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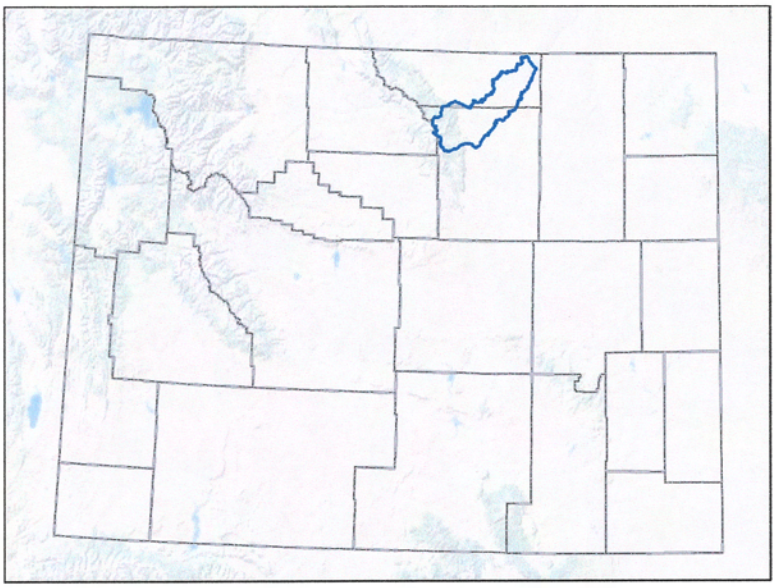
Final Report

Clear Creek Watershed, Level I Study



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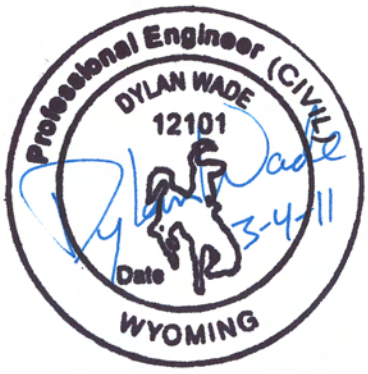

March 2011

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I. Introduction

In June 2008 States West Water Resources Corporation (States West) entered into a contract with the Wyoming Water Development Commission (WWDC) to provide professional services for the Clear Creek Watershed – Level I Study. The purpose of the contracted services was to render technical and professional services to assess, describe, and inventory the watershed and then develop management and rehabilitation plans for the watershed. This watershed study provides practical and economical solutions to issues identified during the inventory and assessment of Clear Creek Watershed components.

Additionally, this study analyzes the potential for developing surface water within the Clear Creek watershed. States West has taken an in-depth look at the watershed for potential multiuse water storage facilities to supply water and benefit to various users including the irrigators in the watershed and the City of Buffalo. During the analyses, States West has taken a big picture approach in order to identify multipurpose projects that could potentially draw funding from multiple sources.

The study was conducted in association with Dowl HKM (DOWL), Anderson Consulting Engineers, Inc. (ACE), RJH Consultants, Inc. (RJH), Western EcoSystems Technology, Inc. (WEST), and Watts and Associates, Inc. (WATTS).

1.1 PROJECT OVERVIEW

The State of Wyoming recognizes the benefits of basin planning efforts on the basis of watershed areas which do not necessarily adhere to political boundaries such as cities, counties, or states. The WWDC describes the watershed planning process as follows:

> *"Today, conservation by watershed is an old concept with new horizons. Watersheds have long been recognized in the western United States for their significant natural resources and the interrelationships found contained in land areas connected by stream systems. These relationships were recognized by John Wesley Powell from his early expeditions of the west and resulted in proposed conservation, low density open grazing, irrigation systems and state boundaries based on watershed areas.*
>
> *The conservation concept developed over time to coalesce in the early 1930's with the formation of special districts whose boundaries were often based on watersheds. At that time the relationship between stream systems and landscape function was recognized. This relationship was broadened to embrace watershed condition and quality and its response to human influences. This further provided some understanding of the historic land use effect on watershed condition and how management and restoration needs to be based on local landscape characteristics.*
>
> *Today, these relationships are embraced by the Wyoming Water Development Commission and Office through a watershed study program. On behalf of a local community sponsor, a watershed study can provide a comprehensive evaluation,*

analysis and description of the resources associated with a watershed and the watershed's water development opportunities. It is best stated that information related to the physical sciences is incorporated into a biological system.

There are three prominent issues that are important considerations in a watershed information review and study. The first is surface water storage. Surface water storage is often of significant interest to a watershed community in order to address seasonal and/or annual shortages of water supply, augment late season stream flow to benefit riparian habitat, fisheries and wildlife, address flood impacts, enhance recreation opportunities, improve water quality and stream channel stability.

Second is the evaluation of irrigation infrastructure and development of information necessary to guide its rehabilitation and conservation. Of interest to local water users are ways to improve water delivery and on-farm irrigation efficiencies often timed to address annual or seasonal shortages of water supply or irrigation water delivery issues. Third is the enhancement of upland water resources and distribution for livestock and wildlife that allows grazing management adjustments for range resource improvement. Benefits to the watershed, through plant community invigoration, reduction of erosion and stream channel stabilization, can be achieved from water development projects being strategically implemented over the watershed. Other issues and opportunities such as making beneficial use of produced water and removal of high water demand invasive species can also be important.

A watershed study, providing management and rehabilitation plans for water storage, irrigation systems and upland water development, can help empower a community to proactively enhance their watershed. Conservation by watershed can be an effective holistic approach to embracing the natural resource challenges and opportunities facing a community. A watershed study can provide the information to meet those challenges." (WWDC)

In 2007, the Lake DeSmet Conservation District (LDCD) conducted a Rapid Watershed Assessment (RWA) for the Clear Creek Watershed. Some of the most significant natural resource issues identified in the RWA were water quantity/quality, water availability/conservation, and the need to improve irrigation systems and water efficiencies within the drainage. Requests from the public were made to both LDCD and Sheridan County Conservation District (SCCD) to work with the WWDC to conduct a Level I Watershed Study. In addition, several irrigation interests expressed the need for assistance with evaluating irrigation infrastructure.

Various meetings were held by Wyoming Water Development Office (WWDO) staff in 2007 and 2008 to inform the community and conservation districts of the WWDC's watershed study process. In 2008, the Lake DeSmet Conservation District (LDCD) and the Sheridan County Conservation District (SCCD) jointly submitted an application to WWDC for a Level I Study of the Clear Creek Watershed. Funding was appropriated for the project following the 2009 legislative session. The consultant selection process took place in the spring of 2009 and work commenced that summer.

The Clear Creek Watershed Study is one of several watershed planning studies completed on behalf of the WWDC. Watershed investigations either completed or in the process of being completed include the following:

Prairie Dog Creek Watershed Study
Popo Agie River Watershed Study
Cottonwood Creek / Grass Creek Watershed Study
Sweetwater River Watershed Study
Thunder Basin Watershed Study
Nowood River Storage / Watershed Study
Kirby Creek Watershed Study
Shell Valley Watershed Study
Buffalo Creek Watershed Study
Thunder Basin Watershed Study

As a direct result of these efforts, numerous additional studies have been initiated and multiple projects have been constructed.

1.2 BACKGROUND

The Clear Creek watershed, located in northwest Johnson County and extending into southeast Sheridan County, is approximately 738,312 acres with land ownership divided among federal, private, and state. The watershed is defined as all the land area that contributes water or otherwise drains to the point where Clear Creek meets the Powder River. The watershed includes one primary river system, the main stem of Clear Creek, and tributaries including French Creek, Rock Creek, Shell Creek, Piney Creek and Buffalo Creek. Figure 1.2-1 generally depicts the Clear Creek Watershed. The watershed encompasses the Towns and surrounding areas of Buffalo, Clearmont, Leiter, Story, Saddlestring, and Ucross.

> *The headwaters for the Clear Creek drainage begin at the top of the Big Horn Mountains on the east slope. The watershed consists of the main stem of Clear Creek, French Creek, Rock Creek, Shell Creek and Piney Creek. The drainage flows through wilderness to summer pastures, recreational sites and cabin sites. There are water storage reservoirs for use by the City of Buffalo and waters for irrigation use. (LDCD, 2006)*

Elevations within the watershed range from less than 3500 feet at the confluence of Clear Creek with the Powder River, to over 13,000 feet at peaks within the Bighorn Mountains, resulting in overall relief of more than 9,500 feet. Figure 1.2-2 shows the Clear Creek watershed in relation to the Big Horn Mountains and the Powder River Basin. This figure clearly shows the topographic variability in the study area. The southwestern portion of the watershed consists of the east slope of the Big Horn Mountains while the northeastern portion lies primarily in rolling hills.

According to historical data collected by the Western Regional Climate Center (http://www.wrcc.dri.edu/wrccmssn.html), annual precipitation amounts vary with respect to elevation from 12 to 37 inches per year in the southwestern portion of the basin compared to 13 to 15 inches per year in the northeastern portion of the basin.

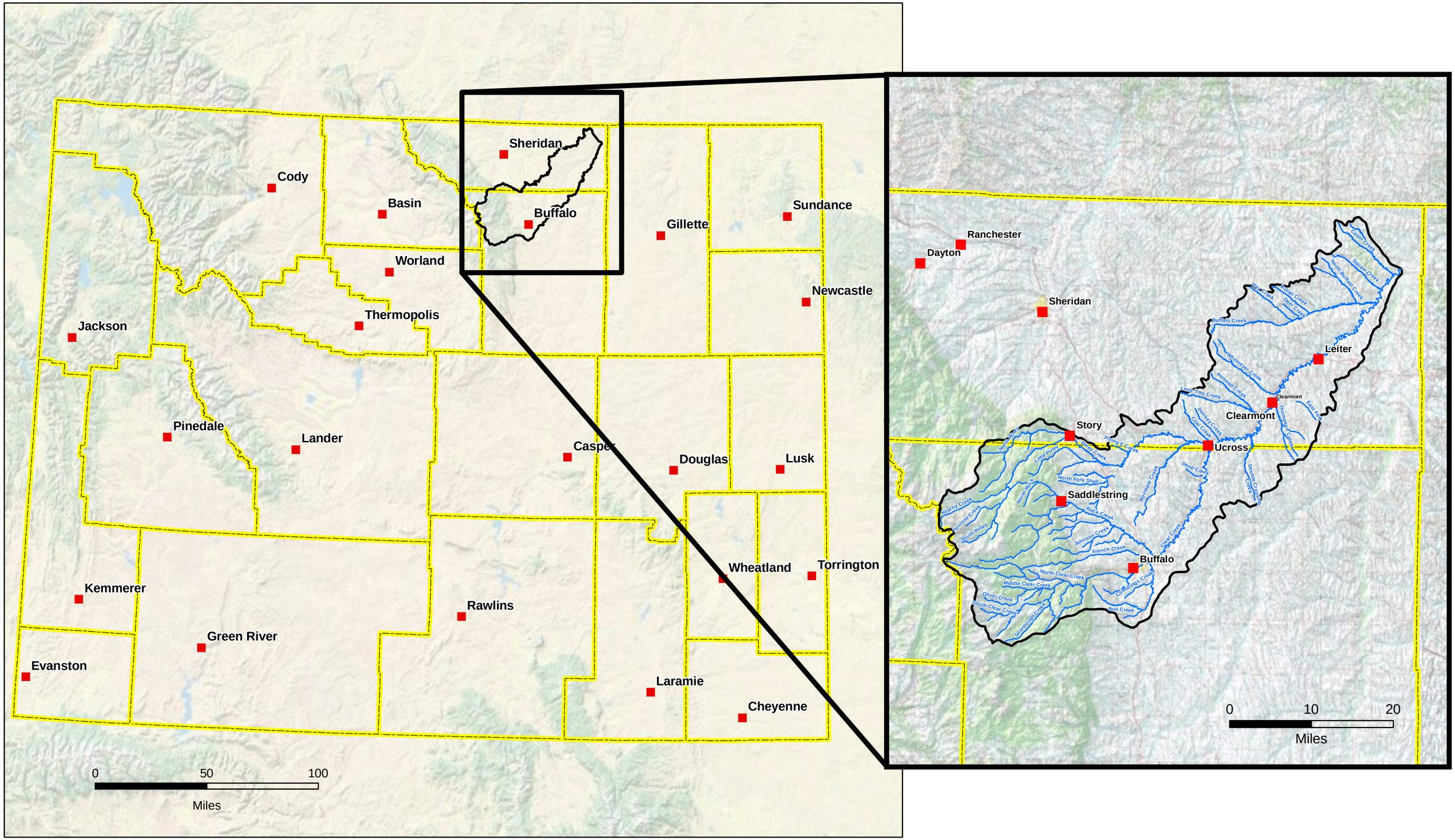


Figure 1.2-1
Wyoming Overview:
Clear Creek Watershed

The majority of land within the basin is privately owned. The privately owned parcels account for about 60% of all land within the watershed. Public lands account for 39% of the landownership within the basin (US Forest Service – 25.67%, State of Wyoming – 10.47%, Bureau of Land Management – 3.04%).

Figure 1.2-2 Overview of the Clear Creek Watershed looking upstream (southwest) from the confluence with the Powder River

In general, some of the issues related to water within the basin and utilization of resources are as follows:

Runoff Quantity and Timing Issues

- The Clear Creek drainage generates a significant amount of runoff. Generally, peak streamflow occurs early in the year when irrigation demands on the system are low. Shortages occur during the late season low flow periods. Several reservoirs in the watershed reduce late season irrigation shortages, however, demands upstream of these storage facilities exist.
- The City of Buffalo occasionally has flood events occur during spring runoff periods. Since 1962, Clear Creek has risen above flood stage at Buffalo four times.
- Late season irrigation shortages could potentially be mitigated by capturing spring runoff and releasing during low flow periods.
- Late season flows through the City of Buffalo are reduced due to upstream irrigation diversions.
- Multiple-use storage reservoirs located above the areas of need could provide numerous economic benefits to the surrounding area including: flow through town, agricultural enhancements, recreational opportunities, environmental benefits, wildlife and fishery enhancement, habitat enhancement, potential flood mitigation, etc.

Grazing Issues

- Grazing of livestock is one of the primary land uses within the study area; the livestock industry has played an important role in the economy and character of the area.
- The Bureau of Land Management – Buffalo Field office and U.S. Forest Service administer grazing allotments for federal land within Clear Creek watershed. There are approximately 57 BLM individual grazing allotments and 14 USFS individual grazing allotments within the watershed.
- Various NRCS programs have been utilized over the years to develop upland water opportunities throughout the watershed.
- There are further opportunities to develop additional upland water supplies for livestock/wildlife watering.
- The Clear Creek watershed range conditions appear to be generally in "high fair" to "good" ecological condition.
- Riparian areas appear to be heavily relied upon for their wildlife and livestock water, feed values, and cover.

Channel Stability Issues

- During the evaluation of existing channel conditions, several impaired reaches were identified.
- Within the mountainous areas, the channels are steep and bounded by very coarse, resistant materials. As a result, the channels are typically laterally and vertically stable.
- As the major stream channels descend into the Clear Creek basin, the channel slope lessens and the boundary materials become less coarse. Within this region, the streams tend to display meandering channel dynamics.
- Within the lower reaches of the watershed, Clear Creek maintains its nature of being a meandering stream.
- Riparian vegetation degradation has occurred in the lower reaches of Clear Creek. Little or no riparian buffer has been maintained in these areas.
- Generally, the Clear Creek system appears to have stable bank and channel characteristics. Some localized instances of stream bank erosion are evident.
- Actively eroding portions of stream-bank within the watershed were inspected per the request of local landowners.

Irrigation Issues

- The Clear Creek watershed contains approximately 40,000 acres of irrigated lands served by surface water sources. An additional 6,000 acres are served by trans-basin diversions. The ditches typically range in size from those conveying 1.5 cfs to ditches designed to convey 300 cfs.
- Numerous improvements to existing irrigation facilities could be made to improve the efficiencies of water delivery, thus increasing conservation.
- Several opportunities exist which would allow multiple ditches to be combined in a more efficient manner. This could improve water delivery efficiencies, promote water conservation, and improve economies of scale.
- Structural evaluations conducted throughout the watershed revealed that some of the existing structures are beyond the point of repair and could require replacement while other deficiencies could be easily remediated.
- Operational deficiencies result in both the over-utilization and under-utilization of irrigation appropriations.

- Projects have been prioritized according to facility deficiencies and the anticipated repair/replacement cost of facilities.
- Late season irrigation is frequently curtailed in the upper basin with the shortage of water in streams.
- Reservoir storage, coupled with irrigation improvements may conserve water and create opportunities that would benefit irrigators and other water users within the watershed.
- Opportunity exists by the way of using and modifying existing Lake DeSmet infrastructure to provide irrigators below the City of Buffalo with additional storage water and potentially increase water availability upstream via exchanges.

1.3 PURPOSE AND SCOPE

The primary purposes of the Clear Creek Watershed – Level I Study are to:

- Review Existing Background Information for the Clear Creek drainage,
- Describe and Inventory the Clear Creek Watershed to provide a holistic view of the natural resources,
- Implement Temporary Stream Gauging on Clear Creek tributaries,
- Develop a Watershed Management and Rehabilitation Plan for the Clear Creek drainage,
- Analyze permitting requirements for Clear Creek Watershed improvement projects, highlight potential “fatal flaws” associated with storage projects, and provide a solid foundation for the NEPA process,
- Develop cost estimates for Clear Creek Watershed improvement projects,
- Provide economic analyses for Clear Creek Watershed reservoir projects,
- Analyze financing opportunities for Clear Creek Watershed improvement projects,
- Prepare a report summarizing the findings of the Level I Study, and
- Compile and collate all of the relevant natural resources spatial data available into a comprehensive Geographic Information System (GIS) to facilitate the completion of this project and also to be available as a resource for future work.

II. Project Meetings

2.1 INTRODUCTION

Various meetings were held by Wyoming Water Development Office (WWDO) staff in 2007 and 2008 to inform the community and conservation districts of the WWDC's watershed study process. The meetings held were as follows:

- October 23, 2007 – Buffalo Landowner Meeting
- November 13, 2007 – Sheridan Landowner Meeting
- May 21, 2008 – Clearmont Landowner Meeting
- July 16, 2008 – Buffalo Landowner Meeting
- July 17, 2008 – Sheridan Landowner Meeting
- December 16, 2008 – LCCD Board Meeting
- January 13, 2009 – SCCD Board Meeting
- March 17, 2009 – Pre-proposal Tour
- May 7, 2009 – Consultant Interviews/Selection w/ Sponsors

During the course of the study, States West conducted several meetings in conjunction with the WWDO. The first meeting held was the project scoping meeting on July 9, 2009. This meeting was held to familiarize all interested parties including the project sponsor and the public with the process and overall scope of the study and to provide an opportunity for input from the various stakeholders in relation to the scope. During the scoping meeting, a presentation with visual aids was made to explain the Level I Study.

During the course of the study, eight additional project meetings were held in cooperation with the Wyoming Water Development Office and the project sponsors. The meetings held were as follows:

- October 29, 2009 – LDCD Office
- December 8th, 2009 – Open House – LDCD Office
- December 9th, 2009– Open House – Clearmont Library
- March 16th, 2010 – LDCD Office
- April 21st, 2010 – LDCD Office
- June 8th, 2010 – SCCD Office
- June 17th, 2010 – Johnson County Fire Hall
- February 15th, 2011 – DRAFT Report Presentation

States West also created a project website for the Clear Creek Watershed – Level I Study. The website was kept current with project information and updates. The project website contained monthly updates prepared by the project engineer which detailed the progress of specific tasks being undertaken over the course of the study. The newsletters hosted on this website also contained information on upcoming project meetings. The website was advertised during each project meeting and accessible via the internet at:

http://groups.google.com/group/clearcreekwatershedstudy?pli=1

Project meetings were generally well attended during the course of the study. Through phone calls, emails, mailing list, project website, sponsor announcements, post cards, newspaper ads and articles, and local radio announcements the meeting dates, times, and locations were well circulated. Additionally, following the June 17th, 2010 project meeting the Buffalo Bulletin conducted an interview of the WWDO Project Manager and key personnel of the project team. A brief article discussing the progress of the study was published on June 24, 2010. Other publications about the project included an article in the Wyoming Livestock Roundup on November 28, 2009 and an article in the Buffalo Bulletin on November 26, 2009.

Attendees of the project meetings frequently included members of key agencies including the Forest Service, Bureau of Land Management, Wyoming Game & Fish Department, Wyoming State Engineers Office, Lake DeSmet Conservation District, Sheridan County Conservation District, the Rock Creek Wilderness Association, the Lake DeSmet County Coalition Joint Powers Board, Ditch Companies, Private Irrigators, City of Buffalo Residents, Buffalo City Council Members, Johnson and Sheridan County Residents, and Johnson County Commissioners.

The States West project team has been engaged in the public outreach and involvement efforts for developing plans within the Clear Creek Watershed. Through these efforts, the project team identified several ideas and areas of concern brought up by constituents of the watershed. Items brought to the project teams attention included:

- Upland Water Development Assessments
- Stream Condition Assessments,
- Irrigation System Inventories and Assessments, and
- Potential Storage Projects

2.2 FIELD VISITS

The project team conducted several field visits over the course of this study to research details associated with potential projects within this study. Additionally, the project team always welcomed input from interested landowners within the watershed. By utilizing anecdotal information from residents of the watershed, the project team was able to gain a more in-depth understanding of how the watershed works.

Temporary Stream Gauging

States West installed temporary stream gauges in the Fall of 2009. Periodic measurements were taken at the temporary gauging sites in order to establish a rating curve for these stations. The use of these temporary stream gauging stations allowed the project team to analyze the amount of runoff contributed to Clear Creek in 2009-2010 by various tributaries throughout the watershed.

Watershed Inventory

The project team conducted tours of the watershed to inventory and describe the current and previous land uses and wetland condition. Additionally, observations made during these tours were used to describe the conditions of the stream channels throughout the watershed.

Irrigation Inventories and Assessments

The project team conducted many irrigation inventories and assessments throughout the watershed. Team members talked with landowners and irrigators regarding project ideas to enhance or develop irrigation operations throughout the watershed. Inventories and assessments were made upon landowners and irrigators request. The requests were generally made during the project meetings or passed along by the Sponsor.

Reservoir Sites Tours

Following the initial screening of potential reservoir sites, an abbreviated list of reservoirs was developed. The project team visited these potential reservoir locations and analyzed them with respect to: permitting, environmental impacts, recreation potential, geotechnical suitability, and the ability to serve the needs of the watershed.

2.3 AGENCY COORDINATION

During the development of conceptual projects, the project team has coordinated with various agencies to identify potential conflicts and/or fatal flaws associated with the concepts presented within this Level I Study. Over the course of the study, discussions took place with the following agencies:

Lake DeSmet Conservation District
Sheridan County Conservation District
Wyoming Game & Fish Department
Wyoming State Engineers Office
Lake DeSmet County Coalition Joint Powers Board
Irrigation Ditch Associations/Companies
United States Forest Service
United States Army Corps of Engineers
Natural Resources Conservation Service

III. Watershed Description and Inventory

3.1 INTRODUCTION

A considerable amount of information exists pertaining to the Clear Creek watershed and its resources. The data spans a wide variety of disciplines and includes basin hydrology, water quality, land use and ownership, geology and soils, and agricultural practices as typical examples. One of the primary goals of watershed planning studies conducted on behalf of the Wyoming Water Development Office (WWDO) is to collect this information and provide it in a single cohesive document. The intent of the project is to provide this information not only for the current project but for other future planning and permitting efforts.

In the remainder of this chapter, the overall data collection process is discussed including the development of the project Geographic Information System (GIS). In addition, information summarizing watershed land use and activities, natural environment, stream geomorphology, water quality, and watershed hydrology is presented.

3.2 DATA COLLECTION AND MANAGEMENT

3.2.1 Collection of Existing Information

A significant amount of information and pertinent data were available from existing sources at the time this project was initiated. In an effort to collect and incorporate as much of this information as possible, the following sources were either contacted directly or information and documents procured via websites, libraries, or personal contacts:

- U.S. Bureau of Land Management (BLM)
- U.S. Forest Service (USFS),
- U.S. Geological Survey (USGS)
- U.S. Department of Agriculture/Natural Resources Conservation Service (NRCS)
- U.S. Department of Agriculture/Farm Service Agency (FSA)
- U.S. Environmental Protection Agency (EPA)
- U.S. Fish and Wildlife Service (FWS)
- Wyoming Water Development Commission (WWDC)
- Wyoming Department of Environmental Quality (WDEQ)
- Wyoming Game and Fish Department (WGFD)
- Wyoming State Engineer's Office (WSEO)
- Wyoming Oil and Gas Conservation Commission (WOGCC)
- Wyoming State Geological Survey (WSGS)
- Wyoming Board of Land Commissioners/State Lands and Investments Board (WBLC/SLIB)

- Wyoming Wildlife and Natural Resources Trust (WWNRT)
- Wyoming Geographic Information Science Center (WyGISC)
- Johnson County
- Johnson County Weed and Pest Control District
- Lake DeSmet Conservation District
- Sheridan County
- Sheridan County Weed and Pest Control District
- Sheridan County Conservation District

3.2.2 Geographic Information System

The results of the data collection efforts were incorporated into a comprehensive Geographic Information System (GIS). A GIS can be thought of as a powerful three-dimensional mapping tool that can be used to evaluate and compare spatial data pertaining to a wide range of topics. Numerous maps can be "stacked" to overlay information; each map, or "theme", incorporates data, or "attributes" pertaining to the theme. For instance, a theme showing the location of irrigation ditches could also include numerical data pertaining to each ditch's irrigated acreage, improvements, etc. As an example, within the project GIS, irrigation inventory assessment reports and photographs are hyperlinked to each specific irrigation structure or canal visited. This is intended to provide the end user easy access to project data and information. When working with landowners, the Conservation Districts can readily access information pertaining to irrigation improvement projects or other small water projects.

Spatial data pertaining to the Clear Creek watershed was collected from a wide range of sources. Agencies providing information included the State of Wyoming, USDA Forest Service, USDI Bureau of Land Management, Wyoming Game and Fish Department, Johnson County, Sheridan County, the USDA Natural Resources Conservation Service, and others. A significant amount of the information was also specifically developed during the course of this investigation. Table 3.2-1 presents a list of the individual themes, maps, and aerial photographs which have been incorporated into the project GIS. Note that associated support data layers may exist which are not individually itemized in this table.

The project GIS was used in the generation of a majority of the figures included in this report. It will be available as a resource for future investigations and a tool for Clear Creek watershed stakeholders to use during pursuit of permits, environmental analyses, mapping projects, etc. GIS software (ArcView 9.x) is required to view and utilize the data to the maximum of its potential. However, free ‘shareware’ data viewers (ArcExplorer) are available which enable the user limited capabilities to view the data. It must be kept in mind when using the shareware versions of the GIS software that certain data layers symbology will vary from what is presented in this report. Also, the shareware software is not capable of simultaneously presenting data layers which were generated in different coordinate systems. Consequently, it may not be possible to view certain layers in the same field of view.

It is also important to note that data presented in the project GIS and within this report are subject to change with time as the agencies creating them continually update their databases. Metadata is available for each dataset which gives information as to when the data was created and updated. The user is encouraged to obtain the most current data available to meet the needs of future endeavors utilizing the project GIS.

Table 3.2-1 List of Data Coverage in the Clear Creek Watershed Investigation Project GIS

Project Study Area	**Fish and WIldlife**
Clear Creek Watershed Boundary	Clear Creek Trout Stream Classification
Political	Big game crucial ranges (All Species)
Cities	Big game migration routes (All Species)
UTM Zones	Big Game habitiats
County Boundaries	Bison hunt area herd unit boundaries
Public Land Survey System	Black bear hunt area herd unit boundaries
Land Management	Mountain lion hunt area herd unit boundaries
BLM Plan of Development Boundaries	Sage Grouse Lek Locations, hunt areas and Core Population Areas
BLM Field Office Boundaries	**Geology, Soils, ESD and Geomorphology**
BLM Allotments: Buffalo Area	1:500K Bedrock Geology layer
USFS Allotments: Clear Creek watershed	1:500K Extraction of Bedrock Geology Layer containing Limestone Formations
Rock Creek Proposed Wilderness Area	1:500K Surficial Geology Layer
Cloud Peak Wilderness Area	Statewide Geologic Formation Layer
Wilderness Study Areas: Statewide	Landslides
BLM Oil and Gas Leases Authorized	Dykes, faults
BLM Rights of Way	Rosgen Level I stream classification
WDEQ LQD Mine Permit Boundaries	Geomorph photo points
WY Conservation Districts: State Wide	Johnson Couny Soils
WY Improvement Districts: State Wide	Sheridan County Soils
Mine Permit Boundaries	Ecological Site Descriptions: Johnson County
Ownership	Ecological Site Descriptions: Sheridan County
Land ownership: Public/State/	General Soils Data: 1:250,000
Johnson County Assessor's Parcel Mapping	**Irrigation**
Sheridan County Assessor's Parcel Mapping	Irrigated Acres
Climate	Ditch inventory locations
Weather Station Locations	Inventoried and Evaluated Structures
Precipitation Zones (PRISM)	Irrigation Districts
Infrastructure	System Rehab: Conceptual Pipe Locations
Oil and Gas Wells	System Rehab: Conceptual Canal Improvements
Electric Transmission Corridors	**Upland Water Supply Projects**
Roads of Importance and Names	Proposed Upland Storage
Minor / Secondary Roads	Proposed Upland Pipeline
Railroads	**Photo/Data Links**
Cell Towers, Microwave Towers	Potential Reservoir Sites
Cultural / Historical	Weather Station Locations
Cultural Sites Eligible for the National Register of Historic Places per PLSS	Temporary Stream Gage Locations
Hydrology	USGS Streamgage locations
Storage Sites: Proposed and Permitted	Inventoried and Evaluated Irrigation Structures
USGS Streamgage locations	Geomorph photo points
Existing Water Quality Monitoring	Wetland Sites Evaluated
Surface hydrography - Named Streams	Irr. System Rehab: Conceptual Pipe Locations
Lakes	**Backgrounds**
HUC 6th Order Watersheds	USGS 30 M Digital Elevation Model
Temporary Stream Gage Locations	USGS Topogographic Mapping Tiled Mosaic
Exising Wells	USGS 1:100K Topographic Mapping
Wetlands	USGS 1:250K Topographic Mapping
National Wetlands Inventory	2009 NAIP County Mosaic 1M Pixel Resolution
Wetland Sites Evaluated	2009 CIR Imagery 1M Pixel Resolution

3.2.3 Digital Library

The Digital Library is a collection of documents, plats, maps, figures, spreadsheets, etc., pertaining to the project. Documents reviewed during the completion of this project were scanned and included in the Digital Library to the extent possible. Copyright protected documents were not included in the Library; however documents published by public agencies were included where feasible.

Individual document files can be accessed directly by "browsing". Documents included in the Digital Library were obtained from the agencies listed in Table 3.2-2. Appendix 3A presents a list of individual documents.

Table 3.2-2 Sources of Information Included in the Digital Library

Johnson County Wyoming
Sheridan County Wyoming
USDI Bureau of Land Management
USDA Natural Resources Conservation Service
United States Environmental Protection Agency
USDA States Forest Service
USDI United States Geologic Survey
Wyoming Department of Environmental Quality
Wyoming Game and Fish Department
Wyoming Natural Diversity Database
Wyoming State Engineers Office
Wyoming Water Development Office
Miscellaneous

3.3 LAND USES AND ACTIVITIES

3.3.1 Land Ownership

The total land area within the Clear Creek watershed is approximately 738,312 acres (1,154 square miles). As indicated in Figure 3.3-1, the watershed spans two counties and consequently two conservation districts. The Johnson County portion of the watershed lies within the Lake Desmet Conservation District (LCDC). This part of the watershed is approximately 439,551 acres, or about 60% of the basin. The Sheridan County portion of the watershed lies within Sheridan County Conservation District (SCCD). This part of the watershed is approximately 298,761 acres or 40% of the entire basin. Figure 3.3-1 also indicates the various land ownership categories within the watershed. Figures 3.3-2a, b, and c show the relative distribution of landownership within the watershed.

Land ownership information was obtained from the respective Johnson County and Sheridan County assessors' offices and incorporated into the project GIS. The majority of the basin is privately owned (445,983 acres or approximately 60.39%). The largest portion of public lands is managed by the United States Forest Service (189,550 acres or approximately 25.66%) This portion of the watershed includes 92,317 acres within the Cloud Peak Wilderness area. (This distribution of lands does not include accounting of the proposed Rock Creek Wilderness area) The State of Wyoming owns 77,322 acres (approximately 10.47 %) and about 22,462 acres (3.04 %) are federal lands administered by the Bureau of Land Management. Approximately 3,245 acres (0.44%) are open water.

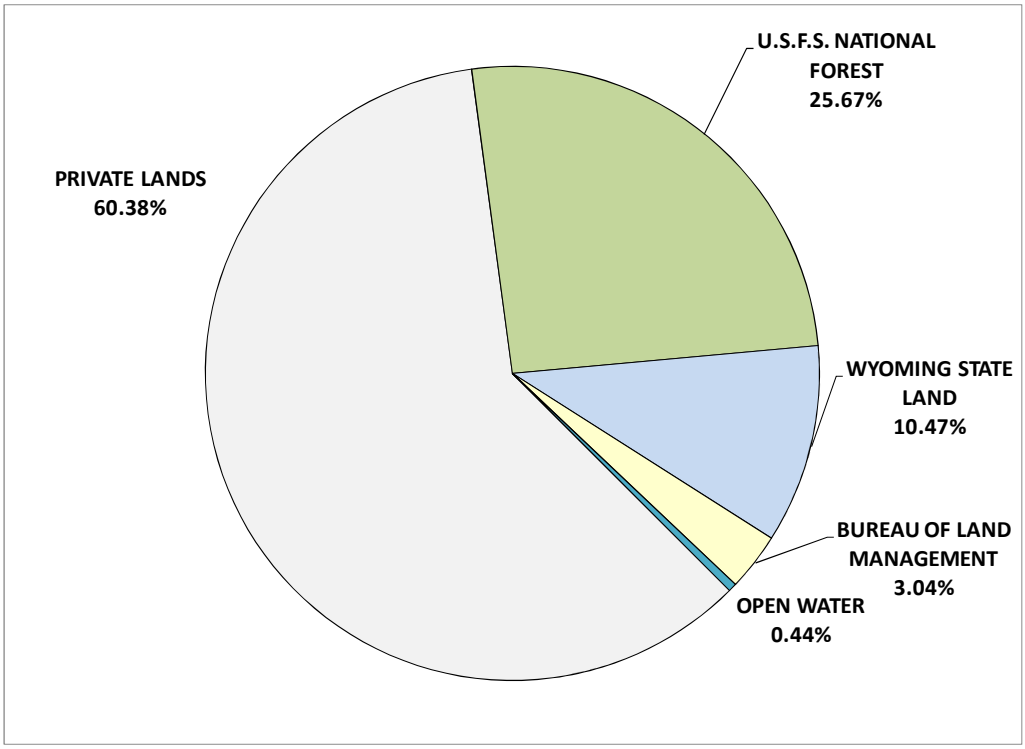


Figure 3.3-2a Relative Distribution of Watershed by Land Ownership

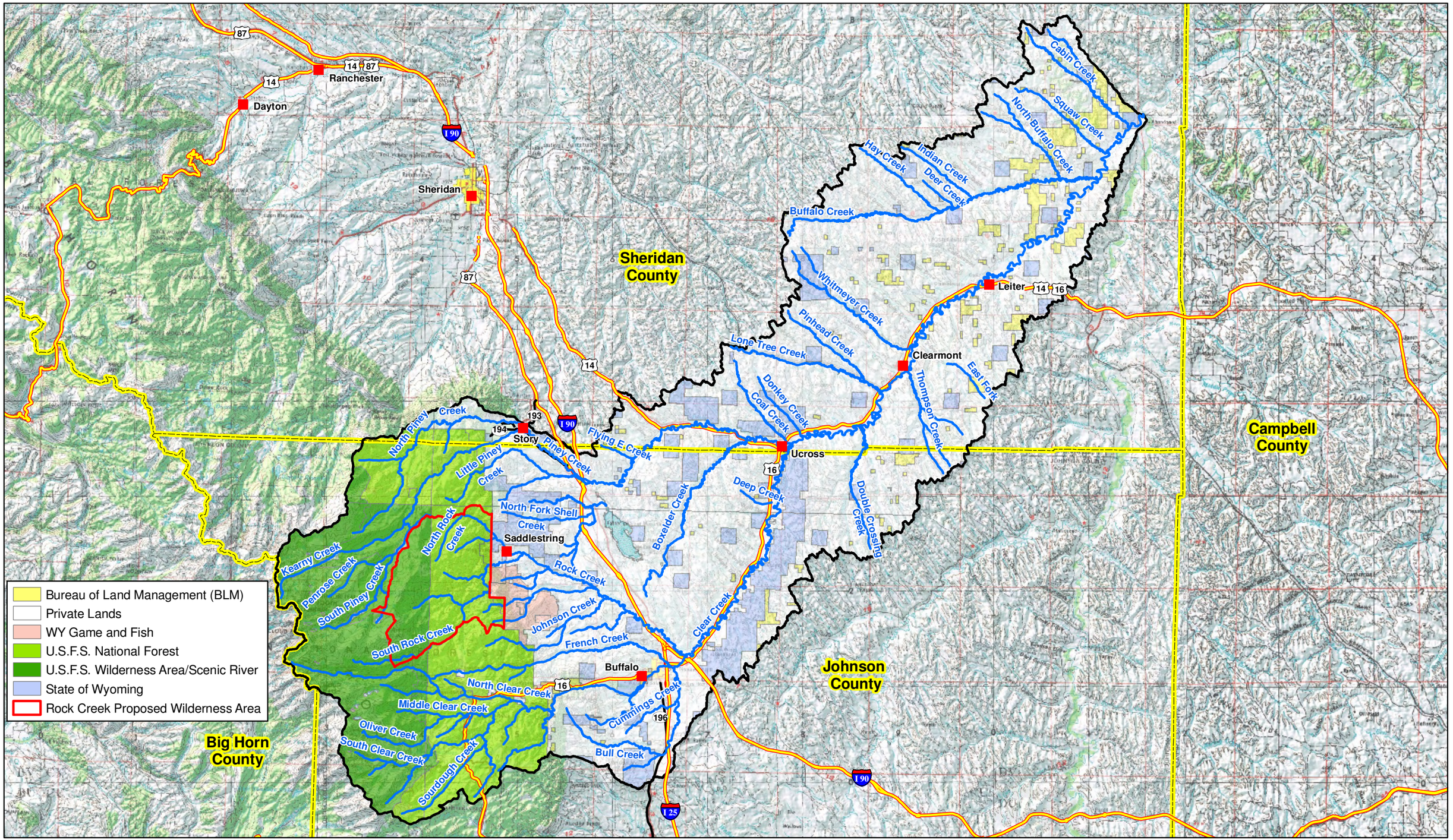


Figure 3.3-1. Clear Creek Watershed: Land Ownership

The distribution of land ownership in the watershed was further broken down by county. The Sheridan County Conservation District portion of the watershed contains 242,996 acres or approximately 81.3% private land; 33,732 acres or approximately 11.3% State land; 18,141 acres or approximately 6.1% federal lands administered by the Bureau of Land Management; 2,936 acres or approximately 1.0% United States Forest Service; and 1,097 acres or approximately 0.4% open water (Figure3.3-2b). The Lake DeSmet Conservation District portion of the watershed contains 202,987 acres or approximately 46.2% private land; 43,590 acres or approximately 10.0% State land; 4,321 acres or approximately 1.0% federal lands administered by the Bureau of Land Management; 186,614 acres or approximately 42.5% United States Forest Service; and 2,148 acres or approximately 0.5% open water (Figure 3.3-2c).

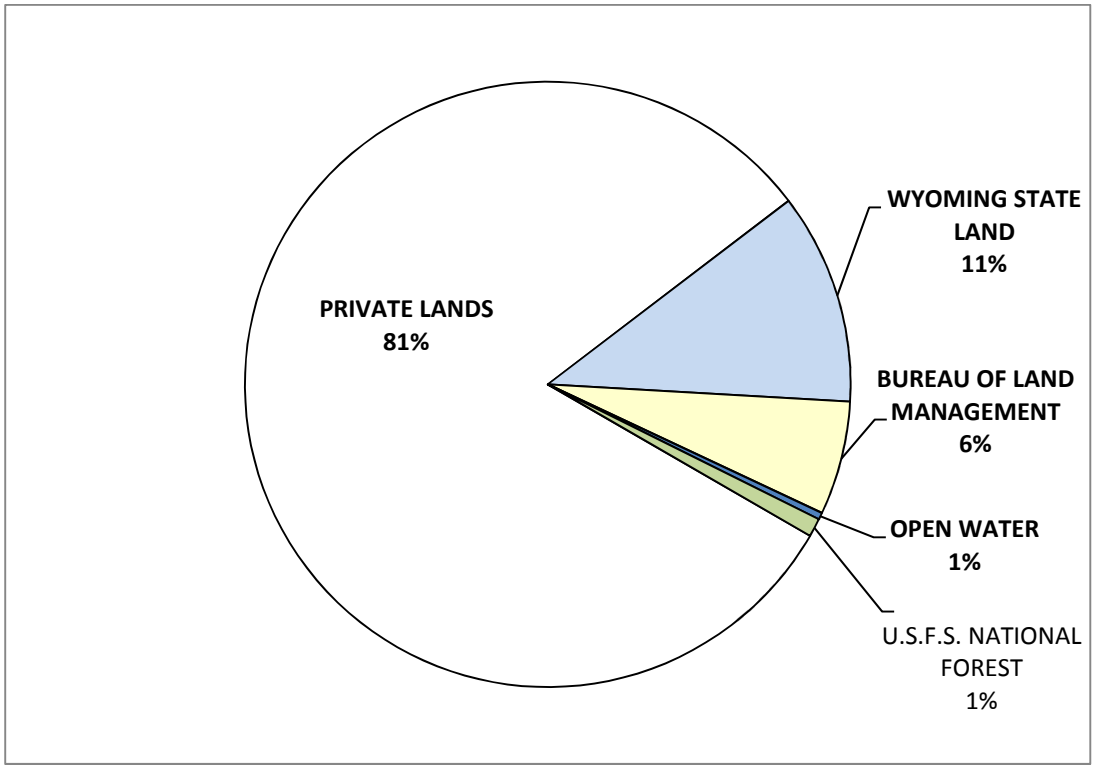


Figure 3.3-2b Relative Distribution of SCCD Portion of Watershed by Land Ownership

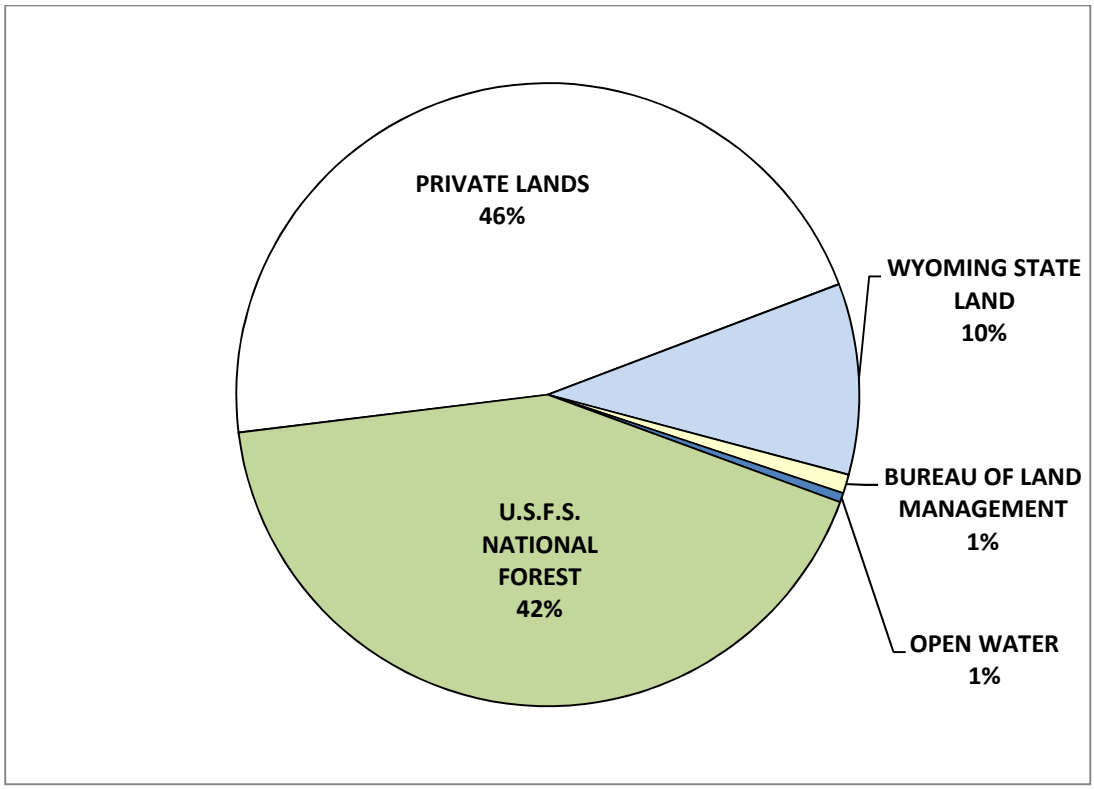


Figure 3.3-2c Relative Distribution of LDCD Portion of Watershed by Land Ownership

3.3.2 Transportation, Energy and Communication Infrastructure

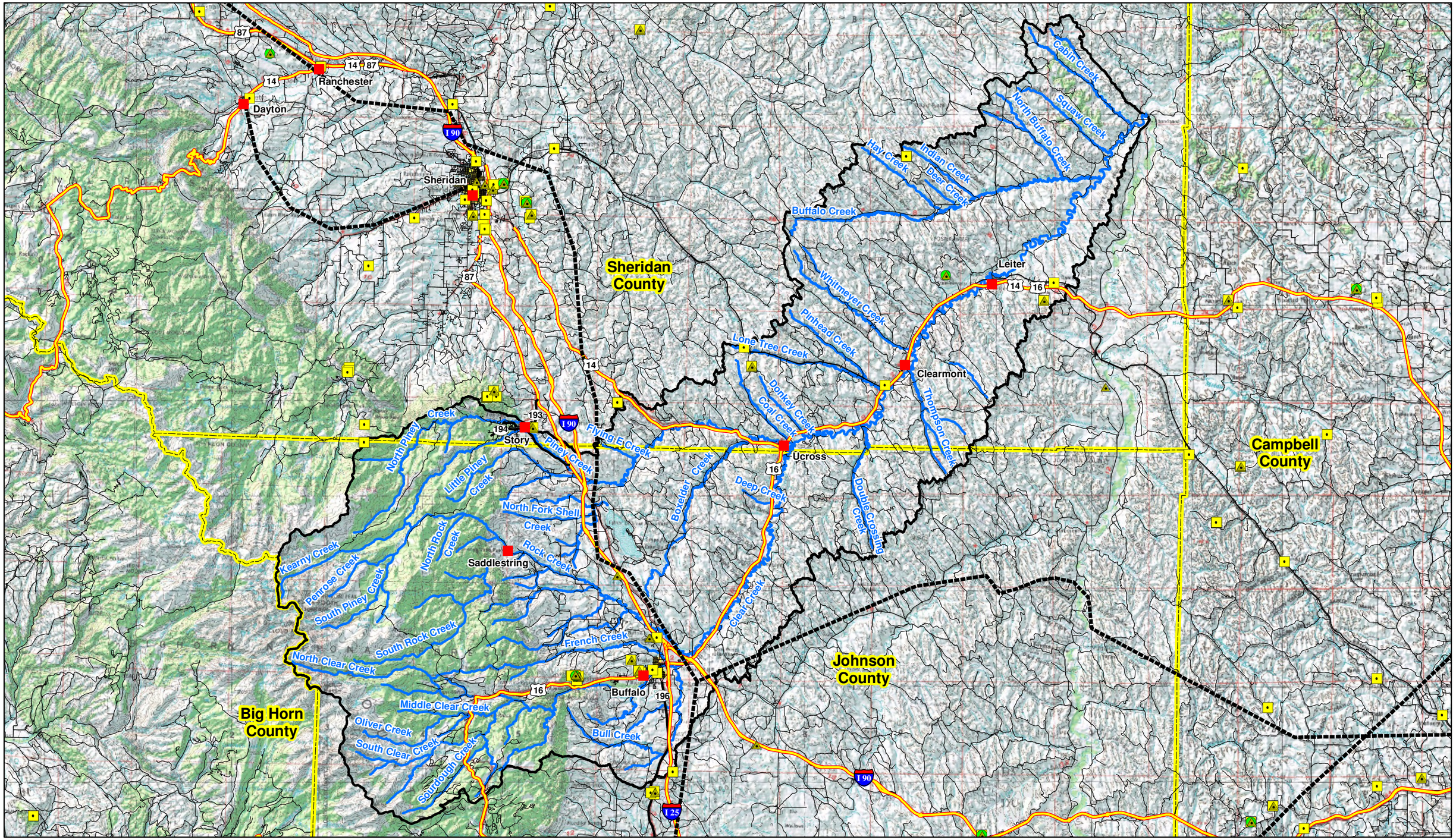
The Clear Creek watershed area is served by two Interstate Highways (Figure 3.3-3). I-90 enters Johnson County from the east, turns northward at Buffalo and crosses into Montana approximately 25 miles north of Sheridan, Wyoming. I-25 crosses into Johnson County from the south and ends at I-90 at the City of Buffalo.

A rail line; known as the Orin Line and owned by BNSF traverses the study area as indicated in Figure 3.3-3.

The principal two-lane highways within the watershed are U.S. Highways 16 and 14. Highway 16, which enters the watershed from the east, passes through the City of Buffalo and serves as the southern route across the Big Horn Mountains. The highway enters the Town of Tensleep and the City of Worland after crossing the Big Horns. Highway 14 enters the watershed from the north, follows the Piney Creek drainage, and joins Highway 16 at Ucross.

Electric power service in the project area is provided by PacificCorp Company. Mapping of their distribution infrastructure was not available; however, most of the existing distribution lines are located along the major paved and county-maintained gravel roads in the watershed. In addition, the following transmission lines were noted:

- Basin Electric operates a 230 kV transmission line which runs from Gillette to Sheridan.



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- Cities
- Antenna
- Cellular Tower
- Microwave Tower
- Electric Transmission Corridors
- Streams
- Highway
- Railroad
- Secondary Road
- Clear Creek Watershed
- County Boundary

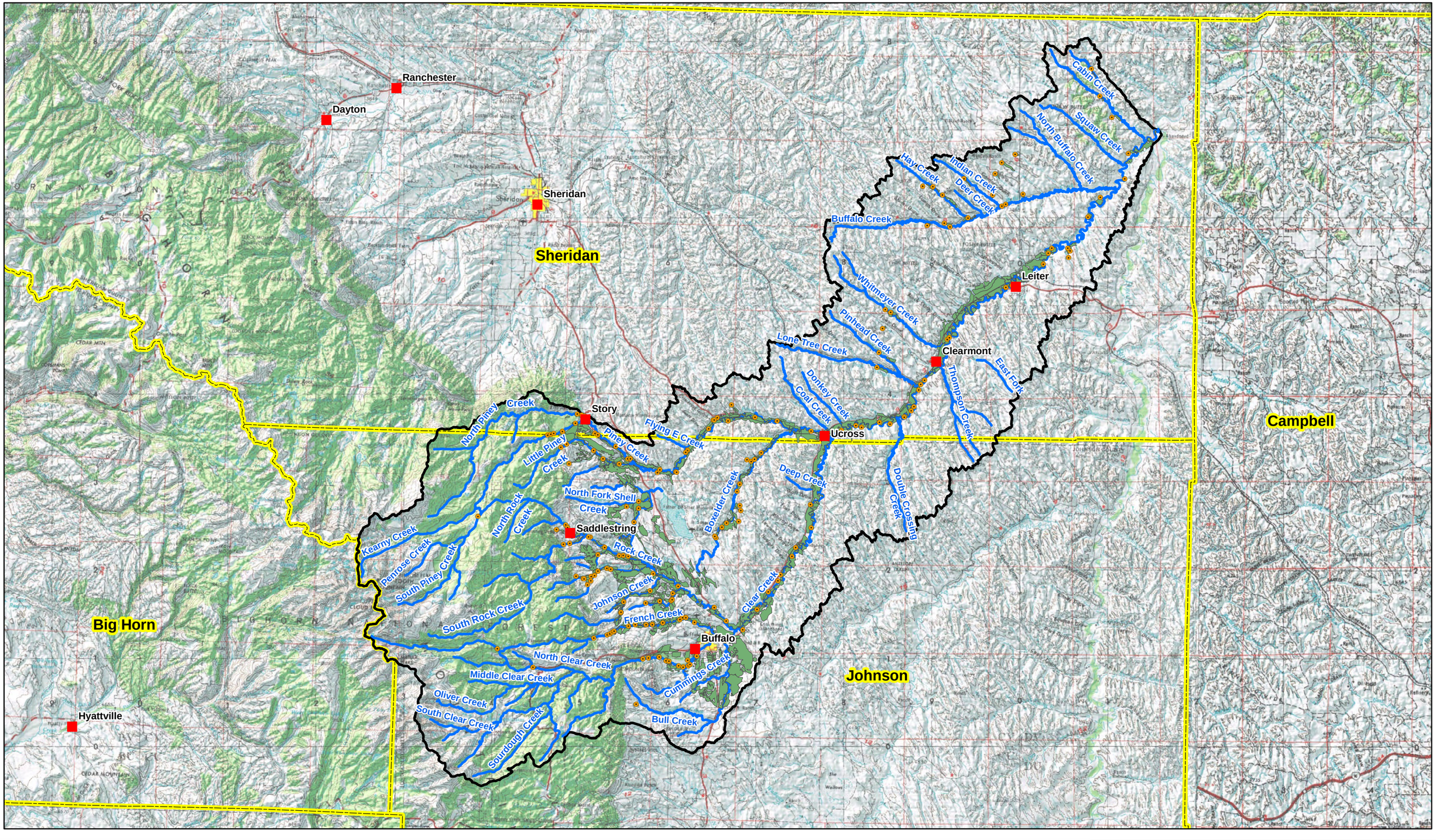
Figure 3.3-3. Clear Creek Watershed: Communications and Transportation

- Rocky Mountain Power operates a 230 kV transmission line which runs from Sheridan to Buffalo to Gillette.
- Powder River Energy has several lower voltage lines throughout the area that have been constructed to support Coal Bed Methane infrastructure. All of these lines are less than 230kV with most being either 46kV or 115 kV.

Numerous radio antennae, cellular phone towers, and microwave towers are scattered throughout the watershed as indicated in Figure 3.3-3. Ownership information and data related to these structures (other than their location) was not available.

3.3.3 Irrigation

Evaluation of Irrigated lands was initiated using mapping information generated by the Powder / Tongue River Basin Planning Study conducted by the WWDC (HKM 2002). During the completion of the WWDC study, irrigated lands within the Powder / Tongue basin (which includes the entire Clear Creek watershed), were mapped using GIS methods. Using stereo aerial photography dated 1994/1996, the irrigated parcels were delineated. This information was then provided in GIS format. At the initiation of the current project, more recent and higher quality imagery was available. Color aerial photography dated 2009 was acquired through the National Agricultural Imagery Program (NAIP). The NAIP imagery is of a higher resolution than the previously used images. In an effort to update the irrigated lands mapping, the previously mapped parcels were overlain on the 2009 NAIP imagery and any new irrigated lands were added to the layer. There were very few changes. The results of this effort indicate that approximately 40,000 acres are irrigated within the Clear Creek watershed. The majority of these lands lie within the floodplains of Clear Creek, Piney Creek, Rock Creek and French Creek. Additional irrigated parcels are scattered throughout the watershed, primarily within other tributary floodplains. At this level of study it was not feasible to conduct a thorough reconnaissance to further ground-check the irrigated lands mapping. Figure 3.3-4 displays the individual points of diversion according to data provided in the Powder / Tongue River Basin Planning documents and updated irrigated lands mapping. Information from the Powder / Tongue River Basin Plan pertaining to the major irrigation diversions and other water uses in the watershed is contained in Appendix 3I. Appendix 3G contains a tabulation of surface water rights in the watershed. The dominant irrigated crops within the Clear Creek watershed are alfalfa, grass hay, and pasture grass. Corn and small grains are grown to a lesser extent. Irrigators depend on irrigated lands to provide winter feed and summer grazing. The vast majority of irrigation conveyance within the watershed is through unlined earthen ditches and canals. A majority of lands are served by flood irrigation; however, there has been some conversion to center pivot and side roll sprinklers. Gated pipe is also being used for application throughout the watershed. There was interest in additional conversion to sprinkler delivery. See Section 5 for additional information on irrigation system assessments and rehabilitation.



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- Cities
- Points of Diversion
- Irrigated Acres
- Streams
- Clear Creek Watershed
- County Boundary

Figure 3.3-4 Clear Creek Watershed: Irrigated Acres

3.3.4 Range Conditions/ Grazing Practices

3.3.4.1 Grazing Allotments Administration

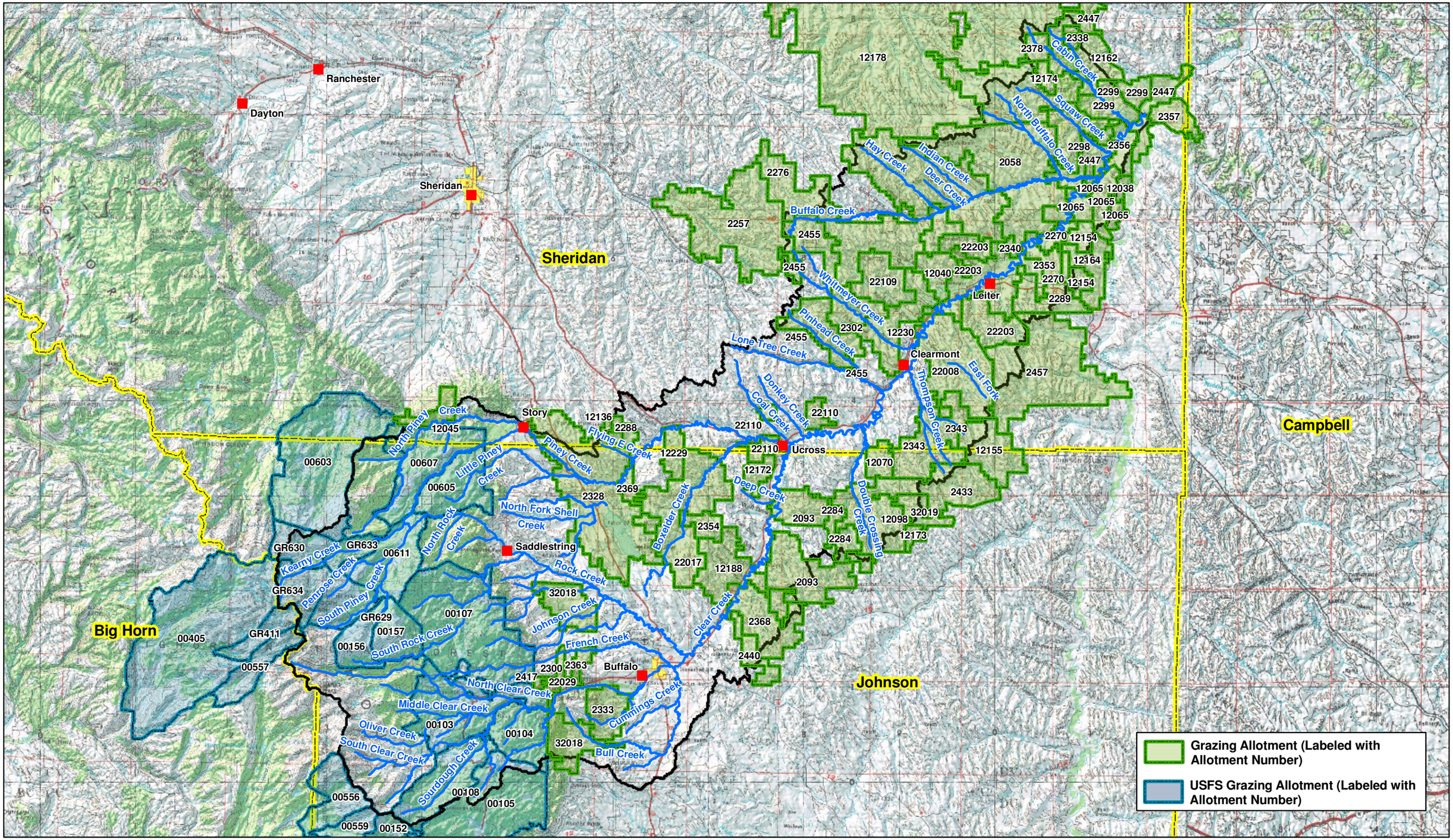
Grazing on federal lands within the Clear Creek watershed is administered by the United States Forest Service and the Bureau of Land Management. The USFS-administered allotments are located at higher elevations within the Big Horn National Forest. The allotments consist entirely of federal lands. There are fourteen USFS individual allotments as indicated in Figure 3.3-5. The BLM-administered allotments typically include intermingled private, state, and federally-administered lands used for grazing. In the Clear Creek watershed, BLM allotments consist primarily of private lands with interspersed federally owned parcels. Based upon information collected from the BLM, there are approximately 57 individual allotments (Figure 3.3-5). Note that some of these allotments may be located primarily in adjacent watersheds and "spill" over the watershed divide. Appendix 3B lists the allotments and pertinent data associated with them.

On USFS lands, livestock grazing is permitted through a permit system and allotment management plans (AMPs). The role of the AMP is discussed in the following paragraph extracted from the Final Environmental Impact Statement for the Bighorn National Forest Revised Land and Resource Management Plan (2005):

"The magnitude of the influence depends on the timing of use, the kind of livestock (sheep vs. cattle), the intensity of grazing use, the duration and frequency of grazing, and the associated management practices, including the level of permittee interest and involvement.

Most allotments are managed through a rotation grazing system, designed specifically for the allotment. Management calls for sheep to be herded and moved to new bed-grounds each night. Most cattle allotments are managed under some kind of pasture rotation system that will use most or all of the pastures each year but will generally avoid the use of an individual pasture at the same time in succeeding years. A few cattle allotments are grazed under a season-long system where livestock distribution is controlled with water, salt, and herding. Salt is located to help draw livestock away from riparian areas, and most permit holders regularly move livestock out of riparian areas and into other areas of available forage.

Site-specific NEPA analysis is completed during the allotment management planning process. The Bighorn National Forest is on a 15-year schedule to update and revise allotment management plans as mandated by the 1995 Rescissions Act. To date (August 2005), 46 of the 86 allotments underwent updated rangeland analysis followed by project level NEPA decisions with resultant updates and revisions of the allotment management plans. Project level allotment NEPA decisions are developed using the goals and objectives as well as the standards and guidelines of the approved forest plan. More specific grazing prescriptions can be developed during the allotment management planning process to address site-specific issues.



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- Cities
- Streams
- Clear Creek Watershed
- County Boundary

Figure 3.3-5. Clear Creek Watershed: BLM Grazing Allotments

Permitted livestock grazing levels are often based on historic actual and permitted use levels. Allotment management plans establish site-specific goals and objectives, and management strategies to achieve them. Management strategies may include levels of grazing use, seasons of use, rotations, and a schedule for implementing range improvement projects such as fences and water developments.

Permitted use by cattle and sheep is nearly always authorized through term grazing permits, normally issued for 10 years. These permits include numerous terms and conditions that describe responsibilities of the permit holder such as validation, payment of grazing fees, ownership requirements of livestock and base property, livestock management, range improvement maintenance and construction, and more. Allotment management plans become part of the permit. General consequences of permit non-compliance are described in the permit."

Under the umbrella of the Buffalo Resource Management Plan, management of BLM grazing allotments is prioritized based on the classification of the allotments into one of three management categories; Improve (I), Maintain (M), and Custodial (C). These categories broadly define management objectives of the BLM-administered public lands in the allotment (BLM, 2009). The majority of allotments administered by the BLM within the study area are classified as Custodial. These allotments are typically smaller parcels surrounded by deeded lands and are generally not administered with allotment management plans. Based upon review of the Buffalo Field Office's 2009 document, *Summary of the Analysis of the Management Situation Buffalo Resource Management Plan Revision* none of the allotments within the study area have had management plans developed.

Livestock grazing is managed in accordance with the principles of multiple use and sustained yield embodied in the Federal Land Policy and Management Act (1976) and the Taylor Grazing Act (1934). BLM's specific objectives and procedures for managing livestock grazing are contained in the agency's grazing regulations. BLM's grazing regulations were revised in 1995 to ensure that livestock grazing is conducted in a manner that will sustain or improve the fundamental ecological health of public rangelands.

Grazing on BLM lands to meet these requirements is managed under the Standards for Healthy Rangelands and Guidelines for Livestock Grazing Management for the Public Lands Administered by the BLM in the State of Wyoming (BLM, 2007). Among the full suite of grazing management guidelines, those most applicable to this watershed study are summarized as follows:

- Ensure that conditions after grazing use will support infiltration, maintain soil moisture storage, stabilize soils, release sufficient water to maintain overall system function, and maintain soil permeability rates and other appropriate processes;
- Restore, maintain, or improve riparian plant communities to sustain adequate residual plant cover for sediment capture and groundwater recharge;

- Implement riparian improvements (e.g., instream structures, water troughs, etc.) to maintain or enhance appropriate stream channel morphology; develop springs, seeps, reservoirs, wells or other water development projects in a manner protective of watershed ecological and hydrological functions; and implement range improvements away from riparian areas to avoid conflicts in achieving or maintaining riparian function; and
- Adopt management practices and implement range improvements that protect vegetative cover and thereby maintain, restore or enhance water quality.

A set of six standards have been established to meet the above guidelines (BLM, 2007). Each standard sets a specific objective, explains the function and importance of the objective, and provides indicators to assess the attainment of the objective. Detailed information regarding the BLM standards and guidelines is available at:

http://www.blm.gov/wy/st/en/programs/grazing/standards_and_guidelines.html

State Grazing Leases. Most of the state lands within the Clear Creek watershed are leased to private landowners for grazing. These leases are typically issued by the Board of Land Commissioners and administered by the Office of State Lands and Investments (OSLI). Grazing management, practices and improvements on state lands are usually established and implemented by the lessee. Improvements are normally paid for and owned by the lessee with reimbursement by the new lessee upon transfer of the lease.

Grazing on Private Lands. Grazing practices on private lands are established by the landowner, often with technical assistance from the local NRCS staff and/or a range consultant. Range improvement projects implemented under NRCS program (e.g., EQIP or PL566) follow the guidelines established in the plan of operations developed for the property and/or applicable NRCS technical guidelines as adapted for local conditions

3.3.4.2 Existing Water Supply

The Clear Creek watershed has the good fortune of possessing numerous reliable water sources for wildlife and livestock. These sources include:

- Perennial and intermittent streams
- Springs
- Ponds
- Guzzlers
- Stock tanks
- Reservoirs, etc.,

According to representatives of the NRCS and the Lake DeSmet Conservation District, upland water supply needs have largely been addressed in the Johnson County portion of the watershed. Numerous upland wildlife / livestock water supply projects have been completed in coordination with the NRCS and using EQIP funding. That portion of the watershed lying in Sheridan County is also reported to be relatively well supplied with upland sources of water for wildlife and livestock, however, not to the extent that the Johnson County portion of the watershed is.

Perennial and intermittent streams (when flowing) have historically served as reliable sources of water for both livestock and wildlife. The lower, drier region of the study area is dominated by intermittent and ephemeral streams. Consequently, surface water sources do not provide reliable sources of water over a large portion of the watershed. In these areas, numerous stock reservoirs have been built throughout the years in an effort to augment existing surfaces sources by retaining spring runoff and runoff during precipitation events.

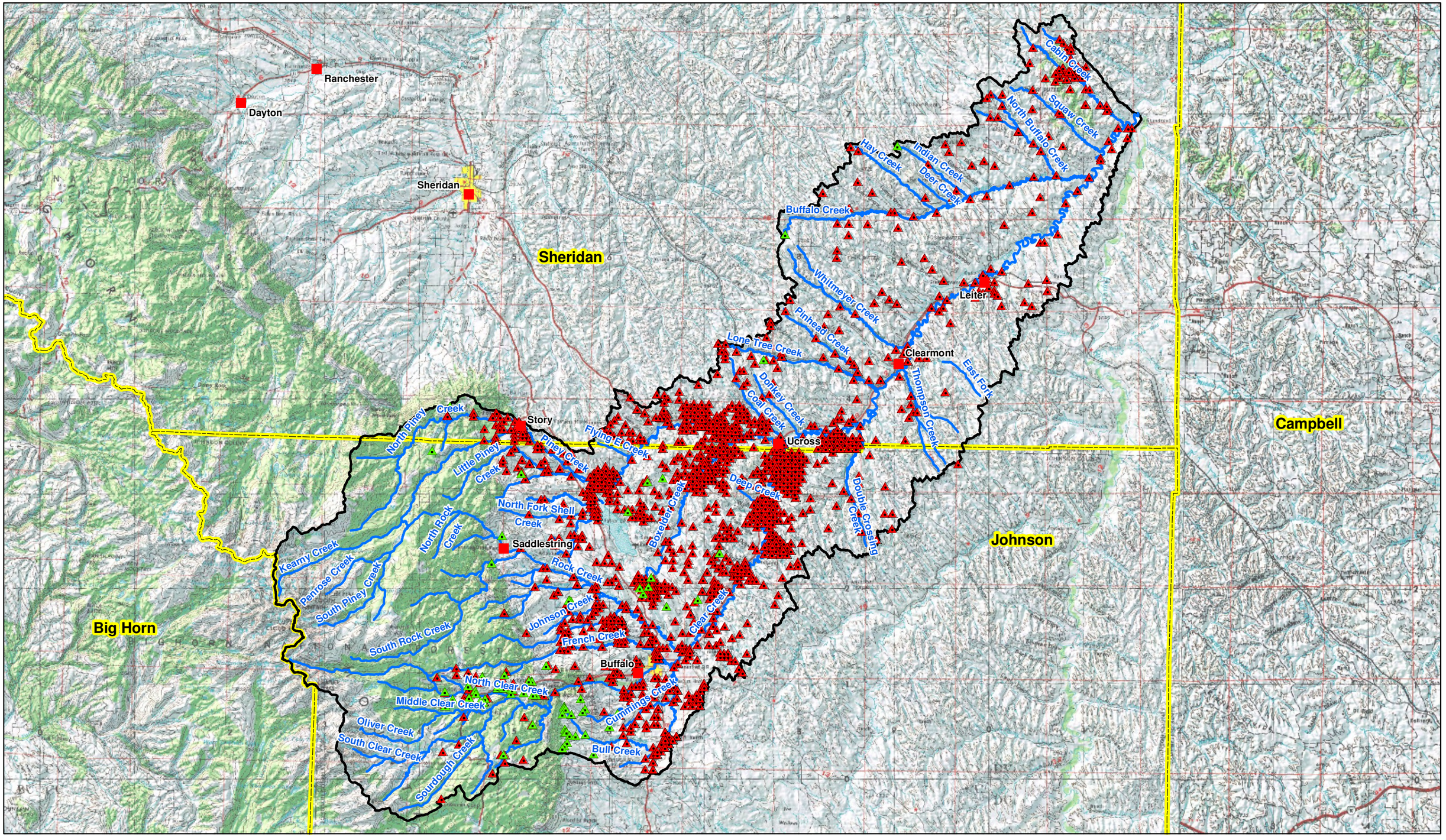
In an effort to evaluate the general availability of upland water sources, a query of the Wyoming State Engineers Office water rights database was conducted. Figure 3.3-6 displays the locations of all wells within the watershed which include stock water usage as one of the permitted uses. Also displayed in this figure are springs indicated on available USGS topographic mapping.

A qualitative assessment of stock reservoirs was completed by overlying the reservoir locations on aerial photography obtained in 2009. The WSEO database indicated the presence of approximately 466 permitted stock reservoirs in the study area. It is our understanding that many of the reservoirs have either failed or have filled with sediment and are no longer viable sources of livestock and wildlife water. Those containing water can be assumed to be viable sources. Physical breaches were visible on many of the reservoirs. Likewise, many were visibly filled with sediment and also classified as “non-viable”. Others were simply empty and firm conclusions could not be drawn. These sites could have been dry at the time of the photography but remain viable sources following precipitation events. Figure 3.3-7 displays an example of this process. Note the breach of the embankment which is clearly visible in the photo. Although numerous stock reservoirs appear to be no longer viable, the majority of the reservoirs examined appear to remain viable sources of water for wildlife and livestock. Figure 3.3-8 displays the results of this analysis. Of the 466 total permitted stock reservoirs, approximately 332 appear to provide viable sources of water for livestock and wildlife based upon the procedure described above.

3.3.4.3 Ecological Site Descriptions

The concept of “Ecological Sites” are described by the NRCS as follows:

> “A *distinctive kind of land with specific soil and physical characteristics that differs from other kinds of land in its ability to produce distinctive kinds and*



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- Cities
- Springs From USGS Topo
- Stock Permit Wells
- Streams
- Clear Creek Watershed
- County Boundary

Figure 3.3-6. Clear Creek Watershed: Existing Wells Permitted for Livestock Watering Purposes and Springs

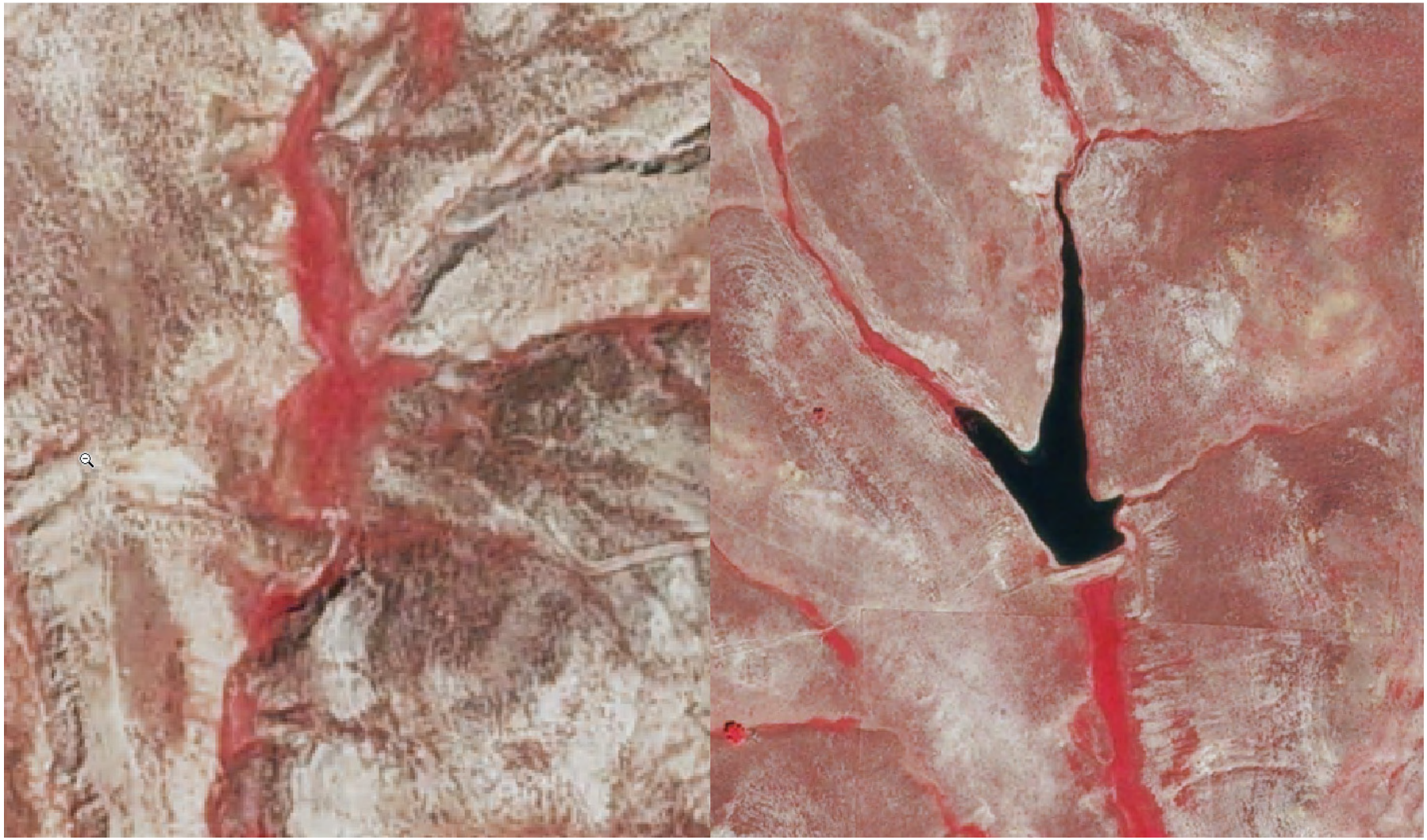
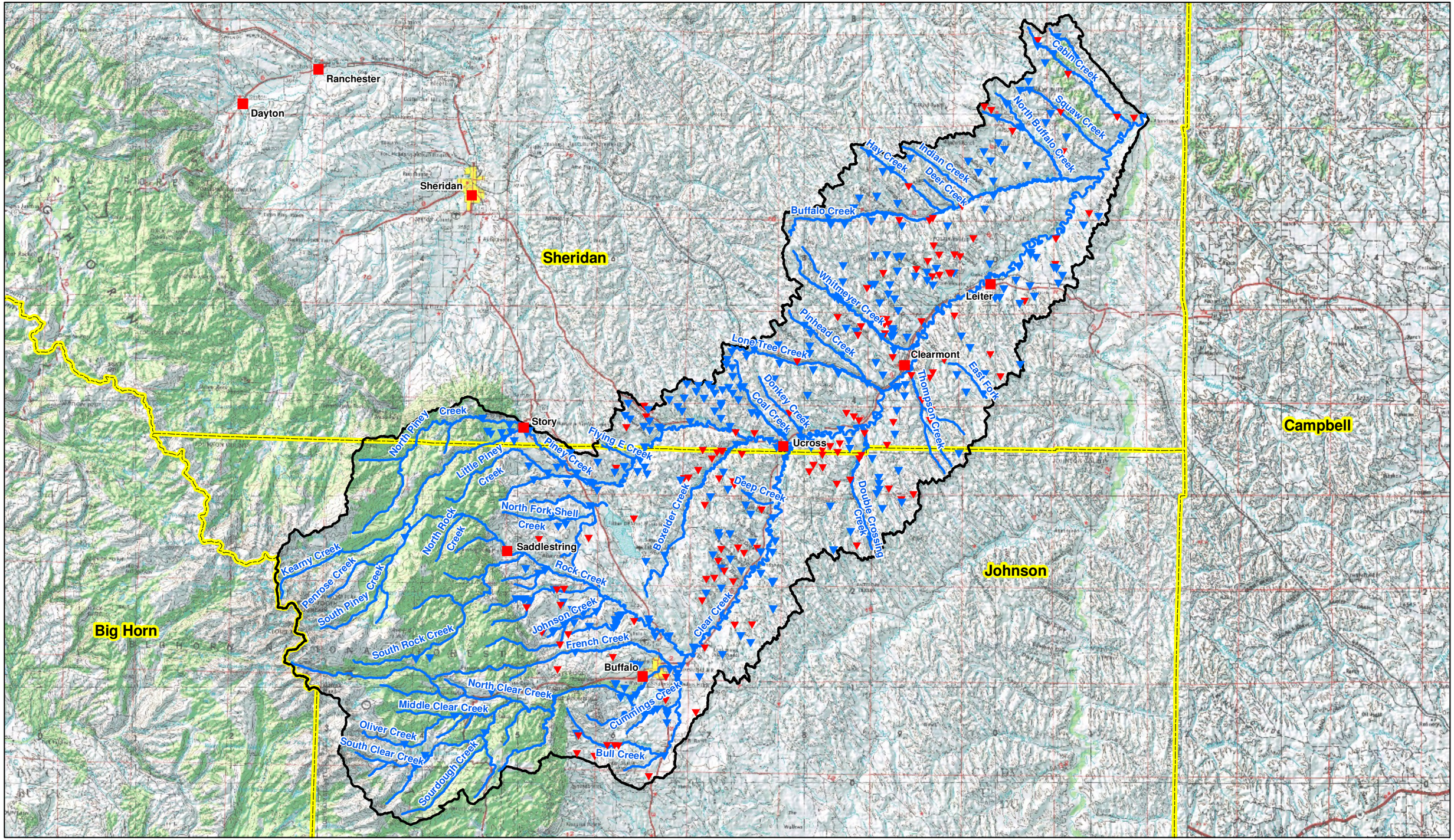


Figure 3.3-7 Evaluation of Stock Reservoirs in the Project GIS Environment



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- Cities
- Viable Stock Reservoir
- Stock Reservoir (Uncertain Viability)
- Streams
- Clear Creek Watershed
- County Boundary

Figure 3.3-8. Clear Creek Watershed: Permitted Stock Reservoirs

amounts of vegetation, and in its ability to respond similarly to management actions and natural disturbances."

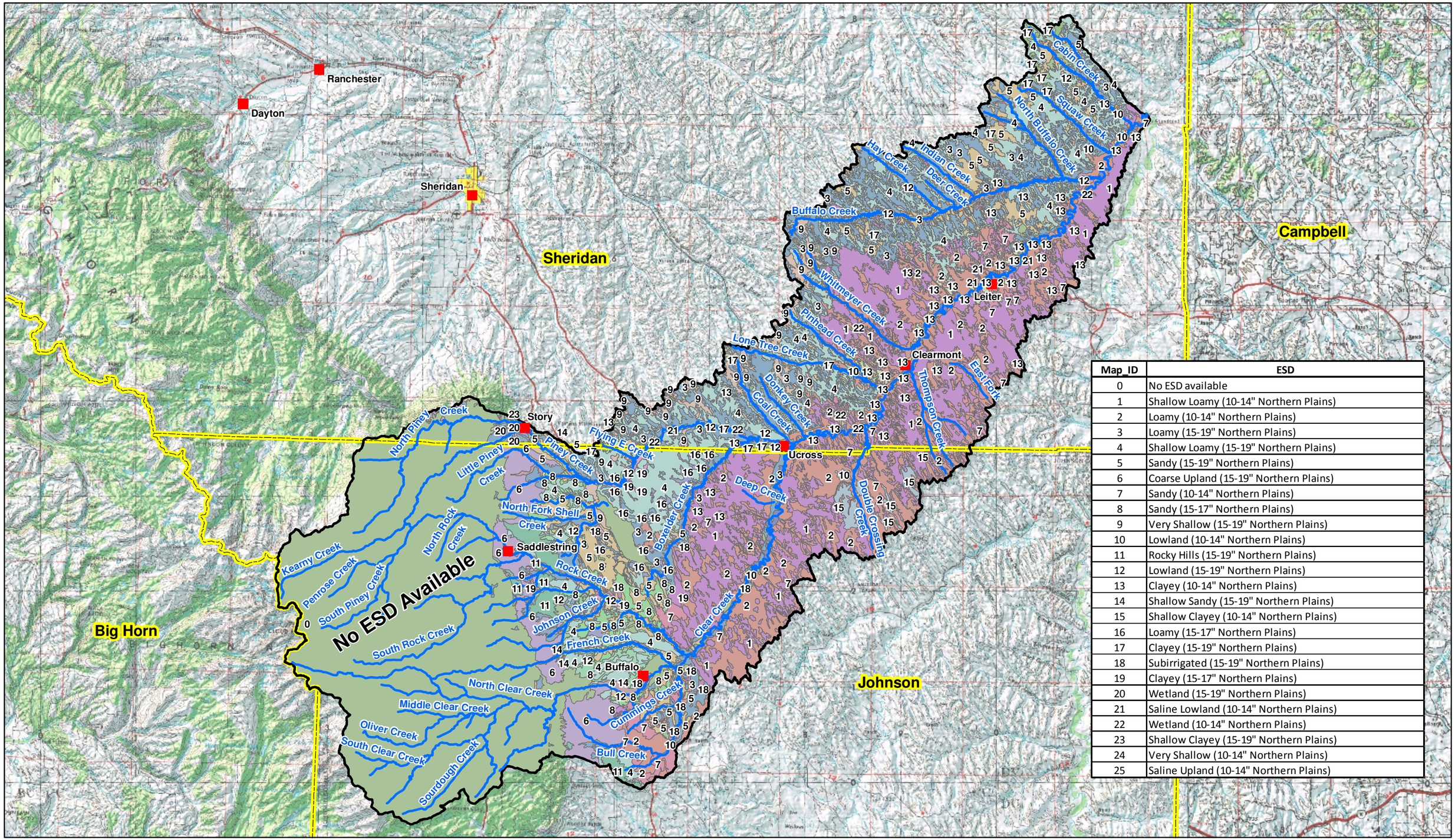
Ecological Site Descriptions (ESDs) are reports available from the NRCS that describe the following for each Ecological Site:

- **Site Characteristics:** Identifies the site and describes the physiographic, climate, soil, and water features associated with the site.
- **Plant Communities**: Describes the ecological dynamics and the common plant communities comprising the various vegetation states of the site. The disturbances that cause a shift from one state to another are also described.
- **Site Interpretations:** Interpretive information pertinent to the use and management of the site and its related resources.
- **Supporting Information**: Provides information on sources of information and data utilized in developing the site description and the relationship of the site to other ecological sites (NRCS, 2009).

More information regarding ESDs and their application is available at:
http://esis.sc.egov.usda.gov/ESIS/About.aspx.

The ESDs can be used to compare what is growing on the rangeland with what each site is capable of growing. By comparing the present vegetative composition to the potential compositions, the relative health of the range resource can be evaluated. Production of each site is closely related to the ecological condition of the site.

Ecological Sites are defined based upon their location within defined Ecological Precipitation Zones and soil characteristics. Using database tools provided by the NRCS, the available soils mapping was evaluated and Ecological Sites defined within the study area. Table 3.3-1 contains a list of the sites. Figure 3.3-9 displays their location within the study area.



Map_ID	ESD
0	No ESD available
1	Shallow Loamy (10-14" Northern Plains)
2	Loamy (10-14" Northern Plains)
3	Loamy (15-19" Northern Plains)
4	Shallow Loamy (15-19" Northern Plains)
5	Sandy (15-19" Northern Plains)
6	Coarse Upland (15-19" Northern Plains)
7	Sandy (10-14" Northern Plains)
8	Sandy (15-17" Northern Plains)
9	Very Shallow (15-19" Northern Plains)
10	Lowland (10-14" Northern Plains)
11	Rocky Hills (15-19" Northern Plains)
12	Lowland (15-19" Northern Plains)
13	Clayey (10-14" Northern Plains)
14	Shallow Sandy (15-19" Northern Plains)
15	Shallow Clayey (10-14" Northern Plains)
16	Loamy (15-17" Northern Plains)
17	Clayey (15-19" Northern Plains)
18	Subirrigated (15-19" Northern Plains)
19	Clayey (15-17" Northern Plains)
20	Wetland (15-19" Northern Plains)
21	Saline Lowland (10-14" Northern Plains)
22	Wetland (10-14" Northern Plains)
23	Shallow Clayey (15-19" Northern Plains)
24	Very Shallow (10-14" Northern Plains)
25	Saline Upland (10-14" Northern Plains)

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- Cities
- Streams
- Clear Creek Watershed
- County Boundary

Figure 3.3-9. Clear Creek Watershed: Ecological Sites

Table 3.3-1 Ecological Site Descriptions

Ecological Site Identifier	Map ID	Acres	Percent of Watershed	Ecological Site Description
NA	0	216,895	29.4%	No ESD available
R058BY162WY	1	103,160	14.0%	Shallow Loamy (10-14" Northern Plains)
R058BY122WY	2	96,445	13.1%	Loamy (10-14" Northern Plains)
R043XY422WY	3	92,675	12.5%	Loamy (15-19" Northern Plains)
R043XY462WY	4	87,061	11.8%	Shallow Loamy (15-19" Northern Plains)
R043XY450WY	5	33,487	4.5%	Sandy (15-19" Northern Plains)
R043XY408WY	6	23,243	3.1%	Coarse Upland (15-19" Northern Plains)
R058BY150WY	7	16,562	2.2%	Sandy (10-14" Northern Plains)
R058BY250WY	8	10,125	1.4%	Sandy (15-17" Northern Plains)
R043XY476WY	9	9,789	1.3%	Very Shallow (15-19" Northern Plains)
R058BY128WY	10	8,093	1.1%	Lowland (10-14" Northern Plains)
R043BY434WY	11	7,498	1.0%	Rocky Hills (15-19" Northern Plains)
R046XY128WY	12	6,635	0.9%	Lowland (15-19" Northern Plains)
R058BY104WY	13	5,660	0.8%	Clayey (10-14" Northern Plains)
R043XY466WY	14	5,345	0.7%	Shallow Sandy (15-19" Northern Plains)
R058BY158WY	15	3,743	0.5%	Shallow Clayey (10-14" Northern Plains)
R058BY222WY	16	3,693	0.5%	Loamy (15-17" Northern Plains)
R043XY404WY	17	3,304	0.4%	Clayey (15-19" Northern Plains)
R043XY474WY	18	2,515	0.3%	Subirrigated (15-19" Northern Plains)
R058BY204WY	19	1,352	0.2%	Clayey (15-17" Northern Plains)
R043XY478WY	20	450	0.1%	Wetland (15-19" Northern Plains)
R058BY138WY	21	396	0.1%	Saline Lowland (10-14" Northern Plains)
R058BY178WY	22	325	0.04%	Wetland (10-14" Northern Plains)
R043XY458WY	23	82	0.01%	Shallow Clayey (15-19" Northern Plains)
R058BY176WY	24	21	<0.01%	Very Shallow (10-14" Northern Plains)
R058BY144WY	25	10	<0.01%	Saline Upland (10-14" Northern Plains)

The relative distribution of the sites is displayed in Figure 3.3-10. As is evident in this figure, there are several ecological sites which dominate the study area; four Ecological Sites comprise over 50 percent of the mapped area. Based upon this analysis, the four ecological sites most likely to be encountered in the study area are:

- Shallow Loamy 10-14 inch precipitation zone, Northern Plains
- Shallow Loamy 15-19 inch precipitation zone, Northern Plains
- Loamy 10-14 inch precipitation zone, Northern Plains
- Loamy 15-19 inch precipitation zone, Northern Plains

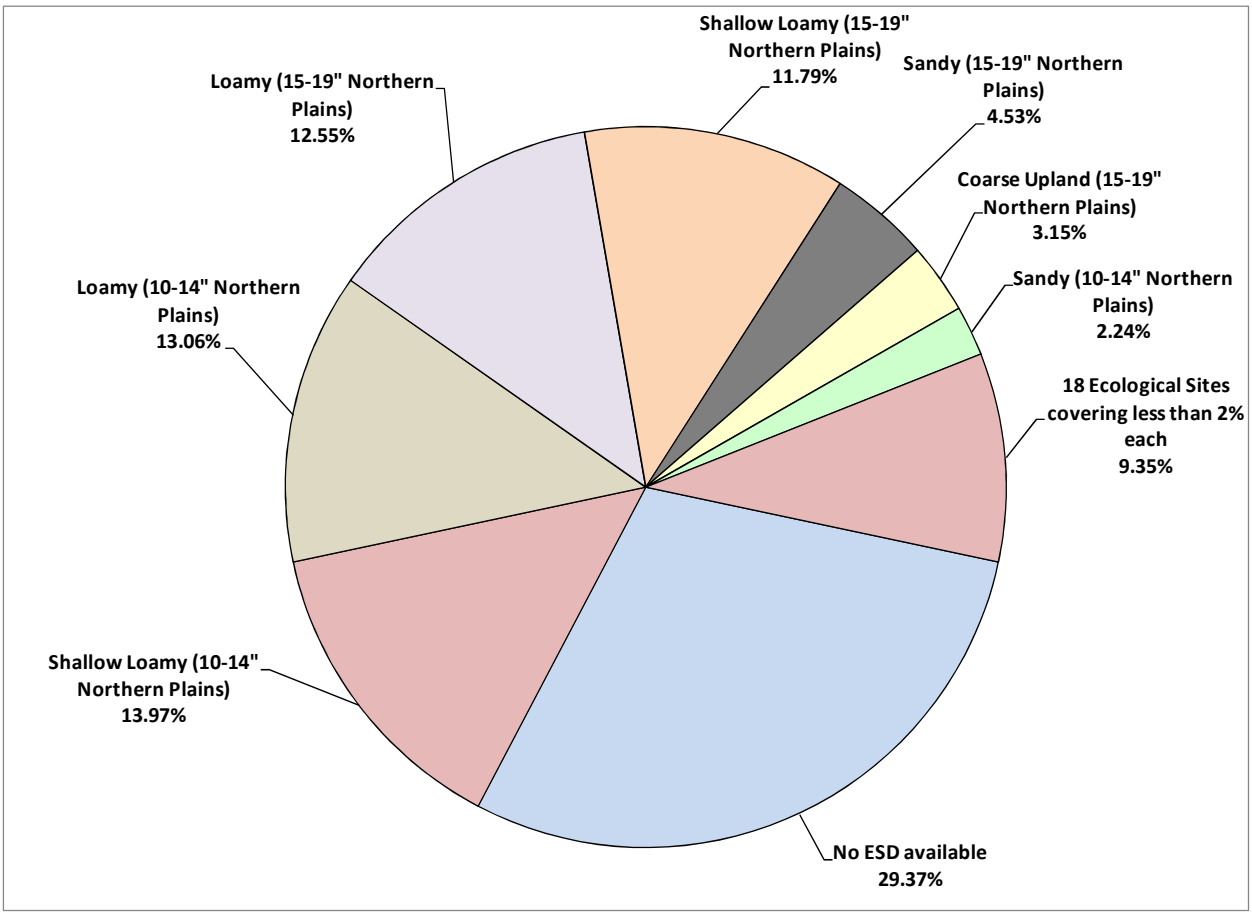


Figure 3.3-10 Clear Creek Watershed: Relative Distribution of Ecological Sites

The following descriptions of the Historic Climax Plant Communities (HCPC) associated with these ESDs are extracted from the NRCS descriptions (NRCS, 2008):

Shallow Loamy 10-14 inch and 15 to 19 inch precipitation zones, Northern Plains

"The Historic Climax Plant Community is the Rhizomatous wheatgrasses / Needleandthread / Blue Grama Plant Community . This state evolved with grazing by large herbivores and is well suited for grazing by domestic livestock. Potential vegetation is about 75% grasses or grass-like plants, 15% forbs, and 10% woody plants for the 10 to 14 inch zone (80% grasses or grass-like plants, 10% forbs, and 10% woody plants for the 15 to 19 inch zone). The state is dominated by cool season midgrasses. The major grasses include western wheatgrass, bluebunch wheatgrass, needleandthread, and little bluestem. Other grasses occurring on the state include Cusick's and Sandberg bluegrass, blue grama, and prairie junegrass. Big sagebrush is a conspicuous element of this state, occurring in a mosaic pattern, and makes up 5 to 10% of the annual production. Big sagebrush may become dominant on some areas with absence of fire. Natural fire occurred frequently in this community and prevented big sagebrush from being the dominant landscape. Wildfires are actively controlled in recent times so chemical control using herbicides has replaced the historic role of fire on this state. Recently controlled burning has regained some popularity.

The total annual production (air-dry weight) of this state is about 900 pounds per acre, but it can range from about 450 lbs./acre in unfavorable years to about 1200 lbs./acre in above average years.

The state is extremely stable and well adapted to the Northern Great Plains climatic conditions. The diversity in plant species allows for high drought resistance. This is a sustainable plant community (site/soil stability, watershed function, and biologic integrity).

Transitions or pathways leading to other plant communities are as follows:

- *Protection from grazing and fire will convert this plant community to the Heavy Sagebrush Vegetation State.*
- *Moderate, continuous season-long grazing will convert the plant community to the Mixed Sagebrush/Grass Vegetation State.*
- *Frequent and severe grazing and brush management will convert the plant community to the Blue Grama Vegetation State."*

Loamy 10-14 inch and 15 to 19 inch precipitation zones, Northern Plains

"The Historic Climax Plant Community (HCPC) is the Rhizomatous wheatgrasses / Needleandthread / Blue Grama Plant Community . This plant community evolved with grazing by large herbivores and is well suited for grazing by domestic livestock. This plant community can be found on areas that are properly managed with grazing and/or prescribed burning, and sometimes on areas receiving occasional short periods of rest. The potential vegetation is about 75% grasses or grass-like plants, 15% forbs, and 10% woody plants for both zones . This state is dominated by cool season mid-grasses.

The major grasses include western wheatgrass, needleandthread, and green needlegrass. Other grasses occurring in this state include Cusick's and Sandberg's bluegrass, bluebunch wheatgrass, and blue grama. A variety of forbs and half-shrubs also occur, as shown in the preceding table. Big sagebrush is a conspicuous element of this state, occurs in a mosaic pattern, and makes up 5 to 10% of the annual production. Plant diversity is high.

The total annual production (air-dry weight) of this state is about 1,200 lbs./acre, but it can range from about 700 lbs./acre in unfavorable years to about 1,500 lbs./acre in above average years.

This plant community is extremely stable and well adapted to the Northern Great Plains climatic conditions. The diversity in plant species allows for high drought tolerance. This is a sustainable plant community (site/soil stability, watershed function, and biologic integrity).

Transitions or pathways leading to other plant communities are as follows:

- *No use and no fire for 20 years or more will convert this plant community to the Heavy Sagebrush Plant Community.*
- *Moderate, continuous season-long grazing will convert the plant community to the Mixed Sagebrush/Grass Plant Community.*
- *Moderate continuous season-long grazing, where greasewood occurs adjacent to the site, will convert the plant community to the Greasewood Plant Community.*
- *When cropped annually and then abandoned without reseeding, the site is converted to the Go-back Land Plant Community"*

Appendix 3C contains the entire ESD associated with these four ecological sites.

3.3.4.4 Range Condition and Needs

The majority of the Clear Creek study area has been grazed by domestic livestock (both cattle and sheep) since the late 1800's. Wildlife also plays an important role in the grazing utilization of the area. Detailed and site-specific evaluations of range conditions were beyond the scope of this Level I investigation..

An important factor needed to facilitate grazing management is well distributed, reliable water. Despite the relative ample water supplies within the watershed, good grazing systems control both the time (amount of time spent in an area), and the timing (the time of the year) that the livestock spend in a pasture. Grasses and other plants need to recover from the last grazing event before being grazed again. This is because food reserves in the roots must be utilized for new plant growth. If they do not get to replace these root reserves, the plants are weakened and may eventually die. Less desirable plants eventually take over and plant densities decrease.

Without well distributed livestock water, areas near water (frequently riparian areas) are grazed heavily while many other areas are under-utilized. Livestock water must also be reliable so that each pasture can be used as needed in a grazing rotation. Otherwise, the same pastures with reliable water get grazed repeatedly at the same crucial time of the year.

Because plants grow rapidly during the growing season, re-growth is frequently grazed multiple times during each grazing period. This results in depleted root reserves. Because of this, it is often desirable to combine herds so livestock can spend shorter time periods in one pasture. This requires adequate quantities of water to accommodate larger herds.

In addition to restoration of more healthy conditions in currently impacted riparian areas, continuing adjustments in overall range management will contribute to the maintenance, recovery or improvement of a variety of interrelated aspects of watershed function, including but not necessarily limited to:

- Improved infiltration of snowmelt and rainfall;
- Retention of soil moisture;
- Groundwater recharge;
- Sustained release of soil moisture and groundwater as seeps/springs; and
- Stabilization of soils against erosion into streams.

In general, most range improvement practices which improve watershed and livestock values also improve wildlife habitat values. With important and sensitive species such as sage grouse, care must be taken to ensure that practices are beneficial rather than detrimental to their habitat values. Examples of this include the need for mixed age stands of sagebrush, adequate vegetative residues, wildlife escape ramps from livestock tanks, and provisions for wildlife water.

Alternatives to address the need for additional wildlife/livestock watering sites are presented in Chapter 4. It is important to consider that to be cost-effective, any range improvement practices/facilities that may be implemented must be followed up with a good grazing system. Otherwise, any short term gains will be lost, and often made worse. Since the key to any good grazing system is usually a good, reliable livestock water system, this usually is the most cost-effective practice to initiate the process. The best value for the investment of resources usually occurs on the more productive land. Land that is too steep or shallow can only show limited returns on investments. Finally, to work in the long run, any change in range management must be supported by the land user.

3.3.5 Oil and Gas Production and Resources

Expansion of the oil and gas industry has been rapid and extensive in the Powder River basin. Considerable information is available pertaining to the development of these resources through various EIS documents, the BLM, and through private industry. For the purposes of this Level I

investigation, a query of databases available through the Wyoming Oil and Gas Conservation Commission (WOGCC) was conducted. Active wells within the study area are shown on Figure 3.3-11.

