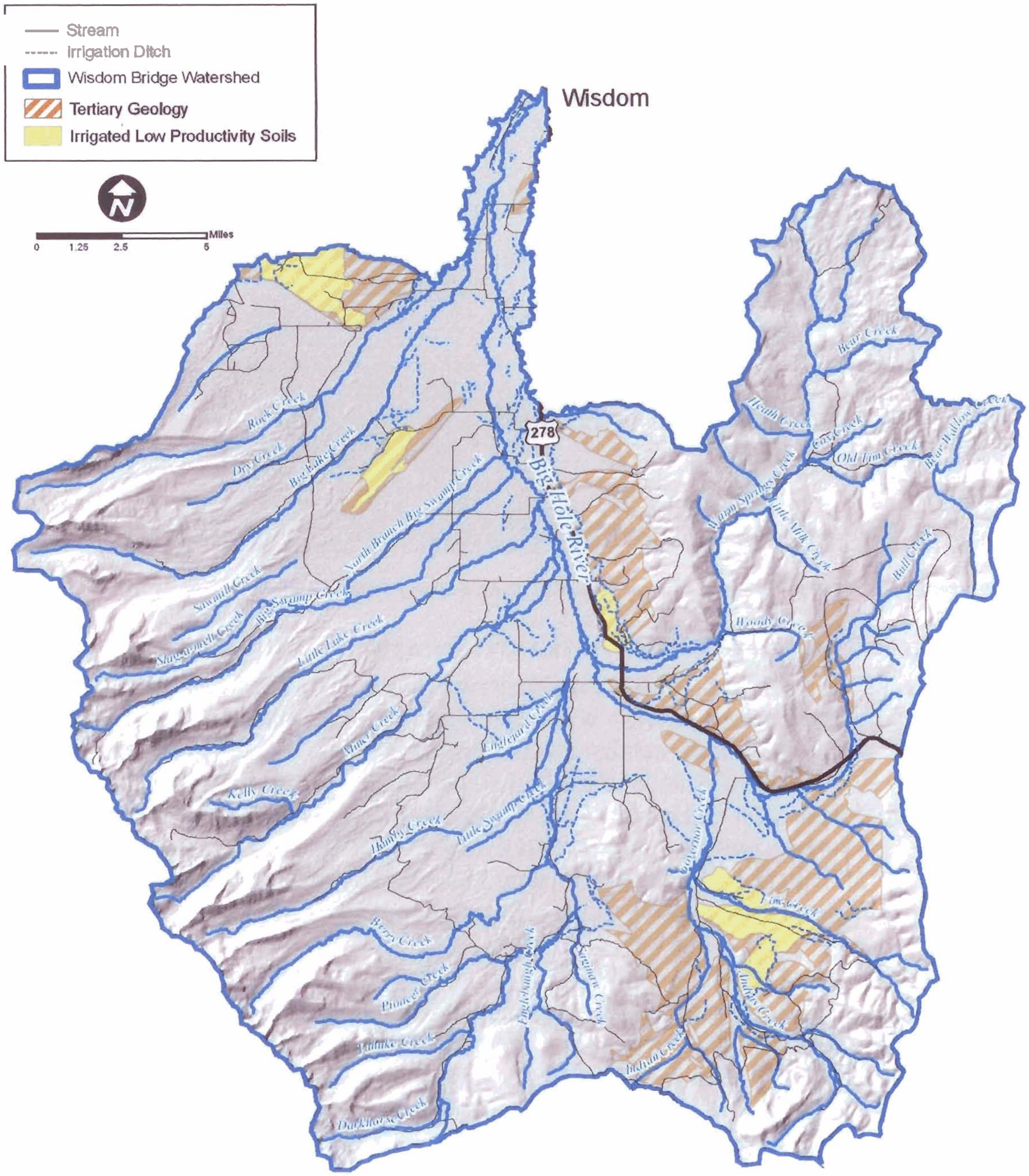


Figure 2-7: Location of irrigated low productivity soils.

Advantages

This alternative addresses areas where forage production is less than optimal due to low productivity soils. Therefore, the value of water in these areas is lower than in areas where soil quality is better. This situation results in lower costs of providing replacement pasture or forage to compensate for areas potentially taken out of production. As with other alternatives, these action can help landowners comply with CCAA agreements and qualify for EQIP funding.

Disadvantages

As with other alternatives that reduce pasture irrigation, it is difficult to determine the best areas to apply the alternative. Pilot projects with willing landowners, combined with monitoring programs, are recommended to determine the optimal areas to make this land use changes.

2.2.4. Purchase Water

In 1995, the Montana legislature amended the state's water code to allow water right holders to lease some or all of their water rights to allow water to remain in a stream for the beneficial use of fisheries. Montana Code Annotated 85-2-408 allows a water right holder to voluntarily make a temporary change in appropriation of their rights to maintain or enhance instream flow. Montana Department of Fish, Wildlife and Parks holds instream flow leases, as do a number of non-governmental, non-profit organizations. Leases typically involve financial compensation for a temporary change in appropriation to instream flow, although a myriad of options exist for willing sellers and willing buyers to structure such an arrangement. The following alternative addresses the leasing of water rights to provide instream flows.

Alternative 6. Water Lease

This alternative involves the temporary lease of water to maintain adequate instream flow for the arctic grayling within the critical reach of the Big Hole River. Willing water right holders would develop leases with willing buyers so that they would not divert a specified amount of water during a determined period of time, for which the owner of the water right would be compensated in some manner. Compensation might take the form of cash payments, or might involve the exchange of goods or services. For example, a water lease might be structured so that compensation is measured in tons of hay delivered to the lessee.

Location and Availability

Many of the water management alternatives discussed in this report that involve a reduction in irrigated area could be facilitated by a water lease. Groups such as the Montana Water Trust (www.montanawatertrust.org) facilitate water leases by acquiring private funding and seeking landowners with critical water rights that could benefit instream flow. Payments for leased water are typically based on the value of the commodity lost by not irrigating. The most likely candidates for water leasing are the landowners that divert water within the critically dewatered section. This would minimize the amount of monitoring and enforcement required to ensure that leased water reached the critical reach.

Advantages

This alternative is a potential means to facilitate many of the alternatives discussed in this document. Alternatives 1 through 5 all involve reducing irrigated areas. Pilot test projects with guaranteed forage replacement or water leasing could provide compensation for landowners willing to make these reductions. It is very likely that in some areas reducing water application will not reduce and may increase the amount of forage production.

Disadvantages

Private funding for the purchase of water rights is limited in Montana, and the availability of funding varies from year to year. Water leasing can have a significant impact on instream flows, but will likely be a relatively small part of a comprehensive solution for the Big Hole River.

2.2.5. Purchase Land

A framework to lease water provides only a temporary means of ensuring instream flows for fish. A permanent measure involves the outright purchase of land to acquire the associated water rights. Like water leasing, land purchase would also involve a willing buyer and willing seller. Land suitable for purchase would need to satisfy a variety of criteria, the most important of which are: an adequate quantity of irrigation water held as relatively senior water rights, and located in close proximity to the critical reach of the Big Hole River. The purchase of land would also require the establishment of a non-profit organization to manage the ranch, or acceptance by the State of Montana to do so.

The purchase of land has a number of secondary benefits that would facilitate the implementation of some other non-storage water management alternatives. For example, hay grown on an acquired ranch could serve as a source of livestock forage (alternative forage as described in previously identified alternatives). Pasture on the ranch can provide livestock grazing opportunities (for alternatives that involve use of alternative pasture).

Alternative 7. Purchase Lands with Important Water Rights

This alternative involves the purchase of one or more ranches with suitable water rights (those with appropriate quantity, seniority and location, as mentioned previously). A portion of the ranch water rights would be leased. The ranch would likely be managed to maintain some level of grass production (as hay and/or pasture), meaning that some irrigation would continue. It is likely that an irrigation plan would be established that provided a system of irrigating the most productive land for some periods or for alternating years. This alternative includes the cost of land purchase but does not include the costs associated with ranch management, nor the benefits of producing alternative forage or providing alternative pasture. We have assumed the ranch would be managed so that the costs of operation would be offset by the profits from hay sales and pasture leasing.

Of secondary interest are irrigated bench lands with low or moderate productivity soils. These lands would be less expensive to purchase, but would not provide the same opportunities for forage production as valley bottom areas.

Location and Availability

The most likely lands to consider for purchase are the large ranches with significant water rights in the critically dewatered reach above Wisdom. Irrigated bench lands on low or moderately productive soils

Advantages

The advantages of purchasing lands with large water rights in the critically dewatered reach of the Big Hole River is that this alone could provide enough water to keep instream flows well above the critical levels for grayling survival. These lands could also be leased or provided to other landowners in the basin as alternative pasture as outlined in Alternative 2. Irrigated bench lands with low productivity soils also consume large amounts of water that would benefit instream flows, and would be less expensive to purchase.

Disadvantages

Purchasing valley bottom lands with large water rights will have high capital costs. However, when amortized over 30 years (the same period for amortizing reservoir storage costs) the cost per acre-foot of water is very reasonable. The challenge of making sure additional flows reach the dewatered reach is also removed.

Purchasing irrigated bench lands will involve lower capital costs, but due to their distance from the dewatered reach, getting the water to the critically dewatered reach is more difficult to ensure.

2.2.6. Increase Water Yield

Another avenue for increasing the quantity of water in the river is to modify the source of water in the upper Big Hole River basin. Two alternatives address measures to increase the source of water in the basin: through weather modification and through direct inter-basin transfer of water.

Alternative 8. Cloud Seeding

Flow in the river is a result of snowmelt and precipitation in the basin. The majority of flow is a result of snow that accumulates in the higher elevations in the watershed, where total snowpack depth can reach many feet. This alternative involves modifying weather patterns, using a technique referred to as cloud seeding in order to increase the total amount of snow that accumulates in the upper watershed. This alternative involves a number of considerations, including the timing, technical, and legal aspects of cloud seeding.

Timing Considerations

As snow gradually melts throughout the spring it releases water to the tributaries, resulting in high flow in the river during May and June. Snowmelt and runoff also recharge the groundwater during this period. Increased snowpack would contribute to additional spring runoff. However, to provide additional flow in the river during the critical low water period of July and August, some of the spring runoff would need to be stored for later release. Storage could be accomplished through traditional measures (that is, using reservoirs and impoundments) as well as non-traditional measures. Some non-traditional measures include the techniques described later in this document, and include the development of managed wetlands and the reintroduction of beavers (to raise the groundwater level and create beaver ponds). To adjust an increase in winter snowpack to an increase in late summer base flow in the river, we have assumed a 10% conversion of snow water content into late season flows (that is, we have assumed that 10% of the snow water equivalent will be converted to stream flow in July and August).

Technical Considerations

Clouds form when warm, moist air rises in an updraft and subsequently cools, causing condensation and the formation of cloud droplets. If the temperature in the cloud falls below freezing, the water becomes supercooled. When enough of these droplets accumulate on a nucleus (typically dust, sand or ice crystals), they become too heavy to be maintained by the updraft and fall to the ground as snow or precipitation. In Montana, the updraft process is a result of easterly moving air that encounters high elevation mountain ranges. For the Big Hole River basin, moisture-bearing air moves across Idaho and rises along the west side of the Continental Divide where precipitation falls on the Bitterroot and Beaverhead Mountains. Thus, snow in the upper Big Hole River basin is a result of cloud formation that begins in Idaho.

Cloud seeding is the process of providing additional nuclei to attract moisture in the atmosphere. Silver iodide (AgI) formulations using ammonium iodide (NH_4I) are commonly used as particulates for cloud seeding. Artificial nuclei are applied into the upper portion of clouds with an airplane or are released from a series of small ground-based generators where updrafts carry them into the cloud core. From there, the natural process of precipitation formation continues.

Cloud seeding programs typically have an objective of increasing snowpack by 5-10% over background, although there are reports of average snowpack increases of 13-14% (Solak et. al. 2003, Stauffer and Williams 2000). Research suggests that the downwind effect of cloud seeding does not extend beyond 125 miles from the seeding source (Solak et. al. 2003).

Legal Considerations

State and private organizations maintain annual cloud seeding operations in a number of western states to increase water availability, particularly in Idaho, Wyoming, Utah and Nevada. The states fund many of these programs. For example, in 1973 the Utah Legislature passed the Utah Cloud Seeding Act and has since provided financial assistance to local cloud seeding sponsors in the range of 30-50% of total cost.
In contrast, the Montana law presents a conservative approach to cloud seeding. The Montana Constitution (Article IX, Section 3) recognizes "atmospheric waters within the boundary of the state as property of the state for the use of its people" and acknowledges that atmospheric waters are "subject to appropriation for beneficial uses as provided by

law". As such, cloud seeding requires a water right permit similar to that of surface or ground water put to beneficial use. Furthermore, Montana Code Annotated 85-3 sets the framework for Atmospheric Water Weather Modification, which involves public hearings, licensure, permit fees, bonding, and creation of a county weather modification authority. In short, cloud seeding in Montana requires a complicated and untested process of public and agency approval.

In the current legislative session, proposed House Bill 399 calls for modifying the environmental study, permitting, fees and public notice restrictions currently in place. On March 3rd, this bill passed the House on a 87-11 vote. As of March 31st, this bill was tabled in the Senate Natural Resources Committee. Rep. Debbie Barrett, R-Dillon is a co-sponsor of this bill. At the same time, acting Beaverhead County Commissioner Mike McGinley is leading an effort to ask the courts for an injunction to force Idaho to stop cloud seeding programs.

It should be reiterated that for cloud seeding to benefit the upper Big Hole basin, the actual seeding activities would have to occur in Idaho. The Idaho statutes do not appear to regulate atmospheric waters or cloud seeding to the extent that Montana does. In fact, we could find no laws in the Idaho Statutes or Constitution that regulate cloud seeding.

Location and Availability

As stated above, cloud seeding would take place in Idaho with the areas targeted to receive additional snowfall in the southwest portion of the watershed.

Advantages

Cloud seeding has been used successfully in Idaho and Utah to augment runoff that supplies municipal drinking water. These areas have storage reservoirs, however, to capture the increased runoff.

Disadvantages

Most of the increased snowmelt will run off during peak flows and only approximately 10% of the increased snowpack will run off during the critical late summer months. This greatly increases the cost of this alternative. Re-creating natural storage conditions with beaver re-introduction in headwater watersheds would improve the economics of cloud seeding and possibly make it a viable alternative.

