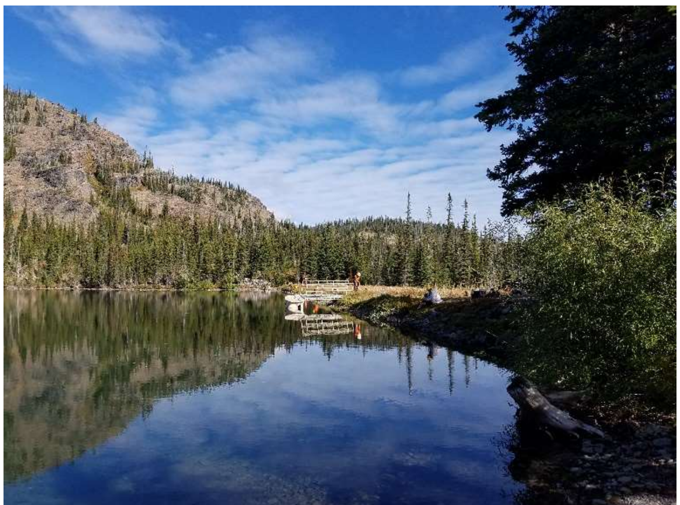

# Chapter 9 Rattlesnake Dams Feasibility Study

2018 Water System Master Plan

*Missoula, Montana*

## 9.1 Introduction

Between 1911 and 1923, 10 dams were built on eight high mountain lakes in the present-day Rattlesnake Wilderness Area to augment water supply for the City of Missoula, see Figure 9-1. The City of Missoula acquired the dams and associated water rights from Mountain Water Company in 2017. The City of Missoula is now the owner and caretaker of these assets for the community. The purpose of this feasibility study is to determine the range of available options for the dams moving forward, and evaluate those options in terms of the relevant criteria including capital costs, life cycle costs, water rights, climate change, long-term community needs, regulatory agency requirements and goals, and environmental impacts among other benefits.

## 9.2 History

Rattlesnake Creek was the original water supply for the early settlers in Missoula, providing water for lumber mills and homesteaders, and because of the early water rights filing the City of Missoula now holds some of the most senior, year-round water rights in the basin dating back to 1866, a full 23 years before Montana became a state. The flow on Rattlesnake Creek is variable and between 1911 and 1923 10 dams were constructed on eight high mountain lakes in order to augment the water supply, which dwindled in late summer and early fall.

In the 1930s, Montana Power Company purchased most of the privately held land in the drainage on the west side of Rattlesnake Creek in order to protect the watershed. In 1980, the land was designated as the Rattlesnake Wilderness and National Recreation Area.

The Rattlesnake Creek portion of the water system was discontinued as a daily water supply source after *Giardia* was discovered in 1983. Since then, the intake dam, caretaker's house (which has since been demolished), the present-day log cabin, and the Rattlesnake dams themselves have been maintained as part of an emergency backup water supply system. The Rattlesnake Creek water is separated from the present-day distribution system via an above-ground air gap. The City estimates that water from Rattlesnake Creek could be connected to the distribution system in about 30 minutes if necessary; however, because there is no mechanism for treating the water, appropriate precautions would need to be taken, including placing the system under an order to boil the water.

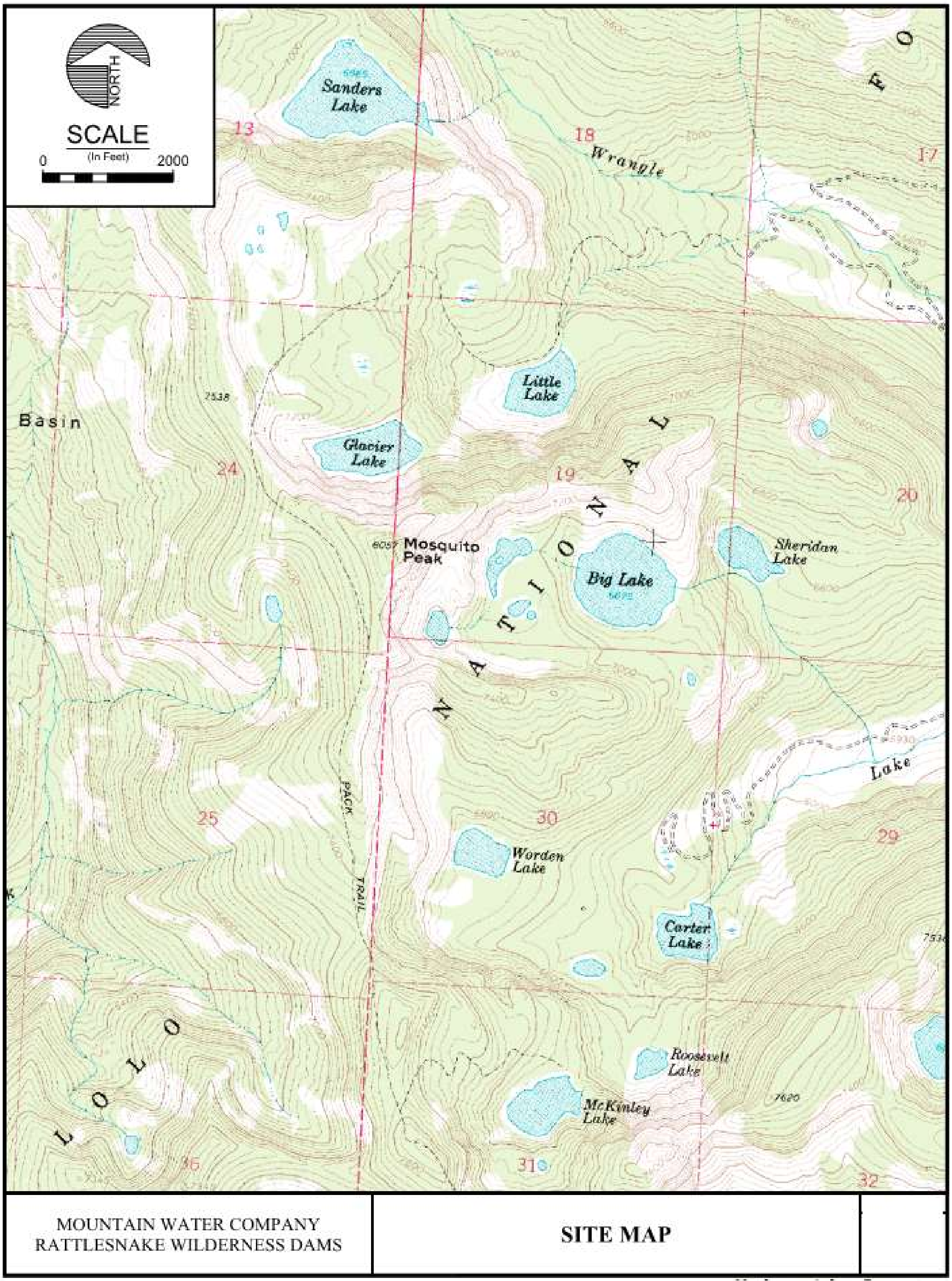


**Figure 9-1. Site Map, Rattlesnake Wilderness Dams**

## 9.3 Regulatory Framework

### 9.3.1 Special Use Permit and Easement

The regulatory environment for these dams has changed over the years, and may currently be in flux. Under the current version of the Forest Service Manual (FSM), the Forest Service (FS) has authority over all dams having Special Use Permits, which includes five dams owned by the City. The current FSM also states that the FS has no authority over "…dams authorized by a pre-Federal Land Policy Management Act right-of-way or to congressionally withdrawn water projects." This provision includes the remaining five City dams located on easements. However, the FS has requested to be involved in actions associated with the easement dams because most dam-related actions directly or indirectly immediately affect FS resources and public values. The State of Montana permits high hazard dams only and does not regulate dams located on federal property, so currently the regulatory authority of the right-of-way, or "easement," dams is unclear. The FS and Montana DNRC are in the process of developing a Memorandum of Understanding regarding regulatory authority over Special Use and Easement dams. The selection of Special Use and Easement dams to be regulated by the DNRC would be done on a case by case basis.

This section summarizes the requirements of the Special Use Permit (Appendix L), the requirements for the easement dams, and the dam safety standards used for evaluation as well as guidance for other alternatives including decommissioning of the dams.

The Rattlesnake Wilderness dams are listed in **Error! Reference source not found.**.

**Table 9-1. Rattlesnake Wilderness Dams**

| Name of Lake | Permit or Easement[a] | Hazard Classification | Maximum Storage Volume (acre-feet)[b] | Drainage |
|---|---|---|---|---|
| Big Lake | Easement | Significant | 621 | Lake Creek |
| Carter Lake | Permit | Low | 161 | Lake Creek |
| Glacier Lake | Easement | Significant | 240 | Wrangle Creek |
| Little Lake | Easement | Significant | 298 | Wrangle Creek |
| McKinley Lake | Easement | Significant | 168 | Lake Creek |
| Sanders South Lake | Permit | Significant | 897 | Wrangle Creek |
| Sanders North Lake | Easement | Significant | 897 | Wrangle Creek |
| Sheridan East Lake | Permit | Significant | 130 | Lake Creek |
| Sheridan West Lake | Permit | Significant | 130 | Lake Creek |
| Worden Lake | Permit | Significant | 70 | Lake Creek |
| | TOTAL | | 2,585 | |

**Table 9-1. Rattlesnake Wilderness Dams**

| Name of Lake | Permit or Easement[a] | Hazard Classification | Maximum Storage Volume (acre-feet)[b] | Drainage |
|---|---|---|---|---|

[a] *Permit* refers to a special-use permit from the U.S. Forest Service, which authorizes specific use of the land for a period of time. The current special-use permit expires in 2036.

*Easement* refers to an easement that was granted from the U.S. Forest Service.

[b] This volume refers to the maximum storage volume available. The storage volume according to the water right may be different.

## 9.3.2 Special Use Permit

The City of Missoula is authorized to use and occupy National Forest lands in the Rattlesnake vicinity of the Lolo National Forest, subject to the terms and conditions of their special use permit. The permit covers 22 flooded acres and 3.14 miles of road. Of the ten dams owned by the City, five are administered under the special use permit and five exist under easements and are not under the direct jurisdiction of the US Forest Service.

The purpose of the special use permit is to authorize the operation and maintenance of the five existing dams on National Forest land, as well as to maintain and use existing roads and trails for access to the water storage sites. The current permit expires on December 31, 2036. Key information from the special use permit is summarized below.

### General Terms

- Permit issued pursuant to Federal Land Policy and Management Act, amended 1976.
- Dam/Reservoir management in compliance with the Rattlesnake National Recreation Area and Wilderness Act of 1980.
- The permit is not renewable. Prior to the permit expiration, the City of Missoula may apply for a new permit no less than six months prior to the permit expiration. The type of use and occupancy to be authorized by a potential new permit should be consistent with the prior permit.
- The existing permit may be amended by the FS to incorporate new laws and directives as deemed necessary by the authorized officer.
- The use or occupancy authorized by this permit is not exclusive. The lands and waters covered by this permit shall remain open to the public for all lawful purposes.

### Improvements

- The permit does not give or imply permission to build or maintain any structure not specifically authorized by the permit.
- Any plans for the development or construction of improvements in the permit area must have written approval from the authorized officer before they are implemented.

## Operations

- Use or occupancy of the permit area shall be exercised every day of the year.
- The permit holder shall maintain the permit area to standards of repair and orderliness acceptable to the authorized officer and consistent with the provisions of the permit.
- The City shall prepare and annually revise by June 1 an Operating and Maintenance Plan. The plan shall outline steps the permit holder will take to protect public health, safety, and the environment, and shall include sufficient detail and standards to enable the FS to monitor the City's operations for compliance.
- The FS reserves the right to inspect the permit area and transmission facilities at any time for compliance with the terms of the permit.

## Rights and Liabilities

- The permit constitutes a federal license.
- The permit does not provide for the furnishing of road or trail maintenance, water, fire protection, or any other such service by a government agency, association or individual.
- The permit holder assumes all risk of loss associated with use or occupancy of the permit area, including theft, vandalism, fire and fire-fighting activities, avalanches, or other forces of nature. If substantial damage occurs to facilities within the permit area and rebuilding is not deemed allowable, the permit will terminate.
- The permit holder has a duty to protect the property of the United States from damage. The permit holder shall avoid damaging or contaminating the environment, including the soil, vegetation, surface water, and groundwater, and will be liable for any damage that they cause.
- The permit holder shall immediately repair inflicted damage to the permit area at no expense to the United States.
- The permit holder shall plan to prevent the establishment and spread of invasive species.
- The permit holder shall indemnify the United States for any costs or damages arising from past, present, and future acts or omissions of the holder in connection with the use or occupancy authorized by this permit.
- The permit holder shall be strictly liable to the United States for $1 million per occurrence for any injury, loss, or damage arising in tort under the permit.
- The permit holder shall furnish proof of insurance to the authorized officer prior to issuance of this permit and each year thereafter that this permit is in effect. Minimum amounts of coverage and other insurance requirements are subject to change.

## Resource Protection

- The permit holder shall comply with all applicable federal, state, and local environmental laws and regulations.

- Pesticides may not be used outside of buildings without prior written approval from the authorized officer.
- The permit holder shall notify the authorized officer of all antiquities or other objects of historic or scientific interest discovered in the permit area.
- The holder shall not store any hazardous materials at the site without prior written approval from the authorized officer.
- The permit holder shall clean up or otherwise remediate any release, threat of release, or discharge of hazardous materials that occurs in the permit area.

### Land Use Fee and Accounting Issues

- The use or occupancy authorized by this permit is exempt from a land use fee or the land use fee has been waived in full.
- The land use fee may be revised whenever necessary to reflect the market value of the authorized use. If that is the case, payments would be subject to interest rates and late fees.

### Revocation, Suspension, and Termination

- The authorized officer may revoke or suspend this permit in whole or in part:
  - For noncompliance with federal, state, or local law.
  - For noncompliance with the terms of the permit.
  - For abandonment or other failure of the permit holder to exercise the privileges granted.
  - With the consent of the holder.
  - For specific and compelling reasons in the public interest.
- The authorized officer may immediately suspend this permit in whole or in part when necessary to protect public health, safety, or the environment.
- Upon revocation or termination of the permit without renewal of the authorized use, the permit holder shall remove all structures and improvements, except those owned by the United States, and shall restore the site to the satisfaction of the authorized officer.

### Miscellaneous Provisions

- The permit holder shall assure that the discharge from the project area is a continuous, minimum flow pursuant to state water rights. No diversion of water will be permitted contrary to state water rights.
- The special use permit does not confer any water rights on the holder. Any necessary water rights must be acquired by the permit holder in accordance with state law.
- The FS reserves the right to issue additional authorizations to other applicants to increase the storage capacity of this site if such action proves feasible.

- The permit holder shall be responsible for the prevention and control of noxious weeds in the permit area, and will submit a control plan subject to FS approval.
- The authorized officer may order an immediate temporary suspension of all human activities permitted by this authorization and, if needed, suspend or revoke the special use authorization when such action is necessary to prevent conflict between humans and grizzly bears.
- The permit holder must comply with the requirements of the Grizzly Bear Management and Protection Plan for the permit area.
- Acts by the permit holder that result in the injury or death of a grizzly bear will be cause for suspension or revocation of this authorization in whole or in part.
- The permit holder shall submit a Reservoir/Dam Operation and Maintenance Plan consisting of the following sections:
    - Water storage and releases, including dates and/or criteria for filling and release.
    - Procedures for flood conditions.
    - Inspection and safety requirements.
    - Erosion prevention in reservoir area and spillway channel.
    - Trash and debris removal.
    - Maintenance requirements as necessary.
    - Date of plan and relevant signatures.
- Beginning in 2017 and every five years thereafter, the permit holder shall have a dam safety evaluation performed by a professional engineer to verify the safety of the dam.
- The permit holder shall have operation and maintenance inspections of the dams and appurtenant structures conducted in accordance with Table 9-2. A summary of the existing dams can be seen in Tables 9-3 and 9-4.

**Table 9-2. Dam Inspection Requirements**

| Hazard Assessment Classification[d] | Inspection Type | Inspection Frequency (Years) | Level of Expertise Required |
|---|---|---|---|
| Low | O & M | 10 | Qualified Engineer |
| | Hazard Assessment | 10[a] | Qualified Engineer |
| | Special | b. | Qualified Engineer |
| Significant | O & M | 5 | Qualified Engineer |
| | Hazard Assessment | 5[a] | Qualified Engineer |
| | Special | b. | Qualified Engineer |
| High | O & M | 1 | Qualified Engineer[c] |
| | Safety | 5[a] | Qualified Engineer |
| | Special | b. | Qualified Engineer |

a. Perform hazard assessment more frequently if downstream development is observed.

b. A special inspection must be performed by a qualified engineer.

c. A qualified engineer must review and approve in writing the annual O & M inspection reports for dams with a high hazard assessment classification. At a minimum, the annual onsite inspection must be completed by someone familiar with the operation of the dam.

d. FSM 7500: Hazard Potential Classification. A system that categorizes dams according to the degree of adverse incremental consequences from their failure or misoperation, that does not reflect in any way on their current condition (that is, their safety, structural integrity, or flood routing capacity), and that includes the following categories:

1. Low. A classification that includes dams whose failure, malfunction, or misoperation would result in no probable loss of human life and minor damages limited to undeveloped or agricultural lands and for which significant improvements are not planned in the foreseeable future.
2. Significant. A classification that includes dams whose failure, malfunction, or misoperation would result in no probable loss of human life but could cause economic loss, disruption of lifeline facilities, or other significant impacts and would result in non-recoverable environmental damage.
3. High. A classification that includes dams whose failure, malfunction, or misoperation would result in a probable loss of human life.

**Table 9-3. Hazard Assessment Classification Permit Dams**

| Name | Hazard Assessment Classification | Dam Type |
|---|---|---|
| Sanders #2 (South) | Significant | Earthen with Rock Crib |
| Sheridan #1 (East) | Significant | Earthen with Rock Crib |
| Sheridan #2 (West) | Significant | Earthen with Rock Crib |
| Worden | Significant | Earthen* |
| Carter | Low | Earthen with Rock Crib** |

*Original construction drawings indicate no rock crib. This has not been verified.

**Original construction drawings indicate no rock crib but a subsequent investigation indicated the presence of a crib structure.

**Table 9-4. Hazard Assessment Classification Easement Dams**

| Name | Hazard Assessment Classification | Dam Type |
|---|---|---|
| Big Lake | Significant | Rock Crib |
| Glacier Lake | Significant | Rock Crib |
| Little Lake | Significant | Rock Crib |
| McKinley Lake | Significant | Earthen* |
| Sanders Lake (North) | Significant | Rock Crib |

*Original construction drawings indicate no rock crib. This has not been verified.

## 9.3.3 Dam Safety Regulations

As stated above, according to the current version of the Forest Service Manual (FSM), the FS has authority over all dams having Special Use Permits, which includes five dams owned by the City.

The State of Montana permits high hazard dams only and does not regulate dams located on federal property, so the regulatory authority of the easement dams is unclear.

In the absence of clear direction and authority on the easement dams, it is logical to look to the FSM for dam safety criteria. Historically, the dams have been operated and maintained in accordance with FS regulatory criteria which are found in FSM 7500. As the City evaluates alternatives for the dams, there may be areas where the distinction becomes important and these shall be noted throughout the evaluation.

## 9.4 Water Rights

The City of Missoula has partnered with Trout Unlimited to remove the Rattlesnake intake dam. This dam is located on Rattlesnake Creek, below the Rattlesnake Wilderness and National Recreation Area. See Figure 9-2. While the intake dam is not a subject of this chapter, a cursory water rights evaluation was conducted by Trout Unlimited and WGM Group. These evaluations provide some insight and guidance on the Rattlesnake Wilderness Dams water rights. This section provides a summary of those evaluations.

### 9.4.1 Overview of Rattlesnake Water Rights

The Rattlesnake Creek water rights include Statements of Claim for surface water from Rattlesnake Creek, eight Statements of Claim to store water in the lakes near the headwaters of Rattlesnake Creek, and seven Statements of Claim for water directly diverted from the creek without storage. The storage and direct- flow water rights, combined in their use, provided a reliable year-round source of supply for several decades as the city of Missoula grew in population and water demands. All Rattlesnake water rights have a period of use from January 1 to December 31. A summary of these water rights is provided in Table 10-5 below.

In 1983, the water system moved to groundwater wells due to contamination concerns (giardia) in the Rattlesnake Creek surface water. In an effort to protect the senior water rights from non-use and potential abandonment concerns, the seven direct-flow rights were changed in 1998 to add eight wells (3A, 3B, 21, 30, 31, 32, 33, and 24) as additional points of diversion that are hydrologically connected to surface water. The eight lake storage rights were not changed to allow diversion from the hydrologically connected wells, but it remains an option to do so.