3.3.6 Mining and Mineral Resources

Current mine permit boundary information is tabulated and displayed graphically in Figure 3.3-12. This figure indicates that sand and gravel operations dominate the existing mining activity in the watershed. Other mining permits in the study area are limited to scoria mining. Based upon a conversation with WDEQ LQD, there has only been minimal coal mining activity within the Clear Creek watershed.

3.3.7 Wildlife

Previously documented occurrences of federally listed species and other species of concern within the Clear Creek Basin were determined through searching the Wyoming Natural Diversity Database (WYNDD) maintained by the University of Wyoming. To obtain information on big game habitats in the basin, digital big game herd unit maps were obtained from the Wyoming Game and Fish Department (WGFD). Maps of greater sage-grouse core use areas were also obtained from the WGFD and overlaid on maps of the basin.

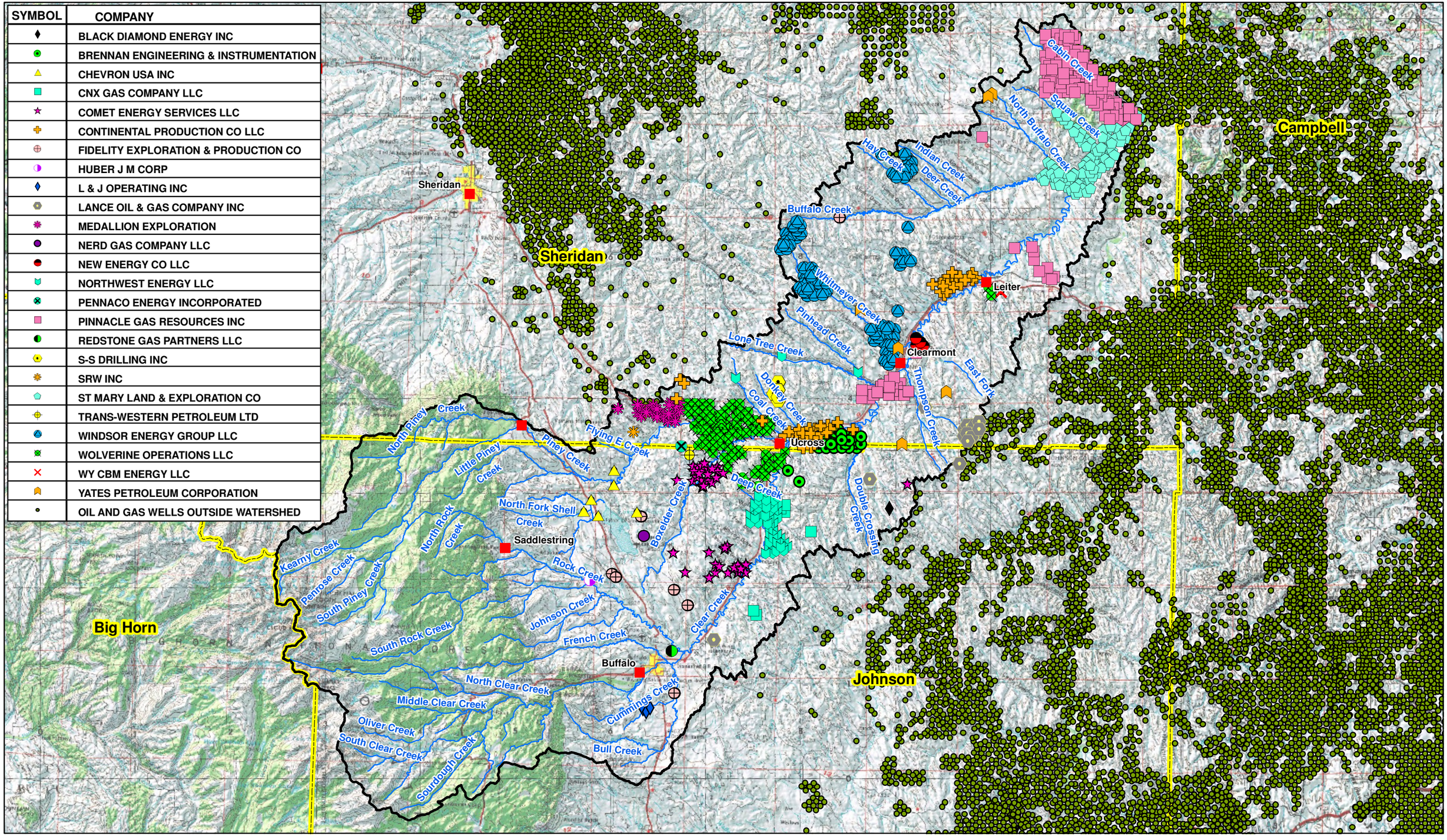
3.3.7.1 Big Game

Most of the lower portions of the basin are considered yearlong range for pronghorn antelope (Figure 3.3-13). A relatively small portion of the basin in the vicinity of Clearmont is considered pronghorn winter/yearlong range. The upper end of the basin, primarily that portion within the Bighorn National Forest, is not considered pronghorn antelope habitat, and there are no pronghorn crucial ranges within the basin.

Most of that portion of the basin located primarily within the Bighorn National Forest is classified as mule deer spring/summer/fall range (Figure 3.3-14). The remainder of the basin is classified as either winter/yearlong or yearlong range for mule deer. There are no crucial habitats for mule deer in the basin. Portions of Clear Creek Basin, especially along the east flanks of the Bighorn Mountains and along major riparian corridors, are considered yearlong range for white-tailed deer (Figure 3.3-15). No crucial habitat for white-tailed deer is present in the basin.

Most of that portion of the basin located primarily within the Bighorn National Forest is classified as spring/summer/fall range for elk (Figure 3.3-16). A relatively small portion of the basin located within the French Creek and Clear Creek drainages east of Buffalo, as well as other areas along the east flank of the Bighorn Mountains, are classified as elk crucial winter range. Other areas along the east flank of the Bighorns are classified as winter/yearlong range. Most of the basin is not considered to provide elk habitat.

SYMBOL	COMPANY
♦	BLACK DIAMOND ENERGY INC
●	BRENNAN ENGINEERING & INSTRUMENTATION
▲	CHEVRON USA INC
■	CNX GAS COMPANY LLC
★	COMET ENERGY SERVICES LLC
✚	CONTINENTAL PRODUCTION CO LLC
⊕	FIDELITY EXPLORATION & PRODUCTION CO
◑	HUBER J M CORP
♦	L & J OPERATING INC
⬢	LANCE OIL & GAS COMPANY INC
✸	MEDALLION EXPLORATION
●	NERD GAS COMPANY LLC
◓	NEW ENERGY CO LLC
⬟	NORTHWEST ENERGY LLC
⊗	PENNACO ENERGY INCORPORATED
■	PINNACLE GAS RESOURCES INC
◐	REDSTONE GAS PARTNERS LLC
⊙	S-S DRILLING INC
✸	SRW INC
⬠	ST MARY LAND & EXPLORATION CO
⊕	TRANS-WESTERN PETROLEUM LTD
◭	WINDSOR ENERGY GROUP LLC
⊗	WOLVERINE OPERATIONS LLC
✕	WY CBM ENERGY LLC
⬟	YATES PETROLEUM CORPORATION
•	OIL AND GAS WELLS OUTSIDE WATERSHED



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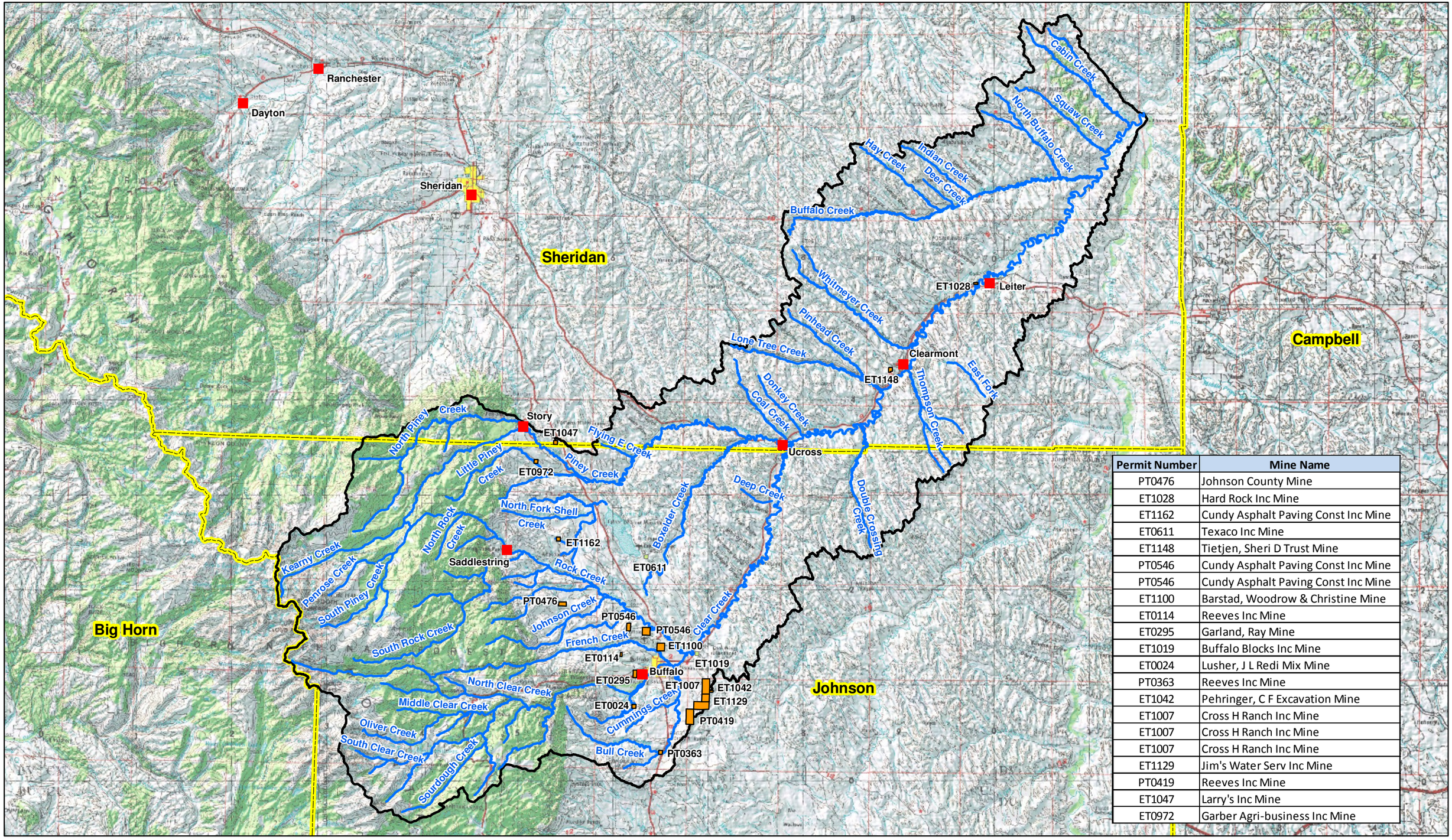
- Cities
- Streams
- Clear Creek Watershed
- County Boundary

Figure 3.3-11. Clear Creek Watershed: Oil and Gas Wells



Permit Number	Mine Name
PT0476	Johnson County Mine
ET1028	Hard Rock Inc Mine
ET1162	Cundy Asphalt Paving Const Inc Mine
ET0611	Texaco Inc Mine
ET1148	Tietjen, Sheri D Trust Mine
PT0546	Cundy Asphalt Paving Const Inc Mine
PT0546	Cundy Asphalt Paving Const Inc Mine
ET1100	Barstad, Woodrow & Christine Mine
ET0114	Reeves Inc Mine
ET0295	Garland, Ray Mine
ET1019	Buffalo Blocks Inc Mine
ET0024	Lusher, J L Redi Mix Mine
PT0363	Reeves Inc Mine
ET1042	Pehringer, C F Excavation Mine
ET1007	Cross H Ranch Inc Mine
ET1007	Cross H Ranch Inc Mine
ET1007	Cross H Ranch Inc Mine
ET1129	Jim's Water Serv Inc Mine
PT0419	Reeves Inc Mine
ET1047	Larry's Inc Mine
ET0972	Garber Agri-business Inc Mine

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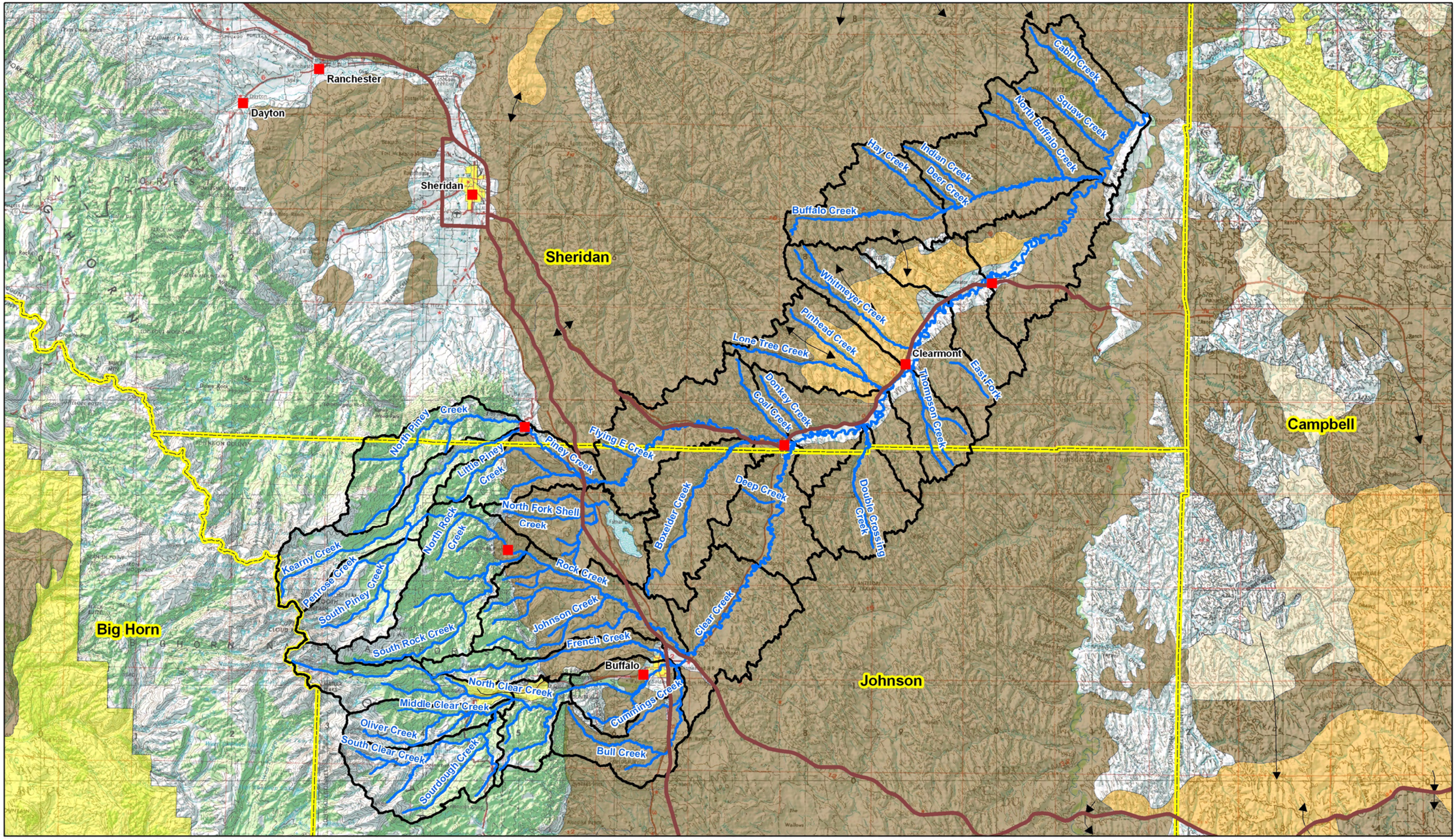
- Cities
- Sand & Gravel
- Scoria
- Streams
- Clear Creek Watershed
- County Boundary

Figure 3.3-12. Clear Creek Watershed: Mine Permit Boundaries



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Pronghorn

- Spring/Summer/Fall
- Winter
- Winter/Yearlong
- Yearlong
- Pronghorn Migration Barriers
- Pronghorn Migration Routes
- Cities
- Streams
- Watershed
- County Boundary

Figure 3.3-13 Pronghorn Antelope Ranges in the Clear Creek Basin

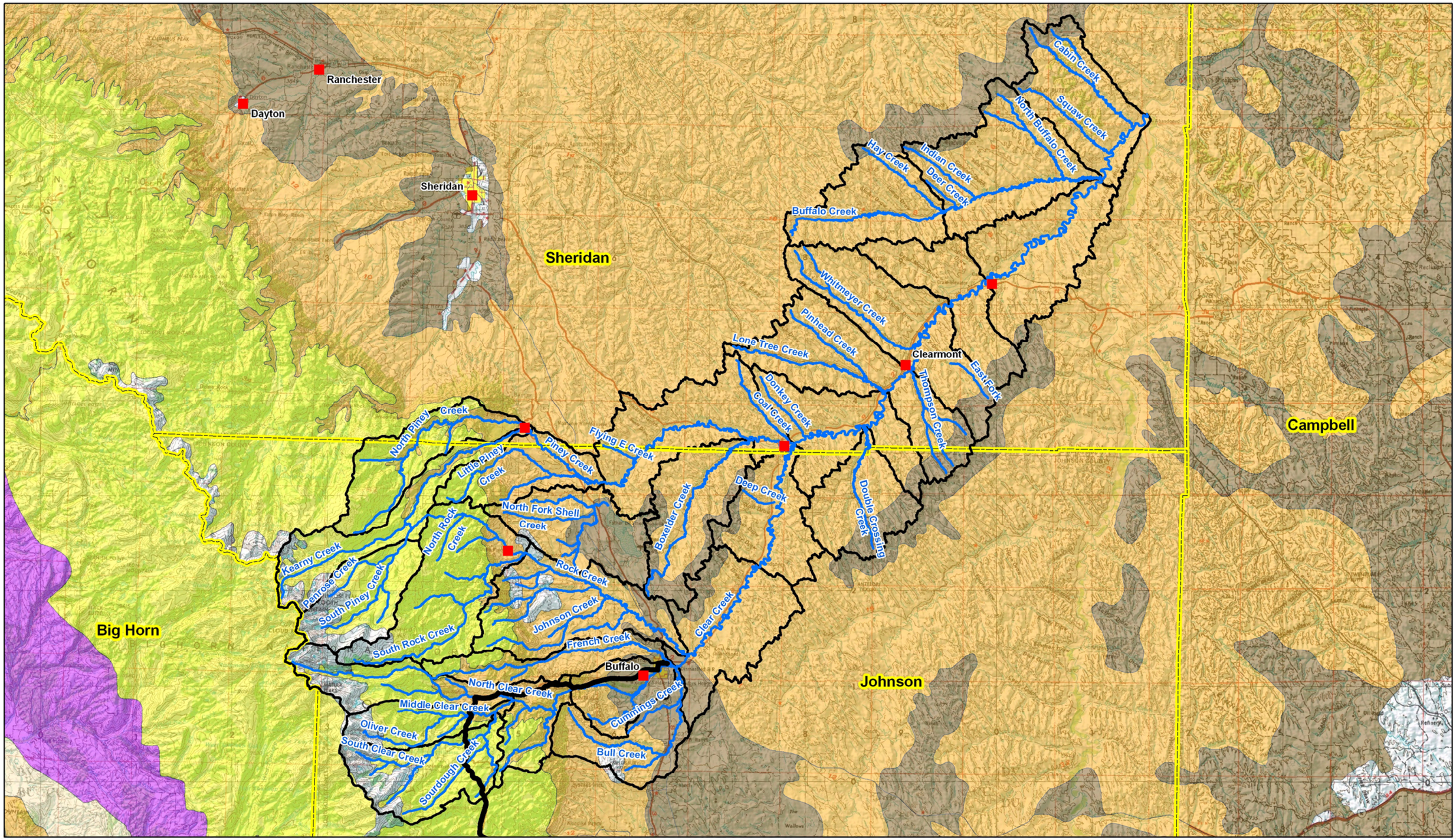


Figure 3.3-14 Mule Deer Ranges in the Clear Creek Basin

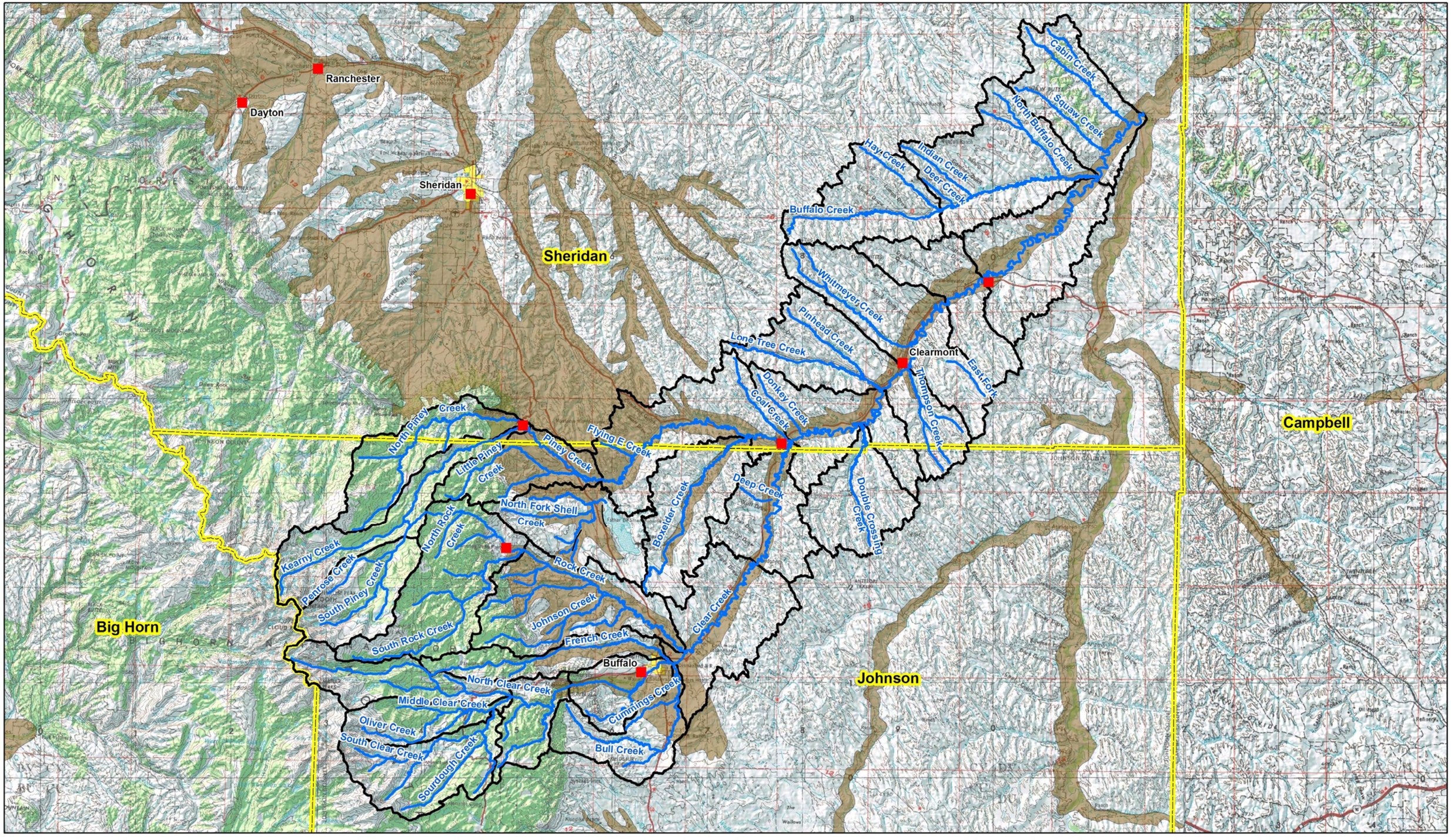


Figure 3.3-15 White Tailed Deer Ranges in the Clear Creek Basin

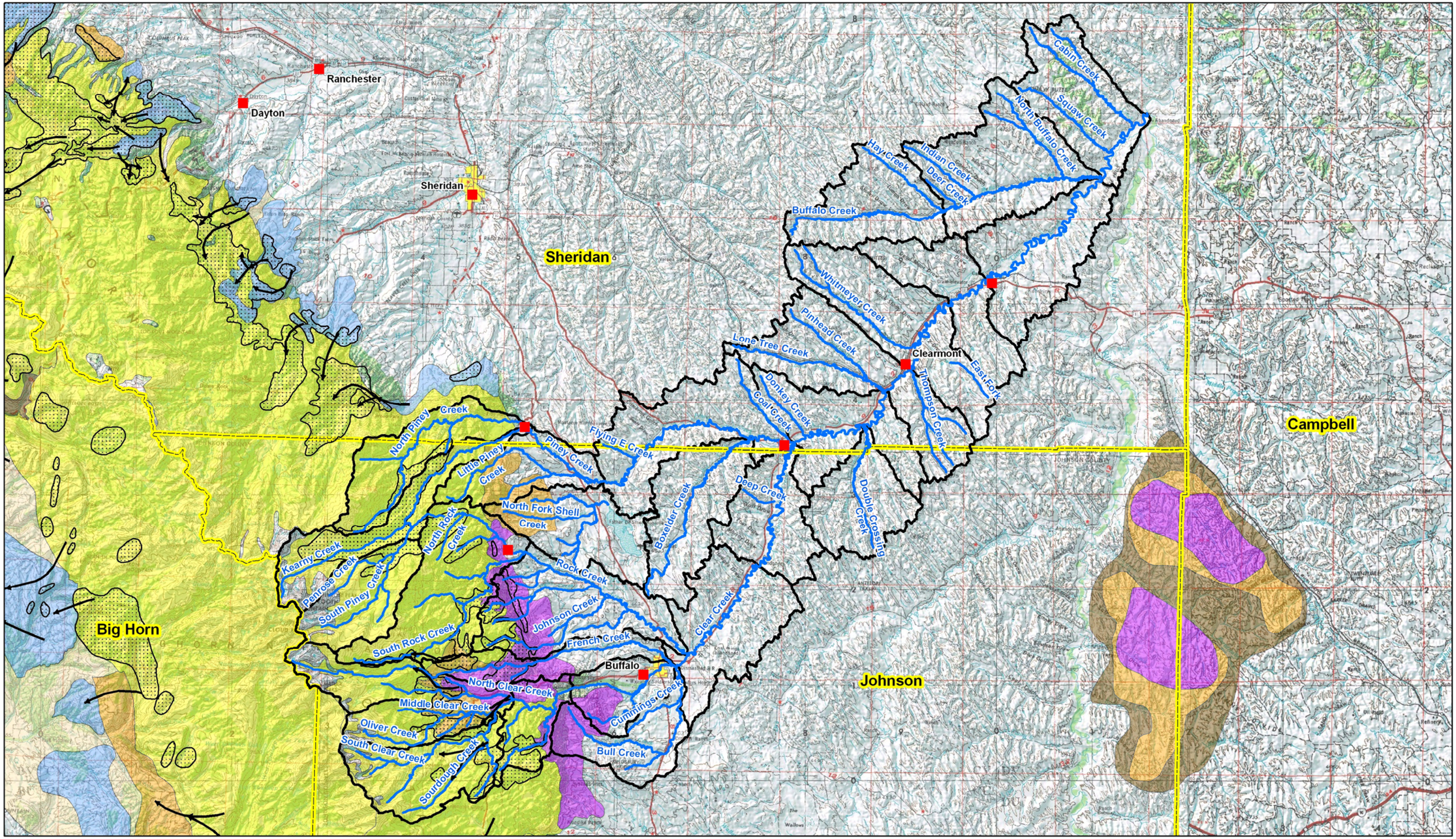


Figure 3.3-16 Elk Ranges in the Clear Creek Basin

Small portions of the upper end of the basin within the Bighorn National Forest are classified as spring/summer/fall range for moose (Figure 3.3-17). Other areas located within the upper end of the basin are classified as moose yearlong range, and a small portion of the extreme north end of the basin is classified as moose winter/yearlong range. No crucial moose habitats are present within the basin.

3.3.7.2 Greater sage-grouse

The Wyoming Game and Fish Department recently completed a map showing sage grouse "Core Population Areas" within the state of Wyoming, and the Governor issued an Executive Order mandating that new development within Core Population Areas should be authorized or conducted only when it can be demonstrated that the activity will not cause declines in greater sage-grouse populations. A small area within the south-central portion of Clear Creek Basin east and northeast of Buffalo is mapped as a greater sage-grouse core population area (Figure 3.3-18), including most of the Double Crossing Creek drainage. Given the Governor's executive order, it may be difficult to obtain state approval for reservoir sites within the core area if significant areas of sage-grouse habitat are inundated.

3.3.7.3 Sensitive Species

Northern leopard frogs, considered a sensitive species, have been documented in the extreme eastern end of the Clear Creek Basin, as well as in a few other locations scattered across the basin (Figure 3.3-19). Fifteen species of sensitive birds have been documented in or near the Clear Creek Basin (Figure 3.3-20). None of these species are federally listed; however, the mountain plover, which has a few records in the vicinity of Johnson Creek northwest of Buffalo, has recently been proposed for listing as threatened by the U.S. Fish & Wildlife Service. Portions of the project area are in areas considered historical range for grizzly bears, wolves, and black-footed ferret (Figure 3.3-21), but these species are not expected to occur in the area now. Two species of bats, classified as sensitive species, have been documented in the basin. The only federally listed species with records in the project area is Canada lynx, which are generally confined to spruce/fir forests at higher elevations. Only one sensitive species of plant (Williams' waferparsnip) has been documented in the project area, all of which occur on the Bighorn National Forest (Figure 3.3-22). Table 3.3-2 contains a list from the Wyoming Natural Resources Diversity Database of sensitive plant and animal species potentially found in the watershed. Other BLM and U.S. Forest Service sensitive species may occur in the project area. Prior to constructing reservoirs or other projects in this area, surveys for sensitive wildlife and plant species would likely be required, especially for any sites on the Bighorn National Forest or on BLM land. If any sensitive species are found, mitigation measures would likely be required.

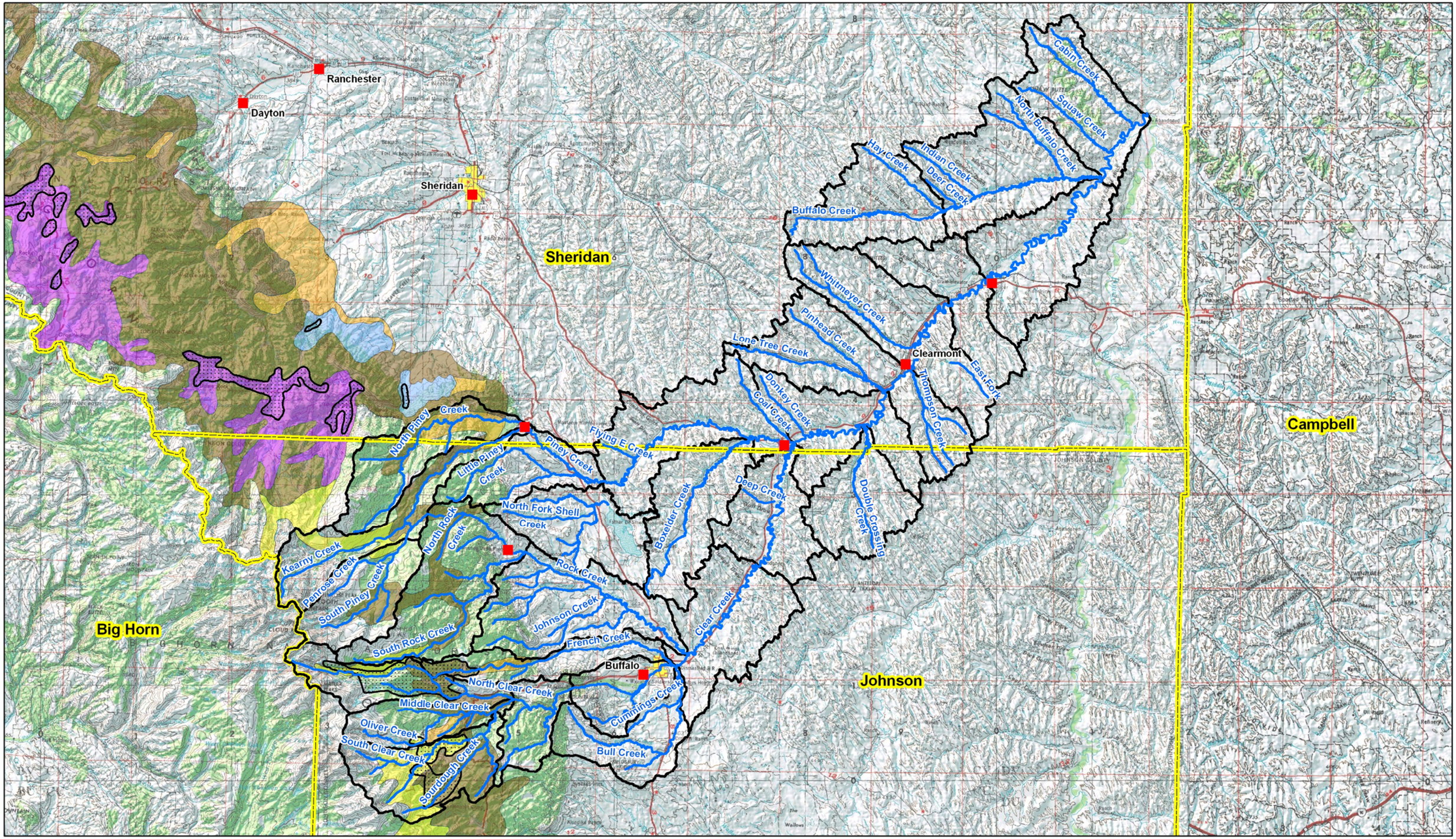


Figure 3.3-17 Moose Ranges in the Clear Creek Basin

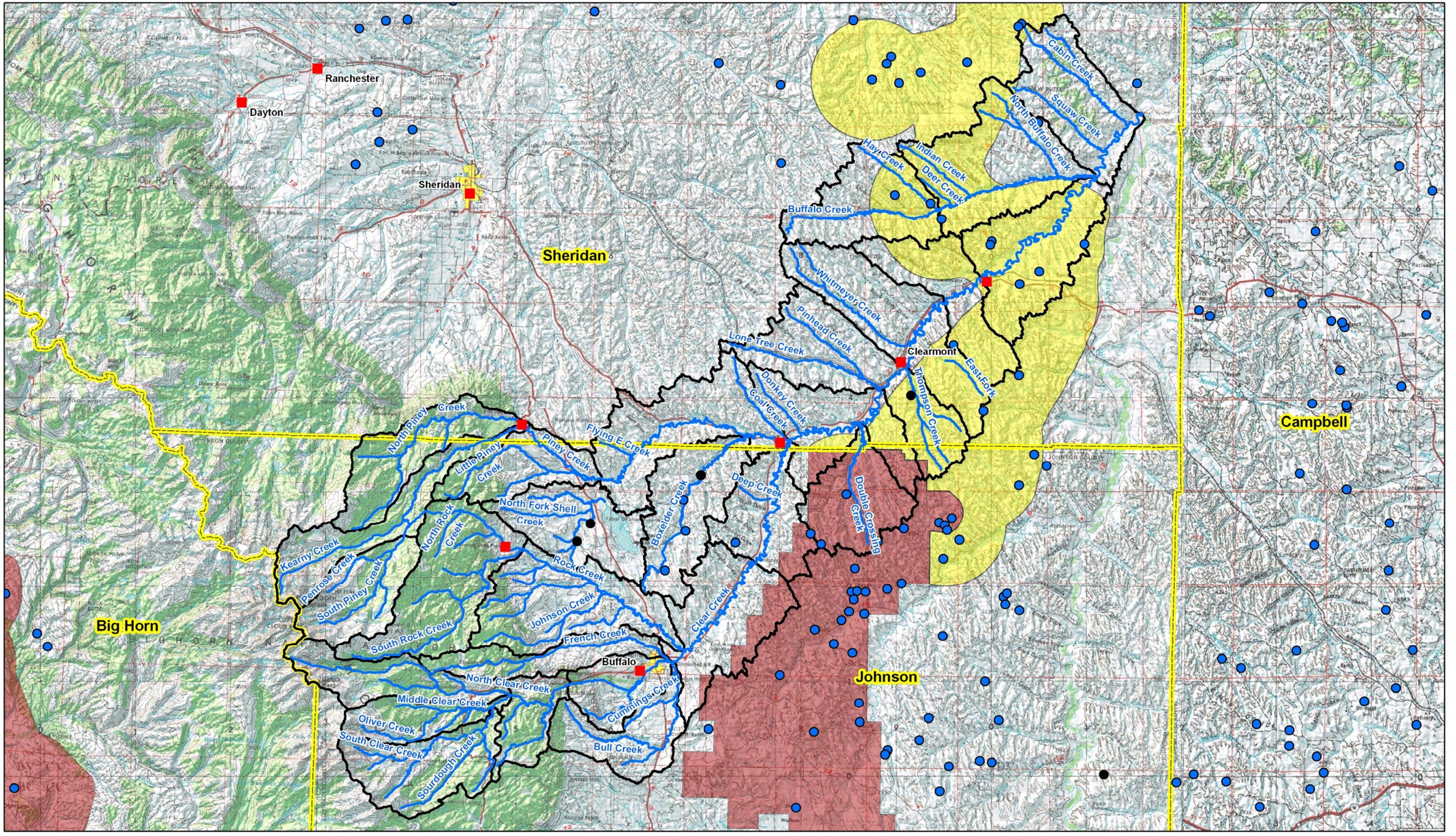


Figure 3.3-18 Greater Sage Grouse Core Population Areas in the Clear Creek Basin

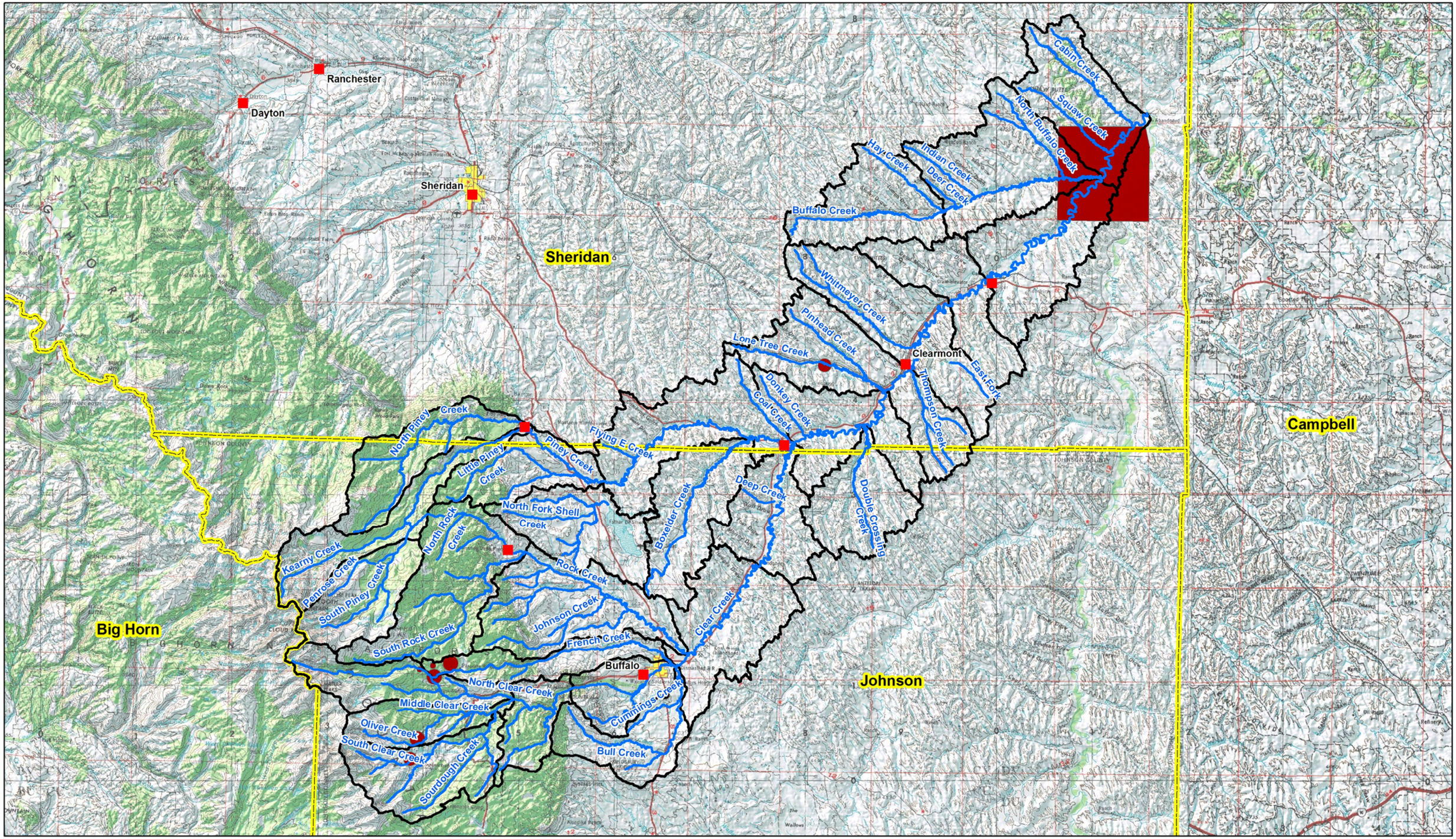


Figure 3.3-19 Sensitive Species in the Clear Creek Basin (amphibians)

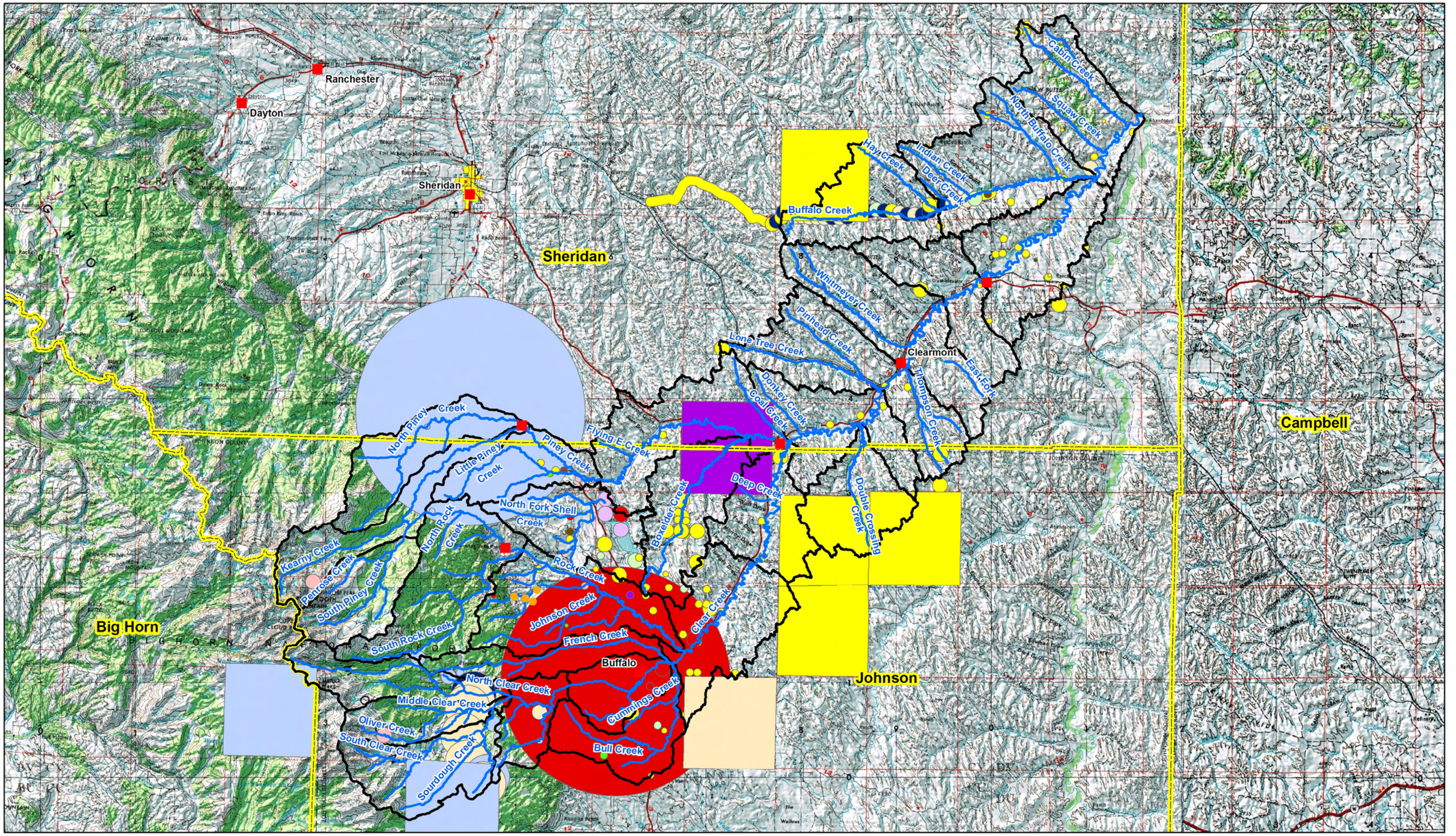
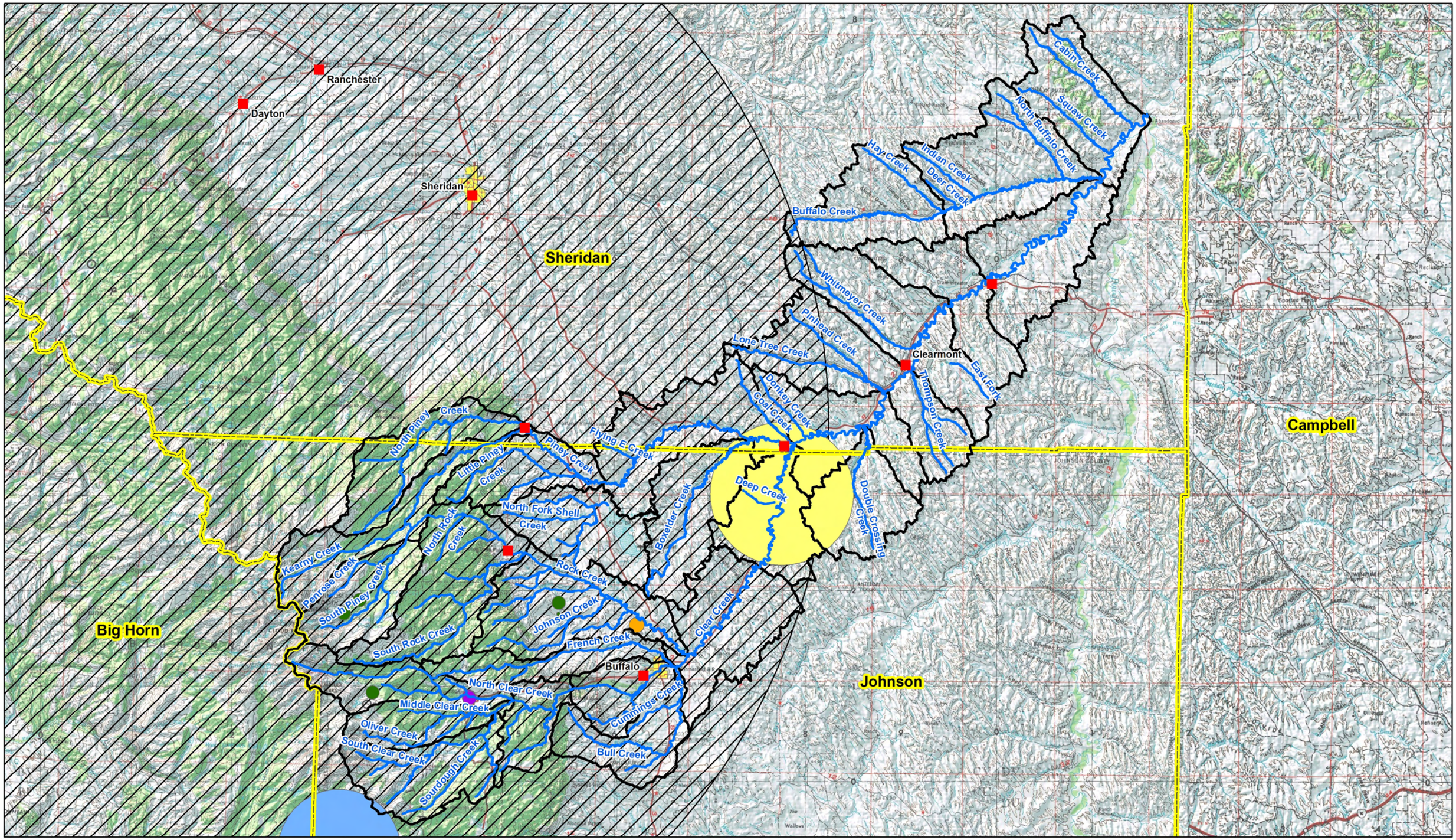


Figure 3.3-20 Sensitive Species in the Clear Creek Basin (birds)



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Miles

Legend

Cities
Streams
Watershed
County Boundary

Sensitive Species - Mammals

Townsend's Big-eared Bat
Long-eared Myotis
Grizzly Bear
Gray Wolf
Canada Lynx
Black-footed Ferret

Figure 3.3-21 Sensitive Species in the Clear Creek Basin (amphibians)

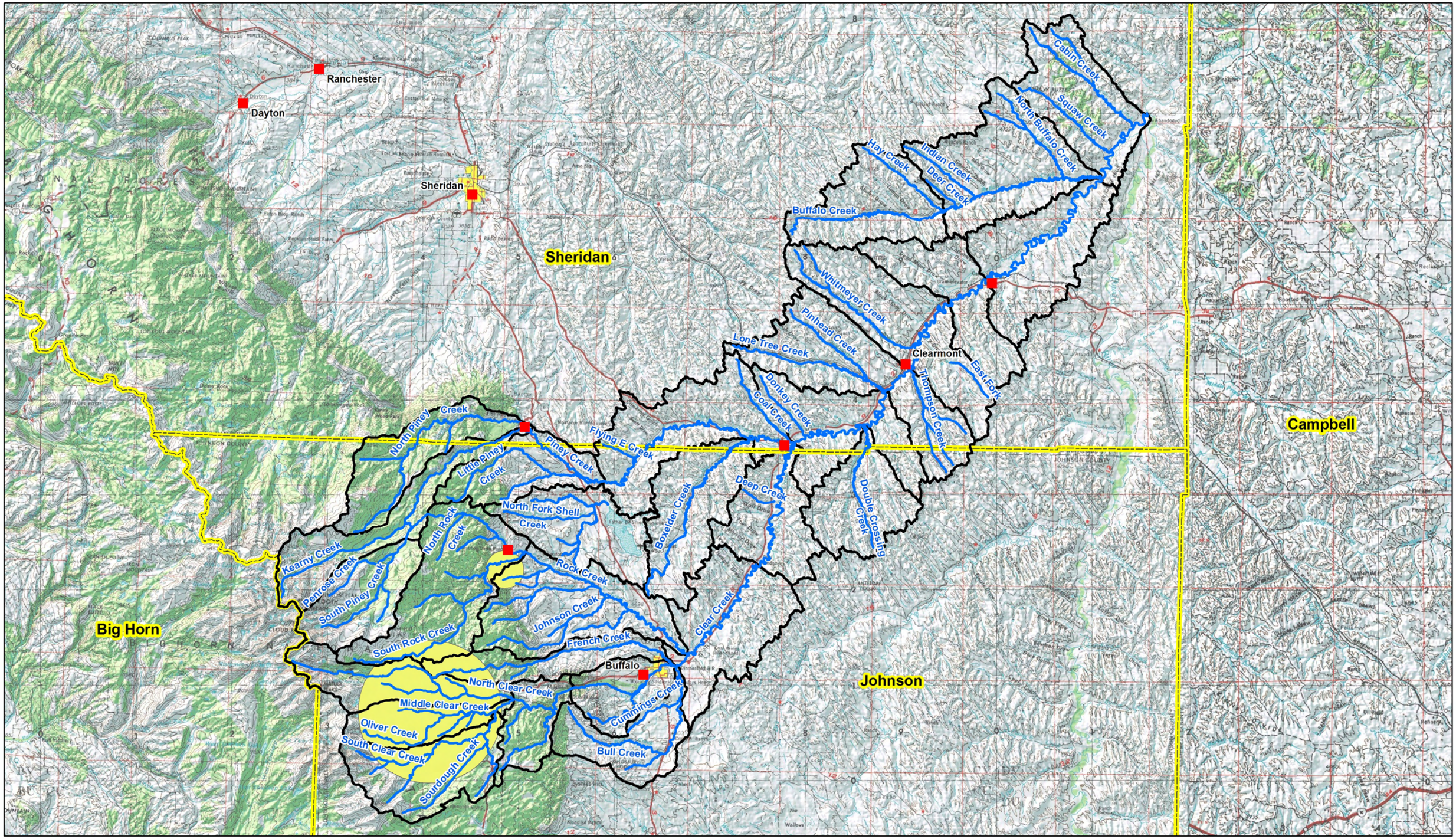


Figure 3.3-22 Sensitive Species in the Clear Creek Basin (plants)

Table 3.3-2 Wyoming Natural Resources Diversity Database Species

Scientific Name	Common Name	Type	Global Rank[1]	State Rank[2]	USFWS Status[3]	BLM Status[4]	Forest Service Status[5]	WGFD Status[6]
Rana pipiens	Northern Leopard Frog	Amphibian	G5	S3	Petitioned	WY BLM SSL	S-R2	NSS4, SGCN
Accipiter gentilis	Northern Goshawk	Bird	G5	S3	Listing Denied	WY BLM SSL	S-R2, R4	NSS4, SGCN
Ammodramus bairdii	Baird's Sparrow	Bird	G4	S1B?		WY BLM SSL		NSS4
Amphispiza belli	Sage Sparrow	Bird	G5	S3		WY BLM SSL	S-R2	NSS4, SGCN
Athene cunicularia	Burrowing Owl	Bird	G4	S3		WY BLM SSL	S-R2	NSS4, SGCN
Buteo regalis	Ferruginous Hawk	Bird	G4	S4B, S5N		WY BLM SSL	S-R2	NSS3, SGCN
Centrocercus urophasianus	Greater Sage Grouse	Bird	G4	S4	Candidate	WY BLM SSL	S-R2, R4	NSS2, SGCN
Charadrius montanus	Mountain Plover	Bird	G2	S2	Listing Denied		S-R2, R4	NSS4, SGCN
Cinclus mexicanus	American Dipper	Bird	G5	S4	Petitioned			
Coccyzus americanus	Yellow-billed Cuckoo	Bird	G5	S1	Candidate	WY BLM SSL	S-R2, R4	NSS2, SGCN
Falco peregrinus anatum	American Peregrine Falcon	Bird	G4T4	S2	Delisted	WY BLM SSL	S-R2, R4	NSS3, SGCN
Lanius ludovicianus	Loggerhead Shrike	Bird	G4	S3		WY BLM SSL	S-R2	NSS3, SGCN
Numenius americanus	Long-billed Curlew	Bird	G5	S3B		WY BLM SSL	S-R2	
Oreoscoptes montanus	Sage Thrasher	Bird	G5	S5		WY BLM SSL		NSS4, SGCN
Plegadis chihi	White-faced Ibis	Bird	G5	S1B		WY BLM SSL		NSS3, SGCN
Spizella breweri	Brewer's Sparrow	Bird	G5	S5		WY BLM SSL	S-R2	NSS4, SGCN
Canis lupus	Gray Wolf	Mammal	G4	S1	Threatened (EXPN)		S – R2, R4	

Corynorhinus townsendii	Townsend's Big-eared Bat	Mammal	G4	S2		WY BLM SSL	S – R2, R4	NSS2, SGCN
Lynx canadensis	Canada Lynx	Mammal	G5	S1	Threatened			NSS1, SGCN
Mustela nigripes	Black-footed Ferret	Mammal	G1	S1	Endangered (EXPN)			NSS1, SGCN
Myotis evotis	Long-eared Myotis	Mammal	G5	S4		WY BLM SSL		NSS2, SGCN
Ursus arctos horribilis	Grizzly Bear	Mammal	G4T3T4	S1	Threatened (not YNP)		S-R2	NSS3, SGCN
Cymopterus williamsii	Williams' waferparsnip	Plant	G3	S2S3		WY BLM SSL		

[1]Global Rank: G = Global rank assigned by NatureServe: range-wide probability of extinction for a species
T = Trinomial rank: refers to the range-wide probability of extinction for a subspecies or variety
1 = Critically imperiled because of extreme rarity (often <5 extant occurrences) or because some factor makes it highly vulnerable to extinction
2 = Imperiled because of rarity (often 6-20 extant occurrences) or because of factors making it vulnerable to extinction
3 = Rare or local throughout its range or found locally in a restricted range (often 21-100 known occurrences)
4 = Apparently secure, although it may be quite rare in parts of its range, especially at the periphery
5 = Demonstrably secure, although it may be rare in parts of its range, especially at the periphery

[2]State Rank: S = State rank assigned by WYNDD biologists: probability of extinction from Wyoming
1 = Critically imperiled because of extreme rarity (often <5 extant occurrences) or because some factor makes it highly vulnerable to extinction
2 = Imperiled because of rarity (often 6-20 extant occurrences) or because of factors making it vulnerable to extinction
3 = Rare or local throughout its range or found locally in a restricted range (often 21-100 known occurrences)
4 = Apparently secure, although it may be quite rare in parts of its range, especially at the periphery
B = Breeding rank: indicates the status of a migratory species during the breeding season; applied only to animals
N = Non-breeding rank: indicates the status of a migratory species during the non-breeding season; applied only to animals
? = Questions exist regarding the assigned numeric score

[3]USFWS Status: Petitioned: A petition to list as Endangered or Threatened has been received by USFWS; awaiting USFWS review
Listing Denied: A formal proposal for listing as Endangered or Threatened was recently denied
Candidate: Existing biological information supports a formal proposal to list as Endangered or Threatened, but developing a listing regulation is precluded by higher priority listing activities.
Delisted: Delisted from Endangered or Threatened status
Threatened: Likely to become Endangered in the near future. For plants this applies to all of a taxon's range; for animals this may apply to only a portion of a taxon's range (EXPN = Experimental Population, Non-Essential), (not YNP = Threatened status excludes the Distinct Population Segment)

Endangered: In danger of extinction. For plants this applies to all of a taxon's range; for animals this may apply to only a portion of a taxon's range (EXPN = Experimental Population, Non-Essential)

[4]BLM Status: WY BLM SSL: On Sensitive Species List in Wyoming

[5]Forest Service: S-R2: Sensitive in Bighorn, Black Hills, Medicine Bow, and Shoshone National Forests, and the Thunder Basin National Grassland
S-R4: Sensitive in Bridger-Teton, Caribou, Targhee, Wasatch-Cache, and Ashley (including Flaming Gorge National Recreation Area) National Forests

[6]WGFD Status: A 1-4 "Native Species Status" (NSS) score is used to rank the status of vertebrate and invertebrate animal Species of Greatest Conservation Need (SGCN):
NSS1 = Populations greatly restricted or declining, extirpation possible. -OR-
Ongoing significant loss of habitat.
NSS2 = Populations declining, extirpation possible; habitat restricted or vulnerable but no recent or ongoing significant loss; species likely sensitive to human disturbance. -OR-
Populations declining or restricted in numbers or distribution, extirpation not imminent; ongoing significant loss of habitat.
NSS3 = Populations greatly restricted or declining, extirpation possible; habitat not restricted, vulnerable but no loss; species not sensitive to human disturbance. -OR-
Populations declining or restricted in numbers or distribution, extirpation not imminent; habitat restricted or vulnerable but no recent or ongoing significant loss; species likely sensitive to human disturbance. -OR-
Species widely distributed; population status or trends unknown but suspected to be stable; on-going significant loss of habitat.
NSS4 = Populations greatly restricted or declining, extirpation possible; habitat stable and not restricted. -OR-
Populations declining or restricted in numbers or distribution, extirpation not imminent; habitat not restricted, vulnerable but no loss; species not sensitive to human disturbance. -OR-
Species widely distributed, population status or trends unknown but suspected to be stable; habitat restricted or vulnerable but no recent or on-going significant loss; species likely sensitive to human disturbance. -OR-
Populations stable or increasing and not restricted in numbers or distribution; on-going significant loss of habitat.

3.3.7.4 Fisheries

The rivers, lakes, and reservoirs in the Clear Creek watershed support a diverse population of fish. The upper watershed supports primarily non-native sport fishery resources. These species include rainbow, brown and brook trout. Both native and non-native species are present in the lower reaches of the watershed. These species include channel catfish, sauger, mountain whitefish, black bullhead, stonecat, flathead chub, lake chub, plains minnow, sturgeon chub, western silvery minnow, goldeye, shovelnose sturgeon, mountain sucker, river carpsucker, and shorthead redhorse (WGFD 2008).

The Wyoming Game and Fish Department (WGFD) completed a fish bypass project in the spring of 2010 around the Kendrick diversion dam on lower Clear Creek about five miles upstream from the confluence with the Powder River. The dam had blocked all upstream fish movement for over 100 years (WGFD 2010). The Powder River basin contains a unique assemblage of fishes adapted to river habitat with relatively unstable substrate and high turbidity (WGFD 2010). This assemblage includes the shovelnose sturgeon, plains minnow, western silvery

minnow, sturgeon chub, flathead chub, sauger, and goldeye. The Powder River is one of the last free-flowing prairie streams in the entire Missouri River basin. A conservation area has been established for Clear Creek below Hwy 16. Conservation areas are established to identify priorities in managing the species of greatest conservation need (SGCN). Species such as sauger, shovelnose sturgeon and goldeye are SGCN and live much of the year in the lower Powder River or Yellowstone River, however, it is anticipated that these fish will migrate up the Powder River to Clear Creek where they will spawn before returning downstream. Other native fish such as catfish are expected to re-establish longer term residency in Clear Creek now that the Kendrick diversion dam bypass is complete (WGFD). Other improvements to fish passage have been made in the watershed. A number of small irrigation diversions have been converted from push-up dams to rock cross-vane structures, which allow for passage of mature trout. The step pool structures constructed create plunging flow rather than streaming flow. These structures do not allow passage of non-game species, which are predominately bottom-oriented swimmers that do not jump (WGFD). Several obstacles to fish passage have been identified in the watershed, notably the Clear Creek I-25 underpass and several large irrigation diversion structures in the watershed. The Clear Creek I-25 underpass is in the WYDOT construction budget for 2014 to modify this structure. It should be noted that some barriers may be warranted to control the distribution of non-desirable species. Other concerns identified in the watershed include entrainment of fish in irrigation ditches. The NRCS has implemented some experimental designs in irrigation diversion structure rehabilitation projects to address fish entrainment. For example, the Watt ditch diversion was rehabilitated with a rock cross-vane structure, and a Coanda screen intake structure was installed at the crest of the cross-vane structure to screen diverted flows. Other diversion rehabilitation projects have incorporated behavioral deterrents. Fish friendly structures are encouraged when rehabilitating and constructing diversions and road crossings. In addition, coordination with the WGFD is encouraged when implementing projects.

Figure 3.3-23 shows the WGFD trout stream classes in the Clear Creek watershed. The trout stream classes are as follows:

- Blue Ribbon Trout Stream: National importance; >600 lbs of trout per mile
- Red Ribbon Trout Stream: Statewide importance; 300-600 lbs of trout per mile
- Yellow Ribbon Trout Stream: Regional importance; 50-300 lbs of trout per mile
- Green Ribbon Trout Stream: Local importance; <50 lbs of trout per mile
- Orange: Any cool or warmwater game fish present
- Clear: No trout present

The WGFD conducted instream flow studies on Clear Creek for the red ribbon trout stream section above Buffalo in a report dated August 1994 (WGFD 1994). This report made flow recommendations needed to maintain the trout fishery in this section. The recommended flow for the reach from the confluence with the North Fork Clear Creek downstream to the City of Buffalo municipal diversion are as follows: April 1 to June 30 = 40 cfs, July 1 to September 30 = 30 cfs, October 1 to March 31 = 7.9 cfs. The recommended flow for the reach from the City of

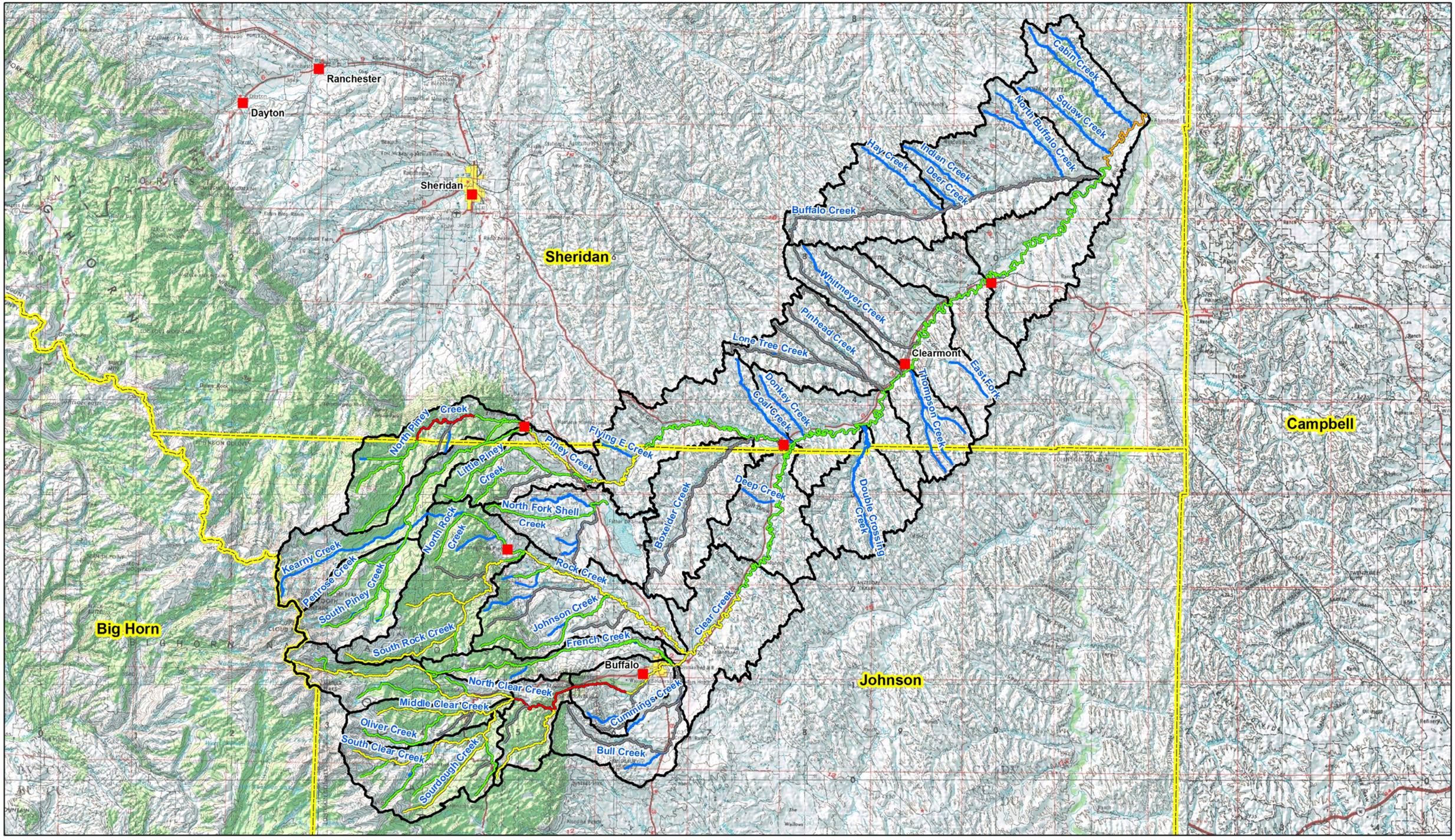


Figure 3.3-23 Clear Creek Watershed: WGFD Trout Stream Class

Buffalo municipal diversion downstream to the Johnson County ditch diversion are as follows: April 1 to June 30 = 40 cfs, July 1 to September 30 = 25 cfs, October 1 to March 31 = 6.0 cfs. Application for instream flow permits have been submitted to the SEO for these two segments with a priority date of 10/06/1994. The hearings for both segments were held on November 28, 2006, however, the permits have not been issued nor have they been adjudicated (T. Annear, WGFD, email correspondence 2010).

3.3.8 Cultural Resources

Over the last 20 years, different levels of cultural resource inventory have been performed in the watershed. Generally, these inventories were in response to proposed undertakings on federal lands, including energy exploration, highway construction, and natural resource extraction activities. Due to the location on federal land and the potential for ground disturbance, these activities required compliance with Section 106 of the National Historic Preservation Act, which stipulates that archaeological reconnaissance be conducted in the area of the ground disturbing activity.

The Wyoming State Historic Preservation Office (SHPO) maintains an in-progress database of inventoried historic sites within the state. A determination of each site's eligibility for inclusion in the National Register of Historic Places (Register) is included in the database. The WYGISC website has available a spatial data file from SHPO which generalizes cultural resource inventory to the section level. This "location fuzzing" of the archaeological data is to protect the sites from unauthorized disturbance. The attributes recorded for each section include: site count, inventory acres, report numbers, and eligible site number. Figure 3.3-24 displays the results of the database retrieval in a graphical format. Each section within the study area has been color coded based upon the number of sites within it determined to be eligible for inclusion on the Register.

The National Register of Historic Places is the nation's official list of cultural resources worthy of preservation. Administered on a federal level by the National Park Service and managed locally by the State Historic Preservation Office, the National Register is part of a program to coordinate and support both public and private efforts to identify, evaluate, and protect historic and archeological resources. The National Register recognizes the accomplishments of those who have contributed to the history and heritage of the United States, the state, and local communities.

Listing a property on the National Register of Historic Places is a form of acknowledgment and prestige, which places no restraints on the property. The National Register does not restrict the rights of property owners to use, develop, or sell the property. Although placing a property on the National Register neither stops alterations to a building nor requires owners to provide the public access to the property, it can provide the owner with eligibility for certain financial incentives (NPS, 2009 at http://www.nps.gov/history/nr/).

Ranchester
Dayton
Sheridan
Sheridan County
Campbell County
Big Horn County
Johnson County
Story
Ucross
Saddlestring
Buffalo
Leiter
Clearmont
Cabin Creek
Squaw Creek
North Buffalo Creek
Hay Creek
Indian Creek
Deer Creek
Buffalo Creek
Whitmeyer Creek
Pinhead Creek
Lone Tree Creek
Donkey Creek
Coal Creek
Thompson Creek
East Fork
Flying E Creek
Deep Creek
Double Crossing Creek
Boxelder Creek
North Piney Creek
Little Piney Creek
Piney Creek
North Fork Shell Creek
North Rock Creek
Kearny Creek
Penrose Creek
South Piney Creek
Rock Creek
Johnson Creek
French Creek
Clear Creek
South Rock Creek
North Clear Creek
Middle Clear Creek
Oliver Creek
South Clear Creek
Sourdough Creek
Cummings Creek
Bull Creek

Number of Cultural Sites Eligible for Inclusion on the National Register of Historic Places (Per PLSS Section)

1 2 3 4 5 6 13

N W E S

0 5 10

Miles

Legend

- Streams
- Cities
- Clear Creek Watershed
- County Boundary

Figure 3.3-24. Clear Creek Watershed: Cultural Sites

To date, fourteen sites within the study area have been included in the Register (Table 3.3-3). Appendix 3D contains descriptions of the sites obtained from the Wyoming State Preservation Office website at: http://wyoshpo.state.wy.us/NationalRegister/

Table 3.3-3 Sites Included in the National Register of Historic Places

Site Name	Smithsonian Number	Description	Photo
Big Red Ranch Complex	48SH690	*The Big Red Ranch was the headquarters of one of the largest cattle operations in Wyoming. It was a leader in agricultural development in the area beginning with the large open range cattle period, moving to sheep ranching and the development of irrigation projects, and*	
Buffalo Main Post Office	*48JO245*	*The Buffalo Main Post Office is included within a thematic study including twelve post offices owned and administered by the U.S. Postal Service (USPS) throughout the State of Wyoming*	
Buffalo Main Street Historic District	*48JO1079*	*The Buffalo Main Street Historic District contains historically significant buildings primarily dating from 1900 to 1932*	
Carnegie Public Library	*48JO101*	*The Johnson County Library Building is situated on the northwest corner of the County Courthouse grounds. It was built in 1909 of native stone.*	
Clearmont Jail	48SH689	*Clearmont, founded in 1892 by the Burlington Missouri Railroad, is primarily an agricultural community located in the northeast portion of the state of Wyoming. Clearmont was incorporated in 1919*	
Fort McKinney	*48JO104*	Built in 1876 as an army post during early Wyoming settlement. Named "Fort McKinney" in honor of Lt. J. A. McKinney (killed in the battle with the Cheyenne on Red Fork of Powder River, November 25, 1876), this post was occupied through the spring of 1878	
HF Bar Ranch	***48JO138***	*The HF Bar Ranch is a working cattle/dude ranch complex consisting of 36 buildings predominately of rustic frame and log construction built primarily between 1898 and 1921*	
Holland House	*48JO1486*	*The Holland House , constructed in 1883 along the town's main street by successful rancher William H. Holland, was one of the first brick residences built in Buffalo, Wyoming and is a good example of a late Victorian vernacular brick house.*	
Johnson County Court House	*48JO100*	*The Johnson County Court House , constructed in 1884, is a good example of the Italianate style of architecture.*	
Lake Desmet Segment - Bozeman Trail	*48JO134*	*A discernible set of trail ruts make up this segment of the Bozeman Trail. The downhill set of ruts, thought often faint, can be found on the down slope side of the hill overlooking Lake Desmet*	No Photo Available
Methodist Episcopal Church	*48JO98*	*The cornerstone of the Methodist Episcopal Church , also known as the First United Methodist Church, was laid August 17, 1898,*	
Peloux Bridge on Clear Creek	48JO999	This bridge was certified as a historic location on Friday February 22, 1985. This location is a protected historic place because of historical significance relating to transportation.	No Photo Available
St. Luke's Episcopal Church	48JO99	*St. Luke's Episcopal Church was built in 1889 of red brick, in the Gothic Revival style of architecture*	
Union Congregational Church	48JO915	*The Union Congregational Church , one of the first two churches established in northern Wyoming Territory and the first church in Buffalo, was incorporated in 1884, the same year the town of Buffalo was chartered*	

3.4 NATURAL ENVIRONMENT

3.4.1 Major Plant Communities

Major plant communities in the Clear Creek watershed were determined by reviewing a variety of existing data sources. Wyoming GAP data provides state-wide mapping of natural and semi-natural vegetation, but this source not is intended to be used at scales larger than 1:100,000. LANDFIRE data provides mapping of existing and potential vegetation. The existing vegetation layers include vegetation type, cover, and height. Due to scale, these sources were not used in this section, however, both Wyoming GAP and LANDFIRE data are included in the project GIS. Wyoming land use/land cover data was used to map and describe the major plant communities in Clear Creek watershed. The source of this data is the National Land Cover Database from 2001 (Zone 29), available through the U.S. Geological Survey, and produced through a partnership of federal agencies and based on interpretation of satellite imagery (Homer et al. 2004). In addition to these mapping sources, Ecological Site Description reports were reviewed. As stated in section 3.3.4.3, Ecological Site Descriptions are produced by the Natural Resources Conservation Service and provide an inventory and analysis of landscapes at the ecological site level. Ecological Site Description reports are available online at http://esis.sc.egov.usda.gov/. An ecological site is defined as a distinctive kind of land with specific physical characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation (NRCS 2010). An ecological site can be rangeland or forest land.

According to the National Land Cover Database, fourteen land cover classes occur in the Clear Creek watershed; these are described in the table below (Table 3.4-1) and shown on Figure 3.4-1:

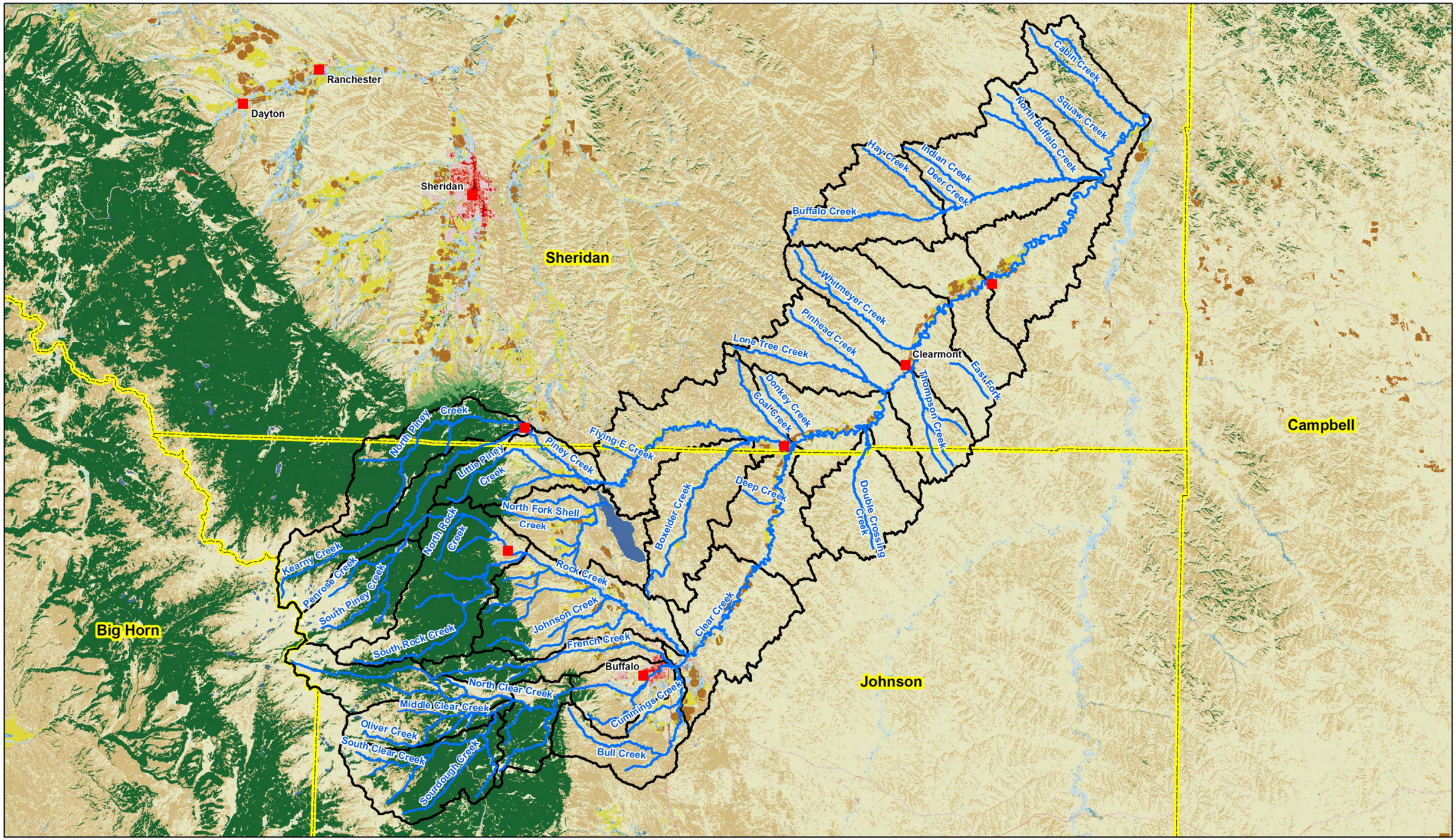


Figure 3.4-1 Land Cover/Land Use – Clear Creek Watershed

Table 3.4-1 Land Cover Classes in the Clear Creek Watershed

Land Cover Class	Description	Acres	Percent Composition
Grassland	Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.	344,757	46.7
Scrub-shrub	Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.	200,514	27.2
Evergreen forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.	145,226	19.7
Woody wetlands	Areas where forest or shrub land vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.	12,398	1.7
Pasture/hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.	11,350	1.5
Crops	Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.	6,775	1.0
Developed, open space	Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes	4,721	0.6
Open water	All areas of open water, generally with less than 25% cover or vegetation or soil	4,467	0.6

Land Cover Class	Description	Acres	Percent Composition
Emergent wetlands	Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.	3,010	0.4
Deciduous forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.	2,082	0.3
Developed, low intensity	Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.	1,468	0.2
Barren	Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.	767	0.1
Developed, medium intensity	Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.	467	0.1
Developed, high intensity	Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to100 percent of the total cover.	62	<0.1
Totals		738,064	100.2

Grassland and scrub-shrub are the two most common land cover types in Clear Creek basin, covering nearly three-quarters (73.9 %) of the basin combined; grassland comprises 46.7 % and scrub shrub 27.2 %. As shown in the figure, these cover types extend from the foothills of the Big Horn mountains northeasterly onto the plains. The scrub-shrub community is most predominant in the foothills, but is intermixed with the grasslands on the plains. According to Ecological Site Descriptions for the grassland and scrub-shrub portions of the basin, annual average precipitation ranges from 10 to 14 inches and the landscape is gently undulating rolling land. A variety of soils types can be found, ranging from clayey to loamy to sandy soils; some soils are classified as shallow to very shallow, and others are saline. The following descriptions of the grassland and scrub-shrub land cover types are based on information from Ecological Site Descriptions reports (available online at http://esis.sc.egov.usda.gov/).

In the grasslands, various grass communities can be found depending on soil type. Rhizomatous wheatgrasses/needle-and-thread grass/blue grama plant community is typical on loamy soils, rhizomatous wheatgrasses/green needlegrass community on clayey soils, and needle-and-thread/prairie sandreed community on sandy soils. These communities are considered to be the historic climax plant community for each soil type. They have evolved with grazing by large herbivores and are well suited for grazing by domestic livestock. Grasses or grass-like plants typically comprise about 75% of these communities, forbs about 15%, and woody plants about 10%. Both cool and warm season grasses occur, and plant diversity is typically high. The diversity in plant species allows for high drought tolerance. These are stable, sustainable plant communities (site/soil stability, watershed function, and biologic integrity), adapted to the northern Great Plains climatic conditions. They are typically fairly resistant to erosive forces; for example, grass and forb cover reduces raindrop impact and slows overland flow, providing increased time for infiltration. In the absence of grazing and fire, these grass communities will convert to sagebrush on clayey and loamy soils. With moderate season-long grazing, shrubs, fringed sagewort, threadleaf sedge, or prickly pear will tend to increase, depending on soils type. Potential invasive species include curlycup gumweed, fringed sagewort, prickly pear cactus, broom snakeweed, threadleaf sedge, big sagebrush, rabbitbrush, yucca, and listed noxious weeds.

The scrub-shrub communities found on the plains in the northeast part of the basin include sagebrush, mixed sagebrush/grass, and greasewood communities found on loamy or clayey soils. These scrub-shrub communities are often a result of moderate season-long grazing or absence of grazing or fire. Big sagebrush is a significant component of scrub-shrub communities on the plains; fringed sagewort, plains pricklypear, and winterfat can also occur. Cool-season grasses make up the majority of the understory with the balance made up of annual cool-season grasses, and various forbs. If greasewood is present, it can invade adjacent sites with season long grazing, particularly areas with saline soils. In the foothills, the scrub-shrubs communities are more common than on the plains. Annual precipitation is also higher, ranging from 15 up to 20 inches. Additional shrub species found in the foothills include three-tip sagebrush, mountain big sagebrush, snowberry, serviceberry, silver sagebrush, and rabbitbrush. In scrub-shrub communities, excessive litter can build up, shading out some of the grasses and forbs. Other plants can become decadent with low vigor. Bunch grasses often

develop dead centers. Eventually, the interspaces between plants can increase in size leaving more soil surface exposed, and organic matter oxidizes in the air rather than being incorporated into the soil. Soil erosion is accelerated because of increased bare ground. Water flow patterns and pedestaling are obvious. Infiltration is reduced and runoff is increased. This plant community is not resistant to change and is more vulnerable to severe disturbance. The introduction of grazing or fire quickly changes the plant community.

Evergreen forest land cover type comprises 20% of the Clear Creek watershed. This type is found in the upper watershed in the Big Horn Mountains. Vegetation is typical of the central Rocky Mountain region, with low-elevation juniper, mid-elevation ponderosa pine and Douglas-fir, and high elevation lodgepole pine and spruce-fir. Numerous large natural openings and gentle slopes at high elevation are found, dominated by big sagebrush and Idaho fescue (Emme and Jellison 2004). Soil type, aspect, elevation, and precipitation are the primary factors affecting the vegetation pattern. The evergreen forests and the soil types in the upper watershed play an important role in release of water to the lower watershed. Effective precipitation at higher elevations comes as snow, and is redistributed by wind, often accumulating in forest openings. The volume of water in a soil that is available to plants is dependent on a number of variables including the ability of the plant to extract water. In general, fine soils hold more water in an available form than coarse soils (Despian 1973). Forest condition can affect the amount of water in the lower watershed. For example, loss of large expanse of forest from fire, disease, pest (e.g., bark beetle), or logging, reduces the amount of evapotranspiration and therefore increases the amount of groundwater, some of which is intercepted by surface waters, increasing surface flows.

Deciduous forest is uncommon in the watershed, comprising 0.3% of the land cover types. Deciduous forest may include aspen stands, which are infrequent in the Big Horn Mountains, and cottonwood riparian forests.

Pasture/hay and crop land cover types make up 2.5% of the watershed. These land cover types primarily occur adjacent to Clear Creek and other waterbodies where surface water is used for irrigation. Irrigation water is also supplied to pasture/hay and crop lands via canals and ditches. Some crop land is irrigated using center pivots.

A small portion of the watershed is developed (<1%). Open water and barren areas make up 0.6% and 0.1% of the watershed respectively. Lake DeSmet is the largest open water body. The reminder of the land cover classes that make up the Clear Creek watershed are wetland land cover types (woody wetlands at 1.7% and emergent wetlands at 0.4%); these are discussed in greater detail in the Wetlands section.

The WYNDD lists one sensitive plant species in the Clear Creek watershed, Williams' waferparsnip (Cymopterus williamsii). There are two records for this species in the upper basin (Figure 3.3-22 – note: the size of the polygon represents locational uncertainty). This species does not receive federal or state protection, but it is listed as sensitive by the Wyoming BLM and is considered rare according to global and state heritage rankings (Table 3.3-2).

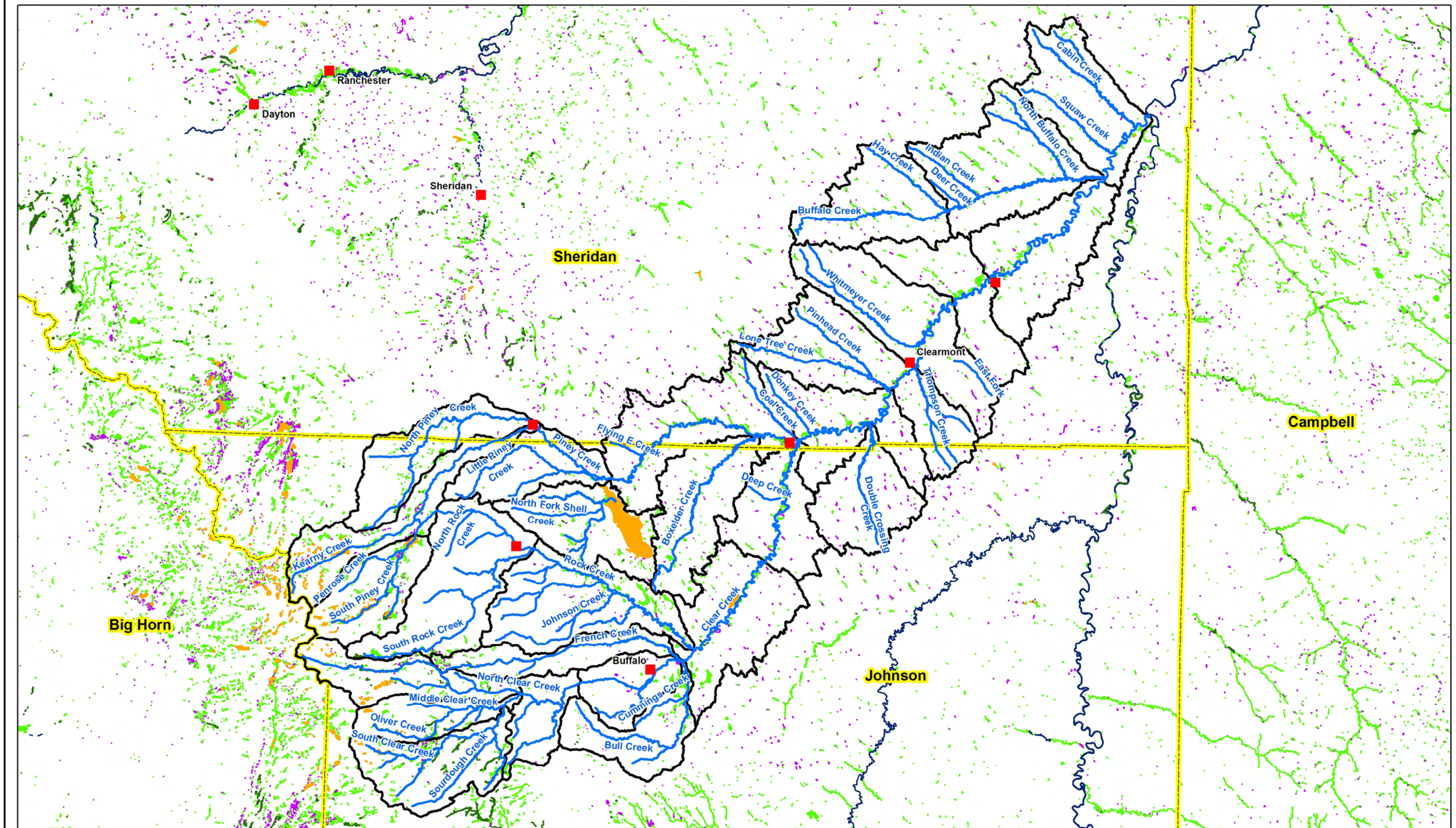
3.4.1.1 Wetlands

Distribution and Nature of Wetlands in Clear Creek Watershed

Wetlands in the Clear Creek watershed were determined by reviewing a variety of existing data sources. The primary source was the U.S. Fish and Wildlife Service's (USFWS) National Wetland Inventory (NWI) maps. The NWI maintains information on the status and extent of the nation's wetlands and deep water habitats. The NWI maps are based primarily on analysis of high altitude aerial photo interpretation, and are accurate at a nominal scale of 1:24,000. The NWI classifies wetlands according to Cowardin et al. (1979), and has developed "wetland types" based on a general description of this wetland classification. Other sources of information reviewed to determine the location and description of wetlands in the watershed include Wyoming GAP data, which consists of state-wide mapping of natural and semi-natural vegetation and intended for use at scales smaller than 1:100,000; the National Land Cover Database, which is based on satellite imagery and provides land cover data on national scale; and Ecological Site Description reports, which provide an inventory and analysis of landscapes at the ecological site level.

For the purposes of this report, wetlands are defined as areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. By contrast, riparian areas are defined as the transition zone between upland and aquatic habitat, such as a river bank. Riparian areas might or might not be wetlands. Both wetland and riparian areas are ecologically important because they function to filter pollutants, prevent erosion, and provide unique habitat for plants and wildlife. Wetlands, in particular, can also function to attenuate flood waters, store surface waters (short or long term), and discharge groundwater.

According to the NWI, two wetland types occur in the watershed: freshwater emergent wetland and freshwater forested/shrub wetland. In addition, areas mapped as freshwater pond, lake, and riverine occur. The distribution of these wetlands and deep water habitats in the watershed are shown in Figure 3.4-2. According to the NWI data, approximately 6,760 acres of wetland and 7,152 acres of deep water habitat occur in the watershed, each comprising approximately 1 percent of the watershed, respectively. A breakdown by wetland type is shown in Table 3.4-2.



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NWI
- Emergent Wetland
- Forested/Shrub Wetland
- Pond
- Lake
- Other
- Riverine
- Cities
- Streams
- Watershed
- County Boundary

Figure 3.4-2 Distribution of Wetlands and Deep Water Habitats

Table 3.4-2 Wetlands and Deep Water Habitats in Clear Creek Watershed

Wetland Type	General Description	Acres	Percent of Watershed
Freshwater emergent wetland	Herbaceous marsh, fen, swale, and wet meadow	5,548	0.8
Freshwater forested/shrub wetland	Forested swamp or wetland shrub bog or wetland	1,213	0.2
Subtotal – wetlands		6,761	1.0
Freshwater pond	Pond	960	0.1
Lake	Lake or reservoir basin	5,152	0.7
Riverine	River or stream channel	1,040	0.1
Subtotal –deep water habitats		7,152	0.9
Total		13,913	1.9

Source: USFWS NWI

NWI data is the most commonly used and accepted data to estimate regulated wetlands in a specific area, such as the Clear Creek watershed. However, since this data is based on aerial photo interpretation, it has been often found to underestimate the amount of wetland. Therefore, other data sources were consulted and a field visit was conducted to verify the extent, distribution, and type of wetlands present in the watershed. Other sources of wetland information for the watershed show varying numbers of wetlands compared to the NWI. According to National Land Cover Database (see section 3.4.1- Major Plant Community Section), 3,010 acres of emergent wetlands and 12,400 acres of woody wetland occur in the watershed. Wyoming GAP data have no emergent wetland or similar category and 31,280 acres of forest-dominated riparian. The reasons for these discrepancies are largely due to the source and scale of imagery used to interpret vegetation and other land cover types, the definition of the vegetative/land cover category, and the purpose of data.

The Bighorn National Forest (BNF) compared NWI mapping to independently mapped wetlands in the BNF (Winters et al. 2004a). They found the area of BNF- mapped wetlands to be three to ten times greater than NWI wetlands. Field validation found an overestimation of wetland by the BNF (e.g., large areas of dry meadows mapped as wetland) and an underestimation by NWI (e.g., connections between wetlands and wetland complexes were missed).

NWI-mapped wetlands within Clear Creek watershed were spot-checked in the field. Sample areas of the various types of NWI wetlands throughout the lower watershed were visited to verify the nature and extent of the mapped wetlands. Wetlands in the upper watershed within the BNF were not checked since the BNF had previously mapped wetlands and completed a comparison with NWI wetlands (Winters et al. 2004a). The field verification found that areas mapped as wetland on NWI maps were generally accurate in nature and size; however, like the BNF, several wetlands were observed that were not mapped on the NWI maps. Similar findings

were made during a separate field visit to investigate potential reservoir sites within the watershed. Wetlands were found at 6 of 10 potential reservoir sites investigated where no wetlands were shown on NWI maps. Both field visits found that wetlands that were not mapped on NWI maps were primarily linear wetlands associated with streams, wetlands at the edges of reservoirs and stock ponds, and wet meadows associated with leakage from canals. Additionally, some areas that were previously upland sites have been converted to wetlands as mitigation for losses of wetlands. Examples of these created wetlands can be found along the Clear Creek trail system in the City of Buffalo.

Based on a review of existing data, the comparison of NWI wetlands and BNF-mapped wetlands (Winters et al. 2004a), and field verification of NWI wetlands, it is assumed that the 6,761 acres of NWI mapped wetlands represents a minimum amount of wetland in Clear Creek watershed. Actual wetland acreage is likely higher.

Wetlands that were mapped as "freshwater emergent" were primarily of two types; wetlands dominated by cattail, often observed in old oxbows along Clear Creek and other major tributaries, and sub-irrigated wet meadows dominated by a variety of hydrophytes including sedges, grasses, and forbs. Wetlands that were mapped as "freshwater forested/shrub" were primarily dominated by willows, either shrubs and/or trees.

Wetland Condition Assessment

Although they make up a small proportion of the watershed, wetlands provide a number of ecological, economic, and social benefits including habitat for fish, wildlife, and a variety of plants. They can also serve as nurseries for many fishes of commercial and recreational importance. Wetlands are important landscape features because they hold and slowly release flood water and snow melt, recharge groundwater, act as filters to cleanse water of impurities, recycle nutrients, and provide recreation and wildlife viewing opportunities. Not all wetlands perform all functions, nor perform them well. The location and size of a wetland, for example, may determine what function a wetland will perform. However, the various functions that each wetland in the watershed plays, influences the chemical, physical, and biological integrity of the watershed as a whole. The importance of wetlands has long been recognized and they are protected under the Clean Water Act. The objective of the Clean Water Act is to "maintain and restore the chemical, physical, and biological integrity of our Nation's waters", which include wetlands.

In 2004, the BNF published an assessment of aquatic, riparian, and wetland ecosystems on the Forest (Winters et al. 2004a-c). They examined both ecological and anthropogenic influences on these ecosystems. Specific to wetlands, ecological influences examined included geology, glacial history, and precipitation regime. Wetlands on the BNF, including those within the upper Clear Creek watershed, tend to have snow-dominated precipitation regimes, are often glaciated and, have primarily non-calcareous rocks. They tend to be found at high elevations and include large wetland complexes in u-shaped valley bottoms, many of which support a large number of fens. Wetlands in lower Clear Creek watershed, below the BNF, tend to have

rain-driven precipitation regimes and occur below the limits reached by glaciers. Geology appears to have little influence on the lower elevation wetlands, particularly on the plains where evapotranspiration rates are high and salts accumulate in meadows, marshes, and flats.

A total of twenty-four anthropogenic activities were examined in use categories such as water use, transportation, recreation, biological mineral extraction, vegetation management, and urbanization (Winters et al. 2004b). In regards to water uses (including stream diversions, ditches, transbasin diversions, reservoirs, and spring development), the study found that water uses are not as abundant within the BNF as outside its boundaries, and appear to be less than other National Forest in the region where population centers are larger. The study also found that wetlands in the Bighorn Mountains and foothills outside the BNF boundary have a high potential for being influenced by anthropogenic activities and the relatively few wetlands on the plains in lower Clear Creek watershed have a moderate potential to be influenced by anthropogenic activities.

Because the wetlands in upper Clear Creek watershed have been well-studied by the BNF as described above, and the results of the BNF studies show that wetlands in the Bighorn Mountains and foothills outside the BNF boundary and on the plains in the lower Clear Creek watershed have moderate to high potential to be influenced by anthropogenic activities, a wetland assessment was conducted in the Clear Creek watershed below the BNF boundary. Seven sample sites were assessed and were chosen based on location, type, and accessibility; six of these were in the mid-watershed and only one was in the lower watershed. A variety of wetland functional assessment methods are available, including the BLM's *Process for Assessing Proper Functioning Condition* (BLM 1993), the Montana Department of Transportation's *Montana's Wetland Assessment Method* (Berglund 1999), and Colorado's *Functional Assessment of Colorado's Wetlands (FACWET) Methodology* (Johnson and Beardsley 2010). These methods are similar in that they require a review of existing data, including maps and aerial photographs, and then completion of a check-list in the field. The BLM approach addresses both wetland and riparian areas and is focused on BLM-managed lands and management activities; therefore this method was not used for the Clear Creek watershed. The Montana and Colorado methods are similar, but the Montana method was selected because it assesses twelve important wetland functions and values, and because of the watershed's proximity to Montana.