Alternative 9. Inter-Basin Water Transfer

A large volume of water that historically flowed in the Big Hole River upstream of Wisdom is now diverted for irrigation before reaching the Wisdom bridge. In addition, ditches that convey water out of the Wisdom bridge watershed now capture tributaries that historically flowed into the Big Hole River. Return flows from these diversions do not return to the Big Hole River until several miles downstream of Wisdom. This process directly contributes to dewatering of the reach above the Wisdom bridge. Two examples where flow is diverted out of the watershed upstream of the critical river reach are described below. Augmenting flow in the river can also be accomplished by diverting runoff from nearby watersheds that normally flow into the river downstream of Wisdom. One such alternative is also described.

Steel Creek Watershed – East of the Big Hole River

Water currently diverted from Warm Springs Creek and the mainstem Big Hole River travels north and east in ditches to irrigated lands in the Steel Creek watershed. The Helming, Huntley, Miller, Dishnow, Chickenhouse, and Maverick ditches all move a portion of the water they carry out of the Wisdom bridge watershed into the Steel Creek watershed (Figure 1-4). Small tributary streams on west facing slopes between Warm Springs Creek and Steel Creek that historically flowed directly into the Big Hole River now flow into these ditches and the Steel Creek watershed. Return flow from this water use likely enters the mainstem Big Hole River via Steel Creek, downstream of the critically dewatered reach. DNRC synoptic flow data from early June 2003 in the Huntley Ditch indicate that at that time, approximately 35 cfs was moving from the Big Hole into the Steel Creek watershed. This represents approximately 10% of the flow at Wisdom in a time of high snowpack and above average runoff. Presumably, additional water was moving from the Big Hole into the Steel Creek watershed at the same time via the Helming, Miller, and Maverick ditches.

Changing the point of diversion source from the Big Hole to Steel Creek or one of its tributaries could replace a portion of the water withdrawn from the Big Hole. However, this likely would not be a large amount due to the limited size of the Steel Creek watershed. The DNRC water rights database indicates that there are 32 permitted water rights with points of diversion on the mainstem Big Hole River and points of use in the Steel Creek watershed. Approval of a change in point of diversion requires that downstream water right holders are not impacted by any change in an upstream water right point of diversion.

The most likely mechanism to facilitate reducing the amount of water removed from the Big Hole and conveyed into Steel Creek is to address the water uses in the Steel Creek watershed through one of the other water management alternatives. One alternative that may work in this area is to convert from flood irrigation to sprinkler, thus reducing the irrigation and water withdrawal requirements. Another potential mechanism, suggested by a number of landowners, is to physically route return irrigation flow in the Steel Creek system back to the Big Hole River above Wisdom rather than letting it simply flow in Steel Creek to its confluence with the river much further downstream. Returning irrigation flow to the river above Wisdom would involve creating an irrigation return ditch from Steel Creek to the river around the area of the airport. While there may be some technical and procedural hurdles, it appears that such an option would be feasible.

Rock and Big Lake Creeks – West of the Big Hole River

Water from both Big Lake Creek and Rock Creek do not follow their historic drainage patterns. Part of the Rock Creek flow is diverted north and enters Swamp Creek, which meets the Big Hole River approximately four miles downstream of the Wisdom bridge

(Figure 1-5). A small portion of Big Lake Creek flow likely enters the Spokane Ditch, and also leaves the Wisdom Bridge watershed (Figure 1-6).

North Fork Big Hole River

Water currently diverted from the mainstem Big Hole River to the Spokane Ditch upstream of Wisdom travels north to irrigated areas. Return flows from this irrigation reach the Big Hole River downstream of Wisdom and the critically dewatered section. As an inter-basin transfer alternative, water could be diverted from the North Fork Big Hole River to replace a portion of this irrigation water taken from the mainstem, thereby leaving more flow in the Big Hole River through this critical reach. Only a small area near the confluence of Swamp Creek and the Big Hole River is accessible by gravity to water from the North Fork Big Hole River. Irrigation of additional land would require pumping from the North Fork, which would not likely be cost effective. Therefore, this alternative has limited merit.

This change in irrigation source would require a modification in the point of diversion for a portion of the existing water right. Conversations with DNRC water rights specialists indicate that this is possible as long as downstream water users are not affected. The downstream users, in this case, would be all water right holders on the North Fork Big Hole River downstream of a the new alternative point of diversion to the confluence of the North Fork and mainstem Big Hole River.

Location and Availability

Both east and west of the Big Hole River above Wisdom, water is diverted from the Big Hole that bypasses Wisdom and reconnects with the Big Hole downstream. Figure 2-8 identifies approximately 15,000 acres of land partially irrigated by water diverted from the Big Hole River in the Wisdom Bridge watershed. Eliminating part of this trans-basin diversion can be accomplished by a variety of means. For example, converting 1200 acres (8% of the area) to pivot irrigation could reduce the July and August water requirements by 1260 acre feet. This would leave an additional 10.6 cfs in the dewatered section of the Big Hole River

Advantages

While inter-basin water transfer would require some capital expenditure for diversion, headgate and ditch construction, in the long-term the cost and effort required would likely be no different than that currently expended for water distribution and irrigation. Inter-basin water transfer would be a matter of establishing a new set of irrigation diversion practices. Changing multiple points of diversion would require administrative effort, which could likely be undertaken with stakeholder consensus.

Disadvantages

Implementing new irrigation diversions and ditch orientations will require that stakeholders feel comfortable with changing long-term, well-used irrigation patterns. They will need to be satisfied that a new system will still provide them with the amount and timing of water as they have traditionally used (that is, for which they have rights).

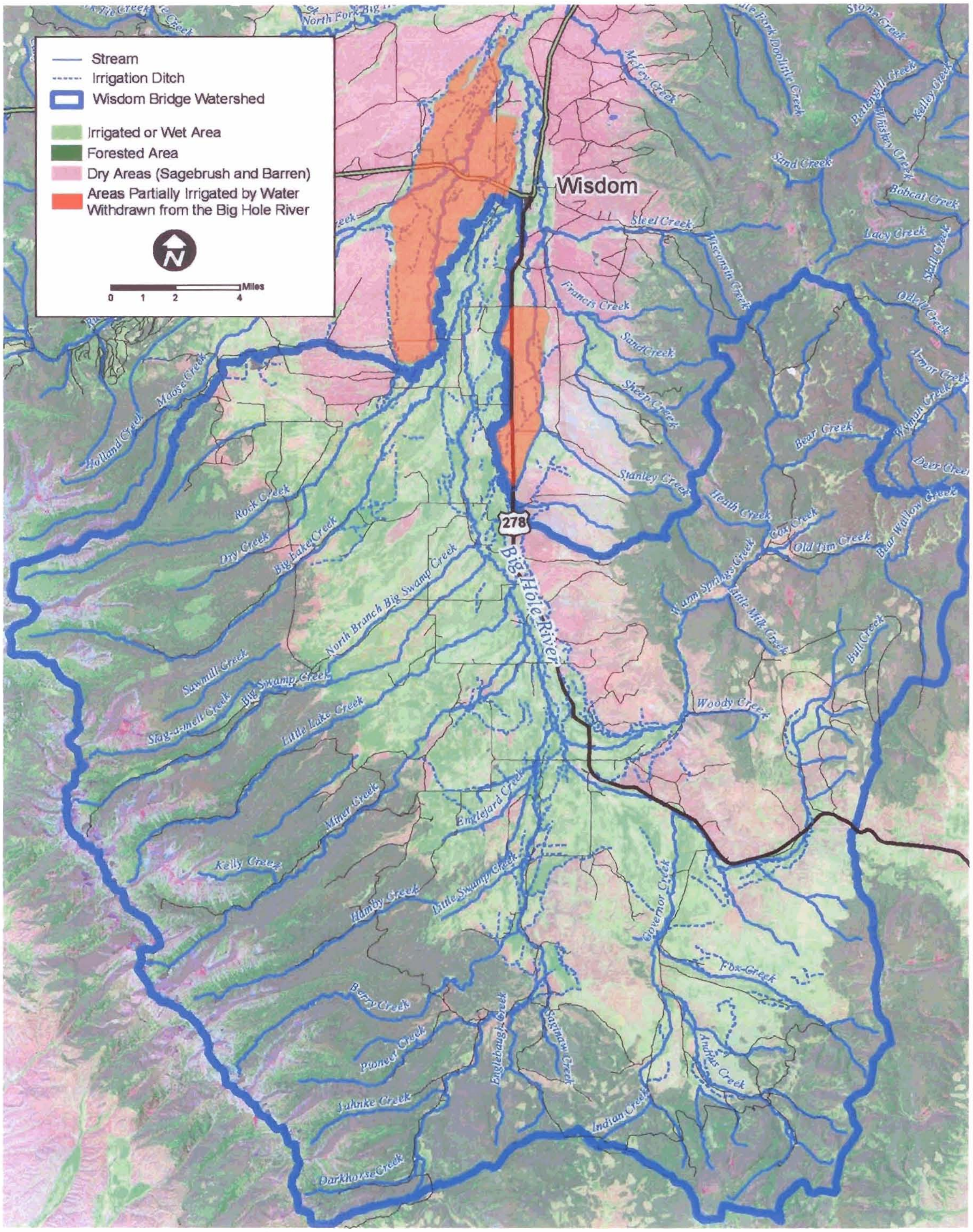


Figure 2-8: Areas partially irrigated by water removed from the Wisdom Bridge watershed

2.2.7. Improve Irrigation Efficiency

Flood irrigation in the upper Big Hole River basin typically involves a process of diverting, transporting and applying water. Water users divert flow from one or more points along a stream or the river. Diversion structures in the channel serve to direct flow to control headgates, from which ditches and canals transport water to the points of use. Once at the point of use, irrigators use multiple smaller ditches that bisect fields along the ground contours. Portable plastic dams are used to regulate ditch water level and provide controlled flooding of portions of the fields. Irrigators typically relocate these dams two to three times daily to spread water evenly across the land.

There is efficiency loss that occurs when irrigators divert water from streams and the river, transport it to their fields in ditches, and apply water to fields using flood irrigation practices. The most significant inefficiencies occur with flood irrigation and with water lost to ditch seepage.

Alternative 10. Convert from Flood Irrigation to Sprinkler

Flood irrigation is the most common means of irrigating land in the upper Big Hole basin. The ranchers we met told of some of the benefits of flood irrigation, such the protection of grass in the spring by flooding when nighttime temperatures fall to below freezing. They also acknowledged that the elevation in the basin precluded multiple cuttings of hay; as such, they felt that the cost for setting up and running sprinkler irrigation systems could not be justified. Most researchers, however, acknowledge that flood irrigation is an inefficient means of providing water to the ground (for example, see NRCS 2001). Efficiency rates for flood irrigation often are often about 45%, meaning that less than half of flow directly contributes to plan growth. This alternative involves the conversion of current flood irrigation practices into some other means of providing water. Two pumped irrigation concepts were considered: handline sprinklers and center pivot sprinklers. The first alternative involves the use of handlines. Handline efficiency is typically about 65%. Ranchers indicated that the limited available labor tended to make this alternative unfeasible. The second alternative involves a center pivot; these are usually 70-80% efficient. Center pivots are much more expensive to install than a handline system. These aforementioned differences in efficiencies were used to estimate the cost and percent improvement of that would result from converting from flood to some other form of sprinkler irrigation. This alternative includes the capital required to design and implement new sprinkler systems, as well as for operation and maintenance.

Location and Availability

Discussions with area landowners suggest that there are many obstacles for successful implementation of sprinkler irrigation. However, sprinkler irrigation may be appropriate in those areas irrigated by water leaving the Wisdom bridge watershed and moving into the Steel Creek and Swamp Creek watersheds. This would reduce the amount of water withdrawn from the Big Hole River in the dewatered section above the Wisdom bridge and leave more water for instream flows in the Big Hole. As mentioned in Alternative Nine Inter-Basin Water Transfer, the water savings from this alternative are significant.

Advantages

The primary advantage of changing from flood to sprinkler irrigation is that less water is used per ton of hay or forage produced. Depending on growing conditions (such as growing season and soil fertility), sprinkler irrigation may not use less water than flood irrigation. Rather, it may just produce more hay with the same amount of water. Since growing conditions in the Big Hole basin are limited (largely by growing season), this condition would likely not occur. In areas of irregular topography where flood irrigation results in patchy forage distribution, sprinkler irrigation may increase the amount of forage produced per acre.

Disadvantages

As stated previously, the ranches we talked to felt that wheel lines would not be practical for the basin due to the lack of available labor, and that the cost for implementing and operating pivot sprinklers could not covered by the value of the hay produced.

Alternative 11. Reduce Ditch Loss

Not all irrigation water diverted into a ditch makes it to where it will be used. Some water is lost to evaporation, some is consumed by plants growing along ditches, and some seeps into the ground. The fact that irrigation ditches tend to leak along their length is the focus of this alternative. The amount of water lost to seepage can be significant where soil is porous. This alternative involves installing a seal of some type along major ditches that traverse porous ground. For a range of applications, we considered three types of ditch lining measures. These include lining with: 1) Bentonite clay; 2) a geosynthetic fabric (such as high-density polyethylene) and soil cover; and 3) a geosynthetic fabric with a shotcrete or gunite cover. For cost calculation purposes, we estimated the costs associated with lining a ditch of a given size, calculated the amount of water such a ditch would carry, estimated a length of ditch to be lined, then calculated an estimated percentage of improved water efficiency that would likely result.

Location and Availability

Ditches that carry a large volume of water across highly porous soils to highly productive hay ground are the best candidates for lining, given their relatively high rate of water loss per lineal foot of ditch and their servicing high producing land. Ditches that deliver water to low producing land (that is, hay fields and pastures on porous soils) should not be considered as viable candidates for lining. It makes little sense to improve the conveyance of ditches that supply land where hay production is low and percolation loss is high. Ditches identified for lining potential are those that cross areas of high infiltration rates associated with Tertiary sedimentary geology. There are over 35 miles of ditches that cross this geology (Figure 2-9). If 10-20% of this length proves feasible for ditch lining, then water savings could be substantial (although the amount would ultimately depend on the amount of water conveyed in the selected ditches). The ditch system that conveys water from Warm Springs Creek to the Steel Creek watershed is the best initial candidate for ditch lining.

Advantages

The cost of ditch lining is low relative to the benefits provided. Implementation is relatively uncomplicated in that there are no environmental limitations or permitting requirements. Selected segments of ditches can also be chosen for lining if some level of ditch loss is desired in certain areas.

Disadvantages

There are few disadvantages of ditch lining. Where there are multiple owners of a single ditch, lining will require the consensus of all stakeholders. Lining will also require some level of periodic capital expenditure (given the short life of most forms of ditch lining).