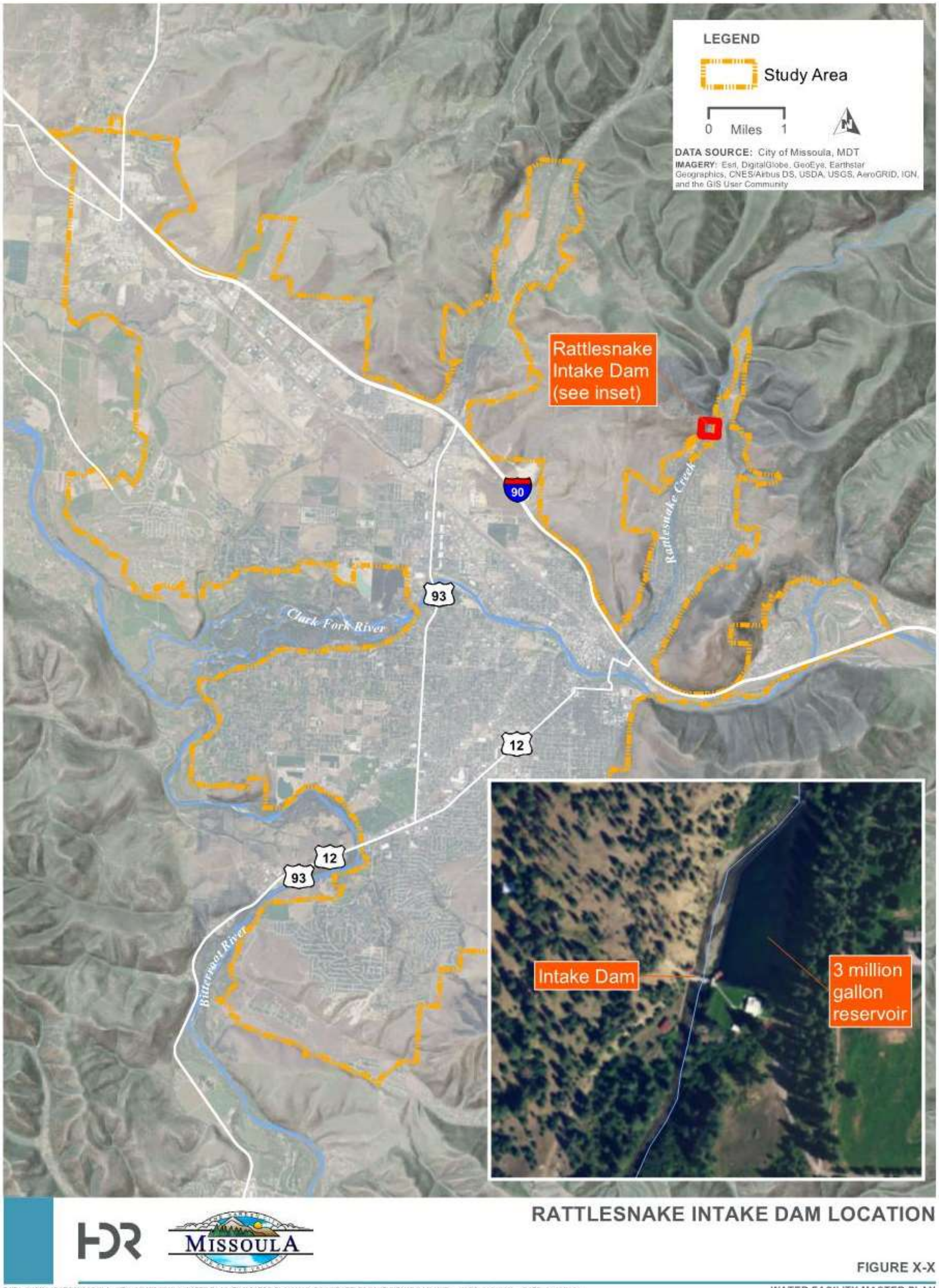


**Figure 9-2. Rattlesnake Intake Dam**

**Table 9-5. Rattlesnake Dams Water Rights Summary**

| Diversion | Water Right | Priority Date | Claimed Flow Rate | Claimed Volume (AF) |
|---|---|---|---|---|
| Little Lake Dam | 76M 26358 00 | 8/30/1919 | 2.50 cfs | 300 |
| Sanders Lake Dam | 76M 26361 00 | 8/30/1919 | 7.54 cfs | 905 |
| Glacier Lake Dam | 76M 26362 00 | 8/30/1919 | 1.76 cfs | 212 |
| Sheridan Lake Dam | 76M 26363 00 | 8/30/1919 | 431 gpm | 115 |
| Big Lake Dam | 76M 26364 00 | 8/30/1919 | 5.22 cfs | 623 |
| Carter Lake Dam | 76M 26365 00 | 11/6/1923 | 1.43 cfs | 170 |
| Worden Lake Dam | 76M 26366 00 | 9/8/1923 | 398 gpm | 104 |
| McKinley Lake Dam | 76M 26367 00 | 8/13/1923 | 1.64 cfs | 195 |
| Intake Dam/Wells | 76M 40170 00 | 4/1/1866 | 23.65 cfs | 17,165 |
| Intake Dam/Wells | 76M 40171 00 | 11/16/1868 | 4 cfs | 2,903 |
| Intake Dam/Wells | 76M 40172 00 | 4/1/1871 | 152.6 gpm | 246 |
| Intake Dam/Wells | 76M 40173 00 | 5/1/1871 | 1.62 cfs | 1,176 |
| Intake Dam/Wells | 76M 40174 00 | 4/1/1881 | 1.16 cfs | 842 |
| Intake Dam/Wells | 76M 40175 00 | 5/1/1881 | 8.7 cfs | 6,314 |
| Intake Dam/Wells | 76M 40176 00 | 6/1/1877 | 16.13 cfs | 11,707 |

The essence of the DNRC change authorization for the seven direct-flow rights is to allow the use of water rights with priority dates that are relatively senior in the Clark Fork Basin to be pumped from wells instead of from Rattlesnake Creek. As part of the change authorization, the flows in Rattlesnake Creek were measured just below the intake dam and the flows in each of the wells was measured with in-line flow meters. When the well flow rates are less than or equal to the creek flows, the wells are deemed to be pumping only creek water. When the well flow rates exceeded creek flows, the wells are pumping creek water up to the creek flow rate and any excess is attributed to the junior water right permits for the wells.

According to records that were submitted for the year 2000, a total volume of 13,266 ac-ft of water was attributed to the Rattlesnake Creek senior water rights that year. The current water rights allow up to a total of 40,588 ac-ft of direct flow Rattlesnake Creek water to be used annually. In addition, the storage rights allow for an annual volume of 2,624 ac-ft. Recent decisions from the Montana Water Court and the Montana Supreme Court may provide protection for any portion of these water rights that may have gone unused in recent years.

### 9.4.2 Rattlesnake Water Rights Evaluation

As part of the Rattlesnake Intake Dam removal project, Trout Unlimited conducted an overview of the status of the City's water rights, and offered several recommendations for how best to protect the existing storage water rights in the Rattlesnake vicinity against abandonment. Montana water law is subject to the “Prior Appropriation Doctrine”, and if one’s water rights are not put to beneficial use over a period of time, they could be deemed abandoned.

Montana water law has consistently struggled to classify what exactly constitutes abandonment[1]. A 2005 Montana Supreme Court case, *City of Helena v. Community of Rimini*, set a low standard for municipal water rights holders to reach in order to create a presumption of non-abandonment. However, it is possible that this favorable ruling for municipal water rights holders will be challenged in coming years as water demands increase.

*Downstream hydropower corporations own water rights that pre-date the City’s well water rights, but do not pre-date the Rattlesnake Wilderness water rights.*

Consequently, it would be prudent for the City of Missoula to take proactive measures to guard against non-use of its Rattlesnake Dam water rights and for a number of years, the use of the dams has been limited.

With this in mind, several options were outlined by Trout Unlimited for the City to move forward to maximize its water rights and protect against abandonment. The first option outlined, considered to be the City’s best by Trout Unlimited, was to remove the mainstem dam on Rattlesnake Creek as well as the non-functional mountain lakes dam infrastructure. The use of the mountain lakes rights would then be changed to instream flow through an Application to Change with DNRC. Trout Unlimited considered this approach to be the best way to maximize the benefit of the water right assets while legally protecting their full use. Limitations regarding the historical period of use may decrease the amount of water that could be protected under this type of change.

The second option outlined was to remove the mainstem dam, repair the dam/storage infrastructure on the mountain lakes, and add instream flow and/or mitigation as a beneficial use to the mountain lake rights. This would allow the City to release storage water into Rattlesnake Creek during periods of low flow and would provide legal security

1 MCA85-2-227 states that a water right that is claimed for municipal use by a city, town, or other public or private entity that operates a public water supply system, as defined in 75-6-102, is presumed to not be abandoned if the city, town, or other private or public entity has used any part of the water right or municipal water supply and there is admissible evidence that the city, town, or other public or private entity also has:

(a) obtained a filtration waiver under the federal Safe Drinking Water Act, 42 U.S.C. 300(f), et seq.;

(b) acquired, constructed, or regularly maintained diversion or conveyance structures for the future municipal use of the water right;

(c) conducted a formal study, prepared by a registered professional engineer or qualified consulting firm, that includes a specific assessment that using the water right for municipal supply is feasible and that the amount of the water right is reasonable for foreseeable future needs; or

(d) maintained facilities connected to the municipal water supply system to apply the water right to:

(i) an emergency municipal water supply;

(ii) a supplemental municipal water supply; or

(iii) any other use approved by the department under Title 85, chapter 2, part 4.

against any claims of abandonment. However, restoring the dam/storage infrastructure of the mountain lakes would likely cost several million dollars. Several other options were outlined by Trout Unlimited that were some combination of these two options.

The letter and accompanying recommendations from Trout Unlimited were subsequently reviewed by WGM Group, and they provided their analysis in a memorandum to the City of Missoula (Appendix J). WGM generally agreed with Trout Unlimited's assessment that steps should be taken to protect the City's existing water rights against abandonment. In addition to this concern, the concern of priority was raised by WGM.

Downstream hydropower corporations hold large power-generation water rights on the Clark Fork River. These power-generation rights pre-date several of the City's well water rights, but not the rights from Rattlesnake Creek. Consequently, it may be in the City's best interest to prioritize protection of its most senior water rights associated with the Rattlesnake lake dams. One way to do this is through an Application to Change similar to the one filed for the direct flow rights.

With the storage rights authorized to be diverted from the wells, the City is exercising its senior Rattlesnake Creek rights whenever creek water is available in excess of the pumping rate of the wells. When the amount of water drops below that threshold, then the City is exercising both its senior creek rights and junior well rights. Those junior rights could be potentially called by downstream hydropower interests.

With that in mind, concerns were raised by WGM regarding Trout Unlimited's preference to remove the mountain lakes infrastructure. It was noted by WGM that without the wilderness dams in place as control structures, it would not be possible to exercise the existing water rights during periods of low flow. While the existing storage rights list year-round use and diversion, the historical practice was likely to store water in the spring for release during low flow periods later in the year. Without the wilderness dams in place, historically stored water would be lost during the spring runoff period and would not be available later in the year to counteract diminished flows. Several other concerns were raised pertaining to changing the designation of the water rights (storage, mitigation, instream, etc.).

*Without the wilderness dams in place, historically stored water would be lost during the spring runoff period and would not be available later in the year to counteract diminished flows.*

Given these concerns, it was concluded by WGM that a variation on Trout Unlimited's second option should be considered. It was suggested by WGM that the mainstem dam and intake be removed, the wilderness dam/dams in the worst condition be removed, the wilderness dam/dams in better condition be rehabilitated, and the existing storage rights be changed to add the valley wells as points of diversion.

Several benefits are offered by this variation. The ability to release water to supplement low flow conditions would be maintained. More importantly, maintaining the existing dams would allow the City to continue to store water under the historical priority dates of the storage rights, providing a level of protection against other water claims that can't be obtained any other way. It was additionally emphasized by WGM that if the wilderness dams were removed, it is unlikely that they could ever be rebuilt.

## 9.5 Environmental Review and Permitting

Regardless of the recommendations, some form of permitting, agency coordination, and NEPA review will be required for raising the dam(s), removing dams, or performing significant rehabilitation or repair work.

### 9.5.1 National Environmental Policy Act (NEPA)

NEPA, the National Environmental Policy Act (42 U.S.C. 4321), requires federal agencies to fully consider the impacts of any of their proposals that carry the potential to affect the human environment. Under the law, the environmental impacts of any proposed federal actions must be evaluated before any further action is taken. These requirements are summarized in the following paragraphs.

### 9.5.2 Montana Environmental Policy Act

The Montana Environmental Policy Act (MEPA), requires state agencies to evaluate the environmental impacts of state proposals before any action can take place. MEPA was patterned after NEPA, and contains three parts. Part One declares Montana's environmental policies, Part Two stipulates how state agencies are to carry out the policies of Part One through environmental review, and Part Three establishes the Environmental Quality Council (EQC).

The fundamental sentiment of MEPA is that one should think before acting. In that regard, MEPA requires state agencies to prepare environmental reviews whenever any of the following three conditions are satisfied:

- The action may impact the human environment.
- The agency intends to take an action, as defined by MEPA and the MEPA Model Rules.
- The action is not an EXEMPT ACTION or excluded from MEPA review.

The degree and intensity of any potential impacts determines the type of environmental review necessary. However, the degree or intensity of any potential impacts is irrelevant in determining whether environmental reviews must be conducted.

MEPA specifies three different levels of environmental review contingent on the magnitude of potential impacts. The levels are Categorical Exclusion (CE), Environmental Assessment (EA), and Environmental Impact Statement (EIS). If it is unclear whether a proposed action carries significant impacts, then an EA may be conducted to determine potential significance. If the EA shows that the proposed action will have significant impacts, then either an Environmental Impact Statement (EIS) must be written or the effects of any proposed action must be mitigated below the level of significance.

The only substantive differences between an EA and an EIS lie in the scope and depth of the analysis.

Actions that seldom cause significant impacts to the human environment may qualify for a categorical exclusion. No further environmental review is required for an action that is deemed to meet the criteria for exclusion by a state agency.

Other actions that do not require review under MEPA include but are not necessarily limited to:

- Administrative Actions
- Ministerial actions
- Actions primarily social or economic in nature that do not otherwise affect the human environment
- Specific actions exempted by the legislature

It's likely that some level of NEPA/MEPA analysis would be required for increasing the reservoir storage levels or decommissioning a dam. Further study is necessary to determine if NEPA/MEPA would be required for the dam rehabilitation options.

### 9.5.3 Wilderness Act

The Wilderness Act of 1964, as enacted September 3, 1964, and amended October 21, 1978 (16 U.S.C. 1131-1136), specifies congressional policy to secure for the American people an enduring resource of wilderness for the enjoyment of present and future generations.  With certain exceptions, the Act prohibits motorized equipment, structures, installations, roads, commercial enterprises, aircraft landings, and mechanical transport. The Act permits mining on valid claims, access to private lands, fire control, insect and disease control, grazing, water resource structures (upon the approval of the President), and visitor use.

The Wilderness designation constrains not only how the public may use the lands (e.g., no off-road vehicles, no bicycles) but also how the agency administers it. In other words, the Wilderness designation intentionally constrains both the public and the federal manager. However, there are minimum requirements exceptions that can be identified through a minimum requirements analysis which allows for certain activities.  These are further described below.

#### Wilderness Act Minimum Requirements

Section 4(c) of the Wilderness Act of 1964 introduces the concept of 'minimum requirements' as shown below.

*4(c) Except as specifically provided for in this Act, and subject to existing private rights, there shall be no commercial enterprise and no permanent road within any wilderness area designated by this Act and except as necessary to meet minimum requirements for the administration of the area for the purpose of this Act (including measures required in emergencies involving the health and safety of persons within the area), there shall be no temporary road, no use of motor vehicles, motorized equipment or motorboats, no landing of aircraft, no other form of mechanical transport, and no structure or installation within any such area.*

Four federal agencies administer wilderness: the Bureau of Land Management (BLM), National Park Service (NPS), US Fish and Wildlife Service (USFWS), and US Forest Service (FS). Each agency has policies and procedures for determining when an otherwise prohibited activity may be employed because it may meet the minimum requirement exception. The agencies joined together to establish a national wilderness training center, the Arthur Carhart Center, in Missoula, Montana. One important function of the Carhart Center is to develop a systematic and consistent standard for applying the exception across agency lines.

The Arthur Carhart National Wilderness Training Center has published the *Minimum Requirements Decision Guide* for the U.S. Forest Service Guidelines, which can be used when making a determination that one of the ‘prohibited uses’ is the minimum necessary requirement. Additional guidance can be found in FSM 2320 – Wilderness Management. Specific aspects that may be critical considerations moving forward include effects on the following wilderness qualities: untrammeled, natural, undeveloped, solitude or primitive and unconfined recreation, and historical value.

It should be noted that the water rights holder (Mountain Water Company until 2017, currently the City of Missoula) has been afforded specific provisions that were explicitly written into the 1980 Rattlesnake Wilderness designation (Appendix N) as follows:

Public Law 96-476 – Oct. 19, 1980, Section 2(d)(2) *Nothing in this Act shall be construed to permit the Secretary to affect or diminish any water right which is vested under either State or Federal law at the time of enactment of this Act, nor the rights of the owner of such water right to the customary and usual access, including necessary motorized use over and along existing roads and trails to any facilities used in connection therewith, and the right to operate and maintain such facilities.*

Dams related work is possible (and protected by law), and it is important to follow the guidance for work in the wilderness area and engage the lead agency, FS, and the public on proposed major work and changes to the dams using the NEPA process.

*The City has the following rights described in Public Law 96-476; “…rights of the owner of such water right to the customary and usual access, including necessary motorized use over and along existing roads and trails to any facilities used in connection therewith, and the right to operate and maintain such facilities.”*

## 9.6 Additional Considerations

This section provides an initial overview of fisheries and Rattlesnake Creek flows.

### 9.6.1 Fisheries

The report titled *“Mountain Lake Surveys and Fisheries Management Recommendations – Rattlesnake Wilderness lakes”* published in 2013 is a good reference for lake information and fisheries/aquatic management considerations. In 2006-2010, Montana Fish Wildlife and Parks (MFWP) and volunteers surveyed nearly all fish-bearing and fishless mountain lakes in the Rattlesnake National Recreation Area and Wilderness (RNRAW) to describe physical and biological characteristics.

The study includes 45 lakes, sixteen of the lakes larger than one acre were found to support trout fisheries, some of which are maintained through stocking. The others are important for fish-less or amphibian/reptile ecosystems. Rattlesnake Creek is a high value fishery, particularly for bull trout, and it is utilized for fish migration. The smaller tributaries in the wilderness area are too steep for bull trout, but bull trout are known to occupy the upper portions of Rattlesnake Creek and tributaries where gradient is not limiting.

Dams and other infrastructure were installed on at least ten of the Rattlesnake unit lakes to enhance storage capacity. These modifications typically exaggerate annual water level fluctuations at these lakes. In the Lake Creek drainage, Big Lake and Sheridan Lake support self-sustaining rainbow trout populations and are likely the primary sources of this species in upper Rattlesnake Creek.

Descriptions given for the Rattlesnake Lakes with dams owned by the City are provided below, and summarized in Table 9-6.

- Big Lake is a large glacial cirque lake that was artificially impounded by a dam at the outlet in 1915. This structure elevates the normal surface water elevation, but may also increase annual water level fluctuations.
- Carter Lake is a relatively small glacial cirque lake that was artificially impounded by a dam at the outlet in 1921. This structure elevates the normal surface water elevation, but may also increase annual water level fluctuations. Carter Lake supports an abundant, stunted population (10 inch max length) of wild westslope cutthroat trout.
- Glacier Lake is a relatively large glacial cirque lake that was artificially impounded by a dam at the outlet in 1911. This structure elevates the normal surface water elevation, but may also increase annual water level fluctuations.
- Little Lake is a moderately sized glacial cirque lake that has been artificially impounded by a dam at the outlet. This structure elevates the normal surface water elevation, but may also increase annual water level fluctuations. Little Lake supports the only Yellowstone cutthroat trout population in the project study area and is likely the source of Yellowstone cutthroat trout hybridization with native westslope cutthroat trout stocks in Rattlesnake Creek.
- McKinley Lake is a moderately sized glacial cirque lake that has been artificially impounded by a dam at the outlet. This structure elevates the normal surface water elevation, but may also increase annual water level fluctuations.
- Sanders Lake is a large glacial cirque lake that has been artificially impounded by a dam at the outlet. This structure elevates the normal surface water elevation, but may also increase annual water level fluctuations.
- Sheridan Lake is a moderate sized glacial cirque lake that has been artificially impounded by a dam at the outlet. This structure elevates the normal surface water elevation, but may also increase annual water level fluctuations.
- Worden Lake is a small glacial cirque lake that has been artificially impounded by a dam at the outlet. This structure elevates the normal surface water elevation, but may also increase annual water level fluctuations. Worden Lake contains wild westslope cutthroat trout.