The assessment considers factors such as relative abundance of the wetland in the watershed, disturbance based on land use within and adjacent to the wetland, and structural diversity of the wetland. Based on these factors, the following 12 functions and values are assessed:

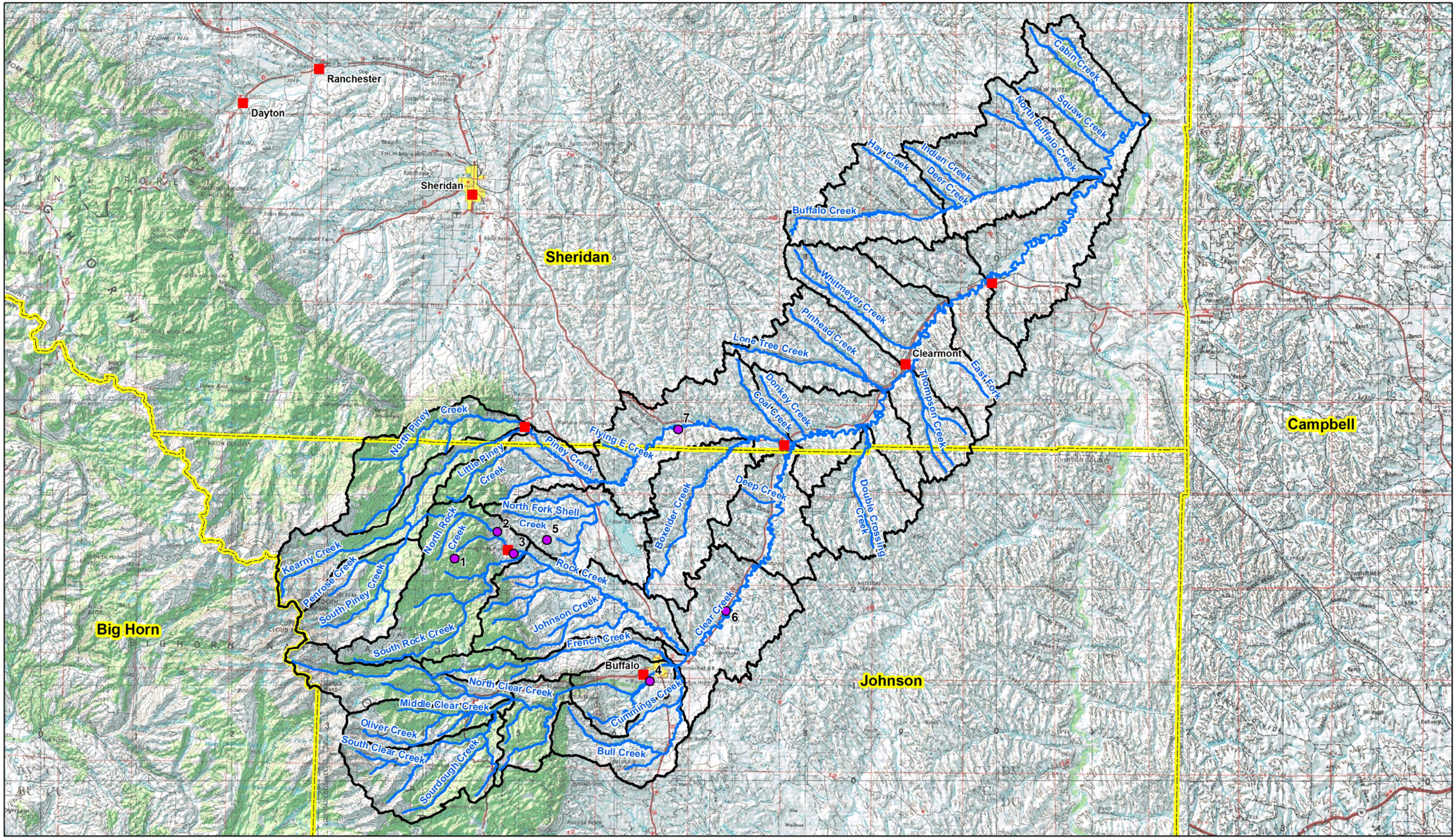
- Habitat for federally listed threatened or endangered species
- Habitat for state listed species
- General wildlife habitat
- General fish/aquatic habitat
- Flood attenuation

- Short and long term surface water storage
- Sediment/nutrient/toxicant removal
- Sediment/shoreline stabilization
- Production export/food chain support
- Groundwater discharge/recharge
- Uniqueness
- Recreation/education potential

These functions and values are rated, and based on the ratings of specific variables and/or the total functional points each wetland is assigned one of four categories. The four categories are described below:

- *Category I* wetlands are of exceptionally high quality and are generally rare to uncommon in the state or are important from a regulatory standpoint. They can provide primary habitat for federal listed species; represent a high quality example of a rare wetland type; provide irreplaceable ecological functions; exhibit exceptionally high flood attenuation capability; or are assigned high ratings for most of the functions and values.
- *Category II* wetlands are more common than Category 1 wetlands, and are those that provide habitat for sensitive plants or animals, function at very high levels for wildlife/fish habitat, are unique in a given region, or are assigned high ratings for many of the assessed functions and values.
- *Category III* wetlands are more common, generally less diverse, and often smaller and more isolated than are Category I and II wetlands. They can provide many functions and values, although they may not be assigned high rating for as many parameters as are Category I and II wetlands.
- *Category IV* wetlands are generally small, isolated, and lack vegetative diversity. These sites provide little in the way of wildlife habitat, and are often directly or indirectly disturbed.

The results of the assessment are summarized in the table below. The sample locations are shown in Figure 3.4-3.



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- Wetland Assessment Site - General Location
- Cities
- Streams
- Watershed
- County Boundary

Figure 3.4-3 Wetland Assessment Sites

Table 3.4-3 Wetland Assessment Summary

Sample Location Number	NWI Wetland Type	Location within Watershed	Category
1	freshwater emergent wetland; freshwater forested/shrub wetland	foothills	III
2	freshwater emergent wetland; freshwater forested/shrub wetland	plains	III
3	freshwater emergent wetland; freshwater forested/shrub wetland	foothills	II
4	freshwater forested/shrub wetland	plains	I
5	freshwater emergent wetland	plains	III
6	freshwater emergent wetland; freshwater forested/shrub wetland	plains	III
7	freshwater emergent wetland	plains	III

As shown, most of the wetlands assessed are Category III wetlands. These wetlands provide many of the functions and values assessed, but do not function at high levels for federal or state threatened or endangered species, wildlife/fish habitat, or uniqueness. The area assessed along Rock Creek was determined to be a Category II wetland because the wetlands in the assessment area function at high levels for wildlife and fish habitat, primarily due to the structural diversity and uneven age classes of the wetlands that are present. Both freshwater emergent and forested/shrub wetlands occur in the assessment area. The wetland assessed within the City of Buffalo Clear Creek Park was given a Category 1 rating because of its high rating for flood attenuation, particularly because residences, businesses, and other features that may be significantly damaged by a flood are located within 0.5 mile downstream of the area assessed.

The assessment shows that most of the wetlands in Clear Creek watershed outside of the BNF are functional wetlands, providing some level of the twelve functions and values that were assessed. A few of the wetlands in the watershed function at higher levels, playing an important role in the landscape for wildlife habitat or flood attenuation. Disturbance within and adjacent to wetlands observed during the field assessment was found to be primarily due to livestock grazing and roads/pathways, see Appendix 3E for wetland assessment reports. Stock ponds and reservoirs tend to increase the amount of wetland, although disturbance associated with these wetlands tends to be high. Similarly, water diversion structures (canals and ditches) tend to increase the amount of wetland either as a linear fringe along the canal or ditch or wet meadows created from canal leakage. Wetlands associated with canals and ditches tend to have high disturbance. Disturbance is an alteration of habitat either natural or human caused.

It is difficult to predict the location of high value wetlands, however, as indicated in the BNF report, the higher value wetlands (including fens) are more likely to be found higher up in the

watershed and tend to have snow-dominated precipitation regimes, and glaciated, u-shaped valley bottoms. Also, non-calcareous bedrock supports suitable landforms for wetland formation. NWI mapping provides information on relative distribution of wetlands, but does not give indication of quality. Quality is difficult to determine without an on-site assessment, however, one indicator of quality is the known presence of a threatened or endangered plant or animal species (e.g. from WYNDD database, Table 3.3-2)

Mitigation for Impacts to Wetlands

The Clean Water Act prohibits the discharge of dredged or fill material into waters of the U.S., which include most wetlands, unless a permit is issued by the Army Corps of Engineers. Fill material could include the material used to construct a dam at one of the potential reservoir sites under consideration in the watershed. For every authorized discharge, adverse impacts to waters of the U.S. must first be avoided and minimized to the extent practicable; for unavoidable impacts, compensatory mitigation is generally required to replace the loss of wetland and aquatic resource functions in the watershed. Compensatory mitigation is the restoration, establishment, enhancement, or in certain circumstances preservation of wetlands, streams, or other aquatic resources for the purpose of offsetting unavoidable impacts.

The Army Corps of Engineers determines the compensatory mitigation based on what is practicable and capable of compensating for the aquatic resource functions that will be lost as a result of the permitted activity. A watershed approach is typically used to establish compensatory mitigation requirements. The goal of a watershed approach is to maintain and improve the quality and quantity of aquatic resources in a watershed through strategic selection of mitigation sites. A watershed approach to mitigation considers the importance of landscape position and resource type of mitigation projects for the sustainability of aquatic resource functions within the watershed. It considers how the types and locations of compensatory mitigation projects will provide the desired aquatic resource functions, and function over time in a changing landscape. A watershed approach may include on-site mitigation, off-site mitigation (including mitigation banks or in-lieu fee programs), or a combination of on-site and off-site mitigation.

In order to gain an understanding of potential wetland mitigation opportunities in the Clear Creek watershed, a GIS analysis was conducted that considered soils, vegetation, slope, and proximity to a permanent water source. The objective of the effort was to identify those lands within the watershed where wetlands could potentially be created or enhanced in conjunction with future mitigation or enhancement projects. The lands identified by the GIS analysis would conceivably bear the physical characteristics desirable for creation of new wetlands.

Specifically, the following data layers were mapped and the intersection of these layers was considered to be areas with the potential for wetland creation. The end result was the delineation of polygons within the Clear Creek watershed which contained the desirable attributes described below:

- **Ecological Site Description (ESD):** Areas mapped as having clayey and loamy soils, as well as lowland areas, sub-irrigated areas, and wetlands according to the Ecological Site Description (ESD) data layer (NRCS, 2010) were included in the analysis. ESD data were not available for lands within the USFS boundary. These lands were not excluded on the premise that site-specific investigations would ultimately be required and it was not within the capability of the GIS tool to eliminate them. Rocky, sandy, coarse, and saline areas were excluded. The wetlands were included because, in some circumstances, enhancement of existing wetlands can be considered compensatory mitigation.
- **LANDFIRE Database – Existing Vegetation Type**: All forested vegetation types, barren areas, developed areas, and snow/ice areas were eliminated. All other existing vegetation types were included.
- **LANDFIRE Database – Slope:** Areas with a topographic slope of 3 degrees or less (5.2 percent or less), were included in the analysis.
- **Cloud Peak Wilderness Area Boundary:** The Cloud Peak Wilderness Area was excluded because wetland creation would not be an allowable activity in a designated wilderness area. No other land uses were considered at this coarse-level analysis.
- **Water Supply:** Areas with shallow groundwater are desirable when creating wetlands, however, depth to groundwater data was unavailable therefore a buffer was used for this coarse-level analysis. Areas within 200 m of existing, permanent water sources (including lakes, streams, and springs) were included. It was estimated that 200 m would be a reasonable maximum distance from a permanent water source given the amount of earth that is necessary to move to reach the water table when creating wetlands. It should be noted that areas of shallow groundwater likely exist beyond the 200 m buffer.

Figure 3.4-4 presents the GIS analysis at watershed scale. This figure shows the distribution of potential wetland mitigation areas. Figure 3.4-5 presents a close-up example of the results of the GIS analysis effort. As would be expected, the lands lie primarily within the floodplains of the established stream channels. Isolated lands associated with existing springs also may provide future mitigation potential.

It is important to note that this mapping of potential wetland creation sites is provided as a general planning tool. It can serve as an initial starting point for future wetland mitigation efforts and provide a coarse-level look at sites that might be physically able to support wetland creation based on the factors listed above. It is not intended to put any limits or restrictions on lands potentially suitable for wetland creation; factors such as land use and land ownership were not considered in this coarse-level look at potential wetland mitigation sites. The data presented within this map were generated entirely within the GIS environment using data layers previously generated by various agencies. The data have not been ground-truthed; any potential future projects would require site-specific investigations to determine the viability of the site and validity of the data.

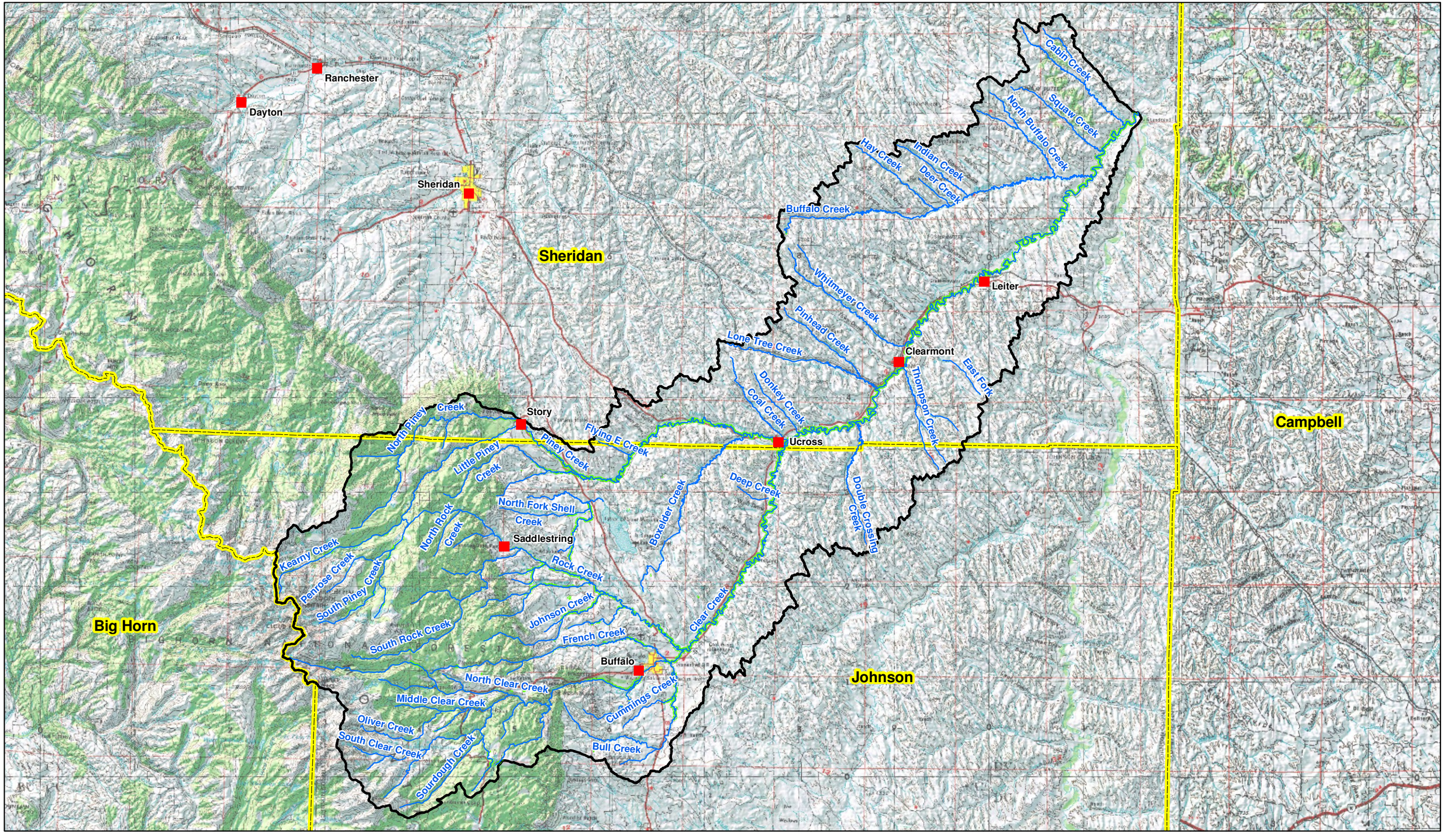
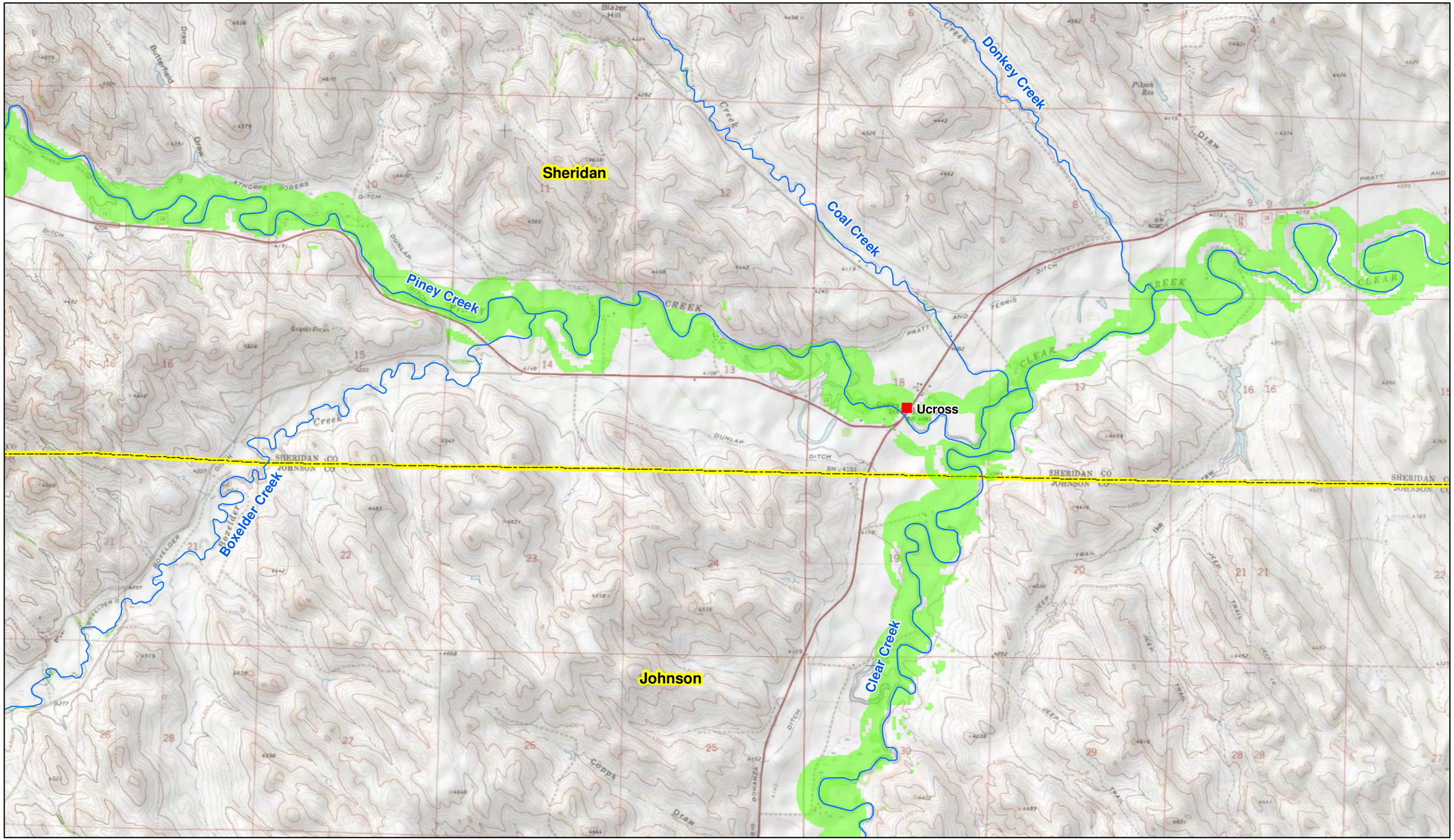


Figure 3.4-4 Clear Creek Watershed: Potential Wetland Mitigation Areas



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- Cities
- Streams
- Potential Wetland Mitigation Areas
- Clear Creek Watershed
- County Boundary

Figure 3.4-5 Clear Creek Watershed: Potential Wetland Mitigation Areas

Depending on the location and specific purposes and circumstances of a wetland mitigation project, additional criteria may be considered. These criteria were not included in the mapping effort, but are presented as potential considerations when selecting a wetland mitigation site and may assist in the prioritization of sites for consideration. These criteria take into account some wetland functions and values that may be important for a particular mitigation project.

Examples of some of the additional criteria include the following:

- Location of the mitigation site in relation to point discharges could provide potential water quality benefits as the wetland could serve as a filter for pollutants.
- Mitigation sites could be designed to serve as habitat for listed threatened and endangered species (see sensitive species maps).
- Location of the mitigation site in relation to groundwater recharge areas could enhance groundwater conditions.
- Location of mitigation sites above towns could provide flood attenuation benefits.

3.4.1.2 Invasive Species

Project personnel discussed invasive species issues with various interested parties during the course of the study. Conversations were initiated between the Lake DeSmet Conservation District, Sheridan County Weed and Pest Control District, and Johnson County Weed and Pest Control District regarding efforts to curtail the spreading of Russian Olive, Leafy Spurge, and Salt Cedar in the Clear Creek Drainage. The following information was obtained pertaining to the following species:

Russian Olive:

The Lake DeSmet Conservation District (LDCD) and local NRCS office have worked on the management of Russian Olive plants in recent years. LDCD has budgeted $50,000 over the past couple of years to aid in this effort. With this budget, the LDCD contracts with the Wyoming State Forestry Conservation Camp to cut large patches of Russian Olive plants. Previous efforts have been made in the areas along Clear Creek west of the Town of Buffalo. Additionally, these funds have been used to hire private contractors using mechanical methods (ie., "Emasticator"). The District and NRCS plan to continue these efforts into the future to help prevent the spreading of these invasive trees. Following the cutting of all Russian Olive Trees, a chemical treatment is applied to the stump to prevent any "Suckers" from coming back and reviving the plant.

The Johnson County Weed and Pest Control District will cost share up to 80% of chemical cost on private lands to treat the stumps once Russian Olive trees have been cleared. The Sheridan County Weed and Pest Control District has not been undertaking any efforts for the management of Russian Olive trees at this point.

Leafy Spurge:

All entities interviewed are actively involved in treating leafy spurge. Numerous methods have been employed by these groups to aid in this effort. According to the local conservation districts, the most effective method to date is an Integrated Pest Management (IPM) approach which utilizes African Boer Goats to graze it down, Flea beetles which stress the plant, and the modified application of 2,4-D and Tordon herbicides. These methods were used in the Thompson Creek and Double Crossing Creek drainages due to widespread infestation. IPM methods have reportedly been successful.

Both the Johnson County and Sheridan County Weed and Pest Control Districts have Cost Share programs for chemicals to be used by Private landowners. These programs will assist landowners with up to 80% of the chemicals and labor needed to apply the chemical for the treatment of Leafy Spurge. Sheridan County will also pay 100% for the Flea beetle approach used for Leafy Spurge Treatment.

> *"Leafy spurge boasts an extensive network of small lateral roots near the soil surface and a taproot that has been known to extend to depths of 20-30 feet. In addition, it produces a vast quantity of seeds which are easily dispersed. There's no trouble in identifying the plant as it grows to three feet high or taller and sports sclusters of showy yellow bracts which open into small yellowish-green flowers from June-October. In dry areas, it is often the only green plant to be seen."* (Keeping ahead of Leafy Spurge, through Integrated Pest Management, Myers. Sue; January 2008)

Salt Cedar:

According to the entities interviewed, Salt Cedar has not been a problem within the Clear Creek Drainage.

3.4.2 Climate

The climate in the Clear Creek watershed varies with topography and elevation. Elevations range from 3,500 feet to over 13,000 feet. The climate is classified as semiarid. Four weather stations are maintained in the watershed through cooperative agreements with the National Weather Service (NWS) and two SNOTEL sites are maintained in the watershed by the Natural Resources Conservation Service (NRCS).

- Buffalo (NWS)
- Story (NWS)
- Clearmont 5 SW (NWS)
- Leiter 9 N (NWS)
- Cloud Peak Reservoir (SNOTEL)
- Hansen Sawmill (SNOTEL)

Figure 3.4-6 shows the location of these weather stations. Data recorded at these sites was obtained from the Western Regional Climate Center and the NRCS and used in the following climatic analysis. Table 3.4-4 provides a summary of climate data. Temperature data at the four NWS stations is shown on Figures 3.4-7, 8, 9, and 10 along with average monthly precipitation pattern. As seen on these figures, the majority of precipitation comes in the spring and to a lesser extent in the fall. Figure 3.4-11 shows the average annual precipitation for each weather station for the past 60 years.

Freezes in mid spring and mid fall are common at the lower elevations in the watershed. The average last occurrence of 32 degrees and 28 degrees in the spring and the average first occurrence of 32 degrees and 28 degrees in the fall along with the average length of the 32 degree and 28 degree growing season at each weather station is shown in Table 3.4-5.

Figure 3.4-6 shows the average annual precipitation in the watershed from 1971 to 2000. The data used to generate this figure was obtained from the PRISM Climate Group at Oregon State University (PRISM http://www.prism.oregonstate.edu). The data sets were created at Oregon State University using the Parameter-elevation Regressions on Independent Slopes Model (PRISM) climate mapping system. This figure shows the distinct differences in precipitation found within the study area. The eastern, lower elevation portions of the watershed receive approximately 15 inches of precipitation per year. Annual precipitation increases with elevation in the western portions of the watershed to over 37 inches. The higher elevations and orographic effects result in much higher precipitation in the mountainous portion or the watershed.

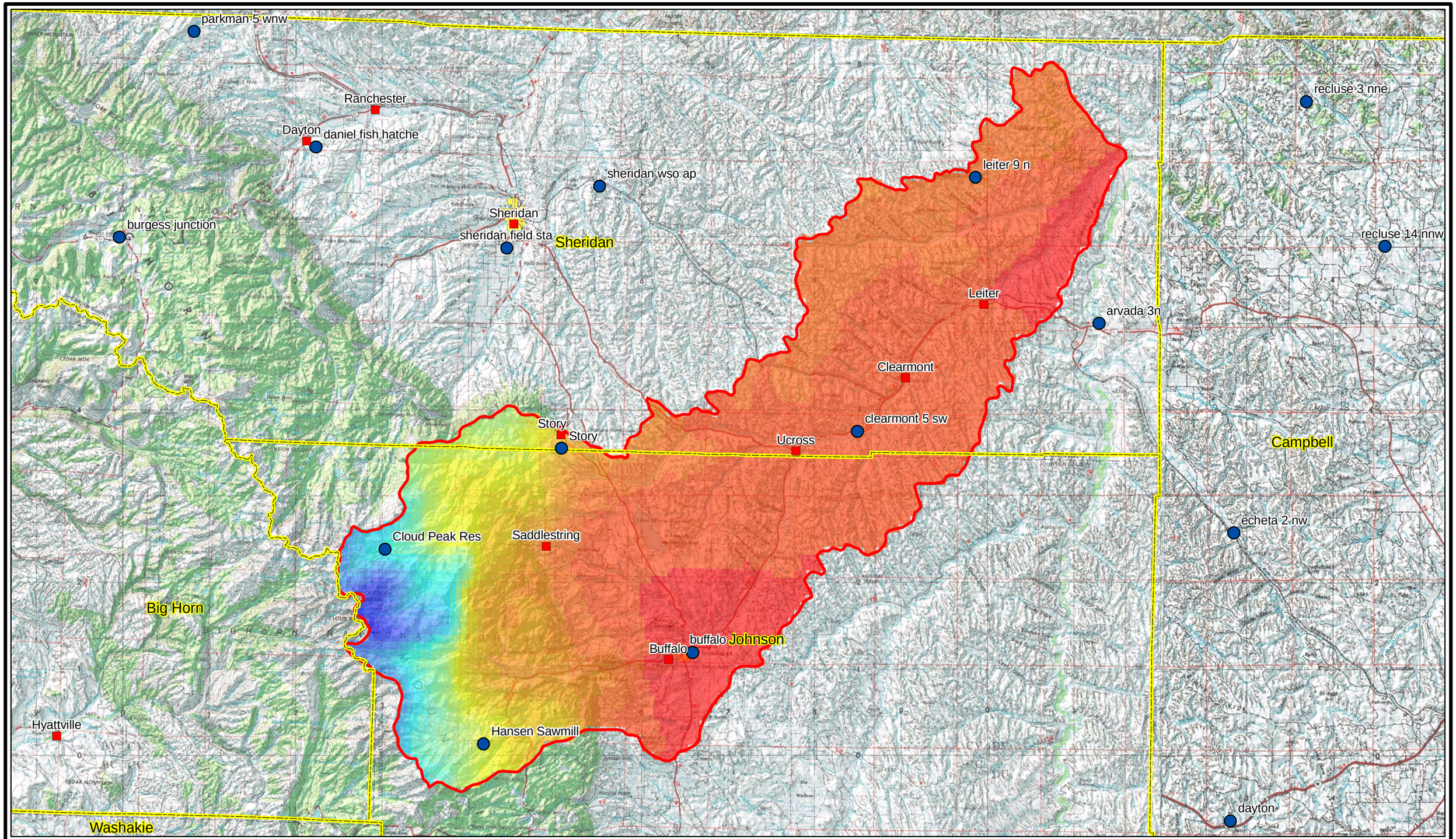


Figure 3.4-6
Average Annual Precipitation
1971-2000
NWS Weather Stations

Table 3.4-4 Summary of Climate Data

NRCS SNOTEL - Snow Water Equivalent Averages: 1971 to 2000 (inches)														
SNOTEL Site	Elevation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Cloud Peak Reservoir	9860	5.7	8.1	10.0	13.5	16.2	7.7	0	0	0	0.1	1.6	3.8	66.7
Hansen Sawmill	8360	3.3	4.2	5.2	6.5	4.9	0.2	0	0	0	0.1	0.9	2.0	27.3

Summary of Climate Data														
Weather Station	Period of Record													
Buffalo (481165)	4/1/1899 to 7/31/2010	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average High Temperature (F)		36.1	39.0	46.6	56.0	66.1	75.8	85.1	83.9	73.0	60.9	47.2	38.2	59.0
Average Low Temperature (F)		9.6	13.4	21.0	30.0	39.1	48.0	54.3	52.5	42.1	31.8	20.7	12.3	31.2
Average Total Precipitation (in)		0.47	0.42	0.75	1.47	2.44	2.17	1.29	0.84	1.30	0.96	0.50	0.46	13.08
Story (488626)	4/16/1950 to 7/31/2010	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average High Temperature (F)		36.6	35.9	42.8	51.4	59.3	68.7	80.6	78.1	68.0	53.2	46.5	34.5	54.6
Average Low Temperature (F)		14.3	13.9	20.2	28.4	37.0	45.3	53.4	50.0	41.7	31.0	24.5	13.6	31.1
Average Total Precipitation (in)		1.33	1.30	2.30	3.38	4.29	3.13	1.99	1.09	2.25	3.31	1.59	1.36	27.32
Clearmont 5 SW (481816)	11/1/1949 to 7/31/2010	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average High Temperature (F)		32.8	37.6	47.2	57.7	67.5	76.9	85.7	84.3	72.8	60.5	44.7	34.3	58.5
Average Low Temperature (F)		5.5	11.2	20.3	29.0	38.1	46.9	52.4	49.9	39.7	29.3	17.3	7.7	28.9
Average Total Precipitation (in)		0.56	0.46	0.79	1.51	2.29	2.19	1.44	1.02	1.17	1.08	0.61	0.47	13.58
Leiter 9 N (485506)	9/12/1964 to 7/31/2010	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average High Temperature (F)		33.5	38.6	47.6	57.9	67.7	78.1	88.6	87.6	75.2	60.7	45.0	34.8	59.6
Average Low Temperature (F)		12.0	16.6	23.8	32.3	41.3	50.0	57.5	56.0	45.7	34.2	22.8	13.6	33.8
Average Total Precipitation (in)		0.57	0.42	1.00	1.76	2.53	2.44	1.51	1.05	1.40	1.43	0.70	0.53	15.34

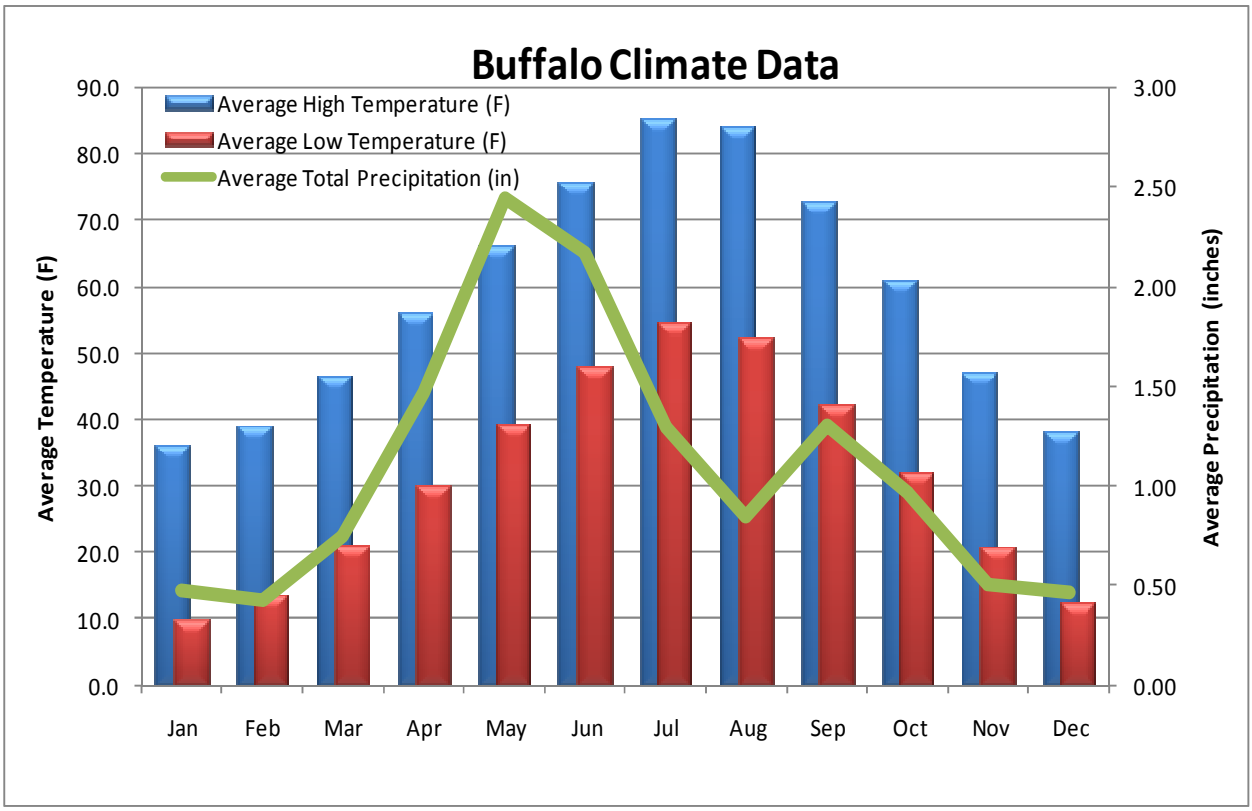


Figure 3.4-7 – Climate data for Buffalo

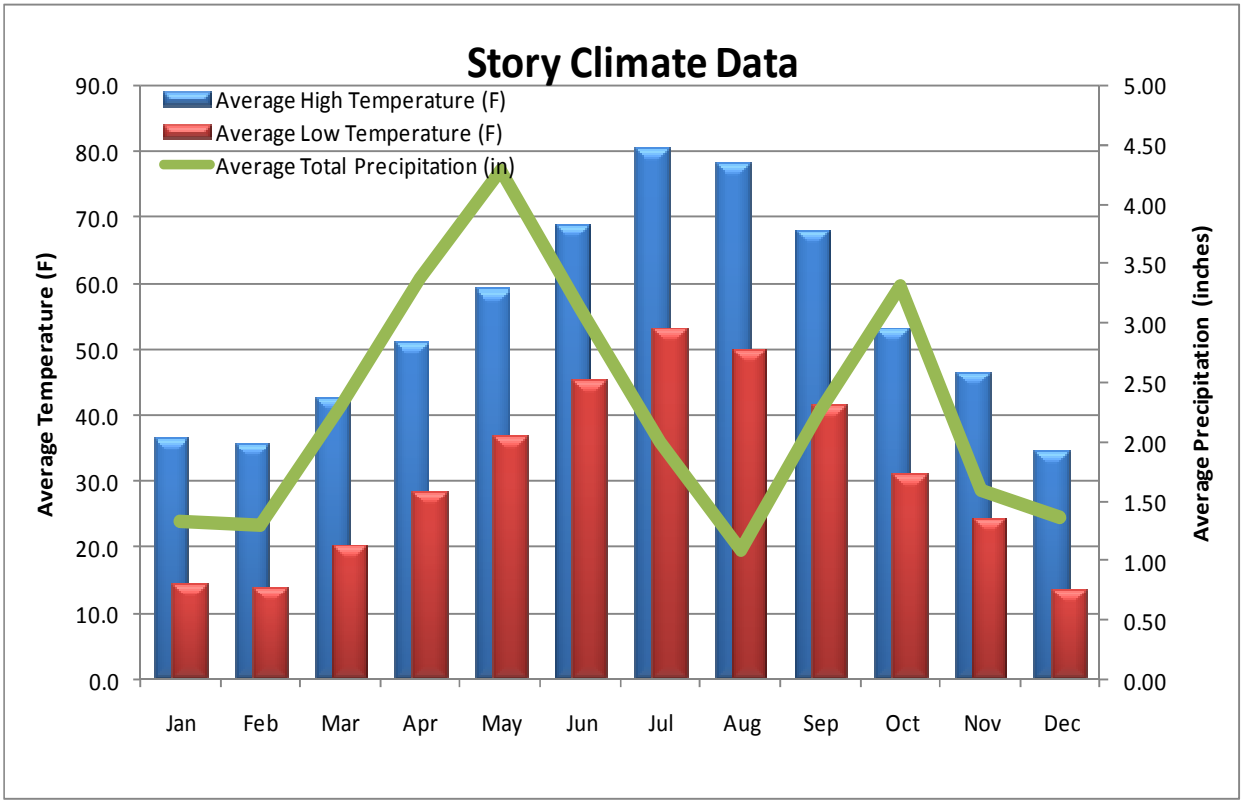


Figure 3.4-8 – Climate data for Story

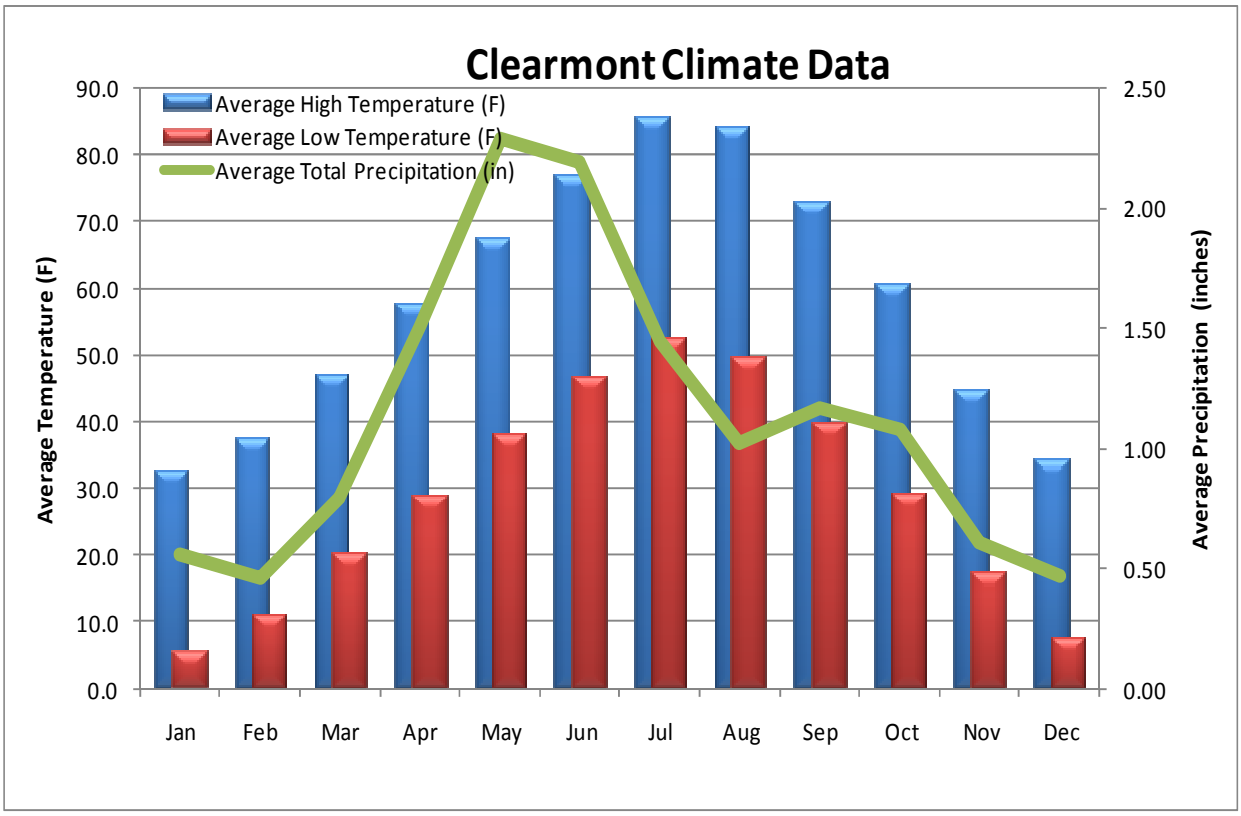


Figure 3.4-9 – Climate data for Clearmont

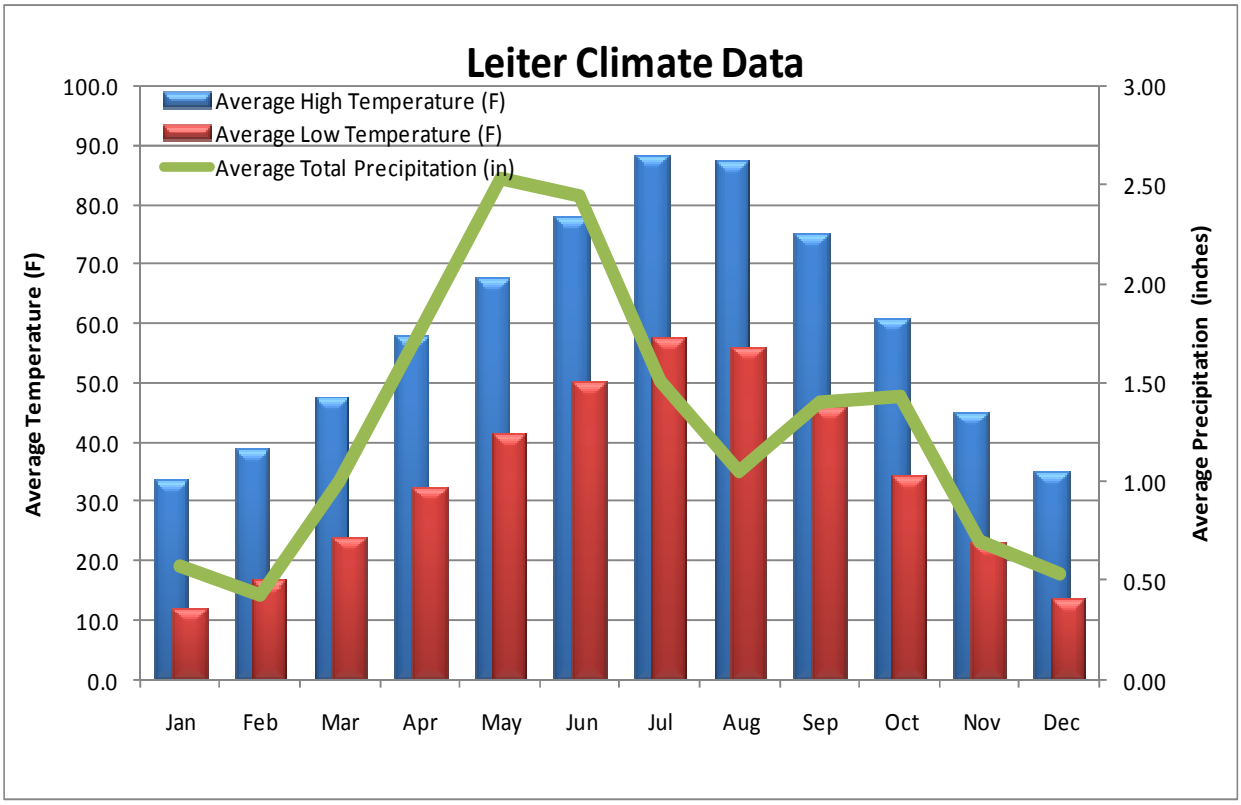


Figure 3.4-10 – Climate data for Leiter

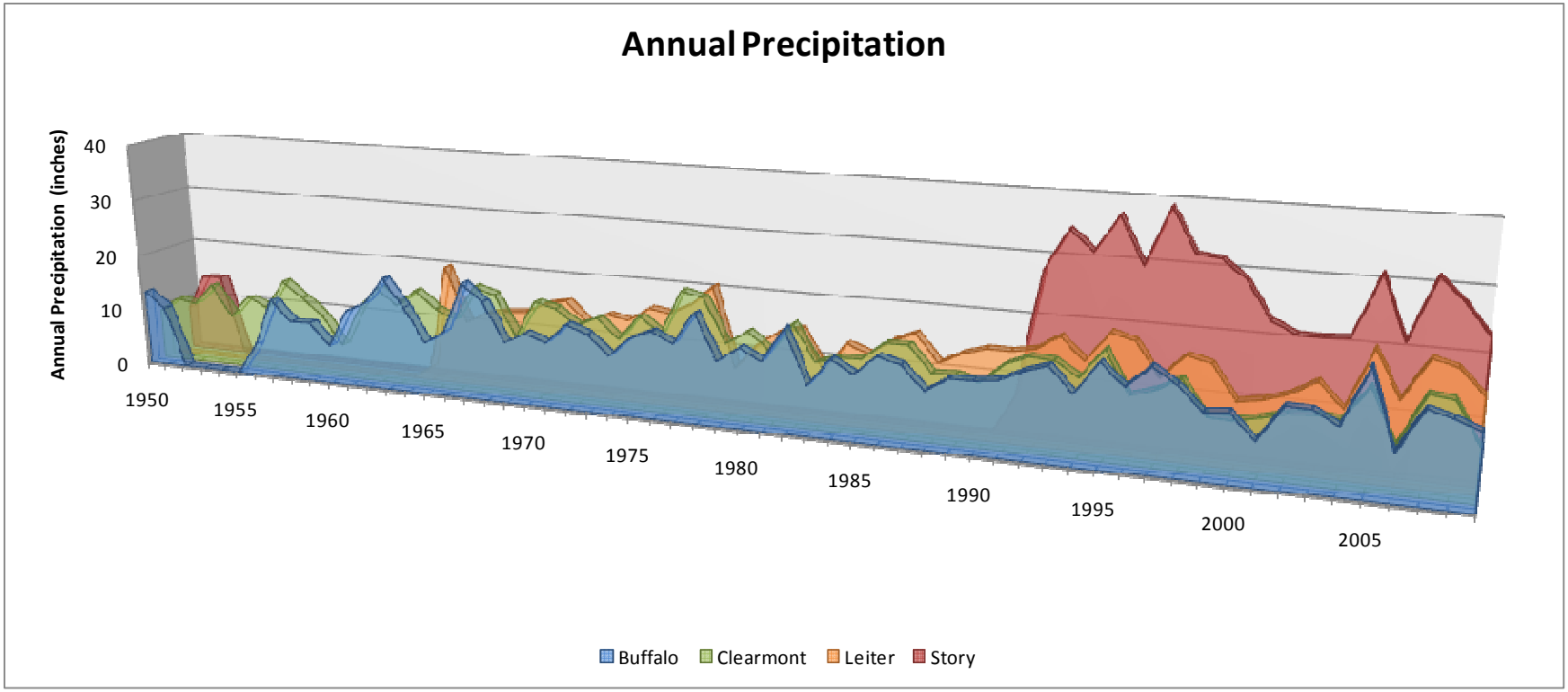


Figure 3.4-11 – Annual precipitation at four weather stations

Table 3.4-5 – Average growing season

Average Growing Season							
Weather Station	Period of Record	Avg. Last occurance of 32 F in Spring	Avg. First occurance of 32 F in Fall	Avg. 32 F Growing Season	Avg. Last occurance of 28 F in Spring	Avg. First occurance of 28 F in Fall	Avg. 28 F Growing Season
Buffalo	1899-2010	April-29	October-15	169 days	April-11	October-25	197 days
Story	1950-2010	May-5	October-5	153 days	May-2	October-11	162 days
Clearmont 5 SW	1950-2010	May-2	October-5	156 days	April-14	October-17	186 days
Leiter 9 N	1964-2010	April-14	October-22	191 days	April-5	October-30	208 days

3.4.3 Regional Geology

The Clear Creek watershed is located within the Great Plains and Middle Rocky Mountain Physiographic Provinces. The far western portion of the drainage basin that is within the Bighorn Mountains is located within the Middle Rocky Mountain Physiographic Province. This province is characterized by rugged mountains with a Precambrian-age (greater than 540 million years old) core of igneous and metamorphic rocks. (West, 1995)

The majority of the Clear Creek watershed is located within the Great Plains Physiographic Province. This province is generally characterized by horizontally bedded, poorly lithified rocks that are Mesozoic or Cenozoic in age (less than 250 million years old) and were deposited during erosion of the Rocky Mountains. In Wyoming, vegetation within the Great Plains is generally characterized as short-grass prairie with cottonwoods and shrubs along the river (West, 1995; www.netstate.com).

3.4.3.1 Surficial Materials

Surficial materials identified by the Wyoming State Geological Survey (Case et al., 1998) within the Clear Creek watershed are shown on Figure 3.4-12 and definitions of surficial materials are provided in Table 3.4-6. Several types of surficial materials are present within the watershed and most areas were mapped as consisting of a mixture of two or more surficial materials. General surficial materials are described below.

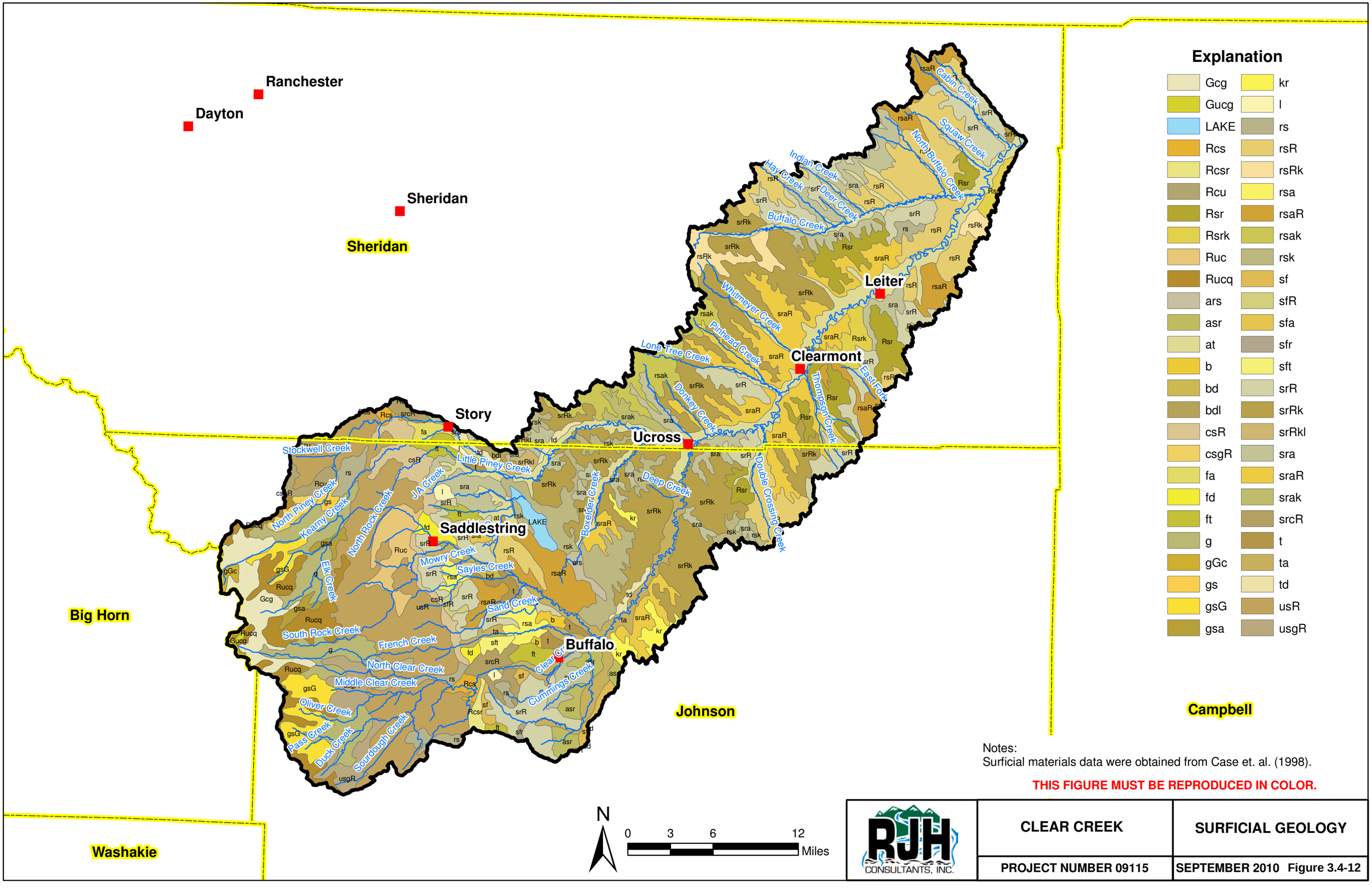
Alluvial materials within the watershed included alluvium, terrace deposits, bench deposits, and alluvial fan deposits. These materials were transported and deposited by streams or rivers. Alluvium is the most recent type of alluvial deposit and consists of clay, silt, sand, or gravel within the active channel or meander belt of streams and rivers. Terrace and bench deposits consist of older alluvial deposits that were located adjacent to streams or rivers at elevations higher than the current floodplain. Alluvial fan deposits were gently sloping deposits located at the mouths of narrow canyons.

Colluvium, slopewash, and landslide deposits within the basin were transported primarily by gravity. Colluvium consists of various mixtures of sand, silt, clay, gravel, and rock fragments that accumulated near the base of a slope. Slopewash was similar to colluvium, but the transport of this material was also assisted by unchannelized water (sheetflow). Landslide deposits consist of relatively intact blocks of bedrock or surficial material that have become destabilized and have traveled downslope.

Residual soil (residuum) was formed in place from weathering of the underlying bedrock. Grus is a specific type of residuum that consists of angular, coarse grained minerals formed from the disintegration of granitic rocks.

Glacial and periglacial deposits were formed from the advancement or retreating of alpine glaciers and consist of rock fragments within a silt and sand matrix. Periglacial deposits are those adjacent to the margins of the glacial extents.

Clinker consists of hard, dense rock that was baked from burning of coal beds within the Wasatch Formation bedrock (Ver Ploeg and Boyd, 2002).



Notes:
Surficial materials data were obtained from Case et. al. (1998).

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CLEAR CREEK	SURFICIAL GEOLOGY
PROJECT NUMBER 09115	SEPTEMBER 2010 Figure 3.4-12

Table 3.4-6 Definitions of Surficial Materials Shown on Figure 3.3-12

Map Symbol	Description
ars	alluvium mixed with residuum and slopewash
asr	slopewash mixed with alluvium and residuum
at	alluvium mixed with terrace deposits
b	bench deposits
bd	dissected bench deposits
bdl	dissected bench deposits mixed with landslide deposits
csgR	colluvium mixed with scattered bedrock outcrops, slopewash, and glacial deposits
csR	colluvium mixed with scattered bedrock outcrops and slopewash
fa	alluvial fan deposits mixed with alluvium
fd	dissected alluvial fan deposits
ft	alluvial fan deposits grading into terrace deposits
g	glacial deposits
Gcg	glaciated bedrock with a mantle of colluvium and glacial deposits
gGc	glacial deposits mixed with colluvium and scattered outcrops of glaciated bedrock
gs	glacial deposits mixed with slopewash
gsa	glacial deposits mixed with slopewash and alluvium
gsG	glacial deposits mixed with slopewash and scattered outcrops of glaciated bedrock
Gucg	glaciated bedrock with a mantle of grus, colluvium, and glacial deposits
kr	clinker mixed with residuum
l	landslide deposit
Lake	lake
Rcs	bedrock mixed with colluvium and slopewash
Rcsr	bedrock mixed with colluvium, slopewash, and residuum
Rcu	bedrock mixed with colluvium and grus
rs	residuum mixed with slopewash
rsa	residuum mixed with slopewash and alluvium
rsak	clinker mixed with residuum, slopewash, and alluvium
rsaR	residuum mixed with scattered bedrock outcrops, slopewash, and alluvium
rsk	clinker mixed with residuum and slopewash
Rsr	bedrock mixed with slopewash and residuum
rsR	residuum mixed with scattered bedrock outcrops and slopewash
Rsrk	bedrock mixed with slopewash, residuum, and clinker
rsRk	clinker mixed with scattered bedrock outcrops, residuum, and slopewash
Ruc	bedrock mixed with grus and colluvium
Rucq	bedrock mixed with grus, colluvium, and periglacial features and deposits
sf	alluvial fan deposits mixed with slopewash
sfa	alluvial fan deposits mixed with slopewash and alluvium
sfR	slopewash mixed with scattered bedrock outcrops and alluvial fan deposits
sfr	alluvial fan deposits mixed with slopewash and residuum
sft	alluvial fan deposits grading into terrace deposits mixed with slopewash
sra	slopewash mixed with residuum and alluvium
srak	clinker mixed with residuum, slopewash, and alluvium
sraR	slopewash mixed with scattered bedrock outcrops, residuum, and alluvium
srcR	slopewash mixed with scattered bedrock outcrops, residuum, and colluvium
srR	slopewash mixed with scattered bedrock outcrops and residuum
srRk	slopewash mixed with scattered bedrock outcrops, residuum, and clinker
srRkl	slopewash mixed with scattered bedrock outcrops, residuum, clinker, and landslide deposits
t	terrace deposits
ta	terrace deposits mixed with alluvium
td	dissected terrace deposits
usgR	glacial deposits mixed with scattered bedrock outcrops, grus, and slopewash
usR	grus mixed with scattered bedrock outcrops and slopewash

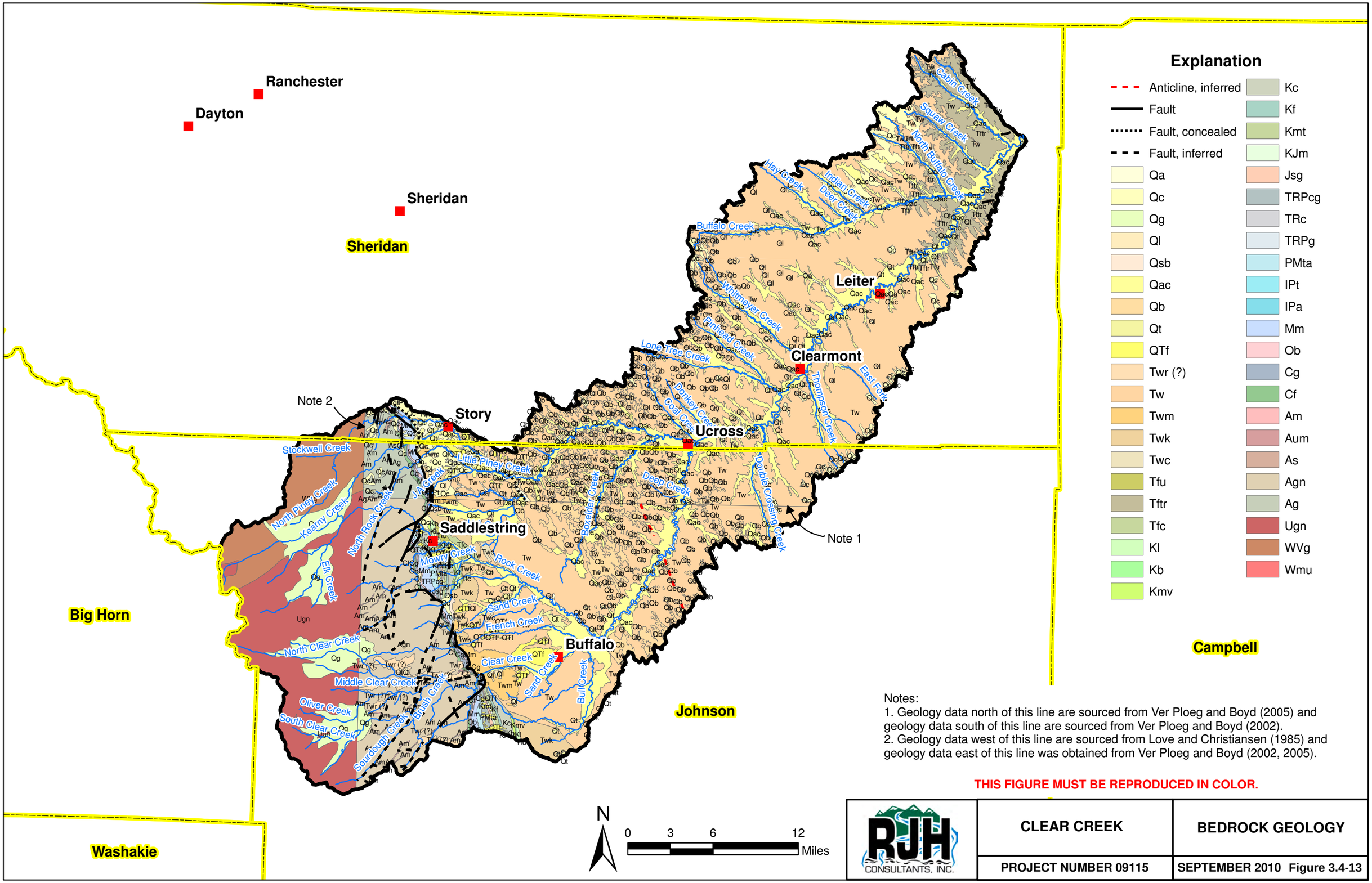
3.4.3.2 Bedrock

Bedrock identified by the Wyoming State Geological Survey (Love and Christiansen, 1985; Ver Ploeg and Boyd, 2002, 2005) within the Clear Creek watershed includes rock formations ranging in age from the Archean Eon (greater than 2,500 million years old) to the Oligocene Epoch (23 to 34 million years old). The bedrock geology is shown on Figure 3.4-13 and formation unit names are provided in Table 3.4-7. In general, older rock formations are located in the uplifted mountains on the west side of the watershed and younger rock formations are located in the prairie on the east side of the watershed.

The Bighorn Mountains within the Bighorn National Forest at the west end of the watershed are composed primarily of Archean-age (greater than 2,500 million years old) rocks. Rock types present within this area included metamorphic rocks (gneiss, quartzite, marble, and schist), mafic igneous rocks (diabase, diorite, metabasalt, gabbro, and peridotite), and felsic igneous rocks (granite, quartz monzonite, and quartz diorite).

Along the east side of the Bighorn Mountains and west of Interstates 25 and 90 are various sedimentary rock formations ranging in age from the Cambrian Period to the Paleocene Epoch (540 million to 56 million years old). These rock formations generally dip to the east, with the steepest dipping formations located along the Bighorn Mountain front. Dip angles become more gradual to the east. These formations generally consist of sandstone, shale, claystone, siltstone, limestone, dolomite, and conglomerate.

The majority of the Clear Creek watershed is underlain by the Early Tertiary-age (34 to 66 million years old) Wasatch Formation. The Wasatch Formation extends from about Interstates 25 and 90 on the west to within about 10 miles of the Clear Creek watershed mouth on the east. The Wasatch Formation is near horizontally bedded and consists of interbedded sandstone, conglomeritic sandstone, shale, claystone, and siltstone with subbituminous and lignitic coal beds (Ver Ploeg and Boyd, 2002, 2005).



Notes:
1. Geology data north of this line are sourced from Ver Ploeg and Boyd (2005) and geology data south of this line are sourced from Ver Ploeg and Boyd (2002).
2. Geology data west of this line are sourced from Love and Christiansen (1985) and geology data east of this line was obtained from Ver Ploeg and Boyd (2002, 2005).

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CLEAR CREEK	BEDROCK GEOLOGY
PROJECT NUMBER 09115	SEPTEMBER 2010 Figure 3.4-13

Table 3.4-7 Definitions of Geologic Units Mapped on Figure 3.4-13

Map Symbol	Description	Age
Qa	Alluvial deposits	Holocene
Qc	Colluvium	Holocene
Qg	Glacial deposits	Holocene/Pleistocene
Ql	Landslide deposits	Holocene/Pleistocene
Qsb	Slump blocks	Holocene/Pleistocene
Qac	Mixed alluvial and colluvial deposits	Holocene/Pleistocene
Qb	Baked and fused rock (clinker)	
Qt	Terrace deposits	Pleistocene
QTf	Older alluvial fan deposits	Pleistocene/Pliocene?
Twr (?)	White River Formation(?)	Oligocene
Tw	Wasatch Formation	Eocene and Paleocene?
Twm	Moncrief Member	
Twk	Kingsbury Member	
Twc	Conglomerate facies	
Tfu	Fort Union Formation (undivided)	Paleocene
Tftr	Tongue River Member	
Tfc	Fort Union Formation conglomerate facies	Paleocene
Kl	Lance and Fox Hills Formations (undivided)	Cretaceous
Kb	Bearpaw Shale	Cretaceous
Kmv	Mesaverde Formation	Cretaceous
Kc	Cody Shale	Cretaceous
Kf	Frontier Formation	Cretaceous
Kmt	Mowry Shale, Muddy Sandstone, and Thermopolis Shale undivided	Cretaceous
KJm	Cloverly and Morrison Formations (undivided)	Cretaceous/Jurassic
Jsg	Sundance and Gypsum Spring Formations (undivided)	Jurassic
TRPcg	Chugwater and Goose Egg Formations (undivided)	Triassic and Permian
TRc	Chugwater Formation	Triassic
TRPg	Goose Egg Formation	Trassic and Permian
PMta	Tensleep Sandstone and Amsden Formation (undivided)	Pennsylvanian and Mississippian
IPt	Tensleep Sandstone	Pennsylvanian
IPa	Amsden Formation	Pennsylvanian
Mm	Madison Limestone	Mississippian
Ob	Bighorn Dolomite	Ordovician
Cg	Gallatin and Gros Ventre Formations (undivided)	Cambrian
Cf	Flathead Sandstone	Cambrian
Am	Mafic rocks	Archean
Aum	Pyroxenite plug	Archean
As	Metasedimentary and metavolcanic rocks	Archean
Agn	Granitic gneiss	Archean
Ag	Granitic rocks	Archean
Ugn	Oldest gneiss complex	Archean
WVg	Plutonic rocks	Archean
Wmu	Metamorphosed maphic and ultramafic rocks	Archean

3.4.3.3 Structural Geology

The locations of faults mapped by the Wyoming State Geological Survey (Ver Ploeg and Boyd, 2002, 2005) within the Clear Creek watershed are shown on Figure 3.4-13. Additional faults have also been mapped to the east of the watershed (Ver Ploeg and Boyd, 2005). A couple of short normal faults oriented east-west to northeast-southwest have been mapped in the eastern portion of the Clear Creek watershed. Several faults have been mapped within and along the front of the Bighorn Mountains. Mapped faults include thrust faults, normal faults, oblique-slip faults, and faults with undetermined motion. The thrust faults have been generally aligned parallel to the mountain front with the upthrown blocks to the west. The remaining faults near the Bighorn Mountains have a variety of orientations, but many faults are generally aligned north-south to northeast-southwest. Right-lateral displacement is the most common for oblique-slip faults in the southwest portion of the drainage basin and left-lateral displacement is the most common in the northwest.

3.4.3.4 Geologic Impacts to Watershed Hydrology

The surficial, bedrock, and structural geology within the watershed impacts the hydrology. Geologic materials that are resistant to erosion generally result in topographic high elevation and geologic materials less resistant to erosion generally result in topographic low elevations. Structural features such as faults can be locations of drainages because of the increased disturbance to geologic materials along the faults. The faulting along the front of the Big Horn Mountains is associated with the uplift of the mountains. The mountains are the primary cause of the generally east flowing streams within and adjacent to the front of the mountains.

3.4.4 Geologic Hazards and Constraints

Based on RJH's review of published information, the primary potential geologic hazards and constraints within the watershed include:

- Ground Shaking
- Liquefaction
- Landslides
- Swelling Soil and Rock
- Karst
- Mine Subsidence
- Clinker

The USGS has not identified any potentially active faults within the watershed; however, potential ground motion could affect the design and construction of embankments. Figure 3.4-13 shows the published mapped faults (Ver Ploeg and Boyd, 2002, 2005). These faults were not categorized by the U.S. Geological Survey (USGS) as active during the Quaternary (during the past 2.6 million years). The closest active fault is the Stagner Creak Fault located 115 miles southwest of the center of the basin according to the USGS Quaternary Fault and Fold Database

(USGS, 2002). Despite the absence of active faults within the watershed, ground motion is expected. The USGS's Ground Motion Calculator was used to estimate the peak horizontal ground acceleration (PGA) for an event with a 5,000-year reoccurrence interval. Values were calculated for points at the western extent, in the center, and at the eastern extent of the watershed. The calculations are shown in Appendix 3H and summarized in the following table. The ground accelerations ranged from 0.22g to 0.30g.

Peak Horizontal Ground Accelerations for an Event with a 5,000-Year Reoccurrence Interval

	Western Extent	Center	Eastern Extent
Peak Horizontal Ground Acceleration	0.28g	0.30g	0.22g

Deposits of relatively loose and saturated granular soils may be susceptible to liquefaction. Liquefaction is a soil behavior phenomenon in which a soil mass loses a significant portion of its strength due to high excess pore-water pressure generated by earthquake ground shaking. Relatively loose and saturated granular soils could be present within the watershed and these in-situ materials could have the potential to liquefy.

Several landslides were mapped within the Clear Creek watershed as shown on Figure 3.4-14. The majority of these slides occurred in materials with low shear strengths such as shale, claystone, and the soils derived from these rocks. Some slides also occurred in the colluvium and mixed alluvium and colluvium deposits on the steeper slopes along the Big Horn Mountain front. The majority of the mapped landslides occurred in the Wasatch Formation, on the valley slopes of the small drainages in the eastern portion of the watershed. The Gallatin and Gros Ventre Formations, within the mountain front, also contained landslides. Seismic ground shaking could also increase the potential for landslides to occur.

Expansive soils and bedrock contain clay minerals that tend to absorb water when wetted, which results in volumetric expansion. These volume changes may cause differential heave and increased soil pressures. Potential differential movement may occur at the contact between expansive and non-expansive soils or bedrock, or at distinct wetting fronts. Shales, claystones, and mudstones, as well as the soils derived from them, can have high swell potentials. Bentonite has an especially high swell potential. Several rock units within the Clear Creek watershed are prone to swelling. The Wasatch and Fort Union Formations contain many shale and claystone layers. These formations are the bedrock units under the gently sloping plains in the eastern portion of the watershed. The Cretaceous aged Bearpaw Shale, Mesaverde Formation, Cody Shale, Frontier Formation, Mowry Shale, and Thermopolis Shale were predominantly shale and contained bentonite beds. These units were identified in the mountain front.

Karst forms by the dissolution of rock as water flows through and enlarges fractures forming underground drainages, caves, and sinkholes. Rocks types most susceptible to karst include limestone, dolomite, and gypsum. Karstic terrain can pose severe seepage problems and is

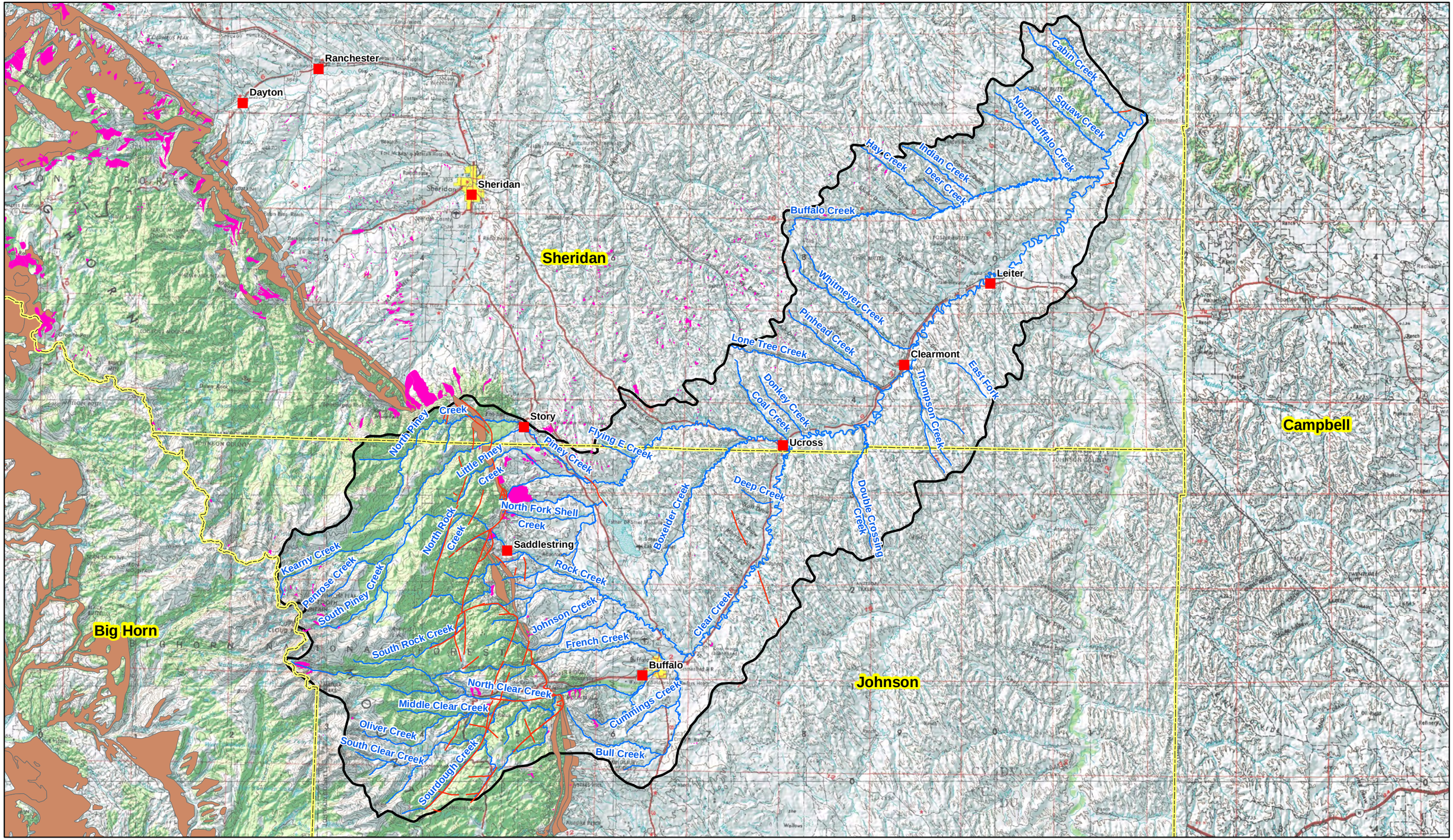

Figure 3.4-14
Geologic Hazards

difficult to fully identify with subsurface investigations. In the Clear Creek Watershed, the Sundance, Gypsum Spring Formations, Chugwater, and Goose Egg Formations contained limestone and thin gypsum beds and lenses. The Madison Limestone is karstic and cavernous, especially in the middle of the formation. The Bighorn Dolomite is less karstic than the Madison Formation. All of these units appear in the steeper slopes of the mountain front. Figure 3.4-14 highlights the formations known to potentially contain karsts.

Mine subsidence is generally related to the subsidence of the ground surface above abandoned underground coal mines in the Wasatch Formation and the Fort Union Formation. This hazard also occurred in areas that were not mined but where coal beds have burned (Dobrovolny, 1981). Sink holes or closed depressions may indicate the presence of underground voids, though surficial evidence is not always present.

Clinker forms when a coal seam burns and the intense heat from the burning coal leads to numerous fractures and vesicles in the overlying rock. These voids provide easy passage for groundwater. Clinker poses a hazard for reservoir construction because of its high permeability. Clinker is common in the Wasatch Formation and the Tongue River Member of the Fort Union Formation, which are the bedrock units of the eastern three-quarters of the watershed. Because clinker is durable, it often caps the local topographic highs. It is also present in discontinuous layers below the surface.

3.4.5 Soils

Soil groups identified by the Natural Resources Conservation Service (NRCS) within the Clear Creek watershed are shown on Figure 3.4-15. Soil group numbers are defined on Figure 3.4-16 and a brief description of each soil group is provided in Appendix 3F. We compiled this information from NRCS soil data (http://soildatamart.nrcs.usda.gov/) that was obtained from Sheridan County, Johnson County, and the Bighorn National Forest. The Clear Creek watershed had been divided into over 350 soil groups. In Johnson County the individual soil groups were generally larger and more continuous and in Sheridan County the soil groups were smaller and more segmented. The same soil group number was assigned to multiple soil group names in the Bighorn National Forest data set. Therefore, multiple soil groups may be represented by soil group numbers 11, 13, 15, and 22.

Ranchester
Dayton
Sheridan
Sheridan
Story
Leiter
Clearmont
Ucross
Saddlestring
Buffalo
Big Horn
Johnson
Campbell
Washakie
Cabin Creek
Squaw Creek
North Buffalo Creek
Hay Creek
Indian Creek
Deer Creek
Buffalo Creek
Timmered Creek
Limited Creek
Lone Tree Creek
Donkey Creek
Coal Creek
East Fork
Thompson Creek
Little Piney Creek
Boxelder Creek
Deep Creek
Double Crossing Creek
Rock Creek
Sand Creek
French Creek
Clear Creek
Cummings Creek
Bull Creek

Note:
Soils data was obtained from the Natural Resources Conservation Service.

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CLEAR CREEK	NRCS SOILS DATA
PROJECT NUMBER 09115	SEPTEMBER 2010 Figure 3.4-15

Explanation

101	130	165	203	240	279	317	637	692	754	860	963	11
102	131	166	204	241	280	318	638	695	756	861	964	125
103	133	167	205	244	281	319	639	697	758	867	968	13
104	136	168	206	246	282	320	640	701	759	879	970	141
105	138	169	207	248	283	321	641	702	760	880	971	15
106	140	170	208	249	284	601	642	703	762	881	973	16
107	141	171	209	252	286	603	645	705	763	893	975	18
108	142	172	212	254	288	604	646	707	766	894	976	186
109	143	173	213	255	289	605	649	708	767	895	977	19
110	144	174	214	256	291	606	652	709	770	901	978	22
111	145	175	215	257	292	607	653	710	775	903	980	25
112	146	177	216	258	293	608	654	711	776	904	982	26
113	148	178	217	260	299	609	655	712	777	905	983	29
114	149	179	220	261	302	612	656	715	780	906	984	31
115	150	180	221	262	303	614	659	717	782	920	987	33
116	152	183	223	263	304	615	661	718	783	921	988	35
117	153	186	224	264	305	618	663	719	784	923	989	36
118	154	190	225	265	306	619	664	720	786	924	990	37
119	155	192	226	266	307	622	665	722	787	925	993	40
120	156	193	228	267	308	623	666	726	788	927	994	41
121	157	194	232	268	309	624	667	727	789	929	995	42
122	158	195	233	269	310	626	670	728	790	933	997	43
123	159	196	234	270	311	628	675	736	791	938	998	W
124	160	197	235	271	312	629	676	740	851	939	999	
125	161	198	236	273	313	633	677	744	853	959	GP	
127	162	199	237	274	314	634	678	748	855	960	M-W	
128	163	201	238	277	315	635	680	750	857	961	10	
129	164	202	239	278	316	636	684	752	859	962		

THIS FIGURE MUST BE REPRODUCED IN COLOR.

Notes:
1. In the Bighorn National Forest dataset, the same soil group number was assigned to multiple soil group names. Thus, multiple soil groups may be represented by soil group numbers 11, 13, 15, and 22.
2. Soils data was obtained from the Natural Resources Conservation Service.

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CLEAR CREEK	NRCS SOILS DATA LEGEND
PROJECT NUMBER 09115	SEPTEMBER 2010 Figure 3.4-16

3.5 STREAM GEOMORPHOLOGY

3.5.1 General

The field of fluvial geomorphology is the study of how land is formed under processes associated with running water. The balance between processes such as erosion, deposition, and sediment transport determines the character and condition of a stream. The objective of the geomorphic evaluation of the Clear Creek watershed is to determine the nature of this balance, and where the balance has been upset.

The condition of a stream can be assessed with respect to its basic form (width, depth, slope, etc.), as well as its state of equilibrium, or geomorphic stability (Thorne, et al, 1996; Johnson, et al., 1999). Stable, or equilibrium, channels are generally defined as those that have achieved a balance between flow energy and sediment delivery, such that sediment is transported at the rate at which it is delivered, and the form and pattern of the channel is maintained (Thorne, et al., 1996). Dynamically stable channels are adjustable in nature, and "stability" does not preclude lateral migration and associated dynamics such as bank erosion and sediment deposition.

In geomorphically stable conditions, minor changes in either sediment supply or transport energy result in gradual adjustment of channel form to accommodate those changes (Lane, 1955). Channels destabilize when changes in those factors are extreme enough that rapid and dramatic alterations in pattern or form occur. Common indicators of channel instability include active downcutting and accelerated bank erosion, major changes in channel width/depth ratios, and increased flooding due to sediment deposition. Geomorphic function is achieved when a channel is in equilibrium, while undergoing processes such as lateral migration, sediment reworking, and occasional overbank flooding that effectively create and sustain quality habitat elements, such as bars, pool/riffles, step/pools, and healthy, regenerating riparian corridors.

Impairments to geomorphic function reflect a significant loss of the functional potential of the green channel segment. These impairments are typically described in general, qualitative terms, and any rehabilitation of impaired channel segments requires a more thorough, site-specific assessment of impacts, impairments, and feasible remedies.

3.5.2 Rosgen Classification System

The literature presents descriptions of numerous systems for classifying and evaluating stream systems. Of these, perhaps the most widely used today is the Rosgen classification system (Rosgen, 1996). This system, based upon the stream's existing channel morphology, was utilized in this study. Parameters such as the sinuosity, slope, width/depth ratio, and size of channel materials are evaluated and used to classify the stream into one of the various "types" included in the system.

There are four levels of classification in the Rosgen system, each being more detailed than the previous level. Figure 3.5-1 displays the hierarchy of the assessment levels and the general nature of effort associated with each. Much of the Level I geomorphic characterization is qualitative and utilizes aerial photography and topographic maps. Streams are divided into eight (8) broad types on the basis of their channel and floodplain geometry. Rosgen's classification system stream types can be thought of in their relative location within the watershed, from their headwaters through lowlands. The major stream types reflect their location in the watershed. For example, "A" type streams are located in headwaters, "C" & "E" stream types are located in meandering lowlands, etc.

The Level II effort provides a more detailed description of the stream using measurements at selected locations. Stream types are further subdivided into 94 subtypes based upon degree of entrenchment, width-to-depth ratio, water surface slope, streambed materials, and sinuosity (Figure 3.5-2). Consequently, the Level II characterization is more quantitative than the Level I effort. Levels III and IV require more extensive data collection and quantification of stream characteristics. The Clear Creek Watershed Study included Level I evaluation of Clear Creek and its major tributaries.

3.5.2.1 Level I Methods

The purpose of the Level I geomorphic classification is to provide an inventory of the Clear Creek watershed's overall stream morphology, character, and condition. It is intended to serve as an initial assessment for use in more detailed assessments and to determine the location and approximate percentage of stream types within the basin. The results of the Level I classification can be integrated directly into the project Geographic Information System (GIS) providing a graphical "snapshot" of the basin. Based upon this initial effort, potential stream reference reaches can be identified for further study in Level II classification efforts. The end product of the Level I classification is the determination of the major stream types, A through G.

Table 3.5-1 presents a brief summary of the different stream types found within the Rosgen Classification System and Figure 3.5-3 shows the relative locations of these stream types within a typical watershed. Brief descriptions of the various stream types encountered in the watershed are presented in the following paragraphs.

A-Type Channels are relatively steep channels that form in headwater areas as well as within bedrock canyons. These channels are entrenched and confined by steep valley margins such that little to no floodplain area borders them (Figure 3.5-4). As the boundaries of A-type channels are typically highly resistant to erosion, these stream types are generally quite resilient with respect to human impacts. The most common cause of geomorphic change within A-type channels is due to large-scale sediment transport events, (landslides, debris flows, debris jam failure) that may result in blockage or deflection of channel flow.

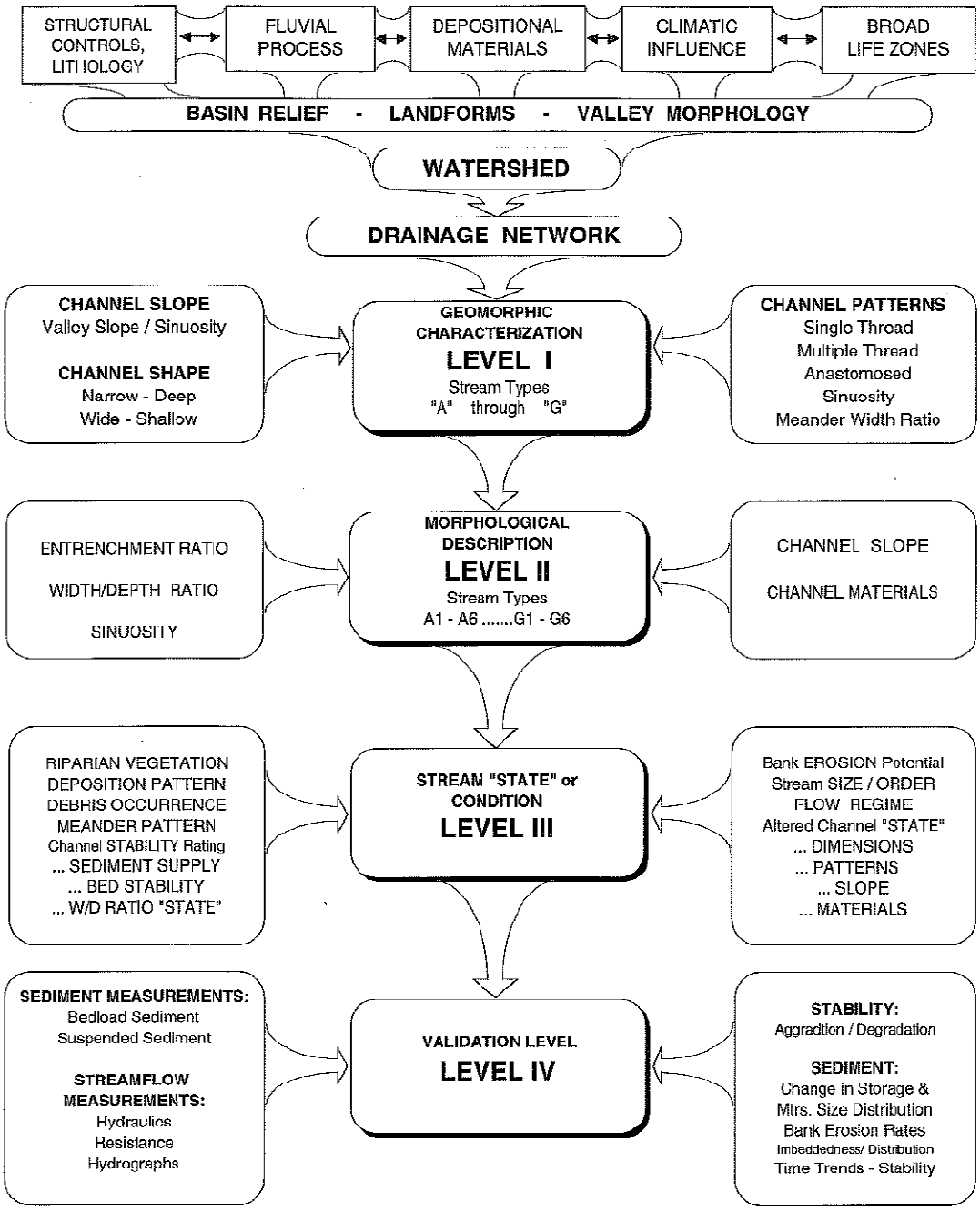


Figure 3.5-1 Hierarchy of the Rosgen Classification System

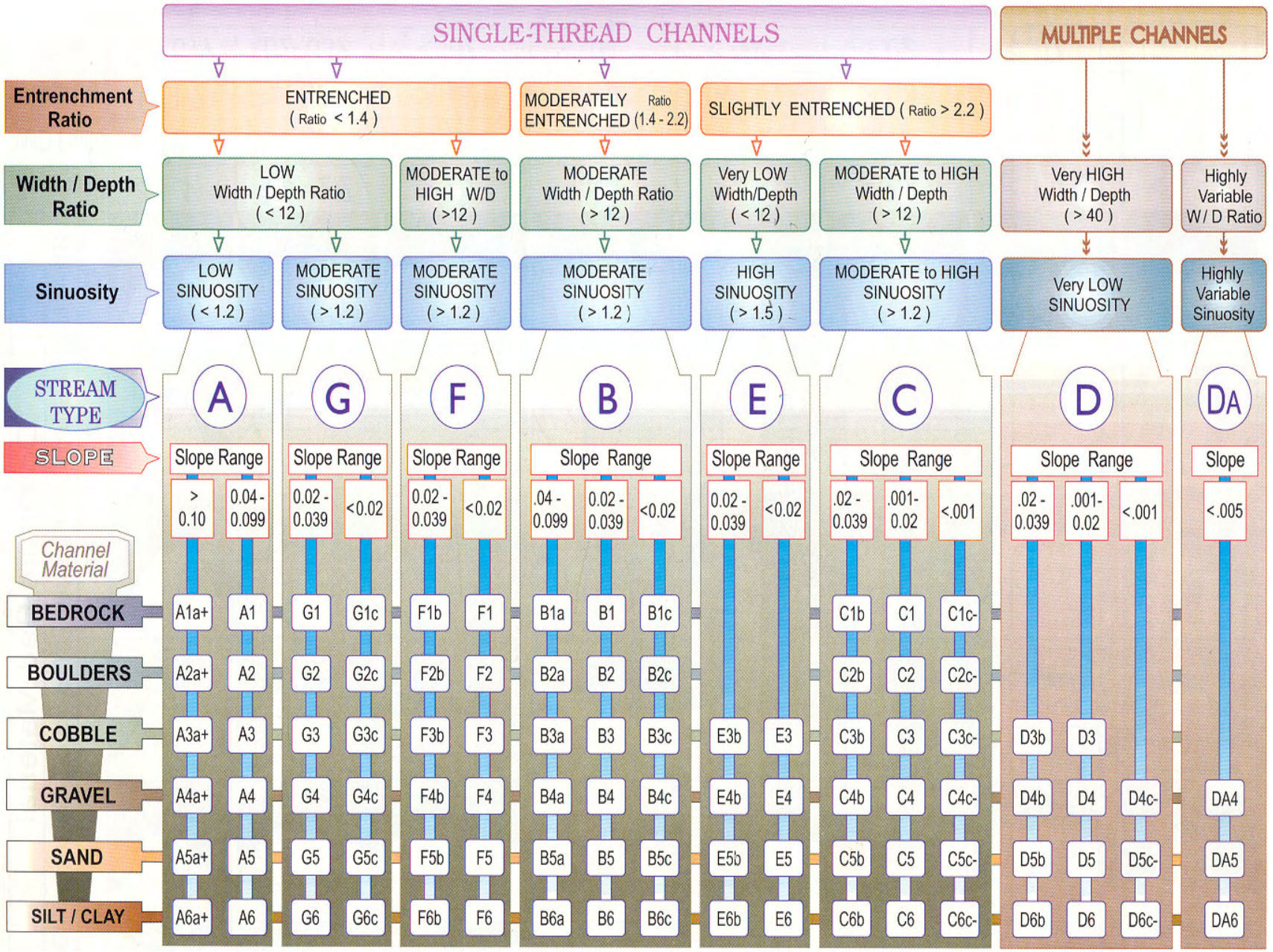


Figure 3.5-2 Rosgen Classification Matrix (Rosgen, 1996)

Stream Type	General Description	Entrenchment Ratio	W/D Ratio	Sinuosity	Slope	Landform/ Soils/Features
Aa+	Very steep, deeply entrenched, debris transport, torrent streams.	<1.4	<12	1.0 to 1.1	>.10	Very high relief. Erosional, bedrock or depositional features; debris flow potential. Deeply entrenched streams. Vertical steps with deep scour pools; waterfalls.
A	Steep, entrenched, cascading, step/pool streams. High energy/debris transport associated with depositional soils. Very stable if bedrock or boulder dominated channel.	<1.4	<12	1.0 to 1.2	.04 to .10	High relief. Erosional or depositional and bedrock forms. Entrenched and confined streams with cascading reaches. Frequently spaced, deep pools in associated step/pool bed morphology.
B	Moderately entrenched, moderate gradient, riffle dominated channel, with infrequently spaced pools. Very stable plan and profile. Stable banks.	1.4 to 2.2	>12	>1.2	.02 to .039	Moderate relief, colluvial deposition, and/or structural. Moderate entrenchment and W/D ratio. Narrow, gently sloping valleys. Rapids predominate w/scour pools.
C	Low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad, well defined floodplains.	>2.2	>12	>1.2	<.02	Broad valleys w/terraces, in association with floodplains, alluvial soils. Slightly entrenched with well-defined meandering channels. Riffle/pool bed morphology.
D	Braided channel with longitudinal and transverse bars. Very wide channel with eroding banks.	n/a	>40	n/a	<.04	Broad valleys with alluvium, steeper fans. Glacial debris and depositional features. Active lateral adjustment, w/abundance of sediment supply. Convergence/divergence bed features, aggradational processes, high bedload and bank erosion.
DA	Anastomosing (multiple channels) narrow and deep with extensive, well vegetated floodplains and associated wetlands. Very gentle relief with highly variable sinuosities and width/depth ratios. Very stable streambanks.	>2.2	Highly variable	Highly variable	<.005	Broad, low-gradient valleys with fine alluvium and/or lacustrine soils. Anastomosed (multiple channel) geologic control creating fine deposition w/well-vegetated bars that are laterally stable with broad wetland floodplains. Very low bedload, high wash load sediment.
E	Low gradient, meandering riffle/pool stream with low width/depth ratio and little deposition. Very efficient and stable. High meander width ratio.	>2.2	<12	>1.5	<.02	Broad valley/meadows. Alluvial materials with floodplains. Highly sinuous with stable, well-vegetated banks. Riffle/pool morphology with very low width/depth ratios.
F	Entrenched meandering riffle/pool channel on low gradients with high width/depth ratio.	<1.4	>12	>1.2	<.02	Entrenched in highly weathered material. Gentle gradients, with a high width/depth ratio. Meandering, laterally unstable with high bank erosion rates. Riffle/pool morphology.
G	Entrenched "gully" step/pool and low width/depth ratio on moderate gradients.	<1.4	<12	>1.2	.02 to .039	Gullies, step/pool morphology w/moderate slopes and low width/depth ratio. Narrow valleys, or deeply incised in alluvial or colluvial materials, i.e., fans or deltas. Unstable, with grade control problems and high bank erosion rates.

Table 3.5-1 Descriptions of Rosgen Stream Types

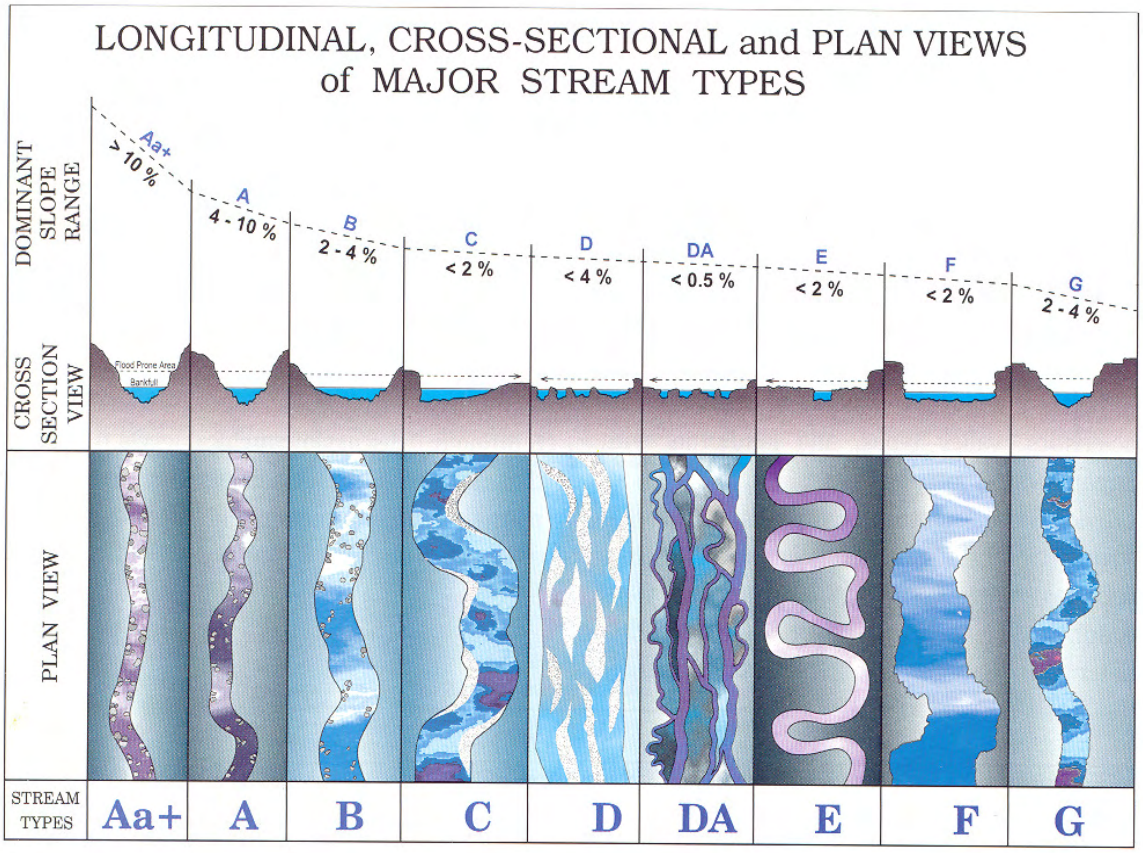


Figure 3.5-3 Major Stream Types within the Rosgen Classification System (Rosgen, 1996)

Figure 3.5-4. Typical Type A Stream Channel: Upper Rock Creek

B-Type Channels tend to form downstream of headwater channels, in areas of moderate slope where the watershed transitions from headwater environments to valley bottoms (Figure 3.5-5). B-Type channels are characterized by moderate slopes, moderate entrenchment, and stable channel boundaries. Due to the relatively steep channel slopes and stable channel boundaries, B-channels are moderately resistant to human impacts, although, their reduced slopes relative to headwater areas can make them prone to sediment deposition and subsequent adjustment following a large sediment transport event such as an upstream landslide, debris flow, or flood.

C-Type Channels are typically characterized by relatively low slopes, meandering planforms (i.e., the shape one would see if viewing from above, as on a map or aerial photo), and pool/riffle sequences (Figure 3.5-6). The channels tend to occur in broad alluvial valleys, and they are typically associated with broad floodplain areas. C-channels tend to be relatively sinuous, as they follow a meandering course within a single channel thread. In stream systems in which the boundaries of C-type channels are composed of alluvial sediments, channels tend to be dynamic in nature, and susceptible to rapid adjustment in response to disturbance.

E-Type Channels are somewhat similar to C channels, as they form as single threads with defined, accessible floodplain areas. However, E channels are different in that they tend to have fine-grained channel margins, which provide cohesion and support dense bankline vegetation. The fine-grained, vegetation-reinforced banklines allow for the development of steep banks, very sinuous planforms, and relatively deep, U-shaped channel cross sections. E-type channels commonly form in low gradient areas with fine-grained source areas, mountain meadows, and in beaver-dominated environments. E-channels tend to have very stable planforms, and efficient sediment transport capacities due to low width/depth ratios.

F-Type Channels typically have relatively low slopes (<2%), similar to C and E channel types. The primary difference between C/E channels and F channels is with respect to entrenchment (Figure 3.5-7). F channels are entrenched, which means that the floodplain is quite narrow relative to the channel width. The entrenchment of alluvial F-type channels typically is an indicator of an historic downcutting event. F-type channels may form in resistant boundary materials (e.g., U-shaped bedrock canyons), and relatively erodible alluvial materials (e.g., arroyos). When the boundary materials are erodible, the steep valley walls are prone to instability, and channel widening commonly occurs within the entrenched channel cross section.

G-Type Channels are narrow, steep entrenched gullies. G-Type channels typically have high bank erosion rates and a high sediment supply. Channel degradation and sideslope rejuvenation processes are typical.

The Level I classification effort was conducted primarily using existing information incorporated into the project GIS. Several analytical tools were developed and integrated into the GIS which allowed the evaluation of various geomorphic parameters (sinuosity, slope, stream station determination). The data collated and incorporated in the Project GIS include digital aerial photography, USGS topographic maps, Landsat color infrared imagery, a digital elevation model

Figure 3.5-5. Typical Type B Stream Channel: Clear Creek upstream of USFS Boundary

Figure 3.5-6 Typical Type C Stream Channel: Clear Creek Near Clearmont

Figure 3.5-7 Typical Type F Stream Channel: Whitmeyer Creek

(DEM), and digitized hydrography information. The most current data available were used in the geomorphic evaluation. Because the DEM was limited to a 30-meter grid, elevations and subsequent slope calculations are approximate. Stream alignments were digitized using 2006 aerial photography and represent the best available estimate of current channel alignment.

The streams evaluated were divided into reaches based upon definable geographic factors (e.g. confluences with tributaries, major road crossings, etc) or where their geomorphic character displayed changes. Each reach was evaluated in light of the characteristics required at the Level I classification.

3.5.2.2 Level I Classification Results

Results of the Level I classification effort are presented in Table 3.5-2 and graphically in Figure 3.5-8. This Figure displays a map of the Clear Creek watershed depicting the various stream types as well as the reach designations used in the classification effort.