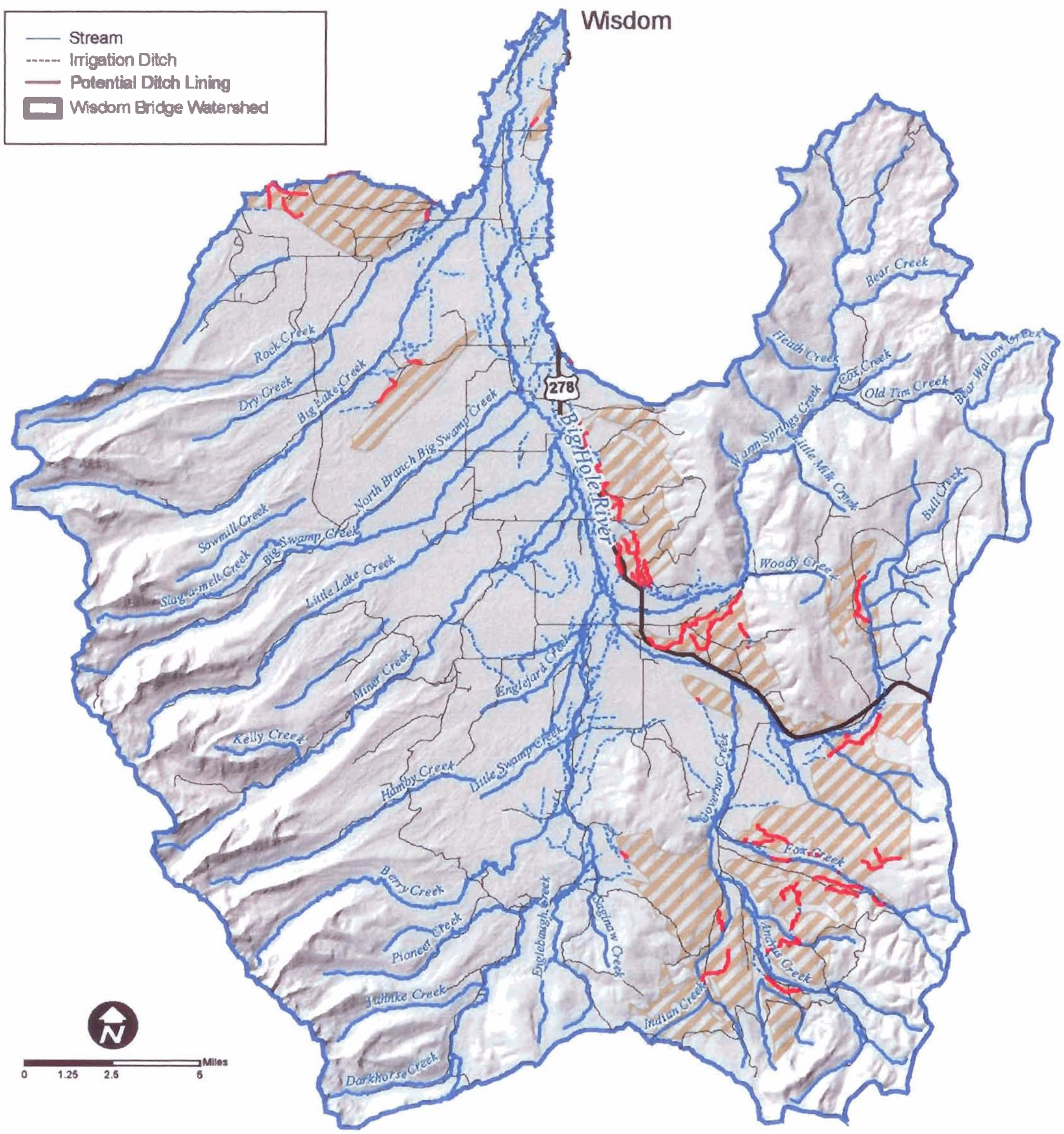


Figure 2-9: Locations of ditches with potential for lining.

2.2.8. Develop Groundwater Resources

Groundwater is a potential source for augmenting flow in the critical reach of the Big Hole River. We identified three alternatives that include the use of groundwater. The first involves developing wells to provide drinking water for livestock, so that flow normally diverted for such purposes could remain in the river. The second involves the installation of controlled drain fields to draw groundwater to the river as surface flow. The third involves the placement of deep wells that pump water into the river. The following sections address these alternatives in further detail.

Alternative 12. Provide Stockwater from Wells

Ranchers commonly withdraw water from streams to provide drinking water for livestock. As with irrigation water, ranchers divert stockwater from streams and convey it via ditches to cattle, horse and sheep pastures (any stock for that mater). As stated previously, there can be a high degree of inefficiency with diverting water and conveying it through ditches. To function properly, ranchers must divert an adequate amount of water at the source to ensure that sufficient water reaches the point of use. In other words, ranchers typically divert enough water to maintain a steady flow to the intended pastures. Ranchers divert water in this manner to maintain a constant flow with depths sufficient to allow stock access. As such, more water is diverted than can be consumed by livestock. We recognize that during the irrigation season, livestock may be drinking water that is diverted for irrigation and not for stockwater. Nonetheless, reducing the amount of water diverted for stockwater is a means of maintaining water in the river. This alternative, therefore, involves installing wells to provide a controlled stockwater source, preventing the need to divert water from streams for that purpose. This alternative includes the initial capital for the wells and watering system as well as annual operations and maintenance (which include electric or solar power costs to run pumps).

Location and Availability

Opportunities to install stock watering wells exist throughout the basin. Since livestock grazing is almost ubiquitous, and a limited number of stock wells have been installed in recent years, these opportunities are not hard to find.

Advantages

The primary advantage of installing stock wells is to keep cattle away from streams. This can benefit habitat measures such as bank stability and riparian vegetation, as well reducing nutrient loading.

Disadvantages

The disadvantages of stock water wells is the relatively small amount of water conserved by utilizing stock wells. However, widespread installation of stock wells throughout the basin could have a significant cumulative beneficial impact.

Alternative 13. Create Drain Fields

Groundwater somewhat close to the ground surface is another potential source for increasing flow in the river. Shallow aquifers are recharged by snowmelt and stream flow, and by flood irrigation and seepage losses from ditches. This groundwater could be taped as a source where groundwater levels are near the surface (that is, within a depth of 5 or 10 feet); where soil porosity, capacity and hydraulic conductivity are appropriate; and where there is an adequate water supply,. This alternative involves installing a series of perforated drains packed in gravel in trenches at an appropriate depth and density. The drains would be capped or gated to allow them to be closed until the time when water in the river was needed. These lines would then be opened in order to drain the stored groundwater. Recharge to the system would occur annually, with limited recharge likely once the system was opened. Flow would be collected in a header pipe and conveyed via pipe or lined ditch to the river. This alternative includes the initial capital to install the drain fields and the annual operations and maintenance.

Location and Availability

This alternative is only viable in the floodplain of the Big Hole River where there is significant increase in elevation outside the floodplain (to store water).

Advantages

The proximity to the critically dewatered section and ability to control release of water are the primary advantages of this alternative.

Disadvantages

Disadvantages of this alternative are the small amount of water gained and high cost.

Alternative 14. Develop Deep Groundwater Production Wells

Deep aquifers are charged by moisture from snow and rain that infiltrate into the ground higher in the basin. The water in deep aquifers is often very old, having traveled slowly over long distances. This alternative involves installing deep wells (we estimated an average depth of 400 feet) with high production rates (approximately 1,500 gallons per minute). This alternative includes the initial capital requirements (well and pump installation) and annual operations and maintenance (electricity to run the pumps). We based this alternative on the premise that the appropriate physical conditions exist that would high capacity groundwater production feasible. This premise would require verification at some point.

Location and Availability

Groundwater production wells would be most applicable in the critically dewatered reach. However, groundwater aquifer conditions need to be favorable for this alternative to work. If removing water from groundwater simply depletes connected surface water, then the alternative is not viable.

Advantages

The advantages of this alternative are its proximity to the dewatered reach and the ability to utilize this alternative on demand, when required.

Disadvantages

There is a significant likelihood that this alternative will not be feasible due to interconnected ground and surface water. Extensive study of groundwater aquifer characteristics is necessary before considering this alternative further.

2.2.9. Delay Runoff

The average annual river hydrograph readily demonstrates the fact that the majority of river flow occurs during spring runoff, and that discharge gradually declines to a point where it reaches a low point in July and August. This late-summer low flow period is critical to the survival of the artic grayling. It is possible to increase flow during this late-summer period by delaying the release of flows that otherwise occur during spring runoff. The following alternatives serve to hold water in the upper watershed, eventually releasing it later in the season. These alternatives are based on the premise that water retained in wetlands or in the form of snow or ice and is gradually released as flow in the river.

Alternative 15. Managed Wetlands

This alternative involves creating shallow water wetlands (less than about 5 feet in depth) in order to impound water as surface and ground water. Wetlands would be constructed in areas of broad, flat lowland where the water table is near the ground surface. These wetlands would generally be constructed on small perennial and ephemeral channels by constructing low-level berms and dikes. To minimize costs, it is unlikely that such wetlands would be excavated; rather the water depth would be a function of the relief between the berm and adjacent ground. Wetlands would likely be created as a series of broad terraces, where the ground elevation would be stepped from one level to the next. The berms between the wetlands would be fitted with means to control the water surface elevation (such as small headgates or gate valves). This alternative includes the design, permitting and construction as well as operation and maintenance.

Location and Availability

Managed wetlands require appropriate ground conditions (that is, gently sloping open land) and water sources, with the capability of eventually transporting flow to the river. Large expanses of land that meet this criteria are at the upstream end of the basin, around the confluence of Governor Creek and Bull Creek and various locations along the mainstem Big Hole River upstream of Little Lake Creek Road. One site in Reach 22 (Upper Big Hole TMDL, 2003) is currently being considered for a managed wetland site.

Advantages

Managed wetlands provide a means to recharge the groundwater aquifer as well as a means to release impounded flow. Aquifer recharge is a natural process that releases water slowly into the streams. The creation of wetlands also has the potential of creating wildlife habitat, providing recreational opportunities (fishing and hunting) and improving aesthetic qualities.

Disadvantages

Managed wetlands require both upfront capital and regular operating and maintenance expenditures. Wetlands would require securing water rights, which can be a lengthy process.

Alternative 16. Channel Morphology and Vegetation Improvements

This alternative involves restoring the river channel and associated side channels to a proper functional condition. Work would involve many of the habitat restoration activities identified in the Upper Big Hole Basin Phase 1 TMDL, such as channel narrowing, side channel re-activation, pool formation and riparian vegetation reestablishment. The premise is that river margins tend to retain water in the soils, and as river flow gradually decreases, this water is slowly released as baseflow. The more extensive and healthy are these margins, the more water that will be held in these areas for eventual natural release. There are few data to provide a foundation from which to estimate the amount of flow that will be released as a result of this alternative; nonetheless, we have provided a rough estimate that allows for cost comparison with other alternatives.

The costs associated with restoring channel morphology and riparian vegetation can be quite high relative to the quantity of water that may eventually be released. The cost estimates we generated, while rather rough, are also rather conservative. It should be recognized that funding for channel and riparian restoration (to achieve TMDL objectives) may be available from a variety of State and Federal sources (such as 319 Grants funded by EPA through the State). If such funding were to be acquired, it would reduce the effective cost of this alternative, making it more financially viable.

Location and Availability

Potential channel morphology and vegetation restoration projects in the upper Big Hole River watershed were identified in the Upper Big Hole TMDL Report (2003) and are currently being refined in subsequent TMDL development efforts. The current CCAA process will also require channel morphology and vegetation improvement in many cases.

Advantages

The advantage of this alternative is the current momentum to implement this type of restoration project as part of the TMDL and CCAA processes. This means that there is available funding to assist in implementation. An additional advantage is the huge benefits to fish habitat, thermal loading and water quality that this type of project provides.

Disadvantages

The disadvantages of this alternative is that by themselves, channel morphology and riparian vegetation restoration projects provide relatively small benefits to instream flows relative to their cost.

Alternative 17. Re-Introduce Beavers

Before the arrival of European settlers, beavers inhabited most small drainages in Montana. In fact, their presence had a major effect on channel geomorphology by maintaining stream systems with multiple channels, small impoundments that varied in location and duration, and wetted boundaries that typically extended to the margins of the floodplain. As a result, beaver provided numerous benefits to vegetation and fish habitat, as well as natural storage of water for gradual release after peak runoff. Loss of this natural storage capacity contributes, along with other factors, to the water shortages that are currently experienced on the Big Hole River. Although beaver activities can conflict with human interests, the potential to utilize beaver to store water for late season flows is significant.

Historic accounts (Nell and Taylor, 1996) of the upper Big Hole River valley indicate that the area was historically choked with willows and home to abundant beaver. Historic aerial photography also indicates the presence of significantly more beaver 50 years ago than today. Valley bottom areas notably had more beaver. Beavers play an important and cost-effective role in maintaining riparian and aquatic ecosystems for multiple uses (Stuebner, 1994). The benefits from beaver activity in an aquatic ecosystem, primarily through dam construction (Olson and Hubert, 1994) include:

- Elevated water tables that enhance riparian vegetation;
- Reduction in bank erosion from reduced water velocity;
- Improved water quality through nutrient storage;
- Protection of cropland and urban development from flooding;
- Enhancement of fish habitat by increasing water depth and production of aquatic invertebrates;
- Improvement of habitat for waterfowl, big game, birds, and other wildlife through vegetation development;
- Improvement in water storage and stabilization of stream flows throughout summer and drought; and
- Increase in forage production, shelter, and water for livestock.

For our assessment, we divided beaver re-introduction in the upper Big Hole River watershed into two distinct parts: beaver re-introduction in headwater areas, primarily on US Forest Service land, and re-introduction in valley foothill areas on private lands. Each provides distinct benefits and challenges. Pilot projects for re-introducing beaver should commence in headwater areas on US Forest Service lands to minimize the costs of management and impact to landowners. Hydrologic monitoring should accompany this initial phase.

Location and Availability

Analysis of aerial photography covering half of the subwatershed identified approximately 2,000 acres in the watershed above the Wisdom Bridge that have good potential for hosting beaver and their pond habitat. Six hundred (600) of these acres are in headwater areas on US Forest Service lands. In addition to the benefits listed above, the 2,000 acres of beaver pond habitat could store and release an estimated 57 cfs during the critical flow period of July and August. Area where aerial photography was not examined will provide additional opportunities for beaver re-introduction.