**Table 9-6. Fisheries Data on Rattlesnake Wilderness Dams, According to FWP**

| Lake | Elevation (ft) | Surface Acres | Max Depth (ft) | Lake Volume (acre-ft) | Dam Infrastructure Present? | Current Fishery | Recommended Future Actions |
|---|---|---|---|---|---|---|---|
| Big Lake | 6,875 | 40.2 | 136 | 2,255 | Yes | Wild rainbow trout | Maintain wild fishery; evaluate removal of rainbow trout and conversion to westslope cutthroat trout fishery |
| Carter Lake | 6,300 | 12.9 | 31 | 171 | Yes | Wild westslope cutthroat trout | Maintain westslope cutthroat trout fishery; confirm that population is self-sustaining |
| Glacier Lake | 6,980 | 18.4 | 71 | - | Yes | fishless | Maintain fishless status: identify any unauthorized fish introductions |
| Little Lake | 6,425 | 13.9 | 52 | 309 | Yes | Wild Yellowstone Cutthroat Trout | Maintain wild fishery; Evaluate removal of YCT and conversion to WCT fishery. |
| McKinley Lake | 6,860 | 15.8 | 28 | 211 | Yes | Wild rainbow trout | Maintain wild fishery; evaluate removal of rainfow trout and conversion to westslope cutthroat trout fishery |
| Sanders Lake | 6,885 | 47.5 | 217 | 3,543 | Yes | Wild westslope cutthroat trout | Maintain westslope cutthroat trout fishery; confirm that population is self-sustaining |
| Sheridan Lake | 6,535 | 9.8 | 33 | 168 | Yes | Wild rainbow trout | Maintain wild fishery; evaluate removal of rainbow trout and conversion to westslope cutthroat fishery |
| Worden Lake | 6,700 | 9.1 | 23 | 112 | Yes | Wild westslope cutthroat trout | Maintain westslope cutthroat trout fishery; confirm that population is self-sustaining |

Source: Mountain Lake Surveys and Fisheries Management Recommendations – Rattlesnake Wilderness lakes, Montana Fish Wildlife and Parks, 2013

## 9.6.2 Rattlesnake Creek

It has been noted that one advantage of the Rattlesnake Wilderness Dams is the ability to store spring runoff and release it for late season flows in Rattlesnake Creek, which has been shown to be important habitat for Bull Trout, a threatened species. In order to understand if the flows would be significant enough to have a noted benefit to Bull Trout, historic stream flow data was evaluated.

The 10 dams owned by the City flow into either the Lake Creek or Wrangle Creek drainages, then into Rattlesnake Creek and ultimately to the Clark Fork River. These impoundments are capable of storing 2,585 acre-feet total or 112,602,600 cubic feet. If the total

*If the total storage volume was released over the course of one month, that would equate to about 43 cubic feet per second (cfs) over the entire month. Rattlesnake Creek low flows have been less than 10 cfs.*

storage volume was released over the course of one month, that would equate to about 43 cfs over the entire month.

The USGS gathered streamflow data on Rattlesnake Creek as far back as 1899, then consistently from 1957 through 1968. This data is shown in Figure 9-3. A new gage was installed and started reporting streamflow data in the fall of 2017, and this data is shown in Figure 9-4.

The minimum stream flow measured by the USGS gage was less than 1 cfs, and 8 cfs by the newly installed stream gage.

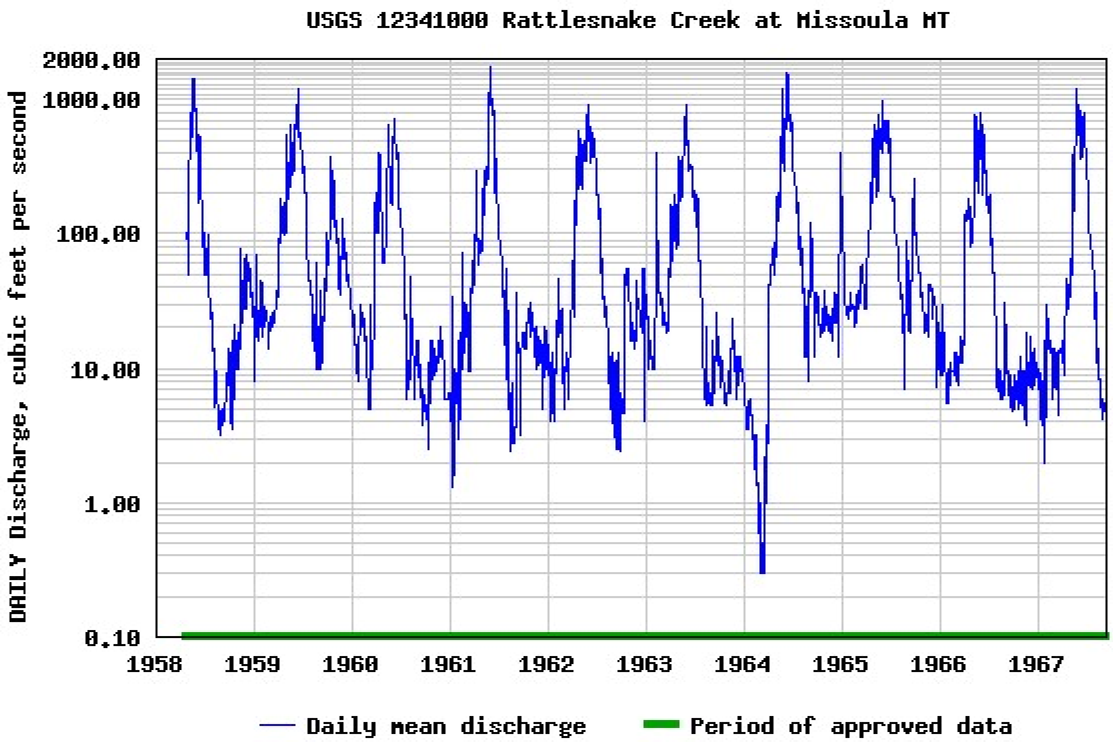


Figure 9-3. Historic Rattlesnake Creek Flow

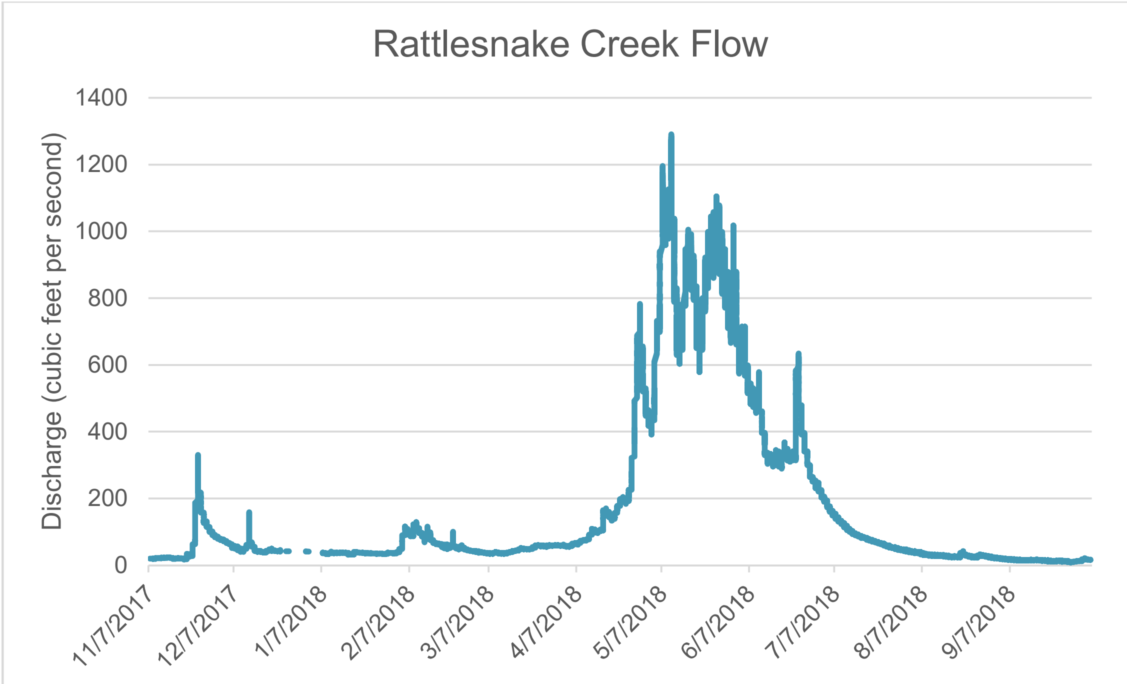


**Figure 9-4. Recent Rattlesnake Creek Flow**

# 9.7 Dam Evaluations

This section describes the existing conditions followed by four general alternatives including no action, rehabilitation, increased storage, and decommissioning.

## 9.7.1 Big Lake Dam

### Current Conditions

A Project Information Sheet for Big Lake Dam is located in Appendix K, which provides detailed information about the dam and reservoir; a summary of current conditions related to different components of the dam and appurtenances; a summary of needed short-term repairs; and a conceptual-level cost estimate for completing short-term repairs.

Big Lake Dam impounds approximately 621 acre-feet of water (the second-largest reservoir in the Wilderness owned by the City of Missoula (out of eight total)). It is an easement dam, meaning the dam and appurtenances are located on a pre-Federal Land Policy Management Act right-of-way. It does not fall under direct FS authority; however the FS has reserved the right to have input regarding actions taken on and around the dam. The dam is classified as having a “Significant” hazard classification, meaning that failure of the dam for any reason results in no probable human loss of life, but can cause non-recoverable environmental damage. A breach failure could result in erosion and sediment transfer to Lake Creek and ultimately to Rattlesnake Creek where bull trout (a threatened species) are present, which is the basis for the dam’s current Significant hazard rating.

The dam was originally built in 1915 as an earthen embankment with a rock timber crib core. The original construction sketches indicate the dam was widened on the downstream side from its initial configuration. As a result the crest of the dam is very wide (approximately 30 feet). Sinkholes have appeared on the crest, aligned with the edge of the timber crib core, and are being monitored. There are also nine water-level measurement piezometers on the crest that are monitored. The upstream slope has a slope of 2:1, is lined with riprap, and is in good condition. The downstream slope is steep with slopes of 0.3 to 0.7:1, but appears to be stable except for an area near the center where erosion occurred due to overtopping during spring runoff. The spillway was enlarged and reinforced with riprap in 2010 and it currently meets FS design criteria.

Foundation seepage is evident in the downstream toe area of the dam. Seepage flows are being monitored by two v-notch weirs and two shallow piezometers in the toe area. The dam has two pipe outlets. The south outlet is a low-level steel pipe that has a corrosion hole with leakage flowing through it. The upstream valve access tower and walkway are in disrepair and need fixing. The north outlet is situated below the spillway. It is a corrugated metal pipe (CMP) with heavy corrosion and some leakage. The control valve on the upstream end is currently operable. Both outlet pipes are 12-inch diameter.

## Alternatives

The following alternatives are presented to aid in deciding the eventual disposition of Big Lake Dam. The actions and costs of each alternative are based on the best available data at this time. Costs and tasks to complete each alternative may change as new information becomes available.

## No Action

The No Action alternative is to keep the dam and appurtenances in their current state with no improvements anticipated for the foreseeable future. The City would continue to monitor the dam, make minor repairs as needed, and take preventative action only if conditions indicate the dam would be in danger of failing.

Advantages:

This alternative does not include initial capital improvement costs. There would still be annual costs for maintenance and owner inspections and a cost every five years for a periodic O&M engineer inspection and hazard assessment, as required by FS regulations.

Disadvantages:

The effects of aging on an already one hundred year old dam will continue. It is impossible to know when serious symptoms related to dam safety may appear, but they would be inevitable in the future. Costs to repair, replace or decommission the dam would eventually have to be expended at the time that serious deficiencies arise. Performing a structural stability analysis of an earthen dam requires a slope stability analysis. Although the FS does not have agency-specific guidance on conducting a structural analysis of an earthen dam, it references other suitable federal agency guidance. FSM 7525.42 states that the design of earthen side slopes can be accomplished using guidelines developed by the U.S. Army Corps of Engineers (USACOE) or U.S. Bureau of Reclamation (USBR). Criteria found in USDA-Natural Resources Conservation Service (NRCS) Technical Release 60 (TR-60) are consistent with USACOE and USBR criteria and is used often on FS dams. A report prepared by GMT Consultants in 1997 (Preliminary Geotechnical Evaluation and Slope Stability Analysis, 6 Dam Sites - Rattlesnake Wilderness) found that the downstream slope produced a safety factor of less than one for one loading condition that included ponded water on the crest and with assumed soil properties. At this time, in the absence of a more detailed slope stability analysis, the downstream slope does not meet FS criteria for slope stability. Therefore, under the No Action alternative the dam would be out of compliance with dam safety regulations and thus increase the City's risk and liability.

Estimated Costs:

| | |
|---|---|
| No capital improvement costs for this alternative | $0 |

(It should be noted that under the no action alternative, regular operations and maintenance costs would still be required, and would likely increase over time.)

### Rehabilitate to Meet Forest Service Standards

The rehabilitation alternative would address deficiencies on the existing dam, as described previously, and bring the dam into compliance with FS standards. Proposed repairs would include:

- Performing a geotechnical investigation and analysis;
- Addressing seepage issues by lining the upstream slope with an impermeable liner;
- Addressing slope stability concerns by adding fill on the downstream slope;
- Slip-lining both outlets with HDPE pipe;
- Replacing the north outlet valve;
- Repairing the south outlet intake tower and walkway;
- Extending the south outlet pipe to accommodate the added fill on the downstream slope; and
- Repairing voids on the dam crest.

The embankment materials at Big Lake Dam are prone to seepage, which can result in embankment piping (internal erosion). The embankment could be reconstructed with suitable embankment materials, but that would be expensive and potentially problematic due to the limited soil resources at the site.

A more reasonable solution to eliminate the piping concern is lining the upstream embankment slope with an impermeable geomembrane liner. This option would require temporarily removing the upstream riprap, preparing the liner subgrade, installing a geomembrane liner with cushion geotextile on both sides, and replacing the upstream riprap.

The photos below provide a visual example of the work necessary to install a geomembrane liner on the upstream dam face.

**Figure 9-5. Mill Lake Dam, Geomembrane Liner Installation**

**Figure 9-6. Mill Lake Dam, Geomembrane Liner and Riprap Installation**

In addition, the steep downstream embankment slope (0.3 to 0.7:1) could be flattened to produce a more stable embankment. The steep slope could be buttressed with new fill consisting of coarse gravel and sand obtained from within the reservoir footprint. Flattening the downstream slope would significantly increase stability, especially in combination with an upstream liner that eliminates the high phreatic surface in the embankment, potential issues from rapid drawdown, and other concerns that earthen embankment dam standards take into consideration. At this time, it is recommended that the downstream slope would be flattened to 1.5:1, based on experience with repairs on similar wilderness dams. The existing 2:1 upstream and proposed 1.5:1 downstream slopes are steeper than recommended in the NRCS Conservation Practice Standard POND (No.) CODE 378. but slope stability analyses would be conducted to verify that the combination of slopes (2:1 upstream and 1.5:1 downstream) with an upstream liner under various loading conditions meet FS criteria. If not, then the downstream slope would be adjusted until criteria are met. The south outlet would need to be extended approximately 20 feet to reach the new dam toe, if a 1.5:1 downstream slope is used.

Advantages:

This alternative would address long-term concerns at the dam and would bring the dam into compliance with FS standards.  The improvements proposed for rehabilitation would likely be necessary to even consider raising the dam to increase storage capacity.

Disadvantages:

This alternative would require a large capital improvement investment as well as ongoing operation and maintenance costs. While most seepage would be blocked, foundation seepage could continue, which has the potential to pipe foundation material and undermine the dam.

Estimated Costs:

Rehabilitation costs are estimated using unit costs from recent wilderness dams repair work. Remote access necessitates helicopter transportation for personnel, equipment and construction materials. Construction costs for remote access dams can be five to ten times that of conventional construction. Estimated costs presented here include mobilization and demobilization costs, engineering and construction management fees, and a contingency of 30 percent. The estimated costs are as follows:

| | |
|---|---|
| Capital improvement costs | $1,312,000 |
| Existing Water Right | 623 ac-ft |
| Cost per acre-foot | $2,106 |

## Increase Storage

The alternative to increase storage would be a combination of raising the embankment height and completing rehabilitation items discussed above. With a surface area of approximately 38 acres, raising Big Lake Dam even a few feet could result in a significant increase in storage capacity. This alternative would be combined with the decommissioning of one or more other dams and would offset the lost storage volume.

Based on the existing crest width of 30 feet, 2:1 upstream slope, and proposed 1.5:1 downstream slope, the dam could be raised 4.5 feet and still have a 14-foot crest width.

The modification would increase the dam height from 19 feet to 23.5 feet and add approximately 175 acre-feet, a 28% increase in storage. FSM recommends a minimum crest width of 12 feet for a 23.5-foot high dam.

Advantages:

This alternative would offset potential loss of storage volume by decommissioning other City-owned dams in the Wilderness, and the City could potentially retain existing water storage and water rights while reducing the number of dams that require future maintenance.

Disadvantages:

There is an initial capital improvement cost associated with this alternative, and the alternative cannot be implemented without completing rehabilitation work. Some cost efficiency would be realized by increasing storage at the time rehabilitation work is completed. Increasing the dam storage capacity would also increase the peak flow in the event of a dam breach, and a revised hazard assessment would be required. An evaluation would be needed to determine the amount of increased storage that could be added without changing the current dam hazard classification.

Estimated Costs:

Costs for Increased Storage are based on the same assumptions as used for the Rehabilitation option. The estimated costs are as follows:

| | |
|---|---|
| Capital improvement costs for this alternative alone* | $472,000 |
| Increased water storage | 175 ac-ft |
| Cost per acre-foot for this alternative alone | $2,696 |
| Capital improvement costs including rehabilitation* | $1,784,000 |
| Existing water right plus increased storage | 798 ac-ft |
| Cost per acre-foot including rehabilitation alternative | $2,235 |

*Costs do not account for potential savings achieved by eliminating repair costs at other dam(s)

## Decommission

The alternative to decommission the dam would involve breaching a portion of the dam and constructing a channel to route flows past the dam to an outlet channel. Breaching the dam would eliminate its storage capacity. A stable breach channel would be excavated through the dam embankment to safely route a 100-year or larger inflow design flood and to avoid any backwater impoundment against the remaining portion of the dam. The channel could feature a control sill to reduce sediment releases until the reservoir beach stabilizes. Excavated material could be dispersed to blend within the surrounding ground in the reservoir footprint. The existing outlet gates and gate tower would be removed. The remaining beach between the current reservoir shore and the remaining natural lake would be seeded. See Figure 9-7 for a conceptual drawing of a dam decommissioning.