Clear Creek and its primary tributaries originate in the steep Big Horn Mountains within the Bighorn National Forest. Within the mountainous areas, the channels are steep and bounded by very coarse, resistant materials that include hillslope colluvium, glacial deposits, and bedrock. As a result, the channels are typically laterally and vertically stable. These conditions also make them geomorphically resilient with respect to human impacts. The channels are A-type or B-type channels which reflects their steep slope and stable boundaries. Examples include upper Clear Creek, Rock Creek, and French Creek

As the major stream channels descend into the Clear Creek Basin, the lateral confinement is reduced as the valleys widen, the channel slope lessens and the boundary materials become less coarse. As a result of these downstream changes in boundary conditions, the lower subreaches tend to display meandering channel dynamics; that is, pool/riffle development and increased lateral channel migration. The channels transition from B channels, which are located in transition zones at the foot of the mountains, to C or F channels, which are gravel bed meandering streams that dominate the lower basin.

Clear Creek was classified as a C-type channel downstream of Buffalo. This classification is based upon the 'processes' observed and not strict adherence to classification based solely upon sinuosity, entrenchment, and slope. Throughout most of its extent, Clear Creek appears to have access to its floodplain on at least one of its banks. There are locations where entrenchment ratios would indicate the channel leans toward an F-type classification. A detailed geomorphic investigation of the Clear Creek could likely result in alternating reaches of C-type and F-type channels.

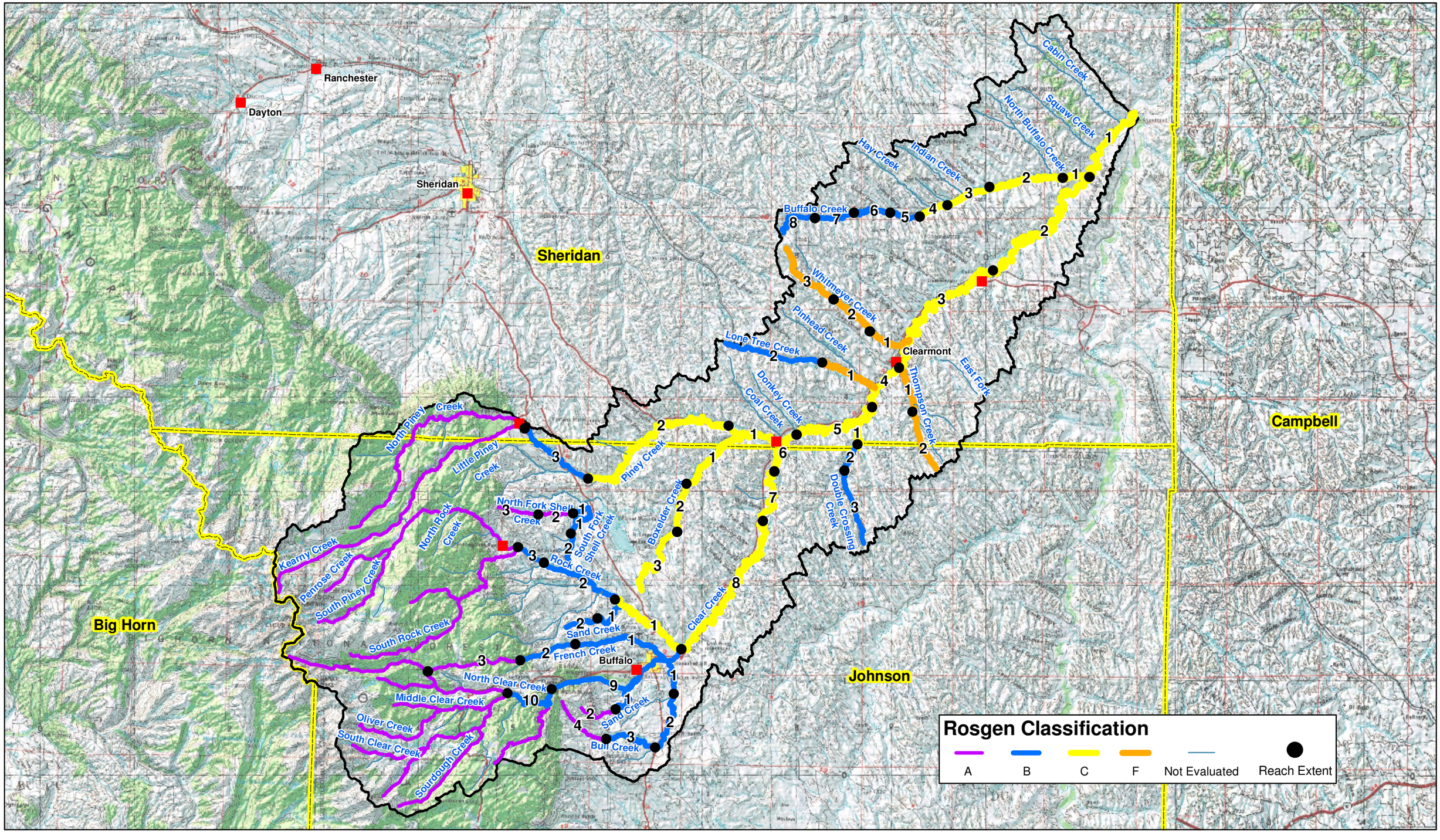


Figure 3.5-8. Clear Creek Watershed: Rosgen Level I Stream Classifications

Stream	Reach Number	Reach Definition			Sinuosity	Slope (ft/ft)	Rosgen Level I Classification
		Station Start (ft from confluence)	Station End (ft from confluence)	Length (ft)			
Boxelder Creek	1	0	50,214	50,214	1.83	0.0044	C
	2	50,214	76,658	26,444	1.53	0.0045	C
	3	76,658	111,042	34,384	1.39	0.0118	C
Buffalo Creek	1	0	19,865	19,865	2.03	0.0031	C
	2	19,865	72,555	52,690	2.05	0.0027	C
	3	72,555	94,964	22,409	1.41	0.0040	C
	4	94,964	113,317	18,353	1.72	0.0029	C
	5	113,317	127,031	13,714	1.27	0.0045	B
	6	127,031	155,111	28,079	2.17	0.0042	B
	7	127,031	148,091	21,059	1.50	0.0087	B
	8	176,170	195,191	19,021	1.27	0.0132	B
Clear Creek	1	0	48,196	48,196	1.72	0.0014	C
	2	48,196	146,284	98,089	2.02	0.0015	C
	3	146,284	251,302	105,018	2.09	0.0017	C
	4	251,302	275,964	24,662	1.41	0.0019	C
	5	275,964	340,510	64,546	2.18	0.0016	C
	6	340,510	366,813	26,304	1.69	0.0023	C
	7	366,813	399,485	32,672	1.73	0.0027	C
	8	399,485	498,437	98,952	1.80	0.0031	B
	9	498,437	555,607	57,170	1.11	0.0216	B
	10	555,607	582,893	27,286	1.34	0.0354	B
Double Crossing Creek	1	0	21,536	21,536	2.48	0.0031	C
	2	21,536	39,256	17,720	1.77	0.0043	C
	3	39,256	69,176	29,921	1.13	0.0099	B
French Creek	1	0	46,130	46,130	1.35	0.0147	B
	2	46,130	66,876	20,745	1.04	0.0456	B
	3	66,876	102,890	36,015	1.11	0.0602	A
Lone Tree Creek	1	0	34,790	34,790	1.73	0.0050	F
	2	34,790	75,851	41,060	1.17	0.0099	B
Piney Creek	1	0	30,568	30,568	1.43	0.0031	C
	2	30,568	128,237	97,669	1.67	0.0041	C
	3	128,237	161,973	33,736	1.20	0.0108	B
Rock Creek	1	0	46,820	46,820	1.63	0.0053	C
	2	46,820	82,534	35,713	1.28	0.0091	B
	3	82,534	93,828	11,294	1.09	0.0191	B
Thompson Creek	1	0	25,284	25,284	1.51	0.0063	F
	2	25,284	47,359	22,075	1.03	0.0150	F
Whitmeyer Creek	1	0	21,005	21,005	1.35	0.0054	F
	2	21,005	46,130	25,125	1.50	0.0069	F
	3	46,130	79,146	33,016	1.27	0.0125	F
North Fork Shell Creek	1	0	6,791	6,791	1.10	0.0161	B
	2	6,791	20,843	14,052	1.14	0.0240	A
	3	20,843	36,565	15,722	1.12	0.0696	A
South Fork Shell Creek	1	0	21,211	21,211	1.51	0.0066	B
	2	21,211	34,124	12,913	1.22	0.0131	B
Sand Creek (Trib to Rock Creek)	1	0	17,546	17,546	1.56	0.0116	B
	2	17,546	34,774	17,228	1.41	0.0177	B
Sand Creek (Trib to Clear Creek)	1	0	22,428	22,428	1.42	0.0155	B
	2	22,428	39,554	17,126	1.22	0.0685	A
Bull Creek	1	0	17,933	17,933	1.52	0.0071	B
	2	17,933	45,814	27,881	1.38	0.0110	B
	3	45,814	71,650	25,837	1.47	0.0127	B
	4	71,650	99,852	28,202	1.31	0.0288	A

Table 3.5-2 Results of the Clear Creek Level I Stream Classification

3.5.3 Impairments

In general, the Clear Creek system appears to be relatively stable with respect to geomorphic processes. While localized instances of channel degradation or bank erosion were observed, they do not appear to be related to systemic, basin-wide processes.

Impairments to stream channels within the study area appear to fall into two broad and interrelated categories:

Riparian Vegetation Degradation: Land use along the lower reaches of Clear Creek and its principal tributaries are dominated by agricultural activities. Irrigated fields and pastures frequently appeared to extend to the edge of the streambank with little or no riparian buffer (Figure 3.5-9). Riparian conditions appear impaired due to the loss or reduction of riparian vegetation along many of the lower elevation stream channels.

Riparian Degradation: As previously discussed, the Clear Creek system does not appear to be experiencing systemic degradation or instability. Generally, banks appear to be stable and few instances of vertical degradation or headcutting were observed. However, localized instances of stream bank erosion were evident. In a system as large and varied as the Clear Creek watershed, this would be expected. That is, bank erosion and channel migration are natural processes associated with meandering streams such as Clear Creek or Piney Creek. As floodplains have become developed (ranches, homesteads, transportation, etc), these process may result in a loss of irrigated lands, pastures, or infrastructure. Consequently, processes jeopardize infrastructure or investments.

Instances of channel processes threatening existing infrastructure were not prevalent and detailed mapping and evaluation of Clear Creek and its tributaries was beyond the scope of this Level I investigation. However, several locations were indentified at the request of landowners. These locations represent typical streambank stability problems encountered throughout the watershed. Their inclusion in this discussion is not intended to imply they represent an all inclusive list of stream channel stabilization recommendations for the watershed.

1. Rock Creek at Last Chance Ditch: At this location, bank erosion on Rock Creek threatens the integrity of the Last Chance Ditch. Lateral migration of the stream has eroded the left bank below the ditch. Currently, the distance between the ditch bank and the stream bank is less than 2 feet (Figure 3.5-10)
2. Piney Creek at Wilwuaka Ranch: At this location, Piney Creek has cut off a meander which has exacerbated stream bank erosion downstream (Figure 3.5-11). Continued erosion at this location could result in additional cutoffs and loss of access to affected properties as well as irrigation diversions.
3. Piney Creek at Ucross: This location on Piney Creek, located near its confluence with Clear Creek, is experiencing considerable bank erosion.(Figure _3.5-12)

4. Clear Creek at Ladd Ditch: At this location, Clear Creek has cut off a meander which has resulted in problematic diversions for the Ladd Ditch. (Figure _3.5-13)

5. Clear Creek at Lawrence Land Company: At this location, erosion of the right bank is resulting in loss of land and fence. (Figure _3.5-14)

3.5.4 Completed Stream Restoration Projects

Several stream restoration projects have taken place within the watershed. The Lake DeSmet Conservation District has implemented a stream restoration project on Clear Creek through the City of Buffalo that involved rock stream structures for streambank stability and fisheries enhancement. The project was implemented in three phases and involved approximately three miles of stream beginning above the City Park and running through town to the By-Pass road (N. Lohse, LDCD, email correspondence 2010).

An Emergency Watershed Protection project through the NRCS occurred on Clear Creek in 2009 and 2010. Three areas were addressed in this project:

1) County Road 256 project: This project included approximately 2 miles of Clear Creek along Upper Clear Creek Road above the City of Buffalo. Rock stream structures were implemented to deflect stream energy away from the county road to reduce the risk of future road damage.
2) Clear Creek Land Ditch project: This project included approximately 1 mile of Clear Creek above the City of Buffalo. Rock stream structures were implemented to maintain the hydraulic gradient of the stream to protect the Clear Creek ditch irrigation diversion.
3) Stewart project: This project included installation of rock stream structures in Clear Creek below the Highway 16 East bridge below the City of Buffalo. These structures were implemented to enhance streambank stability and to deflect stream energy away from threatened homesites.

Figure 3.5-9 Lower Clear Creek: note lack of riparian vegetation.

Figure 3.5-10 Rock Creek and Last Chance Ditch Impingement

Figure 3.5-11 Potential Meander Cutoff on Piney Creek

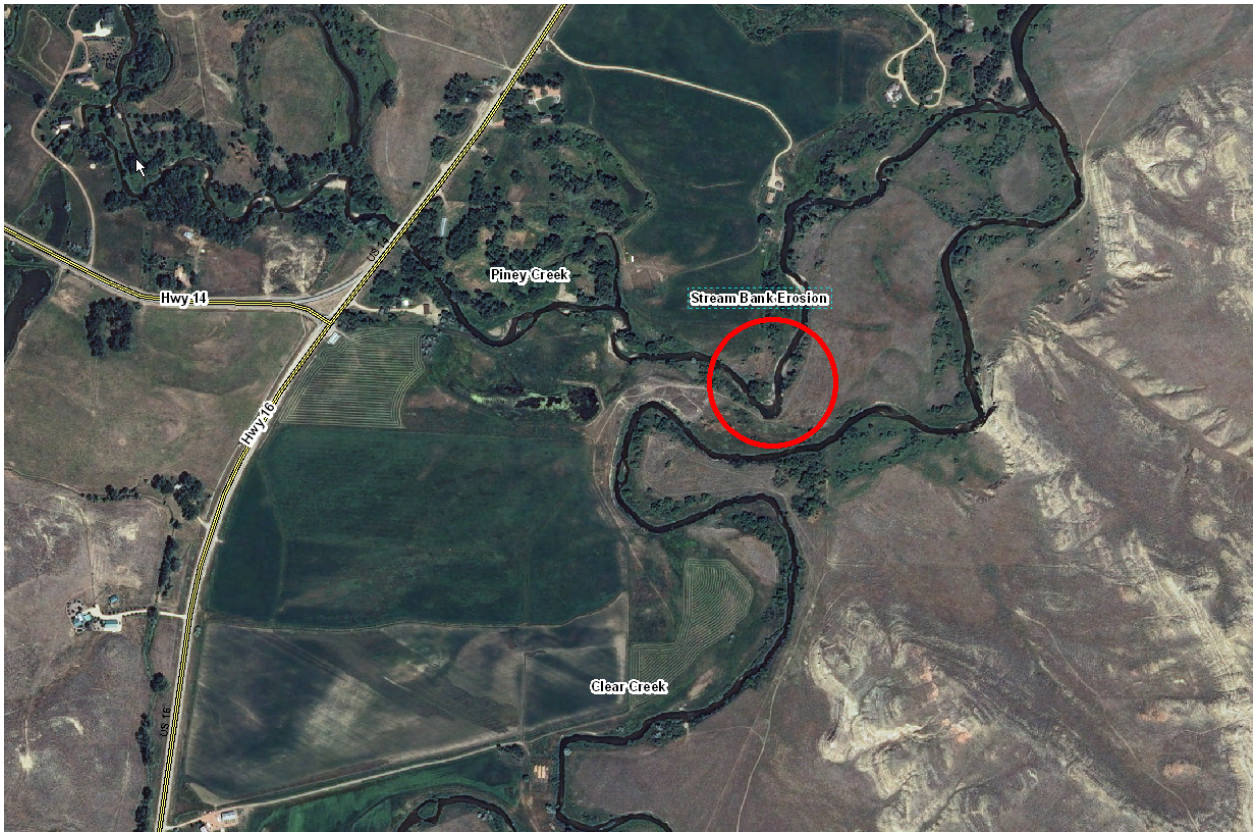


Figure 3.5-12 Streambank Erosion Site Near Mouth of Piney Creek

Figure 3.5-13 Streambank Erosion Site Near Ladd Ditch

Figure 3.5-14 Streambank Erosion Site at Lawrence Land Company Property

3.6 WATER QUALITY

An assessment of water quality of the Clear Creek watershed was conducted by gathering available information from various existing sources. The Wyoming Department of Environmental Quality (WDEQ), Water Quality Division (WQD), is the primary agency responsible for enforcing federal and state water quality laws, including the Clean Water Act, National Pollutant Discharge Elimination System, and Environmental Quality Act, therefore most of the water quality information presented below is summarized from WQD data. Additional sources examined include U.S. Geological Survey and U.S. Forest Service data, and other technical reports. The Clear Creek Monitoring Group was also contacted for water quality data, but their data are not available for public use. The Clear Creek Monitoring Group is a group of landowners along Clear Creek in Johnson and Sheridan Counties that rely on high quality irrigation water. One of their goals is to detect any changes in Clear Creek water quality due to coalbed methane development. This is accomplished by collecting monthly water samples to analyze for sodium bicarbonate, sodium absorption ratio, and conductivity. Landowners also test water temperature, conductivity, and flow twice weekly. The group reports the status of their monitoring efforts and any perceived problems to the DEQ.

Water quality standards are the foundation of the water quality-based control program mandated by the Clean Water Act. Wyoming's water quality standards are applicable to "waters of the State", with the exception of those waters that are within Indian Country. In some limited instances, the definition adopted by Wyoming for "waters of the State" may result in water quality standards that are more comprehensive than required under the Clean Water Act and the implementing federal regulations. Water quality standards define the goals for a waterbody by designating its uses, setting criteria to protect those uses, and establishing provisions to protect water quality from pollutants.

3.6.1 General Assessment

Water quality in the Clear Creek watershed is potentially affected by land uses in the watershed, including gas development, agricultural irrigation, livestock grazing, wildlife grazing, residential development, and other land uses in the watershed (Feck and Nibblelink 2003). Coal bed methane (CBM) development, in particular, has been and continues to be a major concern for water quality in northeast Wyoming, including the Clear Creek watershed. Water quality is monitored by the State and other federal and local government agencies, as well as private entities.

3.6.2 Stream Classification

All streams named on the U.S. Geological Survey 1:500,000 scale hydrologic map of Wyoming and other selected streams have been classified for protection of one or more designated uses by the WQD. Four stream classifications are applicable to the Clear Creek watershed, according to the Wyoming Surface Water Classification List (WDEQ 2001), and are shown on Figure 3.6-1. The four stream classifications are described below, per the Wyoming Surface Water Quality

Ranchester
Dayton
Sheridan
Sheridan
Clearmont
Campbell
Creek
Creek
Creek
Creek
Creek
South Rock Creek
Big Horn
Buffalo
Johnson
N
W
E
S
0
5
10
Miles
Legend
Stream Classification
1
2AB
3B
4A
Cities
Watershed
County Boundary
Clould Peak Wilderness Area

Figure 3.6-1 Clear Creek Watershed: WQD Stream Classifications

Standards (WDEQ 2007). (Note: the current surface water classification list is being updated by the WQD; the updated list is anticipated to be released in mid to late Spring 2011)

- Class 1 – Outstanding Waters. Class 1 waters are those surface waters in which no further water quality degradation by point source discharges other than from dams will be allowed. In designating Class 1 waters, water quality, aesthetic, scenic, recreational, ecological, agricultural, botanical, zoological, municipal, industrial, historical, geological, cultural, archaeological, fish and wildlife, the presence of significant quantities of developable water, and other values of present and future benefit to the people are considered.

- Class 2AB – Class 2AB waters are those known to support game fish populations or spawning and nursery areas at least seasonally and all their perennial tributaries and adjacent wetlands and where a game fishery and drinking water use is otherwise attainable. Class 2AB waters include all permanent and seasonal game fisheries and can be either "cold water" or "warm water" depending upon the predominance of cold water or warm water species present. All Class 2AB waters are designated as cold water game fisheries unless identified as a warm water game fishery by a "ww" notation in the "Wyoming Surface Water Classification List". Unless it is shown otherwise, these waters are presumed to have sufficient water quality and quantity to support drinking water supplies and are protected for that use. Class 2AB waters are also protected for nongame fisheries, fish consumption, aquatic life other than fish, recreation, wildlife, industry, agriculture and scenic value uses.

- Class 3B – Class 3B waters are tributary waters including adjacent wetlands that are not known to support fish populations or drinking water supplies and where those uses are not attainable. Class 3B waters are intermittent and ephemeral streams with sufficient hydrology to normally support and sustain communities of aquatic life including invertebrates, amphibians, or other flora and fauna which inhabit waters of the state at some stage of their life cycles. In general, 3B waters are characterized by frequent linear wetland occurrences or impoundments within or adjacent to the stream channel over its entire length. Such characteristics will be a primary indicator used in identifying Class 3B waters.

- Class 4A - Class 4A waters are artificial canals and ditches that are not known to support fish populations.

All surface waters located within the boundaries of national parks and congressionally designated wilderness areas as of January 1, 1999 are designated Class 1 waters. Therefore all surface waters in the Cloud Peak Wilderness area are designated as Class 1 waters.

Clear Creek and the majority of the streams in the upper part of the watershed outside of the wilderness area are designated as Class 2AB, including Piney Creek, Rock Creek, Sourdough Creek, French Creek, and various tributaries. Under this classification, these streams are

suitable to support game fish populations or spawning and nursery areas at least seasonally, nongame fisheries, fish consumption, aquatic life other than fish, recreation, wildlife, industry, agriculture, and scenic value uses. Water quality standards are set to protect and maintain these uses.

Most of the steams in the lower part of the watershed and a few in the upper watershed including Johnson Creek, Cummings Creek, Bull Creek, and Boxelder Creek are designated as Class 3B. According to this classification, these streams are intermittent and ephemeral and they are not known to support fish populations or drinking water supplies. They do, however, support invertebrates, amphibians, or other flora and fauna that inhabit waters of the State at some stage of their life cycles. Uses designated on Class 3 waters include aquatic life other than fish, recreation, wildlife, industry, agriculture, and scenic values. As with the Class 2AB streams, water quality standards are set to protect and maintain these uses.

Three ditches in the watershed are identified on the surface water classification list as Class 4A waters, including Redman Ditch, Splasher Ditch, and Fort McKinney Ditch. Aquatic life uses are not attainable under State regulations for these waters. Use designations for these waters include recreation, wildlife, industry, agriculture and scenic values and water quality standards are set to protect and maintain these uses.

Unlisted Waters

The waters contained in the surface water classification list are all waters which are named on the USGS 1:500,000 scale hydrologic map of Wyoming and other selected streams that have been classified by the WQD. The classification list does not contain an exhaustive listing of all the surface waters in the state. Those waters which are not specifically listed are classified as follows:

(a) All waters shown as having any species of game fish present in the Wyoming Fame and Fish Department's *Streams and Lakes Database* as submitted to the DEQ in June 2000 are classified as 2AB;

(b) All waters shown as having only nongame fish species present in the Wyoming Game and Fish Department's *Streams and Lakes Database* as submitted to the DEQ in June 2000 are classified as 2C;

(c) All other waters shall be classified as follows:

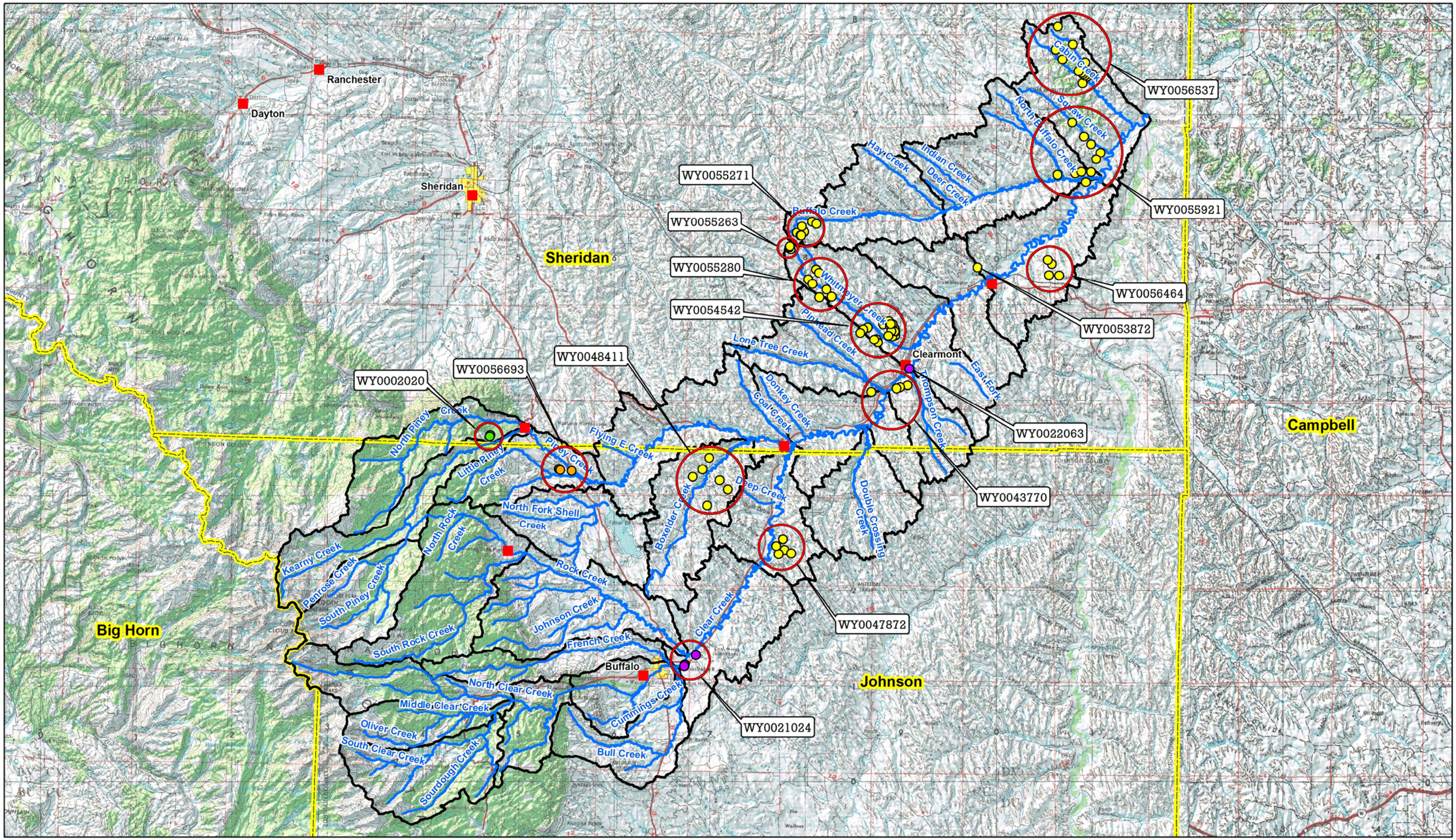
  (i) Those waters supported by an approved UAA containing defensible reasons for not protecting aquatic life uses shall be 4A, 4B, or 4C;

  (ii) The remaining waters shall be 3A, 3B, or 3C.

(d) Wetlands. All adjacent wetlands shall have the same classification as the waters to which they are adjacent.

3.6.3 WYPDES Permitted Discharges

The Wyoming Pollution Discharge Elimination System (WYPDES) program is administered by the WQD, which issues permits to all facilities that discharge water into the environment. The permits contain limitations and conditions that ensure the State's surface water quality standards are protected. A total of 15 active permitted discharges occur in the Clear Creek watershed. Table 3.6-1 summarizes pertinent information regarding these permits. The locations of these discharges are shown on Figure 3.6-2. One of the permits is for the State fish hatchery at Story. Two of the permits are for municipal wastewater (for the towns of Buffalo and Clearmont). A new wastewater treatment plant is being constructed in the town of Buffalo. The new plant will utilize a secondary treatment method, activated sludge; disinfection will utilize UV technology. With these improvements in technology, water quality below the town of Buffalo is likely to improve, however effluent limits are unlikely to change unless outfall locations change. Effluent limits are based on classification and use of the receiving stream. Currently, the town of Buffalo discharges to Clear Creek (Class 2AB water), and Redman or Splasher Ditches (both Class 4A waters). In the past, the existing facility has had difficulty meeting chlorine, total dissolved solids, and mixing zone requirements. Eleven of the permits are for coal bed methane discharges, and one is for an industrial facility. Most of the coal bed methane discharge permits have multiple outfalls on the permit (up to 21 outfalls); Figure 3.6-2 shows the locations of all permitted outfalls. In addition to the WYPDES permits listed in Table 3.6-1, there are thirteen stormwater discharge permits in the watershed.



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WYPDES Outfall
- Coal Bed Methane
- Fish Hatchery
- Industrial
- Sanitary Wastewater
- Cities
- Streams
- Watershed
- County Boundary

Figure 3.6-2 Clear Creek Watershed: WYPDES Permitted Discharges

Table 3.6-1 Summary of WYPDES Permitted Discharges in Clear Creek Watershed

Permit #	Permit Holder	Facility Type	Number of Outfalls	Receiving Water
WY0002020	Wyoming Game and Fish Department	Fish Hatchery	2	Spring Creek (2AB), Powder River Basin
WY0021024	Town of Buffalo	Municipal Wastewater Treatment	3	Redman Ditch & Splasher Ditch (4A), Powder River Basin
WY0022063	Town of Clearmont	Municipal Wastewater Treatment	1	Clear Creek (2AB), Powder River Basin
WY0043770	Pinnacle Gas Resources, Inc.	Coal Bed Methane	5	Powder River (2ABWW) via Clear Creek (2AB) via unnamed ephemeral tributary (3B) via off-channel pit "Rhoades-3" (3B)
WY0047872	Northwest Energy, LLC	Coal Bed Methane	5	Powder River (class 2ABww) via Clear Creek (class 2AB) via off-channel pit (class 4)
WY0048411	Comet Energy, LLC	Coal Bed Methane	6	Powder River (2ABWW) via Clear Creek (2AB) via Piney Creek (2AB) via Boxelder Creek (3B) via unnamed ephemeral tributary (3B) via on-channel reservoir "C3-20" (3B)
WY0053872	Continental Production Company, LLC	Coal Bed Methane	1	Powder River (2AB) via Clear Creek (3B) via an unnamed, ephemeral tributary (3B) via, but not tributary from, Off-Channel Pit "Little 1-19" (4C)
WY0054542	Windsor Energy Group	Coal Bed Methane	21	Powder River (2ABWW), via Clear Creek (2AB), via Whitmeyer Creek (3E), via unnamed ephemeral tributary, via on-channel headwater reservoir "Lower Whit N. 5" (3B)

Table 3.6-1 Continued

Permit #	Permit Holder	Facility Type	Number of Outfalls	Receiving Water
WY0055263	Windsor Energy Group	Coal Bed Methane	3	Powder River (2ABWW) via Clear Creek (2AB) via Buffalo Creek (3B) via unnamed ephemeral tributary (3B) via off-channel pit "FKCC 15-7" (4C)
WY0055271	Windsor Energy Group	Coal Bed Methane	7	Powder River (2ABWW) via Clear Creek (2AB) via Buffalo Creek (3B) via unnamed ephemeral tributary (3B) via on-channel reservoir "FKCC 3-4" (3B)
WY0055280	Windsor Energy Group	Coal Bed Methane	7	Off-channel pit "FKCC 16-20" (4C) located within but not tributary to the Clear Creek (2AB) drainage of the Powder River (2ABWW) Basin
WY0055921	JM Huber Corporation	Coal Bed Methane	10	Powder River (2ABWW) via Clear Creek (2AB) via Buffalo Creek (3B) via unnamed ephemeral tributary (3B) via on-channel reservoir "P56-77-17-13" (3B)
WY0056464	Pinnacle Gas Resources, Inc.	Coal Bed Methane	4	Powder River (2ABWW) via Clear Creek (3B) via Scott Draw (3B) via off-channel pit "Carlock #2" (4C)
WY0056537	Pinnacle Gas Resources, Inc.	Coal Bed Methane	12	Powder River (2ABWW) via Clear Creek (2AB) via Cabin Creek (3B) via off-channel pit "Padlock #1" (4)
WY0056693	Mullinax Concrete Service Company	Industrial	5	Piney Creek (2AB) via an unnamed drainage (3B), Powder River Basin

In addition to the above individual WYPDES permits in the watershed, WQD is currently proposing to issue a greater Clear Creek watershed general permit for coal bed methane (CBM) produced water discharge. CBM produced water is an effluent generated in the process of de-watering coal bearing formations to extract natural gas. This permit is in draft form and has not been issued. If issued in the future, the general permit establishes effluent limits that are protective of Wyoming water quality standards and designated uses and contains monitoring requirements to evaluate any potential impacts the development may have on the drainage.

The WQD has committed to undertake a watershed-based permitting approach to CBM discharges within the Clear Creek watershed to increase coordination in efforts to identify and monitor potential impacts from widespread CBM development, increase permitting efficiency and streamline the permitting process, notify landowners and the general public of proposed development earlier in the process, and allow for discovery and consideration of unique circumstances during the development phase of the general permit. Due to legal challenges of watershed-based CBM permits, including the Clear Creek watershed, it is unknown when and if the permit will be finalized.

3.6.4 Waters Requiring TMDLs

A Total Maximum Daily Load (TMDL) is the amount of pollutant that a stream can accept and still meet its designated uses. TMDLs must be established for each pollutant that is a source of stream impairment. They must be measureable and must consider both point and nonpoint source pollutant loads, natural background conditions, and a margin of safety.

Section 303(d) of the Clean Water Act requires states to:

1) Identify all waters of the state that are impaired; i.e., they contain pollutants that adversely affect the designated use of the water.

2) Prioritize all impaired waterbodies for development of TMDLs. Prioritization is to take into consideration public health and environmental risk. Therefore, point source discharges generally are a higher priority than nonpoint sources of clean sediment.

3) Establish and adopt TMDLs for all impaired waterbodies or for waterbodies that would be impaired if a TMDL was not established.

Three waters within the Clear Creek watershed have been listed as impaired and are on the 303(d) List (WDEQ 2010). These waters include North Piney Creek, Dalton Ditch, and Piney-Cruse Ditch. Table 3.6-2 summarizes pertinent information about these listings:

Table 3.6-2 Impaired Waters in Clear Creek Watershed

Waterbody	Class	Location	Miles/Acres	Uses	Cause(s)	List Date	TMDL Dates*
North Piney Creek	2AB	Confluence with South Piney Creek upstream to an undetermined location below SW, NW Sec 12, T52N, R84W	6.4 mi.	Recreation; use not supported	Fecal Coliform; Source unknown	2006	2015
Dalton Ditch	3B	Within and near the town of Story	0.3 mi.	Recreation; use not supported	Fecal Coliform; Source unknown	2006	2015
Piney-Cruse Ditch	3B	Within and near the town of Story	2.0 mi.	Recreation; use not supported	Fecal Coliform; Source unknown	2008	2021

These three waters were investigated and later listed in response to citizen concerns of suspected sewage contamination in surface waters and failed septic systems (WDEQ 2010). In 2005, DEQ collected *E. coli* samples in several waters in and near Story. Results showed exceedances of the *E. coli* criterion in Dalton Ditch and North Piney Creek. Thus, North Piney Creek from its confluence with South Piney Creek upstream approximately 6.4 miles, and Dalton Ditch and Piney-Cruse Ditch were added to the 303(d) List and TMDLs are expected by 2010. The high *E. coli* levels recorded in 2005 are considered a potentially significant human health concern and these waters have been posted with health risk warnings and have been prioritized for TMDL development (WDEQ 2010). Sheridan County has investigated impacts from septic systems on shallow groundwater and the possibility of linkages between potentially contaminated groundwater and surface water in the area. There are no other known sources of fecal contamination in the area (WDEQ 2010).

Several waterbodies in the watershed have been previously listed on the 303(d) list and have since been removed. A short reach of Hunter Creek in the upper watershed was previously listed in 1998 due to excessive sediment from an adjacent road. Road modifications and changes in maintenance implemented by the U.S. Forest Service has reduced this impact and the creek is now fully supporting all its aquatic life uses and is not longer on the 303(d) list (WDEQ 2010).

Rock Creek and the North and South Forks of Shell Creek were previously listed in 1996 and 2000 respectively. These watershed were threatened by physical degradation of the stream channel due to heavy grazing in a small horse pasture and irrigation diversions and conveyance.

The Lake DeSmet Conservation District has addressed these problems primarily through installation of more efficient irrigation systems and an educational workshop. Data now indicate full support of aquatic life and non-game fisheries uses in these creeks and they are no longer on the 303(d) list (WDEQ 2010).

WDEQ assessment data suggests that Little Piney Creek and Boxelder Creek support their aquatic life uses. WDEQ observed many non-game fish during the assessment of Boxelder Creek; therefore, this creek may be better classified as a non-game fishery.

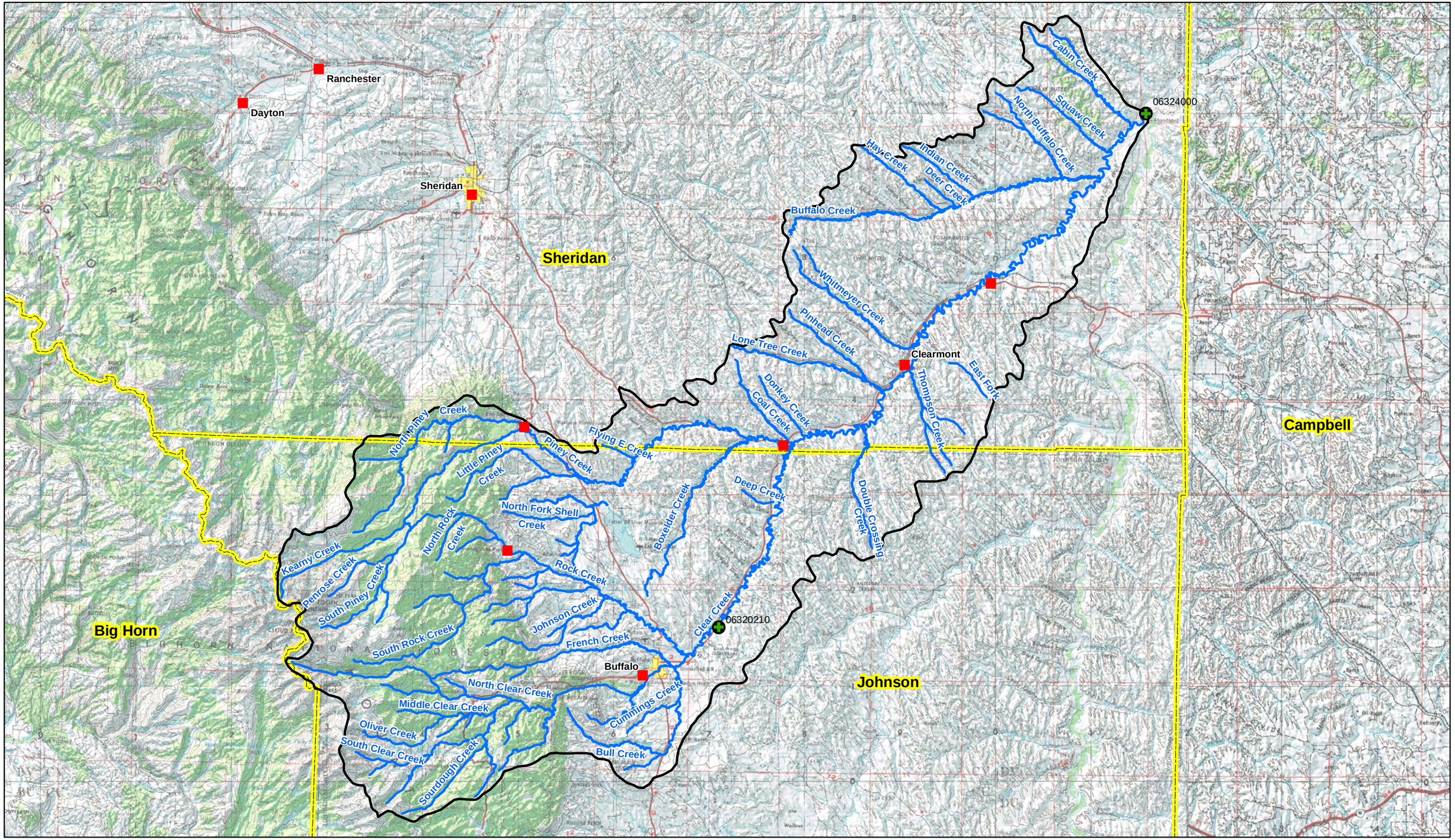
Clear Creek was monitored by QDEQ in 1999, and data indicated full support of aquatic life uses; however, WGFD records indicate that streamflow alterations may sometimes have a negative effect on cold water fishes. Several stream restoration projects on Clear Creek have improved the connection between the stream and its floodplain and improved riparian condition. The potential impacts of future CBM development in the Clear Creek drainage are currently an irrigation concern. WDEQ's CBM monitoring is designed to assess these potential impacts (WDEQ).

WDEQ monitoring in 2004 identified impacts to French Creek from flow augmentation; however, the stream is meeting its aquatic life uses. Although the creek is not currently on the 303(d) List, the Lake DeSmet Conservation District has developed a watershed plan as a proactive measure to improve water quality in this watershed (WDEQ 2010).

3.6.5 Suitability for Irrigation

Two important measures for determining irrigation water quality include the ratio of sodium ions to calcium and magnesium ions, known as the sodium absorption ration (SAR), and specific conductance (electric conductivity), a measure of major ion concentrations. Two USGS water quality monitoring stations located in the Clear Creek watershed provide long-term data, including SAR and specific conductance data (Figure 3.6-3). One station is located on Clear Creek above Kumor Draw near Buffalo (Station Number 06320210) and the second is located on Clear Creek near the confluence with Powder River (Station Number 06324000) (other USGS monitoring stations are present in Clear Creek watershed but relevant water quality data is not collected at these stations).

For the period from 2001 to 2010, 109 samples were analyzed from the monitoring station near Buffalo and 201 samples from the station near Arvada. SAR values ranged from 0.3 to 1.4, with a mean of 0.8 for the station near Buffalo. SAR values ranged from 0.3 to 2.7, with a mean of 1.2 for the station near Arvada. Specific conductance, measured in the field in unfiltered water at 25°C and reported in microsiemens per centimeter (µS/cm), ranged from 104 µS/cm to 1,150 µS/cm, with a mean of 610 µS/cm for the station near Buffalo. Specific conductance ranged from 175 µS/cm to 2,020 µS/cm, with a mean of 1,057 µS/cm for the station near Arvada. Figures 3.6-4 and 3.6-5 display this data graphically.



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- USGS_Monitoring
- Cities
- Streams
- ClearCreekWatershed
- County Boundary

Figure 3.6-3
USGS Water Quality Monitoring Stations

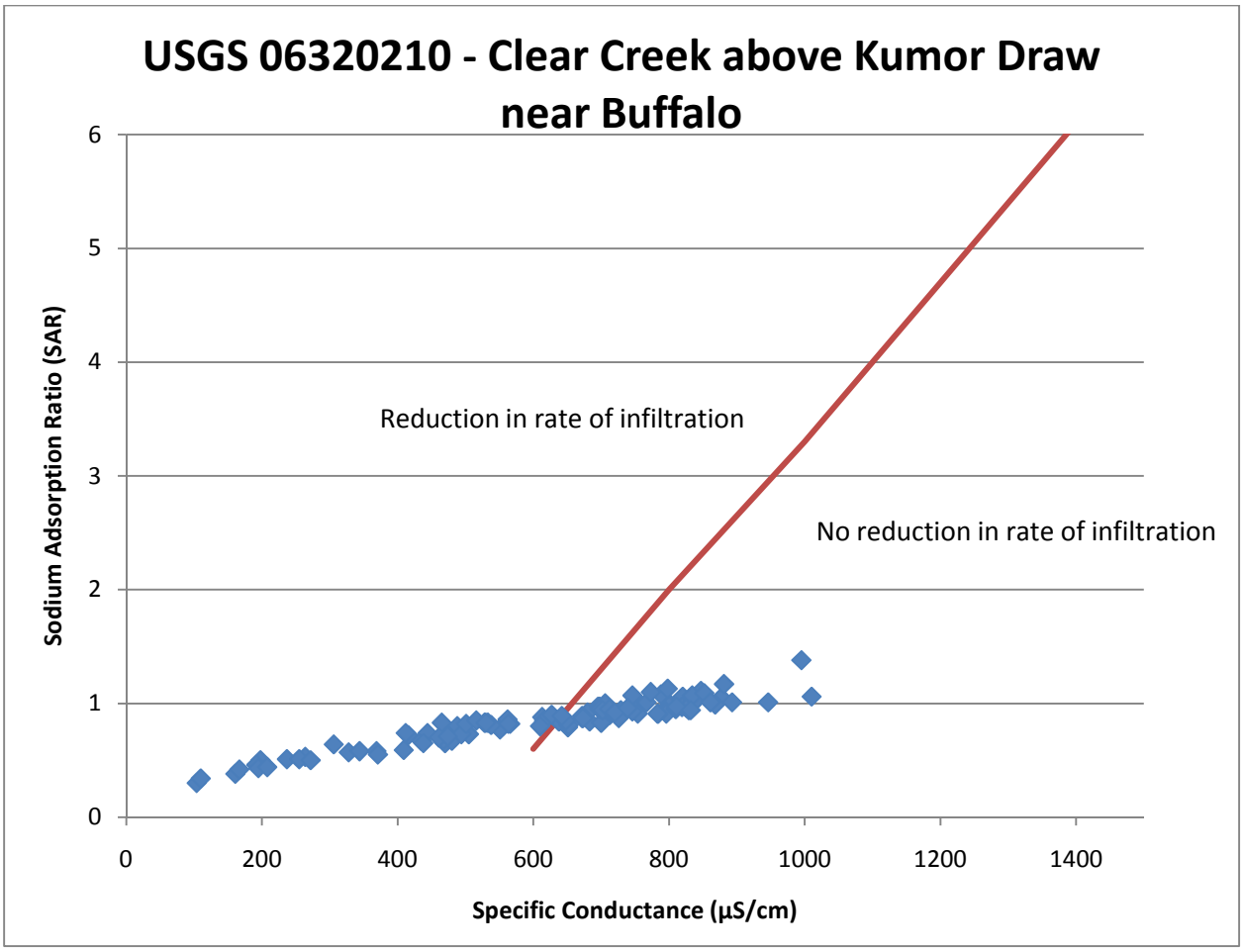


Figure 3.6-4 Relative rate of water infiltration diagram for Clear Creek station above Kumor Draw near Buffalo

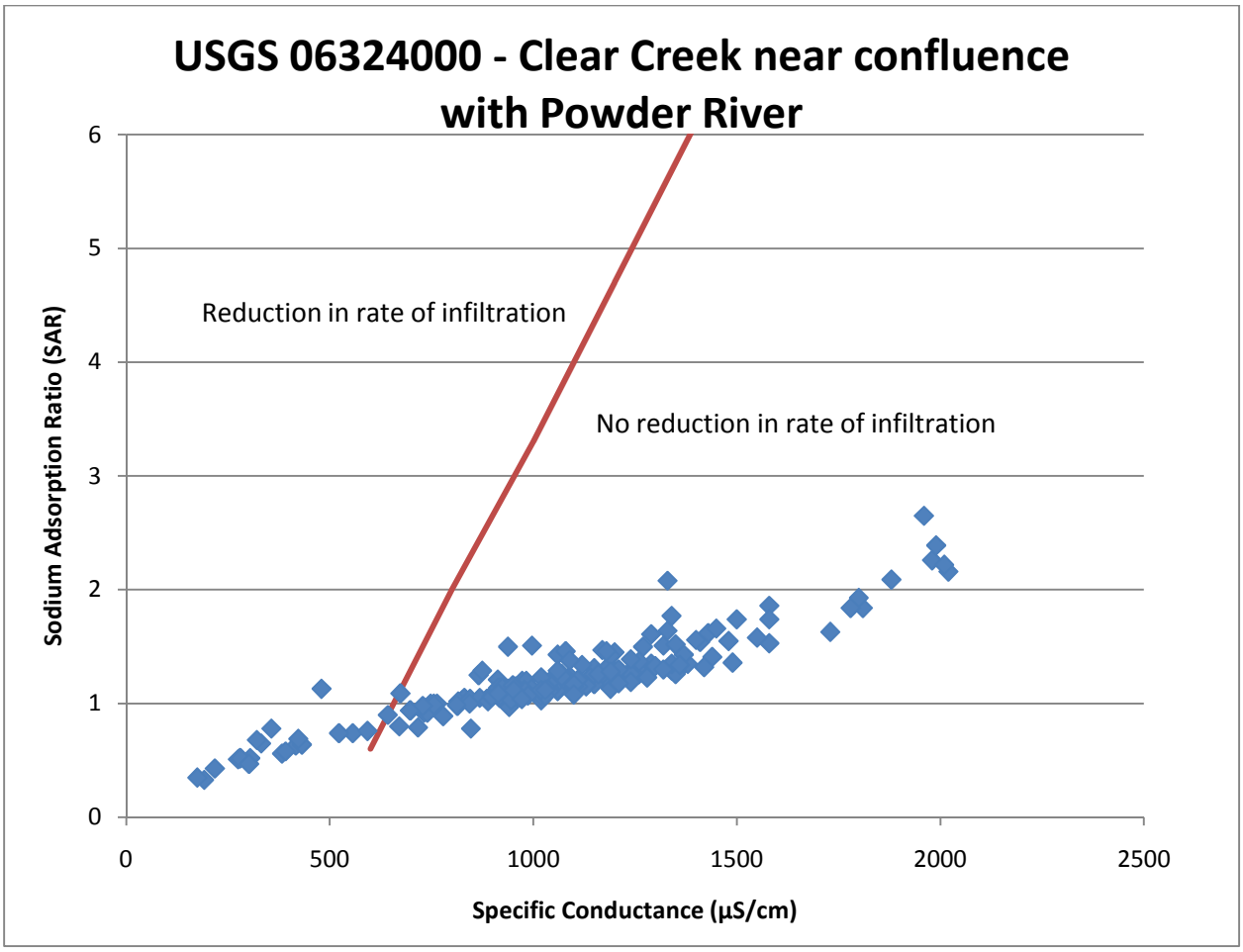


Figure 3.6-5 Relative rate of water infiltration diagram for Clear Creek station near the confluence with the Powder River

In general, the higher the SAR value, the less suitable the water is for irrigation. However, the effect of irrigation water on soil infiltration rates is dependent upon the interaction between the flocculating effects of specific conductance and the dispersion effects of sodium. Soils are able to tolerate irrigation waters that have large SAR values if the specific-conductance values also are large (Hanson et al. 1999). The following table (Table 3.6-3) presents selected guidelines for interpreting water quality for irrigation, from Ayers and Westcott (1985).

Table 3.6-3 Guidelines for Interpretations of Water Quality for Irrigation[1]

Potential Irrigation Problem				Units	Degree of Restriction on Use[4]		
					None	Slight to Moderate	Severe
Salinity*(affects crop water availability)*							
	Specific conductance[2]			µS/cm	< 700	700 – 3,000	> 3,000
Infiltration*(affects infiltration rate of water into the soil. Evaluate using specific conductance and SAR together)*[3]							
SAR	= 0 – 3	**and Specific conductance**	=		> 700	700 – 200	< 200
	= 3 – 6		=		> 1,200	1,200 – 300	< 300
	= 6 – 12		=		> 1,900	1,900 – 5,000	< 500
	= 12 – 20		=		> 2,900	2,900 – 1,300	< 1,300
	= 20 – 40		=		> 5,000	5,000 – 2,900	< 2,900

[1] Ayres and Westcott (1985); adapted from University of California Committee of Consultants 1974.
[2] Ayres and Westcott (1985) report this value as electrical conductivity (ECw), a measure of the water salinity, measured in deciSiemens per metre at 25°C (dS/m). This has been converted to specific conductance in microsiemens/centimeter, to compare to USGS data.
[3] SAR means sodium adsorption ratio. At a given SAR, infiltration rate increases as water salinity increases.
[4] The "Restriction on Use" is divided into three degree of severity: none, slight to moderate, and severe. The divisions are somewhat arbitrary since change occurs gradually and there is no clearcut breaking point. A change of 10 to 20 percent above or below a guideline value has little significance if considered in proper perspective with other factors affecting yield. Field studies, research trials and observations have led to these divisions, but management skill of the water user can alter them. Values shown are applicable under normal field conditions prevailing in most irrigated areas in the arid and semi-arid regions of the world.

Several assumptions are used in the above guidelines; the reader is referred to Ayres and Westcott (1985).

Based on just salinity, Clear Creek water near Buffalo should have no effect to a slight effect on crop water availability. The mean of 610 µS/cm is below the level of effect, and 62 of 147 samples were above 700 µS/cm, the level at which a slight to moderate restriction on use could occur. By contrast, salinity could cause slight to moderate restriction of use in lower Clear Creek near Arvada. The mean of 1,057 µS/cm from the station near Arvada indicates a moderate restriction of use and 181 of 205 samples are within the slight to moderate range. Only 24 samples indicate no use restrictions and none indicate a severe restriction on use.

When SAR and specific conductivity are considered together, providing an indication of infiltration rate into the soil, a slight to moderate restriction on use is indicated for Clear Creek water near Buffalo. At SAR values less than 3, the mean of 610 µS/cm is within the 200 – 700 µS/cm range for slight to moderate (note: 700 µS/cm is the slight end and 200 the moderate end). Clear Creek water near Arvada also has SAR values less than 3, and the mean of 1,057 µS/cm indicates no restrictions on use on average.

Overall, Clear Creek water appears to be suitable for irrigation use; although data indicates slight restrictions on use. Other factors contribute to suitability for irrigation, including soil chemistry and specific crops planted. CBM development in the Powder River basin (including the lower portion of the Clear Creek watershed) has resulted in concerns about the quality of CBM discharge water and its effect on stream water quality, including use of the water for irrigation. A number of studies have been conducted, examining various aspects of CBM discharge water and its effects (e.g., Clark and Mason 2007; Clark et al. 2001; Rice et al. 2000; Ganjegunte et al. 2005). Compared to other watersheds in the Powder River basin and other drainage basins affected by CBM production (i.e., Tongue, Cheyenne, and Belle Fourche River drainage basins), Clear Creek, as well as several waterbodies in the Tongue River drainage basin, were found to have small medians for most major ion constituents and SARs (Clark and Mason 2007). These waterbodies all have their headwaters in the Bighorn Mountains. Streams with their headwaters on the plains have large SAR and major ion concentrations. Generally, dissolved constituents in streams tend to become more concentrated as waters flow downstream and across the plains. Typical changes that occur in dissolved solids as a stream flows from the mountains to the plains were observed in samples from sites on Clear Creek. Clark and Mason (2007) report an increase in the medians observed from upstream to downstream for all major-ion constituents (except chloride and silica), sodium-adsorption ratios, and dissolved solids.

The most recent WYPDES permit for CBM in Clear Creek watershed (a renewal issued in June 2009) provides an indication of CBM discharge water quality that is released in the watershed. CBM effluent discharged by this permitted facility must meet the following limits:

Effluent Constituent	Daily Maximum, each outfall
Dissolved Iron, µg/l	1,000
pH	6.5-9.0
Specific Conductance, micromhos/cm	7,500
Chlorides, mg/l	2,000

3.7 WATERSHED HYDROLOGY

3.7.1 Groundwater

RJH reviewed the previous Powder/Tongue River Basin Plan (HKM, 2002), the Available Groundwater Determination memorandum (HKM, 2002), and the Clearmont CBM Impact Level 1 Study (Weston, 2008). We also searched published geological reports related to groundwater in the basin. We did not identify any relevant published materials from our literature search that were not previously identified. In our opinion, the information provided on the aquifers does not require updating.

There are more than 30 formations exposed on the western margin of the planning area (HKM, 2002). The formations are generally grouped into five principal aquifer systems that have historically been the major groundwater sources of interest in the planning area and are as follows in order from youngest to oldest:

1. Quaternary Alluvial
2. Fort Union/Wasatch
3. Fox Hills/Lance
4. Dakota
5. Madison

Excerpts from the Powder/Tongue River Basin Plan (HKM, 2002) that address the primary aquifers, depths, spring locations, artesian conditions, and groundwater recharge are included in Table 3.7-1

A database containing information on permitted wells within the Clear Creek watershed was obtained from the Wyoming State Engineer's Office (SEO). Information contained in the database includes permit number, priority date, facility name, applicant name, permitted uses, location, appropriation, total depth, static water level, and depth of pump. Table 3.7-2 contains well statistics based on information contained in the database. The locations of existing wells within the watershed are shown on Figure 3.7-1. Figure 3.3-6 shown previously indicates the location of USGS mapped springs in the watershed.

Table 3.7-1
Summary of Ground Water Availability/Development Potential of Major Aquifer Systems, Central and Western Flanks of the Powder River Structural Basin

Major Aquifer System	Geologic Unit	Thickness (Feet)	Lithologic Character	Hydrological Character[A,B]	General Water Quality	Availability / Development Potential[C]	Remarks
Quaternary Alluvial Aquifer System	Alluvium and Terrace Deposits	0-100+	Silt, sand and gravel; unconsolidated and interbedded; present along most streams.	Yield of 50 to 300 gpm may be possible, often through induced recharge. Terraces topographically high and often drained. Specific capacity, 0.3-7 gpm/ft; permeability, 380 and 1100 gpd/ft^2 and transmissivity, 9700 and 20300 gpd/ft from two tests in Sheridan County (Lowry and Cummings, 1966). Coarser deposits have better aquifer properties.	TDS content generally range from about 100 to >4000 mg/l. Chemical characteristics of water differ geographically. Chemical type and mineralization of the water can be expected to vary depending on underlying rock types and the nature and degree of interconnection with surface water. Alluvial deposits in the western part of the planning area generally contain water of better quality than alluvial deposits in the eastern part. Suitability for municipal / public, domestic, irrigation and stock is variable and dependent on location and above factors.	Historical source for municipal / public, domestic and stock use. Production has ranged up to 250 gpm with induced infiltration of surface water. Ground water development potential generally better in coarse-grained deposits and poorer in fine-grained materials. Moderate to high yields might be possible to optimally located and properly designed wells if induced infiltration from surface water can be tolerated in the upper reaches of Powder River, Piney, Clear and Crazy Woman Creeks. Moderate supplies may be able to be developed in thicker deposits of coarse material in the alluvuim of Prairie Dog Creek as well as the alluvium of the Tongue River and Dutch Creek. (Lowry and Cummings, 1966), (Whitcomb,	Quaternary alluvial aquifers generally in hydraulic connection with all bedrock aquifers in outcrop areas and also with surface waters. Alluvial aquifers in larger valleys provide hydraulic interconnection between otherwise hydraulically isolated bedrock aquifers (Whitcomb, 1965). Alluvial aquifers also serve as interchange point and storage for ground water in the hydrologic cycle (Davis and Rechard, 1977), (Davis, 1976). Induced recharge from surface waters is probable in areas of extensive development.
Fort Union / Wasatch Aquifer System	Wasatch Formation	500 to 2000±	Fine- to coarse-grained lenticular sandstones interbedded with shale and coal. Yields water from, lenticular sandstone and to a lesser extent from jointed coal and clinker beds (Hodson, Pearl and Druse, 1977). Divided into two conglomeratic members (Kingsbury and Moncrief Members) near the Bighorn Mountains (Lowry and Cummings, 1966).	Yields generally <15 gpm. Specific capacity of Wasatch wells and those completed in the coarse grained facies of the Wasatch Formation in Sheridan County averaged 0.33 and 1.0 gpm/ft respectivley; permeability, 6.5 gpd/ft^2 (one test - coal, Sheridan County); transmissivity, 520 gpd/ft (one test - coal, Sheridan County) and 2200 gpd/ft (one test - sandstone, Sheridan County). (Lowry and Cummings, 1966)	TDS content of waters is variable and ranges from 141 to 6620 mg/l (Larson, 1984). Sulfate and Iron content range from 0.6 - 4080 mg/l and 0 - 25 mg/l respectively and water varies from soft to very hard. Dominant cations generally are Sodium, Calcium and Magnesium, Sodium and Calcium, or Sodium and Magnesium. (Lowry and Cummings, 1966), (Whitcomb, Lowry and McCullough)	Important local source for domestic and stock water supply. Yields from fine grained facies generally small and barely adequate for stock and domestic use and generally can be expected to be < 15 gpm. Wells completed in the Kingsbury Conglomerate and Moncrief Members may have potential for higher production. Water quality generally suitable for domestic supplies although undesireable constituents may make other water sources more attractive if available. Water quality suitability for stock ranges from poor to good. Generally unsuitable for irrigation due to high salinity and sodium content.	Kingsbury Conglomerate and Moncrief Members located at the base of the mountains in Sheridan Counties.

From Powder/Tongue River Basin Plan Final Report, HKM Engineering Inc., 2002

Table 3.7-1
Summary of Ground Water Availability/Development Potential of Major Aquifer Systems, Central and Western Flanks of the Powder River Structural Basin

Major Aquifer System	Geologic Unit	Thickness (Feet)	Lithologic Character	Hydrological Character[A,B]	General Water Quality	Availability / Development Potential[C]	Remarks
Fort Union / Wasatch Aquifer System (continued)	Fort Union Formation	1200-3900	Sandstone, fine- to medium-grained, lenticular, interbedded with siltstone, coal and shale. "Clinker" associated with coal outcrops.	Flowing yields of 1-60 gpm reported where confined. Pumped yields up to 250 gpm with several hundred feet of drawdown (eastern Campbell County, east of planning area). Specific capacity for 85 wells in Sheridan County averaged 0.42 gpm/ft; permeability (2.5 and 7.9 gpd/ft^2), transmissivity (10 and 95 gpd/ft), and Storage coefficient (9.0 X 10^{-5} and 3.5 X 10^{-4}) for tests performed on two wells in Sheridan County (Lowry and Cummings, 1966). Coal and clinker generally better aquifer properties than sandstones. Locally clinker transmissivity up to 3,000,000 gpd/ft; Anisotropy and leaky confining layers are common.	TDS content of waters is variable and ranges from 484 - 4630 mg/l (Larson, 1984). Sulfate and Iron content range from 0.3 - 1870 mg/l and 0.06 - 19 mg/l respectively. Water varies from soft to very hard and is generally a Sodium Bicarbonate type. (Lowry and Cummings, 1966), (Whitcomb, Cummings and McCullough, 1966) Water co-produced with coal bed methane is predominantly Sodium Bicarbonate type with TDS content and SAR (15 samples), of 540 - 2010 mg/l (mean of 1309 mg/l) and 7.7 - 32 (mean of 19.82) respectively in planning area. (Rice, Ellis & Bullock, 2000). BLM Wyodak EIS assumed average TDS concentration of 764 mg/l (USDI,BLM, 1999).	Important, extensively used relatively shallow (< 1000 feet depth) local source for domestic and stock supply. Low yields, generally less than 25 gpm can be expected. Four of the 12 municipal / public supply wells in service for the City of Gillette (east of planning area) as of 1994 had been tested at pumping rates ranging from 50 to 130 gpm (Wester -Wetstein and Associates, Inc., 1994).	Total of 6820 Coal Bed Methane wells permitted with WSEO in planning area as of 12/31/00. Maximum, minimum and mean depths and range of actual yields listed on permits were 92 -4100 (mean 637) feet below ground surface (bgs), and 1 - 60 (mean 49) gpm respectively. Range of depths to main water bearing zone listed on WSEO Permits were 58 - 3816 (mean 580) feet bgs. BLM Exxon Pistol Point EA assumed average water production for each CBM well to average between 30 and 45 gpm (USDI,BLM, 1992). BLM Lower Prairie Dog Creek EA assumed average water production for each CBM well to be 15 gpm (USDI,BLM, 1999). BLM Wyodak EIS assumed average expected water production to be 12 gpm over the estimated 12 year life of each CBM well (USDI,BLM, 1999). BLM Wyodak Drainage EA assumed average water production for each CBM well to be 11.1 gpm.
Fox Hills/Lance Aquifer System	Lance Formation	600-1900 (North) 1950-3000 (South)	Sandstone, fine- to medium-grained, lenticular, interbedded with sandy siltstone, claystone and shale.	Generally yields less than 15 gpm with specific capacities, 0.03-.16 gpm/ft in planning area. Limited development due to uneconomical drilling depths. In eastern area of Powder River Structural Basin (PRSB), yields up to 350 gpm but with large drawdowns and long well completion intervals; permeability 34 gpd/ft^2; transmissivity, 76-2100 gpd/ft for wells also completed in Fox Hills Sandstone.	TDS content in waters generally range from <500 - 3060 mg/l. Composition variable, mainly Sodium Sulfate or Calcium Sulfate. Variable iron (0 - 6.03 mg/l) and Sulfate (<100 - 1780 mg/l) content, SAR 1.9 - 39. Generally undesireable for domestic water source due to possible high Iron, Manganese and Sulfate content. Generally fair to poor for stock use. Unsuitable for irrigation due to high salinity and / or high SAR.	Historical source for domestic and stock supply. Generally yields less than 15 gpm in planning area. Development limited due to uneconomical drilling depths. Water quality generally suitable for domestic supplies although undesireable constituents may make other water sources more attractive if available. Water quality suitability for stock ranges from poor to good. Generally unsuitable for irrigation due to high salinity and / or Sodium content.	

Table 3.7-1
Summary of Ground Water Availability/Development Potential of Major Aquifer Systems, Central and Western Flanks of the Powder River Structural Basin

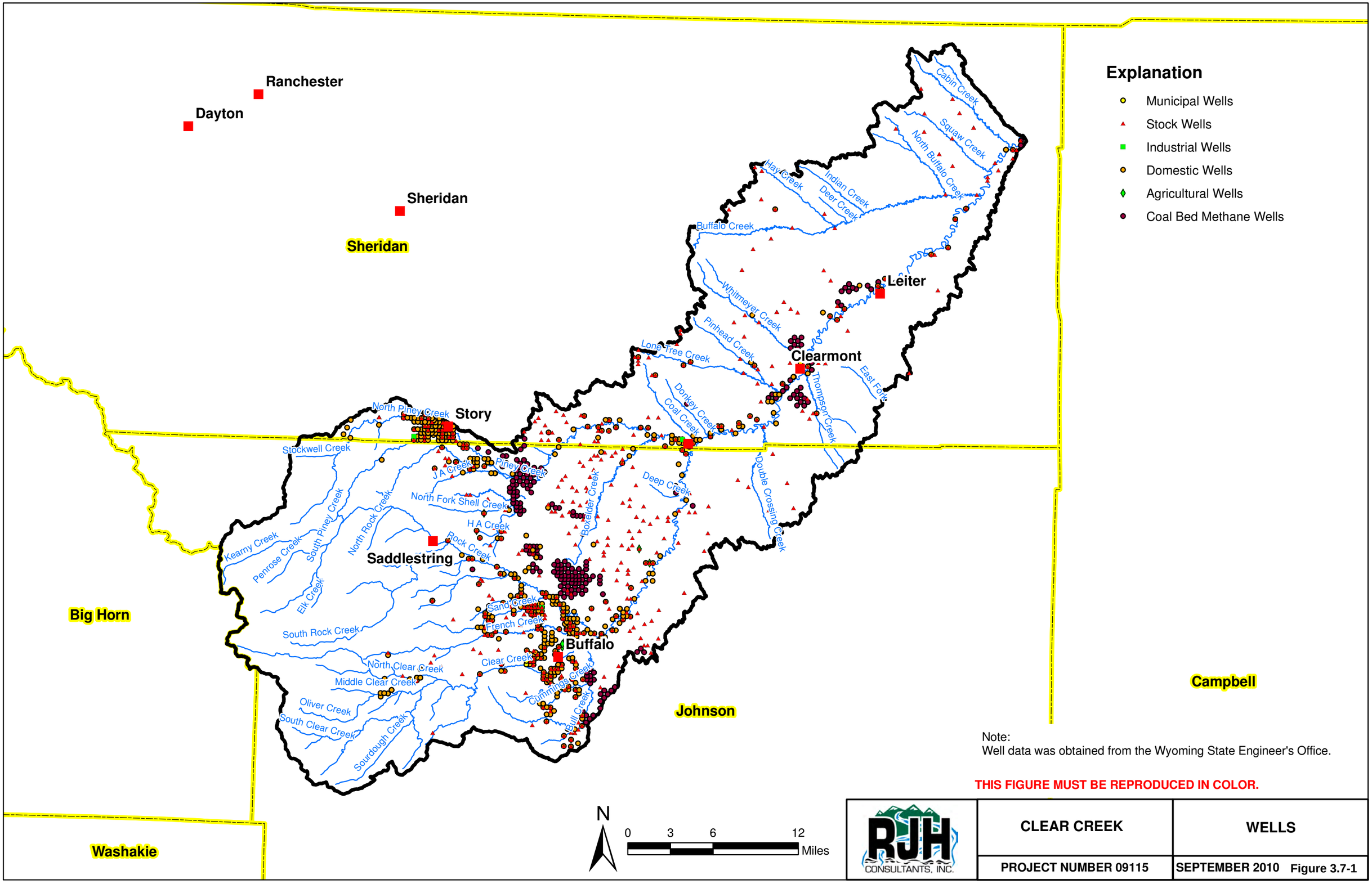
Major Aquifer System	Geologic Unit	Thickness (Feet)	Lithologic Character	Hydrological Character[A,B]	General Water Quality	Availability / Development Potential[C]	Remarks
Fox Hills/Lance Aquifer System (continued)	Fox Hills Sandstone	0-700	Sandstone, fine-to medium-grained, interbedded with shale and siltstone.	Generally yields less than 15 gpm with specific capacities, 0.03-.37 gpm/ft in planning area. Transmissivity, 76-1600 gpd/ft for wells also completed in Lance Formation. Limited development due to uneconomical drilling depths.	Similar to Lance Formation. Water suitable for domestic use usually present only near outcrop. Water suitable for stock use generally found at depths of up to 1000 feet, away from outrop. The quality of water may be unsatisfactory for domestic and stock use where the the aquifer is is deeper than 1000 feet. (Crest and Lowry, 1972)	Historical source for municipal / public, domestic and stock supply. Generally yields less than 15 gpm in planning area. No more than 50 gpm can be expected from wells completed in wells in the planning area (Natrona County). Well for Town of Edgerton produced 25 gpm with a specific capacity of 0.037 gpm/ft. (Crist and Lowry, 1972) Development limited due to uneconomical drilling depths. Tested yields of Gillette municipal / public supply wells (east of planning area) have ranged from 85 to 705 gpm (Wester-Wetstein and Associates, Inc.,	High Fluoride content may be of concern in eastern part of planning area. Has been used as municipal / public water supply source for Town of Edgerton. Has been used for oil well water flooding operations in eastern PRSB.
Dakota Aquifer System	Muddy Sandstone (NewCastle Sandstone)	0-40±	Light gray, fine-grained, lenticular sandstone and siltstone often termed a member of Thermopolis shale.	Minor unit of Dakota Aquifer System. Oil field data (PRSB): porosity, 5-20%; permeability, <7 gpd/ft^2 ; transmissivity, <150 gpd/ft.	No data in planning area.	No data in planning area. Ground water possibilities in planning area generally not known. Probably capable of yielding small quantities of no more than 10 gpm water to wells. Deep drilling depths would probably preclude consideration other than at outcrops. Dakota Aquifer System historical source for domestic and stock use in eastern PRSB.	
	Cloverly Formation	140-150	Interbedded dark shale and brown siltstone with 15-45 feet of basal, fine - to coarse-grained well sorted sandstone.	Flowing yields of 1-40 gpm, up to 250 gpm reported for pumped wells (south of planning area); specific capacity, 0.12-.2 gpm/ft. Oil field data: porosity, 15-18%; permeability, 0.4-4 gpd/ft^2; transmissivity, 7-230 gpd/ft.	Water from Cloverly and Morrison Formations in Natrona County predominantly Sodium Bicarbonate type. Other types include Calcium Bicarbonate, Calcium Sulfate, Sodium Sulfate, and Calcium Sulfate. TDS content range between 300 and 3000 mg/l.	Generally deeply buried in planning area except at outcrops. Yields small supplies to springs at outcrops. Well yields of 5 to 20 gpm may be expected. Yields of greater than 100 gpm may be possible from complete section of rocks.	
Madison Aquifer System	Tensleep Sandstone	50-250 (Northwestern Basin) <500 (Southwestern Basin)	Fine- to medium-grained, massive, crossbedded sandstone with occasional thin dolomite beds.	Unit of Madison Aquifer System. Flowing yields up to 400 gpm; Specific capacity, 1 gpm/ft. Oil field data: porosity, 0-24%; permeability, 0-21 gpd/ft^2; transmissivity, 0-1900 gpd/ft.	Water type is variable (Magnesium Carbonate, Calcium Magnesium Sulfate, Sodium Sulfate,Calcium Sodium Sulfate, Calcium Sulfate) and concentration of TDS varies directly to distance from the outcrop and generally ranges from<300 -3240 mg/l. Generally very hard but suitable for domestic, stock and irrigation use at or near outcrop. (Crist and Lowry, 1972), (Whitcomb, Cummings and McCullough, 1966) TDS content 204 - 2930 mg/l in six samples in Natrona County (Larson, 1984).	Sandstone generally well cemented, but primary permeability is sufficient at most locations to permit yields of 50 gpm to wells. There is potential for higher yields where secondary permeability is high. Yield of 600 gpm reported for an irrigation well at the foot of the Bighorn Mountains in Johnson County . Development may be limited economically due to deep drilling depths in Johnson County in outcrop area or in narrow belt generally less than about one mile paralleling the east margin of the outcrop. (Whitcomb, Lowry, and (McCullough 1966), (Crist and Lowry,	

Table 3.7-1
Summary of Ground Water Availability/Development Potential of Major Aquifer Systems, Central and Western Flanks of the Powder River Structural Basin

Major Aquifer System	Geologic Unit	Thickness (Feet)	Lithologic Character	Hydrological Character[A,B]	General Water Quality	Availability / Development Potential[C]	Remarks
Madison Aquifer System (continued)	Amsden Formation	150-300 (Northwestern Basin) 0-200 (Southwestern Basin)	Red and purple shale with some sandstone, cherty dolomite and limestone.	Aquitard unless fractured.		Generally deeply buried in planning area except at outcrops. Ground water possibility generally not known.	
	Madison Limestone	1100± (Northwestern Basin) 200-400 (Southwestern Basin)	Limestone, dolomitic limestone and dolomite, sandy at base.	Principal unit of Madison Aquifer System. Flowing yields over 4000 gpm but highly variable; specific capacity. <1 to 50 but is flow-dependent; transmissivity, 500-90,000 gpd/ft or higher and highly variable.	Waters at Outcrop (TDS < 600mg/l, predominantly Calcium Magnesium Bicarbonate type water). TDS increase basinward to > 3,000 mg/l, Sodium Sufate Chloride predominating. Fluoride enrichment characteristic of Madison System waters throughout the PRSB basin. Concentrations of radionuclides could be of concern in some areas.	Probably most important high yield aquifer in Wyoming. Historical source for municipal / public water supply, industrial, irrigation and stock use in PRSB. Several fish hatcheries use Pahasapa / Madison aquifer as water source in northeastern part of PRSB. Yields variable geographically and dependent on secondary permeability. Drilling depths may inhibit development.	Total estimated recharge to the Madison Limestone in the PRSB in 1973 was about 75,000 acre feet/year. (WSEO, 1976)
	Bighorn Dolomite	400-500 (Northwestern Basin) absent (Southwestern Basin)	Massive dolomite, becoming thin-bedded at top and sandy at base.	Generally deeply buried except in outcrop areas. Ground water possibilities generally not known.		Ground water possibilities generally not known. Probably would yield water to wells depending on secondary permeability.	
	Flathead Sandstone	345± (Northwestern Basin) 90 (Southwestern Basin)	Tan to reddish sandstone, locally conglomeratic, interbedded with green shale and siltstone.	Minor unit of Madison Aquifer System. Not exploited due to deep burial but a few wells yield water near outcrops.		Ground water possibilities generally not known. Probably would yield water to wells depending on secondary permeability. Generally deeply buried except in outcrop areas. Yields small quantities of water to springs from sandstone and conglomerate in the Bighorn Mountains. (McCullough 1966), (Crist and Lowry, 1972)	

[A]Reported yields may reflect development needs rather than aquifer capability; higher yields can sometimes be expected, with corresponding drawdown increases. Reported water well transmissivities or permeabilities may be for wells completed in two aqu
[B]Oilfield (and USGS test) data are variously derived resulting in internal inconsistencies in this compilation. Permeabilities are measured on cores or derived from other data and transmissivities are from drill stem tests or calculated from permeabilit
[C]Actual development potential will require site specific office and field investigations to define aquifer capability and constraints unique to each project and site.

Taken from: Feathers, Libra, Stephenson and Eisen, 1981, *Occurance and Characteristics of Groundwater in the Powder River Basin, Wyoming*



Note:
Well data was obtained from the Wyoming State Engineer's Office.

THIS FIGURE MUST BE REPRODUCED IN COLOR.

RJH CONSULTANTS, INC.	CLEAR CREEK	WELLS
	PROJECT NUMBER 09115	SEPTEMBER 2010 Figure 3.7-1

Table 3.7-2 Well Statistics

Appropriation (GPM)	# of wells
0 to 5	441
6 to 10	767
11 to 25	1630
26 to 50	435
51 to 100	112
101 to 200	15
201 to 500	2
501 to 1000	2
No data	367

Priority Date	# of wells
1950's	19
1960's	92
1970's	489
1980's	431
1990's	753
2000's	1940
2010's	47

Total Depth (ft)	# of wells
0 to 50	630
51 to 100	359
101 to 200	629
201 to 400	507
401 to 600	108
601 to 800	68
801 to 1000	42
1001 to 1500	101
1501 to 2000	49
2001 to 3000	47
3001 to 4000	16
No data	1215

Use	# of wells
Stock	1202
Irrigation	30
Domestic	1746
Industrial	6
Municipal	5
Monitoring Well	257
CBM	1103

3.7.2 Surface Water

The Clear Creek watershed is a subbasin of the Powder River basin. The Clear Creek watershed encompasses approximately 1,154 square miles. Elevations within the watershed range from less than 3,500 feet at the confluence of Clear Creek with the Powder River, to over 13,000 feet at peaks within the Bighorn Mountains, resulting in overall relief of more than 9,500 feet.

Figure 3.7-2 shows the delineation of subbasins within the Clear Creek watershed. The subbasins represent the HUC 12 (hydrologic unit code) watersheds. The HUCs were delineated by the USGS using digital elevation models. As the HUC number increases, the subbasins get smaller. HUC 12 watersheds are subbasins of HUC 10 watersheds, which are subbasins of HUC 8 watersheds and so forth. Characteristics of the HUC 12 basins, including subbasin names and areas, are shown on Figure 3.7-2.

Streamflows in the mountainous western portions of the study area are generally perennial. Perennial streams have flow year round. These streams are fed by snowmelt runoff in the spring and early summer. Summer, fall and winter flows are fed by baseflow, bank storage, precipitation, and springs. The stream reaches and tributaries in the lower elevation,

Basin Number	HUC_12	Acres	Basin Name
1	100902060507	31036	Cabin Creek
2	100902060506	40936	Lower Buffalo Creek
3	100902060505	28539	Upper Buffalo Creek
4	100902060504	34365	Scott Draw
5	100902060503	24644	Dead Mans Draw
6	100902060502	39063	Whitmeyer Creek
7	100902060501	40839	Lone Tree Creek
8	100902060403	37986	Lower Piney Creek
9	100902060405	28302	Donkey Creek
10	100902060303	25203	North Piney Creek
11	100902060406	23250	Double Crossing Creek
12	100902060304	20040	Upper Piney Creek
13	100902060302	24946	Kearny Creek
14	100902060404	29505	Boxelder Creek
15	100902060402	23490	Cook Draw
16	100902060305	26271	North Prong Shell Creek
17	100902060201	40055	North Rock Creek
18	100902060401	33644	Healy Creek
19	100902060301	21718	South Piney Creek
20	100902060202	37848	Rock Creek
21	100902060106	16911	French Creek
22	100902060103	21001	Seven Brothers Creek
23	100902060105	14637	Sand Creek
24	100902060107	20256	Bull Creek
25	100902060104	12923	Grommund Creek
26	100902060102	14154	Middle Clear Creek
27	100902060101	27033	South Clear Creek

Gage ID	USGS_NUMBER	NAME
A	06321500	North Piney Creek Near Story, WY
B	06319480	South Rock Creek Above Red Canyon, Near Buffalo, WY
C	06319470	South Rock Creek at Forest Boundary, Near Buffalo, WY
D	06317340	Little Sourdough Creek Near Buffalo, WY
E	06317300	Sourdough Creek Near Buffalo, WY
F	NOAA GAGE	Clear Creek in Buffalo City Park, Buffalo, WY
G	06318500	Clear Creek Near Buffalo, WY
H	06320000	Rock Creek Near Buffalo, WY
I	06320200	Clear Creek Below Rock Creek Near Buffalo, WY
J	06321000	South Piney Creek Near Story, WY
K	06323000	Piney Creek at Kearney, WY
L	06324000	Clear Creek Near Arvada, WY
M	06323500	Piney Creek at Ucross, WY
N	SEO GAGE	Rock Creek at Mouth Near Buffalo, WY
O	SEO GAGE	Piney Creek Below Lake DeSmet Tunnel Intake Near Story, WY
P	SEO GAGE	Clear Creek at Double Crossing Near Clearmont, WY
Q	SEO GAGE	Clear Creek Below Healy Reservoir Near Buffalo, WY
R	SEO GAGE	Clear Creek Below P&F No. 3 Ditch Near Clearmont, WY
S	SEO GAGE	Little Piney Creek, WY
T	06320500	South Piney Creek at Willow Park Reservoir, WY
U	06317500	North Clear Creek, WY
V	NOAA GAGE	Clear Creek at Mosier Gulch, WY
W	SEO GAGE	South Piney Creek Above Willow Park Reservoir, WY

Gage ID	Name
AA	North Fork Clear Creek
BB	Upper French Creek
CC	Middle Fork Clear Creek
DD	Lower Rock Creek
EE	Lower French Creek

N W E S

0 5 10

Miles

Legend

- Temporary Stream Gages
- Stream Gages
- Cities
- Clear Creek Subbasin
- Streams
- County

Figure 3.7-2
Hydrologic Units and Stream Flow Gages

northeastern portions of the study area range from intermittent to ephemeral streams. Ephemeral streams are defined as those streams/reaches that flow only in response to direct precipitation events, and where any groundwater inflows are insufficient to sustain streamflow due to losses from evaporation, transpiration, and seepage. Intermittent streams are defined as seasonal streams that only flow for part of the year. Annual runoff is typically low with intermittent and ephemeral streams.

3.7.2.1 Streamflow Gaging Stations

Figure 3.7-2 shows the location of all historic and currently operated stream gauges in the watershed. Table 3.7-3 and Figure 3.7-3 contain information about each gauge station including period of record, drainage area, elevation and whether or not the flow hydrograph is considered natural. Stream gauge stations are considered natural flow stations if the upstream drainage area and streamflow timing and volume are not altered by the influence of man. For example, a stream gauge station is considered natural if there are no stream diversions, transfers, or storage reservoirs upstream of the station. Currently, the USGS operates four realtime stream gauge stations in the watershed (Clear Creek near Arvada, Piney Creek at Kearny, South Piney Creek at Willow Park Reservoir, and Rock Creek near Buffalo). The NOAA National Weather Service and the Wyoming State Engineer's Office now cooperatively operate two realtime stream gauges on Clear Creek. One is located in Buffalo City Park and the other is located upstream near Mosier Gulch. The Wyoming State Engineer's Office operates the Clear Creek below Healy Reservoir and Clear Creek below Rock Creek stream gauges and is currently installing a stream gauge on French Creek at the Forest Service boundary. Realtime streamflow data is available at the following websites:
http://wy.water.usgs.gov/
http://water.weather.gov/ahps2/index.php?wfo=riw

Table 3.7-3 Stream Gage Stations

Agency	Site Number	Site Name	Period of Record	Drainage Area (sq mi)	Gauge Elevation	Natural Flow
USGS	6317300	SOURDOUGH CREEK NEAR BUFFALO, WY	1/1/1985 to 9/30/1990	5.2	7980	Yes
USGS	6317340	LITTLE SOURDOUGH CREEK NEAR BUFFALO, WY	1/1/1985 to 9/30/1988	4.53	7750	Yes
USGS	6317500	NORTH FORK CLEAR CREEK NEAR BUFFALO, WY	10/1/1949 to 9/30/1968	29	6950	No
USGS	6318500	CLEAR CREEK NEAR BUFFALO, WY	7/1/1917 to 1928, 1938 to 9/30/1992	120	5185	No
USGS	6319470	S ROCK CK AT FOREST BOUNDARY NEAR BUFFALO, WY	11/1/1974 to 9/30/1976	40.3		Yes
USGS	6319480	S ROCK CK ABOVE RED CANYON CK NEAR BUFFALO, WY	11/1/1974 to 9/30/1976	40.5		Yes
USGS	6319500	SOUTH FORK ROCK CREEK NEAR BUFFALO, WY	10/1/1950 to 12/31/1953	43.8	5310	No
USGS	6320000	ROCK CREEK NEAR BUFFALO, WY	4/1/1945 to present	60	5280	No
USGS	6320200	CLEAR CK BELOW ROCK CK NEAR BUFFALO WY	USGS: 10/1/1975 to 10/1/1981; SEO: 1971 to 1975, 1982 to 1985, 1987 to present	322		No
USGS	6320400	CLEAR CREEK AT UCROSS, WY	6/1/1976 to 10/1/1981	409	4070	No
USGS	6320500	SOUTH PINEY CREEK AT WILLOW PARK RESERVOIR, WY	7/1/1947 to present	33.6	8540	No
USGS	6321000	SOUTH PINEY CREEK NEAR STORY, WY	6/1/1951 to 9/30/1980	69.4	5590	No
USGS	6321020	MEAD-COFFEEN DITCH ABOVE FISH HATCHERY NR STORY WY	11/1/1974 to 6/6/1979			No
USGS	6321040	MEAD-COFFEEN DITCH BELOW FISH HATCHERY NR STORY WY	11/1/1974 to 6/6/1979			No
USGS	6321100	S PINEY CK BELOW MEAD-COFFEEN DITCH NR STORY WY	11/1/1974 to 7/31/1979	69.5		No
USGS	6321500	NORTH PINEY CREEK NEAR STORY, WY	10/1/1951 to 9/30/1982	36.8	5290	Yes
USGS	6321800	SPRING CK NEAR STORY WY	11/1/1974 to 5/31/1979			No
USGS	6323000	PINEY CREEK AT KEARNY, WY	1902 to 1906, 1910 to 1917, 1919 to 1923, 1941 to present	118	4655	No
USGS	6323500	PINEY CREEK AT UCROSS, WY	USGS: 1917 to 1923, 1980 to 1982, SEO: 1983 to 1987, 1989 to 1998	267	4067	No
USGS	6324000	CLEAR CREEK NEAR ARVADA, WY	1915 to 1919, 1928 to 1929, 1940 to 1982, 2003 to present	1110	3507	No

Agency	Site Number	Site Name	Period of Record	Drainage Area (sq mi)	Gauge Elevation	Natural Flow
SEO		ROCK CREEK AT MOUTH NEAR BUFFALO, WY	WRDS: 1971 to 1975, 1977 to 1978; SEO: 1980 to 1981, 1983, 1985 to 1988, 1990 to 2000	122	4495	No
SEO		S PINEY CK ABOVE WILLOW PARK RESERVOIR, WY	1972 to present		8640	No
SEO		PINEY CREEK BELOW LAKE DESMET TUNNEL INTAKE NEAR STORY, WY	WRDS: 1971 to 1973, 1977, 1979; SEO: 1980 to 1984, 1986 to present			No
SEO		CLEAR CREEK AT DOUBLE CROSSING NEAR CLEARMONT, WY	WRDS: 1973 to 1978, SEO: 1980 to 1996, 1998 to present			No
SEO		CLEAR CREEK BELOW HEALY RESERVOIR NEAR BUFFALO, WY	1971 to present			No
SEO		CLEAR CREEK BELOW P&F No. 3 DITCH NEAR CLEARMONT, WY	WRDS: 1978; SEO: 1980 to 2003			No
SEO		LITTLE PINEY CREEK, WY	SEO: 1981, 1983, 1985 to 1986, 1988, 1991 to 1999			No
SEO		FRENCH CREEK AT FOREST BOUNDARY	Installed Winter 2010	11.9	6040	No
NOAA	BCCW4	CLEAR CREEK AT BUFFALO	WRDS: 1971 to 1978; SEO 1987 to 1999; NOAA 1999 to present		4650	No
NOAA	MGHW4	CLEAR CREEK AT MOSIER GULCH	2007 to present		5730	No

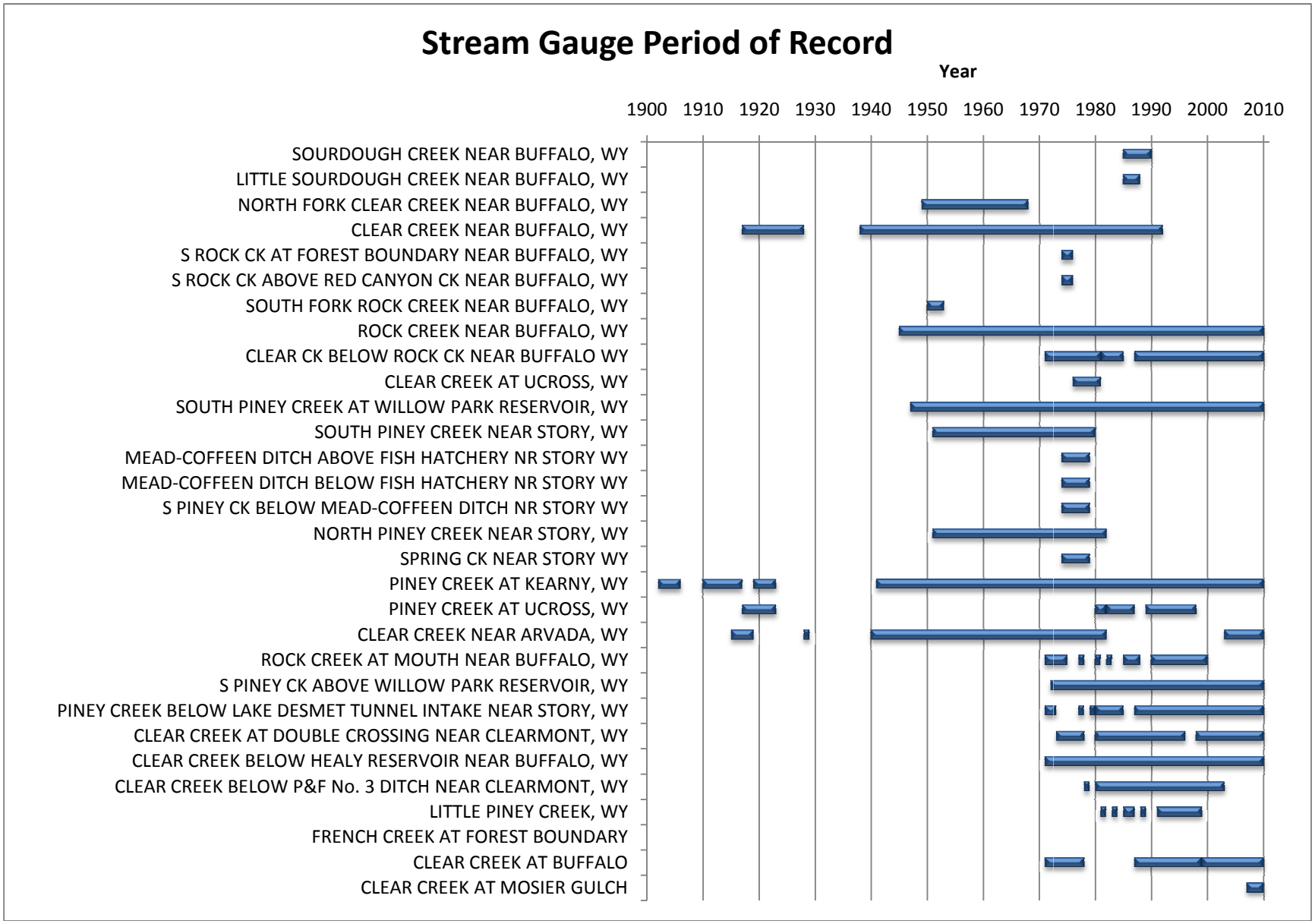


Figure 3.7-3 Stream Gage Period of Record

Table 3.7-4 and Figure 3.7-4 contain average monthly streamflow data for four long term stream gauges in the watershed. This data generally depicts the streamflow timing and relative volume of the three major streams in the watershed (Piney, Clear, and Rock Creek). The streamflow hydrographs peak in May and June which reflects typical spring snowmelt runoff patterns. Streamflows decrease significantly late summer through fall as the streams return to winter baseflow conditions.

Table 3.7-4 Average Monthly Streamflow

Average Monthly Stream Flow													
USGS Gauge	Period of Record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
CLEAR CREEK NEAR BUFFALO, WY	7/1/1917 to 1928, 1938 to 9/30/1992	8.3	7.2	9.4	35	169	258	119	48	33	28	18	12
ROCK CREEK NEAR BUFFALO, WY	4/1/1945 to 2009	4.6	4.4	4.8	15	100	142	60	40	21	9.2	7.1	5.6
PINEY CREEK AT KEARNY, WY	1902 to 1906, 1910 to 1917, 1919 to 1923, 1941 to 2009	27	26	31	70	271	362	93	29	25	30	36	31
CLEAR CREEK NEAR ARVADA, WY	1915 to 1919, 1928 to 1929, 1940 to 1982, 2003 to 2009	71	81	151	170	432	674	186	62	77	95	102	84

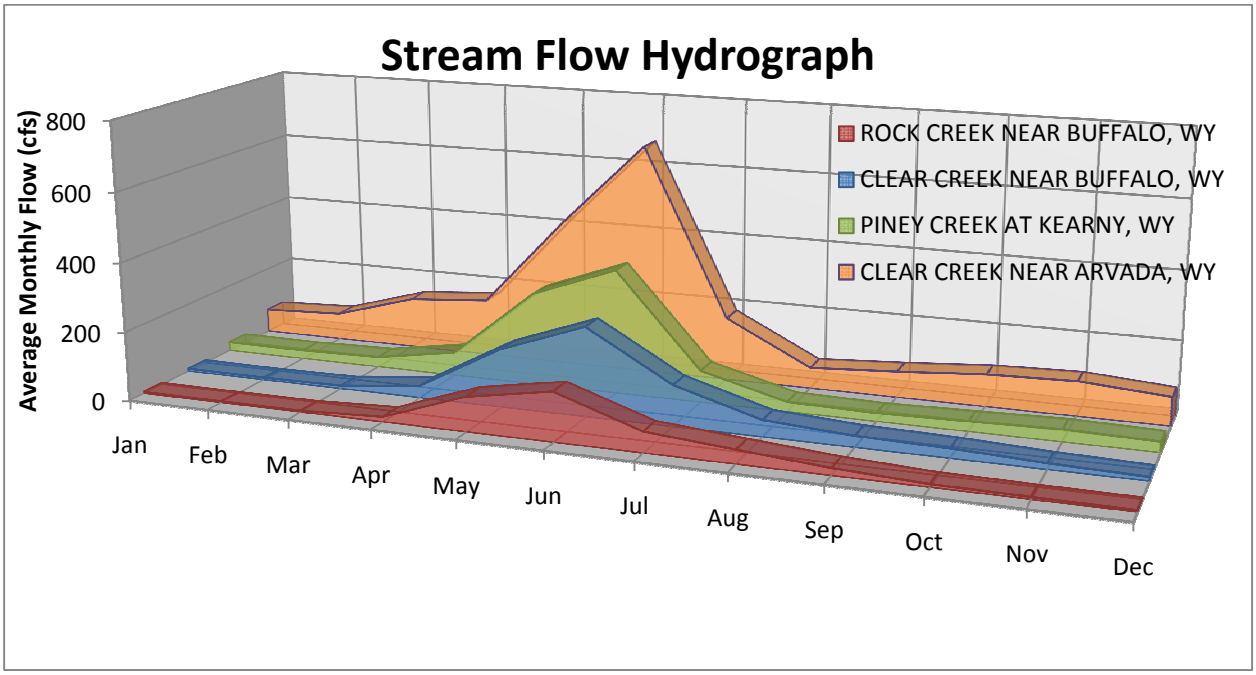


Figure 3.7-4 Average Streamflow Hydrographs

3.7.2.2 Temporary Stream Gaging Stations

During the initiation of this study, a hydrologic model for tributaries in the Clear Creek watershed seemed to be unrealistic. The lack of streamflow data induced uncertainty into the existing hydrologic models and water availability analysis.

In order to relieve some of this uncertainty, the project team sited five temporary stream gaging locations based upon watershed hydrology, stream gage coverage, stream gage period of record, and potential reservoir sites. Figure 3.7-2 depicts the location of the temporary

stream gages installed as part of this project. The stream gages were placed within the watershed at the following locations:

- Middle Fork Clear Creek
- North Fork Clear Creek
- Upper French Creek at Forest Boundary
- Lower French Creek at mouth, and
- Lower Rock Creek at mouth

With the addition of these temporary stream gages, some of the hydrologic uncertainty concerns may be alleviated. The project team has correlated the data collected from these temporary stream gages with previously established gaging stations. By doing so, more accurate estimates of basin and reservoir yield can be developed.

Prior to the temporary stream gage installations, the project team received the appropriate clearances from landowners and the United States Forest Service. Each of the five temporary stream gages consists of a water level sensing pressure transducer and data collector. For the purpose of this study, Global Water, Inc. WL16 water level loggers were used for this task. These units were set to take recordings at 15 minute intervals. Gauging stations were sited in stream reaches that had straight, non-braided channels, sections with well-defined, steep banks that will contain a reasonably high flow, and a stable stream bed.

Each of the pressure transducers and data collectors were properly calibrated prior to their installation in the gaged section. In order to develop accurate flow estimates, flow measurements were taken at the gaged section at varying flow rates to develop rating curves, which relate water depth to flow rate for the gaged sections. Copies of the data collected in developing the rating curves for each of the temporary stream gages have been included within Appendix 3J.

The rating curves developed at each site were utilized to determine the flow rates based upon water level data collected by the pressure transducer and data collector. The project team periodically visited these temporary stream gage locations to download data stored in the device, replace batteries in the units, and check the operation of the temporary stream gages. The pressure transducers and data collector were removed during the winter months in order to avoid potential damage caused by shelf-ice. Information pertaining to the data recorded by the data loggers is available electronically.

Middle Fork Clear Creek

Data was collected at this temporary gaging site between April 23rd, 2010 and October 28th, 2010. During the period of record, this tributary contributed 11,470 ac-ft to Clear Creek. Figure 3.7-5 shown below displays the fluctuations in flow rate seen at this gaging site as well as the estimated cumulative volume which passed by the gage from April 23, 2010 through October 28th, 2010.