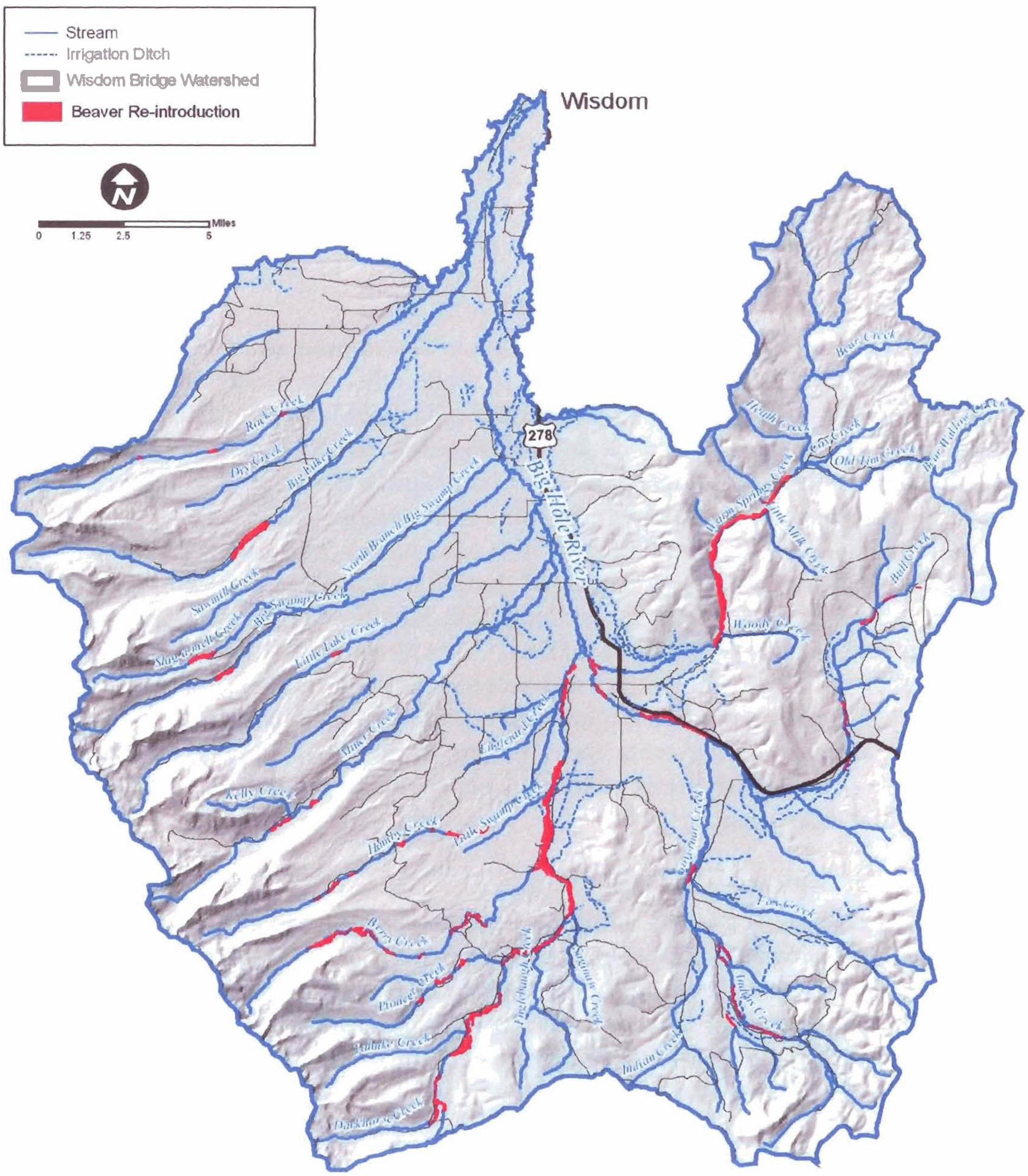


Figure 2-10: Potential locations for beaver re-introduction in the upper Big Hole River watershed.

Advantages

The primary advantage of reintroduction is that the multiple dams constructed and maintained by beavers will re-establish the natural water storage processes of the upper basin. Although beaver populations will have to be managed, reintroduction can be thought of as a means of "farming" beaver to increase water storage by raising the local water table. Reintroduction will have positive secondary environmental benefits, such as the expansion of riparian corridors that provide wildlife habitat and the stabilization of stream segments resulting in reduced downstream sediment contribution.

Disadvantages

Ranchers often have a negative perception of beavers. This is partly due to the fact that water storage caused by beaver dams can adversely affect land management. For example, while an increased water table improves water storage, the unpredictable nature of beaver activity can make it difficult for ranchers to control water flow amount and direction. Additionally, while beaver dams result in expanded willow growth that benefits wildlife, it removes land from forage production.

Alternative 18. Ice Management

As stated previously, runoff is largely a function of the amount and rate of snowmelt. Some snowmelt is converted directly to runoff, while other snowmelt contributes to baseflow (and thus late season flow). A number of stakeholders suggested the idea of creating large expanses of ice as an alternative to delay runoff. Indeed, a researcher at Montana Tech proposed this concept over 10 years ago, with the goal of implementing a demonstration project using ice as a means of water storage. The project never came to fruition, though it serves as the nucleus for this alternative. The alternative of ice management would involve the diversion of flow from a small stream during the winter at a slow but consistent rate to an area of land with suitable typography. The water would repeatedly freeze until it was many feet thick. The premise is that the ice would melt at a slower rate than snow (due to its mass and density), thereby releasing flow after snowmelt runoff. The alternative might include some measure to insulate the ice (such as weed-free hay spread over the ice surface), thereby further delaying early season runoff. The alternative of ice management includes some capital improvement, as well as annual operations and management.

Location and Availability

The most likely locations to successfully implement ice management are areas that have topographic depressions to hold water to make ice, are in higher elevation areas so that runoff does not occur until later in the summer, and have vegetation cover to maintain ice as long as possible into the summer. The glacial till dominated area in the headwaters of the Big Hole mainstem on US Forest Service lands fits these criteria and would be the likely place for this alternative.

Advantages

We did not identify any advantages of ice management.

Disadvantages

Ice management presents a number of disadvantages, including the following.

- Ice management would require regular, almost daily oversight during the winter months, and the amount of ice produced would depend on the capabilities of the persons responsible for this oversight.
- Water diverted from streams during the winter to create ice might reduce instream flows during the diversion period, adversely affecting habitat for fish that might reside in the affected reach of stream.
- The location of ice development in the upper watershed means that any increased runoff resulting from ice management must travel a significant distance to the critical reach of the Big Hole River to be effective. Given the potential interception of such increased runoff by water users, there is limited likelihood of the flow reaching Wisdom.
- The period of runoff production from ice melt would likely not occur during the critical period of July and August.
- The success of ice management depends on seasonal weather patterns, and as such, the results from year to year would be unpredictable.

Alternative 19. Snow Management

The concept of snow management is very similar to that of ice management, in that techniques would be implemented to increase local snow accumulation. A common technique for managing snow accumulation in dryland areas is the use of snow fences to trap blowing and drifting snow. This technique could be employed in the upper Big Hole Basin where snow accumulation is generally moderate (but not extensive). Slatted snow fences would be installed in parallel rows at some specified distance (calculated according to snow and wind characteristics). Snow drifts tend to form on the leeward side of these fences. As the snow melts, it would release water, which would be contributed to surface flow and groundwater. This alternative includes the required capitalization (which would be relatively small) and annual operations and maintenance (which would also be limited).

Location and Availability

Snow management is best applied where elevations and moisture conditions result in moderate snow accumulation, where slatted snow fences would function. The measures could not be applied in locations where normal snow accumulation would be greater than the functional depth of the fences. Furthermore, the fences would need to be located in fairly open areas where blowing snow could be captured. The water content in accumulated snow (snow water equivalent) is generally a small percentage of the total volume of snow, which means that the relative increase in runoff from snow management measures may be very small.

Advantages

Snow management requires no operation and maintenance other than periodic repair of the wooden slat fences. Maintenance would occur during the summer months when site access would be straightforward.

Disadvantages

The location of snow accumulation high in the watershed means that any increased runoff resulting from snow management must travel a long distance to the critical reach of the Big Hole River to be effective. Given the potential interception of such increased runoff by water users, there is limited likelihood of the flow reaching Wisdom. Furthermore, the period of runoff production from snowmelt would likely not occur during the critical period of July and August. Lastly, the success of snow management depends on seasonal weather patterns, and as such the results from year to year would be unpredictable.

3. Cost of Alternatives

We estimated the costs for the various non-storage water alternatives to allow comparison of the relative financial requirement to implement each of the nineteen preliminary alternatives. In order to provide a common basis, the cost for each alternative was expressed in terms of the cost of an acre-foot of water that would flow in the river within the critical reach. Appendix A contains a summary of all alternatives, their estimated costs, and related information.

An acre-foot of water is equivalent to the amount of water that is one-foot deep spread over an acre of surface area (roughly 200 feet by 200 feet). An acre-foot equals 325,900 gallons. An acre-foot of water is not a flow rate or flow volume, although an acre-foot of water can be expressed as a given amount of water flowing for a finite period of time. For example, an acre-foot of water is equivalent to 0.5 cubic feet per second flowing for 24 hours, or 1 cubic foot per second flowing for 12 hours.

3.1. Spreadsheet Development

A series of numerical spreadsheets (called a workbook) facilitate the determination and comparison of the cost of the nineteen preliminary alternatives. The following sections describe the development of these spreadsheets. Appendix A contains the cost spreadsheets.

3.1.1. Input Data

Spreadsheet development started with a list all of the variables required to calculate the costs of the various non-storage alternatives (Table 3-1). These variables, called the input data, reflect the various amounts, quantities and costs that form the basis for subsequent calculation of alternative costs. The input data are grouped according to general categories (such as irrigation and hay production, to name the first two). This data input spreadsheet lists the average unit for each variable (and where available, minimum and maximum values). For example, the input data spreadsheet shows that under Irrigation data, the *Irrigation rate of pasture during the season (continuous)* averages 1.0 miner's inch per acre. This spreadsheet also shows the alternatives to which the variables are applied. In the preceding case, the irrigation rate of pasture applies to Alternatives 1, 2, 3, 6 and 7.

We used the average data values to calculate an estimated cost to implement each non-storage alternative. Some values applied to more than one alternative. To provide a means to modify the quantity of an input variable upon which a number of alternatives might be based, the input variables link to the applicable Alternative Calculation Sheets. Therefore, if a number is changed in the Input Data Spreadsheet, it is automatically changed in each applicable Alternative Calculation Sheet.

Table 3-1: Input data for cost spreadsheet.

Alternative	Input Data	Minimum	Average	Maximum	Units
	Irrigation				
	Critical low flow period during irrigation season Jul 15 to Sep 15		60		days
	Critical low flow period during irrigation season Jul 15 to Sep 16		60		days
1	Irrigation rate of hay during the season (continuous)		1.0		miner's inches/acre
1, 2, 3, 6, 7	Irrigation rate of pasture during the season (continuous)		1.0		miner's inches/acre
4	Irrigation rate of wet meadow during the season (continuous)		1.0		miner's inches/acre
5	Irrigation rate of low productivity soils during the season (continuous)		3.0	4.0	miner's inches/acre
	Hay Production				
1	Seasonal cost to grow and harvest hay		$75		$/ton
1, 7	Hay produced during the season (fertilized ground)	1.5	2	2.5	ton/acre
1, 7	Hay produced during the season (unfertilized ground)	0.75	1	1.75	ton/acre
3, 5	Length of alternative forage - pasture		60		days
4	Length of alternative forage - wet meadow		30		days
	Cattle Production				
1	Monthly consumption of hay by cattle	0.4	0.5	0.6	tons/AUM
6, 7	Cattle grazing rate in pasture areas during the season	0.6	0.66	0.75	AUM/acre
	Cattle grazing rate in low productivity soils during the season	0.3	0.33	0.4	AUM/acre
2	Cost to transport cattle to/from alternative pasture (round trip)	$5	$6	$7	$/head
2	Cost to lease alternative pasture		$60		$/AUM/season
2	Labor to manage cattle on alternative pastures	$2.00	$3.50	$5.00	$/AUM/season
3, 4, 5	Cattle forage consumption	0.4	0.5	0.6	tons/month
3, 4, 5	Cost to feed forage to cattle	$20	$25	$28	$/AUM/season
	Ranch Operational Costs				
7	Annual cost to manage and operate ranch		$50		$/acre
7	Annual revenue from leasing ranch		$50		$/acre
7	Value of conservation easements		$50		$/acre
7	Amortization period		30		years
7	Loan Period		30		years

Alternative	Input Data	Minimum	Average	Maximum	Units
7	Interest rate on loan		6%		%
7	Value of ranch land in the valley		$2,000		$/acre
	Water Rights				
6	Cost for leased water rights	19.50		29.84	acre-ft
	Cloud Seeding				
8	Capitalization and O&M costs for cloud seeding		$20,000		$/subwatershed unit
8	Average inches of snow in subwatershed unit		120		inches
8	Increase in snow pack from cloud seeding		10%		%
8	Subwatershed unit area		10,000		acres
8	Snow water equivalent		20%		% of snow depth
8	Cost for runoff from cloud seeding		$1.02		$/acre-ft
	Inter-Basin Transfer				
9	Capital costs to set up inter-basin water transfer		$1,000,000		$/system
9	O&M costs for inter-basin water transfer		$5,000		$/system
9	Amortization period		30		years
9	Quantity of water that would remain in the Big Hole River		500		acre-ft
	Irrigation Efficiency				
10	Annual O&M costs to provide flood irrigation (labor, materials, repairs)		$10		$/acre
10	Capital costs to convert to sprinkler system		$350		$/acre
10	Annual O&M costs to operate sprinklers		$50		$/acre/season
10	Amortization period		30		years
10	Efficiency of flood irrigation		45%		%
10	Efficiency of sprinklers		70%	80%	%
10	Hay production with sprinkler irrigation		4	5	ton/acre
	Ditch Loss				
11	Capital costs to reduce ditch loss	$11	$27	$52	$/foot of ditch
11	O&M costs to reduce ditch loss	$1.10	$2.60	$1.60	$/foot/season
11	Average ditch conveyance		10		cfs
11	Amortization period for ditch lining		20		years
11	Average acres irrigated by average ditch		400		acres
11	Average ditch length per acre irrigated		500		ft/acre
11	Reduction of water loss by ditch improvement		10		%
	Stockwater				