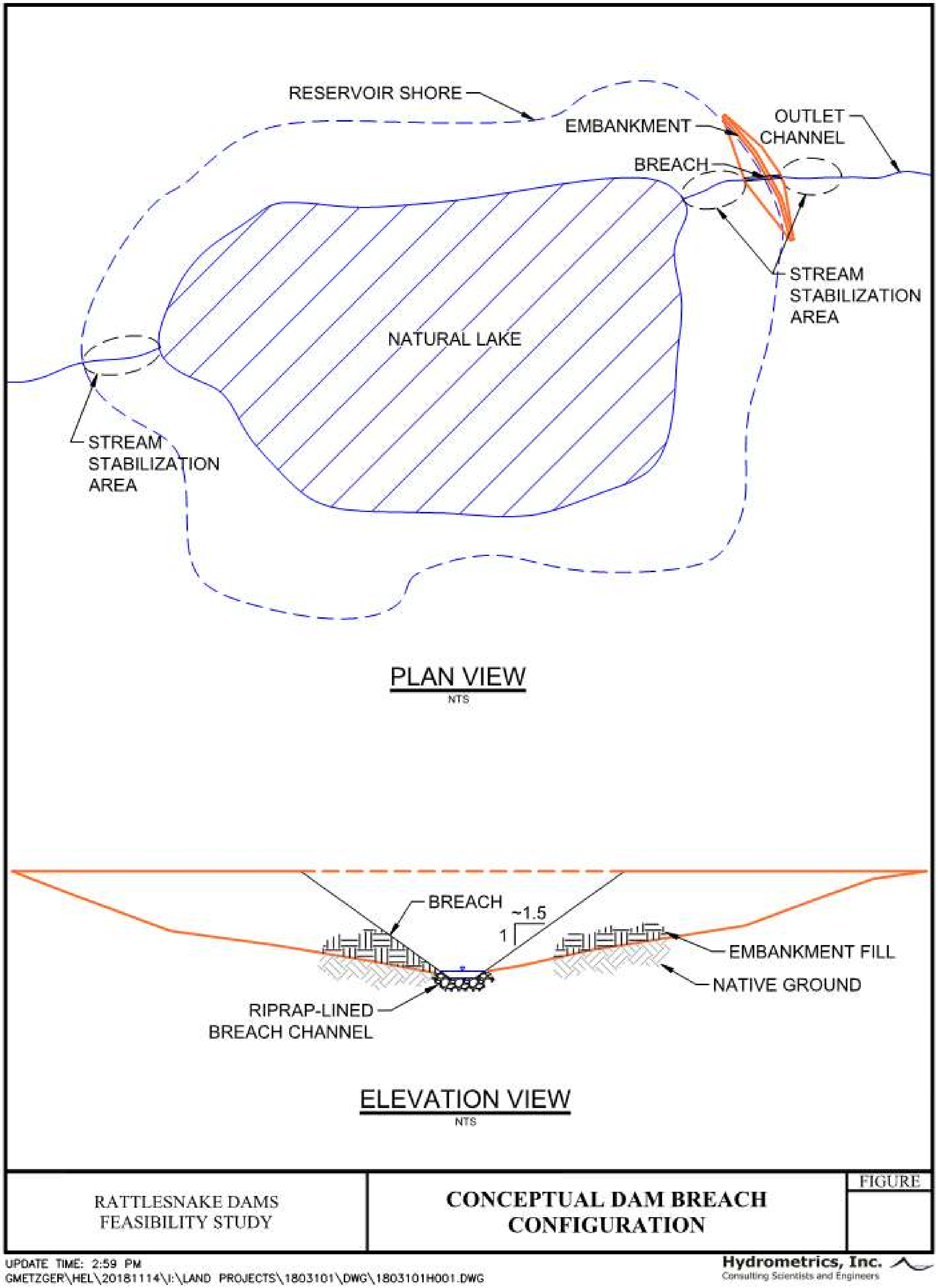


**Figure 9-7. Conceptual Dam Breach Configuration**

The description above presents the probable minimum requirements for decommissioning the dam. A larger effort may be required to satisfy outside interests. This could involve reconstructing a natural channel upstream and downstream of the dam, completely removing the embankment material, or other major construction tasks.

The cost estimate assumes a breach channel would be excavated through the embankment capable of passing a 500-year flood with a peak flow of 88 cubic feet per second (cfs). Designing to this flood event would result in a stable channel during extreme flood events and minimize the potential for backwater impoundment against the dam. Changing the design flood would not significantly affect costs. The channel would be armored with riprap, and 5 acres of reservoir beach would be seeded. The seeding and re-vegetation plan would be prepared to minimize the introduction of invasive species and could incorporate seed collected on site.

According to the Forest Service, a dam is ‘any artificial barrier, including appurtenant works, that impounds or diverts water, either temporarily or long term, but not including a facility that is 6 feet or less in height or that impounds no more than 15 acre-feet of water’, and is classified as low hazard. The decommissioning alternative could be modified such that some combination of dam height reduction and storage reduction essentially turned the dam into a pond. This sub-alternative may have advantages in terms of cost, aquatic life, and re-vegetation limits and could be further developed in the next phase of overall project development and analysis.

Advantages:

This alternative would eliminate current and future maintenance requirements, except for possible short-term maintenance while conditions equilibrate. The easement could be relinquished and ownership of the former dam and reservoir could be returned to the FS. Decommissioning costs would likely be lower than rehabilitation costs, although that could depend on the scope of decommissioning work and FS requirements for restoration to simulate natural conditions.

Disadvantages:

With its water storage capacity eliminated, the water rights associated with Big Lake Dam would need to be modified or abandoned. Reestablishing vegetation on the reservoir beach would take years, and the remaining embankment section could be considered an aesthetic drawback. Potential late-season flow releases to Rattlesnake Creek would be lost, and the overall recreational appeal of the dam site could decrease.

Estimated Costs:

Costs for the Decommission option are based on the same assumptions as used for the Rehabilitation option. The estimated costs are as follows:

| | |
|---|---|
| Capital costs for this alternative | $401,000 |

## 9.7.2 Carter Lake Dam

### Current Conditions

A Project Information Sheet for Carter Lake Dam is located in Appendix K of this report, which provides detailed information about the dam and reservoir; a summary of current conditions related to different components of the dam and appurtenances; a summary of needed short-term repairs; and a conceptual-level cost estimate for completing short-term repairs.

Carter Lake Dam impounds approximately 161 acre-feet of water (the sixth-largest reservoir (out of eight total)) in the Wilderness owned by the City of Missoula). It operates under a Special Use Permit issued by the Lolo National Forest of the U.S. FS. It is regulated under the authority of the FS dam safety laws. The dam is classified as having a "Low" hazard classification, the only City-owned dam in the Wilderness with this classification. All others are "Significant" hazard dams. A Low hazard classification means that failure of the dam for any reason results in no probable loss of human life and no significant environmental damage. Carter Lake Dam's classification was changed from Significant to Low in (date) by a FS reclassification study that found that Lake Creek, the drainage on which the dam is located, does not have bull trout residing within it. Bull trout are a threatened species. From dam breach modeling, it was shown that the breach failure flood from Carter Dam attenuates to a peak flow below the 100-year flood level of Rattlesnake Creek (which is inhabited by bull trout) by the time it reaches the confluence of Lake Creek and Rattlesnake Creek. According to FS criteria, damage or danger to potential hazards from a breach flood is considered until it reaches the level of a 100-year flood.

The dam was originally built in 1921 as an earthen embankment, as shown on the dam's original construction drawings, with no cribbing in the core. A subsequent geophysical investigation by Glacier Engineering, P.C. in 1999 indicated that imaging showed material anomalies consistent with a timber rock crib core in the dam. The dam's crest is narrow (approximately 5 feet wide) which does not meet FS criteria. There is one area on the downstream shoulder of the crest that indicates erosion from overtopping during spring runoff. There is no instrumentation, such as piezometers, on the dam.

The upstream slope ranges from 3:1 to 4:1, is lined with riprap, and is in good condition. The downstream slope is steep with a slope of 0.3:1, but appears to be stable except for the small erosion area mentioned above. Excessive vegetation is growing through the rock on the downstream slope that needs to be cut. The upstream section of the spillway is in good condition. Annual maintenance is needed to clear logs and other debris from the spillway approach channel. The downstream section is a timber corduroy structure that was completely rebuilt several years ago, but is a continual maintenance concern with replacing displaced riprap downstream of the timber structure and with replacing timbers that have been damaged. It currently meets FS design criteria, which was set specifically for this dam and established when the dam reclassification was completed.

The reclassification analysis established that the spillway design flow shall be 200 cubic feet per second (cfs), which is approximately equal to the 500-year return period flood for Lake Creek at the dam. This is higher than the normal FS spillway flood criteria for low hazard dams, which is the 100-year return period flood. Foundation seepage is evident in the downstream toe area of the dam by ponding water. No seepage flows have been observed. The dam has one pipe outlet, which is a corrugated metal pipe (CMP) with heavy corrosion and deterioration. The control valve on the upstream end operates but remains open to keep the reservoir level low.

## Alternatives

The following alternatives are presented to aid in deciding the eventual disposition of Carter Lake Dam. The actions and costs of each alternative are based on the best available data at this time. Costs and tasks to complete each alternative may change as new information becomes available. Costs include construction and engineering design and construction oversight.

## No Action

The No Action alternative is to keep the dam and appurtenances in their current state with no improvements anticipated for the foreseeable future. The City would continue to monitor the dam, make minor repairs as needed, and take preventative action only if conditions indicate the dam would be in danger of failing.

Advantages:

This alternative does not include initial capital improvement costs. There would still be annual costs for maintenance and owner inspections and a cost for a periodic O&M engineer inspection which according to the dam's Special Use Permit and FSM 7514.5 is every ten years, but the City may opt to perform an engineer's periodic O&M inspection once every five years to match the schedule for the other Significant hazard dam, and hazard assessment, as required by FS regulations.

Disadvantages:

The effects of aging on a nearly one hundred year old dam will continue. It is impossible to know when serious symptoms related to dam safety may appear, but they would be inevitable in the future. Costs to repair, replace or decommission the dam would eventually have to be expended at the time that serious deficiencies arise. Performing a structural stability analysis of an earthen dam requires a slope stability analysis. Although the FS does not have agency-specific guidance on conducting a structural analysis of an earthen dam, it references other suitable federal agency guidance. FSM 7525.42 states that the design of earthen side slopes can be accomplished using guidelines developed by the U.S. Army Corps of Engineers (USACOE) or U.S. Bureau of Reclamation (USBR). Criteria found in USDA-Natural Resources Conservation Service (NRCS) Technical Release 60 (TR-60) are consistent with USACOE and USBR criteria and is used often on FS dams. A report prepared by GMT Consultants in 1997 (*Preliminary Geotechnical Evaluation and Slope Stability Analysis, 6 Dam Sites - Rattlesnake Wilderness*) evaluated the downstream slope and it produced a safety factor of 1.20. However, the report indicated that the slope was input to the model as 0.9:1 which is flatter than the actual slope, and that it was modeled as a stacked-rock slope, which may be accurate. In 2002, another slope stability analysis *Carter Lake Dam Stability Evaluation* was conducted by Portage, Inc. Portage found a lower factor of safety (1.0) for the same downstream slope analysis conducted by GMT because Portage used steeper slopes that were closer to actual. The factor of safety increased if it was assumed the internal rock core served as a drain to lower the phreatic surface in the dam, which is possible. Both Portage and GMT assumed soil properties for the embankment. In the absence of a more detailed geotechnical investigation and slope stability analysis, the actual downstream slope stability is unknown. Considering the narrow width of the crest and the uncertainty of the 1997 and 2002 slope stability analyses, the no action alternative for the dam would be out of compliance with dam safety regulations and thus increase the City's risk and liability.

Estimated Costs:

| | |
|---|---|
| No capital improvement costs for this alternative | $0 |

(It should be noted that under the no action alternative, regular operations and maintenance costs would still be required, and would likely increase over time.)

### Rehabilitate to Meet Forest Service Standards

The rehabilitation alternative would address deficiencies on the existing dam, as previously described, and bring the dam into compliance with FS standards. Proposed repairs would include:

- Performing a geotechnical investigation and analysis;
- Addressing seepage issues by lining the upstream slope with an impermeable liner;
- Addressing the narrow crest and slope stability concerns by adding fill on the downstream slope;
- Full replacement of the outlet pipe;
- Replacing the outlet valve;
- Rebuilding the outlet intake tower;
- Extending the outlet pipe to accommodate the added fill on the downstream slope; and
- Repairing the spillway.

The embankment materials at Carter Lake Dam are prone to seepage, which can result in embankment piping (internal erosion). The embankment could be reconstructed with suitable embankment materials, but that would be expensive and potentially problematic due to the limited soil resources at the site.

A more reasonable solution to eliminate the piping concern is lining the upstream embankment slope with an impermeable geomembrane liner. This option would require temporarily removing the upstream riprap, preparing the liner subgrade, installing a geomembrane liner with cushion geotextile on both sides, and replacing the upstream riprap.

In addition, the crest is narrow and needs to be widened to a minimum of 10 feet in order to meet FS criteria. Along with this, the steep downstream embankment slope (0.3:1) could be flattened to produce a more stable embankment. The new fill material could be coarse gravel and sand obtained from within the reservoir footprint. Flattening the downstream slope would significantly increase stability, especially in combination with an upstream liner that eliminates the high phreatic surface in the embankment, potential issues from rapid drawdown, and other concerns that earthen embankment dam standards take into consideration. At this time, it is recommended that the downstream slope would be flattened to 1.5:1, based on experience with repairs on similar wilderness dams. The proposed 1.5:1 downstream slope is steeper than recommended in the NRCS Conservation Practice Standard POND (No.) CODE 378, while the 3:1 or flatter upstream slope meets the NRCS recommendation. Slope stability analyses would be conducted to verify that the combination of slopes (3:1 upstream and 1.5:1 downstream) with an upstream liner under various loading conditions meet FS criteria. If not, then the downstream slope would be flattened until criteria are met. The new outlet pipe would need to be extended approximately 21 feet longer than the existing pipe to reach the new dam toe, if a 1.5:1 downstream slope is used. A blanket filter along the rehabilitated toe is also recommended as a preventative measure against piping from foundation seepage. The filter material would consist of soil meeting a gradation that prevents soil migration while allowing foundation seepage to drain.

Spillway repair would consist of abandoning the log corduroy structure and constructing an engineered spillway channel that would have erosion control features determined during analysis. The area near the dam has significant riprap rock available that hopefully could be utilized. The channel would have to be designed to pass the required flow and at the same time prevent headcutting.

Advantages:

This alternative would address long-term concerns at the dam and would bring the dam into compliance with FS standards. The improvements proposed for rehabilitation would likely be necessary to even consider raising the dam to increase storage capacity.

Disadvantages:

This alternative would require a large capital improvement investment as well as ongoing operation and maintenance costs. Even with a blanket filter in place, it is possible that foundation seepage could continue, which has the potential to pipe foundation material and undermine the dam.

Estimated Costs:

Rehabilitation costs are estimated using unit costs from recent wilderness dams repair work. Remote access necessitates helicopter transportation for personnel, equipment and construction materials. However, Carter Lake is within a quarter of a mile to a maintenance access road used by the City only for periodic maintenance. It is possible that some personnel or small equipment transport could occur via the maintenance access road if it meets FS requirements. Construction costs for remote access dams can be five to ten times that of conventional construction. Estimated costs presented here include mobilization and demobilization costs, engineering and construction management fees, and a contingency of 30 percent. The estimated costs are as follows:

| | |
|---|---|
| Capital improvement costs | $706,000 |
| Existing Water Right | 170 ac-ft |
| Cost per acre-foot | $4,155 |

## Increase Storage

The alternative to increase storage would be a combination of raising the embankment height and completing rehabilitation items discussed above. With a surface area of approximately 14.6 acres, raising Carter Lake Dam even a few feet could result in a significant increase in storage capacity. This alternative would be combined with the decommissioning of one or more other dams and would offset the lost storage volume.

Because of the already narrow dam crest, raising the dam approximately 4 feet (which is estimated only for purposes of this analysis – actual increase in height would be based on a cost:benefit analysis) would require additional fill beyond that estimated for rehabilitation. Raising the dam 4 feet would increase the height from 14 to 18 feet, which requires a minimum crest width of 10.6 feet to meet FS standards. Additional required embankment material was estimated assuming an 11-foot crest width, 3:1 upstream slope, and 1.5:1 downstream slope. The outlet pipe would need to be extended 20 feet. The modification would increase reservoir storage approximately 59 acre-feet, a 37% increase.

Advantages:

This alternative would offset potential loss of storage volume by decommissioning other City-owned dams in the Wilderness, and the City could potentially retain existing water storage and water rights while reducing the number of dams that require future maintenance.

Disadvantages:

There is an initial capital improvement cost associated with this alternative, and the alternative cannot be implemented without completing rehabilitation work. Some cost efficiency would be realized by increasing storage at the time rehabilitation work is completed. Increasing the dam storage capacity would also increase the peak flow in the event of a dam breach, and a revised hazard assessment would be required. An evaluation would be needed to determine the effect on the current dam hazard classification. Since the current classification and spillway capacity criteria are based on the effect from dam failure, the amount of increased storage that could be added without changing the current dam hazard classification would have to be examined closely.

Estimated Costs:

Costs for Increased Storage are based on the same assumptions as used for the Rehabilitation option. The estimated costs are as follows:

| | |
|---|---|
| Capital improvement costs for this alternative alone* | $428,000 |
| Increased water storage | 60 ac-ft |
| Cost per acre-foot for this alternative alone | $7,133 |
| Capital improvement costs including rehabilitation* | $1,134,000 |
| Total water storage with increase | 230 ac-ft |
| Cost per acre-foot including rehabilitation alternative | $4,932 |

**Costs do not account for potential savings achieved by eliminating repair costs at other dam(s)*

### Decommission

The alternative to decommission the dam would involve breaching a portion of the dam and constructing a channel to route flows past the dam to an outlet channel. Breaching the dam would eliminate its storage capacity. A stable breach channel would be excavated through the dam embankment to safely route a 100-year or larger inflow design flood and to avoid any backwater impoundment against the remaining portion of the dam. The channel could feature a control sill to reduce sediment releases until the reservoir beach stabilizes. Excavated material could be dispersed to blend within the surrounding ground in the reservoir footprint. The existing outlet gates and gate tower would be removed. The beach between the current reservoir shore and the remaining natural lake would be seeded.

The description above presents the probable minimum requirements for decommissioning the dam. A larger effort may be required to satisfy outside interests. This could involve reconstructing a natural channel upstream and downstream of the dam, completely removing the embankment material, or other major construction tasks.

The cost estimate assumes a breach channel would be excavated through the embankment capable of passing a 500-year flood with a peak flow of 127 cubic feet per second (cfs). Designing to this flood event would result in a stable channel during extreme flood events and minimize the potential for backwater impoundment against the dam. Changing the design flood would not significantly affect costs. The channel would be armored with riprap, and 5 acres of reservoir beach would be seeded. The seeding and re-vegetation plan would be prepared to minimize the introduction of invasive species and could incorporate seed collected on site.

According to FSM 2709.11, Dam Safety Definitions, a dam is ‘any artificial barrier, including appurtenant works, that impounds or diverts water, either temporarily or long term, but not including a facility that is 6 feet or less in height or that impounds no more than 15 acre-feet of water’. The decommissioning alternative could be modified such that some combination of dam height reduction and storage reduction essentially turned the dam into a pond. This sub-alternative may have advantages in terms of cost, aquatic life, and re-vegetation limits and could be further developed in the next phase of overall project development and analysis.

Advantages:

This alternative would eliminate current and future maintenance requirements, except for possible short-term maintenance while conditions equilibrate. Ownership of the former dam and reservoir could be returned to the FS. Decommissioning costs would likely be lower than rehabilitation costs, although that could depend on the scope of decommissioning work and FS requirements for restoration to simulate natural conditions.

Disadvantages:

With its water storage capacity eliminated, the water rights associated with Carter Lake Dam would need to be modified or abandoned. Reestablishing vegetation on the reservoir beach would take years, and the remaining embankment section could be considered an aesthetic drawback. Potential late-season flow releases to Rattlesnake Creek would be lost, and the overall recreational appeal of the dam site could decrease.

Estimated Costs:

Costs for the Decommission option are based on the same assumptions as used for the Rehabilitation option. The estimated costs are as follows:

| | |
|---|---|
| Capital costs for this alternative | $180,000 |

## 9.7.3 Glacier Lake Dam

### Current Conditions

A Project Information Sheet for Glacier Lake Dam is located in Appendix K of this report, which provides detailed information about the dam and reservoir; a summary of current conditions related to different components of the dam and appurtenances; a summary of needed short-term repairs; and a conceptual-level cost estimate for completing short-term repairs.

Glacier Lake Dam impounds approximately 240 acre-feet of water the fourth-largest reservoir out of eight total in the Wilderness owned by the City of Missoula. It is an easement dam, meaning the dam and appurtenances are located on a pre-Federal Land Policy Management Act right-of-way. It does not fall under direct U.S. FS authority; however, the FS has reserved the right to have input regarding actions taken on and around the dam. The dam is classified as having a “Significant” hazard classification, meaning that failure of the dam for any reason results in no probable human loss of life, but can cause non-recoverable environmental damage. A breach failure could result in erosion and sediment transfer to Little Lake and then possibly Wrangle Creek and ultimately to Rattlesnake Creek where bull trout (a threatened species) are present, which is the basis for the dam’s current Significant hazard rating. The dam was originally built in 1911 as an earthen embankment with a timber rock crib core, as shown on the dam’s original construction drawings. The embankment crest is narrow (approximately 5 feet wide) which does not meet FS criteria. There is no instrumentation, such as piezometers, on the dam.

The upstream and downstream slopes are approximately 2:1 each. The upstream slope is lined with riprap, and is in good condition. The downstream slope has intermittent rock and vegetative cover. The embankment does not exhibit signs of instability. Some excessive vegetation on all surfaces needs to be cut. The spillway channel has a headcut that is currently being monitored for movement using set rebar monuments and measuring any erosion progress. Annual maintenance is needed to clear logs and other debris from the spillway approach channel. It currently meets FS design criteria for significant hazard dams. Foundation seepage has been observed in the past near the outlet during high reservoir levels. The dam has one pipe outlet, which is a corrugated metal pipe (CMP) with heavy corrosion. The control valve on the upstream end operates but remains open to keep the reservoir level low. The valve access timber structure is heavily damaged and needs replacement.