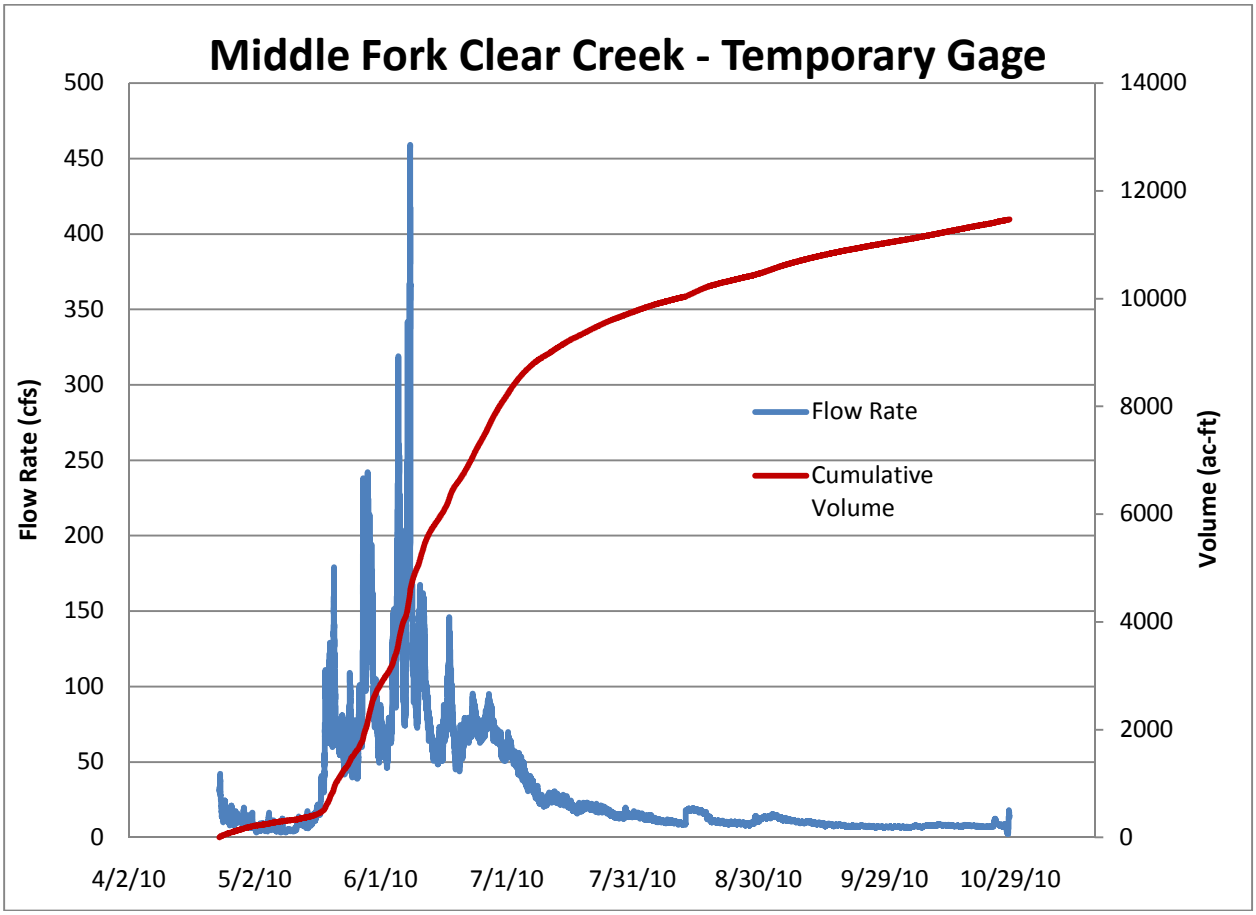


Figure 3.7-5 – Middle Fork Clear Creek Temporary Stream Gaging Results

North Fork Clear Creek

Data was collected at this temporary gaging site between April 22nd, 2010 and November 8th, 2010. During the period of record, this tributary contributed 12,230 ac-ft to Clear Creek. Figure 3.7-6 shown below displays the fluctuations in flow rate seen at this gaging site as well as the estimated cumulative volume which passed by the gage from April 22, 2010 through November 8th, 2010. The sudden decrease in flow shown on June 11th, 2010 is likely due to the trans-basin diversion from the North Fork of Clear Creek to French Creek.

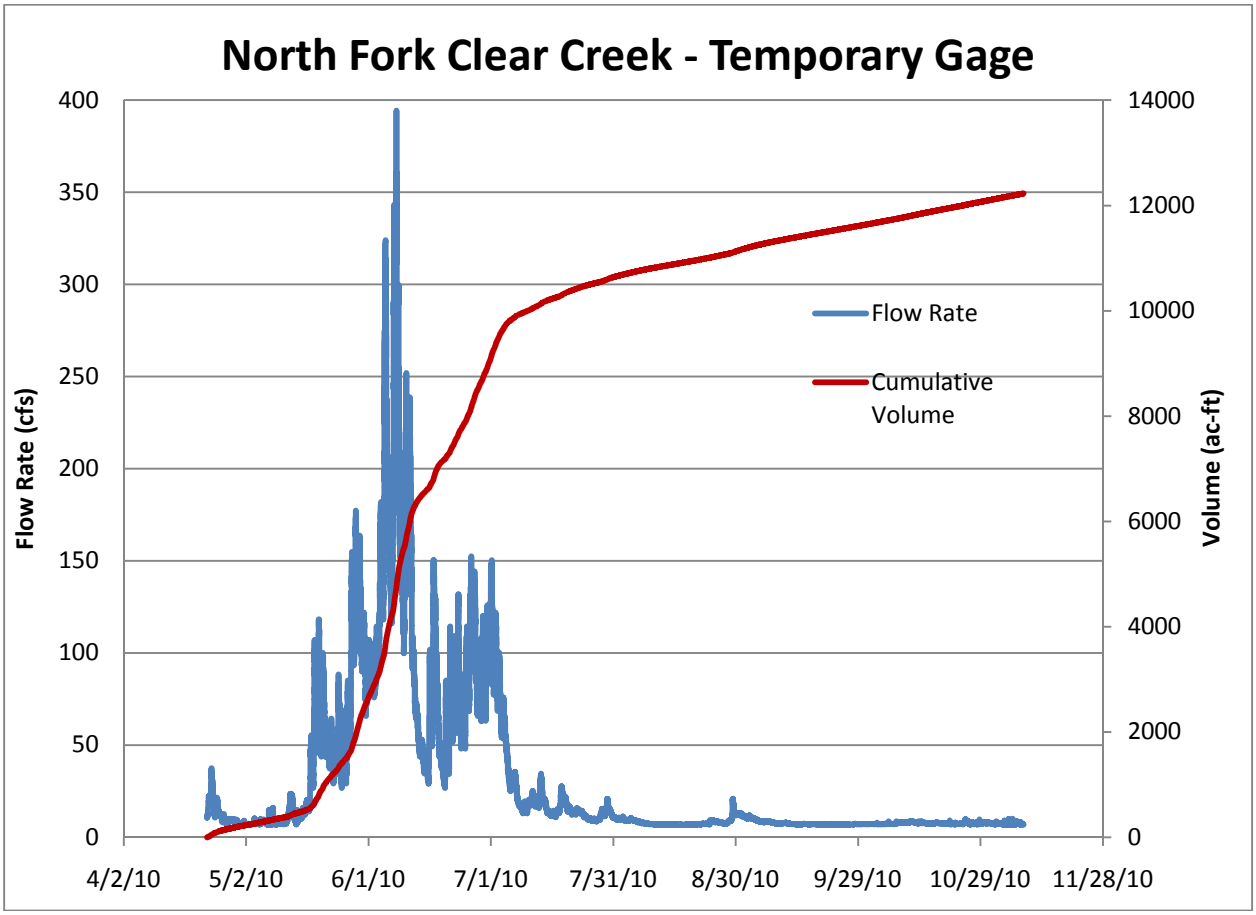


Figure 3.7-6 – North Fork Clear Creek Temporary Stream Gaging Results

Upper French Creek

Data was collected at this temporary gaging site between April 1st, 2010 and October 7th, 2010. During the period of record, this gage discharged 8,464 ac-ft. Figure 3.7-7 shown below displays the fluctuations in flow rate seen at this gaging site as well as the estimated cumulative volume which passed by the gage from April 1, 2010 through October 7th, 2010. The sudden increase in flow shown on June 11th, 2010 is due to the trans-basin diversion of water from North Clear Creek to French Creek via the Four Lakes and French Creek diversion.

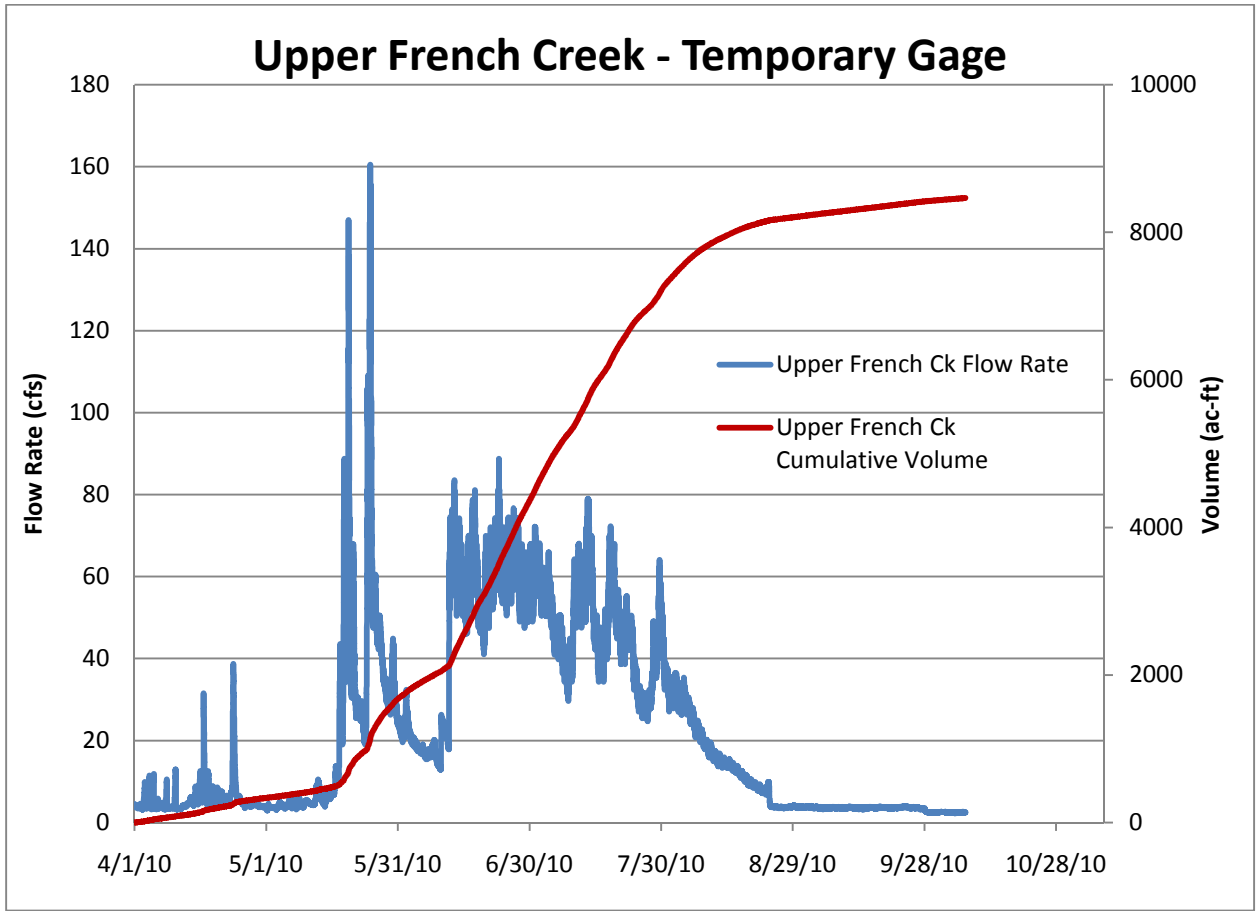


Figure 3.7-7 – Upper French Creek Temporary Stream Gaging Results

Lower French Creek

Data was collected at this temporary gaging site between May 26th, 2010 and November 15th, 2010. During the period of record, this gage discharged 2,819 ac-ft to Clear Creek. Figure 3.7-8 shown below displays the fluctuations in flow rate seen at this gaging site as well as the estimated cumulative volume which passed by the gage from May 26, 2010 through November 15th, 2010. In addition, Figure 3.7-8 displays flow rate and cumulative volume which passed by the Upper French Creek temporary gage for comparison purposes. The sudden increase in flow shown on June 11th, 2010 is due to the trans-basin diversion of water from North Clear Creek to French Creek via the Four Lakes and French Creek diversion.

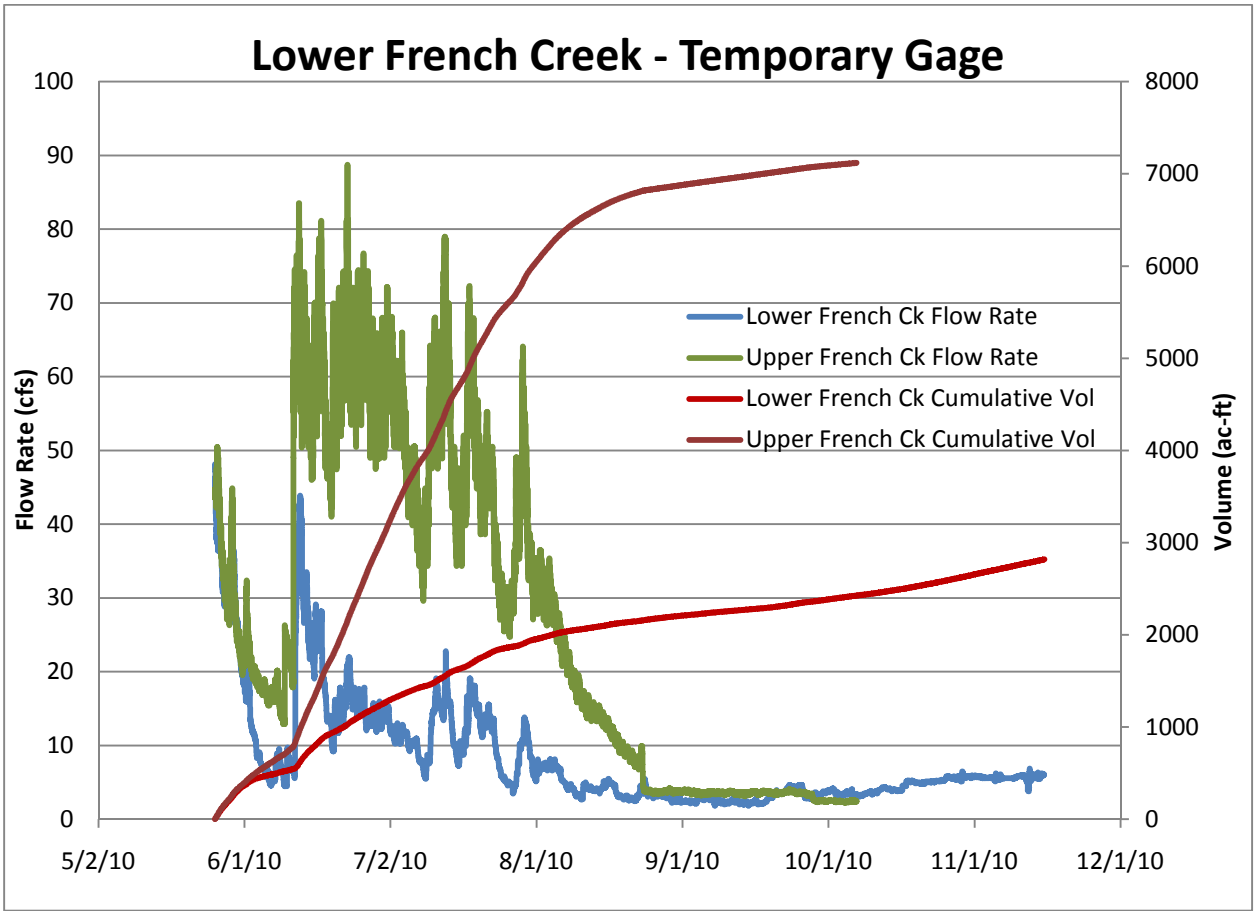


Figure 3.7-8 – Lower French Creek Temporary Stream Gaging Results

Lower Rock Creek

Data was collected at this temporary gaging site between June 24th, 2010 and November 15th, 2010. During the period of record, this gage discharged 3,671 ac-ft to Clear Creek. Figure 3.7-9 shown below displays the fluctuations in flow rate seen at this gaging site as well as the estimated cumulative volume which passed by the gage from June 24th, 2010 through November 15th, 2010. In addition, Figure 3.7-9 displays flow rate and cumulative volume which passed by the USGS gage 06320000 at Upper Rock Creek from June 24th, 2010 through September 30th, 2010. During this time, 9,164 ac-ft of water passed by the USGS stream gage.

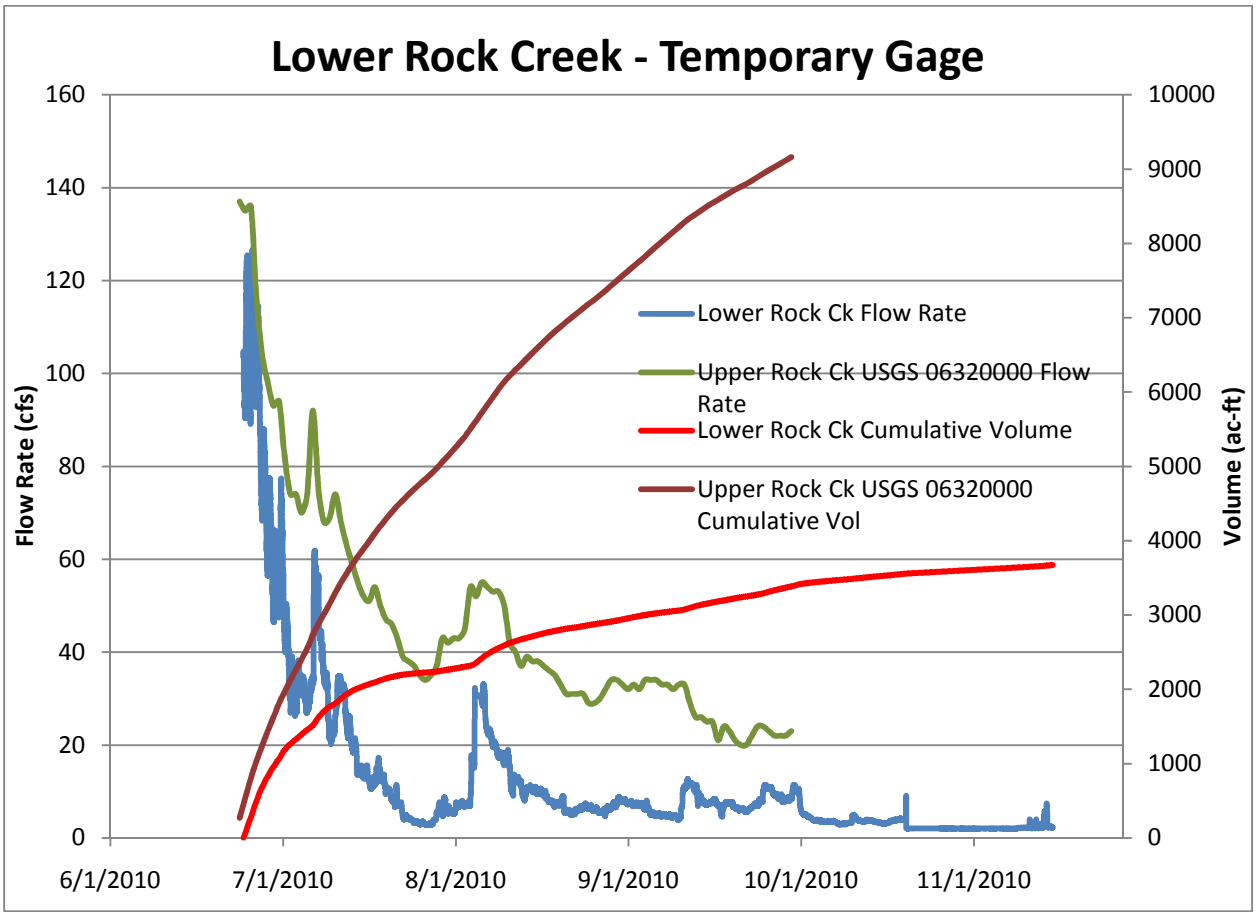


Figure 3.7-9 – Lower and Upper Rock Creek Stream Gaging Results

Comparison to Historic Flow Records

An analysis was performed on the stream gage located on Clear Creek near the City of Buffalo for comparative purposes. The USGS has archived data for Stream Gaging Site #06318500 from the years of 1917 through 1992. An analysis of historic data from this stream gage is presented below showing the wet, dry, and average year scenarios. This information was compared to the 2010 flow records of two nearby sites to evaluate the type of year which has been recorded by the temporary stream gaging sites discussed previously.

Wet Year Scenario

Upon review of the available USGS records for Gaging Site 06318500, it was revealed that 1924 was the wettest year on record, as defined by having the highest average annual flow recorded for this site. The average daily flow dataset was acquired and used to generate a hydrograph and cumulative volume estimate for this year, calculated over the same period of record as the available 2010 streamflow dataset, April 28th – September 30th. In performing this analysis, it was revealed that the wettest year scenario generates an estimated 73,300 ac-ft of runoff for the dates described. A graph depicting this scenario is shown below as Figure 3.7-10. The Powder / Tongue River Basin Plan (HKM 2002) spreadsheet model indicates the wet year flow volume at this gage location for the modeling period of 1970 to 1999 is 65,600 ac-ft of cumulative volume between April 28th and September 30th.

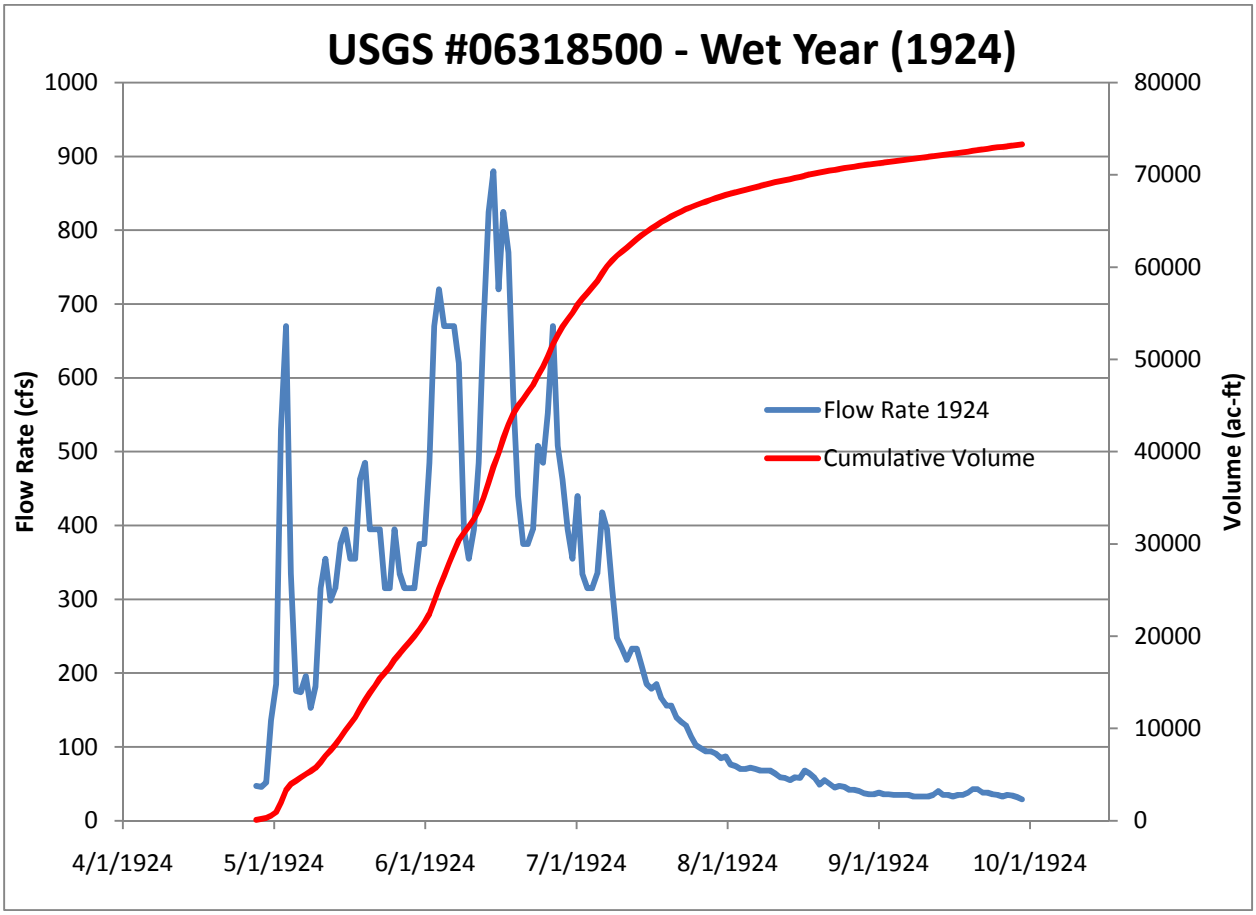


Figure 3.7-10 – Clear Creek USGS Stream Gaging Station #06318500 – Wet Year

Average Year Scenario

Upon review of the available USGS records for Gaging Site 06318500, it was revealed that 1986 was an average year, as defined by having the closest average annual flow recorded compared to the entire average annual flow dataset for this site. The average daily flow dataset was acquired and used to generate a hydrograph and cumulative volume estimate for this year, calculated over the same period of record as the available 2010 streamflow dataset, April 28th – September 30th. In performing this analysis, it was revealed that the average year scenario generates an estimated 37,700 ac-ft of runoff for the dates described. A graph depicting this scenario is shown below as Figure 3.7-11. The Powder / Tongue River Basin Plan (HKM 2002) spreadsheet model indicates the normal year flow volume at this gage location for the modeling period of 1970 to 1999 is 43,500 ac-ft of cumulative volume between April 28th and September 30th.

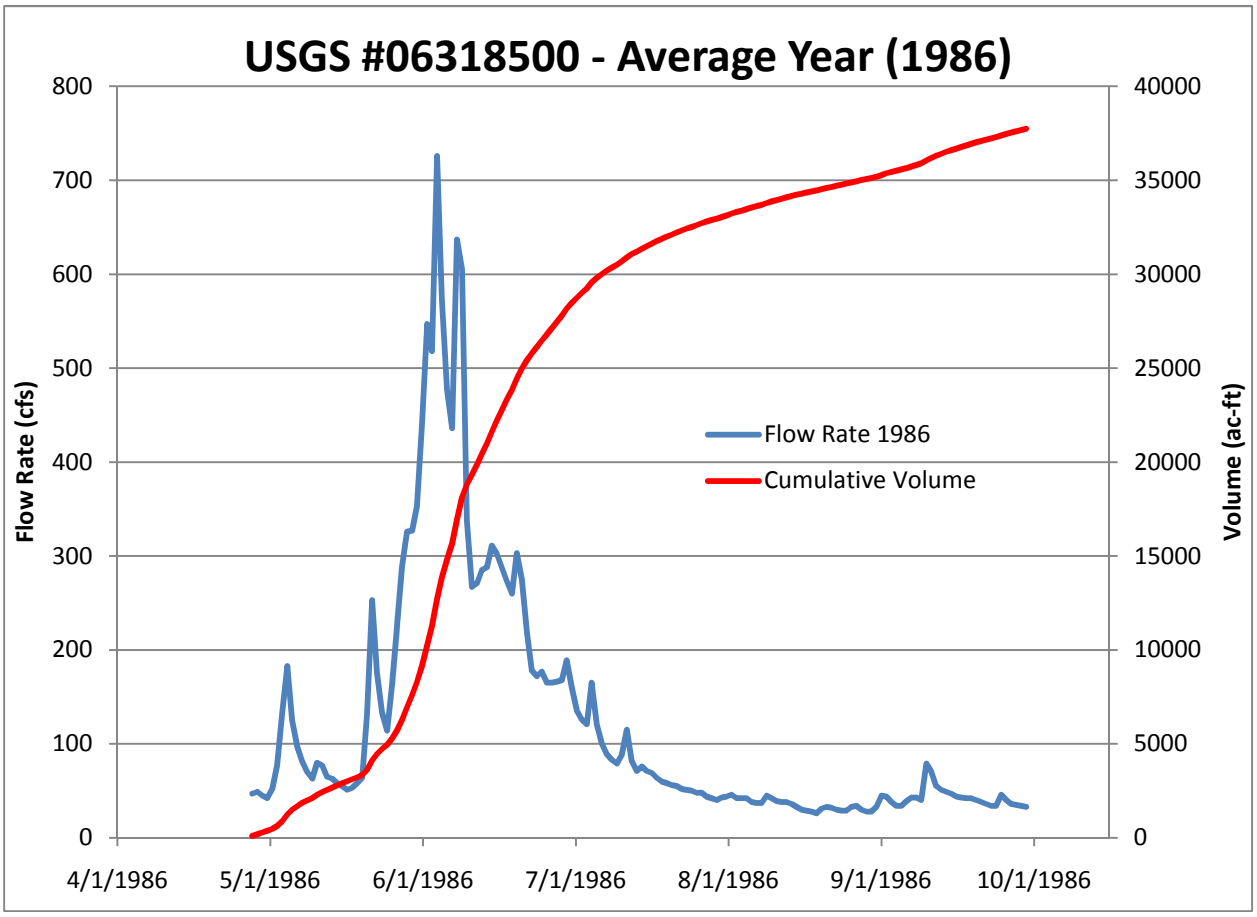


Figure 3.7-11 – Clear Creek USGS Stream Gaging Station #06318500 – Average Year

Dry Year Scenario

Upon review of the available USGS records for Gaging Site 06318500, it was revealed that 1954 was the driest year on record, as defined by having the lowest average annual flow recorded for this site. The average daily flow dataset was acquired and used to generate a hydrograph and cumulative volume estimate for this year, calculated over the same period of record as the available 2010 streamflow dataset, April 28th – September 30th. In performing this analysis, it was revealed that the driest year scenario generates an estimated 12,000 ac-ft of runoff for the dates described. A graph depicting this scenario is shown below as Figure 3.7-12. The Powder / Tongue River Basin Plan (HKM 2002) spreadsheet model indicates the dry year flow volume at this gage location for the modeling period of 1970 to 1999 is 31,100 ac-ft of cumulative volume between April 28th and September 30th.

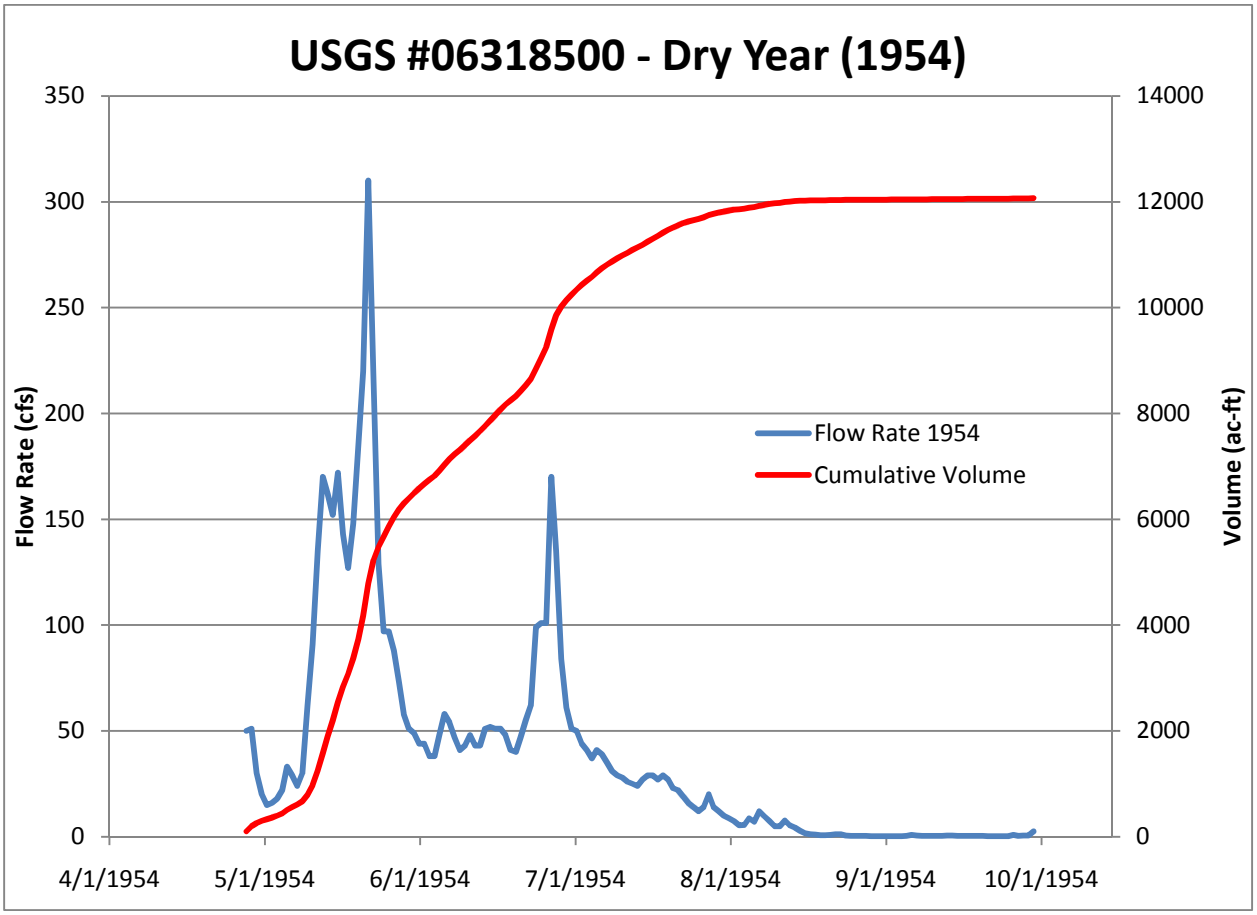


Figure 3.7-12 – Clear Creek USGS Stream Gaging Station #06318500 – Dry Year

2010 Stream-flow

The National Weather Service and the Wyoming State Engineers' Office now cooperatively operate stream gage BCCW4 on Clear Creek in Buffalo City Park and MGHW4 on Clear Creek at Mosier Gulch. Review of the stream-flow records from April 28th, 2010 through September 30th, 2010 reveals that these gages have passed 43,850 and 45,500 ac-ft of water respectively during the period analyzed. A graph depicting the 2010 stream-flow for the dates indicated is presented below as Figures 3.7-13 and 3.7-14.

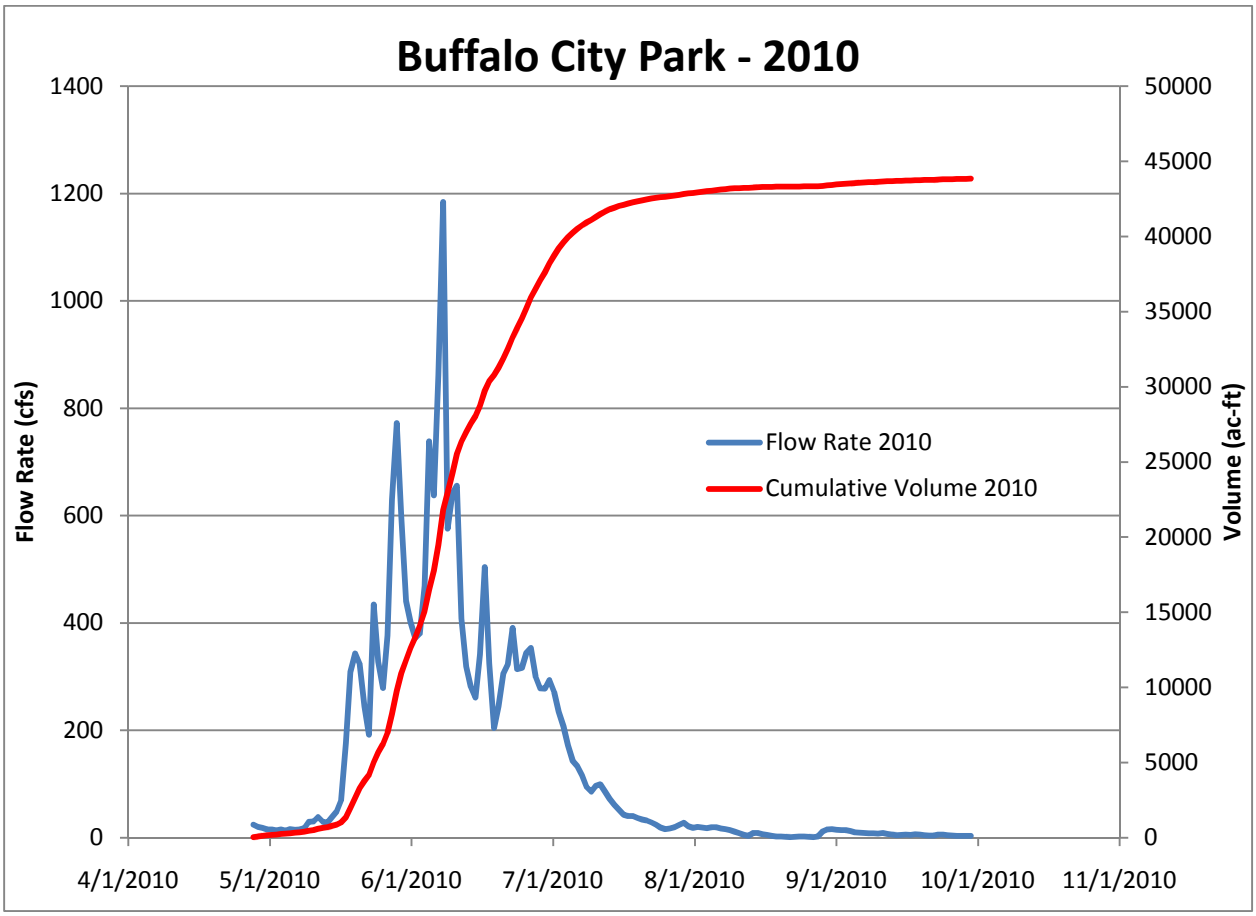


Figure 3.7-13 – 2010 Clear Creek Stream Flow Data in the City of Buffalo

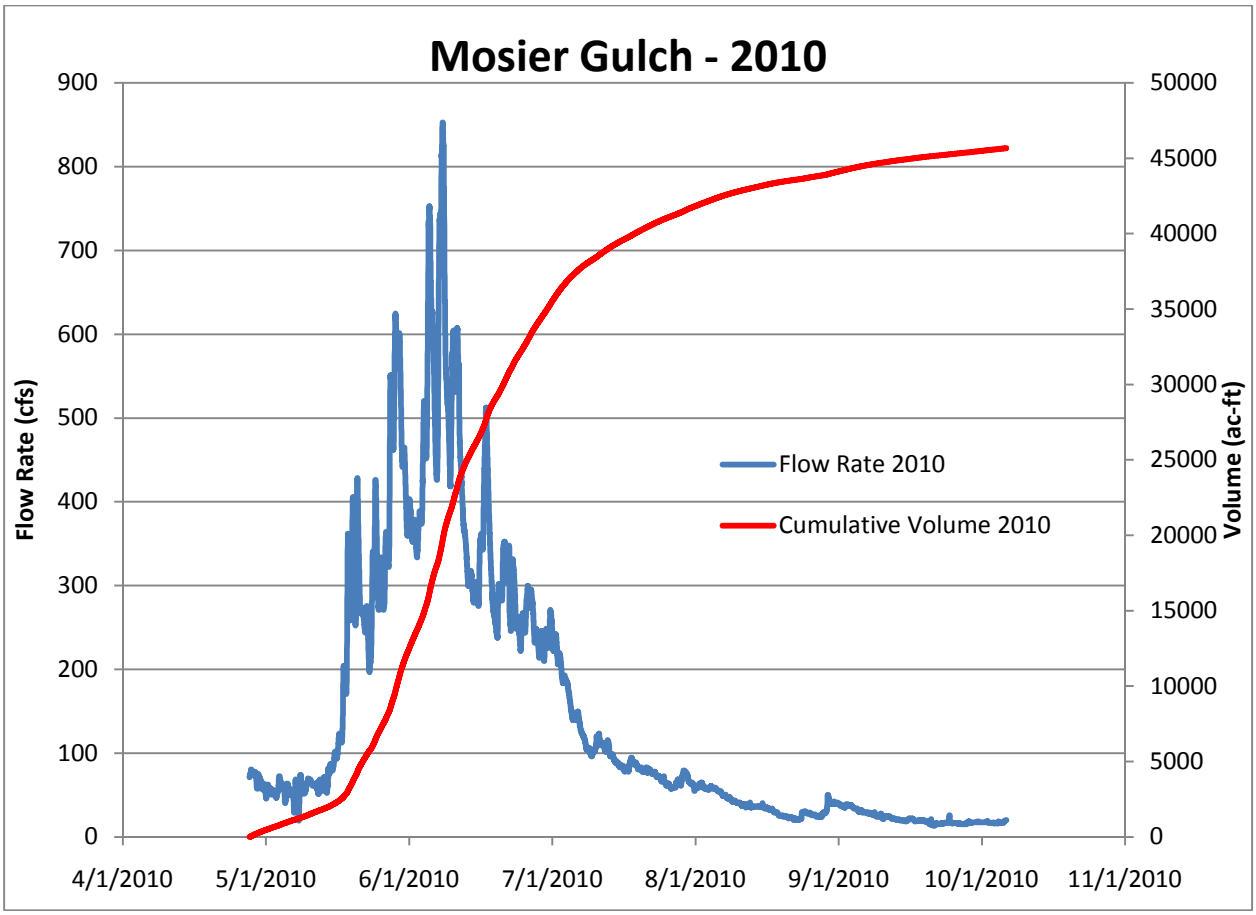


Figure 3.7-14 – 2010 Clear Creek Stream Flow Data at Mosier Gulch

Conclusion

Based upon historic streamflow records, it appears that the Clear Creek drainage had an above average water year in 2010. Based on the Powder / Tongue River Basin spreadsheet model, it appears that the Clear Creek drainage had an average to slightly above average water year in 2010. As such, the data that has been collected from the temporary stream gages should be considered to be above average also. According to the cumulative volumes which have passed the Clear Creek stream gage in Buffalo City Park and Mosier Gulch, there has been approximately 16% and 20% more water respectively conveyed in Clear Creek in 2010 than during the average year measured in 1986 at USGS 06318500. The Buffalo City Park and Mosier Gulch stream gages, when compared to the spreadsheet model normal year dataset for USGS 06318500, have conveyed approximately 1% and 5% more water in 2010. The USGS 06318500 gage was discontinued in 1992. As a result, it is difficult to make direct comparison of historic Clear Creek streamflow to 2010 streamflow. The Mosier Gulch stream gage is located approximately 3 miles upstream of the USGS 06318500 site and records a similar flow regime, however, the gauge is relatively new and as a result the rating table may not be as complete. The Buffalo City Park gage is located approximately 4.1 miles downstream of the USGS 06318500 site and is below a number of additional irrigation diversions. The comparisons made between the USGS gauge and the Mosier Gulch and Buffalo City Park gages are for general comparison only as all of these gages are non-natural streamflow gages. Figure 3.7-15

shows a comparison of the cumulative runoff volume for the various water years between April 28th and September 30th.

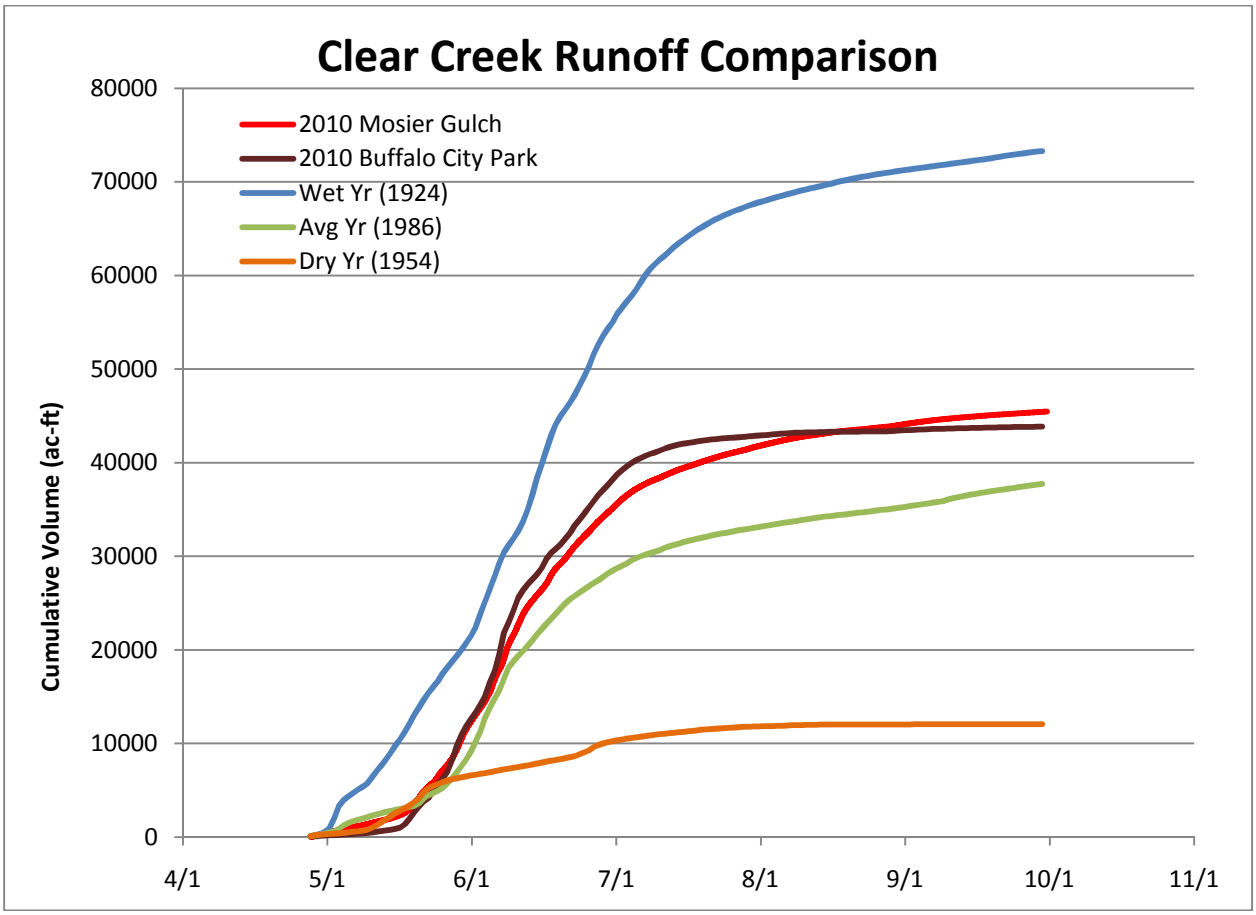


Figure 3.7-15 – 2010 Clear Creek Stream Flow Comparison

A similar analysis was performed on the USGS gage 06320000 on Rock Creek. The USGS has archived data for this non-natural flow site from the years of 1945 through 2010. Upon review of the available USGS records, it was revealed that 1996 was an average year, as defined by having the closest average annual flow recorded compared to the entire average annual flow dataset for this site. The average daily flow dataset was acquired and used to generate the cumulative runoff volume estimate for this year, calculated over the same period of record as the available 2010 streamflow dataset, April 7th – September 30th. According to the cumulative volumes which have passed the Rock Creek USGS 06320000 stream gage, there has been approximately 16% more water conveyed in Rock Creek in 2010 than during the average year measured in 1996. The Rock Creek USGS stream gage, when compared to the Powder / Tongue River spreadsheet model normal year dataset for this stream gage, has conveyed approximately 9% more water in 2010. Based upon historic streamflow records and the Powder / Tongue River spreadsheet model, it appears that the Rock Creek drainage had a slightly above to above average water year in 2010.

Results

The additional data acquired by the temporary installation of devices to measure stream flow and diversions can be used to supplement existing stream flow records. Hydrologic models may still be operated on a monthly time step to identify the most likely locations for construction of new dams and reservoirs. However, the temporary installation of gages will provide additional data that may justify additional analysis of stream flow on either a weekly or daily time step, which would provide engineers additional information to maximize the size of the reservoir and to better describe reservoir operations.

Data collection term could vary depending on the type of water year collected i.e. wet, normal, or dry year, parameters of the modeling effort, and the overall goals of the project. Reservoir yields are calculated based on the reservoir facility's ability to store water in normal and dry years. Temporary stream flow gaging in wet years may not produce results to accurately predict reservoir yield. Data collection during dry and normal water years is preferred, and when correlated with long term gaging stations, estimates of basin and reservoir yield can be more accurately determined.

3.7.3 Existing Storage Facilities

An inventory of existing reservoir storage facilities located within the Clear Creek watershed was completed using information contained in the Powder / Tongue River Basin Plan (HKM 2002). The storage reservoirs of significance in the watershed are as follows (>1,000 acre-feet capacity):

- Cloud Peak Reservoir
- Healy Reservoir
- Kearney Lake
- Lake DeSmet
- Tie Hack Reservoir
- Willow Park Reservoir

Appendix 3I contains detailed information about these storage facilities in addition to all other storage facilities in the watershed which contain more than 50 acre-feet of storage or are more than 20 feet high. In addition, Appendix 3G contains a tabulation of surface water rights in the watershed.

IV. Watershed Management Plan

4.1 INTRODUCTION

As stated previously, the objective of this study is to generate a watershed management plan that is not only technically sound, but also one that is practical and economically feasible. In conjunction with the development of a database for the watershed, the investigative phase of this study focused on an assessment of the watershed and the identification and evaluation of improvements to address those issues described in Section 3. Potential improvements developed and categorized in this portion of the report include the following:

- **Livestock / Wildlife Upland Watering Opportunities**. Based upon an evaluation of existing water sources and the condition of upland grazing resources, potential upland water source development projects were identified.

- **Stream Channel Condition and Stability**. Stream channels within the watershed were characterized with respect to their condition and stability. Impaired channels were identified for further evaluation and alternative improvements developed.

- **Grazing Management Opportunities**. Based upon a review of the pertinent Ecological Site Descriptions (ESDs) and the ambient vegetation and soil conditions, grazing management strategies are presented.

- **Other Upland Management Opportunities**. Additional watershed management alternatives were identified.

4.2 UPLAND WILDLIFE AND LIVESTOCK WATERING SOURCES

4.2.1 Alternative New Watering Opportunities

Even though there has been extensive work done in the watershed with respect to development of upland water sources for wildlife and livestock, numerous opportunities are still present to develop additional sources. Potential sources which could be utilized include existing wells which are permitted for stock watering uses, springs, and stock reservoirs. The springs and wells represent a major portion of the potential water sources available to develop as individual watering sites or to use to feed multiple sites utilizing a pipeline/tank system. Springs flowing in excess of about 2 gallons per minute could be developed and provide additional upland sources. Newly constructed or rehabilitated stock reservoirs could provide upland water sources where wells or springs are not available. These could provide at least seasonal watering in locations which could open underutilized range lands to more productive use. Figures 4.2-1 and 4.2-2 display the locations of permitted stock wells and springs and stock reservoirs, respectively.

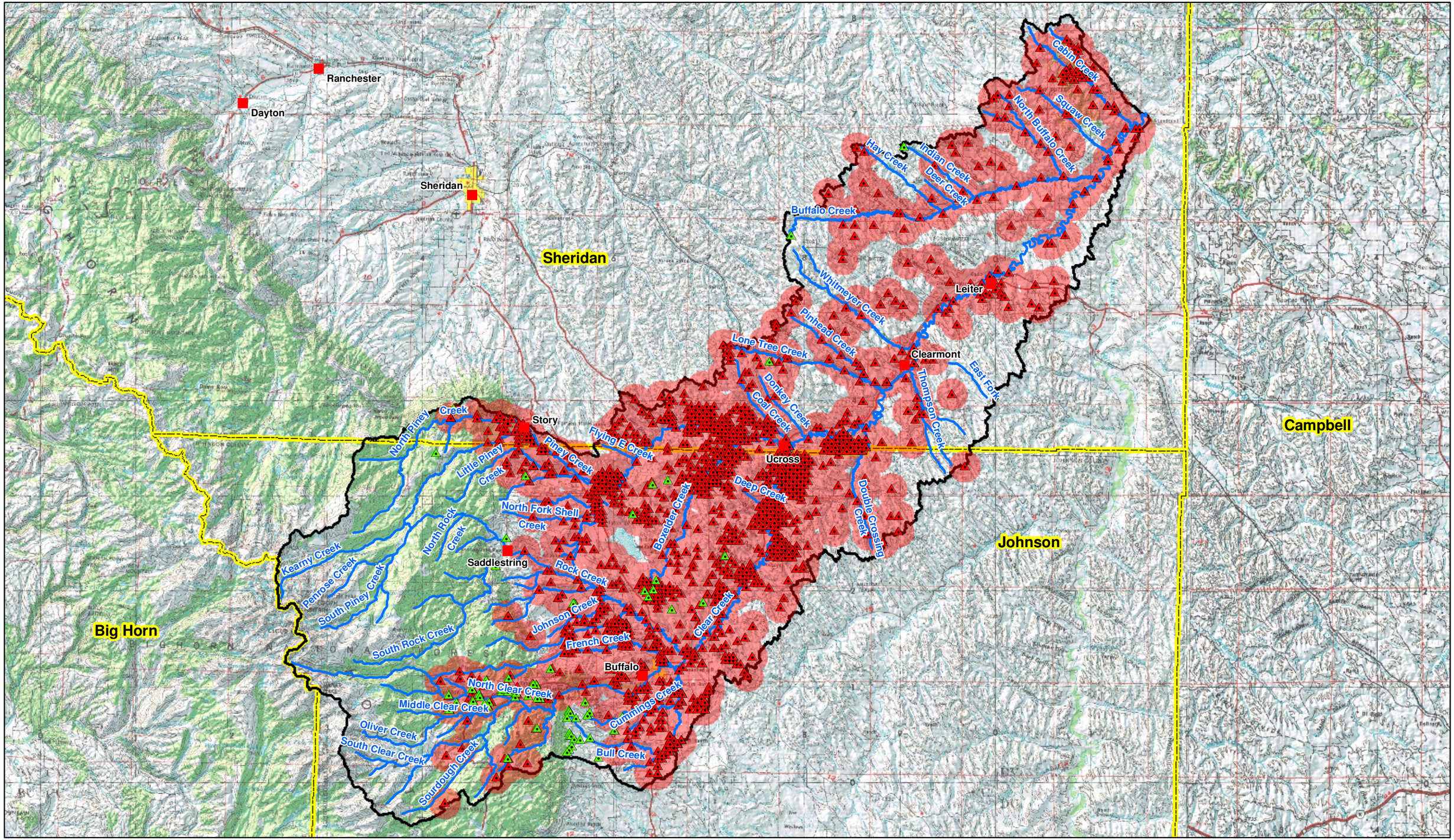


Figure 4.2-1. Existing Upland Water Sources: Permitted Stock Wells

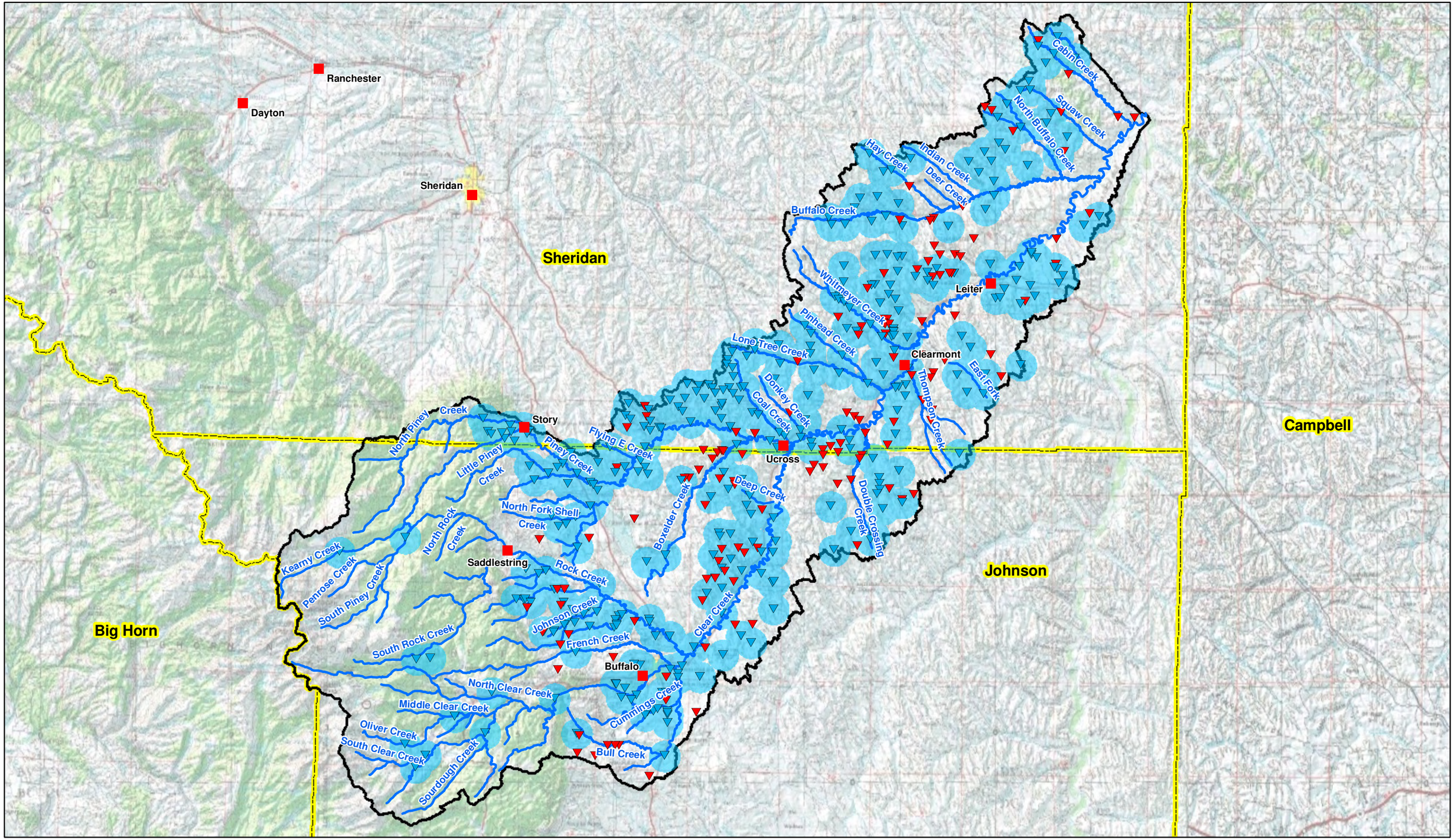


Figure 4.2-2. Existing Upland Water Sources: Permitted Stock Reservoirs

Given the relatively gentle topography throughout the majority of the watershed, existing water sources were assumed to be capable of providing water to livestock within a one-mile radius. It is understood that the effective radius around a water source could be shorter depending upon numerous factors including topography, water quality, natural and man-made barriers, etc. For example, steeper or more rugged terrain could limit the effective radius of water sources as would fencing, roads, and other infrastructure. However, for the purposes of the Level I study and the data available to it, one-mile was assumed to be a reasonable radius to use for planning purposes.

Based upon this premise, buffers were drawn around documented existing water sources described in Section 3 and included in Figures 4.2-1 and 4.2-2. It must be remembered that there are additional sources which are not indicated on this figure. A number of pipeline/tank projects have been constructed on private and federal lands, however, mapping of their locations was not available. In addition, water co-produced during gas production can provide a source for upland wildlife/livestock usage depending upon its water quality character.

As indicated in these figures, much of the grazing lands in the watershed appear to be within one mile of a water source. When reviewing these figures, however, it must be kept in mind that numerous upland water development projects are known to exist but are not indicated on these figures. These figures do, however, graphically display the fact that the majority of the grazed portion of the watershed has been provided with a water source at one time.

Final planning and design of additional upland wildlife / livestock water sources should include onsite consultation as appropriate with landowners, allotment permittees, NRCS, LDCD, SCCD, and either the USFS or BLM (if federal lands are involved), to verify location of the planned improvements in relation to existing sources. It should be kept in mind that upland water supply development may be desirable and/or necessary even in areas appearing well watered under this approach due to the fact topography, physical barriers and other limiting factors mentioned above were not considered during the analysis.

One of the objectives of this phase of the project was to evaluate alternatives to surface water streams as water sources for wildlife and livestock. Consequently, Figures 4.2-1 and 4.2-2 do not show buffers about perennial / intermittent streams. As indicated in this figure, a large portion of the watershed appears to be adequately supplied with water sources. However, it must be kept in mind that the water supply associated with stock ponds can be unreliable and a function of timing of rainfall events.

In Appendix 4A, various alternative types of watering improvements/developments are described in more detail. These alternative water source improvements include:

- Spring developments
- Existing Wells with conventional windmills, wind turbines and combined solar / wind systems,
- New Wells

- Pipeline / tank systems
- Stock ponds
- Storage reservoirs
- Guzzlers.

Note that alternative watering tanks applicable to use with essentially any of the water sources are addressed in the discussion of pipeline / tank systems. Options for power where pumping is required are also presented in Appendix 4A.

4.2.2 Upland Wildlife / Livestock Water Development Projects

Allotment management plans (AMPs) for USFS or BLM allotments typically include recommended projects targeting development of upland water sources for wildlife and livestock. Within the project study area, the BLM allotments did not have prescribed AMPs. Review of USFS AMPs indicated that several range improvement projects, including development of upland water sources, are included within them. USFS representatives indicated that the AMPs are intended to be dynamic documents and the specific project recommendations may not be applicable for specific inclusion in this report. Consequently, the USFS should be consulted prior to initiation of upland water development projects on USFS lands to determine compatibility with specific allotment management objectives.

A list of interested land owners and allotment permittees was generated based upon input obtained at project meetings and from input obtained through project team member activities and interviews conducted during the completion of the project. Individual meetings with the landowners were scheduled and completed to gain their input on the water needs of their respective geographical areas of interest. Based upon the results of these interviews and the information presented above pertaining to existing water supplies and areas in need of upland water development, several conceptual water development projects were identified.

It should be noted that additional opportunities for upland water development and range improvement may exist and should not be assumed to be invalid because they are not included in this report. The projects presented in this report were developed based upon input received from the interested landowners and do not represent a comprehensive list of watershed needs.

The general objective of this effort was to provide means of providing reliable sources of livestock / wildlife drinking water in water-short portions of the watershed as well as alternative water supplies to riparian corridors. In the following paragraphs, several alternatives are presented at the conceptual level. For each project, a conceptual design is also presented. It must be kept in mind that these designs are conceptual only and if implemented, detailed design would be required. Figure 4.2-3 displays the general location of livestock/wildlife water opportunity projects included in this report. Table 4.2-1 displays cost estimates for the potential projects.

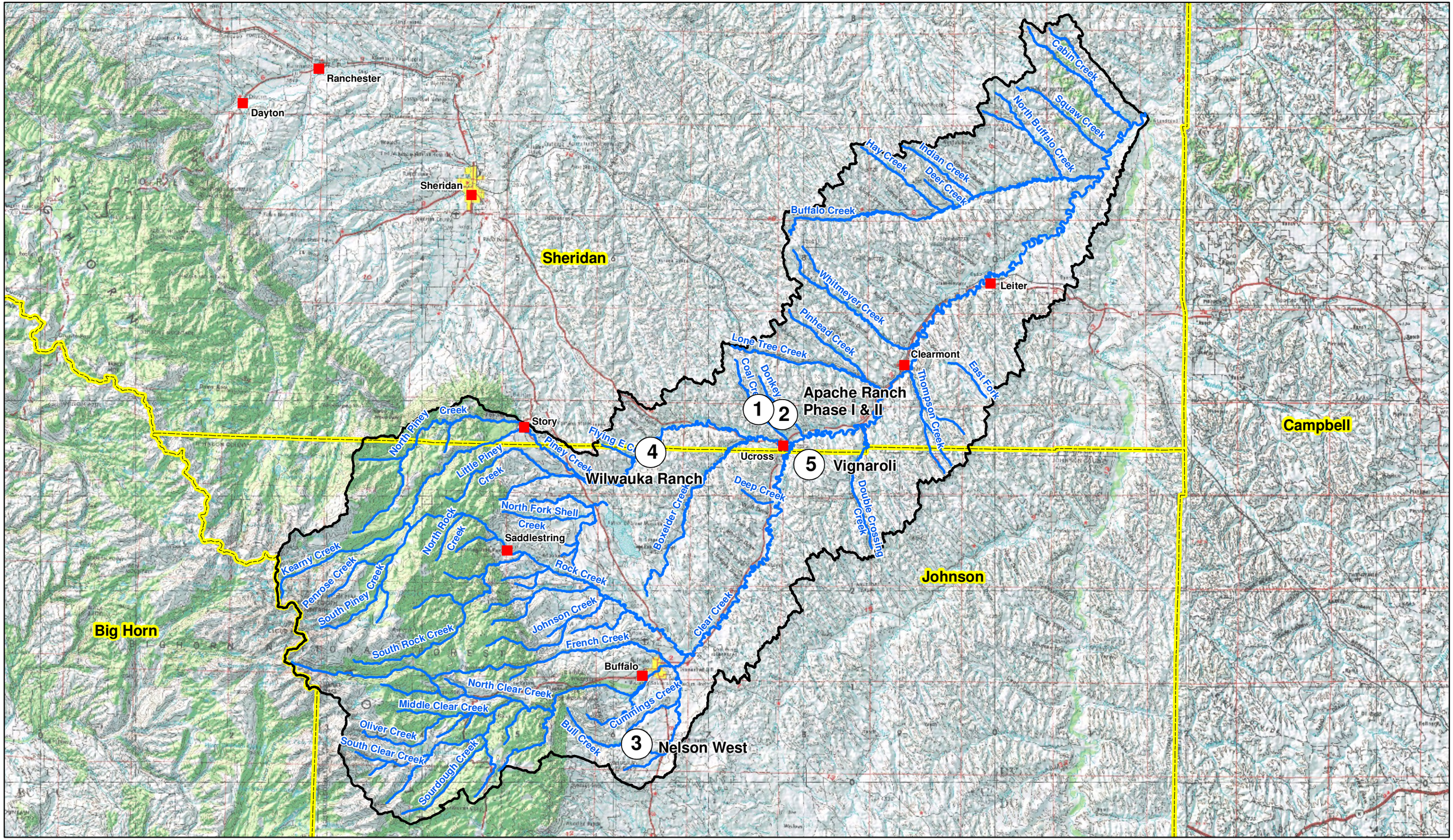


Figure 4.2-3. Watershed Management Plan: Upland Wildlife/Livestock Water Development Projects

Table 4.2-1 Upland water projects cost estimates

Project Name		Apache Ranch Phase I	Apache Ranch Phase II	Nelson	Wilwauka Ranch	Vignaroli
Project Component	**Allotment Directly Benefitted**	**Sahara Draw**	**Sahara Draw**	**T.W.**	**Private Lands**	**State Lands**
Well Construction / Spring Development	Mobilization	$3,000	$3,000	$3,000	$3,000	$3,000
	Well / Spring	Existing Well	Well	Well	Spring	Rehabilitation of Existing System
	Units (each)	0	0	0	1	0
	Depth Each	NA	NA	NA	NA	NA
	Unit Cost ($/LF wells or $/EA springs	$5,000	$5,000	$5,000	$5,000	$5,000
	Well Screen (LF each well)					
	Well Screen ($/LF)					
	Component Subtotal	$3,000	$3,000	$3,000	$8,000	$3,000
Pump	Units (EA)	1	0	NA	0	0
	Type	Solar	Solar		Solar	Solar
	Unit Cost (EA)	$8,640	$48,800		$8,640	$8,640
	Component Subtotal	$8,640	$0		$0	$0
Pipeline	Units (LF)	36,375	33,000	4,500	800	32,125
	Unit Cost (EA)	$2.00	$2.00	$1.34	$1.34	$2.00
	Component Subtotal	$72,750	$66,000	$6,030	$1,072	$64,250
Additional Storage Tanks / Fencing / Etc	Units (EA)	NA	NA	NA	0	0
	Size (gal)				15,000	15,000
	Unit Cost ($/gal)				$1	$1
	Component Subtotal				$0	$0
Water Tanks	Units (EA)	7	5	1	1	7
	Size (gal)	1,200	1,200	1,200	1,200	1,200
	Unit Cost	$3,000	$3,000	$3,000	$3,000	$3,000
	Component	$21,000	$15,000	$3,000	$3,000	$21,000
Miscellaneous	Item	Frost free hydrants	Frost free hydrants	NA	Fencing	Fencing
	Units (Each)	4	4			
	Unit Cost ($/ea)	$250	$250			
	Component Subtotal	$1,000	$1,000			
Construction Subtotal		$106,390	$85,000	$12,030	$12,072	$88,250
Engineering (10%)		$10,639	$8,500	$1,203	$1,207	$8,825
Construction and Engineering Subtotal		$117,029	$93,500	$13,233	$13,279	$97,075
Contingency (15%)		$17,554	$14,025	$1,985	$1,992	$14,561
Total Construction Cost		$134,583	$107,525	$15,218	$15,271	$111,636
Final Plans and Specs		$2,000	$2,000	$2,000	$1,000	$2,000
Additional		$0	$0	$0	$0	$0
Permitting / Legal Fees / Access and Rights of Way		$1,000	$1,000	$1,000	$1,000	$1,000
Total Project Cost		**$137,583**	**$110,525**	**$18,218**	**$17,271**	**$114,636**

Each of the upland water development projects could involve coordination as appropriate with the NRCS, LDCD, and/or SCCD and the USFS or BLM (if federal lands are involved) in order for construction to occur. Written agreements would be required which define the maintenance responsibility and ownership liability associated with each project. In addition, environmental evaluations would be required for the impacts indentified with each project. If federal lands are involved, either the USFS or BLM typically conducts these evaluations, however, the NRCS or other agencies may provide input, particularly on archaeological or cultural resources issues. Consequently, implementation would be partially contingent upon BLM scheduling and manpower for their completion of the requisite evaluation and documentation.

4.2.2.1 Livestock / Wildlife Alternative 1: Apache Ranch Pipeline (Phase 1)

The objective of this project would be to enhance water distribution in the northern portion of the watershed. Specifically, the project would result in a reliable source of water for livestock and wildlife in an area dominated by riparian sources: Coal Creek, Donkey Creek, and Sahara Draw. The project could potentially benefit wildlife species in the area including mule deer, pronghorn, and whitetail deer. The project was proposed by the Apache Ranch as a part of their long-term management plan. Given the extent of the overall project, the project was divided into two individual phases. Figure 4.2-4 displays the general configuration of Phase I.

The project would utilize an existing CBM well located in Section 11, Township 53 North, Range 81 West. According to the Wyoming State Engineers Office (WSEO) database, the well is permitted to Wolverine Operations LLC (stock water is a permitted use). Use of the well as a supply source for the project would be contingent upon procurement of a written agreement with the well owner and verification of sufficient yield.

Under this alternative, the following components would be utilized:

- The existing well would be equipped with a pump and solar power source in order to pump the water upslope to a storage tank.
- An existing storage tank (15,000 gallon capacity) is located at a high point providing gravity flow conditions to the remainder of the system.
- A pipeline branch would run westerly within Coal Creek drainage providing alternative sources of upland water and relieving pressures on riparian zones.
- The total length of HDPE pipeline (1.5-inch diameter) would be approximately 36,375 linear feet.
- Seven (7) stock tanks (1,200 gallon capacity) would be constructed. Their locations would be selected to optimize management of upland resources.
- Four (4) frost-free hydrants would be installed to provide a means to irrigate trees planted by the ranch to enhance wildlife habitat.
- The pipeline would be buried below frost lines to facilitate winter use.

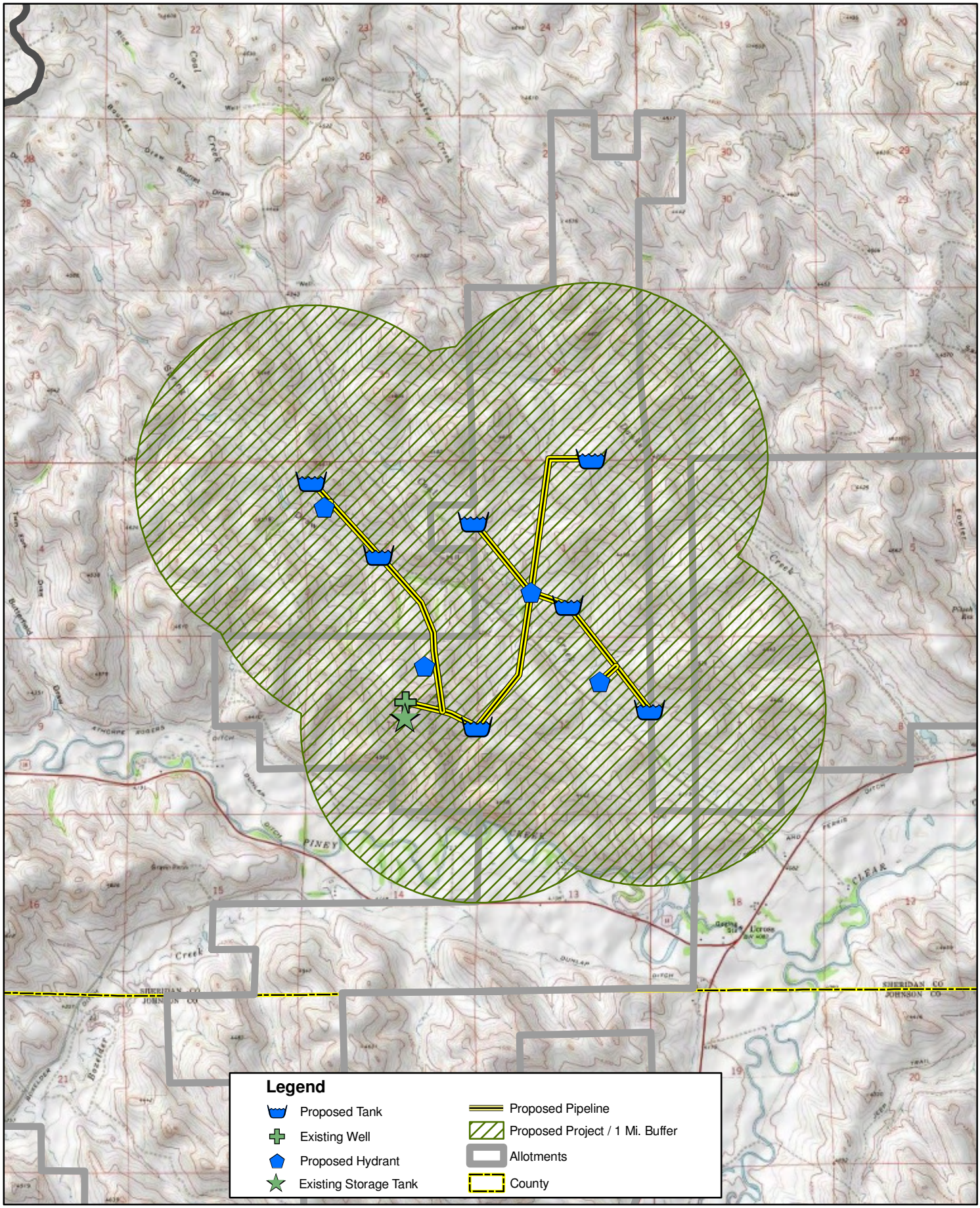


Figure 4.2-4. Upland Wildlife / Livestock Water Development Project 1: Apache Ranch Phase I

4.2.2.2 Livestock / Wildlife Alternative 2: Apache Ranch Pipeline (Phase 2)

Completion of this project would be contingent upon the completion of the Phase I portion of the Apache Ranch Pipeline Project described above. The objective of the second phase of the project would be to provide additional upland water sources within the Coal Creek, Donkey Creek and Sahara Draw subwatershed and reduce pressures on riparian areas. Figure 4.2-5 displays the general configuration of Phase II of the project assuming Phase I has been completed.

Under this alternative, the following components would be utilized:

- The Phase I pipeline project would be extended by adding approximately 33,000 linear feet of HDPE pipeline (1.5-inch diameter as indicated in Figure 4.2-5.
- Five (5) stock tanks (1,200 gallon capacity) would be constructed. Their locations would be selected to optimize management of upland resources.
- Four (4) frost-free hydrants would be installed to provide a means to irrigate trees planted by the ranch to enhance wildlife habitat.

4.2.2.3 Livestock / Wildlife Alternative 3: Nelson West Pipeline

The objective of this project would be to enhance water distribution in the Bull Creek subwatershed which is situated in the upper portions of the Clear Creek watershed along its southern border. The project would result in a reliable source of water for livestock and wildlife in an area dominated by riparian sources within the T.W. grazing allotment. The project could potentially benefit wildlife species in the area including mule deer, pronghorn, and greater sage-grouse. Figure 4.2-6 displays the general configuration of the project. An existing well would be utilized as the source of water for the pipeline project (stock water is a permitted use).

Under this alternative, the following components would be utilized:

- The existing well would be equipped with a pump and solar power array.
- Approximately 4,500 linear feet of HDPE pipeline (1.5-inch diameter) would be installed as indicated in Figure 4.2-6.
- One (1) stock tank (1,200 gallon capacity) would be constructed. The location would be selected to optimize management of upland resources.

4.2.2.4 Livestock / Wildlife Alternative 4: Wilwauka Pipeline Project

The objective of this project would be to enhance water distribution on private lands within the central portion of the Piney Creek subwatershed. The project would result in a reliable source of water for livestock and wildlife and protect riparian areas associated with an existing spring. The project could potentially benefit wildlife species in the area including mule deer, pronghorn, and whitetail deer. Figure 4.2-7 displays the general configuration of the project.

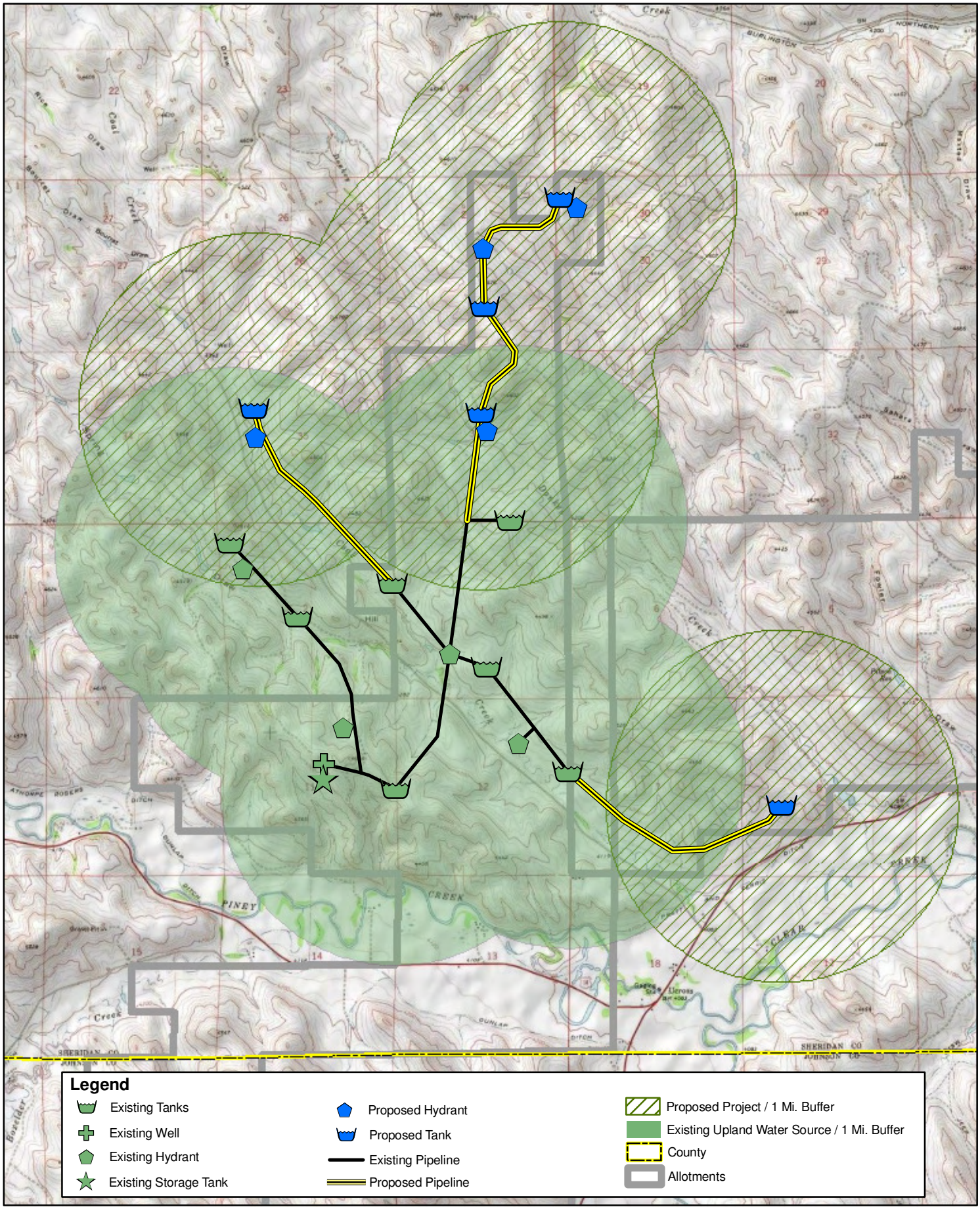


Figure 4.2-5. Upland Wildlife / Livestock Water Development Project 2: Apache Ranch Phase II

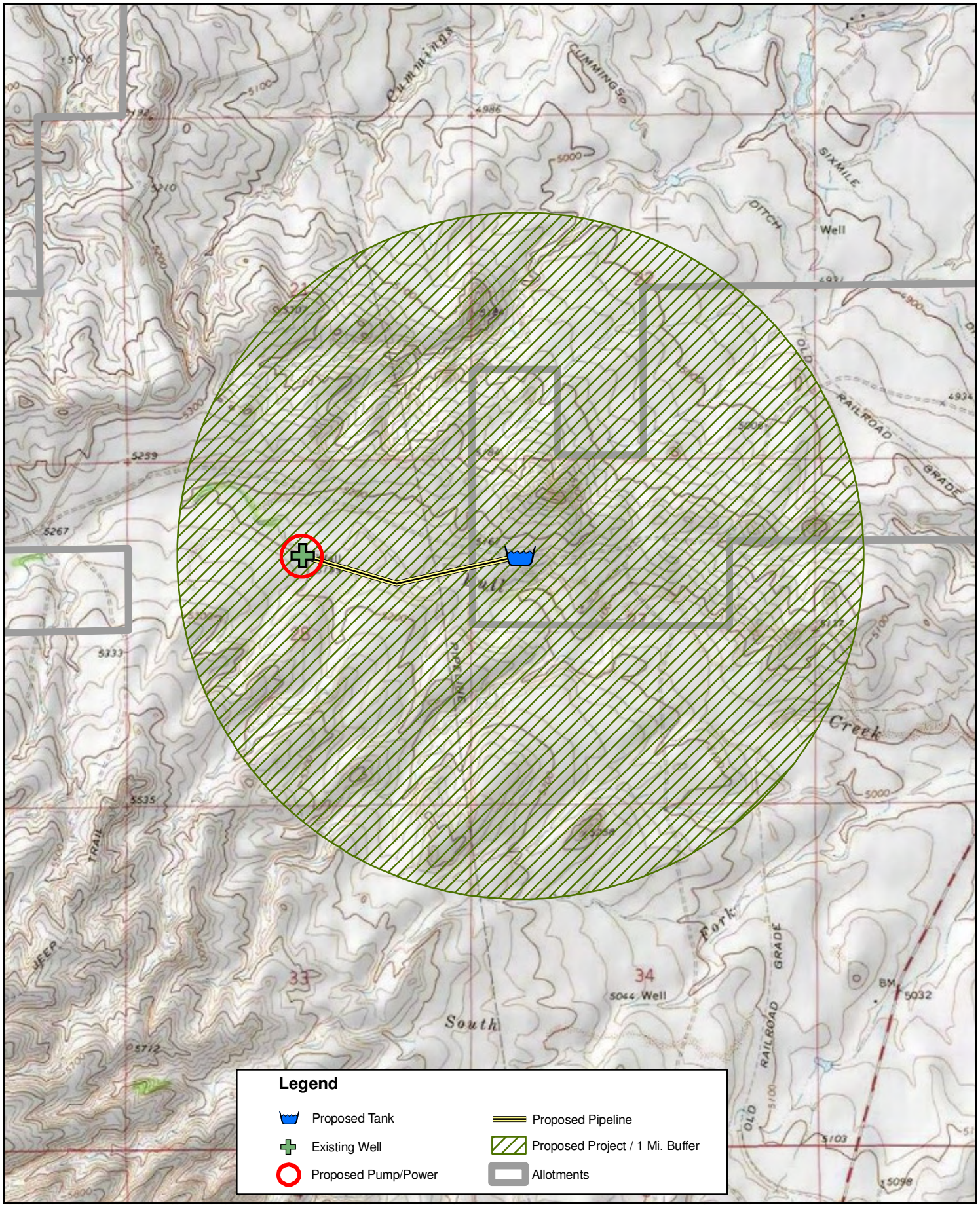


Figure 4.2-6. Upland Wildlife / Livestock Water Development Project 3: Nelson West Pipeline Project

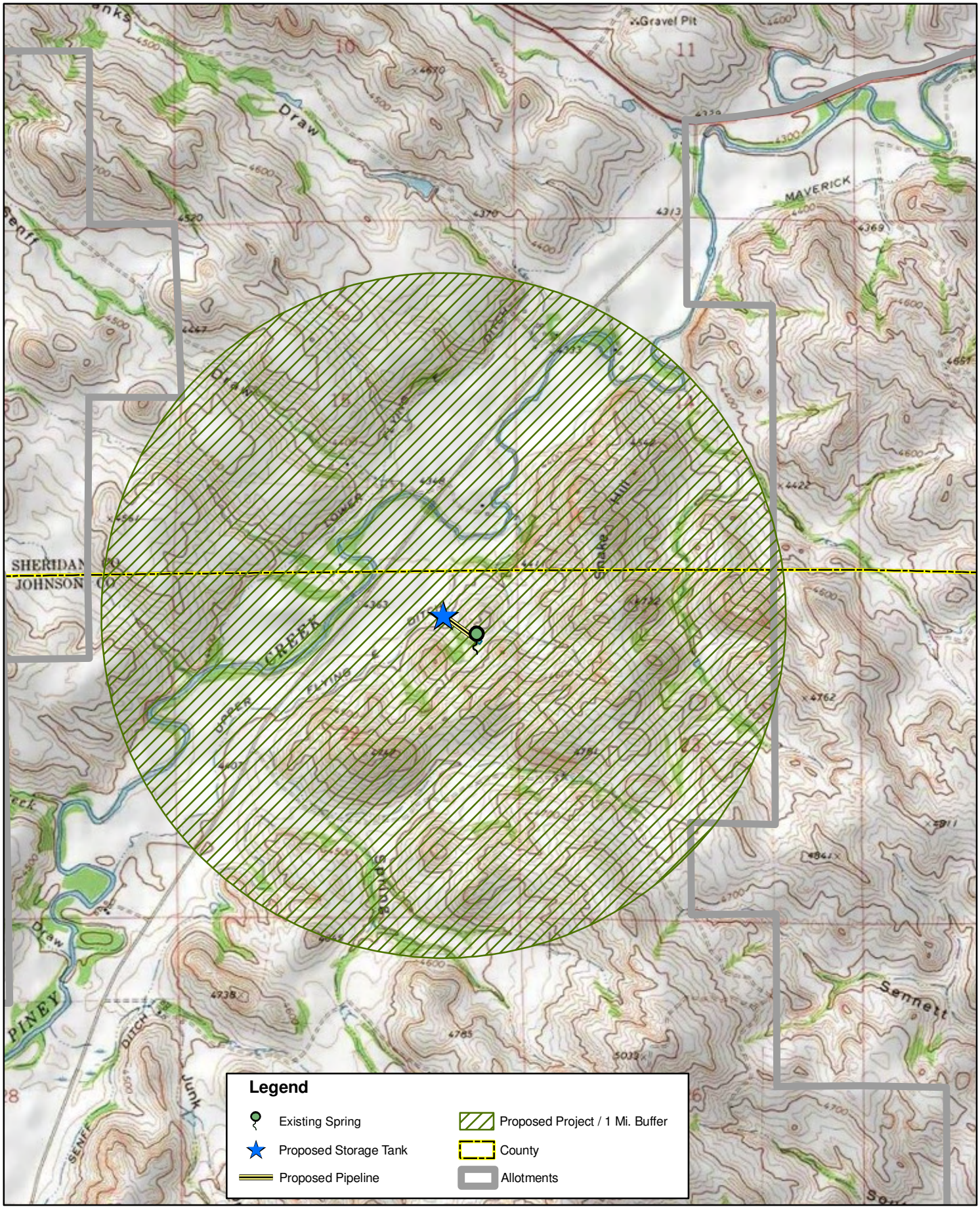


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Figure 4.2-7. Upland Wildlife / Livestock Water Development Project 4: Wilwauka Ranch Spring Development

Under this alternative, the following components would be utilized:

- An existing spring would be developed and would provide a source of water for the project.
- Approximately 800 linear feet of HDPE pipeline (1.5-inch diameter) would be installed.
- One (1) stock tank (1,200 gallon capacity) would be constructed.
- The existing spring would be fenced to protect the area from future wildlife and livestock usage.

4.2.2.5 Livestock / Wildlife Alternative 5: Vignaroli Pipeline Project

The objective of this project is to replace an existing pipeline system experiencing frequent failures. The existing system was installed approximately twenty years ago. According to the landowner, joints are failing and the original system was constructed using materials of inadequate strength. Replacement of the system would result in a reliable stock watering system for livestock and wildlife in the Ike Draw portion of the study area within Johnson County. The project could potentially benefit wildlife species in the area including mule deer, pronghorn, whitetail deer, and greater sage-grouse. Figure 4.2-8 displays the general configuration of the project.

Based upon our understanding of the problem and existing infrastructure, the following components would likely be required:

- The existing pipeline would be replaced with approximately 32,125 linear feet of HDPE pipeline (1.5 inch diameter) including appropriate valves and fittings.
- An existing well would provide a source of water to the system.
- An existing storage tank would store water pumped from the well and provide water via gravity flow to the system.
- The existing tanks would be inspected to determine their condition and need for replacement. Based upon the results of this inspection, up to seven (7) stock tanks (1,200 gallon capacity) would be replaced.

4.3 STREAM CHANNEL CONDITION AND STABILITY

The general condition of the principal stream channels and primary tributaries were evaluated during the geomorphic investigation. Results of that study are presented in Section 3. During the evaluation of existing channel conditions, several impaired reaches were identified and four general classes of impairments noted. The general categories of impairments were classified as indicated below:

- Channel degradation/incision;
- Riparian vegetation degradation:
- Bank erosion associated with channel migration and/or widening, and
- Barriers to fish passage or entrainment by irrigation diversions

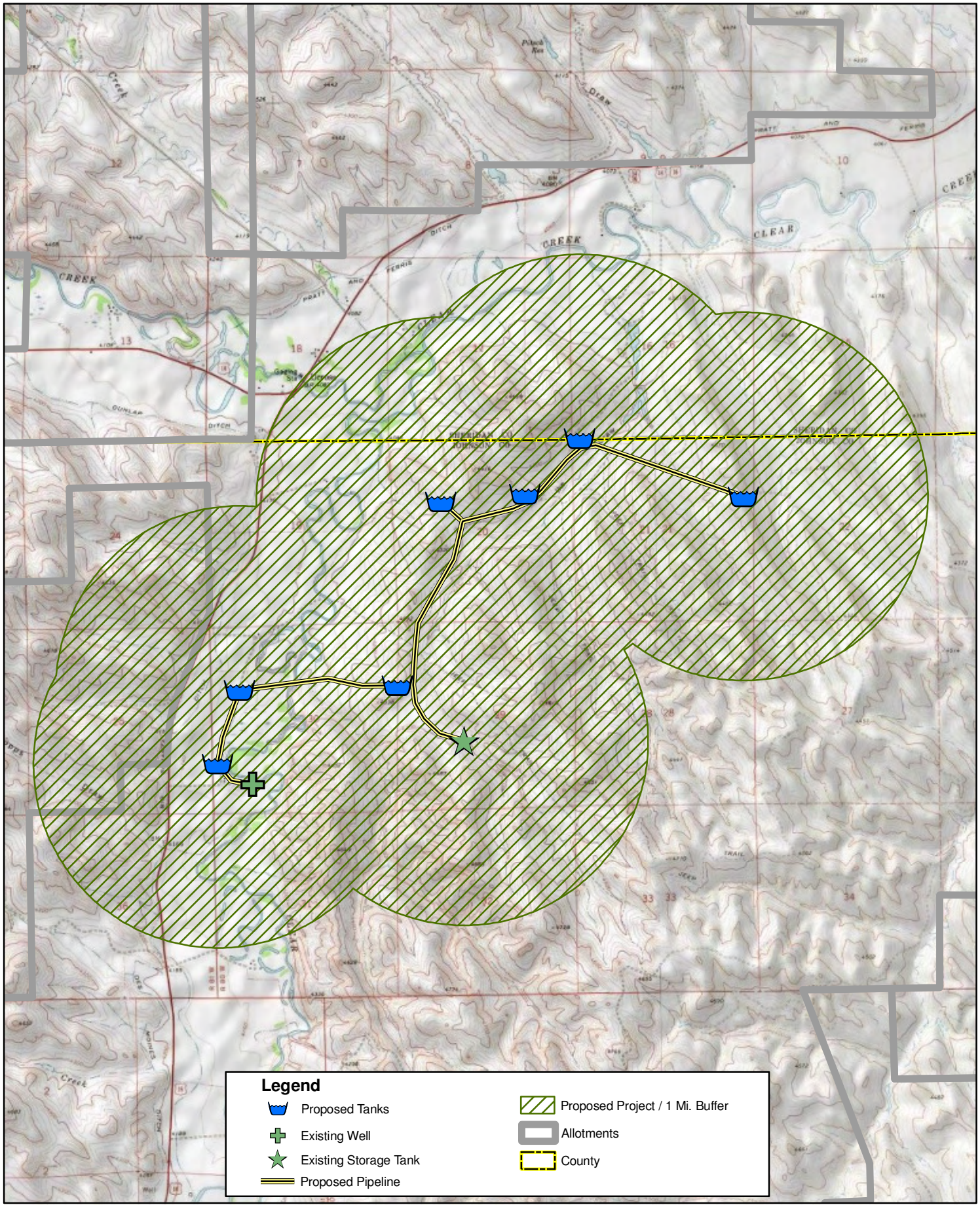


Figure 4.2-8. Upland Wildlife / Livestock Water Development Project 5: Vignaroli Pipeline Replacement

4.3.1 Stream Channel Restoration Strategies

Various approaches can be taken during channel restoration and stabilization efforts, including both "hard" engineering and "soft" approaches and combinations of the two. Examples of "hard" approaches would include construction of channel structures or reconstruction of channels themselves. The selection of the appropriate mitigation/restoration technique depends upon site-specific information and critical review of hydrologic and hydraulic data. Installation of an inappropriate type of structure or improper installation could exacerbate conditions.

For instance, methods of restoring incised channels may include construction of gradient restoration facilities (i.e., drop structures, check structures) within the incised channel. Figure 4.3-1 displays a diagram of a typical stream channel stabilization strategy for small channels where log check dams are placed in series within a problematic reach. Figure 4.3-2 shows an alternative form of stream stabilization: the rock filled gabion.

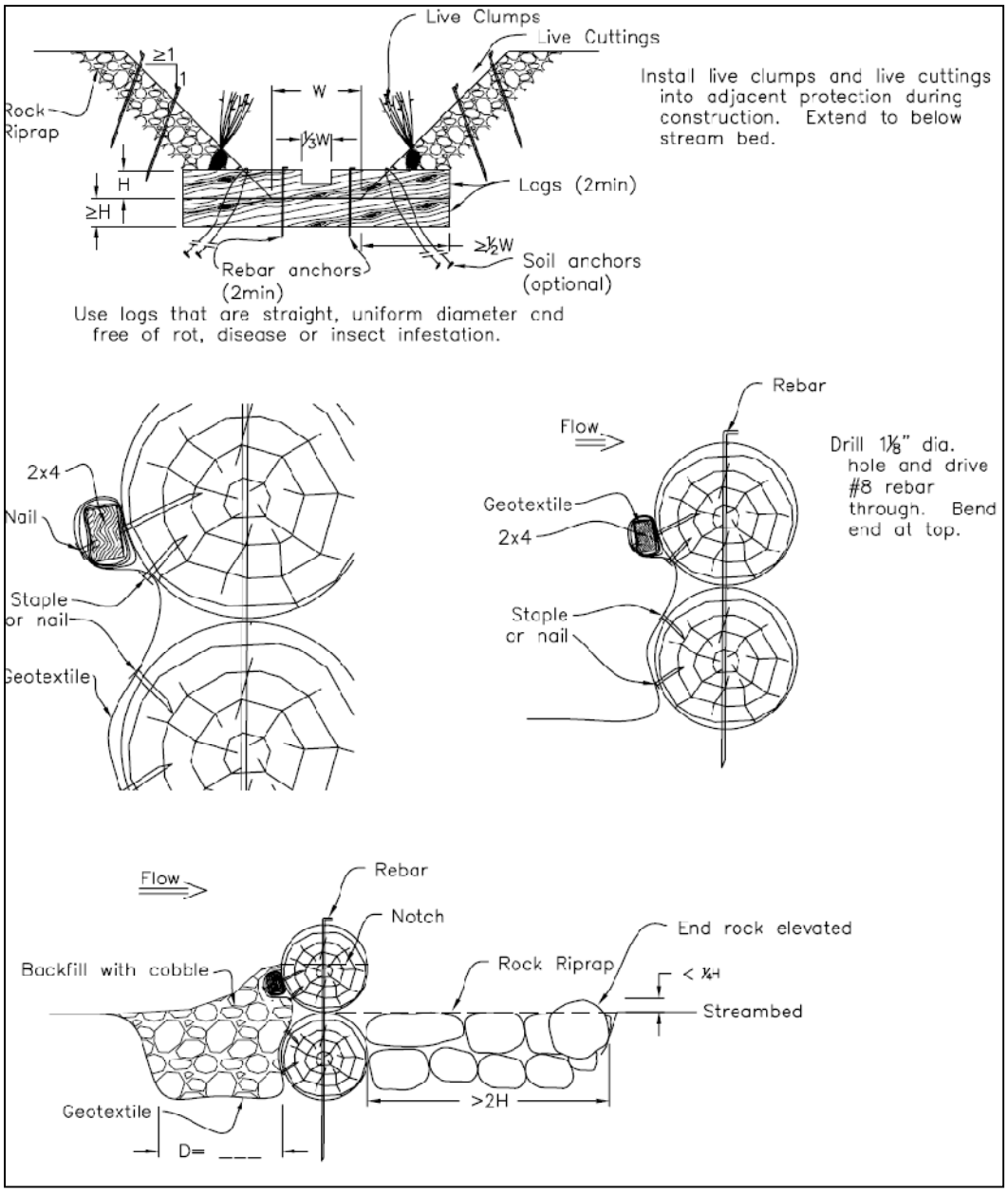


Figure 4.3-1. Conceptual Design: Log Check Dam

Figure 4.3-2 Stream Stabilization Structure:
Rock Filled Gabion

Examples of "soft" approaches include a variety of Best Management Practices (BMPs). Examples of potentially applicable BMPs designed for channel restoration activities include those that result in reducing or, at least temporarily, excluding wildlife and livestock from accessing designated riparian zones, establishment of riparian buffers, etc. The proposed and potential wildlife/livestock water developments discussed previously (and others that may be identified in the future) can be considered elements of a range management BMP that will help restore over time those areas of channel impairment. Figure 4.3-3 displays a photo of willow fascine installation. This strategy could be employed on many of the perennial channels or intermittent where sufficient flow exists to support the vegetation, in an effort to restore riparian habitat and stabilize streambanks.

Figure 4.3-3 Stream Stabilization Measure:
Willow Fascine Installation

These examples of "hard" and "soft" approaches represent both extremes of the continuum of channel restoration strategies that exist. In practice, it must be kept in mind that it is generally a combination of strategies, integrated into a cohesive plan that provides the most effective solution. Table 4.3-1 presents a summary of some of these channel restoration strategies which can be employed during future restoration efforts. Development of more specific projects and BMPs was beyond the scope of this Level I study. Such projects can be identified and developed on the basis of more detailed geomorphic analysis of impaired stream reaches.

Table 4.3-1 Summary of Potential Channel Stabilization/Restoration Techniques

Flow-Redirection Techniques	**Biotechnical Techniques**
Vanes	Woody Plantings
Groins	Herbaceous Cover
Buried Groins	Soil Reinforcement
Barbs	Coir Logs
Engineered Log Jams	Bank Reshaping
Drop Structures	**Internal Bank-Drainage Techniques**
Porous Weirs	Subsurface Drainage Systems
Structural Techniques	**Avulsion-Prevention Techniques**
Anchor Points	Floodplain Roughness
Roughness Trees	Floodplain Grade Control
Riprap	Floodplain Flow Spreaders
Log Toes	**Other Techniques**
Roughened-Rock Toes	Channel Modifications
Log Cribwalls	Riparian-Buffer Management
Manufactured Retention Systems	Spawning-Habitat Restoration
	Fish Ladders / bypass structures
	Fish Screens / entrainment prevention

If further study of reservoir storage is planned within the watershed, the potential effects of such storage on stream stability/geomorphic conditions should be evaluated in appropriate detail as part of those studies. This may also result in identification of further opportunities not only to minimize impacts of any such new storage, but to improve stream conditions with proper reservoir operations management and implementation of appropriate "hard" and/or "soft" measures as described above.

4.3.2 Stream Channel Components of the Watershed Management Plan

Based on the information presented above, the following items are presented for inclusion in the Clear Creek watershed management plan:

- Installation of stream channel degradation/incision mitigation measures based upon site-specific evaluation of conditions. Appropriate mitigation measures could be 'hard' engineering, 'soft' approaches, or combinations of both.