Alternative	Input Data	Minimum	Average	Maximum	Units
12	Capital costs to provide stockwater	$10,000	$13,000	$15,000	$/system
12	O&M costs to provide stockwater	$200	$300	$400	$/system/season
12	Amortization period for stockwater wells		30		years
12	Number of AUM watered by a stockwater system		200		AUM/system
12	Surface water flow (stock water in ditch) used to provide water to AUM	10	20	40	gpm
12	Critical duration when stockwater is provided		60		days
	Drainfield Development				
13	Capital costs to install drain fields		$20,000		$/acre
13	O&M costs to maintain drain fields		$350		$/acre/season
13	Amortization period for drainfield		30		years
13	Flow produced by drain fields	0.7	1.1	1.5	gpm/acre
13	Critical duration when water is provided		90		days
	Production Well Development				
14	Capital costs to install deep groundwater production wells	$200,000	$250,000	$300,000	$/well
14	O&M costs to maintain deep groundwater production wells	$10,000	$15,000	$20,000	$/well/season
14	Amortization period for production wells		30		years
14	Flow produced by deep production wells	1,000	1,500	2,000	gpm/well
14	Seasonal production period July 1-Sept 1		60		days
	Managed Wetlands				
15	Capital costs to develop managed wetlands	$5,000	$10,000	$15,000	$/acre
15	O&M costs to manage managed wetlands	$200	$500	$800	$/acre/annual
15	Amortization period for managed wetlands		30		years
15	Flow produced by managed wetlands	10.0	15.0	20.0	gpm/acre
15	Period of time flow is produced by managed wetlands		60		days
	Stream Habitat Improvement				
16	Capital costs to improve habitat	$10	$50	$100	$/foot channel
16	O&M costs to maintain habitat	$0	$2	$5	$/foot channel
16	Amortization period for stream habitat improvement		30		years
16	Flow produced by improved habitat	0.1	0.2	0.3	gpm/foot
16	Period of time flow is produced by stream habitat improvement		60		days
	Introduce Beaver				
17	Capital costs to introduce beaver		$50,000		$/sub-watershed
17	O&M costs to manage beaver		$25,000		$/sub-watershed

Alternative	Input Data	Minimum	Average	Maximum	Units
17	Average size of subwatershed improved by beaver introduction		1,200		acres/sub-watershed
17	Amortization period for introduced beaver		30		years
17	Flow produced by introduced beaver	1.0	4.2	7.4	gpm/acre/season
17	Period of time flow is produced by introduced beaver		60		days
	Ice and Snow pack Management				
18	Capital costs to set up ice management		$500		$/acre
18	O&M costs to manage ice		$100		$/acre
18	Amortization period for ice management		20		years
18	Ice depth produced by ice management		5		ft/acre/season
18	Percent of runoff from ice that would occur during the critical 60 day period		25%		percent
19	Capital costs to set up snow pack management		$2,000		$/acre
19	O&M costs to manage snow pack management		$1,000		$/acre
19	Amortization period for snow pack management		5		years
19	Increase in snow accumulation from snow pack management		36		inches depth/acre
19	Conversion from snow depth to water depth [snow water equivalent]		20%		percent
19	Percent of runoff from snowmelt that occurs during the critical 60 day period		10%		percent

3.1.2. Sources of Costing Data

Several sources were used to determine or estimate the numerical input data values. These included:

- Literature and research articles on technical topics;
- Discussions with area ranchers during an informal meeting specifically for the purpose of identifying quantities and costs associated with irrigation, hay production and ranch operations;
- Discussions with professionals and practitioners regarding quantities and costs associated with a particular topic (for example, cloud seeding); and
- Engineering calculations based on some general assumptions (for such aspects as well and drainfield production and ditch lining).

Where information was lacking, we used our professional judgment to assign values to particular variables. For example, to estimate the amount of water that would be released from bank storage following stream bank restoration. In all cases, the numbers used in calculating the costs for the various alternatives are shown in the Input Data table (Table 3-1).

For projects that required some level of capital expenditure, two different methods of determining the capitalization period were applied. For capitalization periods involving institutional issues (such as loans on land purchase), we used a 30-year conventional loan period. For projects with a limited lifespan, we estimated the period of capitalization based on the likely functional life expectancy of the proposed activity. This approach was applied to such aspects as ditch lining and ice and snow pack management. Again, all capitalization and amortization periods are indicated in the Input Data table (Table 3-1).

3.1.3. Individual Alternative Calculation Sheets

The spreadsheets contain nineteen worksheets used to calculate the cost to implement each of the nineteen preliminary alternatives. We have called these worksheets Alternative Calculation Sheets. Each of the calculation sheets is organized in a similar manner. Each includes the title, assumptions, input values and calculations. As an example, Table 3-2 shows the calculation sheet for *Alternative 2 Reduce Pasture Irrigation in Valley Bottom Areas by Providing Alternative Pastures*. The input values, red text in yellow shaded areas, are those taken from the Input Data Spreadsheet. As described previously, each of these values links to the corresponding value in the Input Data Spreadsheet. Note that if a value in the Input Data Spreadsheet changes, the corresponding value in the appropriate Alternative Calculation Sheet(s) also changes. The final product of each Alternative Calculation Sheet is an estimated cost per acre-foot of water for each alternative.

Preliminary Non-Storage Alternative No. 2		
Type	**Method**	**Result**
Reduce pasture irrigation in valley bottom areas	Provide alternative pastures	Cease or reduce irrigation of pastures at onset of low flows
Assumptions		
The irrigation required for alternative pastures is not considered to deplete the Big Hole River in the critical reach		
Input Values		= Input Value
Average irrigation rate of pasture during the season	1.0	miners inches/acre
Transportation to/from alternative pasture	$6.00	per head
Leasing of alternative pasture land	$60.00	head/season
Addition labor	$3.50	head/season
Length of lease of alternative pasture land	60	days
Length of irrigation season	60	days
Average cattle grazing in pastures during the season	0.66	AUM/acre
Calculations		
COSTS		
Total cost to lease land, transport and care for cattle on alternative pastures	$70	head/season
Cost per acre per season based on AUM per acre	$46	acre/season
FLOW BENEFITS		
Savings in pasture irrigation water during the season	3.0	acre-ft/acre/season
COST PER ACRE-FT PER SEASON		
Cost for reduced irrigation water used	$15.29	acre-ft

Table 3-2: Example alternative cost calculation spread sheet.

The electronic spreadsheet workbook allowed us to consider the effects of altering the Input Data. This alteration of input variables might be undertaken if more refined or differing values are encountered, or to test the relative sensitivity of a particular value on the overall cost of one or more alternatives.

3.1.4. Master Spreadsheet

The results of each Alternative Calculation Sheet (as cost per acre-foot of water) are listed in a single table, called the Master Spreadsheet (Table 3-3). This table is a summary of the estimated costs to implement each of the nineteen preliminary non-storage alternatives, based on the values from the Input Data and the calculations in the individual Alternative Calculation Sheets. As indicated, the implementation cost is expressed as a cost to generate, save or retain one acre-foot of water in the river. In one instance (for inter-basin transfer of water) the cost were not estimated, as site-specific information is required (such as the point of diversion and the length of a ditch). The summary of the cost per acre-foot of the 19 preliminary non-storage alternatives is based on the values from the Input Data and the calculations in the individual Alternative Calculation Sheets. We selected those with costs in green for further consideration and those in gray for no further evaluation. We used a cost of $50 per acre-foot of water as a somewhat arbitrary basis for this recommendation.

This summary provided the information to refine the non-storage alternatives to undergo further evaluation. We selected a unit cost of $50 per acre-foot of water to segregate the alternatives into two categories. This figure, though somewhat arbitrary, divides the group equally. Furthermore, $50 per acre-foot is less than the 30-year costs determined for the reservoir storage alternatives. The Master Spreadsheet shows the estimated costs for the non-storage alternative costs in grey (> $50 per acre-foot) and green (≤$50 per acre-foot). We recommend that there be no further consideration of those non-storage alternatives with costs estimated to be greater than $50 per acre-foot. Conversely, those with costs less than $50 per acre-foot should be further considered. Based on this framework, we recommend that nine alternatives be advanced.

3.2. Recommended Alternatives for Further Consideration

Nine alternatives are recommended for further consideration based on the estimated cost per acre-foot of water produced. These alternatives (highlighted in green in Table 3-3) include: reduction of irrigation by providing alternative pastures and sources of forage; purchasing water and land; irrigation efficiency reducing ditch loss and reintroducing beaver. The cost for these alternatives to generate, save or retain one acre-foot of water in the river ranges from about $6 to $50 per acre-foot of water. Two exceptions to this cost threshold are the implementation of habitat improvements and stockwater wells. Since both of these types of projects have numerous additional benefits, and are facilitated and funded by other programs (TMDL, CCAA, EQIP), we have included them in the list of alternatives for further consideration.

Alt. No.	Alternative Type	Method	Result	Cost Per Acre-foot
1	Reduce Pasture Irrigation in Valley Bottom Areas	On land not currently producing hay, put additional land into hay production	Cease or reduce irrigation when cutting hay during low flows	N/A
2	"	Provide alternative pastures	Cease or reduce irrigation of pastures at onset of low flows	$15.29
3	"	Provide alternative source of forage (hay/alfalfa) from off-site	Cease or reduce irrigation of pastures at onset of low flows	$24.83
4	Reduce Pasture Irrigation in Wet Meadow Areas	Provide fall forage	Cease or reduce irrigation in meadow areas (nutgrass)	$16.58
5	Reduce Pasture Irrigation on Low Productivity Soils	Provide alternative source of forage (hay/alfalfa from off-site)	Cease or reduce irrigation of pastures at onset of low flows	$5.53
6	Purchase Water	Lease water or compensate for reduced irrigation	Cease or reduce irrigation	$50.00
7	Purchase Land	Purchase key lands with water rights and/or hay bank potential	Manage flows, create hay bank, pasture bank, etc.	$23.56
8	Increase Water Yield	Cloud seeding	Increase rainfall	$100.00
9	"	Inter-basin water transfer	Increase stream flow	N/A
10	Improve Irrigation Efficiency	Convert from flood irrigation to hand lines, wheel lines, and pivots	Reduce irrigation water needs	$50.00
11	"	Reduce ditch loss	Reduce irrigation water needs	$6.88
12	Develop Groundwater Resources	Provide stockwater from wells	Decrease stockwater needs from streams, improve habitat	$152.78
13	"	Drain fields	Increase base flow by tapping near surface groundwater adjacent to Big Hole River	$2,567
14	"	Deep groundwater production wells	Increase base flow by tapping deep GW and adding to surface flow in Big Hole	$64.81
15	Delay Runoff	Managed wetlands	Stored water for gradual release	$231
16	"	Habitat improvements (channel morphology and riparian vegetation)	Reduce evaporation, increase recharge, increase travel time	$76.39
17	"	Reintroduce beavers	Stored water for gradual release	$22.05
18	"	Ice management	Divert winter runoff and create ice	$100
19	"	Snow pack management	Increase source of runoff	$23,333

Recommend Continued Evaluation of Alternative: ≤$50/acre-foot
Recommend No Further Evaluation of Alternative: > $50/acre-foot

Table 3-3: Master spreadsheet summarizing cost estimates for the initial 19 alternatives.

4. Recommendations

This section provides a series of recommendations regarding the non-storage alternatives evaluated as part of this study. In this section, we provide recommendations that the Big Hole Watershed Committee eliminate a number of alternatives from further consideration. We recommend continued evaluation of those alternatives that appear to be the most favorable, and we offer some considerations for maximizing benefits by combining certain alternatives. Lastly, we suggest a number of pilot projects that the Watershed Committee could implement to demonstrate the viability of some of the recommended alternatives.

4.1. Alternatives Eliminated from Further Consideration

Ten alternatives do not appear feasible based on the analysis presented in this document (Table 3-3). As such, we recommend eliminating these alternatives from further consideration as measures to improve water storage in the watershed. For the most part, these alternatives are not cost-effective. Our analysis suggests that the cost per acre-foot of water provided by these alternatives is higher than $50 per acre-foot.

4.2. Recommended Alternatives

We recommend that the Big Hole Watershed Committee and Big Hole River Foundation consider 11 non-storage alternatives as potentially viable (Table 4-1). Section 3 of this document discusses each of these alternatives in detail. We recommend that these alternatives receive further evaluation and pilot project development (as discussed below).

NRCS personnel provided input on potential farm bill funding sources that could help implement some of these management alternatives. Ten of the eleven viable management alternatives have potential to receive funding from NRCS farm bill programs. This funding could lower the cost and increase the feasibility of implementation of these alternatives.

Alt. No.	Alternative Type	Method	Result	Cost Per Acre-foot	NRCS Funding?
2	Reduce Pasture Irrigation in Valley Bottom Areas	Provide alternative pastures	Cease or reduce irrigation of pastures at onset of low flows	$15	EQIP
3	Reduce Pasture Irrigation in Valley Bottom Areas	Provide alternative source of forage (hay/alfalfa) from off-site	Cease or reduce irrigation of pastures at onset of low flows	$25	EQIP
4	Reduce Pasture Irrigation in Wet Meadow Areas	Provide fall forage	Cease or reduce irrigation in meadow areas (nutgrass)	$17	IWM Plan
5	Reduce Pasture Irrigation on Low Productivity Soils	Provide alternative source of forage (hay/alfalfa from off-site)	Cease or reduce irrigation of pastures at onset of low flows	$6	IWM Plan
6	Purchase Water	Lease water or compensate for reduced irrigation	Cease or reduce irrigation	$50	EQIP
7	Purchase Land	Purchase key lands with water rights and/or hay bank potential	Manage flows, create hay bank, pasture bank. etc.	$24	N/A
10	Improve Irrigation Efficiency	Convert from flood irrigation to hand lines, wheel lines, and pivots	Reduce irrigation water needs	$50	EQIP and ground and surface water program
	Improve Irrigation Efficiency	Reduce ditch loss	Reduce irrigation water needs	$11	EQIP and ground and surface water program
12	Develop Groundwater Resources	Provide stockwater from wells	Decrease stockwater needs from streams, improve habitat	$153	EQIP and ground and surface water program
16	Delay Runoff	Habitat improvements (channel morphology and riparian vegetation)	Reduce evaporation, increase recharge, increase travel time	$110	WIP, EQIP, CRP
17	Delay Runoff	Reintroduce beavers	Stored water for gradual release	$22	Possible

Table 4-1: Table of recommended alternatives. Costs under $50/acre-ft are in green.

4.3. Recommended Next Steps

We recommend that the Big Role River Watershed Committee and Big Hole River Foundation facilitate implementation of pilot projects for individual or combinations of water management alternatives. These pilot projects will serve several purposes including:

- Ascertain the willingness of landowners to implement water management alternatives on a limited basis;
- Provide a mechanism to test the proposed water management alternatives for their viability in certain locations;
- Monitor the effectiveness of the water management alternatives to better quantify water savings;
- Identify potential problems with the water management alternatives that can be addressed before implementation on a larger scale; and
- Develop working models of water management that can be demonstrated to other landowners and help gain acceptance of the modified land use practices.

The following recommendations are not in order of cost or other factors. Some recommendations are generic and apply to the entire basin.