### Alternatives

The following alternatives are presented to aid in deciding the eventual disposition of Glacier Lake Dam. The actions and costs of each alternative are based on the best available data at this time. Costs and tasks to complete each alternative may change as new information becomes available. Costs include construction, engineering design and construction oversight.

## No Action

The No Action alternative is to keep the dam and appurtenances in their current state with no improvements anticipated for the foreseeable future. The City would continue to monitor the dam, make minor repairs as needed, and take preventative action only if conditions indicate the dam would be in danger of failing.

Advantages:

The No Action alternative does not include initial capital improvement costs. There would still be annual costs for maintenance and owner inspections, and a cost for a periodic O&M engineer inspection once every five years and hazard assessment, as required by FS regulations.

Disadvantages:

The effects of aging on a dam over one hundred years old will continue. It is impossible to know when serious symptoms related to dam safety may appear, but they would be inevitable in the future. Costs to repair, replace or decommission the dam would eventually have to be expended at the time that serious deficiencies arise. Performing a structural stability analysis of an earthen dam requires a slope stability analysis. Although the FS does not have agency-specific guidance on conducting a structural analysis of an earthen dam, it references other suitable federal agency guidance. FSM 7525.42 states that the design of earthen side slopes can be accomplished using guidelines developed by the U.S. Army Corps of Engineers (USACOE) or U.S. Bureau of Reclamation (USBR). Criteria found in USDA-Natural Resources Conservation Service (NRCS) Technical Release 60 (TR-60) are consistent with USACOE and USBR criteria and is used often on FS dams. No geotechnical investigations or analyses have been completed on the dam. Even with 2:1 slopes on both the upstream and downstream sides, which are flatter than many of the City wilderness dams, the fact that the crest does not meet FS standards means it is out of compliance. The no action alternative for the dam would increase the City's risk and liability.

Estimated Costs:

| | |
|---|---|
| No capital improvement costs for this alternative | $0 |

(It should be noted that under the no action alternative, regular operations and maintenance costs would still be required, and would likely increase over time.)

## Rehabilitate to Meet Forest Service Standards

The rehabilitation alternative would address deficiencies on the existing dam, as described previously, and bring the dam into compliance with FS standards. Proposed repairs would include:

- Performing a geotechnical investigation and analysis;
- Addressing any seepage issues by lining the upstream slope with an impermeable liner;
- Addressing the narrow crest and potential slope stability concerns by adding fill on the downstream slope;
- Slip-lining of the outlet pipe and extending to accommodate added fill;

- Rebuilding the outlet intake tower;
- Extending the outlet pipe to accommodate the added fill on the downstream slope; and
- Repairing the spillway.

The embankment materials at Glacier Lake Dam are prone to seepage, which can result in embankment piping (internal erosion). The embankment could be reconstructed with more suitable embankment materials, but that would be expensive and potentially problematic due to the limited soil resources at the site.

A more reasonable solution to eliminate the piping concern is lining the upstream embankment slope with an impermeable geomembrane liner. This option would require temporarily removing the upstream riprap, preparing the liner subgrade, installing a geomembrane liner with cushion geotextile on both sides, and replacing the upstream riprap.

In addition, the crest is narrow and needs to be widened to a minimum of 10 feet in order to meet FS criteria. In order to accomplish this, fill would be placed on the downstream slope. The current downstream slope could likely remain the same (2:1) and still maintain a stable embankment. The new fill material could be coarse gravel and sand obtained from within the reservoir footprint. Maintaining the downstream slope, in combination with an upstream liner that eliminates a high phreatic surface in the embankment, would address potential issues from rapid drawdown, and other concerns that earthen embankment dam standards take into consideration. The existing 2:1 upstream slope is steeper than recommended in the NRCS Conservation Practice Standard POND (No.) CODE 378. Slope stability analyses would be conducted to verify that the combination of slopes (2:1 for both upstream and downstream) with an upstream liner under various loading conditions meet FS criteria. If not, then the downstream slope would be flattened until criteria are met. The slip-lined outlet pipe would need to be extended approximately 5 feet longer than the existing pipe to reach the new dam toe, if the crest is widened another 5 feet.

Spillway repair would consist of replacing eroded material in the area of the headcut with large riprap or other erosion-resistant material, and grading to transition to the natural channel. Another option would be to design and construct a stable drop structure that would dissipate the energy of spillway flows prior to entering the natural channel. The area near the dam or around the reservoir has significant riprap rock available that hopefully could be utilized. The channel would have to be designed to pass the required flow and at the same time prevent erosion and headcutting.

Advantages:

This alternative would address long-term concerns at the dam and would bring the dam into compliance with FS standards. The improvements proposed for rehabilitation would likely be necessary to even consider raising the dam to increase storage capacity.

Disadvantages:

This alternative would require a large capital improvement investment as well as ongoing operation and maintenance costs. While most seepage would be blocked, it is possible that foundation seepage could occur, which has the potential to pipe foundation material and undermine the dam.

Estimated Costs:

Rehabilitation costs are estimated using unit costs from recent wilderness dams repair work. Remote access necessitates helicopter transportation for personnel, equipment and construction materials. Construction costs for remote access dams can be five to ten times that of conventional construction. Estimated costs presented here include mobilization and demobilization costs, engineering and construction management fees, and a contingency of 30 percent. The estimated costs are as follows:

| | |
|---|---|
| Capital improvement costs | $475,000 |
| Existing Water Right | 212 ac-ft |
| Cost per acre-foot | $2,240 |

## Increase Storage

The alternative to increase storage would be a combination of raising the embankment height and completing rehabilitation items discussed above. With a surface area of approximately 20.4 acres, raising Glacier Lake Dam even a few feet could result in a significant increase in storage capacity. This alternative would be combined with the decommissioning of one or more other dams and would offset the lost storage volume.

Because of the already narrow dam crest, raising the dam approximately 4 feet (which is estimated only for purposes of this analysis – actual increase in height would be based on a cost:benefit analysis) would require additional fill beyond that estimated for rehabilitation. Raising the dam 4 feet would increase the height from 12 to 16 feet, which requires a minimum crest width of 10.2 feet to meet FS standards. Additional required embankment material was estimated assuming a 10.2-foot crest width, 2:1 upstream slope, and 2:1 downstream slope. The outlet pipe would need to be extended 16 feet. The modification would increase reservoir storage approximately 84 acre-feet, a 39% increase.

Advantages:

This alternative would offset potential loss of storage volume by decommissioning other City-owned dams in the Wilderness, and the City could potentially retain existing water storage and water rights while reducing the number of dams that require future maintenance.

Disadvantages:

There is an initial capital improvement cost associated with this alternative, and the alternative cannot be implemented without completing rehabilitation work. Some cost efficiency would be realized by increasing storage at the time rehabilitation work is completed. Increasing the dam storage capacity would also increase the peak flow in the event of a dam breach, and a revised hazard assessment would be required. An evaluation would be needed to determine the effect on the current dam hazard classification. Since the current classification and spillway capacity criteria are based on the effect from dam failure, the amount of increased storage that could be added without changing the current dam hazard classification would have to be examined closely.

Estimated Costs:

Costs for Increased Storage are based on the same assumptions as used for the Rehabilitation option. The estimated costs are as follows:

| | |
|---|---|
| Capital improvement costs for this alternative alone* | $343,000 |
| Increased water storage | 84 ac-ft |
| Cost per acre-foot for this alternative alone | $4,086 |
| Capital improvement costs including rehabilitation* | $818,000 |
| Existing water right plus increased storage | 296 ac-ft |
| Cost per acre-foot including rehabilitation alternative | $2,764 |

**Costs do not account for potential savings achieved by eliminating repair costs at other dam(s)*

### Decommission

The alternative to decommission the dam would involve breaching a portion of the dam and constructing a channel to route flows past the dam to an outlet channel. Breaching the dam would eliminate its storage capacity. A stable breach channel would be excavated through the dam embankment to safely route a 100-year or larger inflow design flood and to avoid any backwater impoundment against the remaining portion of the dam. The channel could feature a control sill to reduce sediment releases until the reservoir beach stabilizes. Excavated material could be dispersed to blend within the surrounding ground in the reservoir footprint. The existing outlet gates and gate tower would be removed. The beach between the current reservoir shore and the remaining natural lake would be seeded.

The description above presents the probable minimum requirements for decommissioning the dam. A larger effort may be required to satisfy outside interests. This could involve reconstructing a natural channel upstream and downstream of the dam, completely removing the embankment material, or other major construction tasks.

The cost estimate assumes a breach channel would be excavated through the embankment capable of passing a 500-year flood with a peak flow of 76 cubic feet per second (cfs). Designing to this flood event would result in a stable channel during extreme flood events and minimize the potential for backwater impoundment against the dam. Changing the design flood would not significantly affect costs. The channel would be armored with riprap, and 2 acres of reservoir beach would be seeded. The seeding and re-vegetation plan would be prepared to minimize the introduction of invasive species and could incorporate seed collected on site.

According to FSM 2709.11, Dam Safety Definitions, a dam is ‘any artificial barrier, including appurtenant works, that impounds or diverts water, either temporarily or long term, but not including a facility that is 6 feet or less in height or that impounds no more than 15 acre-feet of water’. The decommissioning alternative could be modified such that some combination of dam height reduction and storage reduction essentially turned the dam into a pond. This sub-alternative may have advantages in terms of cost, aquatic life, and re-vegetation limits and could be further developed in the next phase of overall project development and analysis.

Advantages:

This alternative would eliminate current and future maintenance requirements, except for possible short-term maintenance while conditions equilibrate. Ownership of the former dam and reservoir could be returned to the FS. Decommissioning costs would likely be lower than rehabilitation costs, although that could depend on the scope of decommissioning work and FS requirements for restoration to simulate natural conditions.

Disadvantages:

With its water storage capacity eliminated, the water rights associated with Glacier Lake Dam would need to be modified or abandoned. Reestablishing vegetation on the reservoir beach would take years, and the remaining embankment section could be considered an aesthetic drawback. Potential late-season flow releases to Rattlesnake Creek would be lost, and the overall recreational appeal of the dam site could decrease.

Estimated Costs:

Costs for the Decommission option are based on the same assumptions as used for the Rehabilitation option. The estimated costs are as follows:

| | |
|---|---|
| Capital costs for this alternative | $127,000 |

## 9.7.4 Little Lake Dam

### Current Conditions

A Project Information Sheet for Little Lake Dam is located in Appendix K of this report, which provides detailed information about the dam and reservoir; a summary of current conditions related to different components of the dam and appurtenances; a summary of needed short-term repairs; and a conceptual-level cost estimate for completing short-term repairs.

Little Lake Dam impounds approximately 298 acre-feet of water (the third-largest reservoir (out of eight total) in the Wilderness owned by the City of Missoula). It is an easement dam, meaning the dam and appurtenances are located on a pre-Federal Land Policy Management Act right-of-way. It does not fall under direct U.S. Forest Service authority; however, the FS has reserved the right to have input regarding actions taken on and around the dam. The dam is classified as having a “Significant” hazard classification, meaning that failure of the dam for any reason results in no probable human loss of life, but can cause non-recoverable environmental damage. A breach failure could result in erosion and sediment transfer to a tributary of Wrangle Creek, main stem Wrangle Creek, and ultimately to Rattlesnake Creek where bull trout (a threatened species) are present, which is the basis for the dam’s current Significant hazard rating.

The dam was originally built in 1912 as an earthen embankment with a timber rock crib core, as shown on the dam’s original construction drawings. The embankment crest is narrow (approximately 4 feet wide) which does not meet FS criteria. There is no instrumentation, such as piezometers, on the dam. The upstream slope is approximately 2:1 and is lined with riprap. It is in generally good condition except for evidence of a sinkhole that developed in 1996. The downstream slope is steep with slopes of 1 to 1.5:1 above a toe berm that was constructed as an emergency measure to stabilize the dam when the sinkhole developed. The steep slope portion has minor sloughing in places. Some excessive vegetation on all surfaces needs to be cut.

The spillway channel is in generally in good condition. The spillway was excavated to a low elevation in 1996 to prevent the reservoir from reaching the sinkhole elevation. Annual maintenance is needed to clear logs and other debris from the spillway channel and address minor erosion. It currently meets Forest Service design criteria for significant hazard dams. Seepage has not been observed recently because the reservoir is maintained at a low level. The dam has one pipe outlet, which is a smooth metal pipe with corrosion. The control valve is located on the downstream end, and the pipe also has a large bulge near the downstream end due to back pressure from the valve.

*Little Lake Dam developed a sinkhole in 1996 and the spillway was excavated at that time to prevent the reservoir from reaching the sinkhole elevation. Therefore, the dam currently impounds little beyond the natural lake level.*

## Alternatives

The following alternatives are presented to aid in deciding the eventual disposition of Little Lake Dam. The actions and costs of each alternative are based on the best available data at this time. Costs and tasks to complete each alternative may change as new information becomes available. Costs include construction and engineering design and construction oversight.

## No Action

The No Action alternative is to keep the dam and appurtenances in their current state with no improvements anticipated for the foreseeable future. The City would continue to monitor the dam, make minor repairs as needed, and take preventative action only if conditions indicate the dam would be in danger of failing.

Advantages:

The No Action alternative does not include initial capital improvement costs. There would still be annual costs for maintenance and owner inspections, and a cost for a periodic O&M engineer inspection once every five years and hazard assessment, as required by FS regulations.

Disadvantages:

The effects of aging on a dam over one hundred years old will continue. It is impossible to know when serious symptoms related to dam safety may appear, but they would be inevitable in the future. Due to current deficiencies, the ability of the dam to impound water is very limited. Costs to repair, replace or decommission the dam would eventually have to be expended in order to make the dam serviceable or address continued deterioration. Performing a structural stability analysis of an earthen dam requires a slope stability analysis. Although the FS does not have agency-specific guidance on conducting a structural analysis of an earthen dam, it references other suitable federal agency guidance. FSM 7525.42 states that the design of earthen side slopes can be accomplished using guidelines developed by the U.S. Army Corps of Engineers (USACOE) or U.S. Bureau of Reclamation (USBR). Criteria found in USDA-Natural Resources Conservation Service (NRCS) Technical Release 60 (TR-60) are consistent with USACOE and USBR criteria and is used often on FS dams. No geotechnical investigations or analyses have been completed on the dam. Sloughing on the downstream slope indicates the dam is not stable in its current condition, and the crest width is not in compliance with FS standards. The no action alternative for the dam would increase the City's risk and liability.

Estimated Costs:

| | |
|---|---|
| No capital improvement costs for this alternative | $0 |

(It should be noted that under the no action alternative, regular operations and maintenance costs would still be required, and would likely increase over time.)

### Rehabilitate to Meet Forest Service Standards

The rehabilitation alternative would address deficiencies on the existing dam, as described in the Current Conditions section, and bring the dam into compliance with FS standards. Proposed repairs would include:

- Performing a geotechnical investigation and analysis;
- Addressing any seepage issues by lining the upstream slope with an impermeable liner;
- Addressing the narrow crest and potential slope stability concerns by adding fill on the downstream slope;
- Replacing the outlet valve;
- Slip-lining of the outlet pipe;
- Extending the outlet pipe to accommodate the added fill on the downstream slope; and
- Repairing the spillway.

The embankment materials at Little Lake Dam are prone to seepage, which can result in embankment piping (internal erosion). The embankment could be reconstructed with more suitable embankment materials, but that would be expensive and potentially problematic due to the limited soil resources at the site.

A more reasonable solution to eliminate the piping concern is lining the upstream embankment slope with an impermeable geomembrane liner. This option would require temporarily removing the upstream riprap, preparing the liner subgrade, installing a geomembrane liner with cushion geotextile on both sides, and replacing the upstream riprap.

In addition, the crest is narrow and needs to be widened to a minimum of 12 feet in order to meet FS criteria. In order to accomplish this, fill would be placed on the downstream slope. The new fill material could be coarse gravel and sand obtained from within the reservoir footprint. At this time, it is recommended that the downstream slope would be flattened to 1.5:1, based on experience with repairs on similar wilderness dams. The existing 2:1 upstream and proposed 1.5:1 downstream slopes are steeper than recommended in the NRCS Conservation Practice Standard POND (No.) CODE 378;

however, the upstream liner would eliminate the high phreatic surface in the embankment and address potential issues from rapid drawdown and other concerns that earthen embankment dam standards take into consideration. Slope stability analyses would be conducted to verify that the combination of slopes (2:1 upstream and 1.5:1 downstream) with an upstream liner under various loading conditions meet FS criteria. If not, then the downstream slope would be adjusted until criteria are met. The new material on the downstream slope would effectively cover the existing toe berm. The outlet would need to be extended approximately 10 feet to reach the new dam toe, depending on the actual downstream slope and a new valve would need to be installed on the downstream side.

Spillway repair would consist of rebuilding the portion of the spillway that was excavated as an emergency measure in 1996. The new portion could be constructed with earthen fill and lined with local riprap for channel stability. The modified spillway would be designed to pass the required flow with a stable transition into the natural channel.

Advantages:

The rehabilitation alternative would address long-term concerns at the dam and would bring the dam into compliance with FS standards. With a stable dam embankment and a higher spillway crest, the reservoir impoundment volume will be increased to the level it was prior to the 1996 emergency repairs. The improvements proposed for rehabilitation would likely be necessary to even consider raising the dam to increase storage capacity.

Disadvantages:

The rehabilitation alternative would require a large capital improvement investment as well as ongoing operation and maintenance costs. While most seepage would be blocked, it is possible that foundation seepage could occur, which has the potential to pipe foundation material and undermine the dam.

Estimated Costs:

Rehabilitation costs are estimated using unit costs from recent wilderness dams repair work. Remote access necessitates helicopter transportation for personnel, equipment and construction materials. Construction costs for remote access dams can be five to ten times that of conventional construction. Estimated costs presented here include mobilization and demobilization costs, engineering and construction management fees, and a contingency of 30 percent. The estimated costs are as follows:

| | |
|---|---|
| Capital improvement costs | $1,125,000 |
| Existing Water Right | 300 ac-ft |
| Cost per acre-foot | $3,751 |

### Increase Storage

The alternative to increase storage would be a combination of raising the embankment height and completing rehabilitation items discussed above. With a surface area of approximately 17.9 acres, raising Little Lake Dam even a few feet could result in a significant increase in storage capacity. This alternative would be combined with the decommissioning of one or more other dams and would offset the lost storage volume.

Because of the already narrow dam crest, raising the dam approximately 4 feet (which is estimated only for purposes of this analysis – actual increase in height would be based on a cost:benefit analysis) would require additional fill beyond that estimated for rehabilitation. Raising the dam 4 feet would increase the height from 25 to 29 feet, which requires a minimum crest width of 12.8 feet to meet FS standards. Additional required embankment material was estimated assuming a 13-foot crest width, 2:1 upstream slope, and 1.5:1 downstream slope. The outlet pipe would need to be extended 15 feet. The modification would add approximately 74 acre-feet of reservoir storage, a 25% increase.

Advantages:

The Increase Storage alternative would offset potential loss of storage volume by decommissioning other City-owned dams in the Wilderness, and the City could potentially retain existing water storage and water rights while reducing the number of dams that require future maintenance.

Disadvantages:

There is an initial capital improvement cost associated with this alternative, and the alternative cannot be implemented without completing rehabilitation work. Some cost efficiency would be realized by increasing storage at the time rehabilitation work is completed. Increasing the dam storage capacity would also increase the peak flow in the event of a dam breach, and a revised hazard assessment would be required. An evaluation would be needed to determine the effect on the current dam hazard classification. Since the current classification and spillway capacity criteria are based on the effect from dam failure, the amount of increased storage that could be added without changing the current dam hazard classification would have to be examined closely.

Estimated Costs:

Costs for Increased Storage are based on the same assumptions as used for the Rehabilitation option. The estimated costs are as follows:

| | |
|---|---|
| Capital improvement costs for this alternative alone* | $895,000 |
| Increased water storage | 74 ac-ft |
| Cost per acre-foot for this alternative alone | $12,096 |
| Capital improvement costs including rehabilitation* | $2,020,000 |
| Existing water right plus increased storage | 374 ac-ft |
| Cost per acre-foot including rehabilitation alternative | $5,402 |

**Costs do not account for potential savings achieved by eliminating repair costs at other dam(s)*

### Decommission

The alternative to decommission the dam would involve breaching a portion of the dam and constructing a channel to route flows past the dam to an outlet channel. Breaching the dam would eliminate its storage capacity. A stable breach channel would be excavated through the dam embankment to safely route a 100-year or larger inflow design flood and to avoid any backwater impoundment against the remaining portion of the dam. The channel could feature a control sill to reduce sediment releases until the reservoir beach stabilizes. Excavated material could be dispersed to blend within the surrounding ground in the reservoir footprint.  The existing outlet gates and gate tower would be removed. The beach between the current reservoir shore and the remaining natural lake would be seeded.