- Installation of stream bank erosion mitigation measures based upon site-specific evaluation of conditions. Appropriate mitigation measures could be 'hard' engineering, 'soft' approaches, or combinations of both.

- Rehabilitation/replacement of structures posing barriers to fish migration and / or entrainment.

Five specific instances of channel stability issues were identified in Section 3 and investigated at the request of the landowners. Development of remediation alternatives would require site-specific evaluations and designs which are beyond the scope of this level I investigation. However, typical remediation measures appropriate for these sites are provided below.

- Rock Creek at Last Chance Ditch: Remediation strategies at this location are consistent with irrigation rehabilitation methods. Consequently, this site is included in the irrigation rehabilitation section of the watershed management plan. As presented in Section 5, remediation at this site includes bank protection to reduce further erosion of the stream bank in conjunction with piping approximately 215 feet of the Last Chance Ditch to prevent ditch seepage from exacerbating the potential for bank failure.

- Piney Creek at Wilwauka Ranch: As discussed in Section 3, bank erosion and natural channel migration at this location threatens to cutoff a meander of the channel resulting in loss of pasture and irrigation diversion capabilities. Should the meander cutoff occur, an additional cutoff could occur downstream at the next meander bend. Bank protection measures such as J-hook vanes could reduce erosion and thereby reduce the chances of a cutoff occurring.

- Piney Creek at Ucross: This location on Piney Creek, located near its confluence with Clear Creek, is experiencing considerable bank erosion. Bank protection measures such as J-hook vanes could reduce erosion and thereby reduce the chances of a cutoff occurring. Streamflow concentrating structures, such as cross-vane weirs, could also be employed to deflect streamflow from the eroding bank.

- Clear Creek at Ladd Ditch: At this location, Clear Creek has cut off a meander which has resulted in problematic diversions for the Ladd Ditch. Remediation efforts at this location would likely require placement of cross vane weirs designed to restore the hydraulic gradient of the stream channel. A design objective of restoration efforts at this location would be to restore diversion capabilities of the Ladd Ditch headgate.

- Clear Creek at Lawrence Land Company: At this location, erosion of the right bank is resulting in loss of land and fence. Bank protection measures such as J-hook vanes could reduce erosion and thereby reduce the chances of a cutoff occurring. Streamflow concentrating structures, such as cross vane weirs, could also be employed to deflect streamflow from the eroding bank.

4.4 GRAZING MANAGEMENT OPPORTUNITIES

4.4.1 State and Transition Models

In Section 3, the ecological sites found within the watershed were presented and the concept of the ecological site description (ESD) was introduced. The ESD for a given ecological site contains a wealth of information pertaining to the site and its community. Within each ESD is a State and Transition model.

State and transition models describe the patterns, causes, and indicators of transitions between communities within an ecological site based upon the ecological site description (ESD). In a graphical form, they display information obtained from literature supplemented by the knowledge and experience of range scientists and managers. Basically, they display the response of a given ecological site to various range management practices or disturbances. They help to distinguish changes in vegetation and soils that are easily reversible versus changes that are subject to thresholds beyond which reversal is costly or unlikely. By being aware of the predicted response of a given ecological site to a treatment, the land manager can use this knowledge to best prescribe land management practices or treatments to direct the transition in a desirable direction. For instance, land management strategies can be prescribed which could result in restoration of the Historic Climax Plant Community (HCPC) under the right circumstances. Utilization of the ESDs and management tools provided within them requires site-specific evaluation of range conditions and management needs. The ESDs contain recommended management tools and strategies based upon typical conditions.

Based upon the analysis presented in Section 3, the four ecological sites most likely to be found within the Clear Creek Watershed are:

- Shallow Loamy 10-14 inch precipitation zone, Northern Plains
- Shallow Loamy 15-19 inch precipitation zone, Northern Plains
- Loamy 10-14 inch precipitation zone, Northern Plains
- Loamy 15-19 inch precipitation zone, Northern Plains

Note that the Shallow Loamy 10-14 inch precipitation zone and the Shallow Loamy 15-19 inch precipitation zone ESDs share identical State and Transition Models. Likewise, the Loamy 10-14 inch precipitation zone and the Loamy 15-19 inch precipitation zone ESDs are similar enough that there are no differences between their State and Transition Models

4.4.1.1 Shallow Loamy 10-14 inch / 15–19 precipitation zones, Northern Plains

The ESD for these two sites states the following:

> *"As this site deteriorates, species such as blue grama and big sagebrush will increase. Cool season grasses such as bluebunch wheatgrass and rhizomatous wheatgrasses will decrease in frequency and production."*

The State and Transition Model Diagram for these sites describes the common plant communities (states) that can occur on the site and the transitions between these communities (Figure 4.4-1). As indicated in the diagram, transitions or pathways leading to other plant communities are as follows:

- Protection from grazing and fire will convert this plant community to the Heavy Sagebrush Vegetation State.

- Moderate, continuous season-long grazing will convert the plant community to the Mixed Sagebrush/Grass Vegetation State.
- Frequent and severe grazing and brush management will convert the plant community to the Blue Grama Vegetation State.

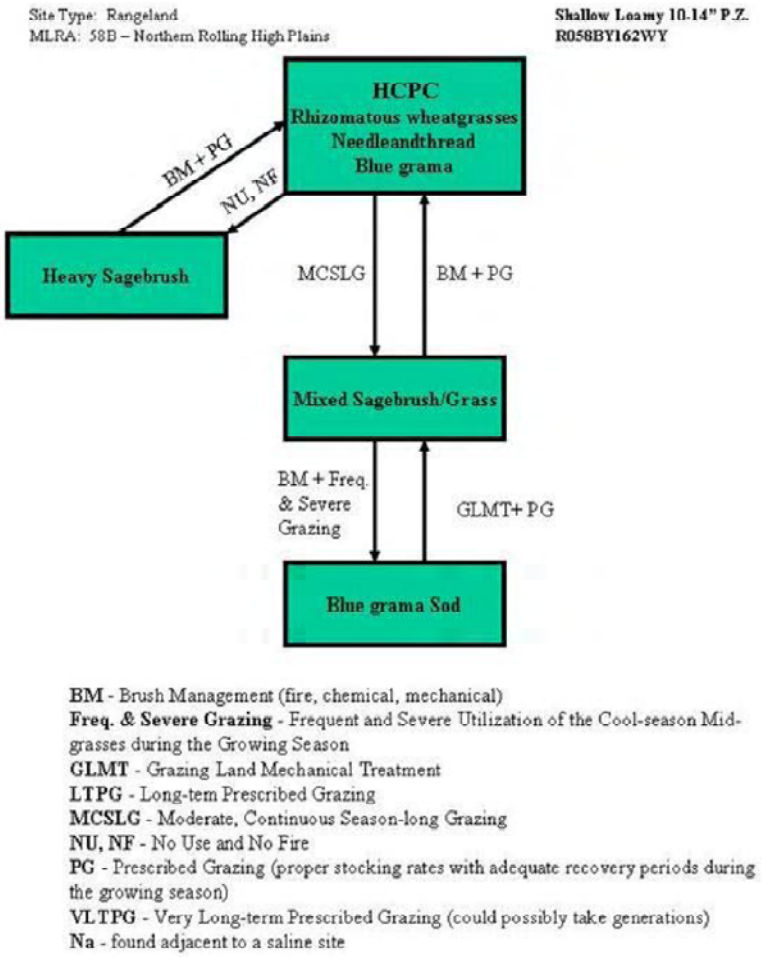


Figure 4.4-1 State and Transition Model for Shallow Loamy High Plains Ecological Sites

4.4.1.2 Loamy 10-14 inch / 15-19 inch precipitation zones, Northern Plains

The ESD for these two sites states the following:

"As this site deteriorates because of a combination of frequent and severe grazing, species such as blue grama and big sagebrush will increase. Cool-season grasses such as green needlegrass, needleandthread, and rhizomatous wheatgrasses will decrease in frequency and production. Big sagebrush may become dominant on some areas with an absence of fire. Wildfires are actively controlled in recent times so chemical control using herbicides has replaced the historic role of fire on this site. Recently, prescribed burning has regained some popularity. Due to the amount

and pattern of the precipitation, the big sagebrush component typically is not resilient once it has been removed if a healthy and vigorous stand of grass exists and is maintained. The exception to this is where the herbaceous component is severely degraded at the time of treatment, growing conditions are unfavorable after treatment, and/or recovery periods are inadequate."

The State and Transition Model Diagram for these sites illustrate the common plant communities (states) that can occur on the site and the transitions between these communities (Figure 4.4-2). As indicated in the diagram, transitions or pathways leading to other plant communities are as follows:

- No use and no fire for 20 years or more will convert this plant community to the Heavy Sagebrush Plant Community.
- Moderate, continuous season-long grazing will convert the plant community to the Mixed Sagebrush/Grass Plant Community.
- Moderate continuous season-long grazing, where greasewood occurs adjacent to the site, will convert the plant community to the Greasewood Plant Community.

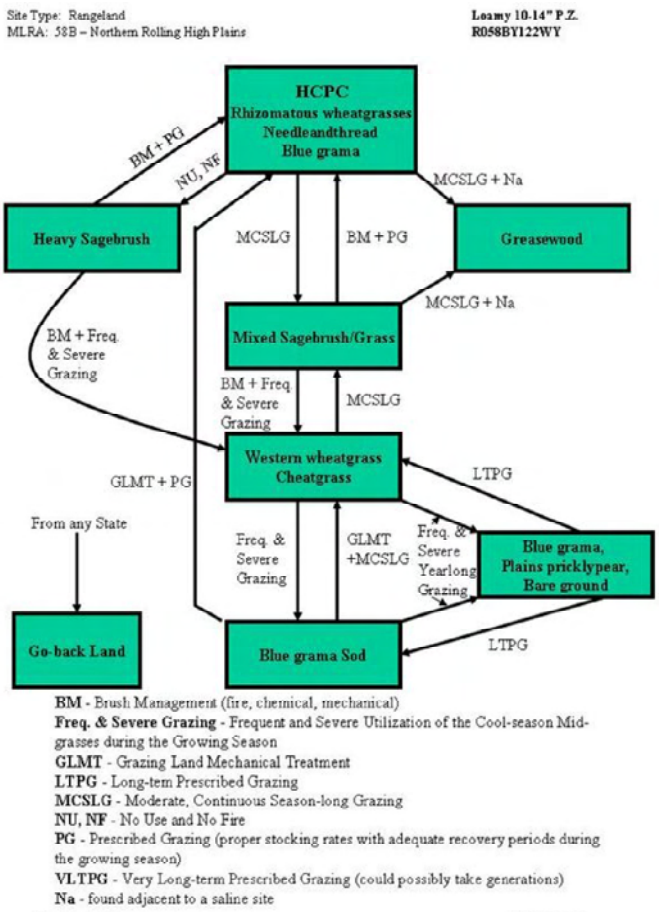


Figure 4.4-2 State and Transition Model for Loamy High Plains Ecological Sites

4.4.2 Range and Grazing Management Considerations

Based on the information presented above, the following items are presented for inclusion in the Clear Creek watershed management plan:

- Water developments can be used to expand grazing distribution to areas that do not currently have reliable water. Riparian area plant community condition can be enhanced by development of water into upland areas.
- Fencing to create pastures of similar ecological condition can enable a rest-rotation grazing system.
- Strategic salting and herding are other tools that can be used to enhance grazing distribution.
- Most range improvement practices which improve watershed condition, may also improve wildlife habitat. Wildlife needs should be considered when installing practices such as wildlife friendly fences, wildlife escape ramps from tanks, and wildlife watering facilities.
- Strategies recommended in the state and transition models associated with NRCS descriptions of the ecological sites found within the watershed should be adopted and employed to optimize range conditions through prescribed grazing management and best management practices.

These tools can be used to maintain and/or improve watershed function particularly when coupled with implementation of appropriate grazing management strategies.

4.5 OTHER UPLAND MANAGEMENT OPPORTUNITIES

4.5.1 Prescribed Fire

Prescribed fire can be used as a tool to restore conditions promoting desirable range species and reduction of invasive species and other species affecting rangeland production and watershed function. As a result of these treatments, production of desirable forage increases, benefiting both livestock and wildlife. Watershed values improve overall by decreasing bare ground, decreasing runoff, and improving infiltration, again to the benefit of wildlife and stock. Base flows in creeks sustained by groundwater discharges can extend later into the summer, benefiting the riparian environment and aquatic habitat in these reaches. Disadvantages of prescribed fire include temporary increases in rates of soil erosion and decreases in water quality, increases in soil temperature extremes, initial loss of vegetative productivity, reduction in soil moisture level, and requires a minimum of one growing season rest (BLM Rangeland Mechanical Treatment Guide). The BLM, through its Buffalo Field Office, implements about two or three prescribed burns annually covering 600 to 2,000 acres per year.

4.5.2 Mechanical Treatment

Mechanical treatments including chiseling or scalping, furrowing, and plowing and seeding may be considered as an alternative method of increasing vegetative production and improving watershed condition. Treatment feasibility could be considered where grazing management

systems cannot reach desired goals in a realistic time (BLM Rangeland Mechanical Treatment Guide). Advantages to mechanical treatments include increased vegetation production, diversity and vigor, increased soil moisture, improved vegetative ground cover, and can improve water quality. Disadvantages include the process is labor intensive and equipment and maintenance costs are high, livestock and wildlife as well as vehicles can be affected as furrows can impede movement, and runoff to reservoirs and other downstream uses can be reduced (BLM Rangeland Mechanical Treatment Guide). Other methods of mechanical rangeland treatment include aerating/seeding and Dixie harrowing/seeding. The LDCD's Sagebrush/Grassland Habitat Restoration Program has completed aeration and seeding on enrolled ranchlands to enhance sagebrush and grassland communities. The aeration/seeding process has also been used by the LDCD to enhance riparian sites for sage-grouse brood rearing. The aeration or Dixie harrow method is designed to diversify the age class of desirable shrub species and improve their productivity (BLM 2004). The method intends to remove the old, decadent sagebrush and leave desirable grasses, forbs, and young sagebrush mostly intact. It should be noted that mechanical treatment of sagebrush land should not be done in such a manner to adversely impact sage-grouse populations.

4.5.3 Invasive Species Treatment

The appropriate treatment strategy and method(s) depends on a large number of factors including: maturity stage of the infestation; density of the stand(s); predominance of tamarisk versus more desirable native species; location in the floodplain/overbank; accessibility; season/weather; etc. It is important to implement appropriate management practices to encourage development of healthy riparian and related vegetation in any areas in which tamarisk and/or Russian olive have been removed to prevent a return of the target species or invasion by other noxious weeds and undesirable plant species. It may also be desirable to plant appropriate species to replace lost wildlife habitat values (i.e., Silverleaf buffalo berry to replace Russian olive).

Both the Johnson County and Sheridan County Weed and Pest Control Districts have implemented programs to control the establishment and spread of invasive weed species. Through a cooperative venture between the landowner, the County Weed and Pest Districts, Conservation Districts and NRCS Buffalo Field Office, Integrated Pest Management Programs (IPMs) have been initiated targeting invasive species; specifically leafy spurge. Bio-agents were used in combination with light application rates of Tordon, as part of an Integrated Pest Management (IPM) program on several ranches. The objective was to use goats to stress leafy spurge and create an environment where flea beetles could be successful.

With respect to Russian Olive treatment and as presented in Section 3, the Lake DeSmet Conservation District (LDCD) and local NRCS office have worked on the management efforts of Russian Olive plants in recent years. LDCD has budgeted $50,000 over the past couple of years to aid in this effort. With this budget, the LDCD contracts with the Wyoming State Forestry Conservation Camp to cut large patches of Russian Olive plants. Previous efforts have been made in the areas along Clear Creek west of the Town of Buffalo. Additionally, these funds have

been used to hire private contractors using mechanical methods (ie., “Emasticator”). The District and NRCS plan to continue these efforts into the future to help prevent the spreading of these invasive trees. Following the cutting of all Russian Olive Trees, a chemical treatment is applied to the stump to prevent any “Suckers” from coming back and reviving the plant.

Likewise, the Johnson County Weed and Pest Control District will cost share up to 80% of chemical cost on private lands to treat the stumps once Russian Olive trees have been cleared. The Sheridan County Weed and Pest Control District has not been undertaking any efforts for the management of Russian Olive trees at this point.

The most effective overall strategy going forward would appear to be to assist the Districts in applying for additional grant funding, participate with in-kind efforts on work days and attend/support workshops and planning sessions.

V. Irrigation System Inventory and Rehabilitation

The Clear Creek watershed contains approximately 40,000 acres of irrigated lands served by surface water sources, and an additional 6,000 acres served by trans-basin diversions that originate in the watershed. Landowners have converted some deliveries to center pivot and side roll sprinklers; however, the majority of the watershed irrigation deliveries are flood irrigation. Gated pipe has also been implemented, in part, on systems.

Irrigated lands in the study area are primarily associated with forage production for livestock. Ranchers depend on irrigated lands to provide winter feed and summer grazing. The dominant crops within the study area are alfalfa, grass hay, and pasture grass. There are also small grains and corn production, but on a much lesser scale.

5.1 Irrigation System Inventory

5.1.1 Overview

Project personnel met with the Sheridan County and Lake DeSmet Conservation Districts at the beginning of the project. These interviews were conducted to identify ditch systems with known operational issues. In addition, signup sheets were present at the initial kickoff meeting and project open houses for landowners who had interest in the project. Interested irrigators were contacted and visited to discuss their operational issues, as well as potential improvements. The characterizations of each ditch system are presented below and were divided by drainage. Nearly all of the ditches within the basin are open channel, unlined earthen ditches.

A number of irrigation GIS layers were created during the Powder/Tongue River Basin Water Plan of 2002. Points of diversion, canals and ditches, and irrigated lands layers from this previous study were used as base layers for this irrigation assessment.

5.1.2 Ditch Characterization

The ditch characterizations are divided by drainage, and are in order starting at the most upstream diversion and working downstream. The characterizations identify location, diversion appropriation, irrigated acres, ditch type and deficiencies to the extent that the information could be collected. This was based on interviews, field visits, and previous reports such as the Powder/Tongue River Basin Plan, prepared for the Wyoming Water Development Commission (February 2002). Only systems that were visited are discussed below. Evaluated ditch locations can be referenced from the overview map, Figure 5.1-1. These ditch locations were digitized using the 2002 Powder/Tongue River Basin. Irrigated lands within the watershed are also included in Figure 5.1-1. Points of diversion, while included in system specific maps, are not included in Figure 5.1-1.

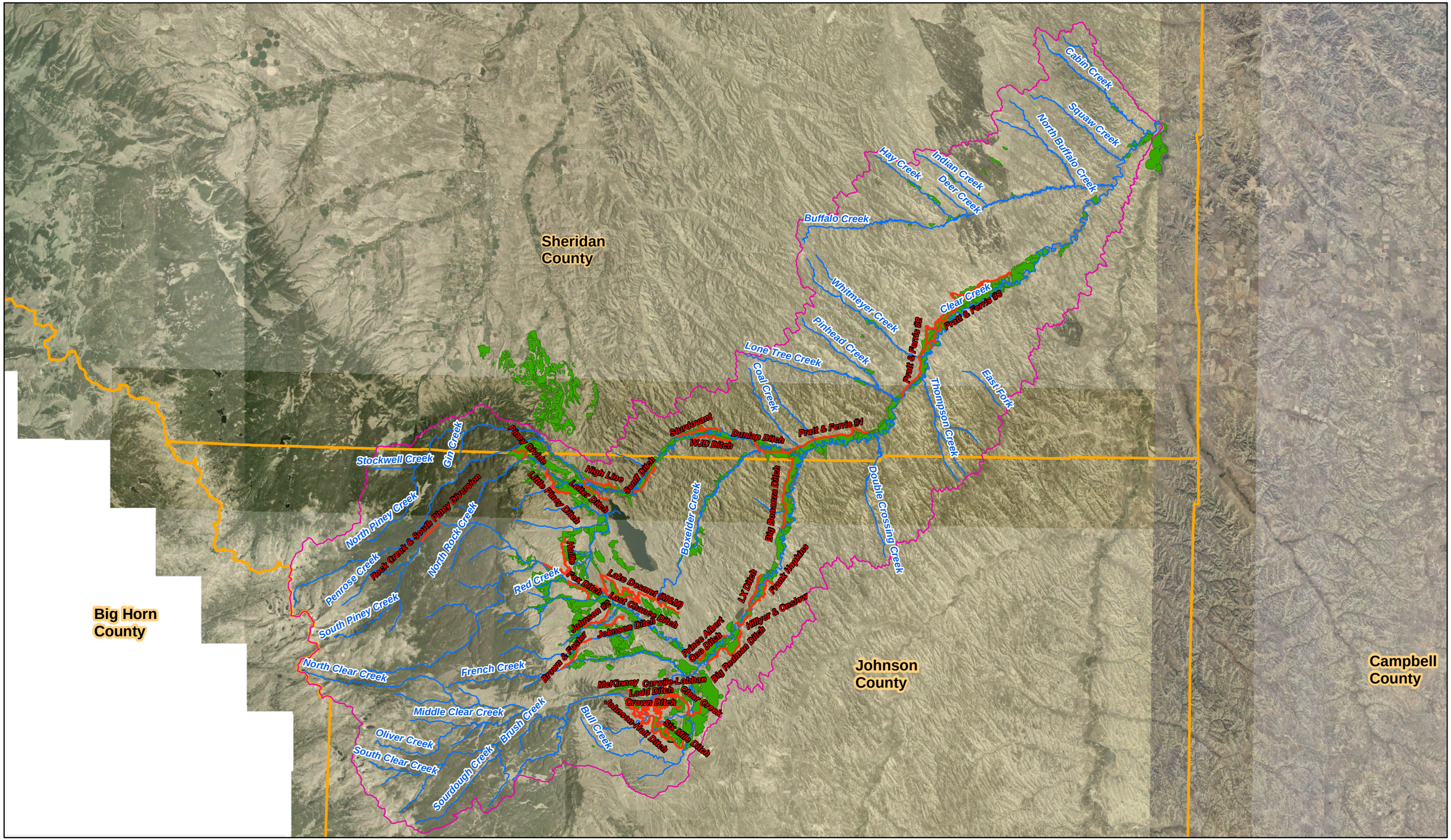


Figure 5.1-1
Clear Creek Irrigation Assessment Overview

5.1.3 Irrigation System Reports

The reports of the field inventories performed on the irrigation systems follow. The systems are grouped by drainage. The maps of the individual systems are in Appendix 5-D. The information sheets for each specific site or system are contained in Appendix 5-E.

5.1.3.1 Clear Creek Irrigation Systems

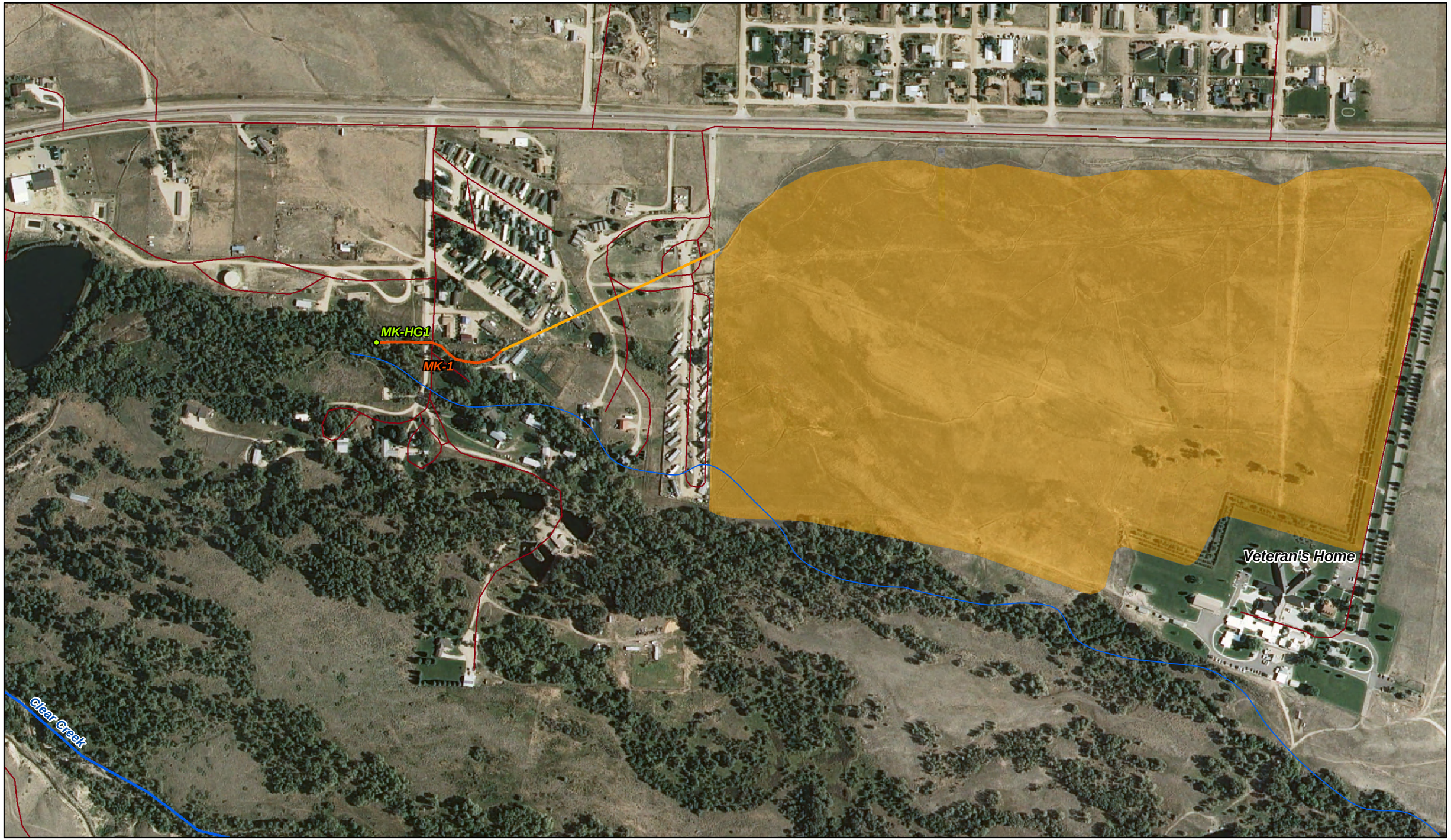
Ft. McKinney Ditch

Figure 5-D – 1

Structure Reports: MK-HG1, Appendix 5-E

Canal Reports: MK-1, Appendix 5-E

The Ft. McKinney ditch irrigates state lands west of the Veteran's Home, which are leased by the irrigator. The irrigator indicated that the ditch has the oldest water right on Clear Creek. This ditch diverts approximately 4 cfs from a side channel of Clear Creek that flows down from the water treatment plant, according to irrigator interviews. The head gate consists of a concrete throat structure with a spillway notch, and 24" steel slide gate. The headgate does not seal well, and the irrigator indicated that he has to use canvas or plastic to seal off the gate. The ditch section immediately downstream of the headgate is very wide and deep compared to the flow that it conveys. This has resulted in this section being choked with cattails. This may be due to a high crossing culvert under Turkey Lane. Downstream of Turkey Lane, the ditch flows for approximately 600 feet before entering a pipeline that conveys flows across the trailer park and camp ground. It then flows into a concrete division box that allows flows to waste to the ditch, serve the uppermost main lateral, or supply flow to a pipeline. This pipeline was funded through the NRCS and provides the irrigator with water to a series of laterals served by risers off of the pipeline.



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Miles

Legend

- Associated Irrigated Lands
- Evaluated Structures
- Streams
- Roads
- McKinney Pipeline
- McKinney Ditch

Figure 5-D - 1
Clear Creek Irrigation Assessment
Fort McKinney Ditch

Local Name: Fort McKinney Headgate

HKM ID:	**MK-HG1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Fort McKinney Ditch**			***Structure Type:***	**Headgate**
UTM Zone:	**13**	***Coordinates:***	**360011.8, 4910504.1**	***Total # of Photos:***	**4**

Notes: This structure is the headgate for the Fort McKinney ditch headgate consists of a concrete throat structure with a spillway notch, and 24" steel slide gate. The headgate does not seal well, and the irrigator indicated that he has to use canvas or plastic to seal off the gate. The ditch section immediately downstream of the headgate is very wide and deep compared to the flow that it conveys. This has resulted in this section being choked with cattails. This ditch section is discussed in the canal evaluation. Remediation for the headgate includes a new gate as well as a trash rack. Replacement assumes a 'replace-in-kind' scenario.

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	27,000.0	$	$1.03	$27,810.00
2.5-ft x 2.5-ft Slide Gate	1.0	Each	$3,072.83	$3,072.83
Trash Rack	10.0	SF	$34.22	$342.20
			Total Field Cost:	$31,225.03
			Active Dewatering: 7.5%	$2,341.88
			Contingencies: 10%	$3,122.50
			Subtotal:	$36,689.41
			Engineering: 10%	$3,668.94
			Mobilization: 10%	$3,668.94
			Total Rehabilitation Cost:	**$44,027.29**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	27,000.0	$	$1.03	$27,810.00
CIP Concrete	3.0	CY	$1,135.47	$3,406.41
2.5-ft x 2.5-ft Slide Gate	1.0	Each	$3,072.83	$3,072.83
Concrete Demo. & Disposal	3.0	CY	$209.94	$629.82
RCP 30" D	4.0	FT	$99.93	$399.72
Trash Rack	10.0	SF	$34.22	$342.20
Structural Fill	8.0	CY	$36.65	$293.20
Structural Excavation	8.0	CY	$22.95	$183.60
Check Guides: Replace	6.0	FT	$19.87	$119.22
			Total Field Cost:	$36,257.00
			Active Dewatering: 7.5%	$2,719.28
			Contingencies: 10%	$3,625.70
			Subtotal:	$42,601.98
			Engineering: 10%	$4,260.20
			Mobilization: 10%	$4,260.20
			Current Replacement Value (CRV):	**$51,122.37**

Facilities Condition Index (FCI):	0.86
Asset Priority Index (API):	60
Remediation Priority Index (RPI):	52

Deficiency

Category: CMDM

Rating: Minor

Pipeline Rehabilitation Report

HKM ID:	MK-1	Division:	Clear Creek		
Canal Name:	Fort McKinney Ditch [MK-1]	Length:	600 ft	Total # of Photos:	7

Notes: This section is an open channel, unlined reach that is from the headgate to the start of the piped reach. This section is very wide and deep compared to the flow that it conveys. This has resulted in this section being choked with cattails. This may be due to a high crossing culvert under Turkey Lane. Because there is a piped section downstream, it is recommended that the reach be piped from the headgate and tie into the existing pipeline.

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 18" Pipe	600.0	FT	$21.93	$13,158.00

Total Field Cost:		$13,158.00
Contingencies:	10%	$1,315.80
Subtotal:		$14,473.80
Engineering:	10%	$1,447.38
Mobilization:	10%	$1,447.38
Total Rehabilitation Cost:		**$17,368.56**
Average Rehabilitation Cost per Foot:		**$28.95**

Deficiency

Category: CMDM

Rating: Serious

Johnson Holt Ditch

Figure 5-D – 2
Structure Reports: JH-SPN1 / JH-HG1, Appendix 5-E
Canal Reports: JH-1 / JH-2, Appendix 5-E
Concept Improvements: Section 5.5.1

This ditch diverts out of Clear Creek, southwest of Buffalo. This ditch has an appropriation of 22.4 cfs and serves approximately 1,570 acres. It was indicated that the ditch is usually shut off in July due to a junior water right. The head gate consists of a single 4.2 x 2.6-foot rectangular steel gate operated with Waterman-type screw, mounted to a concrete headwall. Interviews indicated that the channel upstream of the head gate has to be cleaned every few years due to sediment accumulation. There are no fish screens or associated fish structures to keep aquatic life from entering the system.

The ditch is an unlined earthen ditch that flows southeast from the diversion and, apart from serving approximately 55 acres just downstream of the diversion, flows approximately five miles without a turnout. Interviews with landowners indicated that the canal can no longer carry its full appropriation due to canal constrictions. This appears to be due to the introduction of sediment into the system. The ditch crosses 'Sand Draw' and intercepts all storm runoff from this drainage, which introduces high sediment loads. This could also be a point of seepage concern. There is no flume or siphon to separate the irrigation water from the runoff flowing down this drainage. This is also a ditch safety issue, as the ditch bank could be washed out by large storm flows. The final point of sediment contribution comes from a cut section through a hillside. It appears that the ditch was cut through a hillside to eliminate approximately 1.75 miles of ditch conveyance. This benefits conservation, but the cut section has never been stabilized, and introduces sediment into the canal during storm events.

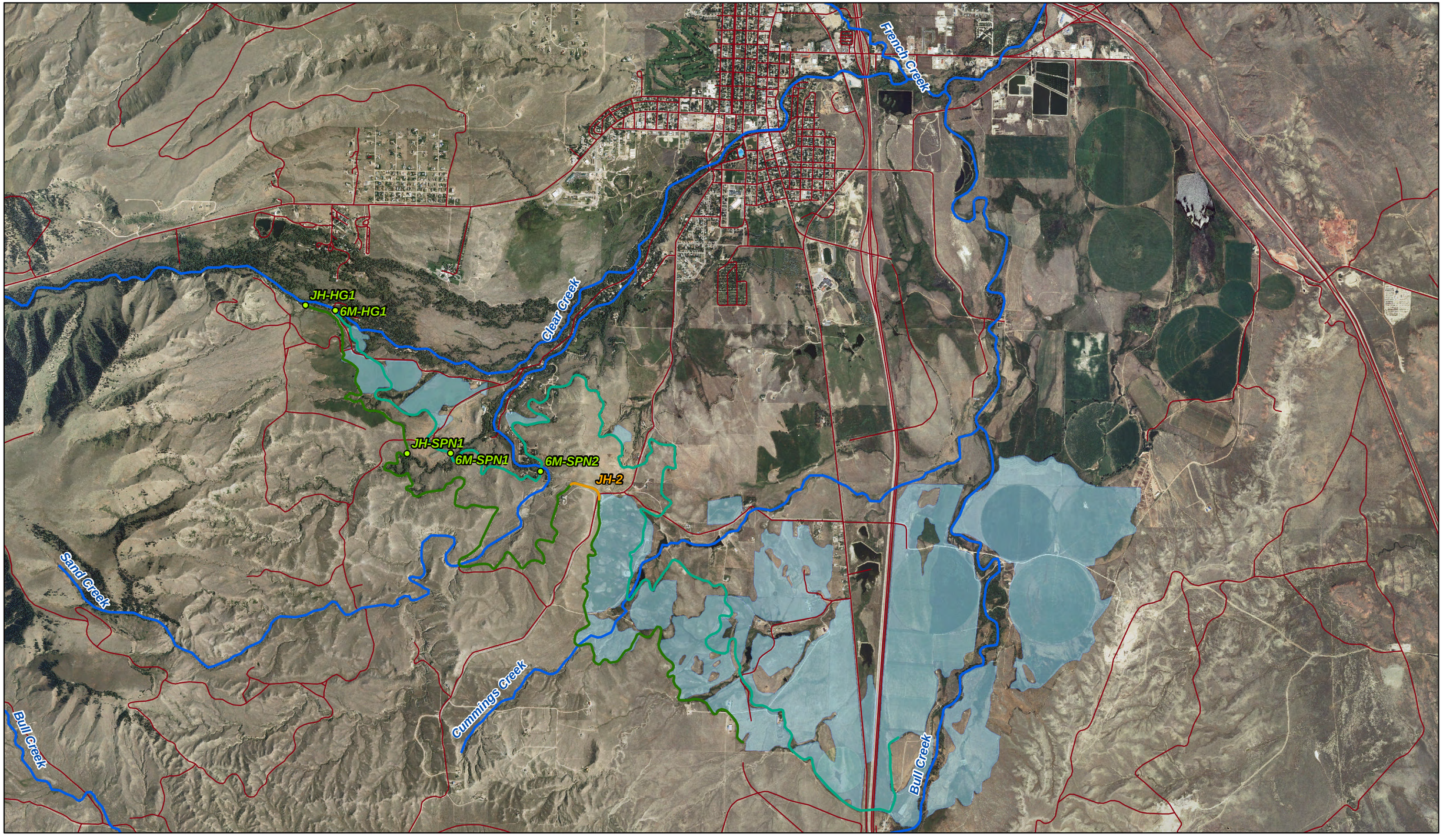
Six Mile Ditch

Figure 5-D – 2
Structure Reports: 6M-HG1 / 6M-SPN2, Appendix 5-E
Canal Reports: 6M-1, Appendix 5-E
Concept Improvements: Section 5.5.1

The Six Mile Ditch diverts out of Clear Creek approximately 0.2 miles downstream of the Johnson Holt Diversion. The Six Mile Ditch has an appropriation of approximately 29.5 cfs, though they typically only run 16 to 20 cfs. It serves approximately 2,060 acres. The head gate consists of a single 3.5 x 5.3-foot rectangular steel gate operated with a Waterman-type screw. The gate is mounted to a concrete headwall and is adjacent to a concrete rock dam. There are no fish screens associated with the structure. Interviews indicated that the head gate operates well, but the stream channel has cut down to the point that it is difficult to divert enough water during the late irrigation season.

The unlined earthen ditch flows southeast from the diversion, paralleling the Johnson Holt Ditch. The ditch flows for over seven miles, and serves a total of approximately 100 acres, before it gets to its larger land appropriations. There are three siphons on the ditch

that allow the ditch to cross Sand Draw, Sand Creek, and Cummings Creek without intercepting the runoff water into the irrigation system. The first siphon, identified on the map as 6M-SPN1 over Sand Draw, is a 27" steel siphon. It had previously begun to leak, but was patched. The landowner indicated that it is scheduled for repair by lining it with polyethylene pipe. For this reason, no action is recommended, and no structure report was developed. The second siphon, 6M-SPN2 over Sand Creek, is in good condition, but was designed to carry only the ditch appropriation. This introduces safety issues, as a large storm event could contribute enough flows to the ditch that the ditch banks could overtop upstream of this structure. The final siphon was in good condition with no issues. It is not detailed on the map. The tail end of the ditch serves approximately 1,150 acres. Nearly all of this acreage is irrigated by center pivot or side roll sprinkler, and nearly all of the sprinklers are gravity fed.



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Miles

Legend

- Evaluated Structures
- Roads
- Johnson-Holt Ditch
- Lands served by selected ditches
- Six Mile Ditch
- Sediment Deposition Canal Section
- Streams

Figure 5-D - 2
Clear Creek Irrigation Assessment
Johnson Holt and Six Mile Ditches

Local Name: Johnson Holt Headgate

HKM ID:	**JH-HG1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Johnson Holt**			***Structure Type:***	**Headgate**
UTM Zone:	**13**	***Coordinates:***	**359818.3, 4909762.4**	***Total # of Photos:***	**5**

Notes: This structure is the Johnson Holt headgate. The head gate consists of a single 4.2 x 2.6-foot rectangular steel gate operated with Waterman-type screw, mounted to a concrete headwall. This is adjacent to a rock dam. Field visits indicated that the headgate is served by a side channel of the creek. Interviews indicated that the channel upstream of the headgate has to be cleaned every few years due to sediment accumulation. Relocating the headgate upstream to the main channel of the creek would be beneficial by an operational/maintenance stand point. Remediation costs assume that the headgate will stay in the same location. Installation of a sluice gate that will return flow from the side channel to the creek is recommended to help eliminate the sediment accumulation. This will be mounted on a cast in place concrete head wall. In addition, a trash rack needs to be added to the headgate. Replacement assumes that the headgate is relocated approximately 300 feet upstream and installed with a rock vane diversion. The ditch flows would then be piped to the existing ditch. Miscellaneous replacement costs reflect a fish screen structure.

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	81,000.0	$	$1.03	$83,430.00
24" Diameter Canal Gate	1.0	Each	$2,868.20	$2,868.20
RCP 24" D	25.0	FT	$89.40	$2,235.00
CIP Concrete	1.0	CY	$1,135.47	$1,135.47
Trash Rack	30.0	SF	$34.22	$1,026.60
Riprap Bank Protection	2.0	CY	$55.40	$110.80
Structural Fill	2.0	CY	$36.65	$73.30
Structural Excavation	2.0	CY	$22.95	$45.90
			Total Field Cost:	$90,925.27
			Active Dewatering: 7.5%	$6,819.40
			Contingencies: 10%	$9,092.53
			Subtotal:	$106,837.19
			Engineering: 15%	$16,025.58
			Mobilization: 10%	$10,683.72
			Total Rehabilitation Cost:	**$133,546.49**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	81,000.0	$	$1.03	$83,430.00
RCP 36" D	320.0	FT	$132.48	$42,393.60
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
Stream Control (Medium)	1.0	Each	$27,559.61	$27,559.61
3-ft x 3-ft Slide Gate	2.0	Each	$3,728.89	$7,457.78
CIP Concrete	5.0	CY	$1,135.47	$5,677.35
Trash Rack	80.0	SF	$34.22	$2,737.60
Structural Fill	30.0	CY	$36.65	$1,099.50
Handrail	16.0	FT	$50.71	$811.36
Structural Excavation	30.0	CY	$22.95	$688.50
Riprap Bank Protection	2.0	CY	$55.40	$110.80
			Total Field Cost:	$202,866.10
			Active Dewatering: 7.5%	$15,214.96
			Contingencies: 10%	$20,286.61
			Subtotal:	$238,367.67
			Engineering: 15%	$35,755.15
			Mobilization: 10%	$23,836.77
			Current Replacement Value (CRV):	**$297,959.59**

Facilities Condition Index (FCI):	0.45
Asset Priority Index (API):	80
Remediation Priority Index (RPI):	36

Deficiency

Category: CRPdm

Rating: Serious

Local Name: Sand Draw Crossing

HKM ID:	**JH-SPN1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Johnson Holt**			***Structure Type:***	**Siphon**
UTM Zone:	**13**	***Coordinates:***	**360876.8, 4908221.0**	***Total # of Photos:***	**3**

Notes: This location on the Johnson Holt ditch is a site where the ditch crosses a drainage, referred to locally as 'Sand Draw'. There is no flume for the ditch or under drain for the drainage, so the ditch intercepts the storm runoff. This water carries significant sediment loads. This is conveyed directly into the ditch which can cause restriction points and significant sediment in the ditch. The ditch should be put in a siphon to eliminate these sediment loads into the ditch.

Remediation Assessment

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
RCP 36" D	250.0	FT	$132.48	$33,120.00
CIP Concrete	5.0	CY	$1,135.47	$5,677.35
Trash Rack	30.0	SF	$34.22	$1,026.60
Structural Fill	8.0	CY	$36.65	$293.20
Structural Excavation	8.0	CY	$22.95	$183.60
			Total Field Cost:	$40,300.75
			Contingencies: 10%	$4,030.08
			Subtotal:	$44,330.83
			Engineering: 10%	$4,433.08
			Mobilization: 10%	$4,433.08
			Current Replacement Value (CRV):	**$53,196.99**

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	70
Remediation Priority Index (RPI):	70

Deficiency

Category: CMDM

Rating: Critical

Cleaning/Reshaping Report

HKM ID:	JH-1	Division:	Clear Creek		
Canal Name:	Johnson Holt [JH-1]	Length:	43,630 ft	Total # of Photos:	2
Notes:	This reach represents cleaning costs associated with the Johnson Holt ditch. This ditch did not have significant seepage areas, but did has sediment issues. These are addressed in other Johnson Holt sections. Cleaning costs assume a cross-section length of 12-feet.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	58,200.0	SY	$0.62	$36,084.00
			Total Field Cost:	$36,084.00
			Contingencies: 10%	$3,608.40
			Subtotal:	$39,692.40
			Engineering: 0%	$0.00
			Mobilization: 10%	$3,969.24
			Total Rehabilitation Cost:	**$43,661.64**
			Average Rehabilitation Cost per Foot:	**$1.00**

Deficiency

Category: C&ODM

Rating: Minor

Sediment Deposition Report

HKM ID:	JH-2	Division:	Clear Creek		
Canal Name:	Johnson Holt [JH-1]	Length:	1,250 ft	Total # of Photos:	3

Notes: This reach passes through a cut section through a hill. It appears that the ditch was cut through a hillside to eliminate approximately 1.75 miles of ditch conveyance. This benefits conservation, but the cut section has never been stabilized, and introduces sands into the canal during storm events. Significant sediment is deposited downstream. Remediation assumes the installation of a pipe through this section, as well as earth work to reduce the height of the cut. The cut material should be used to cover the pipe. A concrete headwall is assumed that the inlet and outlet, as well as a trash rack at the upstream end of the pipe.

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 24" Pipe	1,250.0	FT	$38.03	$47,537.50
Unclassified Excavation	1,500.0	CY	$2.59	$3,885.00
CIP Concrete	1.0	CY	$1,135.47	$1,135.47
Trash Rack	10.0	SF	$34.22	$342.20
Structural Fill	2.0	CY	$36.65	$73.30
Structural Excavation	2.0	CY	$22.95	$45.90

Total Field Cost:		$53,019.37
Contingencies:	10%	$5,301.94
Subtotal:		$58,321.31
Engineering:	10%	$5,832.13
Mobilization:	10%	$5,832.13
Total Rehabilitation Cost:		**$69,985.57**
Average Rehabilitation Cost per Foot:		**$55.99**

Deficiency

Category: CMDM

Rating: Serious

Local Name: Six Mile Headgate

HKM ID:	**6M-HG1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Six Mile**			***Structure Type:***	**Headgate**
UTM Zone:	**13**	***Coordinates:***	**360129.1, 4909709.1**	***Total # of Photos:***	**5**

Notes: The Six Mile Ditch diverts out of Clear Creek approximately 0.2 miles downstream of the Johnson Holt Diversion. The Six Mile Ditch has an appropriation of approximately 29.5 cfs, though they typically only run 16 to 20 cfs, and serves approximately 2,060 acres. The head gate consists of a single 3.5 x 5.3-foot rectangular steel gate operated with a Waterman-type screw. The gate is mounted to a concrete headwall and is adjacent to a concrete rock dam. There are no fish screens associated with the structure. Interviews indicated that the head gate operates well, but the stream channel has cut down to the point that it is difficult to divert enough water during the late irrigation season. Remediation for this structure includes a trash rack and rock vane to aid in diversion. Safety features including handrail and walkway should be installed. Miscellaneous costs reflect the costs of a screening structure, as well as the rated fish screen.

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	105,000.0	$	$1.03	$108,150.00
Trash Rack	24.0	SF	$34.22	$821.28
Walkway (Expanded Steel)	15.0	SF	$17.95	$269.25
Handrail	5.0	FT	$50.71	$253.55
			Total Field Cost:	$109,494.08
			Active Dewatering: 7.5%	$8,212.06
			Contingencies: 10%	$10,949.41
			Subtotal:	$128,655.54
			Engineering: 10%	$12,865.55
			Mobilization: 10%	$12,865.55
			Total Rehabilitation Cost:	**$154,386.65**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	105,000.0	$	$1.03	$108,150.00
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
Stream Control (Medium)	1.0	Each	$27,559.61	$27,559.61
4-ft x 4-ft Slide Gate	1.0	Each	$6,460.84	$6,460.84
NRCS Concrete Check (4'x4' Notch)	1.0	Each	$6,142.94	$6,142.94
Trash Rack	24.0	SF	$34.22	$821.28
Structure Removal: Check (15')	1.0	Each	$756.16	$756.16
Walkway (Expanded Steel)	15.0	SF	$17.95	$269.25
Handrail	5.0	FT	$50.71	$253.55
			Total Field Cost:	$181,313.63
			Active Dewatering: 7.5%	$13,598.52
			Contingencies: 10%	$18,131.36
			Subtotal:	$213,043.52
			Engineering: 10%	$21,304.35
			Mobilization: 10%	$21,304.35
			Current Replacement Value (CRV):	**$255,652.22**

Facilities Condition Index (FCI):	0.6
Asset Priority Index (API):	90
Remediation Priority Index (RPI):	54

Deficiency

Category: CHSci

Rating: Serious

Local Name: Sand Creek Siphon

HKM ID:	**6M-SPN2**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Six Mile**			***Structure Type:***	**Siphon**
UTM Zone:	**13**	***Coordinates:***	**362266.0, 4908035.7**	***Total # of Photos:***	**3**

Notes: This siphon is the second siphon on the Six Mile Ditch. The 30" steel siphon conveys water across Sand Creek and is in good condition, however; it was designed to carry only the ditch appropriation. This introduces safety issues, as a large storm event could contribute enough flows to the ditch, that the ditch banks could overtop upstream of this structure and wash out the ditch. It is recommended that a 30" siphon be installed next to the existing siphon. This would allow for double appropriation flows if they are available, as well as reduce the risk of the siphon overtopping during large storm events. Replacement assumes an upsized RCP siphon.

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
RCP 30" D	500.0	FT	$99.93	$49,965.00
CIP Concrete	3.0	CY	$1,135.47	$3,406.41
Trash Rack	30.0	SF	$34.22	$1,026.60
Structural Fill	10.0	CY	$36.65	$366.50
Structural Excavation	10.0	CY	$22.95	$229.50
			Total Field Cost:	$54,994.01
			Contingencies: 10%	$5,499.40
			Subtotal:	$60,493.41
			Engineering: 10%	$6,049.34
			Mobilization: 10%	$6,049.34
			Total Rehabilitation Cost:	**$72,592.09**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
RCP 42" D	500.0	FT	$176.14	$88,070.00
Precast Turnout	1.0	Each	$4,680.48	$4,680.48
CIP Concrete	4.0	CY	$1,135.47	$4,541.88
Trash Rack	40.0	SF	$34.22	$1,368.80
Structural Fill	15.0	CY	$36.65	$549.75
Structural Excavation	15.0	CY	$22.95	$344.25
			Total Field Cost:	$99,555.16
			Contingencies: 10%	$9,955.52
			Subtotal:	$109,510.68
			Engineering: 10%	$10,951.07
			Mobilization: 10%	$10,951.07
			Current Replacement Value (CRV):	**$131,412.81**

Facilities Condition Index (FCI):	0.55
Asset Priority Index (API):	80
Remediation Priority Index (RPI):	44

Deficiency

Category: CMDM

Rating: Serious

Cleaning/Reshaping Report

HKM ID:	6M-1	Division:	Clear Creek		
Canal Name:	Six Mile [6M-1]	Length:	55,200 ft	Total # of Photos:	1
Notes:	This reach reflects the cleaning costs for the Six Mile ditch. Landowner interviews indicated that the Six Mile ditch does not have any areas of significant seepage, and typically operates well. The beginning of the ditch conveys water for approximately six miles without a significant delivery. Evaporation and seepage losses could be reduced by lining this section; however, losses were not identified as causing concern. The average cross-section length was estimated to be 14-feet.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	86,000.0	SY	$0.62	$53,320.00

Total Field Cost:		$53,320.00
Contingencies:	10%	$5,332.00
Subtotal:		$58,652.00
Engineering:	0%	$0.00
Mobilization:	10%	$5,865.20
Total Rehabilitation Cost:		**$64,517.20**
Average Rehabilitation Cost per Foot:		**$1.17**

Deficiency

Category: C&ODM

Rating: Minor

Crown Ditch

Figure 5-D – 3
Structure Reports: CD-CH1 / CD-CH2, Appendix 5-E
Canal Reports: recommendations addressed in Section 5.5
Concept Improvements: Section 5.5.2

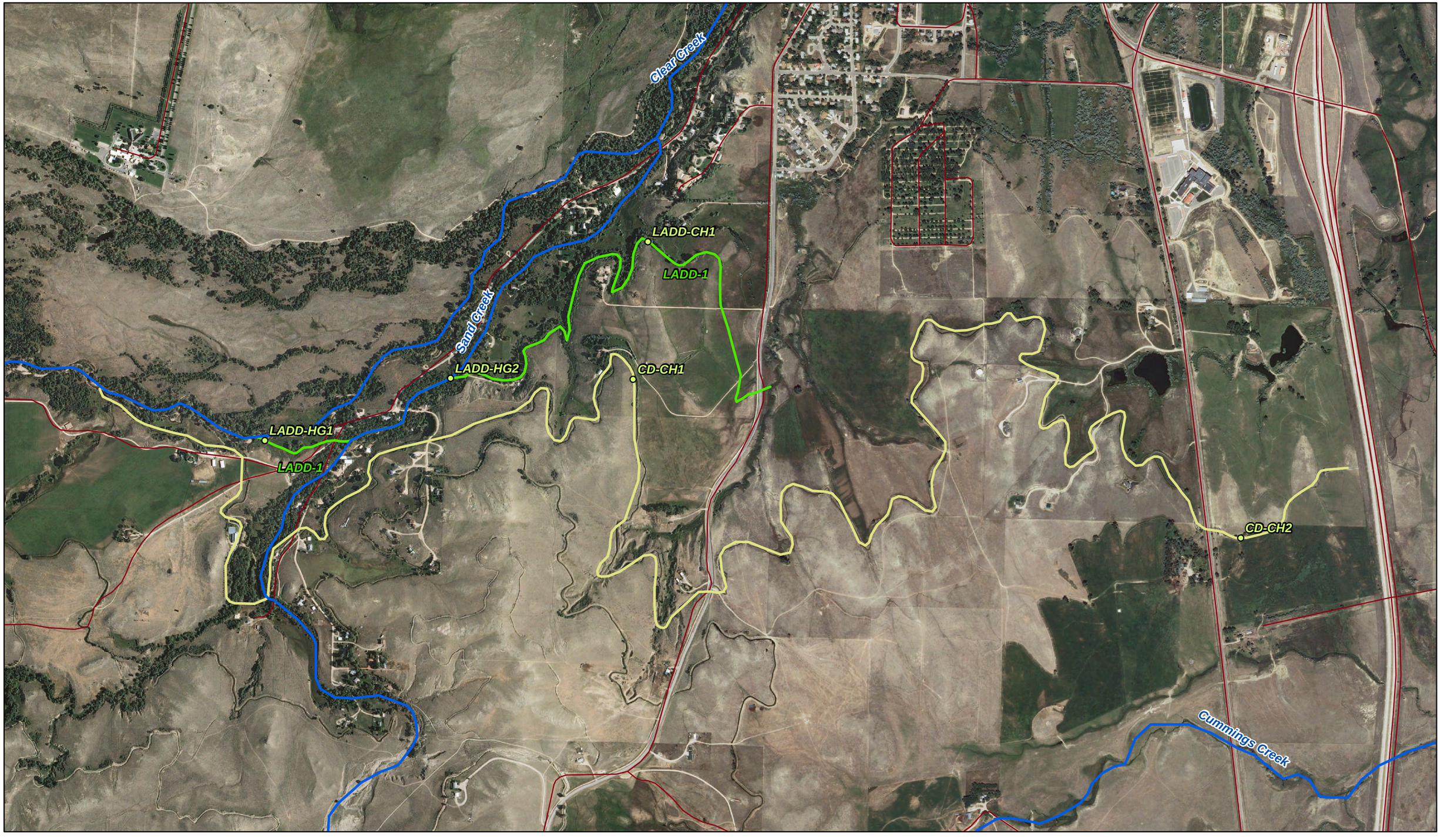
The Crown Ditch diverts out of Clear Creek below the Six Mile diversion. The ditch has a direct flow right of 17.8 cfs. Due to its size and location, it would be beneficial to combine the Ladd and Carwile Lobban Ditches into the Crown Ditch. This would reduce losses associated with seepage and wetting two additional ditches. Associated lands would be served by turnouts from the Crown Ditch to the irrigated lands below. This is discussed in the conceptual design section below. There is significant right stream bank erosion downstream of the headgate. It developed two years ago during high flows. Some remediation has been done, but more work is needed.

Ladd Ditch

Figure 5-D – 3
Structure Reports: LADD-HG1 / LADD-CH1, Appendix 5-E
Canal Reports: LADD-1, Appendix 5-E
Concept Improvements: Section 5.5.2

The Ladd Ditch is a small ditch that diverts out of Clear Creek approximately 0.3 miles below the Crown Ditch Diversion. According to an irrigator interview, the ditch typically runs approximately 4 cfs. The ditch diverts out of Clear Creek and conveys flows in an unlined earthen ditch for approximately 0.2 miles where it flows into Sand Creek. This reach of ditch needs cleaning. In addition, the creek flooded a few years ago and cut off the ox bow on which the diversion is located. Landowners had to create a rock diversion berm to route flows back to the existing headgate. This headgate is a 30" steel slide gate mounted on a concrete headwall. The gate is very leaky, and a notch in the berm had to be excavated last winter to block flow to the headgate and allow water to return to the creek. Ditch flows are conveyed in Sand Creek for approximately 0.3 miles, where they are diverted into the Ladd Ditch. The headgate at this site (LADD-HG2) is a 15" screw gate mounted on a concrete headwall, with a concrete check bay across the creek. This headgate was replaced approximately 10 to 15 years ago, and has functioned well. No action is recommended for this structure, so no report was generated. However, the structure is identified on the map for reference purposes. The final area of concern is a concrete structure that directs flow in a siphon under the Cemetery Ditch to irrigate lands north of the ditch. The siphon is in good condition, but the structure that is supposed to regulate flow to the siphon or down the ditch is in very poor condition. The concrete is cracked and allows significant leakage. In addition, controlling flows to the siphon is difficult, as the gate leading to the siphon cannot be sealed off.

Cleaning is recommended for the ditch. This recommendation is detailed in the canal report (LADD-1) which represents the total reach of the ditch. The Ladd Ditch and Carwile Lobban Ditch parallel each other, and both have small appropriations. It would be beneficial to combine these ditches into the crown ditch and pipe the appropriations from the Crown Ditch down to the lands associated with the Ladd or Cemetery Ditches. This is discussed in the Section 5.5.



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Miles

Legend

Evaluated Structures

Roads

Streams

Irrigation Ditches

Ladd Ditch

Crown Ditch

Figure 5-D - 3
Clear Creek Irrigation Assessment
Ladd and Crown Ditches

Local Name: Kirven Check

HKM ID:	**CD-CH1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Crown Ditch**			***Structure Type:***	**Check**
UTM Zone:	**13**	***Coordinates:***	**363156.0, 4909268.4**	***Total # of Photos:***	**0**

Notes: This site was identified by interviews. It was indicated that the turnout for the fields is a significant height above the bottom of the ditch. It is very difficult to get water high enough to serve the turnout. The ditch section has gotten deep and is fairly wide at this location. Installation of a check structure could aid in the regulation of the ditch, and ease of operation of the turnout. A typical NRCS concrete check is recommended.

Remediation Assessment

Deficiency

Category: CMDM

Rating: Serious

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
NRCS Concrete Check (4'x4' Notch)	1.0	Each	$6,142.94	$6,142.94
			Total Field Cost:	$6,142.94
			Contingencies: 15%	$921.44
			Subtotal:	$7,064.38
			Engineering: 5%	$353.22
			Mobilization: 10%	$706.44
			Current Replacement Value (CRV):	**$8,124.04**

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	60
Remediation Priority Index (RPI):	60

Local Name: Driscoll Check

HKM ID:	**CD-CH2**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Crown Ditch**			***Structure Type:***	**Check**
UTM Zone:	**13**	***Coordinates:***	**365404.4, 4908682.3**	***Total # of Photos:***	**0**

Notes: This site was identified during interviews. The landowner has difficulty regulating flows when he is irrigating, and when downstream landowners need water. Installation of a check would allow the landowner to establish water surface that can serve his turnout, and still allow for passive overflow down the ditch. A typical NRCS concrete check is recommended.

Deficiency

Category: CMDM

Rating: Serious

Remediation Assessment

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
NRCS Concrete Check (4'x4' Notch)	1.0	Each	$6,142.94	$6,142.94
			Total Field Cost:	$6,142.94
			Contingencies: 15%	$921.44
			Subtotal:	$7,064.38
			Engineering: 5%	$353.22
			Mobilization: 10%	$706.44
			Current Replacement Value (CRV):	**$8,124.04**

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	60
Remediation Priority Index (RPI):	60

Local Name: Ladd Siphon

HKM ID:	**LADD-CH1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Ladd Ditch**			***Structure Type:***	**Check**
UTM Zone:	**13**	***Coordinates:***	**363210.6, 4909776.6**	***Total # of Photos:***	**4**

Notes: This structure on the Ladd Ditch is a concrete structure that should regulate flow to in a siphon under the Cemetery Ditch to irrigate lands north of the ditch. It also conveys flows past the siphon to continue flowing down the ditch. The siphon is in good condition, but the structure that is supposed to regulate flow to the siphon or down the ditch is in very poor condition. The concrete is cracked and allows significant leakage. In addition, controlling flows to the siphon is difficult, as the gate leading to the siphon cannot be sealed off. The structure should be narrowed to aid in the operation of the structure. Costs reflect demo of the right wall and floor, and replacement with a new wall and floor. In addition, a screw gate is recommended to control flow to the siphon. Replacement assumes a standard concrete check with a headgate to serve the siphon.

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
CIP Concrete	3.0	CY	$1,135.47	$3,406.41
18" Diameter Canal Gate	1.0	Each	$1,964.36	$1,964.36
Concrete Demo. & Disposal	3.0	CY	$209.94	$629.82
Structural Fill	3.0	CY	$36.65	$109.95
Check Guides: Replace	4.0	FT	$19.87	$79.48
Structural Excavation	3.0	CY	$22.95	$68.85
			Total Field Cost:	$6,258.87
			Contingencies: 10%	$625.89
			Subtotal:	$6,884.76
			Engineering: 10%	$688.48
			Mobilization: 10%	$688.48
			Total Rehabilitation Cost:	**$8,261.71**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
NRCS Concrete Check (4'x4' Notch)	1.0	Each	$6,142.94	$6,142.94
CIP Concrete	2.0	CY	$1,135.47	$2,270.94
18" Diameter Canal Gate	1.0	Each	$1,964.36	$1,964.36
Structural Fill	2.0	CY	$36.65	$73.30
Structural Excavation	2.0	CY	$22.95	$45.90
			Total Field Cost:	$10,497.44
			Contingencies: 10%	$1,049.74
			Subtotal:	$11,547.18
			Engineering: 10%	$1,154.72
			Mobilization: 10%	$1,154.72
			Current Replacement Value (CRV):	**$13,856.62**

Facilities Condition Index (FCI):	0.6
Asset Priority Index (API):	40
Remediation Priority Index (RPI):	24

Deficiency

Category: CMDM

Rating: Serious

Local Name: Ladd Diversion

HKM ID:	**LADD-HG1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Ladd Ditch**			***Structure Type:***	**Headgate**
UTM Zone:	**13**	***Coordinates:***	**361793.1, 4909042.2**	***Total # of Photos:***	**5**

Notes: This structure is the headgate to the Ladd Ditch, which diverts out of Clear Creek and conveys flows in an unlined earthen ditch for approximately 0.2 miles where it flows into Sand Creek. The creek flooded a few years ago and disconnected the ox bow on which the headgate is located. Landowners had to create a rock diversion berm to route flows back to the existing headgate. This headgate is a 30" steel slide gate mounted on a concrete headwall. The gate is very leaky, and could not be sealed this winter. This caused water to flow in the ditch and created an ice problem at a downstream crossing. The county had to excavate a notch in the berm to allow flows to return to the creek. The excavated material was placed in front of the headgate to seal off the gate. The headgate needs to be replaced, and a sluice gate needs to be installed to allow flows to return to the creek if the existing location is kept. Replacement assumes relocating the headgate upstream and piping flows to the existing ditch. It also assumes a new rock vane diversion.

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	27,000.0	$	$1.03	$27,810.00
2.5-ft x 2.5-ft Slide Gate	2.0	Each	$3,072.83	$6,145.66
CIP Concrete	2.0	CY	$1,135.47	$2,270.94
RCP 30" D	10.0	FT	$99.93	$999.30
Handrail	15.0	FT	$50.71	$760.65
Structural Fill	3.0	CY	$36.65	$109.95
Structural Excavation	3.0	CY	$22.95	$68.85
			Total Field Cost:	$38,165.35
			Active Dewatering: 7.5%	$2,862.40
			Contingencies: 10%	$3,816.54
			Subtotal:	$44,844.29
			Engineering: 10%	$4,484.43
			Mobilization: 10%	$4,484.43
			Total Rehabilitation Cost:	**$53,813.14**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
Miscellaneous	27,000.0	$	$1.03	$27,810.00
RCP 30" D	160.0	FT	$99.93	$15,988.80
2.5-ft x 2.5-ft Slide Gate	2.0	Each	$3,072.83	$6,145.66
CIP Concrete	5.0	CY	$1,135.47	$5,677.35
Trash Rack	100.0	SF	$34.22	$3,422.00
Structural Fill	30.0	CY	$36.65	$1,099.50
Structural Excavation	30.0	CY	$22.95	$688.50
			Total Field Cost:	$91,731.81
			Active Dewatering: 7.5%	$6,879.89
			Contingencies: 10%	$9,173.18
			Subtotal:	$107,784.88
			Engineering: 10%	$10,778.49
			Mobilization: 10%	$10,778.49
			Current Replacement Value (CRV):	**$129,341.85**

Facilities Condition Index (FCI):	0.42
Asset Priority Index (API):	60
Remediation Priority Index (RPI):	25

Deficiency

Category: CMDM

Rating: Critical

Cleaning/Reshaping Report

HKM ID:	LADD-1	Division:	Clear Creek		
Canal Name:	Ladd Ditch [LADD-1]	Length:	9,200 ft	Total # of Photos:	3
Notes:	This reach of the Ladd Ditch represents cleaning costs for the length of the ditch. No seepage reaches were identified. Cleaning costs assume a 10-foot cross section.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	10,250.0	SY	$0.62	$6,355.00

Total Field Cost:		$6,355.00
Contingencies:	10%	$635.50
Subtotal:		$6,990.50
Engineering:	0%	$0.00
Mobilization:	10%	$699.05
Total Rehabilitation Cost:		**$7,689.55**
Average Rehabilitation Cost per Foot:		**$0.84**

Deficiency

Category: C&ODM

Rating: Minor

Carwile Lobban (Figure in Concept Design – Section 5.5.2)

Concept Improvements: Section 5.5.2

The Carwile-Lobban Ditch diverts from Sand Creek below the Ladd Ditch headgate. This ditch appears to serve approximately 110 acres, which would amount to an appropriation of approximately 1.5 cfs, assuming one cfs per 70 acres. There is concern regarding maintenance of the ditch due to development in the area. Near the end of the ditch, it is piped under the new high school campus. Interviews indicated that the ditch flows are piped down to the athletic fields to a pump house, and are used to irrigate the fields. There are evidently some operational issues with this, as there are times when the ditch flows are backed up, creating a virtual reservoir at the pipe inlet. For this reason, the ditch has sediment issues, and the ditch upstream of the pipe inlet will overtop and flood the lands below. The ditch upstream of this pipe was recently cleaned, which could help for this irrigation season, but the operational issues associated with the high school needs to be addressed.

Combining this ditch into the Crown Ditch would be beneficial to reduce seepage losses. This would also aid in the operation of the ditch, as it could be controlled by a headgate on the Crown ditch, instead of having to convey flows all the way from Clear Creek. This is discussed in Section 5.5.

Clear Creek Ditch

Concept Improvements: Section 5.5.2

The Clear Creek Ditch diverts out of Clear Creek downstream of the Ladd Ditch diversion. This ditch has a direct flow right of 29.8 cfs, and serves approximately 2,270 acres. A new diversion structure was recently constructed to incorporate fish passage/protection. Approximately 100 acres are irrigated west of the interstate. One issue identified by landowners is that the ditch is piped under the entire high school campus. There are no cleanouts or manholes, and the pipe is apparently CMP. Irrigators east of the school are concerned with the life of the pipe, as well as having trouble cleaning the pipe if it were to become clogged. There is no trash rack at the inlet of the pipe, but wire fence panels have been put across the canal to serve dual purpose of fence and trash rack. A majority of the lands east of the interstate have been converted to sprinkler irrigation. One landowner is building their sprinkler system with the plan of eventually being served by a pipeline system. It would be very beneficial to change the point of diversion for these lands east of the interstate to be combined with the Johnson-Holt or Six Mile Ditch. These could potentially fill a reservoir which could serve the lands east of the interstate. A concept of this is discussed in section 5.5

Big Redman Ditch

Figure 5-D – 4

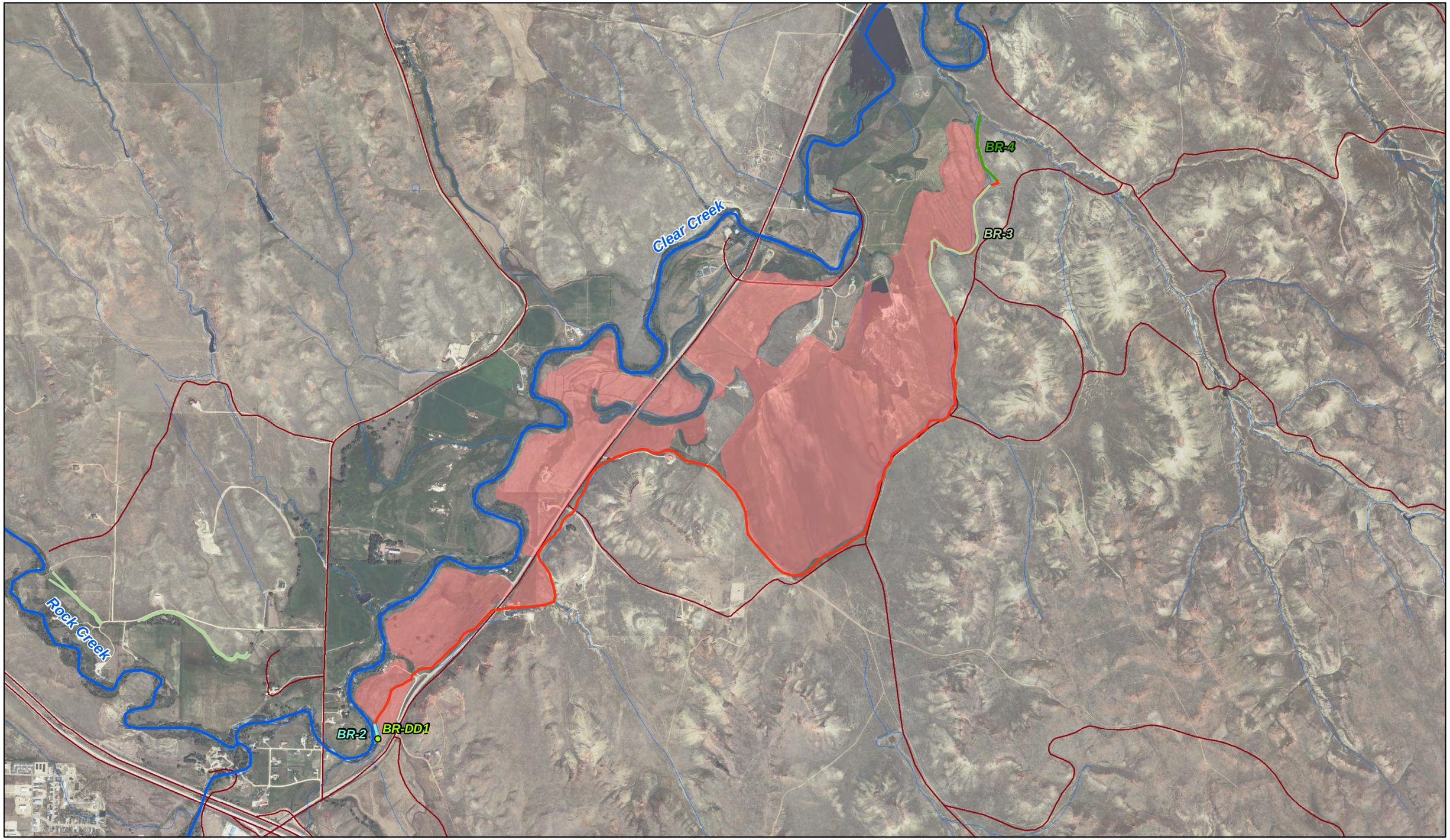
Structure Reports: BR-DD1, Appendix 5-E

Canal Reports: BR-1 / BR-2 / BR-3 / BR-4, Appendix 5-E

The Big Redman Ditch diverts out of Clear Creek approximately 0.6 miles downstream of Rock Creek's confluence with Clear Creek. The ditch has an appropriation of 17.4 cfs and serves approximately 1,200 acres over its 4.9 mile length. The head gate consists of a single 6 x 4.5-foot rectangular steel gate. The gate is mounted to a concrete headwall with flared wing walls. There is no trash rack or fish screen associated with this structure. Recently, a rock vane was installed at the head gate to assist in diverting water to the head gate. Interviews indicated that the concrete footer below the pipe inlet is broken, and allows water to seep and pipe along the concrete 6-foot x 4-foot arch pipe. This has caused the head gate to wash out. Repairs have been made, but there are still issues. Sediment upstream of the head gate has to be excavated each year prior to irrigation. This is due to a lack of a sluice gate on the wing wall that would allow flows diverted toward the head gate during the non-irrigation season to return to the creek.

The unlined earthen ditch flows northeast from the diversion. There is evidence of right bank scour in the creek just below the diversion. The ditch shares this bank, and there is concern of losing this ditch bank during high stream flows. The Big Redman Ditch field tour identified areas of flat grade, seepage, and erosion at the end of the ditch. The grade and seepage could be remediated with canal cleaning and lining. The erosion section at the end of the ditch is a large cut section that started at the return flow confluence with an existing drainage, and has head cut back to the ditch. The lower end of the cut section is approximately 15 feet deep with steep side slopes. It appears that the bottom and sides of the cut have established vegetation, but the upper three feet of the cut walls are nearly vertical with no vegetation. Remediation of this section assumes installing a series of rock check dams along the bottom of the cut section to reduce runoff velocities, and re-grading and re-seeding the top of the cut section to establish vegetation and stop erosion.

The lands served by this ditch are flood irrigated, but there is interest in converting to sprinkler irrigation.



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Legend

- Evaluated Structures
- Streams
- Big Redman Irrigated Lands
- Big Redman Ditch
- Bank Instability
- Seepage Area Lining
- Wasteway Headcutting

Figure 5-D - 4
Clear Creek Irrigation Assessment
Big Redman Ditch

Local Name: Big Redman Diversion

HKM ID:	**BR-DD1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Big Redman**			***Structure Type:***	**Diversion Dam**
UTM Zone:	**13**	***Coordinates:***	**368535.5, 4913300.3**	***Total # of Photos:***	**6**

Notes: The Big Redman Ditch diverts from Clear Creek approximately 0.5 miles east of the Interstate 90 overpass off of US Highway 16 East. The ditch flows approximately 4.5 miles. It has a direct flow water right of 17.4 cfs which can serve approximately 1200 acres. The diversion structure is composed of large concrete wing walls and headwall with a large slide gate that controls flows through a 6' x 4' CMP arch pipe. The concrete footer below the pipe is broken which causes leakage and piping around the arch pipe and actually lead to a complete washout of the pipe. Sediment accumulation at the headgate is an issue. There is no sluice gate that would allow for diverted water to return to the creek during non-irrigation times. The CMP pipe is showing corrosion and should be replaced. Rehabilitation costs reflect the installation of a 36" sluice gate on the left headwall, and replacement and repair of the pipe and footer. Handrail should also be added to the headwall structure and downstream cutoff wall. A rock vane diversion has been installed recently and is in good condition. However, replacement costs include a rock vane diversion. This is to represent the most complete replacement cost if the structure and diversion were to be completely demolished and replaced. Miscellaneous costs reflect a fish screen structure.

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	66,000.0	$	$1.03	$67,980.00
RCP 5' D	18.0	FT	$395.74	$7,123.32
Stream Control (Small)	1.0	Each	$6,812.78	$6,812.78
CIP Concrete	5.0	CY	$1,135.47	$5,677.35
36" Diameter Canal Gate	1.0	Each	$5,314.01	$5,314.01
RCP 36" D	40.0	FT	$132.48	$5,299.20
Trash Rack	150.0	SF	$34.22	$5,133.00
Handrail	60.0	FT	$50.71	$3,042.60
Concrete Demo. & Disposal	5.0	CY	$209.94	$1,049.70
			Total Field Cost:	$107,431.96
			Active Dewatering: 7.5%	$8,057.40
			Contingencies: 10%	$10,743.20
			Subtotal:	$126,232.55
			Engineering: 15%	$18,934.88
			Mobilization: 10%	$12,623.26
			Total Rehabilitation Cost:	**$157,790.69**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	66,000.0	$	$1.03	$67,980.00
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
CIP Concrete	24.0	CY	$1,135.47	$27,251.28
5-ft x 5-ft Slide Gate	1.0	Each	$8,847.60	$8,847.60
Structural Fill	230.0	CY	$36.65	$8,429.50
RCP 5' D	18.0	FT	$395.74	$7,123.32
Stream Control (Small)	1.0	Each	$6,812.78	$6,812.78
36" Diameter Canal Gate	1.0	Each	$5,314.01	$5,314.01
RCP 36" D	40.0	FT	$132.48	$5,299.20
Structural Excavation	230.0	CY	$22.95	$5,278.50
Trash Rack	150.0	SF	$34.22	$5,133.00
Concrete Demo. & Disposal	24.0	CY	$209.94	$5,038.56
Handrail	60.0	FT	$50.71	$3,042.60
			Total Field Cost:	$186,450.35
			Active Dewatering: 7.5%	$13,983.78
			Contingencies: 10%	$18,645.04
			Subtotal:	$219,079.16
			Engineering: 15%	$32,861.88
			Mobilization: 10%	$21,907.92
			Current Replacement Value (CRV):	**$273,848.95**

Facilities Condition Index (FCI):	0.58
Asset Priority Index (API):	80
Remediation Priority Index (RPI):	46

Deficiency

Category: CHSci

Rating: Serious

Cleaning/Reshaping Report

HKM ID:	**BR-1**	**Division:**	**Clear Creek**		
Canal Name:	**Big Redman [BR-1]**	**Length:**	**24,500 ft**	**Total # of Photos:**	**2**
Notes:	This reach is a cleaning and reshaping estimate for the length of the canal. Included is an area that was identified as a very flat grade section that could be a canal constriction. This reach begins along the hillside west of the George residence. It is assumed that it can be remediated with cleaning/reshaping which could put the section back on grade. Cleaning costs assume a 10-foot cross-section.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	27,300.0	SY	$0.62	$16,926.00
			Total Field Cost:	$16,926.00
			Contingencies: 10%	$1,692.60
			Subtotal:	$18,618.60
			Engineering: 0%	$0.00
			Mobilization: 10%	$1,861.86
			Total Rehabilitation Cost:	**$20,480.46**
			Average Rehabilitation Cost per Foot:	**$0.84**

Deficiency

Category: C&ODM

Rating: Minor

Bank Instability Report

HKM ID:	BR-2	Division:	Clear Creek		
Canal Name:	Big Redman [BR-1]	Length:	300 ft	Total # of Photos:	2

Notes: This section of bank instability is from the headgate to approximately 300-feet downstream. The Big Redman ditch shares its left canal bank with Clear Creek. Landowners feel that the creek has began to scour along this shared bank. They also indicated that they have seen the creek overtop the ditch bank. Remediation assumes compacted embankment to raise the canal bank by two feet (assuming 12 feet wide). Additional remediation assumes bank protection 6" thick and 15' from the top of the bank to the toe of the slope.

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Riprap Bank Protection	90.0	CY	$55.40	$4,986.00
Compacted Embankment	300.0	CY	$7.50	$2,250.00
			Total Field Cost:	$7,236.00
			Contingencies: 10%	$723.60
			Subtotal:	$7,959.60
			Engineering: 10%	$795.96
			Mobilization: 10%	$795.96
			Total Rehabilitation Cost:	**$9,551.52**
			Average Rehabilitation Cost per Foot:	**$31.84**

Deficiency

Category: CMDM

Rating: Serious

Seepage Area Lining Report

HKM ID:	BR-3	Division:	Clear Creek		
Canal Name:	Big Redman [BR-1]	Length:	3,700 ft	Total # of Photos:	0

Notes: This reach identifies a reach of the canal with significant seepage. This reduces production do to the sub-irrigation that occurs from the seepage. Landowners indicated that there are times that they can't drive across the field due to the seepage. The remediation requires the lining to cover the cross-section of the ditch, plus five feet on each side to serve as the anchor section. The cost estimate assumes a 10-foot cross-section plus 10-feet for the liner anchor.

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 24" Pipe	3,700.0	FT	$38.03	$140,711.00
CIP Concrete	1.0	CY	$1,135.47	$1,135.47
Trash Rack	15.0	SF	$34.22	$513.30
Structural Fill	2.0	CY	$36.65	$73.30
Structural Excavation	2.0	CY	$22.95	$45.90

Total Field Cost:		$142,478.97
Contingencies:	10%	$14,247.90
Subtotal:		$156,726.87
Engineering:	10%	$15,672.69
Mobilization:	10%	$15,672.69
Total Rehabilitation Cost:		**$188,072.24**
Average Rehabilitation Cost per Foot:		**$50.83**

Deficiency

Category: CMDM

Rating: Serious

Wasteway Headcutting Report

HKM ID:	BR-4	Division:	Clear Creek		
Canal Name:	Big Redman [BR-1]	Length:	1,300 ft	Total # of Photos:	3

Notes: This section of the Big Redman ditch is at the very end. This is the wasteway section of the ditch, as return flows run down the section and eventually returns to Clear Creek. At one time the section was very unstable and has created a cut section that is approximately 30 feet wide and 15 feet deep at the tail end of the reach. Significant vegetation has established in the bottom of the channel, and the lower end appears to be stable. Consideration was given to put the ditch on contour and extend it around the hillside. This would theoretically increase the irrigable lands by approximately 18 acres, based on aerial photos and quad maps. It would be a significant effort to fill the existing ditch to a point that it could be irrigated. Because there is significant vegetation established on the bottom of the channel, the most economical approach would be to add rock check dams in the bottom of the channel. This would slow velocities in the wasteway, and reduce the potential of additional scour. It also allows sediment to drop out behind the dam because velocities are reduced as water filters through the check dam. The rock check is assumed to be three feet high with 1.5:1 side slopes and a width of 15 feet. It is assumed that seven check dams will be installed at even increments down the wasteway. The bottom of the channel appears to be re-vegetated; however, the upper three feet of the wasteway ditch is nearly vertical with no vegetation. It is assumed that this top three feet will be re-graded so that it has a 2:1 slope entering the wasteway ditch. This will require excavation and erosion control to establish vegetation on the slope. This estimate is approximately $60,000 less than filling the wasteway and extending the ditch.

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Erosion Control Blanket	1,800.0	SY	$3.75	$6,750.00
Riprap Bank Protection	60.0	CY	$55.40	$3,324.00
Unclassified Excavation	900.0	CY	$2.59	$2,331.00

Total Field Cost:		$12,405.00
Contingencies:	10%	$1,240.50
Subtotal:		$13,645.50
Engineering:	10%	$1,364.55
Mobilization:	10%	$1,364.55
Total Rehabilitation Cost:		**$16,374.60**
Average Rehabilitation Cost per Foot:		**$12.60**

Deficiency

Category: CMDM

Rating: Serious

Hillyer & Onslow Ditch

Figure 5-D – 5

Structure Reports: HO-SPN1, Appendix 5-E

Canal Reports: HO-1, Appendix 5-E

The Hillyer & Onslow Ditch diverts out of Clear Creek between the Confluences of Clear Creek with Rock and Piney Creeks. Its headgate is located on a large concrete dam just across the highway from the south end of Healy Reservoir. The first 600 feet of the ditch is piped. The ditch is in good condition overall. It was indicated that they can run up to 9 cfs, with a direct flow right of 2.6 cfs. The ditch serves approximately 150 acres. Other than the first 600 feet, the ditch flows in an unlined ditch. Approximately 0.4 miles downstream of the diversion is a siphon that is in poor condition. It was indicated that the siphon leaks over most of the length of it. The irrigator indicated that you can see a silt plume in the creek, indicating that the siphon is leaking. This siphon needs to be replaced. The majority of the irrigated lands under the Hillyer & Onslow Ditch are flood irrigated, with some gated pipe.

Frank G. Hopkins (Smith Hopkins) Ditch

Figure 5-D – 5

Structure Reports: no structure improvements identified

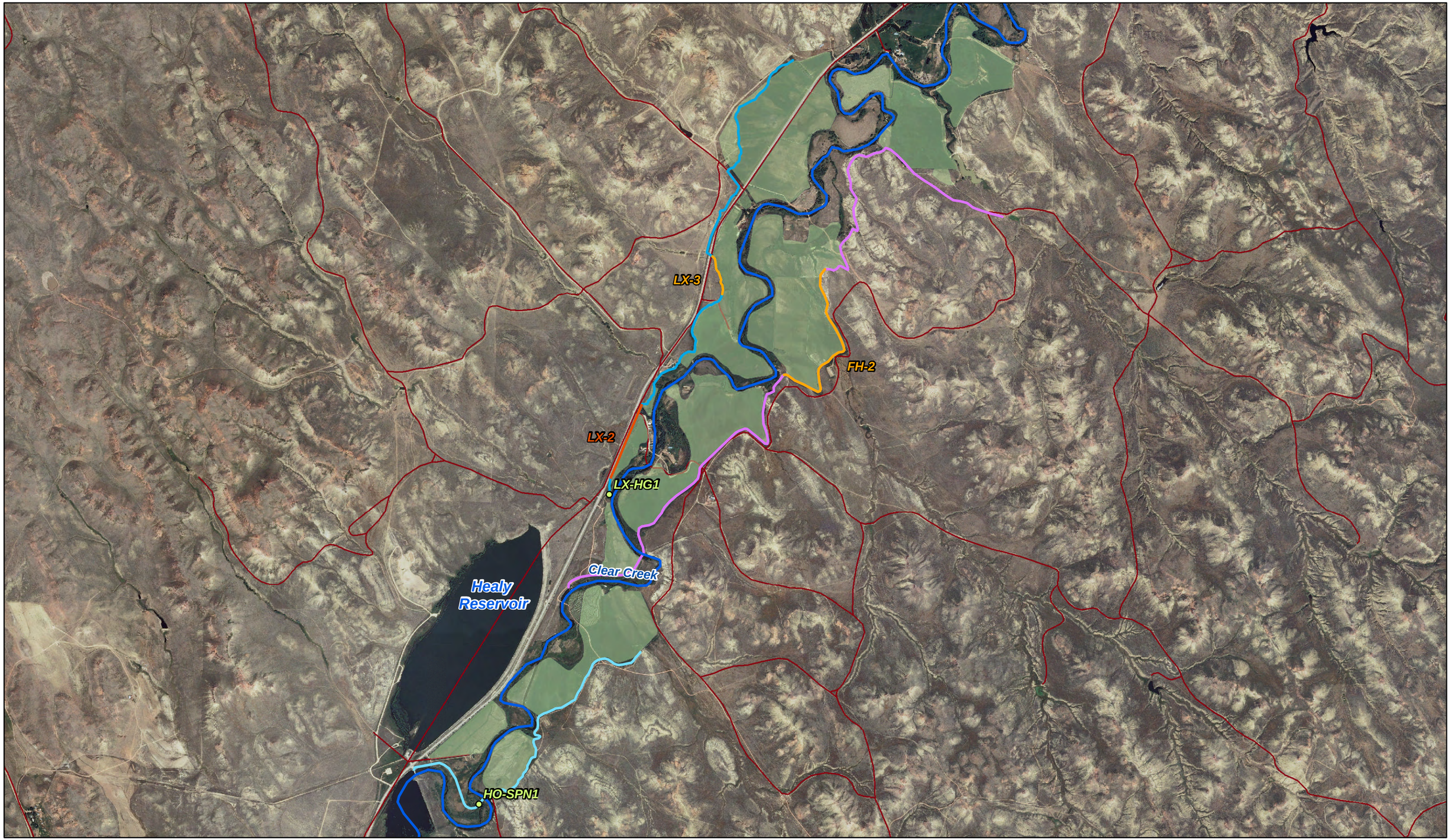
Canal Reports: FH-1 / FH-2, Appendix 5-E

The Frank Hopkins Ditch diverts from Clear Creek approximately one mile downstream of the Hillyer & Onslow Ditch. The ditch has a direct flow right of 7.1 cfs. The ditch flows for approximately four miles in an unlined, earthen ditch, and serves approximately 400 acres. The diversion was recently reconstructed with a rock vane diversion, and it was indicated that it is working well. The ditch is in generally good condition. However, there is one reach on the lower end of the ditch that was identified as having seepage issues. Remediation will be discussed. The majority of the lands below the Frank Hopkins Ditch are flood irrigated, with small areas of gated pipe. The same landowner provided information for the Hillyer & Onslow as well as the Frank Hopkins Ditches. He indicated that he felt that the best way to provide water conservation and improve irrigation would be to pipe ditches and begin converting deliveries to sprinkler irrigation.

LX Ditch

Figure 5-D – 5
Structure Reports: LX-HG1, Appendix 5-E
Canal Reports: LX-1 / LX-2 / LX-3, Appendix 5-E

The LX Ditch diverts out of Clear Creek approximately 0.5 miles north of the Frank Hopkins Ditch. It was indicated that the ditch typically runs between 7 and 8 cfs, accounting for double appropriation. The normal ditch flow is probably closer to 4 cfs, as it serves approximately 230 acres. There is a concrete diversion wall that is approximately 300 feet downstream of the ditch's headgate, and it was indicated that the diversion is washing out. The landowner has to rebuild sections of the diversion with rock each year to maintain its height. This work appears to have directed more flows to the right stream bank, which has undercut and slumped. This could be remediated. When the highway was rebuilt a number of years ago, it was shifted east to a point that the ditch is serving as the road ditch. The side slopes are very steep, and the left bank is fenced, which makes it very difficult to clean. This ditch section could be piped, to eliminate the maintenance issue associated with the reach. Downstream of this is a seepage area. The landowner used to be able to hay the field, but now there is standing water below the ditch, and he can only graze the field. The lands irrigated by the LX Ditch are mainly flood irrigated, with some gated pipe delivery.



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Miles

Legend

- Evaluated Structures
- Streams
- Roads
- Frank Hopkins
- Hillyer & Onslow
- LX Ditch
- Canal Constriction
- Seepage Area Lining
- Associated Lands

Figure 5-D - 5
Clear Creek Irrigation Assessment
Hillyer & Onslow, Frank Hopkins, and LX Ditches

Local Name: Hillyer & Onslow Siphon

HKM ID:	**HO-SPN1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Hillyer & Onslow**			***Structure Type:***	**Siphon**
UTM Zone:	**13**	***Coordinates:***	**371896.7, 4917298.5**	***Total # of Photos:***	**4**

Notes: This siphon is located approximately 0.4 miles downstream of the diversion. It has significant leakage, as identified by the operator. The siphon is a 24" steel siphon that conveys flows under Clear Creek to serve lands east of the creek. It was identified that the siphon leaks and that silt plumes can be seen in the creek resulting from water flowing out of the pipe. The inlet and outlet structures appear to be in good condition, but the pipe needs to be replaced. Replacement assumes a concrete inlet and outlet structure with trash rack.

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
RCP 24" D	350.0	FT	$89.40	$31,290.00
Stream Control (Medium)	1.0	Each	$27,559.61	$27,559.61
			Total Field Cost:	$58,849.61
			Active Dewatering: 7.5%	$4,413.72
			Contingencies: 15%	$8,827.44
			Subtotal:	$72,090.77
			Engineering: 10%	$7,209.08
			Mobilization: 10%	$7,209.08
			Total Rehabilitation Cost:	**$86,508.93**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
RCP 24" D	350.0	FT	$89.40	$31,290.00
Stream Control (Medium)	1.0	Each	$27,559.61	$27,559.61
CIP Concrete	6.0	CY	$1,135.47	$6,812.82
Trash Rack	40.0	SF	$34.22	$1,368.80
Structural Fill	10.0	CY	$36.65	$366.50
Structural Excavation	10.0	CY	$22.95	$229.50
			Total Field Cost:	$67,627.23
			Active Dewatering: 7.5%	$5,072.04
			Contingencies: 15%	$10,144.08
			Subtotal:	$82,843.36
			Engineering: 10%	$8,284.34
			Mobilization: 10%	$8,284.34
			Current Replacement Value (CRV):	**$99,412.03**

Facilities Condition Index (FCI):	0.87
Asset Priority Index (API):	50
Remediation Priority Index (RPI):	44

Deficiency

Category: CMDM

Rating: Critical

Cleaning/Reshaping Report

HKM ID:	**HO-1**	**Division:**	**Clear Creek**		
Canal Name:	**Hillyer & Onslow [HO-1]**	**Length:**	**8,700 ft**	**Total # of Photos:**	**0**
Notes:	The Hilllyer & Onslow Ditch was identified as being in good condition, with no significant seepage issues. The ditch has a direct flow right of 2.58 cfs. General cleaning and reshaping is recommended. This is estimated assuming an 8-foot cross-section.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	7,700.0	SY	$0.62	$4,774.00

Total Field Cost:		$4,774.00
Contingencies:	10%	$477.40
Subtotal:		$5,251.40
Engineering:	0%	$0.00
Mobilization:	10%	$525.14
Total Rehabilitation Cost:		**$5,776.54**
Average Rehabilitation Cost per Foot:		**$0.66**

Deficiency

Category: C&ODM

Rating: Minor

Cleaning/Reshaping Report

HKM ID:	FH-1	Division:	Clear Creek		
Canal Name:	Frank Hopkins [FH-1]	Length:	21,000 ft	Total # of Photos:	0
Notes:	This reach represents cleaning costs for the Frank Hopkins Ditch. The ditch has a direct flow right of 10.1 cfs. Cleaning assumes a cross-section of 10-feet.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	23,500.0	SY	$0.62	$14,570.00
			Total Field Cost:	$14,570.00
			Contingencies: 10%	$1,457.00
			Subtotal:	$16,027.00
			Engineering: 0%	$0.00
			Mobilization: 10%	$1,602.70
			Total Rehabilitation Cost:	**$17,629.70**
			Average Rehabilitation Cost per Foot:	**$0.84**

Deficiency

Category: C&ODM

Rating: Minor

Seepage Area Lining Report

HKM ID:	FH-2	Division:	Clear Creek		
Canal Name:	Frank Hopkins [FH-1]	Length:	4,400 ft	Total # of Photos:	0
Notes:	This reach represents the cost estimate for lining a seepage area along the Frank Hopkins ditch. It was identified by the landowner that there is significant seepage. There is standing water below ditch when it is flowing. Equipment can still be operated in the field but the operator has to be careful. Remediation assumes using HDPE pipe to line the ditch.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 24" Pipe	4,400.0	FT	$38.03	$167,332.00
CIP Concrete	2.0	CY	$1,135.47	$2,270.94
Trash Rack	30.0	SF	$34.22	$1,026.60
Structural Fill	4.0	CY	$36.65	$146.60
Structural Excavation	4.0	CY	$22.95	$91.80

Total Field Cost:		$170,867.94
Contingencies:	10%	$17,086.79
Subtotal:		$187,954.73
Engineering:	10%	$18,795.47
Mobilization:	10%	$18,795.47
Total Rehabilitation Cost:		**$225,545.68**
Average Rehabilitation Cost per Foot:		**$51.26**

Deficiency

Category: CMDM

Rating: Serious

Local Name: LX Diversion and Headgate

HKM ID:	**LX-HG1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**LX Ditch**			***Structure Type:***	**Headgate**
UTM Zone:	**12**	***Coordinates:***	**372838.1, 4919529.2**	***Total # of Photos:***	**7**

Notes: This structure represents the headgate and diversion structure for the LX Ditch. The diversion is approximately 300 feet downstream of the headgate, which has made the regulation difficult. In addition, the diversion is not stable, and has to be re-worked every year. The headgate is a 36" slide gate leaks around the headgate and along the pipe. Efforts have been made to seal the leak around the headgate, including pouring concrete at the outlet. Relocating the diversion upstream would be beneficial as it could better regulate the water surface at the headgate. In addition, the gate needs to be reset. Remediation assumes a rock vane diversion and new headgate. Miscellaneous costs reflect removal of the existing diversion dam and retrofitting a fish screening structure. Replacement assumes a rock vane with new headgate and culvert. In addition, it assumes a sluice gate to prevent sedimentation during non-irrigation flows. Miscellaneous replacement costs reflect a fish screen structure, as well as removal of the existing diversion.

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	37,000.0	$	$1.03	$38,110.00
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
Stream Control (Medium)	1.0	Each	$27,559.61	$27,559.61
3-ft x 3-ft Slide Gate	1.0	Each	$3,728.89	$3,728.89
			Total Field Cost:	$100,298.50
			Active Dewatering: 7.5%	$7,522.39
			Contingencies: 15%	$15,044.78
			Subtotal:	$122,865.66
			Engineering: 10%	$12,286.57
			Mobilization: 10%	$12,286.57
			Total Rehabilitation Cost:	**$147,438.80**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	37,000.0	$	$1.03	$38,110.00
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
Stream Control (Medium)	1.0	Each	$27,559.61	$27,559.61
RCP 36" D	60.0	FT	$132.48	$7,948.80
CIP Concrete	4.0	CY	$1,135.47	$4,541.88
3-ft x 3-ft Slide Gate	1.0	Each	$3,728.89	$3,728.89
2-ft x 2-ft Slide Gate	1.0	Each	$2,670.63	$2,670.63
Structural Fill	10.0	CY	$36.65	$366.50
Structural Excavation	10.0	CY	$22.95	$229.50
			Total Field Cost:	$116,055.81
			Active Dewatering: 7.5%	$8,704.19
			Contingencies: 15%	$17,408.37
			Subtotal:	$142,168.37
			Engineering: 10%	$14,216.84
			Mobilization: 10%	$14,216.84
			Current Replacement Value (CRV):	**$170,602.04**

Facilities Condition Index (FCI):	0.86
Asset Priority Index (API):	60
Remediation Priority Index (RPI):	52

Deficiency

Category: CMDM

Rating: Serious

Cleaning/Reshaping Report

HKM ID:	**LX-1**	**Division:**	**Clear Creek**		
Canal Name:	**LX Ditch [LX-1]**	**Length:**	**13,000 ft**	**Total # of Photos:**	**1**
Notes:	This reach represents the cleaning costs for the length of the LX Ditch. The ditch has a couple of problem areas that are identified in LX-2 and LX-3. The costs assume a cross section of 8-ft.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	11,600.0	SY	$0.62	$7,192.00

Total Field Cost:		$7,192.00
Contingencies:	10%	$719.20
Subtotal:		$7,911.20
Engineering:	0%	$0.00
Mobilization:	10%	$791.12
Total Rehabilitation Cost:		**$8,702.32**
Average Rehabilitation Cost per Foot:		**$0.67**

Deficiency

Category: C&ODM

Rating: Minor

Canal Constriction Report

HKM ID:	LX-2	Division:	Clear Creek		
Canal Name:	LX Ditch [LX-1]	Length:	1,950 ft	Total # of Photos:	0
Notes:	This reach of the LX Ditch represents the length of the ditch that borders the highway. This reach serves as both the irrigation ditch and the road ditch. The side slopes are very steep, and the left bank is fenced, making it very difficult to clean. Remediation assumes the installation of HDPE pipe to pipe the irrigation flows. This includes concrete headwalls at the inlet and outlet as well as a trash rack.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 18" Pipe	1,950.0	FT	$21.93	$42,763.50
CIP Concrete	2.0	CY	$1,135.47	$2,270.94
Trash Rack	30.0	SF	$34.22	$1,026.60
Structural Fill	4.0	CY	$36.65	$146.60
Structural Excavation	4.0	CY	$22.95	$91.80

Total Field Cost:		$46,299.44
Contingencies:	10%	$4,629.94
Subtotal:		$50,929.38
Engineering:	10%	$5,092.94
Mobilization:	10%	$5,092.94
Total Rehabilitation Cost:		**$61,115.26**
Average Rehabilitation Cost per Foot:		**$31.34**

Deficiency

Category: CMDM

Rating: Serious

Seepage Area Lining Report

HKM ID:	LX-3	**Division:**	Clear Creek		
Canal Name:	LX Ditch [LX-1]	**Length:**	1,000 ft	**Total # of Photos:**	3
Notes:	This reach represents a seepage area of the LX Ditch. The landowner used to be able to irrigate the field below, but it now can only be used for grazing. There is standing water below the ditch. Remediation assumes the installation of HDPE pipe to stop the seepage.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 18" Pipe	1,000.0	FT	$21.93	$21,930.00
CIP Concrete	2.0	CY	$1,135.47	$2,270.94
Trash Rack	30.0	SF	$34.22	$1,026.60
Structural Fill	4.0	CY	$36.65	$146.60
Structural Excavation	4.0	CY	$22.95	$91.80

Total Field Cost:		$25,465.94
Contingencies:	10%	$2,546.59
Subtotal:		$28,012.53
Engineering:	10%	$2,801.25
Mobilization:	10%	$2,801.25
Total Rehabilitation Cost:		**$33,615.04**
Average Rehabilitation Cost per Foot:		**$33.62**

Deficiency

Category: CMDM

Rating: Serious

Big Bonanza Ditch (Appendix D, Figure 5-D – 6)

Figure 5-D – 6

Structure Reports: BB-DD1/BB-CH1–4/BB-TO1-12,Appendix 5-E

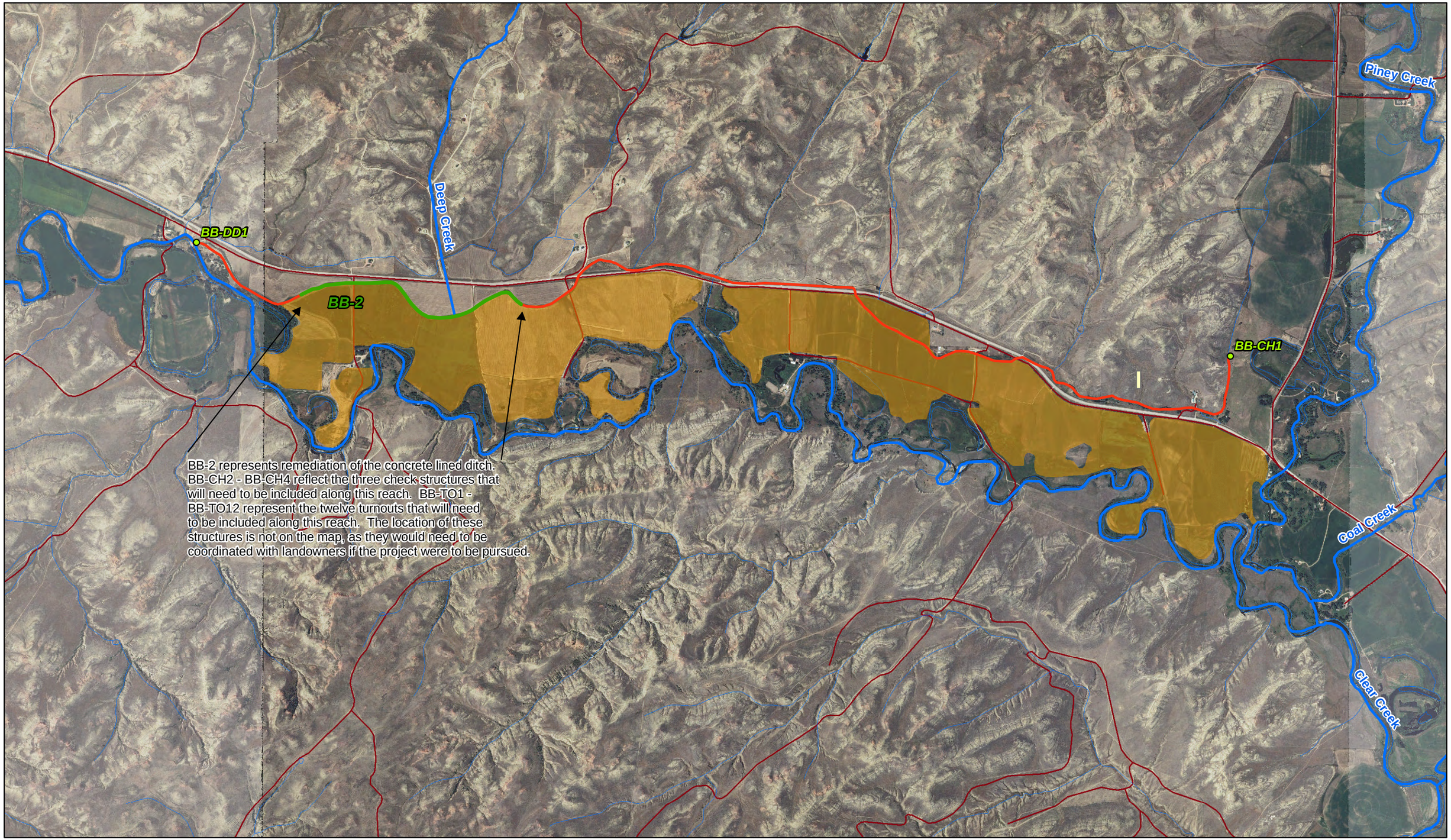
Canal Reports: BB-1 / BB-2, Appendix 5-E

The Big Bonanza Ditch diverts out of Clear Creek approximately 5 miles upstream of the confluence with Piney Creek. The ditch has an appropriation of 22.2 cfs and irrigates approximately 1,550 acres. The head gate consists of a single 4 x 6-foot rectangular steel gate operated with a Waterman-type screw. The gate is mounted on a concrete headwall. There is no trash rack or fish screen associated with the head gate. The diversion has recently been retrofitted to incorporate a fish ladder. Irrigators feel that the fish ladder has reduced their diversion width, and makes it difficult to check water high enough late in the season. In addition, installing check boards in the diversion could be dangerous as there are no safety features. An overshot diversion gate may be a good alternative at this location.