4.3.1. Voluntary Irrigation Education Program

Throughout the process of identifying, assessing and recommending non-storage alternatives, it became very apparent that improvement of existing flood irrigation practices could greatly increase the amount of water in the river upstream of Wisdom. While the recommended alternatives provide a framework for *changing* land use patterns (for example, reducing irrigation by providing alternative forage), they do not address merely *improving* existing practices. To be more specific, it appears to us that more water than is necessary is flooded onto pastures and hay fields. It appears that the amount of water currently used for flood irrigation is more than necessary to produce a maximum quantity of high quality forage. We did not test this observation; however, it nonetheless leads us to a general recommendation.

We recommend that the Big Hole River Watershed Committee and Big Hole River Foundation, through whatever resource agency teaming or funding mechanisms prove applicable, provide interested ranchers with the services of a qualified irrigation and forage manager/consultant such as planned as a part of the current CPI (Conservation Planning Initiative) grant. Such a person or persons would work with willing landowners to evaluate existing irrigation practices (such as application rates, timing and rotation) and forage production (tons per acre as well as forage value) and to collaboratively identify ranch-specific irrigation practices that would maximize forage production (quantity *and* quality). It is our impression that such a program would result in a more efficient use of water, benefiting the rancher by improving forage production and benefiting the river by not over-diverting water.

4.3.2. Monitoring Irrigation Water Application

One of the first steps to implementing any modified land use practice that involves reducing irrigation is to understand the relationship between amount of water applied and forage production. Conversations with landowners in other watersheds who utilize soil moisture monitoring devices indicate that they are often surprised to learn that they typically over-water their lands. The first step in modifying land use practices will be to understand how existing practices affect forage production. In flood irrigated areas, irrigation is often controlled by how much water is available, rather than how much needs to be applied for optimal forage production. If presented with water application rates on an annual basis, landowners can easily make the correlation how much hay they produced with how much water was applied.

Monitoring water application would require the following steps:

- Identify landowners willing to participate,
- Assess current levels of irrigation and forage production,
- Determine water requirements of desired forage species,
- Adjust irrigation rates accordingly, and
- Monitor resultant forage production.

4.3.3. Reduce Over-watering

The first four identified alternatives (Numbers 2, 3, 4, and 5) involving reducing irrigation all apply to areas currently over-watered. The nature of flood irrigation dictates that excess water is applied to a large area to ensure complete coverage. Areas with excess applied water can host or encourage growth of undesirable, water consumptive plant species (Figure 4-1). Identification of these areas through meetings with landowners and field visits will faciliate implementing water management alternatives that will improve forage production. Each specific area currently receiving excess water can benefit from varying actions to reduce water use. For example, if a pasture receives too much water from up-gradient ditch loss, lining a portion of that ditch could cut down on the excess water in that pasture and maintain flows to adjacent areas. The steps involved are as follows:

- Identify landowners willing to participate;
- Meet with landowners and solicit their input on where excess water is applied;
- Follow up with a field visit to characterize those areas;
- Develop a strategy to address those areas with excess water while maintaining water delivery to other areas, this may utilize one or more of the identified water management alternatives; and
- Monitor water application and forage production as described above.

Figure 4-1: Photograph of surface runoff encouraging wetland grasses.

4.3.4. Beaver Reintroduction Pilot Project

Beaver re-introduction (Alternative 17) represents the best mechanism presented in this study to delay runoff by creating temporary storage. We recommend implementation of this alternative initially in headwater streams on US Forest Service lands. This will require up-front costs including identifying the most feasible locations for the pilot test, conducting an Environmental Assessment and the physical costs of re-locating beaver. Management and monitoring will be required and will include installation of lysimeters to measure and monitor groundwater levels associated with beaver dams, and relocate and trap beaver if necessary.

Establishing beaver populations in the headwater tributary streams will take several years to create the estimated 600 acres of water storage area. The first areas to start in are along tributary streams to the uppermost portion of the mainstem Big Hole River (Figure 2-10). This level of enhanced water storage could provide approximately 16 cfs throughout the late summer months. During July and August, this equates to over 2,000 acre-feet.

If beaver re-introduction is successful in headwater areas, re-introduction could also be attempted on private lands in the valley foothills. This would obviously require willing landowners, as well as willing neighbors. The potential storage capacity of the additional

1,450 acres of storage area could provide an additional 40 cfs during the late summer months. This equates to approximately 4,750 acre-feet of water storage.

4.3.5. Irrigation Efficiency

Converting flood irrigated lands to sprinkler (Alternative 10) has been an unpopular idea with landowners at meetings conducted as part of this project. Objections included high cost, short growing season (one cutting of hay) and irregular topography. Other stakeholders raised concerns that pivots resulted in increased water consumption in other basins in southwest Montana. There is one condition where sprinkler irrigation may be viable in the upper Big Hole watershed. That is in areas where water is conveyed out of the Wisdom Bridge watershed into the Steel Creek and Swamp Creek watersheds (Figure 1-2). In these situations, pivot irrigation could reduce the amount of water withdrawn from the Big Hole and thus removed from the dewatered reach. Some of the area in the lower Steel Creek watershed has topography amenable to sprinkler irrigation. In addition, EQIP funding may be available to partially offset costs of implementation.

Ditch lining is a recommended alternative (Number 11) that has relatively low costs to implement. Areas identified for initial consideration for ditch lining consist of those that flow across areas of Tertiary sedimentary geology and correspondingly high soil infiltration rates. Soils mapping released by NRCS in the last month indicate there are additional areas where soils have high infiltration rates that may influence ditch loss. Ditch lining is an attractive alternative due to its flexibility. For example, ditches can be lined for only a portion of their length if some ditch loss is locally desired for subirrigation. Also, ditches can be partially lined, allowing for some ditch loss at certain flows. This allows ditch lining to be used as a flexible method to address over-watered areas when appropriate.

4.3.6. Implement Habitat Improvements

Habitat improvements (Alternative 16) are beneficial to other aspects of water quality, fish habitat and aesthetics in the upper Big Hole River watershed. These include channel restoration, bank stabilization and riparian re-vegetation. These improvements help store smaller quantities of water in soils and shallow groundwater. However, existing programs such as the CCAA and TMDL development provide funding to implement these changes and should be pursued.

4.3.7. Stock Water Wells

Although the cost per acre-foot for saved water is greater than $50, stockwater wells (Alternative 12) provide a simple solution to improving stream habitat. Providing this alternative water source encourages cattle to avoid streams, resulting in reduced bank erosion, improved riparian vegetation and reduced nutrient loading. These benefits, combined with small water savings, make stockwater wells a recommended action for pastures throughout the basin.

4.3.8. Grass/Hay Bank Opportunities

Purchasing land (Alternative 7) and managing those lands as a forage or hay bank could provide a means to implement some of the water management alternatives that involve providing alternate pasture or forage for livestock. The cost per acre-foot of water saved is below $25 for land purchase (see Section 2.2.5), without considering the added benefit of providing forage or pasture to conserve water elsewhere.

4.3.9. Pursue Water Rights Adjudication

Ultimately, water rights adjudication will help ensure that appropriate, legal water use occurs in the basin. Adjudication may leave some landowners with less water than they now divert, especially in dry years. However, proactive implementation of water management and conservation measures over the next 10 years has the potential to provide all landowners with adequate irrigation water through gains in efficiency and management.

4.3.10. Emergency Short Term Water Conservation Measures

Finally, in times of drought and resulting water shortages, water conservation or purchase mechanisms should be developed that can be implemented on short notice. Water leasing (Alternative 6) can provide this mechanism. Water leases can be structured where the lessor has the option to purchase water if drought conditions are present, as indicated by snowpack or streamflows falling below threshold levels at some point in the season.

This type of action should be considered a Band-Aid approach that will ultimately be unnecessary once adequate basin-wide water management and conservation practices are implemented. Water purchase approaches should be phased out after a 10-year period.

4.3.11. Combinations of Alternatives

The eventual locations appropriate for implementation of individual alternatives depend on site-specific ground conditions, land use, funding availability and property owner interest. As the Big Hole River Watershed Committee and Big Hole River Foundation undertake continued evaluation of the recommended alternatives, they should consider combinations of alternatives that work well together.

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A. Appendix A Cost Summary of All Alternatives

	Reservoir Storage Alternatives	Estimated Contribution (acre-ft)	Estimated Capital Cost ($)	Estimated Annual O&M Cost ($)	Estimated Cost (during 30-yr capitalization in $/acre-ft)	Estimated Cost (after 30yr capitalization in $/acre-ft)	Estimated Phase II ($)
1	Lower Big Lake Creek	2,650	$2,600,000	$17,000	$63	$6	Surveying, environmental assess refine design/cost estimate for coi
2	Lower Miner Lake	2,130	$2,000,000	$17,000	$62	$8	Surveying, environmental assess refine design/cost estimate for coi
3	Upper Big Swamp Creek	730	$1,600,000	$17,000	$151	$23	Surveying, environmental assess refine design/cost estimate for co
4	Small Seepage Site	100	$184,000	$2,300	$129	$23	Surveying, detailed design, p

	Non-Reservoir Storage Alternatives	Estimated Contribution (acre-ft)	Estimated Capital Cost ($/acre-ft except as noted)	Estimated Annual O&M Cost ($ per acre/season)	Estimated Cost (during 30-yr capitalization in $/acre-ft except as noted)	Estimated Cost (after 30yr capitalization in $/acre-ft)	Estimated Phase II ($)
2	Reduce Pasture Irrigation in Valley Bottom Areas Provide alternative pastures	1,000	N/A	$46	$15	N/A	$5,000 Planning
	Reduce Pasture Irrigation in Valley Bottom Areas Provide alternative source of forage (hay/alfalfa) from off-site	1,000	N/A	$75	$25	N/A	$5,000 Planning
4	Reduce Pasture Irrigation in Wet Meadow Areas Provide fall forage	2,100 to 2,800	N/A	$50	$17	N/A	$5,000 Planning
	Reduce Pasture Irrigation on Low Productivity Soils Provide alternative source of forage (hay/alfalfa) from off-site	At least 600	N/A	$50	$6	N/A	$5,000 Planning
6	Purchase Water Lease water or compensate for reduced irrigation	1,000	$50	Not Determined	$50	N/A	$5,000 Planning
	Purchase Land Purchase key lands with water rights and/or hay bank potential	3 acre-ft/acre/yr	$2,000 $/acre	$0 Lease Offsets Annual Costs	$24 $/acre-ft/yr (30 yr amortization period)	$0	$5,000 Planning
	Improve Irrigation Efficiency Convert from flood irrigation to hand lines, wheel lines, and pivots	500	$350 $/acre	$50	$50 $/acre-ft/yr (30 yr amortization period)	$38	$10,000 Planning and des
11	Improve Irrigation Efficiency Reduce ditch loss	120 acre-ft (20,000 ft of ditch)	$11 $/ft-ditch	$1 $/ft-ditch/season	$7 $/acre-ft/yr (20 yr amortization period)	N/A	$10,000 Planning and des
12	Develop Groundwater Resources Provide stockwater from wells	5 to 50 depending on the number of wells installed	$13,000 $/system	$300 $/system	$153 $/acre-ft/yr (30 yr amortization period)	N/A	$15,000 Planning, geotechnical analy
16	Delay Runoff Habitat improvements (channel morphology and riparian vegetation)	Potentially up to 500 acre-ft per stream mile	$50 $/lineal foot of river bank	$2 $/lineal foot of river bank	$76 $/acre-ft/yr (30 yr amortization period)	N/A	$20,000 Planning and des
17	Delay Runoff Reintroduce beavers	2,000	$50,000 $/sub-watershed	$25,000 $/sub-watershed	$22 $/acre-ft/yr (30 yr amortization period)	N/A	$20,000 Planning and environmenta

...st	Estimated Implementation Time (years)	Advantages	Disadvantages
...nt, geotechnical, ...uction: $119,000.	4	Good capacity, lager subbasin for yield to fill reservoir, cost effective on $/acre-foot basis, may create recreational opportunity.	Site located on NF with adjacent roadless area. NEPA review may be time consuming and expensive. Functioning wetland and riparian areas would be inundated. Potential for downstream losses.
...nt, geotechnical, ...uction: $118,000.	4	Good capacity, larger subbasin for yield to fill reservoir, cost effective on $/acre-foot basis, may create recreational opportunity.	Site located on NF with adjacent roadless area. NEPA review may be time consuming and expensive. Discharge to mainstem farther upstream from critical reach. Potential for downstream losses.
...nt, geotechnical, ...uction: $91,000.	3	Low initial capital cost and favorable topography. Detailed surveying may show additional capacity and increased cost-benefit.	Cost benefit lower because of smaller capacity. Site located on NF and NEPA review may be time consuming and expensive.
...its: $19,000.	1	Low cost and accelerated timeframe for implementation. Constant inflow and potential constant outflow from springs. Potential participating land owner. Close to mainstem and critical reach for controlled delivery.	Reduced cost-benefit in $/acre-ft because of small storage volume.
...st	Estimated Implementation Time (years)	Advantages	Disadvantages
	1	Readily implemented. Can be applied on a rotational basis. Forage quality may improve with reduced irrigation. EQIP funding potential.	Some trial and error may be needed. Monitoring will be required. Annual costs may vary depending on pasture lease value.
	1	Readily implemented. Can be applied on a rotational basis. Forage quality may improve with reduced irrigation. EQIP funding potential.	Some trial and error may be needed. Monitoring will be required. Annual costs may vary depending on hay prices.
	1	Addresses inefficient use of water. Benefits are high. Forage quality may improve with reduced irrigation.	A pilot project and a monitoring program may be needed to garner landowner support for this alternative. Would require a shift in long-term land use practices
	1	Addresses inefficient use of water. Benefits are high. Lower costs for replacement of forage	A pilot project and monitoring program may be needed to garner landowner support. Would require a shift in long-term land use practices
	1	Readily implemented. Can be applied on a rotational basis. Forage quality may improve with reduced irrigation. EQIP funding potential for leased	A pilot project and monitoring program may be needed to garner landowner support. Would require a shift in long-term land use practices.
	2 to 4	This single alternative could solve the critical dewatering problem. Land could be managed to provide secondary water benefits (such as alternative hay production and pastures)	High initial capital costs, though when amortized over many decades or a century, costs are very low
	2	May allow beneficial use of irrigation water while minimizing diversion of flow to areas outside of the drainage for the critical dewatered reach of the river. EQIP and ground and surface water NRCS funding potential.	Landowners feel this alternative is not economically viable. A pilot project and monitoring program may be needed to garner landowner support.
	2	Cost if very low relative to the benefits provided. Implementation is uncomplicated. Environmental impacts and permitting requirements are negligible. EQIP and ground and surface water NRCS funding potential	Little or no disadvantages. Multiple party ownership of ditches will require consensus
... and design	1	Potential secondary benefits to habitat, water quality, recreational and aesthetic values as livestock no longer access the river for water..	Relatively small impact per installation; would require significant installations to have a cumulative benefit.
	2 (Effects in 5 or more)	Would coincide with the TMDL and CCAA process. Potentially significant secondary benefits to habitat, water quality, recreation and aesthetic values. WHIP, EQIP, and CRP funding potential.	Alone, this measure provides small benefits relative to costs
...ssessment	2 (Effects in 5 or more)	Potentially significant secondary benefits to habitat, water quality, recreation and aesthetic values. Possible NRCS funding if project is related to restoration of declining habitats.	Landowners often have a negative perception of beavers. A pilot project and monitoring program may be needed to garner landowner support

B. Appendix B: Cost Analysis Spread Sheets

Introduction to Sreadsheet Workbook

This spreadsheet workbook provides a quantitative framework to compare the costs and benefits for nineteen non-storage alternatives, which are grouped by general type.