The description above presents the probable minimum requirements for decommissioning the dam. A larger effort may be required to satisfy outside interests. This could involve reconstructing a natural channel upstream and downstream of the dam, completely removing the embankment material, or other major construction tasks.

The cost estimate assumes a breach channel would be excavated through the embankment capable of passing a 500-year flood with a peak flow of 100 cubic feet per second (cfs). Designing to this flood event would result in a stable channel during extreme flood events and minimize the potential for backwater impoundment against the dam. Changing the design flood would not significantly affect costs. The channel would be armored with riprap, and 2 acres of reservoir beach would be seeded. The seeding and re-vegetation plan would be prepared to minimize the introduction of invasive species and could incorporate seed collected on site.

According to FSM 2709.11, Dam Safety Definitions, a dam is ‘any artificial barrier, including appurtenant works, that impounds or diverts water, either temporarily or long term, but not including a facility that is 6 feet or less in height or that impounds no more than 15 acre-feet of water’. The decommissioning alternative could be modified such that some combination of dam height reduction and storage reduction essentially turned the dam into a pond. This sub-alternative may have advantages in terms of cost, aquatic life, and re-vegetation limits and could be further developed in the next phase of overall project development and analysis.

Advantages:

The Decommission alternative would eliminate current and future maintenance requirements, except for possible short-term maintenance while conditions equilibrate. Ownership of the former dam and reservoir could be returned to the FS. Decommissioning costs would likely be lower than rehabilitation costs, although that could depend on the scope of decommissioning work and FS requirements for restoration to simulate natural conditions.

Disadvantages:

With its water storage capacity eliminated, the water rights associated with Little Lake Dam would need to be modified or abandoned. Reestablishing vegetation on the reservoir beach would take years, and the remaining embankment section could be considered an aesthetic drawback. Potential late-season flow releases to Rattlesnake Creek would be lost, and the overall recreational appeal of the dam site could decrease.

Estimated Costs:

Costs for the Decommission option are based on the same assumptions as used for the Rehabilitation option. The estimated costs are as follows:

| | |
|---|---|
| Capital costs for this alternative | $473,000 |

## 9.7.5 McKinley Lake Dam

### Current Conditions

A Project Information Sheet for McKinley Lake Dam is located in Appendix K of this report, which provides detailed information about the dam and reservoir; a summary of current conditions related to different components of the dam and appurtenances; a summary of needed short-term repairs; and a conceptual-level cost estimate for completing short-term repairs.

McKinley Lake Dam impounds approximately 168 acre-feet of water (the fifth-largest reservoir (out of eight total) in the Wilderness owned by the City of Missoula). It is an easement dam, meaning the dam and appurtenances are located on a pre-Federal Land Policy Management Act right-of-way. It does not fall under direct U.S. Forest Service authority; however, the FS has reserved the right to have input regarding actions taken on and around the dam. The dam is classified as having a “Significant” hazard classification, meaning that failure of the dam for any reason results in no probable human loss of life, but can cause non-recoverable environmental damage. A breach failure could result in erosion and sediment transfer to Roosevelt Lake and then Carter Lake and possibly to Lake Creek and ultimately to Rattlesnake Creek where bull trout (a threatened species) are present, which is the basis for the dam’s current Significant hazard rating.

The dam was originally built in 1923 as an earthen embankment. The construction drawings do not show a timber rock crib core, but this has not yet been verified. The embankment crest is 12 feet wide, which meets FS criteria for the approximately 15-foot dam height. There is no instrumentation, such as piezometers, on the dam. The upstream slope varies from around 1:1 to 2:1, while the downstream slope is very steep and estimated at 0.3:1. The upstream slope is lined with riprap and shows some signs of erosion, mostly in the area of the outlet. The crest has been observed in the past to slope slightly to the upstream side in the area of the outlet and has been monitored for many years, however no movement has been observed in recent years. The downstream slope is constructed with stacked rock. With the exception of the crest area near the outlet, the embankment does not exhibit signs of instability. Some excessive vegetation on all surfaces needs to be cut.

*The spillway channel has eroded much of the hillside and a severe headcut is continuing to advance toward the reservoir. Under all alternatives, re-routing the spillway back to the natural channel should be evaluated to eliminate future erosion.*

The existing spillway channel leads to a steep slope that drops over 100 feet before rejoining the main stream channel. As a result, the spillway channel has eroded much of the hillside on which it flows and there is a severe headcut in the spillway channel that is continuing to advance toward the reservoir. The headcut is currently being monitored for movement using set rebar monuments to measure erosion progress. Annual maintenance is needed to clear logs and other debris from the spillway approach channel.

Spillway capacity currently meets FS design criteria for an existing significant hazard dam but would need to be increased if the dam is rehabilitated. Significant seepage has been observed in the past along the dam toe during high reservoir levels. The dam has one pipe outlet, which is a corrugated metal pipe (CMP) with heavy corrosion. The control valve on the upstream end is left open to keep the reservoir level low and minimize flow through the eroding spillway. The valve is protected by a metal structure that is continually damaged by ice and needs replacement.

## Alternatives

The following alternatives are presented to aid in deciding the eventual disposition of McKinley Lake Dam. The actions and costs of each alternative are based on the best available data at this time. Costs and tasks to complete each alternative may change as new information becomes available.  Costs include construction and engineering design and construction oversight.

## No Action

The No Action alternative is to keep the dam and appurtenances in their current state with no improvements anticipated for the foreseeable future. The City would continue to monitor the dam, make minor repairs as needed, and take preventative action only if conditions indicate the dam would be in danger of failing.

Advantages:

The No Action alternative does not include initial capital improvement costs. There would still be annual costs for maintenance and owner inspections, and a cost for a periodic O&M engineer inspection and hazard assessment once every five years, as required by FS regulations.

Disadvantages:

The effects of aging on a dam nearly one hundred years old will continue. It is impossible to know when serious symptoms related to dam safety may appear, but they would be inevitable in the future. Costs to repair, replace or decommission the dam would eventually have to be expended at the time that serious deficiencies arise. Performing a structural stability analysis of an earthen dam requires a slope stability analysis. Although the FS does not have agency-specific guidance on conducting a structural analysis of an earthen dam, it references other suitable federal agency guidance. FSM 7525.42 states that the design of earthen side slopes can be accomplished using guidelines developed by the U.S. Army Corps of Engineers (USACOE) or U.S. Bureau of Reclamation (USBR). Criteria found in USDA-Natural Resources Conservation Service (NRCS) Technical Release 60 (TR-60) are consistent with USACOE and USBR criteria and is used often on FS dams. A report prepared by GMT Consultants in 1997 (*Preliminary Geotechnical Evaluation and Slope Stability Analysis, 6 Dam Sites - Rattlesnake Wilderness*) evaluated the downstream slope and it produced a safety factor of 1.20. However, the report indicated that the slope was input to the model as 0.9:1, which is flatter than the actual slope, and that it was modeled as a stacked-rock slope, which may be accurate. The GMT report also noted that a “critical condition could occur” if the reservoir reaches the spillway level in its current condition. The no action alternative for the dam would increase the City’s risk and liability.

Estimated Costs:

No capital improvement costs for this alternative $0

(It should be noted that under the no action alternative, regular operations and maintenance costs would still be required, and would likely increase over time.)

### Rehabilitate to Meet Forest Service Standards

The rehabilitation alternative would address deficiencies on the existing dam, as described in the Current Conditions section, and bring the dam into compliance with FS standards. Proposed repairs would include:

- Performing a geotechnical investigation and analysis;
- Addressing any seepage issues by lining the upstream slope with an impermeable liner;
- Addressing potential slope stability concerns by adding fill on the upstream and downstream slopes;
- Removing and replacing the outlet pipe and extending to accommodate added fill;
- Rebuilding the outlet intake tower;
- Replacing the outlet valve; and
- Repairing the spillway.

The embankment materials at McKinley Lake Dam are prone to seepage, which can result in embankment piping (internal erosion). The embankment could be reconstructed with more suitable embankment materials, but that would be expensive and potentially problematic due to the limited soil resources at the site.

A more reasonable solution to eliminate the piping concern is lining the upstream embankment slope with an impermeable geomembrane liner. This option would require temporarily removing the upstream riprap, preparing the liner subgrade, installing a geomembrane liner with cushion geotextile on both sides, and replacing the upstream riprap.

In addition, both the upstream and downstream embankment slopes are steep and probably need to be flattened to meet slope stability criteria. The new fill material could be coarse gravel and sand obtained from within the reservoir footprint. An upstream slope of 2:1 and downstream slope of 1.5:1 are proposed conceptually. The existing and proposed slopes are steeper than recommended in the NRCS Conservation Practice Standard POND (No.) CODE 378. Flattening the embankment slopes, in combination with an upstream liner that eliminates a high phreatic surface in the embankment, would address potential issues from rapid drawdown and other concerns that earthen embankment dam standards take into consideration. Slope stability analyses would be conducted to verify that the proposed combination of slopes with an upstream liner under various loading conditions meet FS criteria. If not, then the downstream slope would be flattened until criteria are met. The replacement outlet pipe would be slightly longer than the existing slope because of the added fill.

Spillway repair would consist of either repairing and stabilizing the existing spillway or constructing a new spillway along a new alignment to the natural stream channel. The repair alternative would involve replacing eroded material in the area of the headcut with native borrow material and stabilizing with erosion resistant material. One possible solution is the installation of an articulated concrete block mat. Mobilizing the material to the site would be expensive but may be an effective tool to stabilize the spillway. If a new spillway channel is constructed to tie in to the stream channel, it would likely include riprap stabilization or a drop structure to dissipated energy. The new or repaired channel would be designed to pass the required flow and at the same time prevent erosion and headcutting.

Advantages:

The rehabilitation alternative would address long-term concerns at the dam and would bring the dam into compliance with FS standards. The improvements proposed for rehabilitation would likely be necessary to even consider raising the dam to increase storage capacity.

Disadvantages:

The rehabilitation alternative would require a large capital improvement investment as well as ongoing operation and maintenance costs. While most seepage would be blocked, it is possible that foundation seepage could occur, which has the potential to pipe foundation material and undermine the dam.

Estimated Costs:

Rehabilitation costs are estimated using unit costs from recent wilderness dams repair work. Remote access necessitates helicopter transportation for personnel, equipment and construction materials. Construction costs for remote access dams can be five to ten times that of conventional construction. Estimated costs presented here include mobilization and demobilization costs, engineering and construction management fees, and a contingency of 30 percent. The estimated costs are as follows:

| | |
|---|---|
| Capital improvement costs | $1,084,000 |
| Existing Water Right | 195 ac-ft |
| Cost per acre-foot | $5,577 |

### Increase Storage

The alternative to increase storage would be a combination of raising the embankment height and completing rehabilitation items discussed above. With a surface area of approximately 17.6 acres, raising McKinley Lake Dam even a few feet could result in a significant increase in storage capacity. This alternative would be combined with the decommissioning of one or more other dams and would offset the lost storage volume.

Because of the already narrow dam crest, raising the dam approximately 4 feet (which is estimated only for purposes of this analysis – actual increase in height would be based on a cost:benefit analysis) would require additional fill beyond that estimated for rehabilitation. Raising the dam 4 feet would increase the height from 15 to 19 feet, which requires a minimum crest width of 10.8 feet to meet FS standards. Additional required embankment material was estimated assuming an 11-foot crest width, 2:1 upstream slope, and 1.5:1 downstream slope. The outlet pipe would need to be extended 14 feet. The modification would increase reservoir storage approximately 72 acre-feet, a 37% increase.

Advantages:

The Increase Storage alternative would offset potential loss of storage volume by decommissioning other City-owned dams in the Wilderness, and the City could potentially retain existing water storage while reducing the number of dams that require future maintenance.

Disadvantages:

There is an initial capital improvement cost associated with this alternative, and the alternative cannot be implemented without completing rehabilitation work. Some cost efficiency would be realized by increasing storage at the time rehabilitation work is completed. Increasing the dam storage capacity would also increase the peak flow in the event of a dam breach, and a revised hazard assessment would be required. An evaluation would be needed to determine the effect on the current dam hazard classification. Since the current classification and spillway capacity criteria are based on the effect from dam failure, the amount of increased storage that could be added without changing the current dam hazard classification would have to be examined closely.

Estimated Costs:

Costs for Increased Storage are based on the same assumptions as used for the Rehabilitation option. The estimated costs are as follows:

| | |
|---|---|
| Capital improvement costs for this alternative alone* | $706,000 |
| Increased water storage | 72 ac-ft |
| Cost per acre-foot for this alternative alone | $9,800 |
| Capital improvement costs including rehabilitation* | $1,789,000 |
| Existing water right plus increased storage | 267 ac-ft |
| Cost per acre-foot including rehabilitation alternative | $6,701 |

**Costs do not account for potential savings achieved by eliminating repair costs at other dam(s)*

## Decommission

The alternative to decommission the dam would involve breaching a portion of the dam and constructing a channel to route flows past the dam to an outlet channel. Breaching the dam would eliminate its storage capacity. A stable breach channel would be excavated through the dam embankment to safely route a 100-year or larger inflow design flood and to avoid any backwater impoundment against the remaining portion of the dam. The channel could feature a control sill to reduce sediment releases until the reservoir beach stabilizes. Excavated material could be dispersed to blend within the surrounding ground in the reservoir footprint. The existing outlet gates and gate tower would be removed. The beach between the current reservoir shore and the remaining natural lake would be seeded. Erosion along the existing spillway immediately downstream of the dam would be backfilled and seeded as a stabilization measure.

The description above presents the probable minimum requirements for decommissioning the dam. A larger effort may be required to satisfy outside interests. This could involve reconstructing a natural channel upstream and downstream of the dam, completely removing the embankment material, a greater rehabilitation effort along the existing spillway channel, or other major construction tasks.

The cost estimate assumes a breach channel would be excavated through the embankment capable of passing a 500-year flood with a peak flow of 65 cubic feet per second (cfs). Designing to this flood event would result in a stable channel during extreme flood events and minimize the potential for backwater impoundment against the dam. Changing the design flood would not significantly affect costs. The channel would be armored with riprap, and 5 acres of reservoir beach would be seeded. The seeding and re-vegetation plan would be prepared to minimize the introduction of invasive species and could incorporate seed collected on site.

According to FSM 2709.11, Dam Safety Definitions, a dam is ‘any artificial barrier, including appurtenant works, that impounds or diverts water, either temporarily or long term, but not including a facility that is 6 feet or less in height or that impounds no more than 15 acre-feet of water’. The decommissioning alternative could be modified such that some combination of dam height reduction and storage reduction essentially turned the dam into a pond. This sub-alternative may have advantages in terms of cost, aquatic life, and re-vegetation limits and could be further developed in the next phase of overall project development and analysis.

Advantages:

The Decommission alternative would eliminate current and future maintenance requirements, except for possible short-term maintenance while conditions equilibrate. Ownership of the former dam and reservoir could be returned to the FS. Decommissioning costs would likely be lower than rehabilitation costs, although that could depend on the scope of decommissioning work and FS requirements for restoration to simulate natural conditions.

Disadvantages:

With its water storage capacity eliminated, the water rights associated with McKinley Lake Dam would need to be modified or abandoned. Reestablishing vegetation on the reservoir beach would take years, and the remaining embankment section could be considered an aesthetic drawback. Potential late-season flow releases to Rattlesnake Creek would be lost, and the overall recreational appeal of the dam site could decrease.

Estimated Costs:

Costs for the Decommission option are based on the same assumptions as used for the Rehabilitation option. The estimated costs are as follows:

| | |
|---|---|
| Capital costs for this alternative | $173,000 |

## 9.7.6 Sanders North and South Dams

### Current Conditions

Project Information Sheets for Sanders Lake North Dam and South Dam are located in Appendix K of this report, which provide detailed information about the dams and reservoir; a summary of current conditions related to different components of the dams and appurtenances; a summary of needed short-term repairs; and a conceptual-level cost estimate for completing short-term repairs.

The reservoir at Sanders Lake is created by two dams – the North Dam (Dam No. 1) and South Dam (Dam No. 2). The Sanders Lake dams impound approximately 897 acre-feet of water (the largest reservoir in the Wilderness owned by the City of Missoula (out of 8 total)). The North Dam is an easement dam, meaning the dam and appurtenances are located on a pre-Federal Land Policy Management Act right-of-way. The dam does not fall under direct U.S. Forest Service authority; however, the FS has reserved the right to have input regarding actions taken on and around the dam. The South Dam operates under a Special Use Permit issued by the Lolo National Forest of the U.S. Forest Service and is regulated under the authority of the FS dam safety laws. Both dams are classified as having a “Significant” hazard classification, meaning that failure of a dam for any reason results in no probable human loss of life, but can cause non-recoverable environmental damage. A breach failure could result in erosion and sediment transfer to Wrangle Creek and ultimately to Rattlesnake Creek where bull trout (a threatened species) are present, which is the basis for the current Significant hazard ratings. The North and South dams were originally built in 1913 and 1915, respectively, as earthen embankments with rock timber crib cores.

The smaller North Dam is approximately 10 feet high with a crest width of 7 feet, which does not meet FS criteria of 10 feet minimum. There is no instrumentation, such as piezometers, on the dam. The upstream slope is approximately 2:1, is lined with riprap, and is in good condition. The downstream slope is approximately 1.5:1 and appears stable. Vegetation is growing on much of the embankment that needs to be trimmed. Rodent damage is also prevalent on the embankment. The spillway is in good condition and meets FS design criteria. Significant seepage has been documented in the downstream toe area of the dam with a high reservoir pool. The dam features a downstream weir for measuring seepage flows, but the weir misses some seepage and also captures some of the outlet pipe discharge when the valve is open. A portion of the seepage flow may originate from a spring rather than the dam. The dam has one pipe outlet, which is a corrugated metal pipe (CMP). The pipe is corroded and has several visible cracks near the upstream end. The control valve is located on the upstream end of the pipe and is left open due to difficult access.

The larger South Dam is approximately 14 feet high with a crest width of 5 feet, which also does not meet FS criteria of 10 feet minimum. There is no instrumentation, such as piezometers, on the dam. The upstream slope is approximately 2:1, lined with riprap, and is in fair condition with some wave erosion evident. The rock-lined downstream slope is steep with a slope of 0.3:1. The downstream slope features one notable bulge and areas where rock has fallen from the slope. Woody debris and vegetation on the upstream slope and crest require removal. No seepage is evident downstream of the dam. The Sanders Lake spillway is associated with the North Dam. The South Dam also has one pipe outlet, which is a corrugated metal pipe (CMP) with a 5-foot PVC extension. The pipe is corroded and has one visible hole near the upstream end. The control valve is located on the upstream end of the pipe and is left open. The valve is inaccessible because ice has destroyed the timber access structure.

## Alternatives

The following alternatives are presented to aid in deciding the eventual disposition of the Sanders Lake dams. The actions and costs of each alternative are based on the best available data at this time. Costs and tasks to complete each alternative may change as new information becomes available.  Costs include construction and engineering design and construction oversight.

## No Action

The No Action alternative is to keep the dams and appurtenances in their current state with no improvements anticipated for the foreseeable future. The City would continue to monitor the dams, make minor repairs as needed, and take preventative action only if conditions indicate a dam is in danger of failing.

Advantages:

The No Action alternative does not include initial capital improvement costs. There would still be annual costs for maintenance and owner inspections, and a cost for a periodic O&M engineer inspection and hazard assessment once every five years, as required by FS regulations.

Disadvantages:

The effects of aging on the one hundred year old dams will continue. It is impossible to know when serious symptoms related to dam safety may appear, but they would be inevitable in the future. Costs to repair, replace or decommission the dams would eventually have to be expended to address deficiencies. Performing a structural stability analysis of an earthen dam requires a slope stability analysis. Although the FS does not have agency-specific guidance on conducting a structural analysis of an earthen dam, it references other suitable federal agency guidance. FSM 7525.42 states that the design of earthen side slopes can be accomplished using guidelines developed by the U.S. Army Corps of Engineers (USACOE) or U.S. Bureau of Reclamation (USBR). Criteria found in USDA-Natural Resources Conservation Service (NRCS) Technical Release 60 (TR-60) are consistent with USACOE and USBR criteria and is used often on FS dams. A report prepared by GMT Consultants in 1997 (*Preliminary Geotechnical Evaluation and Slope Stability Analysis, 6 Dam Sites - Rattlesnake Wilderness*) evaluated the downstream slope of both dams. In the most conservative case, the report produced a safety factor of 1.62 for the North Dam and 1.25 for the South Dam. However, the report indicated that the South Dam slope was input to the model as 1.1:1, which is flatter than the actual slope. The crest width is also out of compliance with FS standards on both dams. The no action alternative for the dams would increase the City's risk and liability.