The ditch has sections which are lined with concrete. These sections divert water to the field through small siphon pipes. Irrigators indicated that these reaches are difficult to operate. They don't like the design, and are frustrated with operation of the reaches. They feel that the siphons do not convey enough water, due to the lack of head between the Big Bonanza ditch water surface and the field ditch water surface. In addition, they do not seal well, allowing water to seep into adjacent fields. Replacing these systems with a standard check and turnout system would improve operation, regulation and efficiency of the deliveries. Landowner input indicated there are 12 turnouts needed, as well as three check structures to serve the turnouts.

When the highway was re-designed a number of years ago, an inlet grate was installed to collect drainage from the west drainage ditch along the highway and direct it into an irrigation pipe. This pipe is from a turnout in the ditch, and serves a field ditch east of the highway. The irrigator feels that this grate reduces the head in his turnout pipe. He would like to remove the grate and allow ditch flows to continue down the road ditch. A new turnout is recommended to alleviate this issue, but coordination may need to be made with WYDOT to approve the removal of the road ditch inlet. However, this is a farm delivery, so it falls out of the scope of this project.

The lower end of the ditch has significant erosion issues. It appears that the channel bank has eroded; allowing return flows to travel overland down to an old Piney Creek oxbow. This has created a head cut that started at the oxbow and is continuing back toward the ditch. This also disconnected the ditch so the land owner can no longer irrigate downstream of this location. Remediation assumes installing a division box which would waste water through a pipe to the ox bow, or allow water to continue down the ditch and serve the lands below this point of the ditch. Canal bank sloughing is evident in areas due to livestock crossing and watering in localized areas. This is more of a management issue that can be addressed by landowners/operators. Landowners could fence the reach, and provide armored ditch crossings/water gaps. The majority of the lands served by the ditch are flood irrigated, but there is interest in conversion to sprinkler irrigation.



W S N E

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Miles

Legend

- Evaluated Structures
- Canal Liner Rehabilitation
- Streams
- Roads
- Big Bonanza Ditch
- Big Bonanza Irrigated Lands

Figure 5-D - 6
Clear Creek Irrigation Assessment
Big Bonanza Ditch

Local Name: Big Bonanza Diversion

HKM ID:	**BB-DD1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Big Bonanza**			***Structure Type:***	**Diversion Dam**
UTM Zone:	**13**	***Coordinates:***	**376228.7, 4927504.2**	***Total # of Photos:***	**8**

Notes: The Big Bonanza Ditch diverts out of Clear Creek approximately 5 miles upstream of the confluence with Piney Creek. The ditch has an appropriation of 22.2 cfs and irrigates approximately 1,550 acres. The head gate consists of a single 4 x 6-foot rectangular steel gate operated with a Waterman-type screw. The gate is mounted on a concrete headwall with flared wing walls. There is no trash rack or fish screen associated with the head gate. The diversion consists of three check bays and has recently been retrofitted to incorporate a fish ladder. Rehabilitation recommendations include a trash rack at the headgate, and installation of walkway and handrail across the check/diversion wall. Replacement assumes an overshot gate with new headgate. The overshot gate is included as landowners indicated that they didn't feel that the rock vane diversion would be appropriate at this site. Handrail is recommended at the inlet and outlet of the headgate pipe. Riprap bank stabilization is recommended along the left bank upstream of the headgate. Miscellaneous costs reflect a fish screen structure.

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	81,000.0	$	$1.03	$83,430.00
Handrail	50.0	FT	$50.71	$2,535.50
Walkway (Expanded Steel)	75.0	SF	$17.95	$1,346.25
Trash Rack	36.0	SF	$34.22	$1,231.92
			Total Field Cost:	$88,543.67
			Active Dewatering: 7.5%	$6,640.78
			Contingencies: 10%	$8,854.37
			Subtotal:	$104,038.81
			Engineering: 10%	$10,403.88
			Mobilization: 10%	$10,403.88
			Total Rehabilitation Cost:	**$124,846.58**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Overshot Gate	300.0	SF	$510.96	$153,288.00
Miscellaneous	81,000.0	$	$1.03	$83,430.00
Stream Control (Medium)	1.0	Each	$27,559.61	$27,559.61
Overshot Gate: Compressor & Control	1.0	Each	$18,735.29	$18,735.29
CIP Concrete	15.0	CY	$1,135.47	$17,032.05
4-ft x 4-ft Slide Gate	1.0	Each	$6,460.84	$6,460.84
RCP 48" D	25.0	FT	$256.97	$6,424.25
Structural Fill	70.0	CY	$36.65	$2,565.50
Handrail	50.0	FT	$50.71	$2,535.50
Structural Excavation	70.0	CY	$22.95	$1,606.50
Trash Rack	36.0	SF	$34.22	$1,231.92
			Total Field Cost:	$320,869.46
			Active Dewatering: 7.5%	$24,065.21
			Contingencies: 10%	$32,086.95
			Subtotal:	$377,021.62
			Engineering: 10%	$37,702.16
			Mobilization: 10%	$37,702.16
			Current Replacement Value (CRV):	**$452,425.94**

Facilities Condition Index (FCI):	0.28
Asset Priority Index (API):	80
Remediation Priority Index (RPI):	22

Deficiency

Category: CHSci

Rating: Critical

Local Name: Sonny's Washout

HKM ID:	**BB-CH1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Big Bonanza**			***Structure Type:***	**Wasteway**
UTM Zone:	**13**	***Coordinates:***	**377001.8, 4934787.3**	***Total # of Photos:***	**5**

Notes: This site is at the end of the Big Bonanza ditch. It appears that the ditch bank has broken down; allowing return flows to travel overland down to an old Piney Creek oxbow. This has created a head cut that started at the oxbow and is continuing back toward the ditch. This also disconnected the ditch so the land owner can no longer irrigate downstream of this location. A concrete check structure is recommended at this location which would allow water to spill into a 24" RCP pipe to the outfall, or continue down the ditch to irrigate downstream of the site. This site has been approved for remediation through the NRC and repairs are scheduled. Consequently, this site will not need to be remediated.

Remediation Assessment

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
RCP 24" D	450.0	FT	$89.40	$40,230.00
USBR Baffled Pipe Outlet: No. 3	1.0	Each	$7,546.95	$7,546.95
CIP Concrete	3.0	CY	$1,135.47	$3,406.41
Structural Fill	10.0	CY	$36.65	$366.50
Trash Rack	9.0	SF	$34.22	$307.98
Check Guides: Replace	12.0	FT	$19.87	$238.44
Structural Excavation	10.0	CY	$22.95	$229.50
			Total Field Cost:	$52,325.78
			Contingencies: 15%	$7,848.87
			Subtotal:	$60,174.65
			Engineering: 10%	$6,017.46
			Mobilization: 10%	$6,017.46
			Current Replacement Value (CRV):	**$72,209.58**

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	60
Remediation Priority Index (RPI):	60

Deficiency

Category: CRPci

Rating: Critical

HKM ID:	**BB-CH2**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Big Bonanza**			***Structure Type:***	**Check**
UTM Zone:	**13**	***Coordinates:***	**0.0, 0.0**	***Total # of Photos:***	**0**

Notes: This structure is the first conceptual check structure for the reach of concrete lined ditch on the Big Bonanza Ditch. Recommended improvements to the canal reach is to remove the concrete liner, and reshaping/regrading the ditch. It is recommended that a concrete check be installed to improve regulation. The actual location of the check would depend on landowner coordination during design.

Remediation Assessment

Deficiency

Category: CMDM

Rating: Serious

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
NRCS Concrete Check (4'x4' Notch)	1.0	Each	$6,142.94	$6,142.94
			Total Field Cost:	$6,142.94
			Contingencies: 15%	$921.44
			Subtotal:	$7,064.38
			Engineering: 10%	$706.44
			Mobilization: 10%	$706.44
			Current Replacement Value (CRV):	**$8,477.26**

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	60
Remediation Priority Index (RPI):	60

HKM ID:	**BB-CH3**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Big Bonanza**			***Structure Type:***	**Check**
UTM Zone:	**13**	***Coordinates:***	**376662.1, 4929796.6**	***Total # of Photos:***	**0**

Notes: This structure is the first conceptual check structure for the reach of concrete lined ditch on the Big Bonanza Ditch. Recommended improvements to the canal reach is to remove the concrete liner, and reshaping/regrading the ditch. It is recommended that a concrete check be installed to improve regulation. The actual location of the check would depend on landowner coordination during design.

Remediation Assessment

Deficiency

Category: CMDM

Rating: Serious

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
NRCS Concrete Check (4'x4' Notch)	1.0	Each	$6,142.94	$6,142.94
			Total Field Cost:	$6,142.94
			Contingencies: 15%	$921.44
			Subtotal:	$7,064.38
			Engineering: 10%	$706.44
			Mobilization: 10%	$706.44
			Current Replacement Value (CRV):	**$8,477.26**

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	60
Remediation Priority Index (RPI):	60

HKM ID:	**BB-CH4**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Big Bonanza**			***Structure Type:***	**Check**
UTM Zone:	**13**	***Coordinates:***	**0.0, 0.0**	***Total # of Photos:***	**0**

Notes: This structure is the first conceptual check structure for the reach of concrete lined ditch on the Big Bonanza Ditch. Recommended improvements to the canal reach is to remove the concrete liner, and reshaping/regrading the ditch. It is recommended that a concrete check be installed to improve regulation. The actual location of the check would depend on landowner coordination during design.

Remediation Assessment

Deficiency

Category: CMDM

Rating: Serious

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
NRCS Concrete Check (4'x4' Notch)	1.0	Each	$6,142.94	$6,142.94
			Total Field Cost:	$6,142.94
			Contingencies: 15%	$921.44
			Subtotal:	$7,064.38
			Engineering: 10%	$706.44
			Mobilization: 10%	$706.44
			Current Replacement Value (CRV):	**$8,477.26**

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	60
Remediation Priority Index (RPI):	60

HKM ID:	**BB-TO1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Big Bonanza**			***Structure Type:***	**Turnout**
UTM Zone:	**13**	***Coordinates:***	**376594.6, 4928244.3**	***Total # of Photos:***	**1**

Notes: This structure is a conceptual turnout for the reach of concrete lined ditch on the Big Bonanza Ditch. Recommended improvements to the canal reach is to remove the concrete liner, and reshaping/regrading the ditch. Landowner interviews indicated that there are currently 12 siphon pipes serving water to the fields from the concrete lined ditch. Twelve standard turnouts are recommended for the remediation of this reach.

Remediation Assessment

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Precast Turnout	1.0	Each	$4,680.48	$4,680.48
			Total Field Cost:	$4,680.48
			Contingencies: 15%	$702.07
			Subtotal:	$5,382.55
			Engineering: 5%	$269.13
			Mobilization: 10%	$538.26
			Current Replacement Value (CRV):	**$6,189.93**

Deficiency

Category: CMDM

Rating: Serious

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	40
Remediation Priority Index (RPI):	40

HKM ID:	**BB-TO2**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Big Bonanza**			***Structure Type:***	**Turnout**
UTM Zone:	**13**	***Coordinates:***	**376507.6, 4928623.0**	***Total # of Photos:***	**1**

Notes: This structure is a conceptual turnout for the reach of concrete lined ditch on the Big Bonanza Ditch. Recommended improvements to the canal reach is to remove the concrete liner, and reshaping/regrading the ditch. Landowner interviews indicated that there are currently 12 siphon pipes serving water to the fields from the concrete lined ditch. Twelve standard turnouts are recommended for the remediation of this reach.

Remediation Assessment

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Precast Turnout	1.0	Each	$4,680.48	$4,680.48
			Total Field Cost:	$4,680.48
			Contingencies: 15%	$702.07
			Subtotal:	$5,382.55
			Engineering: 5%	$269.13
			Mobilization: 10%	$538.26
			Current Replacement Value (CRV):	**$6,189.93**

Deficiency

Category: CMDM

Rating: Serious

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	40
Remediation Priority Index (RPI):	40

HKM ID:	**BB-TO3**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Big Bonanza**			***Structure Type:***	**Turnout**
UTM Zone:	**13**	***Coordinates:***	**376517.8, 4928905.6**	***Total # of Photos:***	**0**

Notes: This structure is a conceptual turnout for the reach of concrete lined ditch on the Big Bonanza Ditch. Recommended improvements to the canal reach is to remove the concrete liner, and reshaping/regrading the ditch. Landowner interviews indicated that there are currently 12 siphon pipes serving water to the fields from the concrete lined ditch. Twelve standard turnouts are recommended for the remediation of this reach.

Remediation Assessment

Deficiency

Category: CMDM

Rating: Serious

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Precast Turnout	1.0	Each	$4,680.48	$4,680.48
			Total Field Cost:	$4,680.48
			Contingencies: 15%	$702.07
			Subtotal:	$5,382.55
			Engineering: 5%	$269.13
			Mobilization: 10%	$538.26
			Current Replacement Value (CRV):	**$6,189.93**

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	40
Remediation Priority Index (RPI):	40

HKM ID:	**BB-TO4**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Big Bonanza**			***Structure Type:***	**Turnout**
UTM Zone:	**13**	***Coordinates:***	**376706.9, 4929061.7**	***Total # of Photos:***	**0**

Notes: This structure is a conceptual turnout for the reach of concrete lined ditch on the Big Bonanza Ditch. Recommended improvements to the canal reach is to remove the concrete liner, and reshaping/regrading the ditch. Landowner interviews indicated that there are currently 12 siphon pipes serving water to the fields from the concrete lined ditch. Twelve standard turnouts are recommended for the remediation of this reach.

Remediation Assessment

Deficiency

Category: CMDM

Rating: Serious

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Precast Turnout	1.0	Each	$4,680.48	$4,680.48
			Total Field Cost:	$4,680.48
			Contingencies: 15%	$702.07
			Subtotal:	$5,382.55
			Engineering: 5%	$269.13
			Mobilization: 0%	$0.00
			Current Replacement Value (CRV):	**$5,651.68**

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	40
Remediation Priority Index (RPI):	40

HKM ID:	**BB-TO5**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Big Bonanza**			***Structure Type:***	**Turnout**
UTM Zone:	**13**	***Coordinates:***	**376687.0, 4929470.0**	***Total # of Photos:***	**0**

Notes: This structure is a conceptual turnout for the reach of concrete lined ditch on the Big Bonanza Ditch. Recommended improvements to the canal reach is to remove the concrete liner, and reshaping/regrading the ditch. Landowner interviews indicated that there are currently 12 siphon pipes serving water to the fields from the concrete lined ditch. Twelve standard turnouts are recommended for the remediation of this reach.

Remediation Assessment

Deficiency

Category: CMDM

Rating: Serious

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Precast Turnout	1.0	Each	$4,680.48	$4,680.48
			Total Field Cost:	$4,680.48
			Contingencies: 15%	$702.07
			Subtotal:	$5,382.55
			Engineering: 5%	$269.13
			Mobilization: 0%	$0.00
			Current Replacement Value (CRV):	**$5,651.68**

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	40
Remediation Priority Index (RPI):	40

HKM ID:	**BB-TO6**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Big Bonanza**			***Structure Type:***	**Turnout**
UTM Zone:	**13**	***Coordinates:***	**376570.3, 4929696.1**	***Total # of Photos:***	**0**

Notes: This structure is a conceptual turnout for the reach of concrete lined ditch on the Big Bonanza Ditch. Recommended improvements to the canal reach is to remove the concrete liner, and reshaping/regrading the ditch. Landowner interviews indicated that there are currently 12 siphon pipes serving water to the fields from the concrete lined ditch. Twelve standard turnouts are recommended for the remediation of this reach.

Remediation Assessment

Deficiency

Category: CMDM

Rating: Serious

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Precast Turnout	1.0	Each	$4,680.48	$4,680.48
			Total Field Cost:	$4,680.48
			Contingencies: 15%	$702.07
			Subtotal:	$5,382.55
			Engineering: 5%	$269.13
			Mobilization: 0%	$0.00
			Current Replacement Value (CRV):	**$5,651.68**

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	40
Remediation Priority Index (RPI):	40

HKM ID:	**BB-TO7**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Big Bonanza**			***Structure Type:***	**Turnout**
UTM Zone:	**13**	***Coordinates:***	**0.0, 0.0**	***Total # of Photos:***	**0**

Notes: This structure is a conceptual turnout for the reach of concrete lined ditch on the Big Bonanza Ditch. Recommended improvements to the canal reach is to remove the concrete liner, and reshaping/regrading the ditch. Landowner interviews indicated that there are currently 12 siphon pipes serving water to the fields from the concrete lined ditch. Twelve standard turnouts are recommended for the remediation of this reach.

Remediation Assessment

Deficiency

Category: CMDM

Rating: Serious

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Precast Turnout	1.0	Each	$4,680.48	$4,680.48
			Total Field Cost:	$4,680.48
			Contingencies: 15%	$702.07
			Subtotal:	$5,382.55
			Engineering: 5%	$269.13
			Mobilization: 10%	$538.26
			Current Replacement Value (CRV):	**$6,189.93**

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	40
Remediation Priority Index (RPI):	40

HKM ID:	**BB-TO8**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Big Bonanza**			***Structure Type:***	**Turnout**
UTM Zone:	**13**	***Coordinates:***	**0.0, 0.0**	***Total # of Photos:***	**0**

Notes: This structure is a conceptual turnout for the reach of concrete lined ditch on the Big Bonanza Ditch. Recommended improvements to the canal reach is to remove the concrete liner, and reshaping/regrading the ditch. Landowner interviews indicated that there are currently 12 siphon pipes serving water to the fields from the concrete lined ditch. Twelve standard turnouts are recommended for the remediation of this reach.

Remediation Assessment

Deficiency

Category: CMDM

Rating: Serious

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Precast Turnout	1.0	Each	$4,680.48	$4,680.48
			Total Field Cost:	$4,680.48
			Contingencies: 15%	$702.07
			Subtotal:	$5,382.55
			Engineering: 5%	$269.13
			Mobilization: 10%	$538.26
			Current Replacement Value (CRV):	**$6,189.93**

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	40
Remediation Priority Index (RPI):	40

HKM ID:	**BB-TO9**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Big Bonanza**			***Structure Type:***	**Turnout**
UTM Zone:	**13**	***Coordinates:***	**0.0, 0.0**	***Total # of Photos:***	**0**

Notes: This structure is a conceptual turnout for the reach of concrete lined ditch on the Big Bonanza Ditch. Recommended improvements to the canal reach is to remove the concrete liner, and reshaping/regrading the ditch. Landowner interviews indicated that there are currently 12 siphon pipes serving water to the fields from the concrete lined ditch. Twelve standard turnouts are recommended for the remediation of this reach.

Remediation Assessment

Deficiency

Category: CMDM

Rating: Serious

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Precast Turnout	1.0	Each	$4,680.48	$4,680.48
			Total Field Cost:	$4,680.48
			Contingencies: 15%	$702.07
			Subtotal:	$5,382.55
			Engineering: 5%	$269.13
			Mobilization: 10%	$538.26
			Current Replacement Value (CRV):	**$6,189.93**

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	40
Remediation Priority Index (RPI):	40

HKM ID:	**BB-TO10**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Big Bonanza**			***Structure Type:***	**Turnout**
UTM Zone:	**13**	***Coordinates:***	**0.0, 0.0**	***Total # of Photos:***	**0**

Notes: This structure is a conceptual turnout for the reach of concrete lined ditch on the Big Bonanza Ditch. Recommended improvements to the canal reach is to remove the concrete liner, and reshaping/regrading the ditch. Landowner interviews indicated that there are currently 12 siphon pipes serving water to the fields from the concrete lined ditch. Twelve standard turnouts are recommended for the remediation of this reach.

Remediation Assessment

Deficiency

Category: CMDM

Rating: Serious

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Precast Turnout	1.0	Each	$4,680.48	$4,680.48
			Total Field Cost:	$4,680.48
			Contingencies: 15%	$702.07
			Subtotal:	$5,382.55
			Engineering: 5%	$269.13
			Mobilization: 10%	$538.26
			Current Replacement Value (CRV):	**$6,189.93**

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	40
Remediation Priority Index (RPI):	40

HKM ID:	**BB-TO11**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Big Bonanza**			***Structure Type:***	**Turnout**
UTM Zone:	**13**	***Coordinates:***	**0.0, 0.0**	***Total # of Photos:***	**0**

Notes: This structure is a conceptual turnout for the reach of concrete lined ditch on the Big Bonanza Ditch. Recommended improvements to the canal reach is to remove the concrete liner, and reshaping/regrading the ditch. Landowner interviews indicated that there are currently 12 siphon pipes serving water to the fields from the concrete lined ditch. Twelve standard turnouts are recommended for the remediation of this reach.

Remediation Assessment

Deficiency

Category: CMDM

Rating: Serious

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Precast Turnout	1.0	Each	$4,680.48	$4,680.48
			Total Field Cost:	$4,680.48
			Contingencies: 15%	$702.07
			Subtotal:	$5,382.55
			Engineering: 5%	$269.13
			Mobilization: 10%	$538.26
			Current Replacement Value (CRV):	**$6,189.93**

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	40
Remediation Priority Index (RPI):	40

HKM ID:	**BB-TO12**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Big Bonanza**			***Structure Type:***	**Turnout**
UTM Zone:	**13**	***Coordinates:***	**0.0, 0.0**	***Total # of Photos:***	**0**

Notes: This structure is a conceptual turnout for the reach of concrete lined ditch on the Big Bonanza Ditch. Recommended improvements to the canal reach is to remove the concrete liner, and reshaping/regrading the ditch. Landowner interviews indicated that there are currently 12 siphon pipes serving water to the fields from the concrete lined ditch. Twelve standard turnouts are recommended for the remediation of this reach.

Remediation Assessment

Deficiency

Category: CMDM

Rating: Serious

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Precast Turnout	1.0	Each	$4,680.48	$4,680.48
			Total Field Cost:	$4,680.48
			Contingencies: 15%	$702.07
			Subtotal:	$5,382.55
			Engineering: 5%	$269.13
			Mobilization: 10%	$538.26
			Current Replacement Value (CRV):	**$6,189.93**

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	40
Remediation Priority Index (RPI):	40

Cleaning/Reshaping Report

HKM ID:	BB-1	Division:	Clear Creek		
Canal Name:	Big Bonanza [BB-1]	Length:	28,190 ft	Total # of Photos:	2
Notes:	This reach represents cleaning/reshaping costs associated with the Big Bonanza ditch. Landowner interviews indicated no concern for seepage areas or significant losses within the ditch. The ditch has sections of the ditch which are lined with concrete; however, there were no concerns identified regarding condition of concrete. The cleaning/reshaping costs assume an average cross-section of 12-feet.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	38,000.0	SY	$0.62	$23,560.00
			Total Field Cost:	$23,560.00
			Contingencies: 10%	$2,356.00
			Subtotal:	$25,916.00
			Engineering: 0%	$0.00
			Mobilization: 10%	$2,591.60
			Total Rehabilitation Cost:	**$28,507.60**
			Average Rehabilitation Cost per Foot:	**$1.01**

Deficiency

Category: C&ODM

Rating: Minor

Canal Liner Rehabilitation Report

HKM ID:	**BB-2**	**Division:**	**Clear Creek**		
Canal Name:	**Big Bonanza [BB-1]**	**Length:**	**5,700 ft**	**Total # of Photos:**	**4**

Notes: This reach of the Big Bonanza ditch is a concrete lined reach approximately 0.6 miles downstream from the headgate. The reach was identified by a downstream landowner. The liner appears to be in poor condition. There is significant cracking along the length of the reach. These cracks are significant. It appears that scour under the concrete liner has occurred, as there are numerous areas where the liner has buckled and sunk. The irrigator of the lands served by this section was contacted to discuss the reach. He indicated that the ditch was designed to serve field ditches from short siphon pipes that convey water out of the ditch to the field ditch. He indicated that the siphons do not draw enough water, and the field ditches are not low enough, or have enough slope to convey water appropriately. This causes water to stand and seep. He indicated that this could work alright for grass hay crop, but it is not appropriate for alfalfa. Due to the condition of the ditch, the only way to rehabilitate the concrete would be to remove it and re-pour it. As the current setup is not efficient and is marginally functional, it is recommended that the lining be removed completely. There are no signs of significant ditch seepage above or below this reach. The lining needs to be removed, and the ditch needs to be re-shaped and regraded. Compacted embankment is recommended to bring the ditch grade and sideslopes up approximately 4" to account for the depth of the removed concrete. A cross-section of 12-feet is assumed for cost estimates.

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Concrete Demo. & Disposal	850.0	CY	$209.94	$178,449.00
Compacted Embankment	850.0	CY	$7.50	$6,375.00
			Total Field Cost:	$184,824.00
			Contingencies: 10%	$18,482.40
			Subtotal:	$203,306.40
			Engineering: 10%	$20,330.64
			Mobilization: 10%	$20,330.64
			Total Rehabilitation Cost:	**$243,967.68**
			Average Rehabilitation Cost per Foot:	**$42.80**

Deficiency

Category: CMDM

Rating: Serious

Pratt & Ferris #2 Ditch

Figure 5-D – 7

Structure Reports: 2PF-DD1, Appendix 5-E

Canal Reports: 2PF-1 / 2PF-2, Appendix 5-E

Concept Improvements: Section 5.5.3

The Pratt & Ferris #2 Ditch diverts out of Clear Creek approximately seven miles downstream of the confluence with Piney Creek. The appropriation for the ditch is 28.3 cfs. The ditch serves approximately 1,980 acres along its 12 mile length, when it terminates into the Pratt & Ferris #3 Ditch. The headgate consists of a three-bay concrete structure. The bays are four feet wide with a three foot opening. All three bays are gated but it appears that only the center gate is operable. There is severe spalling on the entire structure and severe breakup on the piers. A six-inch buttress wall has been poured around the piers, but it is beginning to deteriorate away. There is major cracking along the entire concrete structure. Complete replacement of this structure is recommended due to the extent of the damage. Interviews revealed the fact that irrigators feel the diversion wall has settled and does not provide the head it used to.

Interviews indicated that operators would like to increase capacity in the ditch to 45 cfs. The ditch flows through the town of Clearmont, and then parallels the Pratt & Ferris #3 Ditch for approximately seven miles. There is concern that the ditch seeps through Clearmont, and safety of the open channel through the town is a concern. Flow measurements were taken in three locations along the ditch on July 22nd, 2009. Flow measurements were taken near the measurement flume, upstream of town, and downstream of town. The following table indicates the results of these measurements. Seepage losses through the town section of the ditch were minimal on the date of measurement. Further investigation may be needed to quantify seepage loss through town. The majority of the lands under this ditch are flood irrigated. There are some areas that are served by side roll sprinklers. There is one center pivot associated with this appropriation.

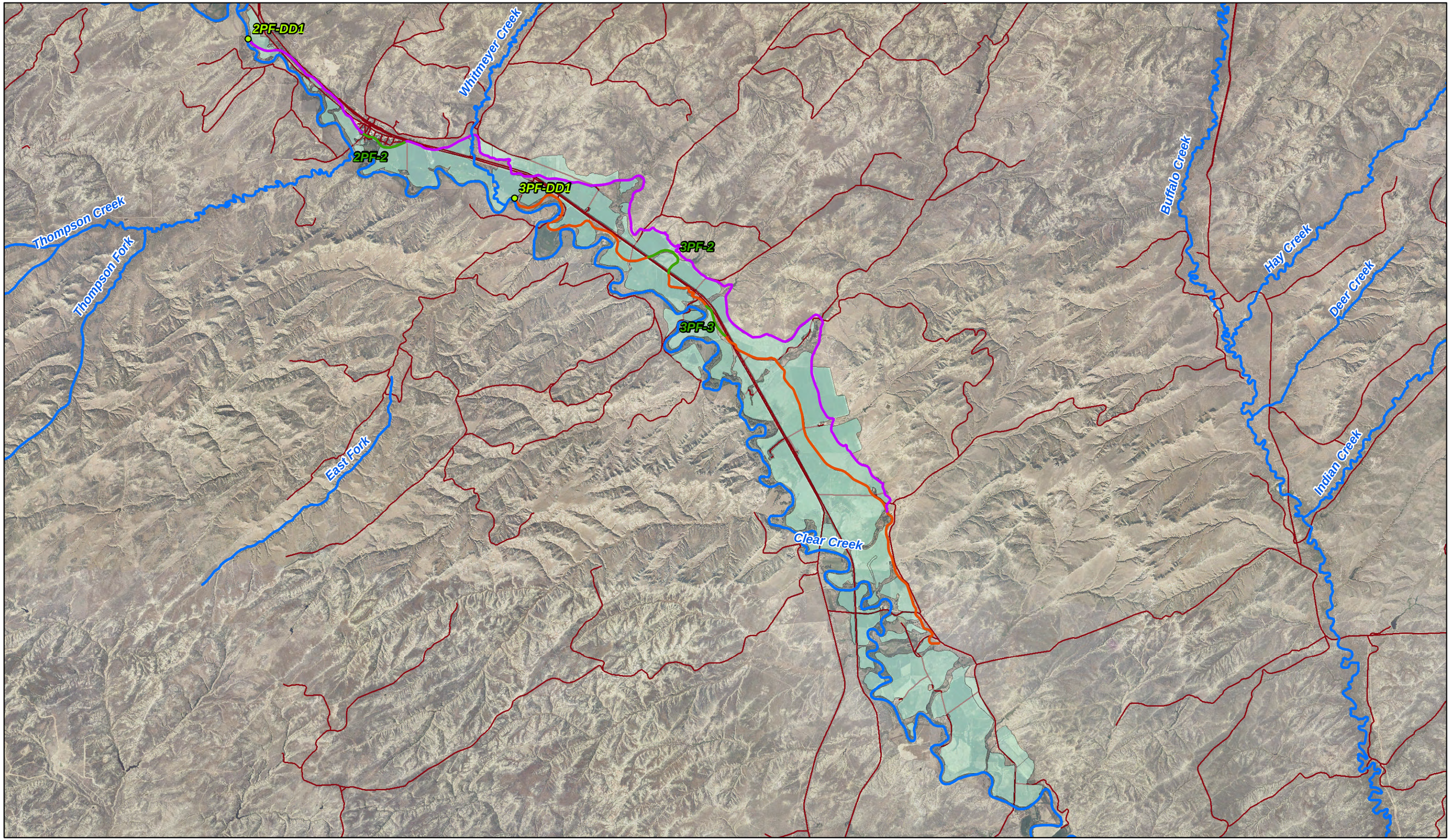
	Flow @ Upstream Flume (cfs)	Flow @ Upstream Clearmont (cfs)	Flow @ Downstream Clearmont (cfs)	Loss between Flume and Upstream town (cfs)	Loss between Upstream town and Downstream town (cfs)
7/22/2009	34.81	31.82	31.41	3.0	0.4

Pratt & Ferris #3 Ditch

Figure 5-D – 7
Structure Reports: 3PF-DD1, Appendix 5-E
Canal Reports: 3PF-1 / 3PF-2 / 3PF-3, Appendix 5-E
Concept Improvements: Section 5.5.3

The Pratt & Ferris #3 Ditch diverts out of Clear Creek approximately four miles downstream of the Pratt & Ferris #2 diversion. The appropriation of the ditch is 40.3 cfs. The ditch serves approximately 2,800 acres. The headgate consists of a four-bay concrete structure with a concrete diversion/spillway that spans the stream channel. Two of the bays have been completely filled with sediment and are inoperable. Only one of the two remaining bays has an operable gate. The concrete shows major spalling, and break up. There is evidence of concrete repairs in the past, but these repairs are failing. There is exposed rebar and cracking. Complete replacement of the head gate is warranted. The diversion/spillway appears to be in good condition. There is no wasteway behind the head gate, and it was revealed that flows over 60 cfs cause ditch bank destruction downstream of the diversion. A wasteway gate or weir is important to help protect downstream infrastructure from flood events.

There is evidence of buried geomembrane lining in sections along the ditch. One ditch section along the highway shows evidence of seepage. The landowner indicated that the fields below were unusable due to their saturation. He dug a collection ditch below the reach of the Pratt & Ferris #3 ditch, which has helped to dry out the lands and they are now irrigable. The upstream and downstream reaches of the ditch are lined with a buried liner. It is unknown if the section that was visited is unlined, or if it is lined with a failed liner. The majority of the irrigation along this ditch is flood irrigation. There is evidence of one center pivot sprinkler. As mentioned above, the Pratt & Ferris #2 Ditch parallels the Pratt & Ferris #3 for approximately seven miles. With both headgates being recommended for replacement, it could be beneficial to combine the ditches into the Pratt & Ferris #2.



0 2 4

Miles

Legend

- Evaluated Structures
- Streams
- Roads
- Pratt & Ferris #2
- Pratt & Ferris #3
- Seepage Area Lining
- Pratt & Ferris #2 & #3 associated lands

Figure 5-D - 7
Clear Creek Irrigation Assessment
Pratt & Ferris #2 & #3 Ditches

Local Name: Pratt & Ferris #2 Diversion

HKM ID:	**2PF-DD1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Pratt & Ferris #2**			***Structure Type:***	**Diversion Dam**
UTM Zone:	**13**	***Coordinates:***	**388758.2, 4941123.2**	***Total # of Photos:***	**12**

Notes: The Pratt & Ferris #2 ditch diverts out of Clear Creek approximately 1.8 miles south of Clearmont. The ditch has a direct flow water right of 28.3 cfs, which can serve approximately 1980 acres. Operators indicated that they typically run around 40 cfs. Irrigators feel that the crest of the diversion spillway has settled and they do not have the available head to push the volume of water they are appropriated. The head gate structure is a three-bay concrete structure. Two of the bays have 3 x 4.5-foot slide gates. The gates no longer seal, so a coffer dam must be build at the end of the irrigation season to prevent flows into the canal. The concrete is in poor condition. There is severe spalling and breakout on the whole structure. A 6" buttress wall was poured around the center piers, but it is cracking and falling away from the original structure. Cracking greater the 1/2" is present on a significant amount of the structure. For cracks greater than 1/2", it is assumed that the structural strength is lost and the section of the structure should be removed and replaced. For this reason, and the diversion elevation issues, the entire structure needs to be replaced. Replacement assumes a 'replace in kind' headgate section with a rock vane diversion; however, wall thicknesses were reduced to one foot. Costs also reflect a concrete weir downstream of the headworks that will spill water back to the creek instead of allowing too much flow down the ditch, which could overtop ditch banks. Miscellaneous costs reflect the costs of a fish screen structure and rated screen.

Remediation Assessment

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	99,000.0	$	$1.03	$101,970.00
CIP Concrete	32.0	CY	$1,135.47	$36,335.04
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
Stream Control (Medium)	1.0	Each	$27,559.61	$27,559.61
4-ft x 4-ft Slide Gate	4.0	Each	$6,460.84	$25,843.36
Concrete Demo. & Disposal	120.0	CY	$209.94	$25,192.80
USBR Concrete Weir (9' Notch)	1.0	Each	$11,710.55	$11,710.55
Trash Rack	108.0	SF	$34.22	$3,695.76
Handrail	65.0	FT	$50.71	$3,296.15
Structural Fill	70.0	CY	$36.65	$2,565.50
Structural Excavation	70.0	CY	$22.95	$1,606.50
Walkway (Expanded Steel)	54.0	SF	$17.95	$969.30
			Total Field Cost:	$271,644.57
			Active Dewatering: 7.5%	$20,373.34
			Contingencies: 10%	$27,164.46
			Subtotal:	$319,182.37
			Engineering: 15%	$47,877.36
			Mobilization: 10%	$31,918.24
			Current Replacement Value (CRV):	**$398,977.97**

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	90
Remediation Priority Index (RPI):	90

Deficiency

Category: CHSci

Rating: Critical

Cleaning/Reshaping Report

HKM ID:	**2PF-1**	**Division:**	**Clear Creek**		
Canal Name:	**Pratt & Ferris #2 [PF-2]**	**Length:**	**66,750 ft**	**Total # of Photos:**	**1**
Notes:	This reach represents the cleaning costs associated with the length of the Pratt & Ferris #2. The average cross-section was assumed to be 14 feet.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	104,000.0	SY	$0.62	$64,480.00
			Total Field Cost:	$64,480.00
			Contingencies: 10%	$6,448.00
			Subtotal:	$70,928.00
			Engineering: 0%	$0.00
			Mobilization: 10%	$7,092.80
			Total Rehabilitation Cost:	**$78,020.80**
			Average Rehabilitation Cost per Foot:	**$1.17**

Deficiency

Category: C&ODM

Rating: Minor

Seepage Area Lining Report

HKM ID:	2PF-2	Division:	Clear Creek		
Canal Name:	Pratt & Ferris #2 [PF-2]	Length:	2,950 ft	Total # of Photos:	1

Notes: This reach of the Pratt & Ferris #2 ditch passes through Clearmont. It was indicated by multiple people that they feel the ditch seeps through town. Flow measurements were taken at multiple locations and indicated minimal seepage through the town. Further investigation may be needed. Cost estimates were developed to quantify potential remediation efforts. Remediation assumes installation of 36" HDPE pipe. This allows for more than double appropriation of the ditch, which would allow for the low-head pipe to flow in a non-pressurized condition. It is assumed that the upstream 15 feet of the ditch above the pipe inlet will be lined with concrete, with safety cable across the ditch and a ladder for a walkout. This accounts for safety concerns identified by numerous land owners.

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 36" Pipe	2,950.0	FT	$65.57	$193,431.50
CIP Concrete	8.0	CY	$1,135.47	$9,083.76
Trash Rack	30.0	SF	$34.22	$1,026.60
Safety Cable	15.0	FT	$36.05	$540.75
Structural Fill	10.0	CY	$36.65	$366.50
Safety Ladder (10 feet)	1.0	Each	$235.66	$235.66
Structural Excavation	10.0	CY	$22.95	$229.50

Total Field Cost:		$204,914.27
Contingencies:	10%	$20,491.43
Subtotal:		$225,405.70
Engineering:	10%	$22,540.57
Mobilization:	10%	$22,540.57
Total Rehabilitation Cost:		**$270,486.84**
Average Rehabilitation Cost per Foot:		**$91.69**

Deficiency

Category: CRPci

Rating: Serious

Local Name: Pratt & Ferris #3 Diversion

HKM ID:	**3PF-DD1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Pratt & Ferris #3**			***Structure Type:***	**Diversion Dam**
UTM Zone:	**13**	***Coordinates:***	**391760.8, 4946201.6**	***Total # of Photos:***	**20**

Notes: The Pratt & Ferris #3 ditch diverts out of Clear Creek approximately four miles downstream of the Pratt & Ferris #2 diversion. The appropriation of the ditch is 40.3 cfs, which serves approximately 2,800 acres. Irrigators indicated that they can run up to 60 cfs. The diversion consists of a four-bay concrete structure with a concrete diversion/spillway that spans the stream channel. Two of the bays have been completely filled with sediment and are inoperable. Only one of the two remaining bays has an operable gate. The concrete shows major spalling, and pop out. There is evidence of concrete repairs in the past, but these repairs are failing. There is exposed rebar and cracking. Complete replacement of the head gate is warranted. The diversion/spillway appears to be in good condition. There is no wasteway behind the head gate, and it was revealed that flows over 60 cfs cause ditch bank destruction downstream of the diversion. A wasteway gate or weir is important to help protect downstream infrastructure from flood events. Replacement of this structure assumes a similar three bay concrete structure with a downstream weir plate to allow excess flows to return to the creek without damaging the downstream ditch. Differences in concrete demo & disposal reflect the removal of the spillway. Replacement of the spillway is accounted for in the Rock Vane diversion costs. Miscellaneous costs reflect a fish screen structure.

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	135,000.0	$	$1.03	$139,050.00
CIP Concrete	45.0	CY	$1,135.47	$51,096.15
Stream Control (Medium)	1.0	Each	$27,559.61	$27,559.61
4-ft x 4-ft Slide Gate	3.0	Each	$6,460.84	$19,382.52
Concrete Demo. & Disposal	80.0	CY	$209.94	$16,795.20
USBR Concrete Weir (9' Notch)	1.0	Each	$11,710.55	$11,710.55
Structural Fill	140.0	CY	$36.65	$5,131.00
Trash Rack	110.0	SF	$34.22	$3,764.20
Structural Excavation	140.0	CY	$22.95	$3,213.00
Handrail	35.0	FT	$50.71	$1,774.85
Walkway (Expanded Steel)	48.0	SF	$17.95	$861.60
			Total Field Cost:	$280,338.68
			Active Dewatering: 7.5%	$21,025.40
			Contingencies: 10%	$28,033.87
			Subtotal:	$329,397.95
			Engineering: 15%	$49,409.69
			Mobilization: 10%	$32,939.80
			Total Rehabilitation Cost:	**$411,747.44**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	135,000.0	$	$1.03	$139,050.00
CIP Concrete	45.0	CY	$1,135.47	$51,096.15
Concrete Demo. & Disposal	150.0	CY	$209.94	$31,491.00
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
Stream Control (Medium)	1.0	Each	$27,559.61	$27,559.61
4-ft x 4-ft Slide Gate	4.0	Each	$6,460.84	$25,843.36
USBR Concrete Weir (9' Notch)	1.0	Each	$11,710.55	$11,710.55
Trash Rack	110.0	SF	$34.22	$3,764.20
Structural Fill	100.0	CY	$36.65	$3,665.00
Structural Excavation	100.0	CY	$22.95	$2,295.00
Handrail	35.0	FT	$50.71	$1,774.85
Walkway (Expanded Steel)	48.0	SF	$17.95	$861.60
			Total Field Cost:	$330,011.32
			Active Dewatering: 7.5%	$24,750.85
			Contingencies: 10%	$33,001.13
			Subtotal:	$387,763.30
			Engineering: 15%	$58,164.50
			Mobilization: 10%	$38,776.33
			Current Replacement Value (CRV):	**$484,704.13**

Facilities Condition Index (FCI):	0.85
Asset Priority Index (API):	100
Remediation Priority Index (RPI):	85

Deficiency

Category: CHSdm

Rating: Critical

Cleaning/Reshaping Report

HKM ID:	3PF-1	Division:	Clear Creek		
Canal Name:	Pratt & Ferris #3 [PF-3]	Length:	49,400 ft	Total # of Photos:	4
Notes:	This reach represents the cleaning costs associated with the Pratt & Ferris #3 ditch. Landowners indicated that they have one seepage problem area but that it was to be remedied last fall (2009). No other problem reaches were identified. For this reason, the only costs for this ditch are for cleaning and reshaping. Average cross-section length was estimated to be 16 feet.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	88,000.0	SY	$0.62	$54,560.00

Total Field Cost:		$54,560.00
Contingencies:	10%	$5,456.00
Subtotal:		$60,016.00
Engineering:	0%	$0.00
Mobilization:	10%	$6,001.60
Total Rehabilitation Cost:		**$66,017.60**
Average Rehabilitation Cost per Foot:		**$1.34**

Deficiency

Category: C&ODM

Rating: Minor

Seepage Area Lining Report

HKM ID:	3PF-2	Division:	Clear Creek		
Canal Name:	Pratt & Ferris #3 [PF-3]	Length:	3,300 ft	Total # of Photos:	2

Notes: This reach of the Pratt & Ferris #3 Ditch is approximately 1.7 miles downstream of the diversion. Irrigator interviews indicated that the lands below the ditch have never been irrigated due to its 'bogginess'. A drainage culvert under the rail road and highway was recently cleaned and improved, and has eliminated standing water along the railroad. Lining the ditch could eliminate seepage and, with the drainage improvements recently completed, could make the lands productive. Costs assume HDPE pipe with concrete headwalls and a trashrack at the inlet.

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 42" Pipe	3,300.0	FT	$100.45	$331,485.00
CIP Concrete	1.0	CY	$1,135.47	$1,135.47
Trash Rack	30.0	SF	$34.22	$1,026.60
Structural Fill	4.0	CY	$36.65	$146.60
Structural Excavation	4.0	CY	$22.95	$91.80

Total Field Cost:		$333,885.47
Contingencies:	10%	$33,388.55
Subtotal:		$367,274.02
Engineering:	10%	$36,727.40
Mobilization:	10%	$36,727.40
Total Rehabilitation Cost:		**$440,728.82**
Average Rehabilitation Cost per Foot:		**$133.55**

Deficiency

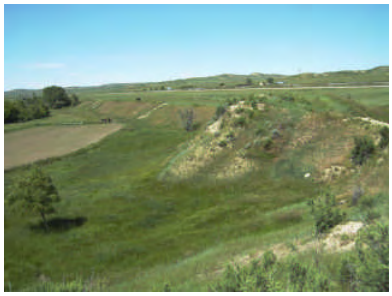
Category: CMDM

Rating: Minor

Seepage Area Lining Report

HKM ID:	3PF-3	Division:	Clear Creek		
Canal Name:	Pratt & Ferris #3 [PF-3]	Length:	2,250 ft	Total # of Photos:	5

Notes: This reach of the Pratt & Ferris #3 Ditch is a section along the highway that shows evidence of seepage. The landowner indicated that the fields below were unusable due to their saturation. He dug a collection ditch below the reach of the Pratt & Ferris #3 ditch, which has helped to dry out the lands and they are now irrigable. The upstream and downstream reaches of the ditch are lined with a buried liner. It is unknown if the section that was visited is unlined, or if it is lined with a failed liner. It is recommended that the reach be piped in HDPE pipe with concrete headwalls and trash rack to remediate the seepage issues.



Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 42" Pipe	2,250.0	FT	$100.45	$226,012.50
CIP Concrete	2.0	CY	$1,135.47	$2,270.94
Trash Rack	30.0	SF	$34.22	$1,026.60
Structural Fill	4.0	CY	$36.65	$146.60
Structural Excavation	4.0	CY	$22.95	$91.80

Total Field Cost:		$229,548.44
Contingencies:	10%	$22,954.84
Subtotal:		$252,503.28
Engineering:	10%	$25,250.33
Mobilization:	10%	$25,250.33
Total Rehabilitation Cost:		**$303,003.94**
Average Rehabilitation Cost per Foot:		**$134.67**

Deficiency

Category: CMDM

Rating: Serious

5.1.3.2 Piney Creek Irrigation Systems

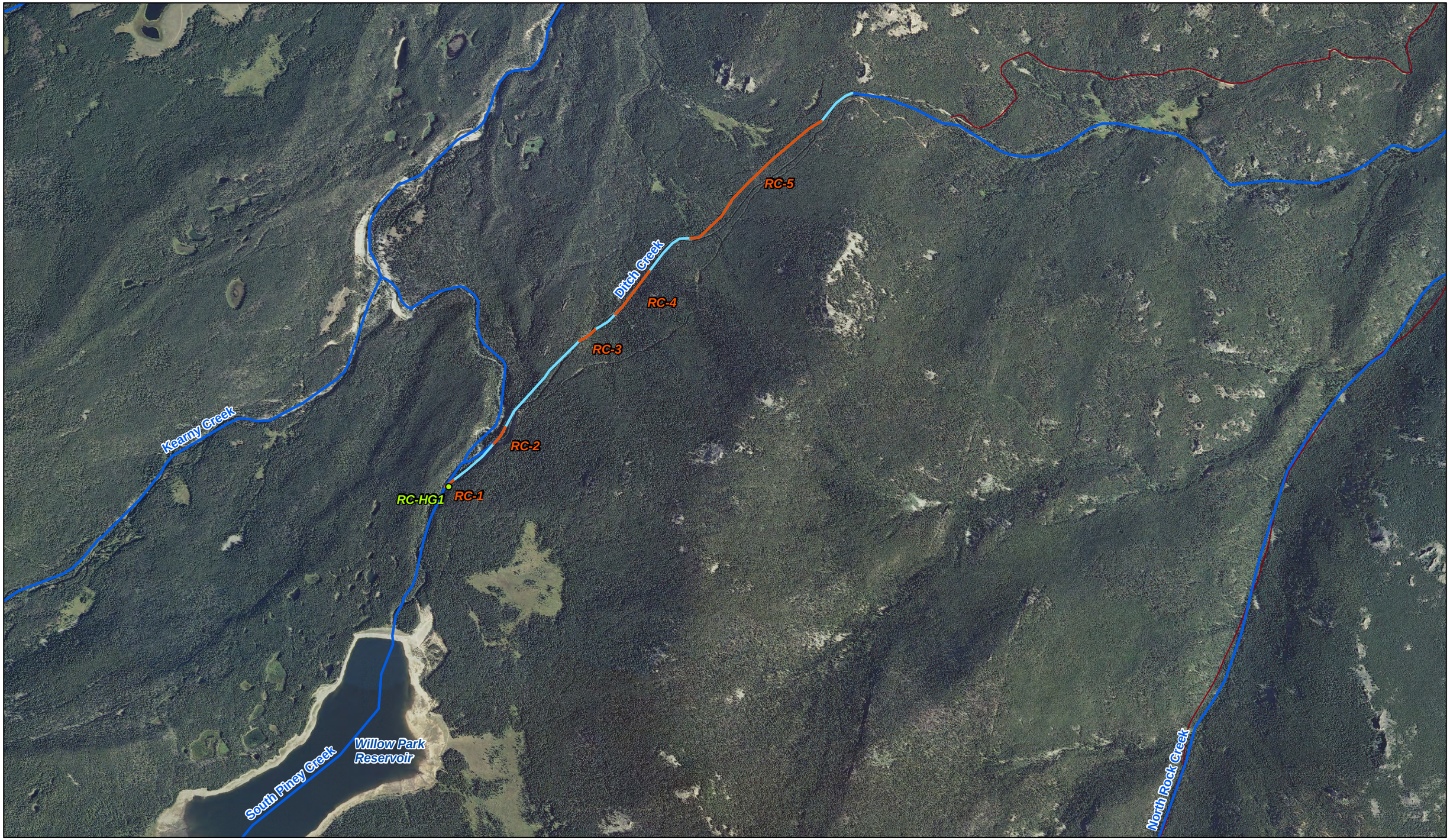
Rock Creek & South Piney Ditch

Figure 5-D – 8

Structure Reports: RC-HG1, Appendix 5-E

Canal Reports: RC-1 / RC-2 / RC-3 / RC-4 / RC-5, Appendix 5-E

The Rock Creek & South Piney Ditch diverts out of South Piney Creek below Willow Park Reservoir. The ditch conveys water from the south fork of Piney Creek to the north fork of Rock Creek. The ditch was excavated in the late 1800's, and is in an area of significant boulders, cobble and gravel. Consequently, there is significant seepage and losses along the ditch. The headgate was reworked in 1959 and the gates seem to seal well. Behind the headgate, there was evidence of water seeping back to the creek. The care taker indicated that late season flows are difficult to divert, and he sometimes has to get in the creek and stack rocks by hand to divert water to the ditch. There are a number of lined sections along the ditch. The liner is a vinyl liner with nylon reinforcement. It was indicated that the liner has been very effective in some areas, and moderately effective in others. At the time of the visit, the ditch was diverting approximately 38 cfs. It was indicated that the ditch was designed to carry 70 cfs, but that no more than 55 cfs can be diverted, due to seepage and low ditch banks. The ditch has a direct flow water right of 38.4 cfs, with the water coming from storage in Willow and Cloud Peak reservoirs. Lining the seepage areas is recommended. It was requested that a gunnite/shotcrete liner be evaluated, due to its ease of installation over large rocks and boulders compared to pipe and exposed liners.



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Legend

- Evaluated Structures
- Seepage Area Lining
- Rock Creek & South Piney Ditch
- Streams
- Roads

Figure 5-D - 8
Clear Creek Irrigation Assessment
Rock Creek & South Piney Ditch

Local Name: Rock Creek & South Piney Ditch Diversion

HKM ID:	**RC-HG1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Rock Creek & South Piney Ditch**	***Structure Type:***	**Headgate**		
UTM Zone:	**13**	***Coordinates:***	**338491.6, 4926111.4**	***Total # of Photos:***	**4**

Notes: This structure is the diversion structure for the Rock Creek & South Piney Ditch. The ditch diverts flows from South Piney Creek and conveys water to the north fork of Rock Creek. The headgate is composed of dual 3.5' slide gates mounted to a concrete headwall. The flume section of the headgate is made of old wooden logs, and water was clearly returning to the creek along these walls. It was indicated that the ditch master has to get in the creek and stack rocks in the later irrigation season to divert enough water to the headgate. This could be remediated by a rock vane diversion structure. Remediation assumes replacing the wooden walls with concrete. In addition, safety features need to be added. No fish screening structure is recommended as the ditch is just a conveyance ditch that feeds a natural drainage. Replacement assumes installation of a sluice gate to prevent any sedimentation at the gate during the non-irrigation season. The assumed concrete sidewalls will address the diverted losses back to the creek. Additional seepage is evident downstream and will be addressed in the canal sections.

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
Stream Control (Medium)	1.0	Each	$27,559.61	$27,559.61
CIP Concrete	6.0	CY	$1,135.47	$6,812.82
Structural Fill	25.0	CY	$36.65	$916.25
Handrail	16.0	FT	$50.71	$811.36
Structural Excavation	25.0	CY	$22.95	$573.75
Walkway (Expanded Steel)	24.0	SF	$17.95	$430.80
			Total Field Cost:	$68,004.59
			Active Dewatering: 7.5%	$5,100.34
			Contingencies: 15%	$10,200.69
			Subtotal:	$83,305.62
			Engineering: 10%	$8,330.56
			Mobilization: 10%	$8,330.56
			Total Rehabilitation Cost:	**$99,966.75**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
Stream Control (Medium)	1.0	Each	$27,559.61	$27,559.61
3.5-ft x 3.5-ft Slide Gate	2.0	Each	$4,516.91	$9,033.82
CIP Concrete	7.0	CY	$1,135.47	$7,948.29
3-ft x 3-ft Slide Gate	1.0	Each	$3,728.89	$3,728.89
Structural Fill	30.0	CY	$36.65	$1,099.50
Handrail	16.0	FT	$50.71	$811.36
Structural Excavation	30.0	CY	$22.95	$688.50
Walkway (Expanded Steel)	24.0	SF	$17.95	$430.80
			Total Field Cost:	$82,200.77
			Active Dewatering: 7.5%	$6,165.06
			Contingencies: 15%	$12,330.12
			Subtotal:	$100,695.94
			Engineering: 10%	$10,069.59
			Mobilization: 10%	$10,069.59
			Current Replacement Value (CRV):	**$120,835.13**

Facilities Condition Index (FCI):	0.83
Asset Priority Index (API):	90
Remediation Priority Index (RPI):	75

Deficiency

Category: CHSci

Rating: Critical

Seepage Area Lining Report

HKM ID:	RC-1	Division:	Clear Creek		
Canal Name:	Rock Creek & South Piney Ditch [RC-1]	Length:	175 ft	Total # of Photos:	1

Notes: This reach is a section of the Rock Creek & South Piney Ditch from the diversion structure to the weir. There were significant losses observed along this section. The ditch is excavated from sandy, gravel material with large boulders in areas. The size of the rocks makes it difficult to prepare the ditch bed appropriately for pipe or even exposed geomembrane liner. Lining on the Rock Creek & South Piney Ditch is assumed to be a gunnite/shotcrete material installed at a thickness of approximately four inches. Some excavation is included to allow for the four inch overlay. A cross-section of 20-feet is assumed.

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Shotcrete lining	3,600.0	SF	$3.33	$11,988.00
Galvanized 2"x2" #12 Steel Mesh	3,600.0	SF	$1.50	$5,400.00
Structural Excavation	40.0	CY	$22.95	$918.00
			Total Field Cost:	$18,306.00
			Contingencies: 10%	$1,830.60
			Subtotal:	$20,136.60
			Engineering: 10%	$2,013.66
			Mobilization: 10%	$2,013.66
			Total Rehabilitation Cost:	**$24,163.92**
			Average Rehabilitation Cost per Foot:	**$138.08**

Deficiency

Category: CMDM

Rating: Critical

Seepage Area Lining Report

HKM ID:	RC-2	Division:	Clear Creek		
Canal Name:	Rock Creek & South Piney Ditch [RC-1]	Length:	330 ft	Total # of Photos:	1

Notes: This reach is a second seepage area on the Rock Creek & South Piney Ditch. The seepage evident along this reach was significant enough that it has formed small channels. Lining this reach is recommended. Lining on the Rock Creek & South Piney Ditch is assumed to be a gunnite/shotcrete material installed at a thickness of approximately four inches. Some excavation is included to allow for the four inch overlay. A cross-section of 20-feet is assumed.

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Shotcrete lining	7,000.0	SF	$3.33	$23,310.00
Galvanized 2"x2" #12 Steel Mesh	7,000.0	SF	$1.50	$10,500.00
Structural Excavation	70.0	CY	$22.95	$1,606.50
			Total Field Cost:	$35,416.50
			Contingencies: 10%	$3,541.65
			Subtotal:	$38,958.15
			Engineering: 10%	$3,895.82
			Mobilization: 10%	$3,895.82
			Total Rehabilitation Cost:	**$46,749.78**
			Average Rehabilitation Cost per Foot:	**$141.67**

Deficiency

Category: CMDM

Rating: Critical

Seepage Area Lining Report

HKM ID:	RC-3	Division:	Clear Creek		
Canal Name:	Rock Creek & South Piney Ditch [RC-1]	Length:	325 ft	Total # of Photos:	0

Notes: This reach is the third reach on the Rock Creek & South Piney Ditch with significant seepage. Lining the reach is recommended. Lining on the Rock Creek & South Piney Ditch is assumed to be a gunnite/shotcrete material installed at a thickness of approximately four inches. Some excavation is included to allow for the four inch overlay. A cross-section of 20-feet is assumed.

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Shotcrete lining	7,000.0	SF	$3.33	$23,310.00
Galvanized 2"x2" #12 Steel Mesh	7,000.0	SF	$1.50	$10,500.00
Structural Excavation	70.0	CY	$22.95	$1,606.50

Total Field Cost:		$35,416.50
Contingencies:	10%	$3,541.65
Subtotal:		$38,958.15
Engineering:	10%	$3,895.82
Mobilization:	10%	$3,895.82
Total Rehabilitation Cost:		**$46,749.78**
Average Rehabilitation Cost per Foot:		**$143.85**

Deficiency

Category: CMDM

Rating: Critical

Seepage Area Lining Report

HKM ID:	RC-4	Division:	Clear Creek		
Canal Name:	Rock Creek & South Piney Ditch [RC-1]	Length:	900 ft	Total # of Photos:	4

Notes: This reach is the forth area of significant seepage along the Rock Creek & South Piney Ditch. Areas within the reach have been repaired with tarps and stacked rocks, however, there is significant flow spilling down the seepage channels. Lining the reach is recommended. Lining on the Rock Creek & South Piney Ditch is assumed to be a gunnite/shotcrete material installed at a thickness of approximately four inches. Some excavation is included to allow for the four inch overlay. A cross-section of 20-feet is assumed.

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Shotcrete lining	19,000.0	SF	$3.33	$63,270.00
Galvanized 2"x2" #12 Steel Mesh	19,000.0	SF	$1.50	$28,500.00
Structural Excavation	230.0	CY	$22.95	$5,278.50
			Total Field Cost:	$97,048.50
			Contingencies: 10%	$9,704.85
			Subtotal:	$106,753.35
			Engineering: 10%	$10,675.34
			Mobilization: 10%	$10,675.34
			Total Rehabilitation Cost:	**$128,104.02**
			Average Rehabilitation Cost per Foot:	**$142.34**

Deficiency

Category: CMDM

Rating: Critical

Seepage Area Lining Report

HKM ID:	RC-5	Division:	Clear Creek		
Canal Name:	Rock Creek & South Piney Ditch [RC-1]	Length:	2,900 ft	Total # of Photos:	5

Notes: This reach is the final reach of significant seepage along the ditch. Below this reach, the diverted flows turn down a natural drainage (Ditch Creek) until it meets the north fork of Rock Creek. The Ditch Creek section is very steep and it is assumed that there are very little losses through the section. Sections within the reach have been improved with a track hoe, but there is still significant seepage. Lining the reach is recommended. Lining on the Rock Creek & South Piney Ditch is assumed to be a gunnite/shotcrete material installed at a thickness of approximately four inches. Some excavation is included to allow for the four inch overlay. A cross-section of 20-feet is assumed.

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Shotcrete lining	60,000.0	SF	$3.33	$199,800.00
Galvanized 2"x2" #12 Steel Mesh	60,000.0	SF	$1.50	$90,000.00
Structural Excavation	750.0	CY	$22.95	$17,212.50

Total Field Cost:		$307,012.50
Contingencies:	10%	$30,701.25
Subtotal:		$337,713.75
Engineering:	10%	$33,771.38
Mobilization:	10%	$33,771.38
Total Rehabilitation Cost:		**$405,256.50**
Average Rehabilitation Cost per Foot:		**$139.74**

Deficiency

Category: CMDM

Rating: Critical

Piney Divide Ditch

Figure 5-D – 9
Structure Reports: PD-HG1, Appendix 5-E
Canal Reports: PD-1 / PD-2, Appendix 5-E

The Piney Divide Ditch diverts out of South Piney Creek and conveys water to Little Piney Creek. It was indicated in the Powder/Tongue study that this ditch is the first segment of a diversion that takes water from the South Fork of Piney Creek to Bear Creek. Irrigation water is conveyed from South Piney Creek to Piney Creek using the Piney Divide Ditch. It is then taken out of Piney Creek by the Little Piney Ditch. The Piney Divide Ditch has a direct flow right of 43.9 cfs, which includes the water that is simply routed to Piney Creek for use in the Little Piney Ditch. The actual appropriation associated with lands irrigated from the Piney Divide Ditch is approximately 18 cfs, and it serves approximately 1,270 acres. The ditch is an unlined earthen channel that flows for approximately 2 miles. Irrigators tend to flood irrigate crops, which typically consist of grass with some alfalfa. The area has seen some conversion to gated pipe and sprinkler irrigation.

The headgate is in poor condition. The left wing wall is broken and diverted water can seep under and around the headwall back into the creek. The left gate is no longer operated for this reason. The structure is a concrete diversion with two 3.5’ x 4’ steel slide gates.

The ditch is in fairly good condition; however, there was evidence of one area of seepage. Irrigation personnel indicated that they feel the ditch crosses over a gravel lens that causes significant seepage. This area could be lined or piped to eliminate these issues.

Little Piney Ditch

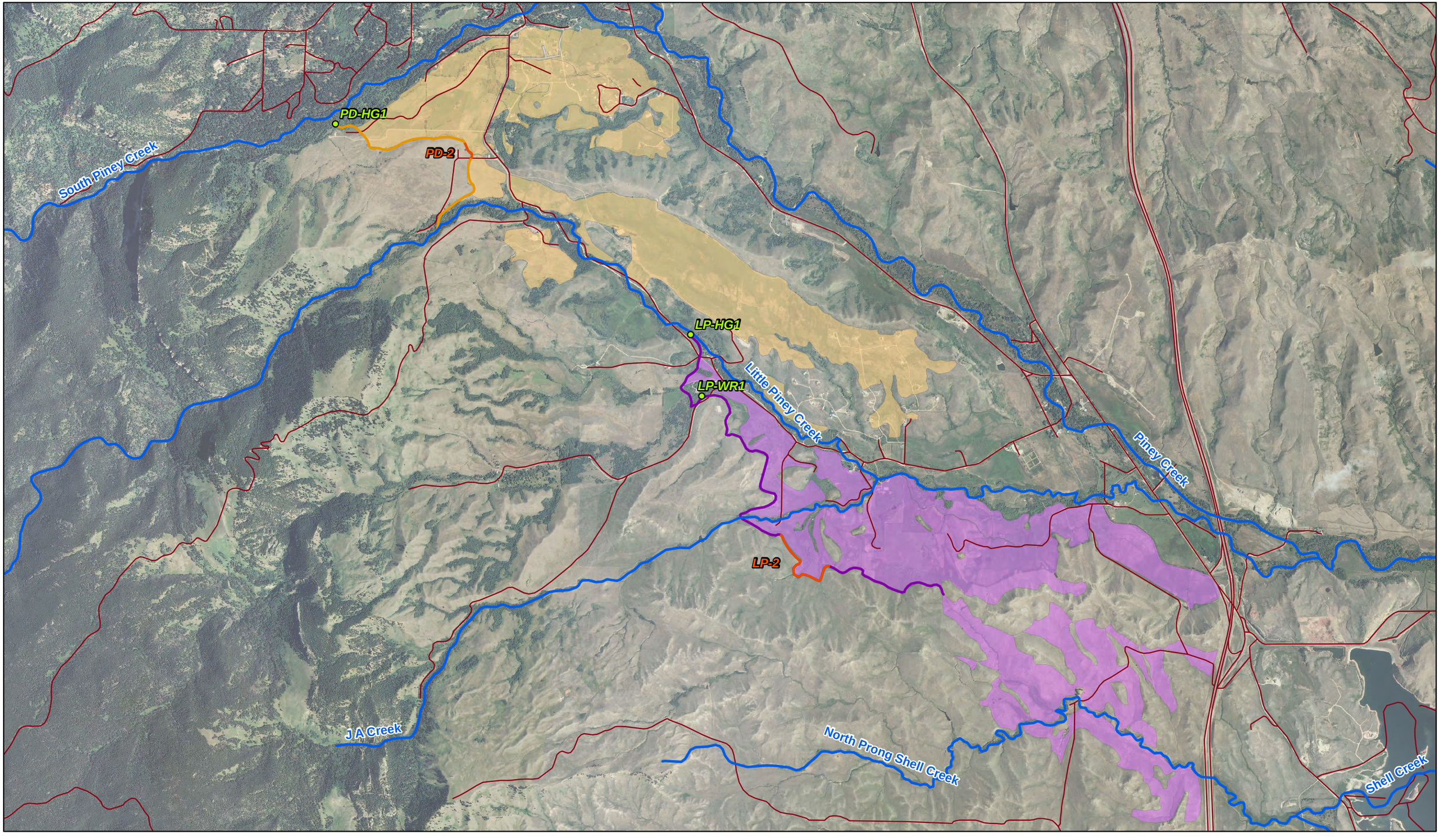
Figure 5-D – 9
Structure Reports: LP-HG1 / LP-WR1, Appendix 5-E
Canal Reports: LP-1 / LP-2, Appendix 5-E

The Little Piney Ditch diverts out of Little Piney Creek. It was indicated in the Powder/Tongue study that this ditch is the first segment of a diversion that takes water from the South Fork of Piney Creek to Bear Creek. Irrigation water is conveyed from South Piney Creek to Little Piney Creek using the Piney Divide Ditch. It is then taken out of Little Piney Creek by the Little Piney Ditch. The system has a direct flow right of 43.9 cfs, which includes the water for both the Piney Divide and Little Piney Ditches, as well as direct flow rights for fish habitat. The actual appropriation associated with lands irrigated from the Little Piney Ditch is approximately 18.6 cfs, and it serves approximately 1,300 acres. The ditch is an unlined earthen channel that flows for approximately 3.6 miles. Irrigators tend to flood irrigate crops, which typically consist of grass with some alfalfa.

The diversion on Little Piney Creek is in poor condition. The diversion is just a rock pile which needs to be reconfigured every year after high water. There is right bank instability in the channel which was identified by a large slump section. A wooden flume used to convey water from the rock diversion to the headgate. The flume has been destroyed, and the left bank of this section is eroding. There is a large bush on this bank, which appears to be the only thing keeping the bank from washing away. The headgate is a 5'x5' steel slide gate on a concrete headwall. There is some corrosion, but the headgate is generally in good condition. A trash rack is recommended. In addition, the diversion needs to be replaced. A sluice gate is recommended to convey water from the headgate back to the creek during the non-irrigation season.

The Little Piney Ditch weir is located just downstream of the Bear Creek diversion. Water is diverted from Little Piney Creek and flows to Bear Creek. From there, it is re-diverted out of Bear Creek and continues down the Little Piney Ditch. Just downstream of this diversion is the weir for the Little Piney Ditch. This weir was identified by the state as being out of level. In addition, water can be seen piping around the headwall and not flowing through the weir throat. The state has asked the ditch company to address these issues. In addition, there is debate as to whether the weir should be relocated to directly below the Little Piney Ditch diversion and headgate. It seems that the current location is appropriate, as it is accounting for the diverted irrigation water that serves vast majority of irrigated lands from the Little Piney Ditch.

The ditch is in fairly good condition; however, there was evidence of one area of significant seepage. Irrigation personnel indicated that during the irrigation season, water can be seen running out below the ditch bank onto the field below. It was identified that it is difficult to walk below the ditch bank due to water seepage. The vegetation changes below the ditch and at low points in the field indicate seepage as well. The irrigators are concerned with the seepage causing ditch bank failure and loss of an irrigation season. This area could be lined or piped to eliminate these issues.



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Legend

- Evaluated Structures
- Roads
- Streams
- Piney Divide Ditch
- Little Piney Ditch
- Seepage Area Lining
- Piney Divide Irrigated Lands
- Little Piney Irrigated Lands

Figure 5-D - 9
Clear Creek Irrigation Assessment
Piney Divide and Little Piney Ditch

Local Name: Piney Divide Headgate

HKM ID:	**PD-HG1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Piney Divide**			***Structure Type:***	**Headgate**
UTM Zone:	**13**	***Coordinates:***	**348089.9, 4935702.5**	***Total # of Photos:***	**4**

Notes: This structure is the headgate and diversion wall for the Piney Divide ditch, located on the South Fork of Piney Creek. The ditch is the first segment of a diversion that takes water from the South Fork of Piney Creek to Bear Creek. The direct flow appropriation for this ditch is 43.9 cfs; however, they typically run around 20 cfs. The headgate is a two bay concrete structure with two 4'x3' slide gates. The left slide gate is undermined, which allows diverted flows to quickly return to the creek. The gates do not seal. Landowners indicated that the diversion wall is in good condition and operates well. The concrete is showing significant cracking on the left wall, probably a result of the undermining. It is recommended that the left wall of the head works portion of the structure be replaced. In addition, the gates should be replaced as well. Safety features need to be added to the structure. Replacement assumes a rock vane diversion.

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
4-ft x 4-ft Slide Gate	2.0	Each	$6,460.84	$12,921.68
Stream Control (Small)	1.0	Each	$6,812.78	$6,812.78
CIP Concrete	4.0	CY	$1,135.47	$4,541.88
Handrail	40.0	FT	$50.71	$2,028.40
Trash Rack	50.0	SF	$34.22	$1,711.00
Walkway (Expanded Steel)	33.0	SF	$17.95	$592.35
Structural Fill	15.0	CY	$36.65	$549.75
Structural Excavation	15.0	CY	$22.95	$344.25
			Total Field Cost:	$29,502.09
			Active Dewatering: 7.5%	$2,212.66
			Contingencies: 10%	$2,950.21
			Subtotal:	$34,664.96
			Engineering: 10%	$3,466.50
			Mobilization: 10%	$3,466.50
			Total Rehabilitation Cost:	**$41,597.95**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
4-ft x 4-ft Slide Gate	2.0	Each	$6,460.84	$12,921.68
CIP Concrete	8.0	CY	$1,135.47	$9,083.76
Stream Control (Small)	1.0	Each	$6,812.78	$6,812.78
2-ft x 2-ft Slide Gate	1.0	Each	$2,670.63	$2,670.63
Handrail	40.0	FT	$50.71	$2,028.40
Trash Rack	50.0	SF	$34.22	$1,711.00
Concrete Demo. & Disposal	8.0	CY	$209.94	$1,679.52
Structural Fill	25.0	CY	$36.65	$916.25
Walkway (Expanded Steel)	33.0	SF	$17.95	$592.35
Structural Excavation	25.0	CY	$22.95	$573.75
			Total Field Cost:	$69,890.12
			Active Dewatering: 7.5%	$5,241.76
			Contingencies: 10%	$6,989.01
			Subtotal:	$82,120.89
			Engineering: 10%	$8,212.09
			Mobilization: 10%	$8,212.09
			Current Replacement Value (CRV):	**$98,545.07**

Facilities Condition Index (FCI):	0.42
Asset Priority Index (API):	100
Remediation Priority Index (RPI):	42

Deficiency

Category: CMDM

Rating: Critical

Cleaning/Reshaping Report

HKM ID:	**PD-1**	**Division:**	**Clear Creek**		
Canal Name:	**Piney Divide [PD-1]**	**Length:**	**8,250 ft**	**Total # of Photos:**	**4**
Notes:	This reach reflects cleaning/reshaping costs associated with the Piney Divide ditch. Seepage issues are addressed in PD-2. The cleaning costs assume a cross-section length of 13-feet.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	12,000.0	SY	$0.62	$7,440.00
			Total Field Cost:	$7,440.00
			Contingencies: 10%	$744.00
			Subtotal:	$8,184.00
			Engineering: 0%	$0.00
			Mobilization: 10%	$818.40
			Total Rehabilitation Cost:	**$9,002.40**
			Average Rehabilitation Cost per Foot:	**$1.09**

Deficiency

Category: C&ODM

Rating: Minor

Seepage Area Lining Report

HKM ID:	PD-2	Division:	Clear Creek		
Canal Name:	Piney Divide [PD-1]	Length:	600 ft	Total # of Photos:	0
Notes:	This reach represents a seepage section within the Piney Divide ditch. The seepage was identified by landowners and is evident on aerial photos. The costs assume installing HDPE pipe through the section with a headwall at the inlet and outlet. Trash rack is assumed at the inlet.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 36" Pipe	600.0	FT	$65.57	$39,342.00
CIP Concrete	1.0	CY	$1,135.47	$1,135.47
Trash Rack	20.0	SF	$34.22	$684.40
Structural Fill	2.0	CY	$36.65	$73.30
Structural Excavation	2.0	CY	$22.95	$45.90

Total Field Cost:		$41,281.07
Contingencies:	10%	$4,128.11
Subtotal:		$45,409.18
Engineering:	10%	$4,540.92
Mobilization:	10%	$4,540.92
Total Rehabilitation Cost:		**$54,491.01**
Average Rehabilitation Cost per Foot:		**$90.82**

Deficiency

Category: CMDM

Rating: Serious

Local Name: Little Piney Diversion

HKM ID:	**LP-HG1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Little Piney Ditch**			***Structure Type:***	**Headgate**
UTM Zone:	**13**	***Coordinates:***	**351595.4, 4933626.8**	***Total # of Photos:***	**6**

Notes: This structure is the diversion on Little Piney Creek. The diversion is just a rock pile which needs to be reconfigured every year after high water. There is right stream bank instability in the channel which was identified by a large slump section. A wooden flume used to convey water from the rock diversion to the headgate. The flume has been destroyed, and the left bank of this section is eroding. There is a large bush on this bank, which appears to be the only thing keeping the bank from washing away. The headgate is a 5'x5' steel slide gate on a concrete headwall. There is some corrosion, but the headgate is generally in good condition. A trash rack is recommended. In addition, the diversion needs to be replaced. A sluice gate is recommended to convey water from the headgate to the creek during the non-irrigation season. Riprap is recommended to stabilize the right stream bank just upstream of the diversion.

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
Stream Control (Small)	1.0	Each	$6,812.78	$6,812.78
2-ft x 2-ft Slide Gate	1.0	Each	$2,670.63	$2,670.63
Trash Rack	75.0	SF	$34.22	$2,566.50
CIP Concrete	2.0	CY	$1,135.47	$2,270.94
Riprap Bank Protection	20.0	CY	$55.40	$1,108.00
HDPE 24" Pipe	25.0	FT	$38.03	$950.75
			Total Field Cost:	$47,279.60
			Active Dewatering: 7.5%	$3,545.97
			Contingencies: 10%	$4,727.96
			Subtotal:	$55,553.53
			Engineering: 15%	$8,333.03
			Mobilization: 10%	$5,555.35
			Total Rehabilitation Cost:	**$69,441.91**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
5-ft x 5-ft Slide Gate	1.0	Each	$8,847.60	$8,847.60
Stream Control (Small)	1.0	Each	$6,812.78	$6,812.78
CIP Concrete	5.0	CY	$1,135.47	$5,677.35
2-ft x 2-ft Slide Gate	1.0	Each	$2,670.63	$2,670.63
Trash Rack	75.0	SF	$34.22	$2,566.50
Riprap Bank Protection	20.0	CY	$55.40	$1,108.00
Concrete Demo. & Disposal	2.0	CY	$209.94	$419.88
HDPE 24" Pipe	1.0	FT	$38.03	$38.03
			Total Field Cost:	$59,040.77
			Active Dewatering: 7.5%	$4,428.06
			Contingencies: 10%	$5,904.08
			Subtotal:	$69,372.91
			Engineering: 15%	$10,405.94
			Mobilization: 10%	$6,937.29
			Current Replacement Value (CRV):	**$86,716.13**

Facilities Condition Index (FCI):	0.8
Asset Priority Index (API):	80
Remediation Priority Index (RPI):	64

Deficiency

Category: CMDM

Rating: Critical

Local Name: Little Piney Weir

HKM ID:	**LP-WR1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Little Piney Ditch**			***Structure Type:***	**Weir**
UTM Zone:	**13**	***Coordinates:***	**351705.2, 4933021.2**	***Total # of Photos:***	**4**

Notes: The Little Piney Ditch weir is located just downstream of the Bear Creek diversion. Water is diverted out of Little Piney Creek and flows to Bear Creek. Irrigation water is then diverted out of Bear Creek and continues down the Little Piney Ditch. Just downstream of this diversion is the weir for the Little Piney Ditch. This weir was identified by the state as being out of level. In addition, water can be seen piping around the headwall and not flowing through the weir throat. The state has asked the ditch company to address these issues. In addition, there is debate as to whether the weir should be relocated to directly below the Little Piney Ditch diversion and headgate. It seems that the current location is appropriate, as it is accounting for the diverted irrigation water that serves vast majority of irrigated lands from the Little Piney Ditch. Re-forming the cutoff walls, leveling, and re-calibrating the weir is recommended. The leveling and recalibration is identified as the miscellaneous cost.

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
CIP Concrete	3.0	CY	$1,135.47	$3,406.41
Miscellaneous	500.0	$	$1.03	$515.00
Concrete Demo. & Disposal	2.0	CY	$209.94	$419.88
			Total Field Cost:	$4,341.29
			Contingencies: 10%	$434.13
			Subtotal:	$4,775.42
			Engineering: 5%	$238.77
			Mobilization: 10%	$477.54
			Total Rehabilitation Cost:	**$5,491.73**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Parshall Flume (35 cfs)	1.0	Each	$4,534.04	$4,534.04
CIP Concrete	3.0	CY	$1,135.47	$3,406.41
Miscellaneous	500.0	$	$1.03	$515.00
Concrete Demo. & Disposal	2.0	CY	$209.94	$419.88
			Total Field Cost:	$8,875.33
			Contingencies: 10%	$887.53
			Subtotal:	$9,762.86
			Engineering: 5%	$488.14
			Mobilization: 10%	$976.29
			Current Replacement Value (CRV):	**$11,227.29**

Facilities Condition Index (FCI):	0.49
Asset Priority Index (API):	60
Remediation Priority Index (RPI):	29

Deficiency

Category: C&ODM

Rating: Serious

Cleaning/Reshaping Report

HKM ID:	LP-1	Division:	Clear Creek		
Canal Name:	Little Piney Ditch [LP-1]	Length:	15,700 ft	Total # of Photos:	0
Notes:	This reach reflects cleaning/reshaping costs associated with the Little Piney ditch. Seepage issues are addressed in LP-2. The cleaning costs assume a cross-section length of 13-feet. The length of the ditch reflects the total length minus the length of identified seepage areas. This includes an area that was recently put in pipe (300 ft).				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	22,700.0	SY	$0.62	$14,074.00

Total Field Cost:		$14,074.00
Contingencies:	10%	$1,407.40
Subtotal:		$15,481.40
Engineering:	0%	$0.00
Mobilization:	10%	$1,548.14
Total Rehabilitation Cost:		**$17,029.54**
Average Rehabilitation Cost per Foot:		**$1.08**

Deficiency

Category: C&ODM

Rating: Minor

Seepage Area Lining Report

HKM ID:	LP-2	Division:	Clear Creek		
Canal Name:	Little Piney Ditch [LP-1]	Length:	3,200 ft	Total # of Photos:	5

Notes: This reach represents an area of seepage on the ditch. Irrigation personnel indicated that during the irrigation season, water can be seen running out below the ditch bank onto the field below. It was identified that it is difficult to walk below the ditch bank due to water seepage. The vegetation changes below the ditch and at low points in the field indicate seepage as well. The irrigators are concerned with the seepage causing ditch bank failure and loss of an irrigation season. A similar reach upstream of this site was recently piped with HDPE pipe (300-feet), and is now performing well. Irrigators were unsure if the recently installed pipe was 30" or 36". For this assessment 30" HDPE is recommended. Additional costs reflect a concrete headwall and trash rack.

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 30" Pipe	3,200.0	FT	$50.61	$161,952.00
CIP Concrete	2.0	CY	$1,135.47	$2,270.94
Trash Rack	25.0	SF	$34.22	$855.50

Total Field Cost:		$165,078.44
Contingencies:	10%	$16,507.84
Subtotal:		$181,586.28
Engineering:	10%	$18,158.63
Mobilization:	10%	$18,158.63
Total Rehabilitation Cost:		**$217,903.54**
Average Rehabilitation Cost per Foot:		**$68.09**

Deficiency

Category:

Rating:

Leiter Ditch

Figure 5-D – 10
Structure Reports: LD-HG1, Appendix 5-E
Canal Reports: LD-1 / LD-2 / LD-3 / LD-4, Appendix 5-E

The Leiter Ditch diverts from Piney Creek approximately 14 miles north-northwest of Buffalo off of Story Road (State Highway 193). The ditch flows approximately 2.5 miles and serves approximately 65 acres before flowing into Lake DeSmet. This ditch is primarily a diversion to convey creek flows to Lake DeSmet. The canal runs when the lake needs to be filled and there is excess water in the creek. It was indicated by irrigation personnel that the ditch was designed to convey up to 300 cfs, but is now unable to carry more than 70 cfs. Additional interviews with State Engineer's Office personnel indicated that the area around the interstate is actually a fill section, which becomes saturated, and there is concern about losing the ditch. It was indicated that approximately 40 cfs is the maximum diversion due to the condition of the ditch.

The headgate for this ditch consists of two 4' x 4' rectangular steel gates mounted on a concrete headwall. The concrete is in fairly good condition, but the headgates do not seal well. This is evident by standing water in the canal. Field personnel indicated that they have sediment and debris issues at the head gate. It was indicated that they typically have to pull logs and branches out from under the gates following the operation of the gates. No trash rack is present.

There is a large cut section that restricts canal flows and causes backwater in the canal. It is believed that this backwater causes seepage along the canal from downstream of the headgate to west of the interstate. This causes significant sub-irrigation, so that the lands below the canal are unusable. Runoff from Interstate 90 makes its way into the ditch just east of the interstate overpass. There is currently a large head cut starting at the ditch and working its way towards the interstate. This head cut is approximately six feet deep and needs to be addressed. Armoring this head cut is recommended. Irrigation personnel indicated that they have been in contact with WYDOT and WYDOT will be addressing the issue.

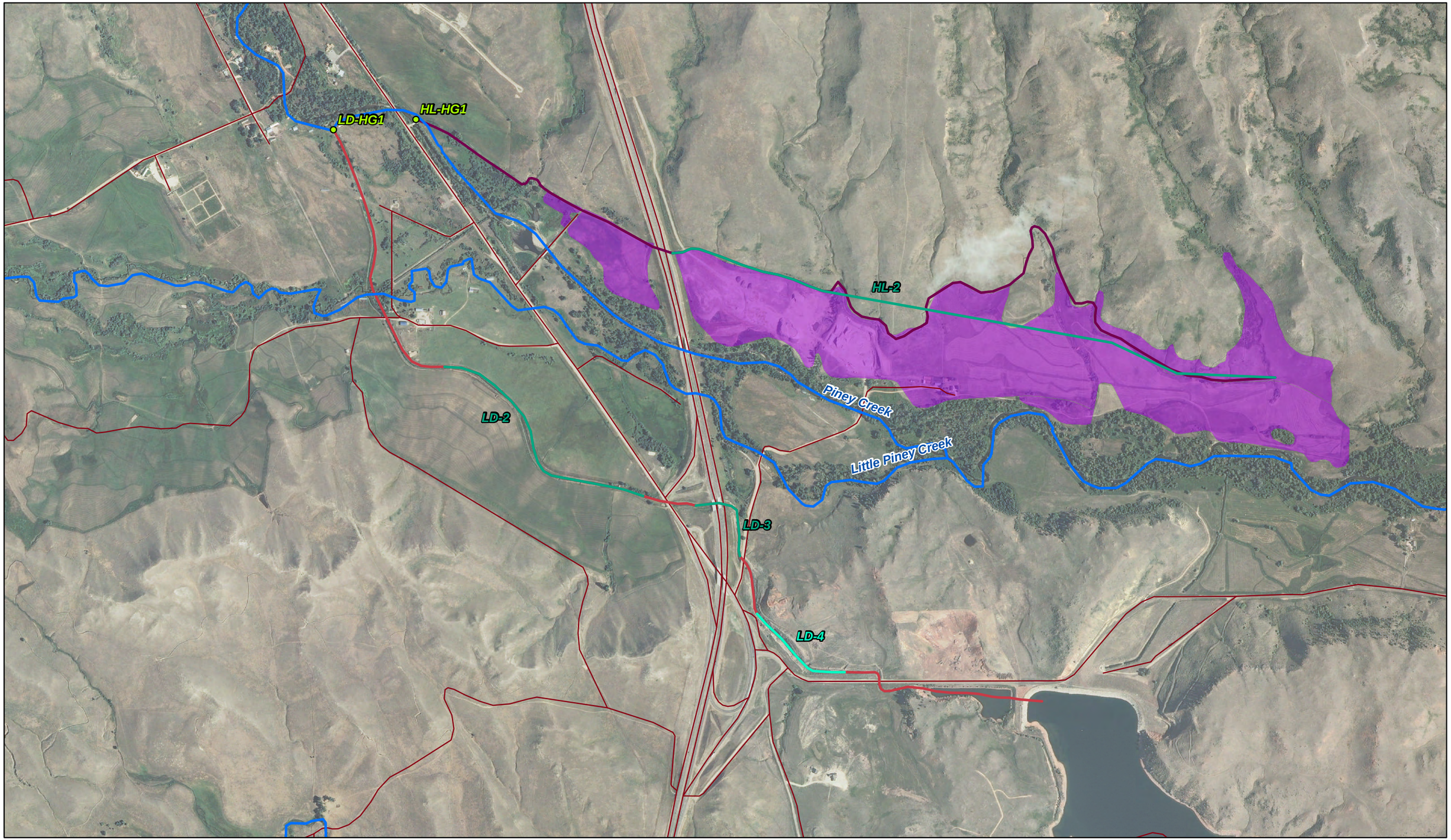
On the lower end of the canal, the canal passes through a very large cut section. This cut section was excavated through a ridge, and has steep side slopes. The side slopes have not re-established vegetation, so over the years, significant sediment has built up in the channel. As a result, there has been significant capacity reduction and increased backwater. At times freeboard near the interstate is only one foot. The channel was recently cleaned by excavating an 8-foot trench through the cut section, but back water is still present in the ditch. Re-grading the ditch is recommended. Piping the canal through the cut section is also recommended.

High Line Ditch

Figure 5-D – 10
Structure Reports: HL-HG1, Appendix 5-E
Canal Reports: HL-1 / HL-2, Appendix 5-E

The High Line Ditch diverts out of Piney Creek and flows east under the interstate, serving lands east of the interstate. The unlined earthen ditch is approximately 2.6 miles long. The ditch has an 1884 water right, and 1,100 acre-ft of appropriated storage right. It originally served approximately 230 acres; however, some of that has been lost due to gravel mining just east of the interstate. This would result in a diversion of 3.3 cfs, based on one cfs for every 70 irrigated acres. Prior to the gravel pit, the lands were irrigated, but there were issues with prairie dogs. Since the mine, the ditch has become more porous, and when water is run in the ditch, it creates springs in the lower fields. Piping the ditch from east of the interstate, to the three fields that are east of the gravel pit would be very beneficial. It could potentially serve sprinklers on these lower fields through gravity.

It was noted that the headgate has debris issues in that high water can force rocks and debris under the headgate. This then has to be removed by hand. A trashrack on the headgate would be very beneficial.



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Legend

- Evaluated Structures
- Roads
- Streams
- High Line Ditch
- Leiter Ditch
- Canal Constriction
- Seepage Area Lining
- High Line Irrigated Lands

Figure 5-D - 10
Clear Creek Irrigation Assessment
Leiter Ditch and High Line Ditch

Local Name: Leiter Ditch Headgate

HKM ID:	**LD-HG1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Leiter Ditch**			***Structure Type:***	**Headgate**
UTM Zone:	**13**	***Coordinates:***	**355460.0, 4932670.9**	***Total # of Photos:***	**6**

Notes: This structure is the headgate for the Leiter Ditch. It is recessed off of Piney Creek. This diversion is a concrete headwall and wing walls with dual 4x4 slide gates. There is minor spalling on the concrete headwall. The diversion has sediment and debris issues. Irrigation personnel indicated that they typically have to pull logs and branches out from under the gates following operation. The diversion could use safety features, a trash rack, and potentially a sweeper log setup to divert large debris and allow it to continue flowing down Piney Creek. This sweeper log is reflected in the miscellaneous costs. In addition, a sluice gate needs to be installed to remediate sediment issues at the headgate during the non-irrigation season. This is reflected by structure ex/fill and CIP concrete for a new headwall, with 24" RCP and slide gate. Replacement assumes that the structure is relocated to the right bank of the channel and will receive flow from a new rock vane diversion. Replacement assumes a 'replace in kind' structure which incorporates a sluice gate for the non-irrigation season. One of the gates was eliminated. This is because it was noted that the safe operation of the ditch is currently approximately 40 cfs. A single 4' RCP could convey approximately 100 cfs, or 2.5 times greater than the safe operating flow currently observed.

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Stream Control (Medium)	1.0	Each	$27,559.61	$27,559.61
4-ft x 4-ft Slide Gate	2.0	Each	$6,460.84	$12,921.68
RCP 24" D	60.0	FT	$89.40	$5,364.00
Miscellaneous	5,000.0	$	$1.03	$5,150.00
CIP Concrete	4.0	CY	$1,135.47	$4,541.88
Trash Rack	120.0	SF	$34.22	$4,106.40
2-ft x 2-ft Slide Gate	1.0	Each	$2,670.63	$2,670.63
Handrail	40.0	FT	$50.71	$2,028.40
Structural Fill	20.0	CY	$36.65	$733.00
Structural Excavation	20.0	CY	$22.95	$459.00
Riprap Bank Protection	1.0	CY	$55.40	$55.40
			Total Field Cost:	$65,590.00
			Active Dewatering: 7.5%	$4,919.25
			Contingencies: 10%	$6,559.00
			Subtotal:	$77,068.25
			Engineering: 15%	$11,560.24
			Mobilization: 10%	$7,706.83
			Total Rehabilitation Cost:	**$96,335.31**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
Stream Control (Medium)	1.0	Each	$27,559.61	$27,559.61
CIP Concrete	12.0	CY	$1,135.47	$13,625.64
RCP 48" D	30.0	FT	$256.97	$7,709.10
4-ft x 4-ft Slide Gate	1.0	Each	$6,460.84	$6,460.84
Trash Rack	120.0	SF	$34.22	$4,106.40
Structural Fill	100.0	CY	$36.65	$3,665.00
RCP 24" D	40.0	FT	$89.40	$3,576.00
2-ft x 2-ft Slide Gate	1.0	Each	$2,670.63	$2,670.63
Handrail	50.0	FT	$50.71	$2,535.50
Structural Excavation	100.0	CY	$22.95	$2,295.00
Concrete Demo. & Disposal	8.0	CY	$209.94	$1,679.52
Riprap Bank Protection	3.0	CY	$55.40	$166.20
			Total Field Cost:	$106,949.44
			Active Dewatering: 7.5%	$8,021.21
			Contingencies: 10%	$10,694.94
			Subtotal:	$125,665.59
			Engineering: 15%	$18,849.84
			Mobilization: 10%	$12,566.56
			Current Replacement Value (CRV):	**$157,081.99**

Facilities Condition Index (FCI):	0.61
Asset Priority Index (API):	100
Remediation Priority Index (RPI):	61

Deficiency

Category: CMDM

Rating: Minor

Cleaning/Reshaping Report

HKM ID:	LD-1	Division:	Clear Creek		
Canal Name:	Leiter Ditch [LD-1]	Length:	7,000 ft	Total # of Photos:	2
Notes:	This reach represents cleaning costs recommended for the Leiter Ditch. Seepage and canal constrictions are remediated in LD-2, LD-3, and LD-4. Cleaning costs assume a cross section of 20 feet.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	15,600.0	SY	$0.62	$9,672.00

Total Field Cost:		$9,672.00
Contingencies:	10%	$967.20
Subtotal:		$10,639.20
Engineering:	0%	$0.00
Mobilization:	10%	$1,063.92
Total Rehabilitation Cost:		**$11,703.12**
Average Rehabilitation Cost per Foot:		**$1.67**

Deficiency

Category: C&ODM

Rating: Minor

Seepage Area Lining Report

HKM ID:	LD-2	Division:	Clear Creek		
Canal Name:	Leiter Ditch [LD-1]	Length:	3,250 ft	Total # of Photos:	1
Notes:	This section is an area of the Leiter Ditch that has significant seepage. It is sub-irrigating the fields below it which has saturated the fields and made them very unproductive. This backwater is caused poor grade and the cut section identified in LD-4. Lining this reach is recommended. The sponsor prefers to spec HDPE pipe for seepage areas. These will not operate under pressure, and alleviate potential cattle impacts that could arise with geomembrane lining systems				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 48" Pipe	3,250.0	FT	$122.77	$399,002.50

Total Field Cost:		$399,002.50
Contingencies:	10%	$39,900.25
Subtotal:		$438,902.75
Engineering:	10%	$43,890.28
Mobilization:	10%	$43,890.28
Total Rehabilitation Cost:		**$526,683.30**
Average Rehabilitation Cost per Foot:		**$162.06**

Deficiency

Category: CMDM

Rating: Serious

Seepage Area Lining Report

HKM ID:	LD-3	Division:	Clear Creek		
Canal Name:	Leiter Ditch [LD-1]	Length:	1,100 ft	Total # of Photos:	8
Notes:	This reach is a section of the Leiter Ditch that passes under the Interstate 90 bridge. It was identified that this reach of the ditch is on a fill section created by the interstate, and consequently can become saturated. There is concern that the ditch may be lost in this section if flows get too high in the canal. Lining this ditch with HDPE pipe is recommended to remediate the seepage issues.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 48" Pipe	1,100.0	FT	$122.77	$135,047.00

Total Field Cost:		$135,047.00
Contingencies:	10%	$13,504.70
Subtotal:		$148,551.70
Engineering:	10%	$14,855.17
Mobilization:	10%	$14,855.17
Total Rehabilitation Cost:		**$178,262.04**
Average Rehabilitation Cost per Foot:		**$162.06**

Deficiency

Category: CMDM

Rating: Serious

Canal Constriction Report

HKM ID:	LD-4	Division:	Clear Creek		
Canal Name:	Leiter Ditch [LD-1]	Length:	1,400 ft	Total # of Photos:	13

Notes: This reach of the canal represents the cut section causing constriction of the canal. This cut section was excavated through a ridge, and has steep side slopes. The side slopes have not re-established vegetation, so over the years, significant sediment has built up in the channel. As a result, there has been significant capacity reduction and increased backwater. At times freeboard near the interstate is only one foot. The channel was recently cleaned by excavating an 8' trench through the cut section, but back water is still present in the ditch. Re-grading the ditch is recommended. Piping the canal through the cut section is also recommended. Costs assume a concrete headwall with 48" RCP. The general fill estimate could be accounted for by actually filling the cut section, or re-grading the hillsides above the cut and using the re-grading cut material to fill the current cut section.

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
RCP 48" D	1,400.0	FT	$256.97	$359,758.00
General Fill	50,000.0	CY	$3.77	$188,500.00
CIP Concrete	10.0	CY	$1,135.47	$11,354.70
Trash Rack	250.0	SF	$34.22	$8,555.00
Structural Fill	10.0	CY	$36.65	$366.50
Structural Excavation	10.0	CY	$22.95	$229.50

Total Field Cost:		$568,763.70
Contingencies:	10%	$56,876.37
Subtotal:		$625,640.07
Engineering:	10%	$62,564.01
Mobilization:	10%	$62,564.01
Total Rehabilitation Cost:		**$750,768.09**
Average Rehabilitation Cost per Foot:		**$536.26**

Deficiency

Category: CMDM

Rating: Serious

Local Name: High Line Headgate

HKM ID:	**HL-HG1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**High Line Ditch**			***Structure Type:***	**Headgate**
UTM Zone:	**13**	***Coordinates:***	**355773.1, 4932710.0**	***Total # of Photos:***	**6**

Notes: The High Line Headgate diverts out of Piney Creek upstream of the large Piney Creek Diversion. The High Line ditch serves approximately 230 acres. The headgate appears to be fairly new. The concrete is in good condition, and the gate is operable. Landowner interviews indicated that the headgate operates well, but there are issues with debris and rocks plugging the gate opening and not allowing the gate to close. No trash rack is present on the diversion headgate. There are two sluice gate bays that do not have gates. They are currently checked up with no means of operation. Rehabilitation costs reflect the installation of trash rack to prevent these issues on both the diversion gate and sluice gates. In addition, slide gates are recommended for the two sluice gate bays. The High Line ditch has issues downstream of the headgate which are addressed in the Canal section.