A Master Spreadsheet lists these alternatives, and provides a summary of estimated unit cost of water for each alternative. The unit cost of water for each alternative is linked to the individual Alternative Calculation Sheets.

An Input Data spreadsheet lists the unit costs that are used in the cost analysis of the alternatives. This is the master data input spreadsheet, to which all the Alternative Calculation Sheets are linked. Thus, changing values in this spreadsheet will alter the Alternative Calculation Sheets and the unit cost of water in the Master Spreadsheet.

Finally, nineteen individual Alternative Calculation Sheets have been created (numbered 1 through 19 to correspond with each alternative). Each spreadsheet lists the assumptions, input values and calculations for each alternative. Input values are shown in yellow cells and are linked to the Input Data spreadsheet. Formulas in the calculation section are embedded as formulas in the spreadsheet; to evaluate the basis for a calculated value, inspect the formula by clicking on the value.

Master Spreadsheet

Summary of the cost per acre-foot of the nineteen preliminary non-storage alternatives, based on the values from the Input Data and the calculations in the individual Alternative Calculation Sheets. Those with costs in blue are recommended for further consideration and those in pink for no further evaluation. A cost of $50 per acre-foot of water was arbitrarily selected as basis for this recommendation.

Alt. No.	Alternative Type	Method	Result	Cost Per Acre-foot
1	Reduce Pasture Irrigation in Valley Bottom Areas	On land not currently producing hay, put additional land into hay production	Cease or reduce irrigation when cutting hay during low flows	N/A
2		Provide alternative pastures	Cease or reduce irrigation of pastures at onset of low flows	$15.29
3		Provide alternative source of forage (hay/alfalfa) from off-site	Cease or reduce irrigation of pastures at onset of low flows	$24.83
4	Reduce Pasture Irrigation in Wet Meadow Areas	Provide fall forage	Cease or reduce irrigation in meadow areas (nutgrass)	$16.58
5	Reduce Pasture Irrigation on Low Productivity Soils	Provide alternative source of forage (hay/alfalfa from off-site)	Cease or reduce irrigation of pastures at onset of low flows	$5.53
6	Purchase Water	Lease water or compensate for reduced irrigation	Cease or reduce irrigation	$50.00
7	Purchase Land	Purchase key lands with water rights and/or hay bank potential	Manage flows, create hay bank, pasture bank, etc.	$23.56
8	Increase Water Yield	Cloud seeding	Increase rainfall	$100.00
9		Inter-basin water transfer	Increase stream flow	N/A
10	Improve Irrigation Efficiency	Convert from flood irrigation to hand lines, wheel lines, and pivots	Reduce irrigation water needs	$49.87
11		Reduce ditch loss	Reduce irrigation water needs	$6.88
12	Develop Groundwater Resources	Provide stockwater from wells	Decrease stockwater needs from streams, improve habitat	$152.78
13		Drain fields	Increase base flow by tapping near surface groundwater adjacent to Big Hole River	$2,567
14		Deep groundwater production wells	Increase base flow by tapping deep GW and adding to surface flow in Big Hole	$64.81
15	Delay Runoff	Managed wetlands	Stored water for gradual release	$231
16		Habitat improvements (channel morphology and riparian vegetation)	Reduce evaporation, increase recharge, increase travel time	$76.39
17		Reintroduce beavers	Stored water for gradual release	$22.05
18		Ice management	Divert winter runoff and create ice	$100
19		Snow pack management	Increase source of runoff	$23,333

Recommend Continued Evaluation of Alternative: ? $50/acre-foot
Recommend No Further Evaluation of Alternative: > $50/acre-foot

Alternative	Input Data	Minimum	Average	Maximum	Units
	Irrigation				
	Critical low flow period during irrigation season Jul 15 to Sep 15		60		days
	Critical low flow period during irrigation season Jul 15 to Sep 16		60		days
1	Irrigation rate of hay during the season (continuous)		1.0		miner's inches/acre
1, 2, 3, 6, 7	Irrigation rate of pasture during the season (continuous)		1.0		miner's inches/acre
4	Irrigation rate of wet meadow during the season (continuous)		1.0		miner's inches/acre
5	Irrigation rate of low productivity soils during the season (continuous)		3.0	4.0	miner's inches/acre
	Hay Production				
1	Seasonal cost to grow and harvest hay		$75		$/ton
1, 7	Hay produced during the season (fertilized ground)	1.5	2	2.5	ton/acre
1, 7	Hay produced during the season (unfertilized ground)	0.75	1	1.75	ton/acre
3, 5	Length of alternative forage - pasture		60		days
4	Length of alternative forage - wet meadow		30		days
	Cattle Production				
1	Monthly consumption of hay by cattle	0.4	0.5	0.6	tons/AUM
6, 7	Cattle grazing rate in pasture areas during the season	0.6	0.66	0.75	AUM/acre
	Cattle grazing rate in low productivity soils during the season	0.3	0.33	0.4	AUM/acre
2	Cost to transport cattle to/from alternative pasture (round trip)	$5	$6	$7	$/head
2	Cost to lease alternative pasture		$60		$/AUM/season
2	Labor to manage cattle on alternative pastures	$2.00	$3.50	$5.00	$/AUM/season
3, 4, 5	Cattle forage consumption	0.4	0.5	0.6	tons/month
3, 4, 5	Cost to feed forage to cattle	$20	$25	$28	$/AUM/season
	Ranch Operational Costs				
7	Annual cost to manage and operate ranch		$50		$/acre
7	Annual revenue from leasing ranch		$50		$/acre
7	Value of conservation easements		$50		$/acre
7	Amortization period		30		years
7	Loan Period		30		years
7	Interest rate on loan		6%		%
7	Value of ranch land in the valley		$2,000		$/acre

Alternative	Input Data	Minimum	Average	Maximum	Units
17	Flow produced by introduced beaver	1.0	4.2	7.4	gpm/acre/season
17	Period of time flow is produced by introduced beaver		60		days
	Ice and Snow pack Management				
18	Capital costs to set up ice management		$500		$/acre
18	O&M costs to manage ice		$100		$/acre
18	Amortization period for ice management		20		years
18	Ice depth produced by ice management		5		ft/acre/season
18	Percent of runoff from ice that would occur during the critical 60 day period		25%		percent
19	Capital costs to set up snow pack management		$2,000		$/acre
19	O&M costs to manage snow pack management		$1,000		$/acre
19	Amortization period for snow pack management		5		years
19	Increase in snow accumulation from snow pack management		36		inches depth/acre
19	Conversion from snow depth to water depth [snow water equivalent]		20%		percent
19	Percent of runoff from snowmelt that occurs during the critical 60 day period		10%		percent

Alternative	Input Data	Minimum	Average	Maximum	Units
12	Amortization period for stockwater wells		30		years
12	Number of AUM watered by a stockwater system		200		AUM/system
12	Surface water flow (stock water in ditch) used to provide water to AUM	10	20	40	gpm
12	Critical duration when stockwater is provided		60		days
	Drainfield Development				
13	Capital costs to install drain fields		$20,000		$/acre
13	O&M costs to maintain drain fields		$350		$/acre/season
13	Amortization period for drainfield		30		years
13	Flow produced by drain fields	0.7	1.1	1.5	gpm/acre
13	Critical duration when water is provided		90		days
	Production Well Development				
14	Capital costs to install deep groundwater production wells	$200,000	$250,000	$300,000	$/well
14	O&M costs to maintain deep groundwater production wells	$10,000	$15,000	$20,000	$/well/season
14	Amortization period for production wells		30		years
14	Flow produced by deep production wells	1,000	1,500	2,000	gpm/well
14	Seasonal production period July 1-Sept 1		60		days
	Managed Wetlands				
15	Capital costs to develop managed wetlands	$5,000	$10,000	$15,000	$/acre
15	O&M costs to manage managed wetlands	$200	$500	$800	$/acre/annual
15	Amortization period for managed wetlands		30		years
15	Flow produced by managed wetlands	10.0	15.0	20.0	gpm/acre
15	Period of time flow is produced by managed wetlands		60		days
	Stream Habitat Improvement				
16	Capital costs to improve habitat	$10	$50	$100	$/foot channel
16	O&M costs to maintain habitat	$0	$2	$5	$/foot channel
16	Amortization period for stream habitat improvement		30		years
16	Flow produced by improved habitat	0.1	0.2	0.3	gpm/foot
16	Period of time flow is produced by stream habitat improvement		60		days
	Introduce Beaver				
17	Capital costs to introduce beaver		$50,000		$/sub-watershed
17	O&M costs to manage beaver		$25,000		$/sub-watershed
17	Average size of subwatershed improved by beaver introduction		1,200		acres/sub-watershed
17	Amortization period for introduced beaver		30		years

Alternative	Input Data	Minimum	Average	Maximum	Units
	Water Rights				
6	Cost for leased water rights	19.50		29.84	acre-ft
	Cloud Seeding				
8	Capitalization and O&M costs for cloud seeding		$20,000		$/subwatershed unit
8	Average inches of snow in subwatershed unit		120		inches
8	Increase in snow pack from cloud seeding		10%		%
8	Subwatershed unit area		10,000		acres
8	Snow water equivalent		20%		% of snow depth
8	Cost for runoff from cloud seeding		$1.02		$/acre-ft
	Inter-Basin Transfer				
9	Capital costs to set up inter-basin water transfer		$1,000,000		$/system
9	O&M costs for inter-basin water transfer		$5,000		$/system
9	Amortization period		30		years
9	Quantity of water that would remain in the Big Hole River		500		acre-ft
	Irrigation Efficiency				
10	Annual O&M costs to provide flood irrigation (labor, materials, repairs)		$10		$/acre
10	Capital costs to convert to sprinkler system		$350		$/acre
10	Annual O&M costs to operate sprinklers		$50		$/acre/season
10	Amortization period		30		years
10	Efficiency of flood irrigation		45%		%
10	Efficiency of sprinklers		70%	80%	%
10	Hay production with sprinkler irrigation		4	5	ton/acre
	Ditch Loss				
11	Capital costs to reduce ditch loss	$11	$27	$52	$/foot of ditch
11	O&M costs to reduce ditch loss	$1.10	$2.60	$1.60	$/foot/season
11	Average ditch conveyance		10		cfs
11	Amortization period for ditch lining		20		years
11	Average acres irrigated by average ditch		400		acres
11	Average ditch length per acre irrigated		500		ft/acre
11	Reduction of water loss by ditch improvement		10		%
	Stockwater				
12	Capital costs to provide stockwater	$10,000	$13,000	$15,000	$/system
12	O&M costs to provide stockwater	$200	$300	$400	$/system/season

Preliminary Non-Storage Alternative No. 2		
Type	**Method**	**Result**
Reduce pasture irrigation in valley bottom areas	Provide alternative pastures	Cease or reduce irrigation of pastures at onset of low flows
Assumptions		
The irrigation required for alternative pastures is not considered to deplete the Big Hole River in the critical reach		
Input Values		= Input Value
Average irrigation rate of pasture during the season	1.0	miners inches/acre
Transportation to/from alternative pasture	$6.00	per head
Leasing of alternative pasture land	$60.00	head/season
Addition labor	$3.50	head/season
Length of lease of alternative pasture land	60	days
Length of irrigation season	60	days
Average cattle grazing in pastures during the season	0.66	AUM/acre
Calculations		
COSTS		
Total cost to lease land, transport and care for cattle on alternative pastures	$70	head/season
Cost per acre per season based on AUM per acre	$46	acre/season
FLOW BENEFITS		
Savings in pasture irrigation water during the season	3.0	acre-ft/acre/season
COST PER ACRE-FT PER SEASON		
Cost for reduced irrigation water used	$15.29	acre-ft

Preliminary Non-Storage Alternative No. 3		
Type	**Method**	**Result**
Reduce pasture irrigation in valley bottom areas	Provide alternative source of forage (hay/alfalfa from off-site)	Cease or reduce irrigation of pastures at onset of low flows
Assumptions		
The irrigation required for alternative forage is not considered to deplete the Big Hole River in the critical reach		
Input Values		= Input Value
Cattle forage consumption	0.5	tons/month/AUM
Cost of alternative forage (delivered but not fed)	$75	per ton
Cost to feed cow-calf pairs	$25	AUM/season
Average irrigation rate of pasture during the season	1.0	miners inches/acre
Length of alternative forage supply	60	days
Length of irrigation season	60	days
Cattle grazing rate in valley bottom areas	0.66	acres/AUM/season
Calculations		
COSTS		
Amount of seasonal alternative forage	0.66	tons/acre/season
Cost for alternative forage (delivered and fed)	$75	acre/season
FLOW BENEFITS		
Savings in pasture irrigation water	3.0	acre-ft/acre/season
COST PER ACRE-FT PER SEASON		
Cost for reduced irrigation water used	$24.83	acre-ft

Preliminary Non-Storage Alternative No. 4		
Type	**Method**	**Result**
Reduce pasture irrigation in wet meadow areas	Provide fall forage	Cease or reduce irrigation in meadow areas (nutgrass)
Assumptions		
The irrigation required for fall forage is not considered to deplete the Big Hole River in the critical reach		
Input Values		= Input Value
Cattle forage consumption	0.5	tons/month/AUM
Cost of alternative forage (delivered but not fed)	$75	per ton
Cost to feed cow-calf pairs	$25	seasonal total per AUM
Average irrigation rate of wet meadow areas during the season	1.0	miners inches/acre
Length of alternative forage supply	30	days
Length of fall forage irrigation	60	days
Cattle grazing rate in wet meadow areas	0.66	acres/AUM/season
Calculations		
COSTS		
Amount of seasonal alternative forage	0.33	tons/acre/season
Cost for alternative forage (delivered and fed)	$50	acre/season
FLOW BENEFITS		
Savings in wet meadow irrigation water	3.0	acre-ft/acre/season
COST PER ACRE-FT PER SEASON		
Cost for reduced irrigation water used	$16.58	acre-ft