Estimated Costs:

| | |
|---|---|
| No capital improvement costs for this alternative | $0 |

(It should be noted that under the no action alternative, regular operations and maintenance costs would still be required, and would likely increase over time.)

## Rehabilitate to Meet Forest Service Standards

The rehabilitation alternative would address deficiencies on the existing dams, as described in the Current Conditions section, and bring the dams into compliance with FS standards. Proposed repairs would include:

- Performing a geotechnical investigation and analysis;
- Addressing seepage issues by lining the upstream slopes with an impermeable liner;
- Addressing the narrow crests and slope stability concerns by adding fill on the downstream slopes;
- Slip-lining the outlet pipes;
- Constructing new outlet access towers;
- Extending the outlet pipe to accommodate the added fill on the downstream slope; and
- Repairing the spillway.

The embankment materials at both Sanders Lake dams are prone to seepage, which can result in embankment piping (internal erosion). The embankments could be reconstructed with suitable embankment materials, but that would be expensive and potentially problematic due to the limited soil resources at the site.

A more reasonable solution to eliminate the piping concern is lining the upstream embankment slopes with an impermeable geomembrane liner. This option would require temporarily removing the upstream riprap, preparing the liner subgrade, installing a geomembrane liner with cushion geotextile on both sides, and replacing the upstream riprap.

In addition, the dam crests are narrow and needs to be widened to a minimum of 10 feet in order to meet FS criteria. Along with this, the steep downstream embankment slope on the South Dam could be flattened to produce a more stable embankment. The new fill material could be coarse gravel and sand obtained from within the reservoir footprint. Additional embankment fill could significantly increase stability, especially in combination with an upstream liner that eliminates the high phreatic surface in the embankment, potential issues from rapid drawdown, and other concerns that earthen embankment dam standards take into consideration. At this time, it is recommended that the downstream slope would be flattened to 1.5:1, based on experience with repairs on similar wilderness dams. The proposed 1.5:1 downstream slopes and existing 2:1 upstream slopes are steeper than recommended in the NRCS Conservation Practice Standard POND (No.) CODE 378. Slope stability analyses would be conducted to verify that the combination of slopes with an upstream liner under various loading conditions meet FS criteria. If not, then the downstream slope would be flattened until criteria are met. The slip-lined outlet pipes would each need to be extended beyond the existing pipe to reach the new dam toe. If a 1.5:1 downstream slope is used, the north outlet would be extended about 4 feet and the south outlet would be extended about 20 feet. At the South Dam, downstream side of the widened embankment could be limited by the cliff located just downstream of the dam. Some fill may also need to be added to the upstream slope to achieve the minimum crest width and flatter downstream slope. Rodent holes would be filled when new embankment material was placed. No spillway improvements are proposed.

Advantages:

The rehabilitation alternative would address long-term concerns at Sanders Lake and would bring the dams into compliance with FS standards. The improvements proposed for rehabilitation would likely be necessary to even consider raising the dam to increase storage capacity.

Disadvantages:

The rehabilitation alternative would require a large capital improvement investment as well as ongoing operation and maintenance costs. While most seepage would be blocked, it is possible that foundation seepage could occur, which has the potential to pipe foundation material and undermine the dam.

Estimated Costs:

Rehabilitation costs are estimated using unit costs from recent wilderness dams repair work. Remote access necessitates helicopter transportation for personnel, equipment and construction materials. Construction costs for remote access dams can be five to ten times that of conventional construction. Estimated costs presented here include mobilization and demobilization costs, engineering and construction management fees, and a contingency of 30 percent. The estimated costs are as follows:

| | |
|---|---|
| Capital improvement costs for North Dam | $388,000 |
| Capital improvement costs for South Dam | $783,000 |
| Total capital improvement costs | $1,171,000 |
| Existing Water Right | 905 ac-ft |
| Cost per acre-foot | $1,294 |

### Increase Storage

*Sanders Dam is the largest impoundment owned by the City, and raising the embankment 4 feet would increase the storage approximately 200 ac-ft.*

The alternative to increase storage would be a combination of raising the embankment crests and completing rehabilitation items discussed above. With a surface area of approximately 47.3 acres, Sanders Lake is the largest of the wilderness reservoirs by area. Raising the Sanders Lake dams a few feet could result in a significant increase in storage capacity. This alternative would be combined with the decommissioning of one or more other dams and would offset the lost storage volume.

Because of the already narrow dam crests, raising the dam approximately 4 feet (which is estimated only for purposes of this analysis – actual increase in height would be based on a cost:benefit analysis) would require additional fill beyond that estimated for rehabilitation. Raising the dams 4 feet would increase the North and South dam heights to 14 and 18 feet, respectively. Crest widths of 10 feet for the North Dam and 11 feet for the South Dam are proposed to meet FS standards. Additional fill would be placed on the downstream slope of the North Dam, but fill would need to be placed on the upstream slope of the South Dam because of the limited downstream space. Required embankment volume was estimated assuming 2:1 upstream slopes and 1.5:1 downstream slopes. The outlet pipes would need to be extended about 15 feet each. The modification would increase reservoir storage approximately 193 acre-feet, a 21% increase.

Advantages:

The Increase Storage alternative would offset potential loss of storage volume by decommissioning other City-owned dams in the Wilderness, and the City could potentially retain existing water storage and water rights while reducing the number of dams that require future maintenance.

Disadvantages:

There is an initial capital improvement cost associated with this alternative, and the alternative cannot be implemented without completing rehabilitation work. Some cost efficiency would be realized by increasing storage at the time rehabilitation work is completed. Increasing the dam storage capacity would also increase the peak flow in the event of a dam breach, and a revised hazard assessment would be required. An evaluation would be needed to determine the effect on the current dam hazard classification. Since the current classification and spillway capacity criteria are based on the effect from dam failure, the amount of increased storage that could be added without changing the current dam hazard classification would have to be examined closely.

Estimated Costs:

Costs for Increased Storage are based on the same assumptions as used for the Rehabilitation option. The estimated costs are as follows:

| | |
|---|---|
| Capital improvement costs for this alternative alone (both dams)* | $1,118,000 |
| Increased water storage | 193 ac-ft |
| Cost per acre-foot for this alternative alone | $5,792 |
| Capital improvement costs including rehabilitation (both dams)* | $2,289,000 |
| Existing water right plus increased storage | 1,098 ac-ft |
| Cost per acre-foot including rehabilitation alternative | $2,084 |

**Costs do not account for potential savings achieved by eliminating repair costs at other dam(s)*

### Decommission

The alternative to decommission the dams would involve breaching a portion of the South Dam and constructing a channel to route flows past the dam to the outlet channel. It appears the South Dam toe is lower than the North Dam, so if it were breached the North Dam would no longer impound water. The South Dam also aligns with the natural channel. Breaching the South Dam would eliminate the reservoir storage capacity. This proposal would keep the North Dam in its current condition. A stable breach channel would be excavated through the dam embankment to safely route a 100-year or larger inflow design flood and to avoid any backwater impoundment against the remaining portion of the dam. The channel could feature a control sill to reduce sediment releases until the reservoir beach stabilizes. Excavated material could be dispersed to blend within the surrounding ground in the reservoir footprint. The existing outlet gate and access structures would be removed. The beach between the current reservoir shore and the remaining natural lake would be seeded.

The description above presents the probable minimum requirements for decommissioning the dam. A larger effort may be required to satisfy outside interests. This could involve reconstructing a natural channel upstream and downstream of the dam, completely removing the embankment material, or other major construction tasks.

The cost estimate assumes a breach channel would be excavated through the embankment capable of passing a 500-year flood with a peak flow of 90 cubic feet per second (cfs). Designing to this flood event would result in a stable channel during extreme flood events and minimize the potential for backwater impoundment against the dam. Changing the design flood would not significantly affect costs. The channel would be armored with riprap, and 7 acres of reservoir beach would be seeded. The seeding and re-vegetation plan would be prepared to minimize the introduction of invasive species and could incorporate seed collected on site.

According to FSM 2709.11, Dam Safety Definitions, a dam is ‘any artificial barrier, including appurtenant works, that impounds or diverts water, either temporarily or long term, but not including a facility that is 6 feet or less in height or that impounds no more than 15 acre-feet of water’. The decommissioning alternative could be modified such that some combination of dam height reduction and storage reduction essentially turned the dam into a pond. This sub-alternative may have advantages in terms of cost, aquatic life, and re-vegetation limits and could be further developed in the next phase of overall project development and analysis.

Advantages:

The Decommission alternative would eliminate current and future maintenance requirements for both dams, except for possible short-term maintenance while conditions equilibrate. Ownership of the former dams and reservoir could be returned to the FS. Decommissioning costs would likely be lower than rehabilitation costs, although that could depend on the scope of decommissioning work and FS requirements for restoration to simulate natural conditions.

Disadvantages:

With its water storage capacity eliminated, the water rights associated with the Sanders Lake Dams would need to be modified or abandoned. Reestablishing vegetation on the reservoir beach would take years, and the remaining embankment section could be considered an aesthetic drawback. Potential late-season flow releases to Rattlesnake Creek would be lost, and the overall recreational appeal of the dam site could decrease.

Estimated Costs:

Costs for the Decommission option are based on the same assumptions as used for the Rehabilitation option. The estimated costs are as follows:

| | |
|---|---|
| Capital costs for this alternative | $159,000 |

## 9.7.7 Sheridan East and West Dams

### Current Conditions

Project Information Sheets for Sheridan Lake East Dam and West Dam are located in Appendix K of this report, which provide detailed information about the dams and reservoir; a summary of current conditions related to different components of the dams and appurtenances; a summary of needed short-term repairs; and a conceptual-level cost estimate for completing short-term repairs.

The reservoir at Sheridan Lake is created by two dams – the East Dam and West Dam. The Sheridan Lake Dams impound approximately 130 acre-feet of water (the second-smallest reservoir in the Wilderness owned by the City of Missoula (out of 8 total)). The dams operate under Special Use Permits issued by the Lolo National Forest of the U.S. Forest Service. The dams are regulated under the authority of the FS dam safety laws. The dams are classified as having a "Significant" hazard classification, meaning that failure of a dam for any reason results in no probable human loss of life, but can cause non-recoverable environmental damage. A breach failure could result in erosion and sediment transfer to Lake Creek and ultimately to Rattlesnake Creek where bull trout (a threatened species) are present, which is the basis for the dam's current Significant hazard rating. The dams were originally built in 1915 as earthen embankments with rock timber crib cores.

The larger East Dam is approximately 8 feet high with a crest width of 8 feet, which does not meet FS criteria of 10 feet minimum. The dam crest features two piezometers near the outlet pipe. The upstream slope is approximately 3:1, is lined with riprap, and is in good condition. The downstream slope is steep with a slope of 0.3:1 and is lined with stacked rock. Vegetation is growing on much of the embankment that needs to be trimmed. The spillway is in good condition. Annual maintenance is needed to clear logs and other debris from the spillway approach channel. Spillway capacity currently meets FS design criteria for an existing significant hazard dam but would need to be increased if the dam is rehabilitated. Significant seepage has been documented through the embankment and in the downstream toe area of the dam with a high reservoir pool. Because of this, a low pool has been maintained in recent years. The dam has one pipe outlet, which is a corrugated metal pipe (CMP). The pipe is severely corroded with many large holes. The control valve is located on the upstream end of the pipe, and the timber access structure is damaged and requires repair.

*The outlet pipe is corrugated metal pipe (CMP), approximately 100 years old. The useful life of CMP typically ranges from 20-40 years.*

The smaller West Dam is approximately 6 feet high with a crest width of 5 feet, which also does not meet FS criteria of 10 feet minimum. There is no instrumentation, such as piezometers, on the dam. The upstream slope is approximately 2:1, is lined with riprap, and is in good condition. The rock-lined downstream slope is steep with a slope of 0.5:1 but also in good condition. Vegetation is growing on much of the embankment that needs to be trimmed. Seepage is evident in the downstream toe area, even with a low reservoir pool. A nearby stream may be the source of the seepage, rather than the reservoir, but the source is not clear. The Sheridan Lake spillway and outlet are associated with the East Dam.

## Alternatives

The following alternatives are presented to aid in deciding the eventual disposition of the Sheridan Lake dams. The actions and costs of each alternative are based on the best available data at this time. Costs and tasks to complete each alternative may change as new information becomes available.  Costs include construction and engineering design and construction oversight.

## No Action

The No Action alternative is to keep the dams and appurtenances in their current state with no improvements anticipated for the foreseeable future. The City would continue to monitor the dams, make minor repairs as needed, and take preventative action only if conditions indicate a dam is in danger of failing.

Advantages:

The No Action alternative does not include initial capital improvement costs. There would still be annual costs for maintenance and owner inspections, and a cost for a periodic O&M engineer inspection and hazard assessment once every five years, as required by FS regulations.

Disadvantages:

The effects of aging on the one hundred year old dams will continue. Significant seepage at high pool is already a concern, and additional dam safety issues would be inevitable in the future. Costs to repair, replace or decommission the dams would eventually have to be expended to address deficiencies. Performing a structural stability analysis of an earthen dam requires a slope stability analysis. Although the FS does not have agency-specific guidance on conducting a structural analysis of an earthen dam, it references other suitable federal agency guidance. FSM 7525.42 states that the design of earthen side slopes can be accomplished using guidelines developed by the U.S. Army Corps of Engineers (USACOE) or U.S. Bureau of Reclamation (USBR). Criteria found in USDA-Natural Resources Conservation Service (NRCS) Technical Release 60 (TR-60) are consistent with USACOE and USBR criteria and is used often on FS dams. No geotechnical investigations or analyses have been completed on the dams.  The downstream slopes currently appear stable, but are much steeper than typically recommended.  The crest width is also out of compliance with FS standards on both dams. The no action alternative for the dams would increase the City’s risk and liability.

Estimated Costs:

| | |
|---|---|
| No capital improvement costs for this alternative | $0 |

(It should be noted that under the no action alternative, regular operations and maintenance costs would still be required, and would likely increase over time.)

## Rehabilitate to Meet Forest Service Standards

The rehabilitation alternative would address deficiencies on the existing dams, as described in the Current Conditions section, and bring the dams into compliance with FS standards. Proposed repairs would include:

- Performing a geotechnical investigation and analysis;

- Addressing seepage issues by lining the upstream slopes with an impermeable liner;
- Addressing the narrow crests and slope stability concerns by adding fill on the downstream slopes;
- Replacing the outlet pipe and valve;
- Rebuilding the outlet intake tower;
- Extending the outlet pipe to accommodate the added fill on the downstream slope; and
- Repairing the spillway.

The embankment materials at Sheridan Lake Dam are prone to seepage, which can result in embankment piping (internal erosion). The embankments could be reconstructed with suitable embankment materials, but that would be expensive and potentially problematic due to the limited soil resources at the site.

A more reasonable solution to eliminate the piping concern is lining the upstream embankment slopes with an impermeable geomembrane liner. This option would require temporarily removing the upstream riprap, preparing the liner subgrade, installing a geomembrane liner with cushion geotextile on both sides, and replacing the upstream riprap.

In addition, the dam crests are narrow and needs to be widened to a minimum of 10 feet in order to meet FS criteria. Along with this, the steep downstream embankment slopes could be flattened to produce a more stable embankment. The new fill material could be coarse gravel and sand obtained from within the reservoir footprint. Flattening the downstream slopes would significantly increase stability, especially in combination with an upstream liner that eliminates the high phreatic surface in the embankment, potential issues from rapid drawdown, and other concerns that earthen embankment dam standards take into consideration. At this time, it is recommended that the downstream slope would be flattened to 1.5:1, based on experience with repairs on similar wilderness dams. The proposed 1.5:1 downstream slopes, as well as the 2:1 upstream slope on the West Dam, are steeper than recommended in the NRCS Conservation Practice Standard POND (No.) CODE 378. Slope stability analyses would be conducted to verify that the combination of slopes with an upstream liner under various loading conditions meet FS criteria. If not, then the downstream slope would be flattened until criteria are met.  The replacement outlet pipe would need to be extended approximately 10 feet longer than the existing pipe to reach the new dam toe, if a 1.5:1 downstream slope is used.

Spillway improvements would consist of enlarging the spillway channel and/or lowering the spillway crest to meet required design capacity and stabilizing the channel with riprap. The area near the dam or around the reservoir has significant riprap rock available that hopefully could be utilized. The channel would have to be designed to pass the required flow and at the same time prevent erosion and headcutting.

Advantages:

The rehabilitation alternative would address long-term concerns at Sheridan Lake and would bring the dams into compliance with FS standards.  The improvements proposed for rehabilitation would likely be necessary to even consider raising the dam to increase storage capacity.

Disadvantages:

The rehabilitation alternative would require a large capital improvement investment as well as ongoing operation and maintenance costs. While most seepage would be blocked, it is possible that foundation seepage could occur, which has the potential to pipe foundation material and undermine the dam.

Estimated Costs:

Rehabilitation costs are estimated using unit costs from recent wilderness dams repair work. Remote access necessitates helicopter transportation for personnel, equipment and construction materials. Construction costs for remote access dams can be five to ten times that of conventional construction. Estimated costs presented here include mobilization and demobilization costs, engineering and construction management fees, and a contingency of 30 percent. The estimated costs are as follows:

| | |
|---|---|
| Capital improvement costs for East Dam | $452,000 |
| Capital improvement costs for West Dam | $96,000 |
| Total capital improvement costs | $548,000 |
| Existing Water Right | 115 ac-ft |
| Cost per acre-foot | $4,763 |

## Increase Storage

The alternative to increase storage would be a combination of raising the embankment crests and completing rehabilitation items discussed above. With a surface area of approximately 10.8 acres, raising the Sheridan Lake dams a few feet could result in a modest increase in storage capacity. This alternative would be combined with the decommissioning of one or more other dams and would offset the lost storage volume.

Because of the already narrow dam crest, raising the dam approximately 4 feet (which is estimated only for purposes of this analysis – actual increase in height would be based on a cost:benefit analysis) would require additional fill beyond that estimated for rehabilitation. Raising the dams 4 feet would increase the East and West dam heights to 12 and 10 feet, respectively, which requires a minimum crest width of 10 feet to meet FS standards. Additional required embankment material was estimated assuming 10-foot crest widths, 3:1 upstream slope (East Dam), 2:1 upstream slope (West Dam), and 1.5:1 downstream slopes. The outlet pipe would need to be extended 18 feet. The modification would increase reservoir storage approximately 45 acre-feet, a 39% increase.

Advantages:

The Increase Storage alternative would offset potential loss of storage volume by decommissioning other City-owned dams in the Wilderness, and the City could potentially retain existing water storage while reducing the number of dams that require future maintenance.

Disadvantages:

There is an initial capital improvement cost associated with this alternative, and the alternative cannot be implemented without completing rehabilitation work. Some cost efficiency would be realized by increasing storage at the time rehabilitation work is completed. Increasing the dam storage capacity would also increase the peak flow in the event of a dam breach, and a revised hazard assessment would be required. An evaluation would be needed to determine the effect on the current dam hazard classification. Since the current classification and spillway capacity criteria are based on the effect from dam failure, the amount of increased storage that could be added without changing the current dam hazard classification would have to be examined closely.

Estimated Costs:

Costs for Increased Storage are based on the same assumptions as used for the Rehabilitation option. The estimated costs are as follows:

| | |
|---|---|
| Capital improvement costs for this alternative alone (both dams)* | $557,000 |
| Increased water storage | 45 ac-ft |
| Cost per acre-foot for this alternative alone | $12,372 |
| Capital improvement costs including rehabilitation (both dams)* | $1,105,000 |
| Existing water right plus increased storage | 160 ac-ft |
| Cost per acre-foot including rehabilitation alternative | $6,903 |

**Costs do not account for potential savings achieved by eliminating repair costs at other dam(s)*

## Decommission

The alternative to decommission the dams would involve breaching a portion of the East Dam and constructing a channel to route flows past the dam to an outlet channel. The smaller West Dam would remain in place because it is not on a natural stream channel. Breaching the dam would eliminate the reservoir storage capacity. A stable breach channel would be excavated through the dam embankment to safely route a 100-year or larger inflow design flood and to avoid any backwater impoundment against the remaining portion of the dam. The channel could feature a control sill to reduce sediment releases until the reservoir beach stabilizes. Excavated material could be dispersed to blend within the surrounding ground in the reservoir footprint. The existing outlet gate and access structure would be removed. The beach between the current reservoir shore and the remaining natural lake would be seeded.

The description above presents the probable minimum requirements for decommissioning the dam. A larger effort may be required to satisfy outside interests. This could involve reconstructing a natural channel upstream and downstream of the dam, completely removing the embankment material, or other major construction tasks.