Preliminary Non-Storage Alternative No. 5		
Type	**Method**	**Result**
Reduce pasture irrigation on low productivity soils	Provide alternative source of forage (hay/alfalfa from off-site)	Cease or reduce irrigation of pastures at onset of low flows
Assumptions		
The irrigation required for alternative forage is not considered to deplete the Big Hole River in the critical reach		
Input Values		= Input Value
Cattle forage consumption	0.5	tons/month/AUM
Cost of alternative forage (delivered but not fed)	$75	per ton
Cost to feed cow-calf pairs	$25	seasonal total per AUM
Average irrigation rate of low productivity soils during the season	3.0	miners inches/acre
Length of alternative forage supply	60	days
Length of irrigation season	60	days
Cattle grazing rate in low productivity soil areas	0.33	acres/AUM/season
Calculations		
COSTS		
Amount of seasonal alternative forage	0.33	tons/acre/season
Cost for alternative forage (delivered and fed)	$50	acre/season
FLOW BENEFITS		
Savings in pasture irrigation water	9.00	acre-ft/acre/season
COST PER ACRE-FT PER SEASON		
Cost for reduced irrigation water used	$5.53	acre-ft

Preliminary Non-Storage Alternative No. 6		
Type	**Method**	**Result**
Purchase water	Lease water or compensate for reduced irrigation	Cease or reduce irrigation
Assumptions		
Value of leased water is the sum of profit minus the sum of expenses		
Input Values		= Input Value
Hay produced during the season	2.0	tons/acre
Value of hay	$75	$/ton
Average pasture irrigation rate	1.0	miners inches/acre
Length of irrigation season	60	days
Calculations		
COSTS		
Value of hay	$150	acre/season
FLOW BENEFITS		
Savings in pasture irrigation water	3.00	acre-ft/acre/season
COST PER ACRE-FT PER SEASON		
Cost for reduced irrigation water used	$50.00	acre-ft

Preliminary Non-Storage Alternative No. 7		
Type	**Method**	**Result**
Purchase land	Purchase key lands with water rights and/or hay bank potential	Manage flows, create hay bank, pasture bank, etc.
Assumptions		
Input Values		= Input Value
Land value	$2,000	per acre
Loan payment period	30	years
Amortization period for down payment and closing costs	30	years
Value of conservation easements		$ per acre
Interest on loan payment	6%	%
Annual cost to manage and operate property	$50	$ per acre/yr
Annual revenue produced from leasing	$50	$ per acre/yr
Average irrigation rate during the season	1.0	miners inches/acre
Length of irrigation season	60.0	days
Calculations		
COSTS		
Net annual cost to acquire property, amortized over period identified above	$70.67	$ per acre/yr
Net annual cost to operate ranch (operations less lease value)	$0.00	$ per acre/yr
Total annual cost of ranch	$70.67	$ per acre/yr
FLOW BENEFITS		
Savings in pasture irrigation water	3.00	acre-ft/acre/season
Alternative pasture provided AND/OR	Not Considered	AUM/acre
Alternative forage produced	Not Considered	tons/acre
COST PER ACRE-FT PER SEASON		
Amortized cost for reduced irrigation water used	$23.56	acre-ft

Preliminary Non-Storage Alternative No. 8		
Type	**Method**	**Result**
Increase water yield	Cloud seeding	Increase rainfall
Assumptions		
Input Values		= Input Value
Annual capitalization and operations and maintenance costs to provide cloud seeding	$20,000	$/subwatershed unit
Average inches of snow in subwatershed unit	120	inches
Increase in snow pack from cloud seeding	10%	percent
Snow water equivalent	20%	percent
Subwatershed unit	10,000	acres
Percent of flow during critical period produced by cloud seeding	10%	%
Calculations		
COSTS		
Net annual cost to provide cloud seeding per acre	$2.00	$/acre
FLOW BENEFITS		
Net increase in runoff	0.02	acre-ft/acre
COST PER ACRE-FT PER SEASON		
Cost for increased runoff due to cloud seeding	$100	acre-ft/season

Preliminary Non-Storage Alternative No. 9		
Type	**Method**	**Result**
Increase water yield	Inter-basin water transfer	Increase stream flow
Assumptions		
Input Values		= Input Value
Initial capital costs to set up inter-basin transfer	$1,000,000	$/system
Amortization period for capital expenditures	30	years
Annual operations and maintenance costs to provide inter-basin transfer	$5,000	$/system
Quantity of water that would remain in the Big Hole River	500	acre-ft
Calculations		
COSTS		
Net annual cost to provide inter-basin transfer, amortized over period identified above	$38,333	$/acre-ft
FLOW BENEFITS		
Quantity of water that would remain in the Big Hole River	500	acre-ft
COST PER ACRE-FT PER SEASON		
Amortized cost for increased runoff	$76.67	acre-ft
	N/A - site specific	

Preliminary Non-Storage Alternative No. 10		
Type	**Method**	**Result**
Improve irrigation efficiency	Convert from flood irrigation to hand lines, wheel lines, and pivots	Reduce irrigation water needs
Assumptions		
Input Values		= Input Value
Annual operations and maintenance costs to provide flood irrigation (labor, materials, repairs)	$10	$/acre
Average flood irrigation rate during the season	1.0	miners inches/acre
Initial capital costs to set up new irrigation system (center pivot)	$350	$/acre
Amortization period for capital expenditures	30	years
Annual operations and maintenance costs to provide new irrigation (power, labor, repairs, depreciation)	$50	$/acre
Increase in efficiency of sprinkler over flood irrigation	35%	percent
Hay production with flood irrigation	2.0	tons/acre
Hay production with sprinkler irrigation	4.0	tons/acre
Value of hay	$75	$/ton
Length of irrigation season	60	days
Calculations		
COSTS		
Net annual cost to flood irrigate	$10	$/acre
Net annual cost to sprinkler irrigate	$62	$/acre
Net annual increase in irrigation cost to transfer from irrigation to sprinkler	$52	$/acre
FLOW BENEFITS		
Assume irrigation water saved by efficiency translates into additional water used for additional production	1.05	acre-ft/acre/season
COST PER ACRE-FT PER SEASON		
Cost for reduced irrigation water used	$50	acre-ft

Preliminary Non-Storage Alternative No. 11		
Improve irrigation efficiency	Reduce ditch loss	Reduce irrigation water needs
Assumptions		
Use bentonite soil amendment		
Input Values		= Input Value
Initial capital costs to reduce ditch loss (improve, seal)	$11.00	$/foot of ditch
Annual operations and maintenance costs to reduce ditch loss (labor, repairs, depreciation)	$1.10	$/foot of ditch/season
Amortization period for capital expenditures	20	years
Average ditch conveyance	10	cfs
Average acres irrigated by ditch	400	acres
Average ditch length per acre irrigated	500	ft/acre
Reduction of water loss by ditch improvement	10	percent
Irrigation season for hay is April 15 to July 15	60	days
Calculations		
COSTS		
Net annual cost to reduce ditch loss	$825	$/acre
FLOW BENEFITS		
Reduction in irrigation water lost to ditches	1.0	cfs during the season
Reduction in irrigation water lost to ditches	120	acre-ft/season
COST PER ACRE-FT PER SEASON		
Cost for reduced irrigation water used	$6.88	acre-ft

Preliminary Non-Storage Alternative No. 12		
Develop groundwater resources	Provide stockwater from wells	Decrease stockwater needs from streams, improve habitat
Assumptions		
Stockwater is provided as a constant flow in a ditch, with adequate volume to ensure cattle access		
The groundwater water required to provide stockwater is not considered to deplete the Big Hole River in the critical reach		
Input Values		= Input Value
Initial capital costs to provide stockwater well system (well, pump, system)	$13,000	$/system
Amortization period for capital expenditures	30	years
Annual operations and maintenance costs to provide stockwater well system (labor, repairs, depreciation)	$300	$/system
Number of AUM serviced by stockwater well system	200	AUM/system
Surface water flow (stock water in ditch) used to provide water to AUM	20	gpm
Critical duration when stockwater is provided	60	days
Calculations		
COSTS		
Net annual cost to provide stockwater well system	$733	$/system
FLOW BENEFITS		
Reduction in stockwater from surface water	5	acre-ft/system/season
COST PER ACRE-FT PER SEASON		
Cost for reduced stockwater from surface water	$152.78	acre-ft

Preliminary Non-Storage Alternative No. 13		
Develop groundwater resources	Drain fields	Increase base flow by tapping near surface groundwater adjacent to Big Hole River
Assumptions		
The groundwater water required to supply the drain fields is not considered to deplete the Big Hole River in the critical reach		
Input Values		= Input Value
Initial capital costs to provide drain fields (drains, installation)	$20,000	$/acre
Amortization period for capital expenditures	30	years
Annual operations and maintenance costs to provide drain fields (labor, repairs, depreciation)	$350	$/acre
Flow produced by drain fields	1.1	gpm/acre/season
Critical duration when water is provided	90	days
Calculations		
COSTS		
Net annual cost to provide drain fields	$1,017	$/system
FLOW BENEFITS		
Contribution to surface water	0.4	acre-ft/system/season
COST PER ACRE-FT PER SEASON		
Cost for drain field contribution to surface water	$2,567	acre-ft

Preliminary Non-Storage Alternative No. 14		
Develop groundwater resources	Deep groundwater production wells	Increase base flow by tapping deep GW and adding to surface flow in Big Hole
Assumptions		
The groundwater water required to supply the production wells is not considered to deplete the Big Hole River in the critical reach		
Input Values		= Input Value
Initial capital costs to provide deep groundwater production wells (well, pump, system)	$250,000	$/well
Amortization period for capital expenditures	30	years
Annual operations and maintenance costs to provide deep groundwater production wells (labor, repairs, depreciation)	$15,000	$/well
Flow produced by production wells	1,500	gpm/well
Seasonal production period July 1-Sept 1	60	days
Calculations		
COSTS		
Net annual cost to provide deep groundwater production wells	$23,333	$/well
FLOW BENEFITS		
Contribution to surface water	360	acre-ft/well/season
COST PER ACRE-FT PER SEASON		
Cost for production well contribution to surface water	$64.81	acre-ft

Preliminary Non-Storage Alternative No. 15		
Delay Runoff	Managed wetlands	Stored water for gradual release
Assumptions		
Input Values		= Input Value
Initial capital costs to develop managed wetlands (earthwork, revegetation, control works)	$10,000	$/acre
Amortization period for capital expenditures	30	years
Annual operations and maintenance costs to manage wetlands (labor, repairs, depreciation)	$500	$/acre
Flow produced by managed wetlands	15.0	gpm/acre
Period of time flow is produced by managed wetlands	60	days
Calculations		
COSTS		
Net annual cost to provide managed wetlands	$833	$/acre
FLOW BENEFITS		
Contribution to surface water	3.60	acre-ft/acre/season
COST PER ACRE-FT PER SEASON		
Cost for flow produced by managed wetlands	$231.48	acre-ft

Preliminary Non-Storage Alternative No. 16		
Delay Runoff	Habitat improvements (channel morphology and riparian vegetation)	Reduce evaporation; increase recharge, storage and release
Assumptions		
Habitat improvement would be intensive and would include the entire channel and associated side channels		
Input Values		= Input Value
Initial capital costs to improve habitat (design, earthwork, revegetation)	$50	$/foot
Amortization period for capital expenditures	30	years
Annual operations and maintenance costs to improve habitat (labor, repairs, depreciation)	$2	$/foot
Flow produced by habitat improvement	0.2	gpm/ft/day
Period of time flow is produced by habitat improvement	60	days
Calculations		
COSTS		
Net annual cost to provide improve habitat	$3.67	$/foot
FLOW BENEFITS		
Contribution to surface water	0.048	acre-ft/ft/season
COST PER ACRE-FT PER SEASON		
Cost for flow produced by habitat improvements	$76.39	acre-ft

Preliminary Non-Storage Alternative No. 17		
Delay Runoff	Reintroduce beaver	Stored water for gradual release
Assumptions		
Input Values		= Input Value
Initial capital costs to reintroduce beaver	$50,000	$/sub-watershed
Amortization period for capital expenditures	30	years
Annual operations and maintenance costs to reintroduce beaver (labor, repairs)	$25,000	$/sub-watershed
Average size of subwatershed improved by beaver introduction	1,200	acres/sub-watershed
Flow produced by beaver reintroduction	4.20	gpm/acre/season
Period of time flow is produced by introduced beaver	60	days
Calculations		
COSTS		
Net annual cost to provide improve habitat	$22.22	$/acre
FLOW BENEFITS		
Contribution to surface water	1.01	acre-ft/acre/season
COST PER ACRE-FT PER SEASON		
Cost for flow produced by habitat improvements	$22.05	acre-ft

Preliminary Non-Storage Alternative No. 18		
Delay Runoff	Ice management	Divert winter runoff and create ice
Assumptions		
Input Values		= Input Value
Initial capital costs to set up ice management	$500	$/acre
Amortization period for capital expenditures	20	years
Annual operations and maintenance costs to provide ice management	$100	$/acre
Ice depth produced by ice management	5.0	ft/acre/season
Percent of flow during critical period produced by ice management	25%	%
Calculations		
COSTS		
Net annual cost to provide ice management, amortized over period identified above	$125	$/acre
FLOW BENEFITS		
Net increase in runoff during critical period	1.25	acre-ft/acre/season
COST PER ACRE-FT PER SEASON		
Amortized cost for increased runoff	$100	acre-ft

Preliminary Non-Storage Alternative No. 19		
Delay Runoff	Snow pack management	Increase source of runoff
Assumptions		
Input Values		= Input Value
Initial capital costs to set up snow pack management	$2,000	$/acre
Amortization period for capital expenditures	5	years
Annual operations and maintenance costs to provide snow pack management	$1,000	$/acre
Increase in snow accumulation resulting from snow pack management	36	inches depth/acre
Conversion from snow depth to water depth [snow water equivalent] (inches)	20%	percent
Percent of flow during critical period produced by ice management	10%	%
Calculations		
COSTS		
Net annual cost to provide ice management, amortized over period identified above	$1,400	$/acre
FLOW BENEFITS		
Total net water depth resulting from snow pack management	7.2	inches depth/acre
Total net water volume resulting from snow pack management	0.60	acre-ft/acre
Net increase in runoff during critical period	0.060	acre-ft/acre
COST PER ACRE-FT PER SEASON		
Cost for increased runoff from snow pack management	$23,333	acre-ft