The cost estimate assumes a breach channel would be excavated through the embankment capable of passing a 500-year flood with a peak flow of 73 cubic feet per second (cfs). Designing to this flood event would result in a stable channel during extreme flood events and minimize the potential for backwater impoundment against the dam. Changing the design flood would not significantly affect costs. The channel would be armored with riprap, and 4 acres of reservoir beach would be seeded. The seeding and re-vegetation plan would be prepared to minimize the introduction of invasive species and could incorporate seed collected on site.

According to FSM 2709.11, Dam Safety Definitions, a dam is ‘any artificial barrier, including appurtenant works, that impounds or diverts water, either temporarily or long term, but not including a facility that is 6 feet or less in height or that impounds no more than 15 acre-feet of water’. The decommissioning alternative could be modified such that some combination of dam height reduction and storage reduction essentially turned the dam into a pond. This sub-alternative may have advantages in terms of cost, aquatic life, and re-vegetation limits and could be further developed in the next phase of overall project development and analysis.

Advantages:

The Decommission alternative would eliminate current and future maintenance requirements for both dams, except for possible short-term maintenance while conditions equilibrate. Ownership of the former dams and reservoir could be returned to the FS. Decommissioning costs would likely be lower than rehabilitation costs, although that could depend on the scope of decommissioning work and FS requirements for restoration to simulate natural conditions.

Disadvantages:

With its water storage capacity eliminated, the water rights associated with the Sheridan Lake Dams would need to be modified or abandoned. Reestablishing vegetation on the reservoir beach would take years, and the remaining embankment section could be considered an aesthetic drawback. Potential late-season flow releases to Rattlesnake Creek would be lost, and the overall recreational appeal of the dam site could decrease.

Estimated Costs:

Costs for the Decommission option are based on the same assumptions as used for the Rehabilitation option. The estimated costs are as follows:

| | |
|---|---|
| Capital costs for this alternative | $100,000 |

### 9.7.8 Worden Dam

*Worden Lake Dam is the smallest impoundment owned by the City.*

#### Current Conditions

A Project Information Sheet for Worden Lake Dam is located in Appendix K of this report, which provides detailed information about the dam and reservoir; a summary of current conditions related to different components of the dam and appurtenances; a summary of needed short-term repairs; and a conceptual-level cost estimate for completing short-term repairs.

Worden Lake Dam impounds approximately 70 acre-feet of water (the smallest reservoir in the Wilderness owned by the City of Missoula). It operates under a Special Use Permit issued by the Lolo National Forest of the U.S. Forest Service. It is regulated under the authority of the FS dam safety laws.  The dam is classified as having a “Significant” hazard classification, meaning that failure of the dam for any reason results in no probable human loss of life, but can cause non-recoverable environmental damage. A breach failure could result in erosion and sediment transfer to Carter Lake and possibly to Lake Creek and ultimately to Rattlesnake Creek where bull trout (a threatened species) are present, which is the basis for the dam's current Significant hazard rating. The dam was originally built in 1921 as an earthen embankment. The original construction drawings do not show a timber rock crib core, but this has not yet been verified. The dam's crest is approximately 9 feet wide which does not meet FS criteria of 10 feet minimum. The dam features one piezometer near the outlet pipe.

The upstream slope is approximately 2:1, is lined with riprap, and is in good condition. The downstream slope is steep with a slope of 0.3:1. Vegetation is growing on much of the embankment that needs to be trimmed. The spillway features a headcut approximately 200 feet downstream of the dam that is being monitored. Annual maintenance is needed to clear logs and other debris from the spillway approach channel. Spillway capacity currently meets FS design criteria for an existing significant hazard dam but would need to be increased if the dam is rehabilitated. Wet areas have been documented near the dam toe, but no seepage flows have been observed. The dam has one pipe outlet, which is a corrugated metal pipe (CMP). The pipe has not been inspected by video, but it is assumed it is in a similar deteriorated condition as the other dams. The control valve is located on the upstream end of the pipe, and the timber access structure is damaged and requires repair.

## Alternatives

The following alternatives are presented to aid in deciding the eventual disposition of Worden Lake Dam. The actions and costs of each alternative are based on the best available data at this time. Costs and tasks to complete each alternative may change as new information becomes available. Costs include construction and engineering design and construction oversight.

## No Action

The No Action alternative is to keep the dam and appurtenances in their current state with no improvements anticipated for the foreseeable future. The City would continue to monitor the dam, make minor repairs as needed, and take preventative action only if conditions indicate the dam would be in danger of failing.

Advantages:

The No Action alternative does not include initial capital improvement costs. There would still be annual costs for maintenance and owner inspections, and a cost for a periodic O&M engineer inspection and hazard assessment once every five years, as required by FS regulations.

Disadvantages:

The effects of aging on a nearly one hundred year old dam will continue. It is impossible to know when serious symptoms related to dam safety may appear, but they would be inevitable in the future. Costs to repair, replace or decommission the dam would eventually have to be expended at the time that serious deficiencies arise. Performing a structural stability analysis of an earthen dam requires a slope stability analysis. Although the FS does not have agency-specific guidance on conducting a structural analysis of an earthen dam, it references other suitable federal agency guidance. FSM 7525.42 states that the design of earthen side slopes can be accomplished using guidelines developed by the U.S. Army Corps of Engineers (USACOE) or U.S. Bureau of Reclamation (USBR). Criteria found in USDA-Natural Resources Conservation Service (NRCS) Technical Release 60 (TR-60) are consistent with USACOE and USBR criteria and is used often on FS dams. A report prepared by GMT Consultants in 1997 (*Preliminary Geotechnical Evaluation and Slope Stability Analysis, 6 Dam Sites - Rattlesnake Wilderness*) evaluated the downstream slope and it produced a safety factor of 1.6. However, the report indicated that the slope was input to the model as 1:1, which is flatter than the actual slope. In the absence of a more detailed geotechnical investigation and slope stability analysis, the actual downstream slope stability is unknown. Considering the width of the crest and the uncertainty of the previous slope stability analysis, the no action alternative for the dam would be out of compliance with dam safety regulations and thus increase the City's risk and liability.

Estimated Costs:

| | |
|---|---|
| No capital improvement costs for this alternative | $0 |

(It should be noted that under the no action alternative, regular operations and maintenance costs would still be required, and would likely increase over time.)

### Rehabilitate to Meet Forest Service Standards

The rehabilitation alternative would address deficiencies on the existing dam, as described in the Current Conditions section, and bring the dam into compliance with FS standards. Proposed repairs would include:

- Performing a geotechnical investigation and analysis;
- Addressing seepage issues by lining the upstream slope with an impermeable liner;
- Addressing the narrow crest and slope stability concerns by adding fill on the downstream slope;
- Slip-lining the outlet pipe;
- Rebuilding the outlet intake tower;
- Extending the outlet pipe to accommodate the added fill on the downstream slope; and
- Repairing the spillway.

The embankment materials at Worden Lake Dam may be prone to seepage, which can result in embankment piping (internal erosion). However, actively flowing seepage has not been observed at the dam and seepage does not seem to be a concern. But, as mentioned below, the embankment crest and slopes do not meet FS criteria, and added material is needed to bring it into compliance. If this is done, and equipment is already on site, it makes sense to provide added protection and reduce the risk of future seepage issues by lining the upstream embankment slope with an impermeable geomembrane liner. This option would require temporarily removing the upstream riprap, preparing the liner subgrade, installing a geomembrane liner with cushion geotextile on both sides, and replacing the upstream riprap.

An alternative to lining the upstream embankment slope could be to flatten the downstream embankment to a 2:1 slope. Slope stability analysis would be required to determine whether 2:1 slopes upstream and downstream are appropriate. A filter diaphragm is also recommended around the outlet pipe if the upstream liner is omitted. This alternative could reduce construction costs by about 30% but would result in a higher risk of seepage and piping issues in the future.

As mentioned above, the crest needs to be widened to a minimum of 10 feet in order to meet FS criteria. Along with this, the steep downstream embankment slope (0.3:1) could be flattened to produce a more stable embankment. The new fill material could be coarse gravel and sand obtained from within the reservoir footprint. Flattening the downstream slope would significantly increase stability, especially in combination with an upstream liner that eliminates the high phreatic surface in the embankment, potential issues from rapid drawdown, and other concerns that earthen embankment dam standards take into consideration. At this time, it is recommended that the downstream slope would be flattened to 1.5:1, based on experience with repairs on similar wilderness dams. The existing 2:1 upstream slope and proposed 1.5:1 downstream slope are steeper than recommended in the NRCS Conservation Practice Standard POND (No.) CODE 378. Slope stability analyses would be conducted to verify that the combination of slopes with an upstream liner under various loading conditions meet FS criteria. If not, then the downstream slope would be flattened until criteria are met. The slip-lined outlet pipe would need to be extended approximately 8 feet longer than the existing pipe to reach the new dam toe, if a 1.5:1 downstream slope is used.

Spillway repair would consist of replacing eroded material in the area of the headcut with large riprap or other erosion-resistant material, and grading to transition to the natural channel. The area near the dam or around the reservoir has significant riprap rock available that hopefully could be utilized. The channel would have to be designed to pass the required flow and at the same time prevent erosion and headcutting.

Advantages:

The rehabilitation alternative would address long-term concerns at the dam and would bring the dam into compliance with FS standards. The improvements proposed for rehabilitation would likely be necessary to even consider raising the dam to increase storage capacity.

Disadvantages:

The rehabilitation alternative would require a large capital improvement investment as well as ongoing operation and maintenance costs. While most seepage would be blocked, it is possible that foundation seepage could occur, which has the potential to pipe foundation material and undermine the dam.

Estimated Costs:

Rehabilitation costs are estimated using unit costs from recent wilderness dams repair work. Remote access necessitates helicopter transportation for personnel, equipment and construction materials. Construction costs for remote access dams can be five to ten times that of conventional construction. Estimated costs presented here include mobilization and demobilization costs, engineering and construction management fees, and a contingency of 30 percent. The estimated costs are as follows:

| | |
|---|---|
| Capital improvement costs | $601,000 |
| Existing Water Right | 104 ac-ft |

| | |
|---|---|
| Cost per acre-foot | $5,777 |

### Increase Storage

The alternative to increase storage would be a combination of raising the embankment height and completing rehabilitation items discussed above. With a surface area of approximately 9.9 acres, raising Worden Lake Dam a few feet could result in a modest increase in storage capacity. This alternative would be combined with the decommissioning of one or more other dams and would offset the lost storage volume.

Because of the already narrow dam crest, raising the dam approximately 4 feet (which is estimated only for purposes of this analysis – actual increase in height would be based on a cost:benefit analysis) would require additional fill beyond that estimated for rehabilitation. Raising the dam 4 feet would increase the height from 11 to 15 feet, which requires a minimum crest width of 10 feet to meet FS standards. Additional required embankment material was estimated assuming a 10-foot crest width, 2:1 upstream slope, and 1.5:1 downstream slope. The outlet pipe would need to be extended 14 feet. The modification would increase reservoir storage approximately 41 acre-feet, a 39% increase.

Advantages:

The Increase Storage alternative would offset potential loss of storage volume by decommissioning other City-owned dams in the Wilderness, and the City could potentially retain existing water storage and water rights while reducing the number of dams that require future maintenance.

Disadvantages:

There is an initial capital improvement cost associated with this alternative, and the alternative cannot be implemented without completing rehabilitation work. Some cost efficiency would be realized by increasing storage at the time rehabilitation work is completed. Increasing the dam storage capacity would also increase the peak flow in the event of a dam breach, and a revised hazard assessment would be required. An evaluation would be needed to determine the effect on the current dam hazard classification. Since the current classification and spillway capacity criteria are based on the effect from dam failure, the amount of increased storage that could be added without changing the current dam hazard classification would have to be examined closely.

Estimated Costs:

Costs for Increased Storage are based on the same assumptions as used for the Rehabilitation option. The estimated costs are as follows:

| | |
|---|---|
| Capital improvement costs for this alternative alone* | $560,000 |
| Increased water storage | 41 ac-ft |
| Cost per acre-foot for this alternative alone | $13,665 |
| Capital improvement costs including rehabilitation* | $1,161,000 |
| Existing water right plus increased storage | 145 ac-ft |
| Cost per acre-foot including rehabilitation alternative | $8,007 |

**Costs do not account for potential savings achieved by eliminating repair costs at other dam(s)*

## Decommission

The alternative to decommission the dam would involve breaching a portion of the dam and constructing a channel to route flows past the dam to an outlet channel. Breaching the dam would eliminate its storage capacity. A stable breach channel would be excavated through the dam embankment to safely route a 100-year or larger inflow design flood and to avoid any backwater impoundment against the remaining portion of the dam. The channel could feature a control sill to reduce sediment releases until the reservoir beach stabilizes. Excavated material could be dispersed to blend within the surrounding ground in the reservoir footprint. The existing outlet gate and access structure would be removed. The beach between the current reservoir shore and the remaining natural lake would be seeded.

The description above presents the probable minimum requirements for decommissioning the dam. A larger effort may be required to satisfy outside interests. This could involve reconstructing a natural channel upstream and downstream of the dam, completely removing the embankment material, or other major construction tasks.

The cost estimate assumes a breach channel would be excavated through the embankment capable of passing a 500-year flood with a peak flow of 101 cubic feet per second (cfs). Designing to this flood event would result in a stable channel during extreme flood events and minimize the potential for backwater impoundment against the dam. Changing the design flood would not significantly affect costs. The channel would be armored with riprap, and 3 acres of reservoir beach would be seeded. The seeding and re-vegetation plan would be prepared to minimize the introduction of invasive species and could incorporate seed collected on site.

According to FSM 2709.11, Dam Safety Definitions, a dam is 'any artificial barrier, including appurtenant works, that impounds or diverts water, either temporarily or long term, but not including a facility that is 6 feet or less in height or that impounds no more than 15 acre-feet of water'. The decommissioning alternative could be modified such that some combination of dam height reduction and storage reduction essentially turned the dam into a pond. This sub-alternative may have advantages in terms of cost, aquatic life, and re-vegetation limits and could be further developed in the next phase of overall project development and analysis.

Advantages:

The Decommission alternative would eliminate current and future maintenance requirements, except for possible short-term maintenance while conditions equilibrate. Ownership of the former dam and reservoir could be returned to the FS. Decommissioning costs would likely be lower than rehabilitation costs, although that could depend on the scope of decommissioning work and FS requirements for restoration to simulate natural conditions.

Disadvantages:

With its water storage capacity eliminated, the water rights associated with Worden Lake Dam would need to be modified or abandoned. Reestablishing vegetation on the reservoir beach would take years, and the remaining embankment section could be considered an aesthetic drawback. Potential late-season flow releases to Rattlesnake Creek would be lost, and the overall recreational appeal of the dam site could decrease.

Estimated Costs:

Costs for the Decommission option are based on the same assumptions as used for the Rehabilitation option. The estimated costs are as follows:

| | |
|---|---|
| Capital costs for this alternative | $115,000 |

## 9.8 Public Involvement

The City has been meeting with the FS, FWPs, and other City agencies and personnel throughout the process of this analysis to discuss alternatives and considerations. Meeting minutes are provided in Appendix O. At some point, after additional data has been collected and analyzed, the City will engage stakeholders in a robust public involvement process.

## 9.9 Summary and Recommendations

The following table includes a summary of planning level cost estimates for the alternatives presented.

### Table 9-7. Summary of Alternatives

| Lake | Rehab Cost ($) | Rehab Cost ($/ac-ft) | Rehab Cost Rank | Increase Storage ($/ac-ft) | Increase Storage Rank | Decommission ($) | Decommission Rank | Existing Storage (ac-ft) | Proposed Increase (ac-ft) | Proposed Final Storage (ac-ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| Big Lake | $1,312,000 | $2,106 | 2 | $2,235 | 2 | $400,530 | 7 | 623 | 175 | 798 |
| Carter Lake | $706,396 | $4,155 | 5 | $4,932 | 4 | $179,985 | 6 | 170 | 60 | 230 |
| Glacier Lake | $474,830 | $2,240 | 3 | $2,764 | 3 | $126,987 | 3 | 212 | 84 | 296 |
| Little Lake | $1,125,346 | $3,751 | 4 | $5,402 | 5 | $473,200 | 8 | 300 | 74 | 374 |
| McKinley Lake | $1,083,533 | $5,557 | 7 | $6,701 | 6 | $172,591 | 5 | 195 | 72 | 267 |
| Sanders Lake | $1,170,884 | $1,294 | 1 | $2,084 | 1 | $159,388 | 4 | 905 | 193 | 1,098 |
| Sheridan Lake | $547,799 | $4,763 | 6 | $6,903 | 7 | $99,509 | 1 | 115 | 45 | 160 |
| Worden Lake | $600,811 | $5,777 | 8 | $8,007 | 8 | $114,672 | 2 | 104 | 41 | 145 |

In order to make recommendations, it's important to understand that there are a number of competing interests in terms of the future of the Rattlesnake Wilderness Dams. It is in the best interest of the City and the community to fully analyze and understand these constraints and work towards optimization of the project goals. These have been identified as follows:

1.) **Preserve the Water Supply for Emergency Backup:** The Rattlesnake Creek water source has been maintained as an emergency backup supply. It has limited value as a backup drinking water source because there is currently no means for water treatment, so any use of the source would require appropriate precautions.

    The City of Missoula is exclusively reliant on groundwater via the Missoula aquifer, which is an unconfined aquifer that is susceptible to contamination. However, the wells are geographically dispersed and widespread contamination is unlikely.

2.) **Store Water for Late Season Flows in Rattlesnake Creek:** Rattlesnake Creek is critical habitat for Bull Trout, which are a threatened species. Rattlesnake Creek flows are influenced by the snow pack and runoff from the watershed, and the flows diminish in late summer early fall, often to less than 10 cfs. The dams provide a means to store spring runoff for release later in the season, which is a benefit for aquatic species and recreation.

3.) **Wilderness Area Considerations:** As described in this report, the Wilderness Act of 1964 puts very strict limitations on wilderness areas in order to preserve the pristine, quiet, contemplative, and natural settings. In addition, the dams are also a part of the history of Missoula and were in place long before the designation of the Wilderness Area and may be considered a historic and cultural resource.

4.) **Financial:** The financial implications of the various alternatives are great. Historically, all the costs associated with the dams have been borne by the water system rate payers. In the future, other funding sources may need to be identified if the future benefits are to fisheries habitat and recreation and less to the water customers.

    Life-Cycle Costs – what are the total life-cycle costs of the alternative including capital costs, operation and maintenance costs, and opportunity costs in terms of preserved or lost water rights.

    Operation and Maintenance Costs – this includes ongoing costs to operate and maintain the dams.

    Rehabilitation or replacement Cost – these include short term capital costs to rehabilitate, replace, or decommission the dam.

5.) **Water Rights Seniority**: The City currently holds some of the most senior water rights in the basin at the Rattlesnake Dams. If the dams were decommissioned, those water right may be lost.

The recommendations of the feasibility study include the following;

Water rights are a major driver for decisions related to the dams because of the seniority and value of the water rights. The first step in the process of rehabilitation and decommissioning should be a thorough water rights evaluation to determine the best approach for a change application. The change application process can take 18 months to 2 years, and major actions, specifically including non-reversible actions such as decommissioning of a dam should not be done until the future of the water rights can be firmly established, thus preserving the senior water rights that can't be obtained any other way.

The value of increasing the dam height and adding storage capacity was not great enough to overcome the likely regulatory work required to permit an increase in dam height.

Preliminary results indicate that in terms of life cycle costs, water rights value, and environmental impacts Big Lake dam, Sanders Lake dams, and Glacier Lake dam are good candidates for rehabilitation as they have the largest storage capacities and the lowest cost / acre-foot to rehabilitate.

All other dams are recommended to be decommissioned. Sheridan Lake dam and Worden Lake dam are the top candidates for decommissioning as they store the least amount of water and have the lowest cost / acre-foot to decommission. In addition, McKinley Lake is another candidate for decommissioning because the spillway has caused erosion and a headcut is migrating towards the dam. Therefore, McKinley, Sheridan, and Worden Lake dams should be the first dams targeted for decommissioning.

The purpose of this feasibility study was to evaluate existing information to analyze basic alternatives for the dams. The next phase of this project should include further analysis of issues and opportunities identified, including the following;

Augmenting Rattlesnake Creek flows for Bull Trout: gather temperature, flow and other data to fully understand temporal and spatial aspects including the ability to meet fisheries goals.

Climate change: Evaluate potential impacts of climate change on stream temperatures, snow pack, runoff timing, stream baseflow, drought periods and other aspects to ensure a long-term strategy is achieved.

Stream morphology and aquatic resources: alternative impacts to erosion, fluvial geomorphic and/or environmental stream mechanics should be evaluated.

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