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	24,000.0	$	$1.03	$24,720.00
3-ft x 3-ft Slide Gate	2.0	Each	$3,728.89	$7,457.78
Trash Rack	75.0	SF	$34.22	$2,566.50
Handrail	45.0	FT	$50.71	$2,281.95
			Total Field Cost:	$37,026.23
			Active Dewatering: 7.5%	$2,776.97
			Contingencies: 10%	$3,702.62
			Subtotal:	$43,505.82
			Engineering: 10%	$4,350.58
			Mobilization: 10%	$4,350.58
			Total Rehabilitation Cost:	**$52,206.98**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
Stream Control (Medium)	1.0	Each	$27,559.61	$27,559.61
Miscellaneous	24,000.0	$	$1.03	$24,720.00
CIP Concrete	13.0	CY	$1,135.47	$14,761.11
RCP 24" D	100.0	FT	$89.40	$8,940.00
3-ft x 3-ft Slide Gate	2.0	Each	$3,728.89	$7,457.78
Concrete Demo. & Disposal	20.0	CY	$209.94	$4,198.80
2-ft x 2-ft Slide Gate	1.0	Each	$2,670.63	$2,670.63
Trash Rack	75.0	SF	$34.22	$2,566.50
Handrail	45.0	FT	$50.71	$2,281.95
			Total Field Cost:	$126,056.38
			Active Dewatering: 7.5%	$9,454.23
			Contingencies: 10%	$12,605.64
			Subtotal:	$148,116.25
			Engineering: 10%	$14,811.62
			Mobilization: 10%	$14,811.62
			Current Replacement Value (CRV):	**$177,739.50**

Facilities Condition Index (FCI):	0.29
Asset Priority Index (API):	60
Remediation Priority Index (RPI):	17

Deficiency

Category: CMDM

Rating: Serious

Cleaning/Reshaping Report

HKM ID:	HL-1	Division:	Clear Creek		
Canal Name:	High Line Ditch [HL-1]	Length:	3,500 ft	Total # of Photos:	1
Notes:	This reach of the High Line Ditch represents the first section of the ditch from the headgate to the interstate. Seepage issues were not identified on this reach. Cleaning/reshaping is recommended. For cost estimation, the ditch cross-section is assumed to be 10-feet.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	3,500.0	SY	$0.62	$2,170.00
			Total Field Cost:	$2,170.00
			Contingencies: 10%	$217.00
			Subtotal:	$2,387.00
			Engineering: 0%	$0.00
			Mobilization: 10%	$238.70
			Total Rehabilitation Cost:	**$2,625.70**
			Average Rehabilitation Cost per Foot:	**$0.75**

Deficiency

Category: C&ODM

Rating: Minor

Seepage Area Lining Report

HKM ID:	HL-2	Division:	Clear Creek		
Canal Name:	High Line Ditch [HL-1]	Length:	7,800 ft	Total # of Photos:	6

Notes: This reach is the second reach on the High Line Ditch. It represents the section from east of the interstate to the end of the ditch. Recently, the lands just east of the interstate have been mined for gravel. Prior to the gravel pit, the lands were irrigated, but there were issues with prairie dogs. Since the mine, the ditch has become more porous, and when they run water in the ditch, they create springs in the lower fields. Piping the ditch from east of the interstate, to three fields that are east of the gravel pit would be beneficial by conserving significant amounts of water lost to seepage, and by providing a potential gravity feed for potential sprinklers. Dissipation at the outfall of the pipe is accounted for in the Pipe Outlet costs. Miscellaneous costs reflect turnout costs associated to flood irrigate the lands, in the event that the landowner does not pursue sprinkler irrigation.

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
12" Irrigation Pipe	7,800.0	FT	$14.42	$112,476.00
Miscellaneous	10,000.0	$	$1.03	$10,300.00
USBR Baffled Pipe Outlet: No. 3	1.0	Each	$7,546.95	$7,546.95

Total Field Cost:		$130,322.95
Contingencies:	10%	$13,032.30
Subtotal:		$143,355.25
Engineering:	10%	$14,335.52
Mobilization:	10%	$14,335.52
Total Rehabilitation Cost:		**$172,026.29**
Average Rehabilitation Cost per Foot:		**$22.05**

Deficiency

Category: CRPci

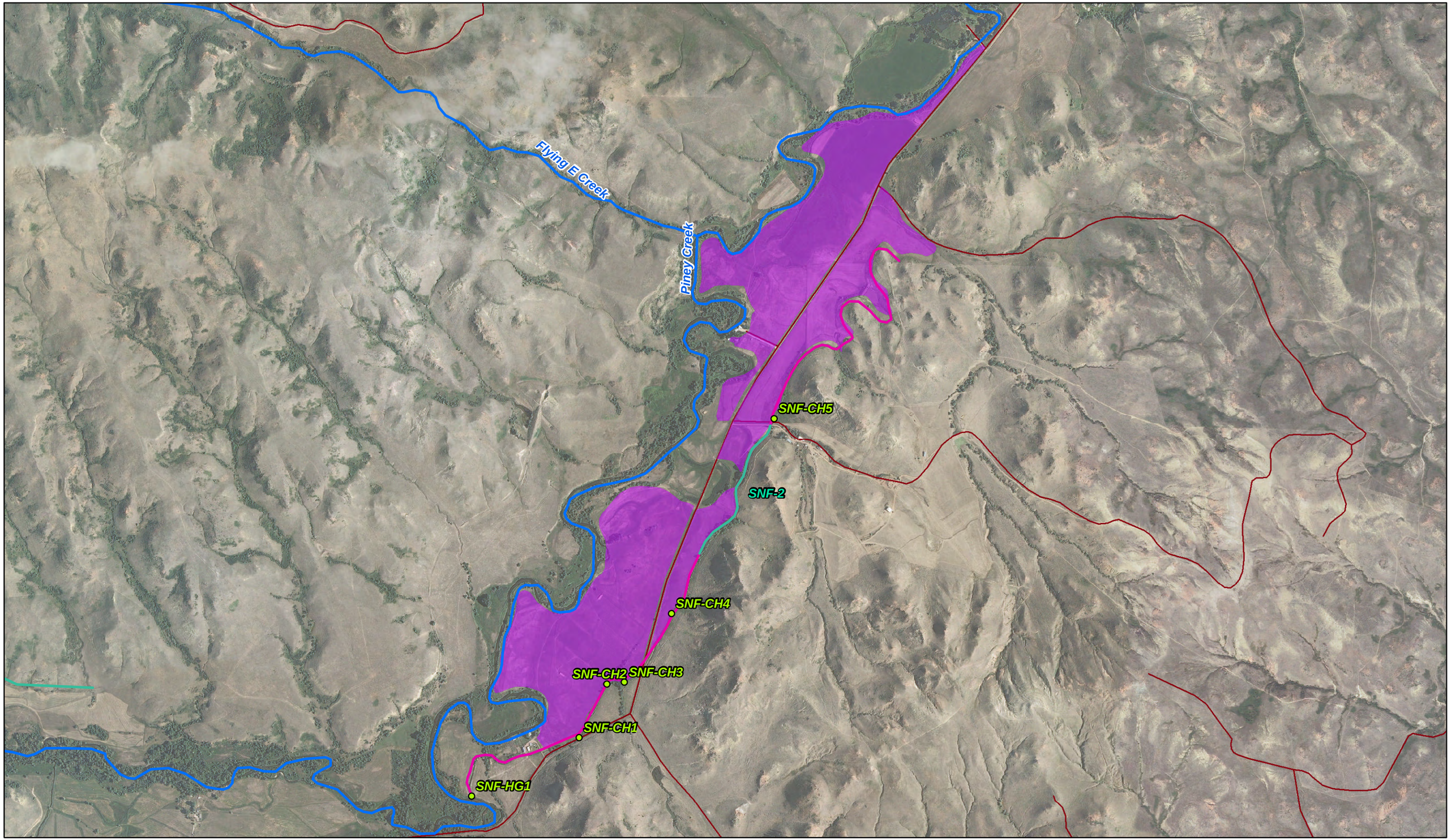
Rating: Critical

Senff Ditch

Figure 5-D – 11
Structure Reports: SNF-HG1 / SNF-CH1 - 5, Appendix 5-E
Canal Reports: SNF-1 / SNF-2, Appendix 5-E

The Senff Ditch diverts out of Piney Creek downstream of its confluence with Little Piney Creek. The unlined earthen ditch flows approximately 2.7 miles and serves approximately 230 acres. Land owner interviews indicated that the ditch appropriation is 3.14 cfs. The majority of the system is flood irrigation, but a downstream landowner would like to install a pipeline system to accommodate gated pipe. The diversion structure for the Senff Ditch is directly downstream of a stream bank erosion site. There is concern from downstream landowners regarding this site. In addition, there is a rock diversion that directs flows to the headgate. This needs to be re-built every few years. Installing a rock vane could eliminate this issue and provide better diversion to the headgate. The canal does not have appropriate flow regulation as irrigators, at times, have to take the whole ditch appropriation due to a lack of appropriate check and turnout structures. Installation of five check structures could remedy this by allowing for passive overflow to continue down the ditch during irrigation.

The ditch diverts from Piney Creek and travels across rather flat terrain for the first 0.9 miles. It then transitions to a hillside section which has significant seepage issues. Lining this hillside section could eliminate seepage and make the approximately 19 acres below the ditch more productive.



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Miles

Legend

- Evaluated Structures
- Streams
- Roads
- Seepage Area Lining
- Senff Irrigated Lands

Figure 5-D - 11
Clear Creek Irrigation Assessment
Senff Ditch

HKM ID:	**SNF-CH1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Senff Ditch**			***Structure Type:***	**Check**
UTM Zone:	**13**	***Coordinates:***	**361439.4, 4931484.0**	***Total # of Photos:***	**1**

Notes: This structure location represents the first of four recommended check locations on the Senff Ditch. This location is on Steve Wuthier's property. He flood irrigates the area and has a difficult time regulating his turnout. He uses steel posts/canvas to check water to his culvert, and sometimes takes the whole ditch flow. A new check is recommended with a precast turnout to improve the operation of the ditch.

Remediation Assessment

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
NRCS Concrete Check (4'x4' Notch)	1.0	Each	$6,142.94	$6,142.94
Precast Turnout	1.0	Each	$4,680.48	$4,680.48
			Total Field Cost:	$10,823.42
			Contingencies: 10%	$1,082.34
			Subtotal:	$11,905.76
			Engineering: 5%	$595.29
			Mobilization: 10%	$1,190.58
			Current Replacement Value (CRV):	**$13,691.63**

Deficiency

Category: CMDM

Rating: Serious

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	40
Remediation Priority Index (RPI):	40

HKM ID:	**SNF-CH2**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Senff Ditch**			***Structure Type:***	**Check**
UTM Zone:	**13**	***Coordinates:***	**361576.1, 4931748.3**	***Total # of Photos:***	**0**

Notes: This structure location represents the second of four recommended check locations on the Senff Ditch. The irrigator flood irrigates the area and has a difficult time regulating his turnout. A new check is recommended with a precast turnout to improve the operation of the ditch.

Remediation Assessment

Deficiency

Category: CMDM

Rating: Serious

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
NRCS Concrete Check (4'x4' Notch)	1.0	Each	$6,142.94	$6,142.94
Precast Turnout	1.0	Each	$4,680.48	$4,680.48
			Total Field Cost:	$10,823.42
			Contingencies: 10%	$1,082.34
			Subtotal:	$11,905.76
			Engineering: 5%	$595.29
			Mobilization: 10%	$1,190.58
			Current Replacement Value (CRV):	**$13,691.63**

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	40
Remediation Priority Index (RPI):	40

HKM ID:	**SNF-CH3**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Senff Ditch**			***Structure Type:***	**Check**
UTM Zone:	**13**	***Coordinates:***	**361662.6, 4931757.4**	***Total # of Photos:***	**1**

Notes: This structure location represents the third of four recommended check locations on the Senff Ditch. The irrigator flood irrigates the area and has a difficult time regulating his turnout. A new check is recommended with a precast turnout to improve the operation of the ditch.

Remediation Assessment

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
NRCS Concrete Check (4'x4' Notch)	1.0	Each	$6,142.94	$6,142.94
Precast Turnout	1.0	Each	$4,680.48	$4,680.48
			Total Field Cost:	$10,823.42
			Contingencies: 10%	$1,082.34
			Subtotal:	$11,905.76
			Engineering: 5%	$595.29
			Mobilization: 10%	$1,190.58
			Current Replacement Value (CRV):	**$13,691.63**

Deficiency

Category: CMDM

Rating: Serious

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	40
Remediation Priority Index (RPI):	40

HKM ID:	**SNF-CH4**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Senff Ditch**			***Structure Type:***	**Check**
UTM Zone:	**13**	***Coordinates:***	**361895.0, 4932094.6**	***Total # of Photos:***	**0**

Notes: This structure location represents the forth of four recommended check locations on the Senff Ditch. The irrigator flood irrigates the area and has a difficult time regulating his turnout. A new check is recommended with a precast turnout to improve the operation of the ditch. This is the start of a hillside section of the ditch, and the landowner indicated that he feels the ditch seeps along the hillside which sub-irrigates the field and reduces productivity. Remediation for the ditch section is identified in the Canals section.

Remediation Assessment

Deficiency

Category: CMDM

Rating: Serious

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
NRCS Concrete Check (4'x4' Notch)	1.0	Each	$6,142.94	$6,142.94
Precast Turnout	1.0	Each	$4,680.48	$4,680.48
			Total Field Cost:	$10,823.42
			Contingencies: 10%	$1,082.34
			Subtotal:	$11,905.76
			Engineering: 5%	$595.29
			Mobilization: 10%	$1,190.58
			Current Replacement Value (CRV):	**$13,691.63**

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	40
Remediation Priority Index (RPI):	40

HKM ID:	**SNF-CH5**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Senff Ditch**			***Structure Type:***	**Check**
UTM Zone:	**13**	***Coordinates:***	**362400.8, 4933054.5**	***Total # of Photos:***	**0**

Notes: This location is the site of an old check that would serve the field below. It would also check water that served lands west of the road. This is in disrepair, but the landowner would like to establish gated pipe on these fields. A new check with precast turnout is recommended to aid in this. The gated pipe configuration is not presented in this section.

Remediation Assessment

Deficiency

Category: CMDM

Rating: Serious

Replacement Costs

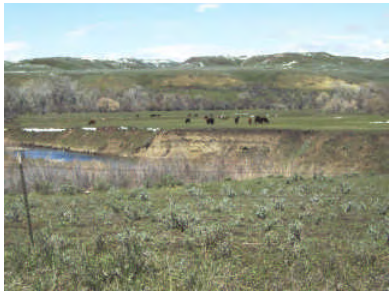
Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
NRCS Concrete Check (4'x4' Notch)	1.0	Each	$6,142.94	$6,142.94
Precast Concrete	1.0	CY	$493.93	$493.93
			Total Field Cost:	$6,636.87
			Contingencies: 10%	$663.69
			Subtotal:	$7,300.56
			Engineering: 5%	$365.03
			Mobilization: 10%	$730.06
			Current Replacement Value (CRV):	**$8,395.64**

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	40
Remediation Priority Index (RPI):	40

Local Name: Senff Headgate

HKM ID:	**SNF-HG1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Senff Ditch**			***Structure Type:***	**Headgate**
UTM Zone:	**13**	***Coordinates:***	**360909.3, 4931196.2**	***Total # of Photos:***	**2**

Notes: This structure is the Senff Headgate. This structure diverts out of Piney Creek, and has an appropriation of 3.14 cfs, according to an irrigator. The headgate seems to operate well. There are concerns about stream bank stability up stream of the structure. It was indicated that the diversion rock wall needs to be rebuilt every few years. A rock vane diversion could stabilize this reach of the stream as well as provide a permanent diversion that would not need to be rebuilt every few years. Miscellaneous costs reflect a fish screen structure.



Deficiency

Category: CMDM

Rating: Serious

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
Miscellaneous	24,000.0	$	$1.03	$24,720.00
Trash Rack	25.0	SF	$34.22	$855.50
Handrail	10.0	FT	$50.71	$507.10
			Total Field Cost:	$56,982.60
			Contingencies: 10%	$5,698.26
			Subtotal:	$62,680.86
			Engineering: 10%	$6,268.09
			Mobilization: 10%	$6,268.09
			Total Rehabilitation Cost:	**$75,217.03**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
Stream Control (Medium)	1.0	Each	$27,559.61	$27,559.61
Miscellaneous	24,000.0	$	$1.03	$24,720.00
2-ft x 2-ft Slide Gate	2.0	Each	$2,670.63	$5,341.26
CIP Concrete	4.0	CY	$1,135.47	$4,541.88
RCP 24" D	40.0	FT	$89.40	$3,576.00
Trash Rack	50.0	SF	$34.22	$1,711.00
Structural Fill	25.0	CY	$36.65	$916.25
Structural Excavation	25.0	CY	$22.95	$573.75
Riprap Bank Protection	2.0	CY	$55.40	$110.80
			Total Field Cost:	$99,950.55
			Contingencies: 10%	$9,995.06
			Subtotal:	$109,945.61
			Engineering: 10%	$10,994.56
			Mobilization: 10%	$10,994.56
			Current Replacement Value (CRV):	**$131,934.73**

Facilities Condition Index (FCI):	0.57
Asset Priority Index (API):	60
Remediation Priority Index (RPI):	34

Cleaning/Reshaping Report

HKM ID:	**SNF-1**	**Division:**	**Clear Creek**		
Canal Name:	**Senff Ditch [SEN-1]**	**Length:**	**4,280 ft**	**Total # of Photos:**	**2**
Notes:	This reach represents the Senff Ditch. This ditch diverts out of Piney Creek and serves three ranches. There is a seepage section identified as SNF-2. Costs assume a cross-section of 8-feet.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	3,850.0	SY	$0.62	$2,387.00
			Total Field Cost:	$2,387.00
			Contingencies: 10%	$238.70
			Subtotal:	$2,625.70
			Engineering: 10%	$262.57
			Mobilization: 0%	$0.00
			Total Rehabilitation Cost:	**$2,888.27**
			Average Rehabilitation Cost per Foot:	**$0.67**

Deficiency

Category: C&ODM

Rating: Minor

Seepage Area Lining Report

HKM ID:	SNF-2	Division:	Clear Creek		
Canal Name:	Senff Ditch [SEN-1]	Length:	2,500 ft	Total # of Photos:	1
Notes:	This reach represents a hillside section of the Senff ditch. It was indicated that there is significant seepage that sub-irrigates the field and reduces productivity. Piping this reach is recommended. It is assumed that the pipe will have a concrete headwall with trash rack.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 18" Pipe	2,500.0	FT	$21.93	$54,825.00
CIP Concrete	1.0	CY	$1,135.47	$1,135.47
Trash Rack	9.0	SF	$34.22	$307.98
Structural Fill	2.0	CY	$36.65	$73.30
Structural Excavation	2.0	CY	$22.95	$45.90

Total Field Cost:		$56,387.65
Contingencies:	10%	$5,638.77
Subtotal:		$62,026.42
Engineering:	10%	$6,202.64
Mobilization:	10%	$6,202.64
Total Rehabilitation Cost:		**$74,431.70**
Average Rehabilitation Cost per Foot:		**$29.77**

Deficiency

Category: CMDM

Rating: Serious

Sturtevant Ditch

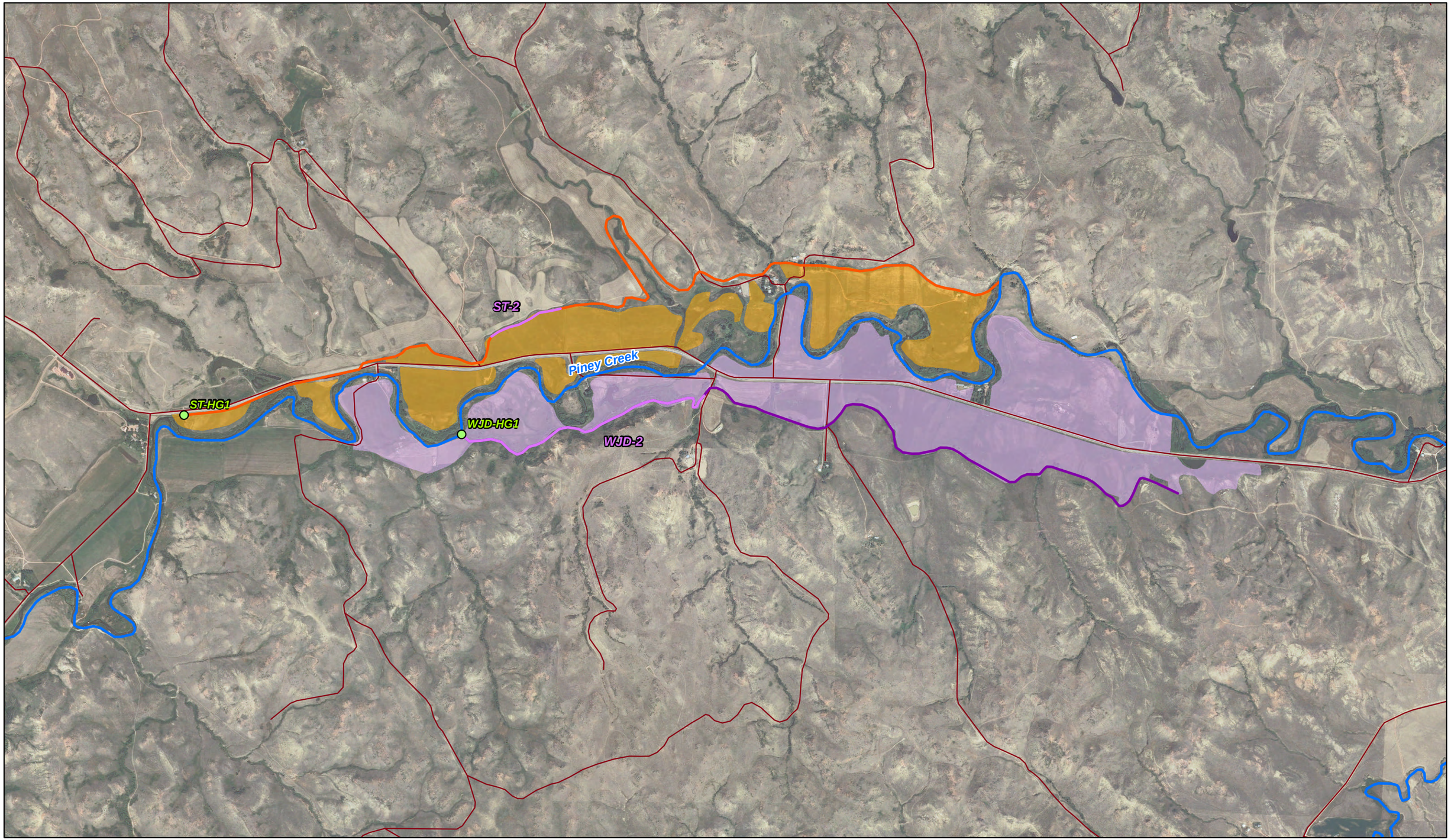
Figure 5-D – 12
Structure Reports: ST-HG1, Appendix 5-E
Canal Reports: ST-1 / ST-2, Appendix 5-E

The Sturtevant Ditch diverts from Piney Creek and serves approximately 205 acres. This equates to an appropriation of 2.9 cfs. The ditch is primarily unlined, with approximately 2,000 feet of the upper end of the ditch in a 36" pipe. This was installed with the re-alignment of the highway. The landowner indicated that they typically run 3 to 4 cfs, but can handle up to 6 or 7 cfs. The ditch flows for approximately 3.8 miles and landowners estimated losses of approximately 15% to 20%. The headgate is recessed off of the creek, and gets water from a small diversion dam on a side channel. Interviews indicated that there is a larger diversion dam on the main channel of Piney Creek which conveys water to the small diversion. From there it diverts to the headgate. The headgate is in good condition and does not leak. It was indicated that the diversions sometimes require significant labor to pound steel posts and use them to increase the diversion height. The landowners on this ditch are very proactive regarding the maintenance of the ditch. It was indicated that the ditches were burned and/or sprayed every year, and that each year they install 1,400 feet of plastic ditch lining. This is not continuous, but is used in areas of known seepage or piping through the ditch banks. Each fall, they remove the liner. This is because the pastures are used for winter feed for cattle. The cattle significantly damage the lining and make it difficult to remove. New rock vanes are recommended at the diversion, which could maintain a constant elevation and eliminate the need for the late season modification. In addition, the 1,400 feet of lining could be replaced with HDPE pipe which would be a permanent solution and would not be impacted by cattle.

WJD (Williams/Jackens/Dickie) Ditch

Figure 5-D – 12
Structure Reports: WJD-HG1, Appendix 5-E
Canal Reports: WJD-1 / WJD-2, Appendix 5-E

The WJD Ditch diverts out of Piney Creek approximately 1.7 miles downstream of the Sturtevant Ditch. This unlined ditch flows for approximately 3 miles. It serves approximately 240 acres, which assumes an appropriation of 3.4 cfs. It was indicated that they can run more if necessary, similar to the Sturtevant Ditch. The headgate for this ditch is located on a ditch that was dug to divert creek flow to the headgate. There is no diversion for this ditch. A weir wall or sluice gate should be installed to allow flows to return to the creek when not irrigating. There is concern that the headgate could wash out during high water, and there is evidence of scour around the headwall. The ditch shows signs of significant seepage. There are areas of cattails below the ditch as well as significant willow/brush growth on the downhill ditch bank for the first mile of the ditch. The ditch bank has failed in a number of locations. One failure site has been remediated by installing 36" HDPE pipe. Piping and seepage is still evident upstream of the pipe. Lining or piping this reach is recommended.



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Legend

- Evaluated Structures
- Seepage Area Lining
- WJD Ditch
- Sturdovant Ditch
- Roads
- Streams
- Sturdovant Irrigated Lands
- WJD Irrigated Lands

Figure 5-D - 12
Clear Creek Irrigation Assessment
Sturdovant and WJD Ditches

Local Name: Sturdovant Headgate

HKM ID:	**ST-HG1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Sturdovant Ditch**			***Structure Type:***	**Headgate**
UTM Zone:	**13**	***Coordinates:***	**365283.4, 4937070.4**	***Total # of Photos:***	**3**

Notes: The Sturdovant Ditch diverts out of Piney Creek, upstream of its confluence with Boxelder Creek. The headgate is recessed on the ditch and receives diverted flows from two diversions. The first diversion is on the main stem of Piney Creek and pushes water to a side channel. The side channel flow is then diverted to the ditch from a second dam. The headgate is in good condition and seals well. There are maintenance issues associated with the dams, which require significant labor, and present safety issues. Remediation assumes replacing the current diversions with rock vane diversions. These provide a permanent, fish friendly diversion that will not require the yearly maintenance currently needed. Replacement assumes relocating the headgate upstream to the beginning of the ditch. It is also recommended that a sluice gate be installed to eliminate sedimentation upstream of the rock vane. Miscellaneous costs reflect a fish screen structure at the headgate.

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Rock Vane Diversion	2.0	Each	$30,900.00	$61,800.00
Miscellaneous	30,000.0	$	$1.03	$30,900.00
Trash Rack	80.0	SF	$34.22	$2,737.60
			Total Field Cost:	$95,437.60
			Active Dewatering: 7.5%	$7,157.82
			Contingencies: 15%	$14,315.64
			Subtotal:	$116,911.06
			Engineering: 10%	$11,691.11
			Mobilization: 10%	$11,691.11
			Total Rehabilitation Cost:	**$140,293.27**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Rock Vane Diversion	2.0	Each	$30,900.00	$61,800.00
Miscellaneous	30,000.0	$	$1.03	$30,900.00
CIP Concrete	8.0	CY	$1,135.47	$9,083.76
3-ft x 3-ft Slide Gate	1.0	Each	$3,728.89	$3,728.89
Trash Rack	80.0	SF	$34.22	$2,737.60
2-ft x 2-ft Slide Gate	1.0	Each	$2,670.63	$2,670.63
RCP 36" D	20.0	FT	$132.48	$2,649.60
Handrail	40.0	FT	$50.71	$2,028.40
RCP 24" D	20.0	FT	$89.40	$1,788.00
Walkway (Expanded Steel)	60.0	SF	$17.95	$1,077.00
Concrete Demo. & Disposal	4.0	CY	$209.94	$839.76
Structural Fill	10.0	CY	$36.65	$366.50
Structural Excavation	10.0	CY	$22.95	$229.50
Riprap Bank Protection	2.0	CY	$55.40	$110.80
			Total Field Cost:	$120,010.44
			Active Dewatering: 7.5%	$9,000.78
			Contingencies: 15%	$18,001.57
			Subtotal:	$147,012.79
			Engineering: 10%	$14,701.28
			Mobilization: 10%	$14,701.28
			Current Replacement Value (CRV):	**$176,415.35**

Deficiency

Category: CMDM

Rating: Serious

Facilities Condition Index (FCI):	0.8
Asset Priority Index (API):	60
Remediation Priority Index (RPI):	48

Cleaning/Reshaping Report

HKM ID:	ST-1	Division:	Clear Creek		
Canal Name:	Sturdovant Ditch [ST-1]	Length:	20,100 ft	Total # of Photos:	2
Notes:	This reach represents the cleaning and reshaping costs associated with the Sturdovant Ditch. This ditch provides flood irrigation on the upper end, and sprinkler irrigation on the lower end. The landowners are very proactive in the maintenance of the system. Cleaning assumes a cross-section of 10-feet. There are seepage areas of concern which are addressed in ST-2.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	22,400.0	SY	$0.62	$13,888.00

Total Field Cost:		$13,888.00
Contingencies:	10%	$1,388.80
Subtotal:		$15,276.80
Engineering:	0%	$0.00
Mobilization:	10%	$1,527.68
Total Rehabilitation Cost:		**$16,804.48**
Average Rehabilitation Cost per Foot:		**$0.84**

Deficiency

Category: C&ODM

Rating: Minor

Seepage Area Lining Report

HKM ID:	ST-2	Division:	Clear Creek		
Canal Name:	Sturdovant Ditch [ST-1]	Length:	1,400 ft	Total # of Photos:	1

Notes: Landowner interviews indicated that they line approximately 1,400 feet of the ditch each irrigation season. It was indicated that there are piping and seepage issues that lining the ditch with plastic lining remediates. The lining is removed each fall. This is because the fields are used as winter pasture for livestock, and the liner would be damaged. It is recommended that the seepage areas be piped using HDPE pipe. This would provide a permanent solution to the cattle impacts as well as the seepage issues. The costs reflect HDPE 30" pipe. The ditch upstream of the seepage area is piped in CMP 36" pipe. The 30" pipe is recommended due to roughness coefficient improvements, as well as providing significant capacity over and above the ditches appropriation.

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 30" Pipe	1,400.0	FT	$50.61	$70,854.00
CIP Concrete	1.0	CY	$1,135.47	$1,135.47
Trash Rack	20.0	SF	$34.22	$684.40
Structural Fill	2.0	CY	$36.65	$73.30
Structural Excavation	2.0	CY	$22.95	$45.90

Total Field Cost:		$72,793.07
Contingencies:	10%	$7,279.31
Subtotal:		$80,072.38
Engineering:	10%	$8,007.24
Mobilization:	10%	$8,007.24
Total Rehabilitation Cost:		**$96,086.85**
Average Rehabilitation Cost per Foot:		**$68.63**

Deficiency

Category: CMDM

Rating: Serious

Local Name: WJD Headgate

HKM ID:	**WJD-HG1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**WJD Ditch**			***Structure Type:***	**Headgate**
UTM Zone:	**13**	***Coordinates:***	**366873.2, 4936960.0**	***Total # of Photos:***	**6**

Notes: This structure is the headgate for the WJD (Williams, Jackens, Dickey) Ditch, which diverts out of Piney Creek. The headgate is recessed off of the creek, and there was no evidence of any diversion structure. There is concern of the headgate overtopping and washing out. There are signs of erosion, and bank sloughing around the headgate. The gate does not hold its seal as evident in the leaking behind the gate. This structure should have a sluice gate that allows flows back to the creek, and would reduce the risk of overtopping. As mentioned, there is no evidence of a diversion, but it was not noted that they have any trouble diverting water down the ditch to the headgate. The main gate needs to be replaced and trash rack needs to be added in addition to the sluice gate installation and drainage channel. Miscellaneous costs reflect the cost of a fish screen structure. No rock vane diversion is recommended for rehab as there was no indication of diversion issues. A rock vane is recommended for the replacement cost as this is a typical diversion structure used in the watershed.

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	30,000.0	$	$1.03	$30,900.00
CIP Concrete	4.0	CY	$1,135.47	$4,541.88
3-ft x 3-ft Slide Gate	1.0	Each	$3,728.89	$3,728.89
2-ft x 2-ft Slide Gate	1.0	Each	$2,670.63	$2,670.63
RCP 24" D	20.0	FT	$89.40	$1,788.00
Trash Rack	30.0	SF	$34.22	$1,026.60
Handrail	20.0	FT	$50.71	$1,014.20
Riprap Bank Protection	10.0	CY	$55.40	$554.00
Walkway (Expanded Steel)	30.0	SF	$17.95	$538.50
Structural Fill	6.0	CY	$36.65	$219.90
Structural Excavation	6.0	CY	$22.95	$137.70
Unclassified Excavation	40.0	CY	$2.59	$103.60
			Total Field Cost:	$47,223.90
			Active Dewatering: 7.5%	$3,541.79
			Contingencies: 15%	$7,083.59
			Subtotal:	$57,849.28
			Engineering: 10%	$5,784.93
			Mobilization: 10%	$5,784.93
			Total Rehabilitation Cost:	**$69,419.13**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
Miscellaneous	30,000.0	$	$1.03	$30,900.00
CIP Concrete	8.0	CY	$1,135.47	$9,083.76
3-ft x 3-ft Slide Gate	1.0	Each	$3,728.89	$3,728.89
2-ft x 2-ft Slide Gate	1.0	Each	$2,670.63	$2,670.63
RCP 24" D	20.0	FT	$89.40	$1,788.00
Trash Rack	30.0	SF	$34.22	$1,026.60
Handrail	20.0	FT	$50.71	$1,014.20
Riprap Bank Protection	10.0	CY	$55.40	$554.00
Structural Fill	15.0	CY	$36.65	$549.75
Walkway (Expanded Steel)	30.0	SF	$17.95	$538.50
Structural Excavation	15.0	CY	$22.95	$344.25
Unclassified Excavation	40.0	CY	$2.59	$103.60
			Total Field Cost:	$83,202.18
			Active Dewatering: 7.5%	$6,240.16
			Contingencies: 15%	$12,480.33
			Subtotal:	$101,922.67
			Engineering: 10%	$10,192.27
			Mobilization: 10%	$10,192.27
			Current Replacement Value (CRV):	**$122,307.21**

Deficiency

Category: C&ODM

Rating: Minor

Facilities Condition Index (FCI):	0.57
Asset Priority Index (API):	60
Remediation Priority Index (RPI):	34

Cleaning/Reshaping Report

HKM ID:	WJD-1	Division:	Clear Creek		
Canal Name:	WJD Ditch [WJD-1]	Length:	16,100 ft	Total # of Photos:	2
Notes:	This reach represents the cleaning and reshaping costs associated with WJD Ditch. The first section of the ditch has significant seepage issues, which are addressed in WJD-2. Cleaning costs assume a cross-section of 10-feet.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	18,000.0	SY	$0.62	$11,160.00
			Total Field Cost:	$11,160.00
			Contingencies: 10%	$1,116.00
			Subtotal:	$12,276.00
			Engineering: 0%	$0.00
			Mobilization: 10%	$1,227.60
			Total Rehabilitation Cost:	**$13,503.60**
			Average Rehabilitation Cost per Foot:	**$0.84**

Deficiency

Category: C&ODM

Rating: Minor

Seepage Area Lining Report

HKM ID:	**WJD-2**	**Division:**	**Clear Creek**		
Canal Name:	**WJD Ditch [WJD-1]**	**Length:**	**5,200 ft**	**Total # of Photos:**	**4**
Notes:	This reach of the WJD Ditch represents the first 5100 feet of the ditch. The ditch has significant seepage issues. The majority of the reach is on a hillside section. There have been a number of spots along the reach that have washed out. One section was remedied by piping approximately 90 feet over the worst section. Piping the reach is recommended. 36" pipe is recommended, as that is what is currently installed in one problem reach, however, this is oversized.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 36" Pipe	5,100.0	FT	$65.57	$334,407.00
			Total Field Cost:	$334,407.00
			Contingencies: 10%	$33,440.70
			Subtotal:	$367,847.70
			Engineering: 10%	$36,784.77
			Mobilization: 10%	$36,784.77
			Total Rehabilitation Cost:	**$441,417.24**
			Average Rehabilitation Cost per Foot:	**$84.89**

Deficiency

Category: CMDM

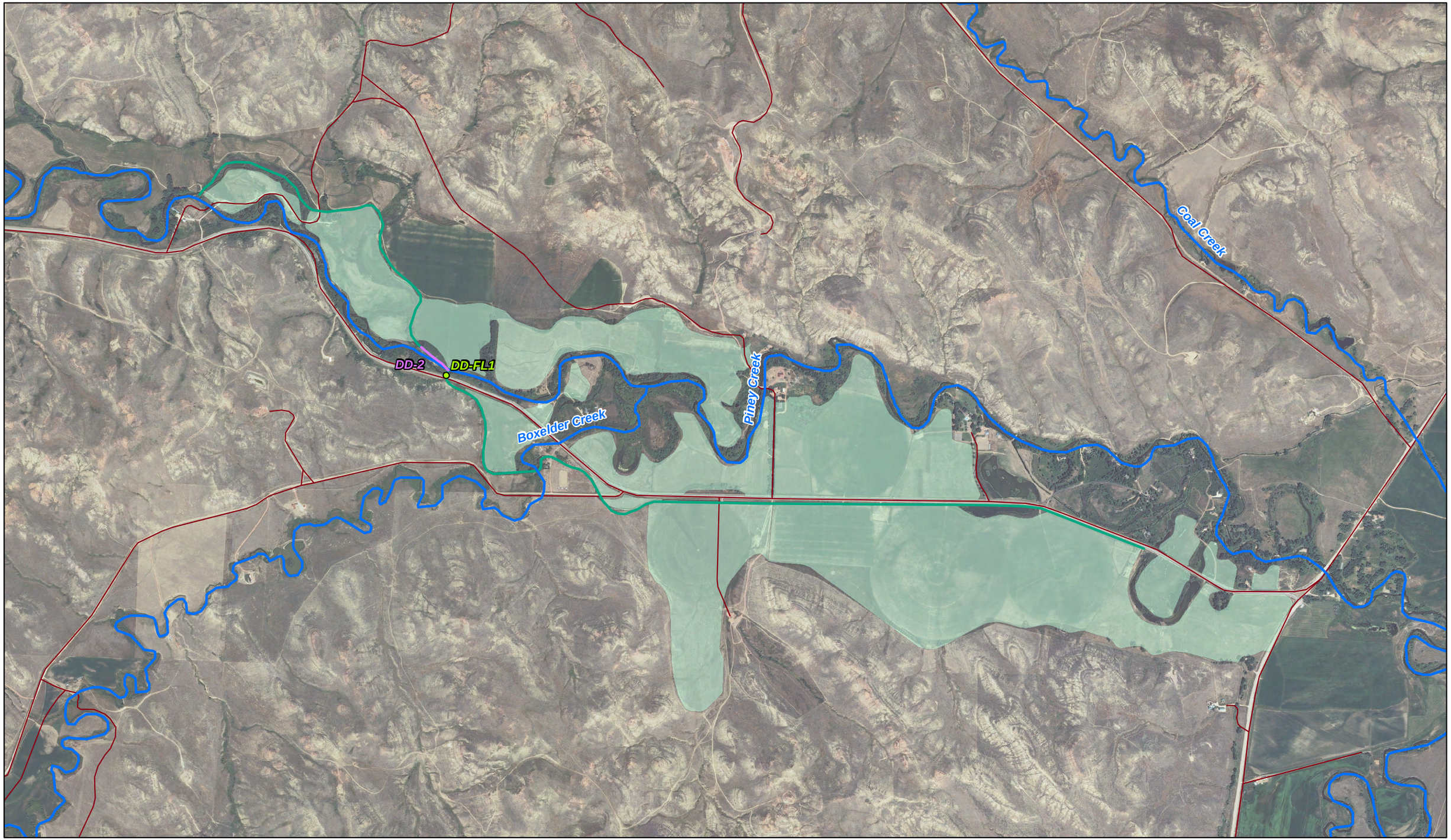
Rating: Critical

Dunlap Ditch

Figure 5-D – 13
Structure Reports: DD-FL1, Appendix 5-E
Canal Reports: DD-1 / DD-2, Appendix 5-E

The Dunlap Ditch diverts out of Piney Creek just upstream of the confluence of Piney Creek and Boxelder Creek. The unlined ditch flows for approximately 3.6 miles. The lower end of the ditch serves center pivot sprinklers which pump from the ditch. The ditch has a direct flow water right of 10.7 cfs and serves approximately 710 acres. The ditch is flumed over Piney Creek and has seepage/bank instability issues upstream of the flume. This section represents an area from approximately 550-ft upstream to the flume over Piney Creek. Landowners indicated that the ditch section washes out almost every year. They feel that there are some downed trees, and the irrigation flows in the ditch will seep until it finds an old root. It then washes down the root until it eventually washes out. Piping or lining this reach would be very beneficial.

The flume is another source of significant losses. The flume conveys ditch flows over Piney Creek through an open-topped structure that is basically half of a 48" CMP culvert. The pipe has corroded through in a number of places and needs to be lined or replaced.



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Legend

- Evaluated Structures
- Streams
- Roads
- Dunlap Ditch
- Seepage Area Lining
- Dunlap Irrigated Lands

Figure 5-D - 13
Clear Creek Irrigation Assessment
Dunlap Ditch

Local Name: Dunlap Ditch Flume

HKM ID:	**DD-FL1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Dunlap Ditch**			***Structure Type:***	**Flume**
UTM Zone:	**13**	***Coordinates:***	**373622.7, 4936105.4**	***Total # of Photos:***	**12**

Notes: This structure is a flume that conveys ditch flows across Piney Creek. The flume is made of half of a 48" CMP pipe. There is a pipe serving the flume, and a pipe that takes flows from the flume, across the road, and to the ditch. Both of these pipes are 36" CMP. It appears that the current 48" CMP half pipe was installed over a failed steel half pipe. The current configuration shows significant corrosion which allows for significant losses through the bottom of the flume. Field investigation indicated that the support structure is in fairly good condition, but the CMP portion of the flume needs to be replaced or lined. Because the support structure is in good condition, the rehabilitation costs assumes removing the existing CMP material, adding additional support strapping, and installing lightweight HDPE pipe to flume across the creek. Miscellaneous costs reflect removal of CMP material and installation of additional pipe support. Replacement assumes installation of a 36" RCP siphon which would tie into the existing inlet and outlet pipes. Miscellaneous costs reflect estimated cost to remove existing flume structure.

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	15,000.0	$	$1.03	$15,450.00
HDPE 36" Pipe	80.0	FT	$65.57	$5,245.60
			Total Field Cost:	$20,695.60
			Active Dewatering: 7.5%	$1,552.17
			Contingencies: 10%	$2,069.56
			Subtotal:	$24,317.33
			Engineering: 10%	$2,431.73
			Mobilization: 10%	$2,431.73
			Total Rehabilitation Cost:	**$29,180.80**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Stream Control (Medium)	1.0	Each	$27,559.61	$27,559.61
RCP 36" D	150.0	FT	$132.48	$19,872.00
Miscellaneous	10,000.0	$	$1.03	$10,300.00
			Total Field Cost:	$57,731.61
			Active Dewatering: 7.5%	$4,329.87
			Contingencies: 10%	$5,773.16
			Subtotal:	$67,834.64
			Engineering: 10%	$6,783.46
			Mobilization: 10%	$6,783.46
			Current Replacement Value (CRV):	**$81,401.57**

Facilities Condition Index (FCI):	0.36
Asset Priority Index (API):	60
Remediation Priority Index (RPI):	22

Deficiency

Category: CMDM

Rating: Serious

Cleaning/Reshaping Report

HKM ID:	DD-1	Division:	Clear Creek		
Canal Name:	Dunlap Ditch [DUN-1]	Length:	11,740 ft	Total # of Photos:	1
Notes:	This reach represents the cleaning/reshaping costs associated with the Dunlap Ditch. There was one section of seepage and bank stability identified by landowners. This section is represented in DD-2. The cross-section length is assumed to be 10-feet.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	13,100.0	SY	$0.62	$8,122.00
			Total Field Cost:	$8,122.00
			Contingencies: 10%	$812.20
			Subtotal:	$8,934.20
			Engineering: 0%	$0.00
			Mobilization: 10%	$893.42
			Total Rehabilitation Cost:	**$9,827.62**
			Average Rehabilitation Cost per Foot:	**$0.84**

Deficiency

Category: C&ODM

Rating: Minor

Seepage Area Lining Report

HKM ID:	DD-2	Division:	Clear Creek		
Canal Name:	Dunlap Ditch [DUN-1]	Length:	550 ft	Total # of Photos:	1

Notes: This section represents an area from approximately 550-ft upstream to the flume over Piney Creek. Landowners indicated that the ditch section washes out almost every year. They feel that there are some downed trees, and the irrigation flows in the ditch will seep until it finds an old root. It then washes down the root until it eventually washes out. Remediation for this problem assumes a geomembrane lining. The cost assumes piping the reach through HDPE pipe. It is assumed that there will be a headwall at the inlet and outlet of the pipe, as well as a trash rack at the inlet.

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 24" Pipe	550.0	FT	$38.03	$20,916.50
CIP Concrete	1.0	CY	$1,135.47	$1,135.47
Trash Rack	15.0	SF	$34.22	$513.30
Structural Fill	2.0	CY	$36.65	$73.30
Structural Excavation	2.0	CY	$22.95	$45.90

Total Field Cost:		$22,684.47
Contingencies:	10%	$2,268.45
Subtotal:		$24,952.92
Engineering:	10%	$2,495.29
Mobilization:	10%	$2,495.29
Total Rehabilitation Cost:		**$29,943.50**
Average Rehabilitation Cost per Foot:		**$54.44**

Deficiency

Category: CMDM

Rating: Critical

Pratt & Ferris #1 Ditch

Figure 5-D – 14

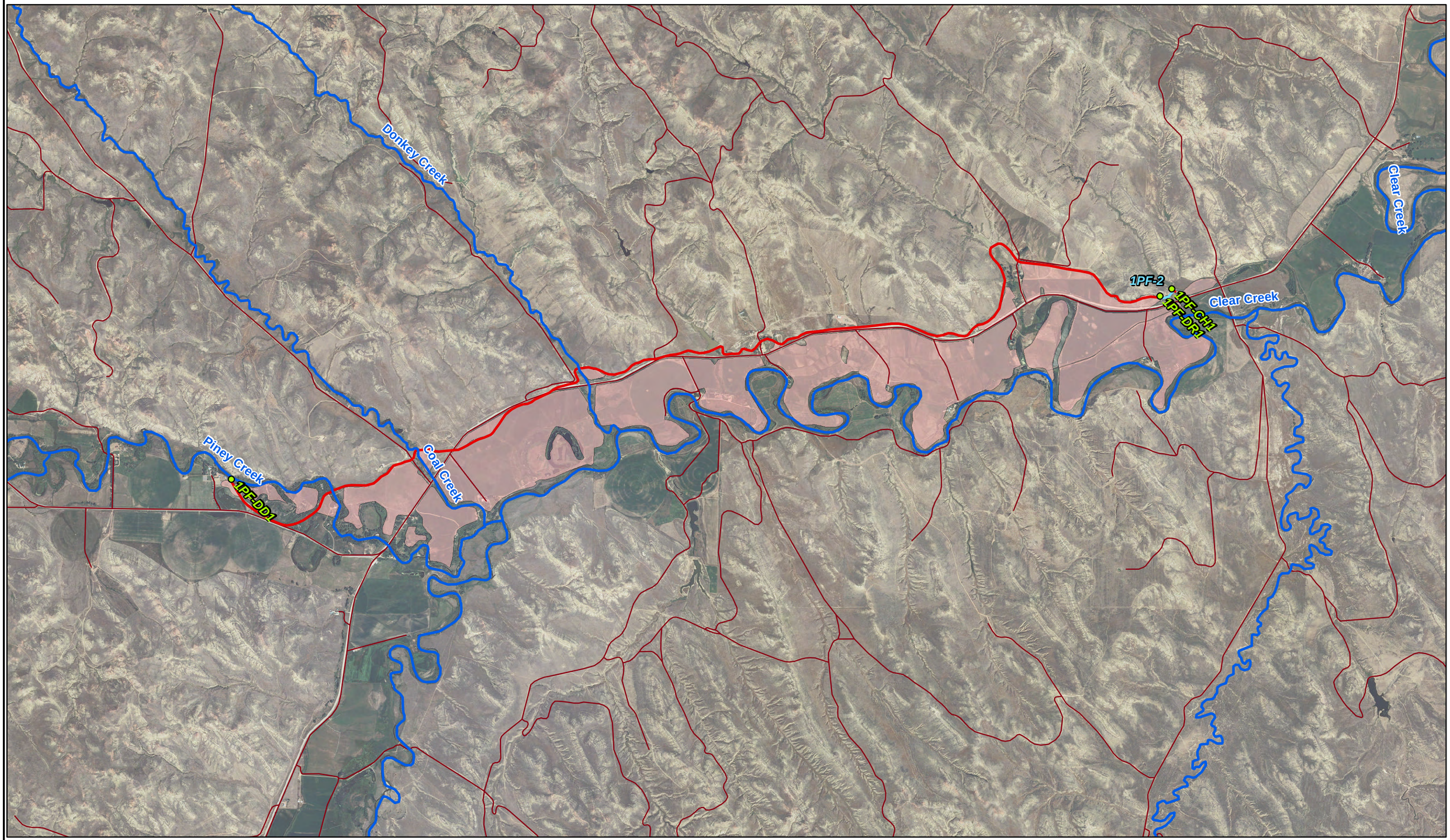
Structure Reports: 1PF-DD1, Appendix 5-E

Canal Reports: 1PF-1 / 1PF-2, Appendix 5-E

The Pratt & Ferris #1 Ditch diverts out of Piney Creek just upstream from Ucross. The ditch conveys flows approximately seven miles and serves approximately 1,270 acres. The ditch has a direct-flow water right of 18.1 cfs, and is in fairly good condition. There are a number of structural issues on the ditch. The first is the headgate. Irrigators feel that the spillway crest may be too low to adequately divert flow to the head gate. The head gate is mounted on a buttressed concrete wall that is in front of the original concrete structure. The spillway has old signs and boards across it to increase its height. The diversion section could be replaced to the proper elevation.

The second problem area is a drop structure near the end of the canal (1PF-DR1). The channel enters a CMP flume section. This flume/chute section has failed and has created significant erosion. The flows in the channel drop from this failed chute section approximately 60 feet to the bottom of the gully. It then meanders approximately 120 feet to where the channel erosion stops and the irrigation ditch is intact. The final structure of concern is downstream of the failed chute. The area is very unstable. Landowner interviews indicated that the current check structure (1PF-CH1) has been re-set three times in the last nine years. Significant erosion has washed out the current check and the wasteway. During the process of this study, this site was remediated. The new structure is a concrete headwall with a low-flow gate and spillover inlet located upstream of the existing chute failure. These inlets divert water into a 24" pipe which conveys flows down the hillside, and can return flows to the wasteway ditch, or serve downstream irrigated lands. Land reclamation was also performed to re-grade a hillside and level the erosion areas. Because the structures have been repaired and improved, no improvements are recommended. No structure reports were developed for this reason, however, the structure locations were included on the map for reference purposes.

This ditch has sections of concrete lining. There was no indication of operational issues associated with these lined sections. The majority of the lands are flood irrigated with the exception of one center pivot.



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Legend

- Evaluated Structures
- Streams
- Roads
- Pratt & Ferris #1
- Bank Instability
- Associated Irrigated Lands

Figure 5-D - 14
Clear Creek Irrigation Assessment
Pratt & Ferris #1 Ditch

Local Name: Pratt & Ferris #1 Diversion

HKM ID:	**1PF-DD1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Pratt & Ferris #1**			***Structure Type:***	**Diversion Dam**
UTM Zone:	**13**	***Coordinates:***	**376306.3, 4935799.7**	***Total # of Photos:***	**5**

Notes: The Pratt & Ferris #1 ditch diverts from Piney Creek. It has a direct flow water right of 18.1 cfs which can serve approximately 1270 acres. Operators indicated that they can run up to 21 cfs. The diversion consists of a concrete diversion spillway across the creek and a 4.5 x 4.5-foot rectangular steel gate on a concrete headwall. The diversion is very old, and the creek at the diversion is rather wide. Irrigators feel that the spillway crest may be too low to adequately divert flow to the head gate. The head gate is mounted on a newer concrete wall that is in front of the original concrete structure. The spillway has old signs and boards across it to increase its height. The spillway needs to be replaced. Handrail should be added at the head gate as well as a trash rack. Miscellaneous costs reflect a fish screen structure.

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	69,000.0	$	$1.03	$71,070.00
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
Stream Control (Medium)	1.0	Each	$27,559.61	$27,559.61
Concrete Demo. & Disposal	75.0	CY	$209.94	$15,745.50
Handrail	80.0	FT	$50.71	$4,056.80
Trash Rack	50.0	SF	$34.22	$1,711.00
			Total Field Cost:	$151,042.91
			Active Dewatering: 7.5%	$11,328.22
			Contingencies: 10%	$15,104.29
			Subtotal:	$177,475.42
			Engineering: 15%	$26,621.31
			Mobilization: 10%	$17,747.54
			Total Rehabilitation Cost:	**$221,844.28**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	69,000.0	$	$1.03	$71,070.00
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
Stream Control (Medium)	1.0	Each	$27,559.61	$27,559.61
Concrete Demo. & Disposal	85.0	CY	$209.94	$17,844.90
CIP Concrete	6.0	CY	$1,135.47	$6,812.82
4-ft x 4-ft Slide Gate	1.0	Each	$6,460.84	$6,460.84
RCP 48" D	25.0	FT	$256.97	$6,424.25
Handrail	80.0	FT	$50.71	$4,056.80
RCP 24" D	35.0	FT	$89.40	$3,129.00
24" Diameter Canal Gate	1.0	Each	$2,868.20	$2,868.20
Trash Rack	80.0	SF	$34.22	$2,737.60
Riprap Bank Protection	2.0	CY	$55.40	$110.80
			Total Field Cost:	$179,974.82
			Active Dewatering: 7.5%	$13,498.11
			Contingencies: 10%	$17,997.48
			Subtotal:	$211,470.41
			Engineering: 15%	$31,720.56
			Mobilization: 10%	$21,147.04
			Current Replacement Value (CRV):	**$264,338.02**

Facilities Condition Index (FCI):	0.84
Asset Priority Index (API):	80
Remediation Priority Index (RPI):	67

Deficiency

Category: CHSci

Rating: Serious

Cleaning/Reshaping Report

HKM ID:	1PF-1	**Division:**	Clear Creek		
Canal Name:	Pratt & Ferris #1 [PF-1]	**Length:**	36,760 ft	**Total # of Photos:**	3
Notes:	This reach reflects the cleaning/reshaping costs associated with the Pratt & Ferris #1 ditch. The reach has stability issues near the end of the ditch. These are addressed in 1PF-2. No other seepage or problem areas were identified during field investigation. The cleaning cost assumes an average cross-section length of 14-feet.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	57,200.0	SY	$0.62	$35,464.00
			Total Field Cost:	$35,464.00
			Contingencies: 10%	$3,546.40
			Subtotal:	$39,010.40
			Engineering: 0%	$0.00
			Mobilization: 10%	$3,901.04
			Total Rehabilitation Cost:	**$42,911.44**
			Average Rehabilitation Cost per Foot:	**$1.17**

Deficiency

Category: C&ODM

Rating: Minor

Bank Instability Report

HKM ID:	1PF-2	Division:	Clear Creek		
Canal Name:	Pratt & Ferris #1 [PF-1]	Length:	500 ft	Total # of Photos:	3
Notes:	This reach represents the channel section from below 1PF-DR1 to 1PF-CH1 (approximately 500-feet). This reach of the canal is very unstable. Landowner interviews indicated that 1PF-CH1 has been re-set three times in the last nine years. Lining the ditch section up to 1PF-CH1 will stabilize the reach. Improvements to 1PF-CH1 will also stabilize the site. This site has been improved since the kick-off of this project. The improvements include a new inlet structure upstream of the failed chute which pipes ditch flows down the hillside and can either waste water back to the creek or serve downstream irrigation. The entire reach is now in pipe, and the site has be reclaimed to eliminate the instability and erosion. No action is necessary.				

Remediation Assessment

Deficiency

Category:

Rating: None

5.1.3.3 Rock Creek Irrigation Systems

Hallie Ditch

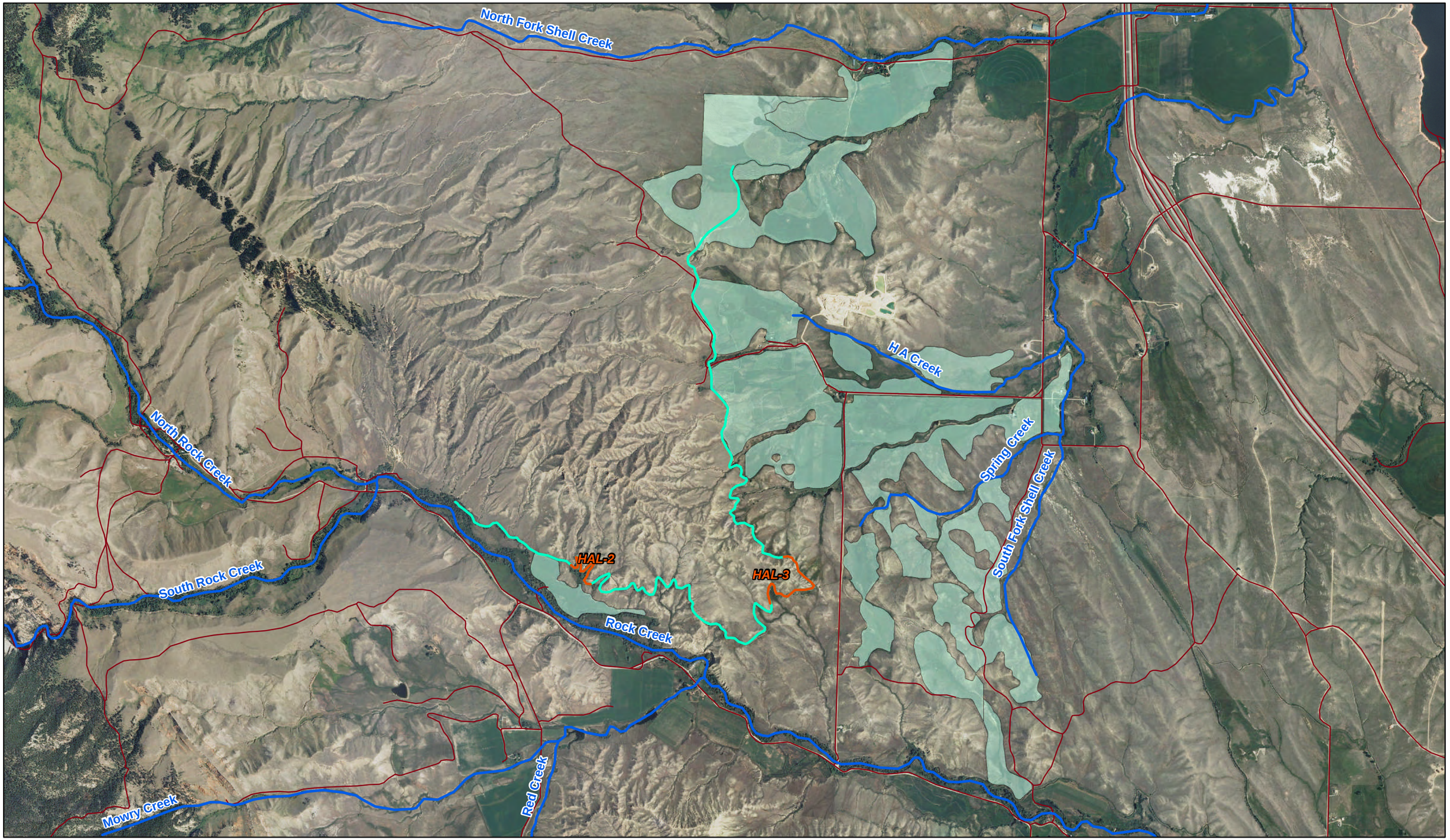
Figure 5-D – 15

Structure Reports: no structure improvements recommended

Canal Reports: HAL-1 / HAL-2 / HAL-3, Appendix 5-E

The Hallie Ditch diverts out of Rock Creek just downstream of where the South Fork and North Fork combine. The ditch has a direct flow water right of 25.7 cfs which can serve approximately 1,800 acres. It was indicated that they typically only run around 12 cfs on average. It was indicated that the headgate is in very good condition, but the ditch has deficiencies. The ditch is an unlined earthen ditch that conveys irrigation water from the headgate approximately six miles to where it terminates at the Little North Fork of Shell Creek. The ditch has seepage issues where significant losses can be seen. The ditch flows across a state land section where the majority of the seepage occurs. Significant losses could be eliminated by lining or piping these reaches of the ditch.

The majority of the lands which irrigate from the Hallie Ditch are flood irrigated with gated pipe. The downstream end of the ditch serves center pivot sprinkler irrigation.



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Miles

Legend

- Streams
- Roads
- Hallie Ditch
- Seepage Area Lining
- Associated Irrigated Lands

Figure 5-D - 15
Clear Creek Irrigation Assessment
Hallie Ditch

Cleaning/Reshaping Report

HKM ID:	HAL-1	Division:	Clear Creek		
Canal Name:	Hallie Ditch [HAL-1]	Length:	32,340 ft	Total # of Photos:	2
Notes:	This reach reflects the costs of cleaning/reshaping the Hallie Ditch. Seepage was identified by landowners and field visits. This is addressed in HAL-2. Cleaning costs assume a cross-section length of 12-feet.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	43,200.0	SY	$0.62	$26,784.00

Total Field Cost:		$26,784.00
Contingencies:	10%	$2,678.40
Subtotal:		$29,462.40
Engineering:	0%	$0.00
Mobilization:	10%	$2,946.24
Total Rehabilitation Cost:		**$32,408.64**
Average Rehabilitation Cost per Foot:		**$1.00**

Deficiency

Category: C&ODM

Rating: Minor

Seepage Area Lining Report

HKM ID:	HAL-2	Division:	Clear Creek		
Canal Name:	Hallie Ditch [HAL-1]	Length:	2,100 ft	Total # of Photos:	0

Notes: This reach was identified as a seepage area. It is located approximately 0.65 miles downstream of the headgate. The reach is approximately 2100 feet. Remediation of the seepage assumes installation of HDPE pipe through the section. It is assumed that the pipe will have a headwall at the inlet and outlet of the structure, and a trash rack at the inlet.

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 30" Pipe	2,100.0	FT	$50.61	$106,281.00
CIP Concrete	1.0	CY	$1,135.47	$1,135.47
Trash Rack	20.0	SF	$34.22	$684.40
Structural Fill	2.0	CY	$36.65	$73.30
Structural Excavation	2.0	CY	$22.95	$45.90

Total Field Cost:		$108,220.07
Contingencies:	10%	$10,822.01
Subtotal:		$119,042.08
Engineering:	10%	$11,904.21
Mobilization:	10%	$11,904.21
Total Rehabilitation Cost:		**$142,850.49**
Average Rehabilitation Cost per Foot:		**$68.02**

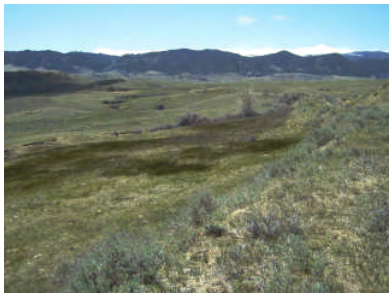
Deficiency

Category: CMDM

Rating: Serious

Seepage Area Lining Report

HKM ID:	HAL-3	Division:	Clear Creek		
Canal Name:	Hallie Ditch [HAL-1]	Length:	3,200 ft	Total # of Photos:	3
Notes:	This is another seepage area identified by landowner/field investigation. The reach is approximately 4,000 feet and appears to lose significant amounts of water to seepage. Cost assumptions are similar to those in HAL-2.				



Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 30" Pipe	3,200.0	FT	$50.61	$161,952.00
CIP Concrete	1.0	CY	$1,135.47	$1,135.47
Trash Rack	20.0	SF	$34.22	$684.40
Structural Fill	2.0	CY	$36.65	$73.30
Structural Excavation	2.0	CY	$22.95	$45.90

Total Field Cost:		$163,891.07
Contingencies:	10%	$16,389.11
Subtotal:		$180,280.18
Engineering:	10%	$18,028.02
Mobilization:	10%	$18,028.02
Total Rehabilitation Cost:		**$216,336.21**
Average Rehabilitation Cost per Foot:		**$67.61**

Deficiency

Category: CMDM

Rating: Serious

Fox Ditch

Figure 5-D – 16
Structure Reports: FOX-HG1, Appendix 5-E
Canal Reports: FOX-1, Appendix 5-E
Concept Improvements: Section 5.5.4

The Fox Ditch diverts out of Rock Creek between the Hallie and Lake DeSmet diversions. A number of years ago, four ditches (Yarwood, Fox, Lilly, and Pride of the Valley) were combined into the Fox Ditch, which has been very beneficial. It was indicated that the ditch usually diverts between 15 and 30 cfs. The irrigated acreage associated with this diversion is approximately 800 acres. The ditch currently supplies water to three ranches. The headgate has leakage issues, which needs to be addressed each irrigation season. In addition, the culvert has corroded through. Interviews indicated that the irrigators have filled the voids within the culvert with rocks, and then tried to seal it with concrete.

The lands served by the Fox Ditch are mainly served by flood irrigation via gated pipe, with some side roll sprinklers. Interest was shown in combining some of the smaller ditches in the Rock Creek drainage and serving these irrigated lands by pipeline. This could improve delivery efficiencies, as well as supply gravity sprinkler irrigation to a majority of the landowners. This would most likely dry up seeps and springs supplied by open channel flows in the ditches. In addition, there would probably be less return flow to the creek, which could make late summer flows in the creek lower. However, the reduction in losses provided by the pipeline could result in less water diverted from the creek, and more in-stream flows.

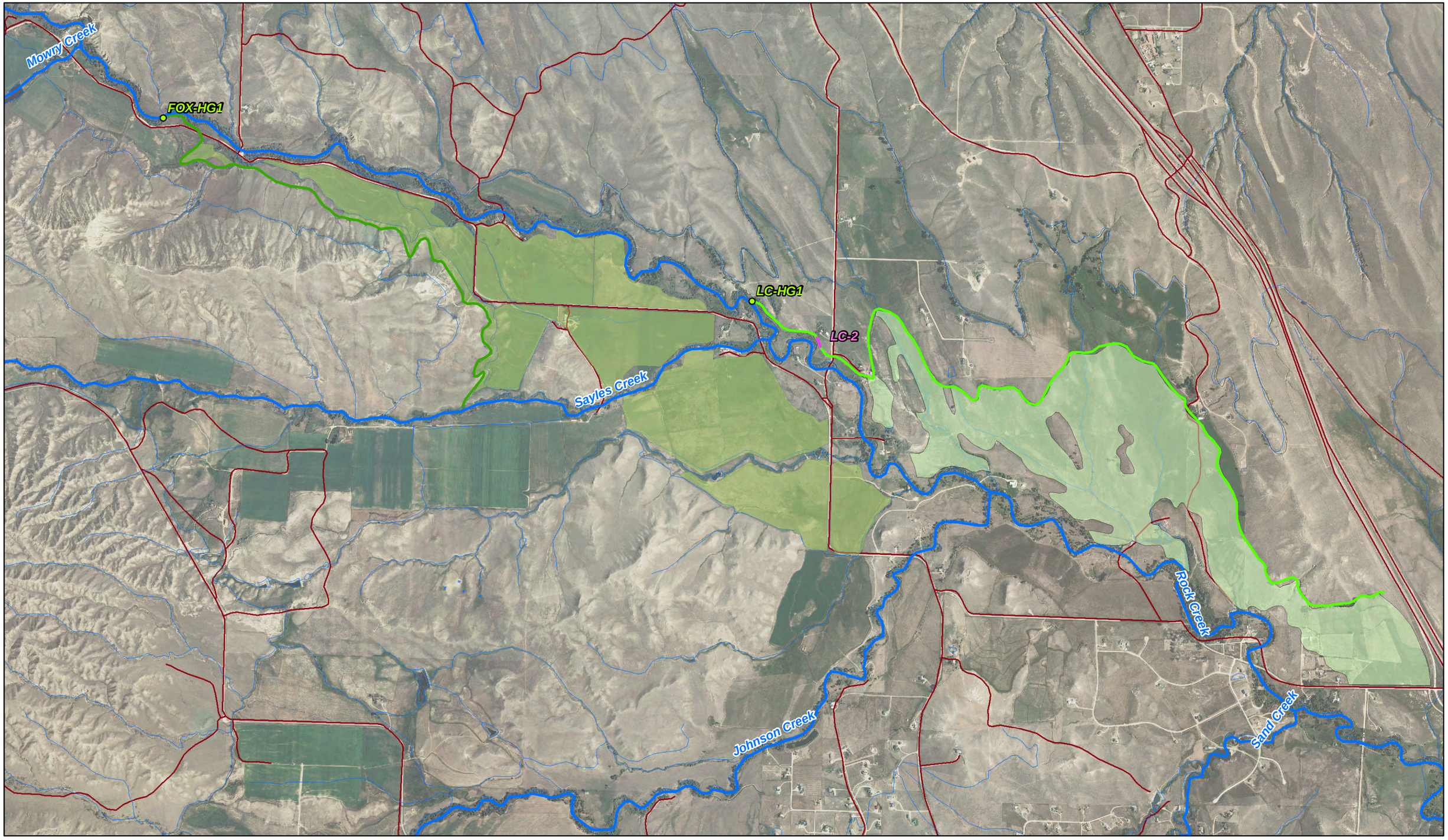
Last Chance Ditch

Figure 5-D – 16
Structure Reports: LC-HG1, Appendix 5-E
Canal Reports: LC-1 / LC-2, Appendix 5-E
Concept Improvements: Section 5.5.4

The Last Chance Ditch diverts out of Rock Creek below the Fox Ditch diversion, and upstream of its crossing with Canal Road. The ditch typically diverts 8 to 9 cfs, and conveys water for approximately 4.2 miles. It serves approximately 600 acres. Interviews indicated that it was difficult to convey much more flow than that. In addition, it was indicated that irrigators feel the ditch has gotten too large for its appropriation, which is allowing vegetation growth, and increasing losses. The headgate is in good condition, but there are issues with beavers around the headgate and in the ditch just downstream of the headgate. The culvert that diverts from the headgate to the ditch is nearly completely corroded through, and needs to be replaced. Approximately 0.3 miles downstream of the headgate there is a problem area on the unlined earthen ditch. The ditch flows across a hillside, which is being eroded by Rock Creek. There is concern that the ditch could be lost due to this stream bank erosion.

The landowner at the downstream end of the ditch, who irrigates approximately 100 acres, indicated that he might like to reduce losses in the ditch by changing his point of diversion downstream so that he could pump directly from the creek to his section of the ditch.

Lands associated with this ditch are flood irrigated.



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Miles

Legend

- Evaluated Structures
- Roads
- Streams
- Bank Instability
- Fox Ditch
- Last Chance Ditch
- Fox Ditch Irrigated Lands
- Last Chance Irrigated Lands

Figure 5-D - 16
Clear Creek Irrigation Assessment
Fox Ditch and Last Chance Ditch

Local Name: Fox Ditch Headgate

HKM ID:	**FOX-HG1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Fox Ditch**			***Structure Type:***	**Headgate**
UTM Zone:	**13**	***Coordinates:***	**353851.1, 4921935.6**	***Total # of Photos:***	**2**

Notes: This structure is the headgate for the Fox Ditch. The ditch usually diverts between 15 and 30 cfs. It currently supplies water to three ranches. The headgate has leakage issues, which need to be addressed each irrigation season. In addition, the culvert has corroded through. Interviews indicated that irrigators have filled the voids within the culvert with rocks, and then tried to seal it with concrete. Rehabilitation assumes replacement of the culvert, and installation of a rock vane diversion and sluice gate. A trash rack needs to be installed to prevent plugging of the headgate. Replacement assumes a new rock vane diversion, with new 36" gate and pipe on a concrete headwall with flared wing walls. A sluice gate is recommended in the left flared wing wall to remediate sedimentation at the headgate during the non-irrigation season. Miscellaneous costs reflect a fish screen structure.

Deficiency

Category: CMDM

Rating: Serious

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	60,000.0	$	$1.03	$61,800.00
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
Precast Turnout	1.0	Each	$4,680.48	$4,680.48
RCP 36" D	20.0	FT	$132.48	$2,649.60
Trash Rack	50.0	SF	$34.22	$1,711.00
			Total Field Cost:	$101,741.08
			Active Dewatering: 7.5%	$7,630.58
			Contingencies: 10%	$10,174.11
			Subtotal:	$119,545.77
			Engineering: 10%	$11,954.58
			Mobilization: 10%	$11,954.58
			Total Rehabilitation Cost:	**$143,454.92**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	60,000.0	$	$1.03	$61,800.00
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
Stream Control (Small)	1.0	Each	$6,812.78	$6,812.78
CIP Concrete	5.0	CY	$1,135.47	$5,677.35
36" Diameter Canal Gate	1.0	Each	$5,314.01	$5,314.01
RCP 36" D	20.0	FT	$132.48	$2,649.60
18" Diameter Canal Gate	1.0	Each	$1,964.36	$1,964.36
RCP 18" D	20.0	FT	$77.87	$1,557.40
Structural Fill	25.0	CY	$36.65	$916.25
Structural Excavation	25.0	CY	$22.95	$573.75
			Total Field Cost:	$118,165.50
			Active Dewatering: 7.5%	$8,862.41
			Contingencies: 10%	$11,816.55
			Subtotal:	$138,844.46
			Engineering: 10%	$13,884.45
			Mobilization: 10%	$13,884.45
			Current Replacement Value (CRV):	**$166,613.36**

Facilities Condition Index (FCI):	0.86
Asset Priority Index (API):	90
Remediation Priority Index (RPI):	77

Cleaning/Reshaping Report

HKM ID:	FOX-1	Division:	Clear Creek		
Canal Name:	Fox Ditch [FOX-1]	Length:	13,680 ft	Total # of Photos:	2
Notes:	The this reach represents the cleaning/reshaping recommended for the Fox ditch. The Fox ditch has combined the flows of the Yarwood, Lilly and Pride of the Valley, which has worked well and reduced overall losses. There is interest in a pipeline that could serve the majority of this valley. This is not addressed in this portion of the report. No areas of significant losses or seepage have been identified. The ditch seems to operate well. Canal cleaning assumes an average cross-section length of 11-feet.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	16,750.0	SY	$0.62	$10,385.00
			Total Field Cost:	$10,385.00
			Contingencies: 10%	$1,038.50
			Subtotal:	$11,423.50
			Engineering: 0%	$0.00
			Mobilization: 10%	$1,142.35
			Total Rehabilitation Cost:	**$12,565.85**
			Average Rehabilitation Cost per Foot:	**$0.92**

Deficiency

Category: C&ODM

Rating: Minor

Local Name: Last Chance Headgate

HKM ID:	**LC-HG1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Last Chance**			***Structure Type:***	**Headgate**
UTM Zone:	**13**	***Coordinates:***	**357817.8, 4920703.7**	***Total # of Photos:***	**2**

Notes: This structure is the headgate for the Last Chance canal. This ditch has an appropriation of approximately 9 cfs, according to a landowner. The majority of the concern is regarding reaches of the ditch. The downstream landowner would like to change his point of diversion from this site, to a site on his land. From there, he would pump his appropriation up to his ditch. For this headgate, there is no trash rack or hand rail, which are recommended. Miscellaneous costs reflect a fish screen structure. During the winter (2010) it was discovered that the culvert from the headgate was nearly completely rusted through. Replacement of this culvert is recommended. The landowner has concerns regarding the ability to get an excavator to the culvert, but feels a tracked vehicle would be the best option.

Deficiency

Category: CMDM

Rating: Minor

Remediation Assessment

Rehabilitation Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	42,000.0	$	$1.03	$43,260.00
RCP 24" D	25.0	FT	$89.40	$2,235.00
Trash Rack	25.0	SF	$34.22	$855.50
Handrail	10.0	FT	$50.71	$507.10
			Total Field Cost:	$46,857.60
			Contingencies: 10%	$4,685.76
			Subtotal:	$51,543.36
			Engineering: 10%	$5,154.34
			Mobilization: 10%	$5,154.34
			Total Rehabilitation Cost:	**$61,852.03**

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Miscellaneous	42,000.0	$	$1.03	$43,260.00
Rock Vane Diversion	1.0	Each	$30,900.00	$30,900.00
Stream Control (Small)	1.0	Each	$6,812.78	$6,812.78
24" Diameter Canal Gate	2.0	Each	$2,868.20	$5,736.40
CIP Concrete	4.0	CY	$1,135.47	$4,541.88
RCP 24" D	25.0	FT	$89.40	$2,235.00
Trash Rack	25.0	SF	$34.22	$855.50
Structural Fill	20.0	CY	$36.65	$733.00
Handrail	10.0	FT	$50.71	$507.10
Structural Excavation	20.0	CY	$22.95	$459.00
			Total Field Cost:	$96,040.66
			Contingencies: 10%	$9,604.07
			Subtotal:	$105,644.73
			Engineering: 10%	$10,564.47
			Mobilization: 10%	$10,564.47
			Current Replacement Value (CRV):	**$126,773.67**

Facilities Condition Index (FCI):	0.49
Asset Priority Index (API):	70
Remediation Priority Index (RPI):	34

Cleaning/Reshaping Report

HKM ID:	**LC-1**	**Division:**	**Clear Creek**		
Canal Name:	**Last Chance [LC-1]**	**Length:**	**22,000 ft**	**Total # of Photos:**	**2**
Notes:	This reach represents the Last Chance ditch cleaning estimate. The cross-section length is assumed to be 9-feet.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	22,000.0	SY	$0.62	$13,640.00
			Total Field Cost:	$13,640.00
			Contingencies: 10%	$1,364.00
			Subtotal:	$15,004.00
			Engineering: 0%	$0.00
			Mobilization: 10%	$1,500.40
			Total Rehabilitation Cost:	**$16,504.40**
			Average Rehabilitation Cost per Foot:	**$0.75**

Deficiency

Category: C&ODM

Rating: Minor

Bank Instability Report

HKM ID:	LC-2	Division:	Clear Creek		
Canal Name:	Last Chance [LC-1]	Length:	215 ft	Total # of Photos:	3
Notes:	This reach of the Last Chance ditch reflects a short segment of approximately 215-feet. The ditch is elevated above Rock Creek, and landowners feel that Rock Creek is migrating toward the ditch. They are concerned that the ditch may be lost if there is more erosion toward the ditch. Remediation assumes piping and covering the reach, and adding bank stabilization along the stream channel. In addition, a concrete headwall at the inlet and outlet is assumed.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 24" Pipe	215.0	FT	$38.03	$8,176.45
Riprap Bank Protection	40.0	CY	$55.40	$2,216.00
CIP Concrete	1.0	CY	$1,135.47	$1,135.47
Trash Rack	9.0	SF	$34.22	$307.98
Structural Fill	2.0	CY	$36.65	$73.30
Structural Excavation	2.0	CY	$22.95	$45.90

Total Field Cost:		$11,955.10
Contingencies:	10%	$1,195.51
Subtotal:		$13,150.61
Engineering:	10%	$1,315.06
Mobilization:	10%	$1,315.06
Total Rehabilitation Cost:		**$15,780.73**
Average Rehabilitation Cost per Foot:		**$73.40**

Deficiency

Category: CMDM

Rating: Serious

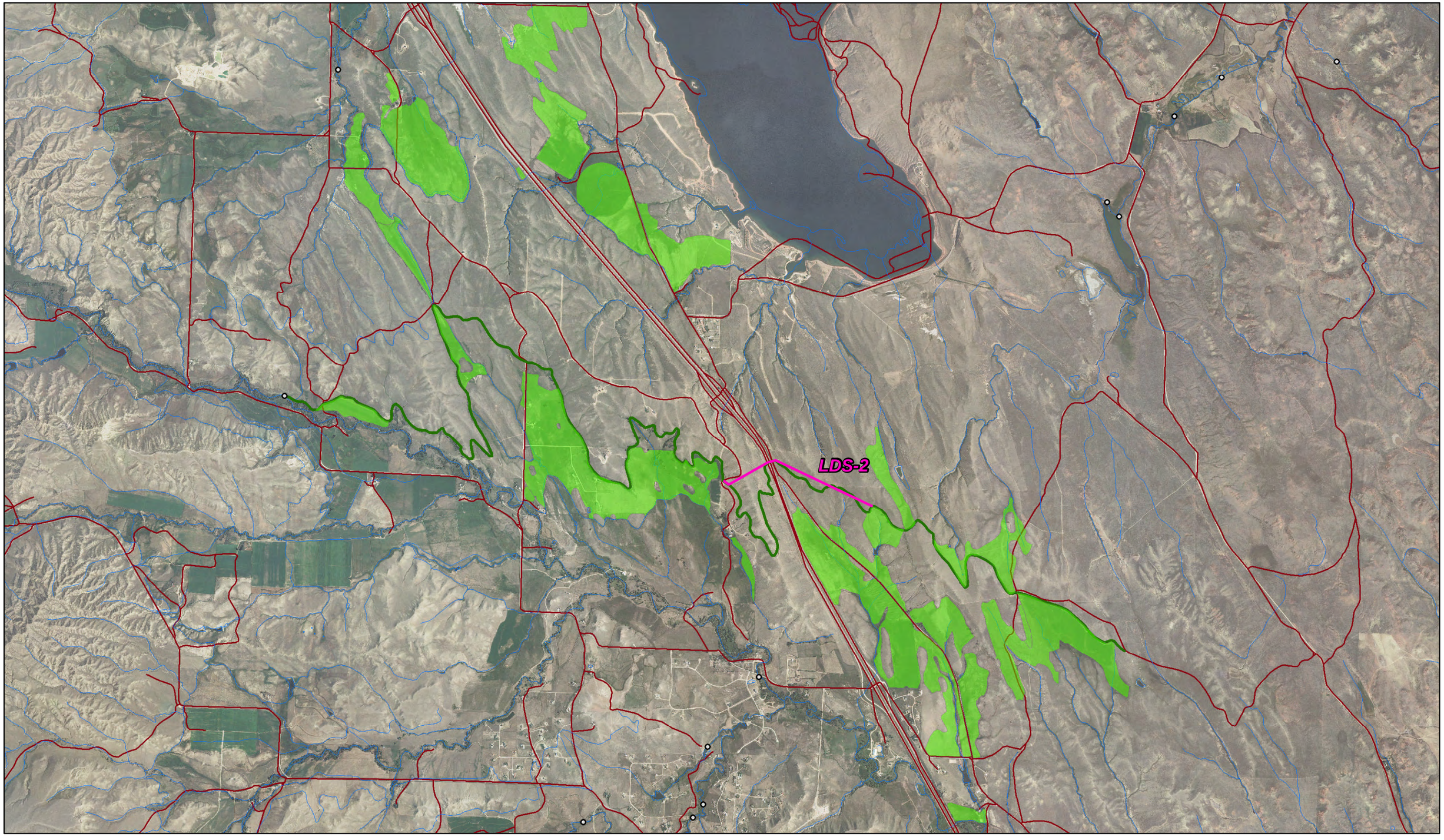
Lake DeSmet (M&M) Ditch

Figure 5-D – 17

Structure Reports: no structure improvements identified

Canal Reports: LDS-1 / LDS-2, Appendix 5-E

The Lake DeSmet Ditch diverts out of Rock Creek between the Fox Ditch and Last Chance Ditch headgates. The Lake DeSmet Ditch has a headgate which is in excellent condition. The headgate diverts an unlined, earthen ditch for approximately 13 miles. The ditch flows through a siphon under Interstate 90. The ditch provides irrigation water to approximately 2,100 acres. This relates to a diversion of approximately 30 cfs, based on an assumption of 70 acres per 1 cfs. There is a larger direct flow right associated with the ditch; however, it is noted in the Powder/Tongue River Basin Study that the maximum appropriation carried by the ditch is 54 cfs due to the condition of the ditch. No significant seepage was evident, however, a pipe section is recommended to eliminate overland flow length. The pipe section is recommended to pipe ditch flows from west to east of the interstate, which would eliminate approximately 2.7 miles of overland flow. This is a reach that flows over that length without a turnout.



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Miles

Legend

- Associated Irrigated Lands
- Lake Desmet (M&M) Ditch
- Seepage Area Lining
- Streams
- Roads

Figure 5-D - 17
Clear Creek Irrigation Assessment
Lake Desmet Ditch

Cleaning/Reshaping Report

HKM ID:	LDS-1	Division:	Clear Creek		
Canal Name:	Lake Desmet Ditch [LDS-1]	Length:	69,300 ft	Total # of Photos:	0
Notes:	This reach represents cleaning costs for the Lake Desmet (M&M) Ditch. This ditch assumes a 20-foot cross-section.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	155,000.0	SY	$0.62	$96,100.00
			Total Field Cost:	$96,100.00
			Contingencies: 10%	$9,610.00
			Subtotal:	$105,710.00
			Engineering: 0%	$0.00
			Mobilization: 10%	$10,571.00
			Total Rehabilitation Cost:	**$116,281.00**
			Average Rehabilitation Cost per Foot:	**$1.68**

Deficiency

Category: C&ODM

Rating: Minor

Seepage Area Lining Report

HKM ID:	LDS-2	Division:	Clear Creek		
Canal Name:	Lake Desmet Ditch [LDS-1]	Length:	6,500 ft	Total # of Photos:	0
Notes:	This reach represents a conceptual pipe section of the Lake Desmet Ditch. Seepage was not identified through this section, however, the ditch flows for approximately 2.7 miles without a turn out. The pipe section is recommended to eliminate the losses through evaporation and infiltration over the length of the open channel.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
18" Irrigation Pipe	6,500.0	FT	$29.87	$194,155.00
CIP Concrete	1.0	CY	$1,135.47	$1,135.47
Trash Rack	15.0	SF	$34.22	$513.30
Structural Fill	2.0	CY	$36.65	$73.30
Structural Excavation	2.0	CY	$22.95	$45.90

Total Field Cost:		$195,922.97
Contingencies:	10%	$19,592.30
Subtotal:		$215,515.27
Engineering:	10%	$21,551.53
Mobilization:	10%	$21,551.53
Total Rehabilitation Cost:		**$258,618.32**
Average Rehabilitation Cost per Foot:		**$39.79**

Deficiency

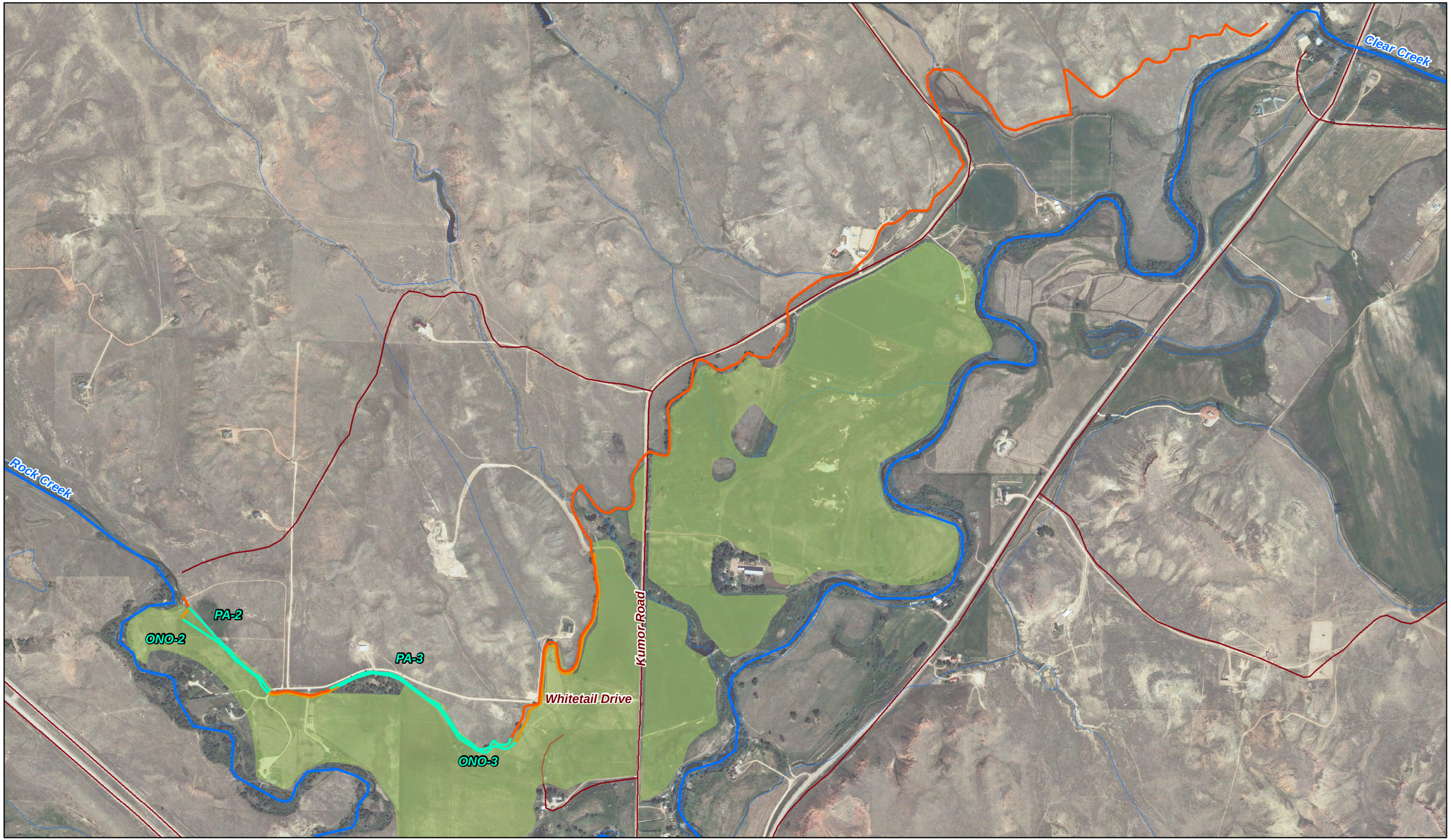
Category: CMDM

Rating: Minor

Prince Albert/Ono Ditches

Figure 5-D – 18
Structure Reports: no structure improvements identified
Canal Reports: ONO-1 / ONO-2 / ONO-3
PA-1 / PA-2 / PA-3, Appendix 5-E
Concept Improvements: Section 5.5.5

The Prince Albert and Ono Ditches divert from the same headgate structure on Rock Creek. The Prince Albert Ditch has a direct flow right of 10.1 cfs, and the Ono Ditch has a smaller appropriation. Both are territorial water rights. The flows are piped from the headgate to approximately 200 feet downstream where they are split into the two ditches through a division box with two headgates. Interviews indicated that the irrigators on the system are happy with the combined headgate. The two ditches then parallel each other for approximately 1.4 miles, to a point near Kumor Road. At this point, the Ono stops and the Prince Albert Ditch continues on to serve more lands. At the time of the field visit, only the Prince Albert gate was open, and the Ono Ditch was dry. Downstream of this location both ditches were flowing water, indicating the seepage losses associated with the Prince Albert Ditch. In addition, there was water in the fields below the ditches. This was due to seepage. Consideration was given to combining these ditches for the first 1.4 miles. Stretches of the ditch could be lined to eliminate seepage. This could make the operation of the ditches easier, as well as reduce losses and provide more water to the bottom land users. It was noted in the Powder/Tongue Study that the Prince Albert Ditch typically carries 200% of its allocation during the early season as per the Wyoming Double Appropriation Doctrine.



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Legend

- Streams
- Roads
- Associated Irrigated Lands
- Ono Ditch
- Prince Albert
- Seepage Area Lining

Figure 5-D - 18
Clear Creek Irrigation Assessment
Prince Albert and Ono Ditches

Cleaning/Reshaping Report

HKM ID:	PA-1	Division:	Clear Creek		
Canal Name:	Prince Albert [PA-1]	Length:	22,500 ft	Total # of Photos:	0
Notes:	This reach represents the cleaning costs associated with Prince Albert Ditch. The Prince Albert Ditch diverts out of Rock Creek from the same headgate that serves the Ono Ditch. These two ditches parallel each other for the length of the Ono Ditch. It could be beneficial to combine the ditches into one. This could reduce seepage lining costs. The cleaning costs assume a 12 foot cross-section.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	30,000.0	SY	$0.62	$18,600.00

Total Field Cost:		$18,600.00
Contingencies:	10%	$1,860.00
Subtotal:		$20,460.00
Engineering:	0%	$0.00
Mobilization:	10%	$2,046.00
Total Rehabilitation Cost:		**$22,506.00**
Average Rehabilitation Cost per Foot:		**$1.00**

Deficiency

Category: C&ODM

Rating: Minor

Seepage Area Lining Report

HKM ID:	PA-2	Division:	Clear Creek		
Canal Name:	Prince Albert [PA-1]	Length:	1,320 ft	Total # of Photos:	1
Notes:	This reach is the first seepage area identified on the Prince Albert Ditch. The seepage is in the same location as the Ono seepage. Remediation assumes HDPE pipe with concrete headwalls. The Prince Albert Ditch is the upper ditch in the photo.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 24" Pipe	1,320.0	FT	$38.03	$50,199.60
CIP Concrete	1.0	CY	$1,135.47	$1,135.47
Trash Rack	15.0	SF	$34.22	$513.30
Structural Fill	2.0	CY	$36.65	$73.30
Structural Excavation	2.0	CY	$22.95	$45.90

Total Field Cost:		$51,967.57
Contingencies:	10%	$5,196.76
Subtotal:		$57,164.33
Engineering:	10%	$5,716.43
Mobilization:	10%	$5,716.43
Total Rehabilitation Cost:		**$68,597.19**
Average Rehabilitation Cost per Foot:		**$51.97**

Deficiency

Category: CMDM

Rating: Serious

Seepage Area Lining Report

HKM ID:	PA-3	Division:	Clear Creek		
Canal Name:	Prince Albert [PA-1]	Length:	1,600 ft	Total # of Photos:	1
Notes:	This reach is the second seepage area identified on the Prince Albert Ditch. Remediation assumes lining the ditch with HDPE pipe. The Prince Albert Ditch is the upper ditch in the photo.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 24" Pipe	1,600.0	FT	$38.03	$60,848.00
CIP Concrete	1.0	CY	$1,135.47	$1,135.47
Trash Rack	15.0	SF	$34.22	$513.30
Structural Fill	2.0	CY	$36.65	$73.30
Structural Excavation	2.0	CY	$22.95	$45.90

Total Field Cost:		$62,615.97
Contingencies:	10%	$6,261.60
Subtotal:		$68,877.57
Engineering:	10%	$6,887.76
Mobilization:	10%	$6,887.76
Total Rehabilitation Cost:		**$82,653.08**
Average Rehabilitation Cost per Foot:		**$51.66**

Deficiency

Category: CMDM

Rating: Serious

Cleaning/Reshaping Report

HKM ID:	**ONO-1**	**Division:**	**Clear Creek**		
Canal Name:	**Ono Ditch [ONO-1]**	**Length:**	**8,000 ft**	**Total # of Photos:**	**0**
Notes:	This reach represents cleaning costs associated with the existing Ono Ditch. The cleaning costs assumes a cross section of 10-ft.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	8,900.0	SY	$0.62	$5,518.00
			Total Field Cost:	$5,518.00
			Contingencies: 10%	$551.80
			Subtotal:	$6,069.80
			Engineering: 0%	$0.00
			Mobilization: 10%	$606.98
			Total Rehabilitation Cost:	**$6,676.78**
			Average Rehabilitation Cost per Foot:	**$0.83**

Deficiency

Category: C&ODM

Rating: Minor

Seepage Area Lining Report

HKM ID:	ONO-2	Division:	Clear Creek		
Canal Name:	Ono Ditch [ONO-1]	Length:	1,300 ft	Total # of Photos:	1
Notes:	This reach is the first seepage area identified on the Ono Ditch. Remediation assumes installation of HDPE 18" pipe with concrete headwall. The Ono Ditch is the lower ditch in the photo.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 18" Pipe	1,300.0	FT	$21.93	$28,509.00
CIP Concrete	1.0	CY	$1,135.47	$1,135.47
Trash Rack	15.0	SF	$34.22	$513.30
Structural Fill	2.0	CY	$36.65	$73.30
Structural Excavation	2.0	CY	$22.95	$45.90

Total Field Cost:		$30,276.97
Contingencies:	10%	$3,027.70
Subtotal:		$33,304.67
Engineering:	10%	$3,330.47
Mobilization:	10%	$3,330.47
Total Rehabilitation Cost:		**$39,965.60**
Average Rehabilitation Cost per Foot:		**$30.74**

Deficiency

Category: CMDM

Rating: Serious

Seepage Area Lining Report

HKM ID:	ONO-3	Division:	Clear Creek		
Canal Name:	Ono Ditch [ONO-1]	Length:	2,400 ft	Total # of Photos:	1
Notes:	This reach is the second seepage area identified on the Ono Ditch. The ditch parallels the Prince Albert ditch and could beneficially be combined together. This would reduce lining costs. Remediation assumes installation of HDPE pipe. The Ono Ditch is the lower ditch in the photo.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 18" Pipe	2,400.0	FT	$21.93	$52,632.00
CIP Concrete	1.0	CY	$1,135.47	$1,135.47
Trash Rack	15.0	SF	$34.22	$513.30
Structural Fill	2.0	CY	$36.65	$73.30
Structural Excavation	2.0	CY	$22.95	$45.90

Total Field Cost:		$54,399.97
Contingencies:	10%	$5,440.00
Subtotal:		$59,839.97
Engineering:	10%	$5,984.00
Mobilization:	10%	$5,984.00
Total Rehabilitation Cost:		**$71,807.96**
Average Rehabilitation Cost per Foot:		**$29.92**

Deficiency

Category: CMDM

Rating: Serious

5.1.3.4 French Creek Irrigation Systems

A large portion of the irrigated lands within the French Creek drainage is incorporated into the Hopkins Producers Irrigation District. The irrigation district serves approximately 2,100 acres. A WWDC Phase I evaluation was conducted in October 2008 on behalf of the Hopkins Producers. No additional evaluation was requested by the district regarding this study.

Brown & Foster Ditch
Figure 5-D – 19
Structure Reports: BF-HG1, Appendix 5-E
Canal Reports: BF-1 / BF-2 / BF-3, Appendix 5-E

This ditch is a small ditch that serves approximately 200 acres. The ditch has an appropriation of 2.9 cfs, assuming one cfs is appropriated for every 70 acres. The channel is an unlined earthen ditch that flows approximately 6 miles from its diversion out of French Creek to where it returns flow to the Sand Creek drainage. At approximately 2.5 miles from the headgate, the ditch drops into a natural drainage channel for approximately one mile. There is significant erosion occurring along this reach. Remediation using a pipeline could eliminate the erosion caused by irrigation flows in the natural drainage. The lower landowner indicated having a significant on-farm pipeline delivery system in place. It would be beneficial if the ditch could be piped down to tie into his existing pipeline system. There would need to be a turnout to allow water to be diverted into sand creek during non-irrigating times. The Steer Head Ranch irrigates approximately 80 acres out of the Brown & Foster Ditch. They also divert water out of French Creek to the Eaglerock Ditch. This ditch diverts approximately 7 cfs and conveys water for approximately three miles without any diversions. At that point it is dumped into Johnson Creek, and diverted out in a lower ditch. This water is eventually conveyed to an existing pipeline. There are significant losses along this ditch. There is interest to change the point of diversion for the Eagle Rock Ditch to the Brown & Foster Ditch, and to pipe the Brown & Foster Ditch. The pipeline could serve the acreages that irrigate out of the Brown & Foster Ditch, as well as convey diverted flows for the downstream pipeline.

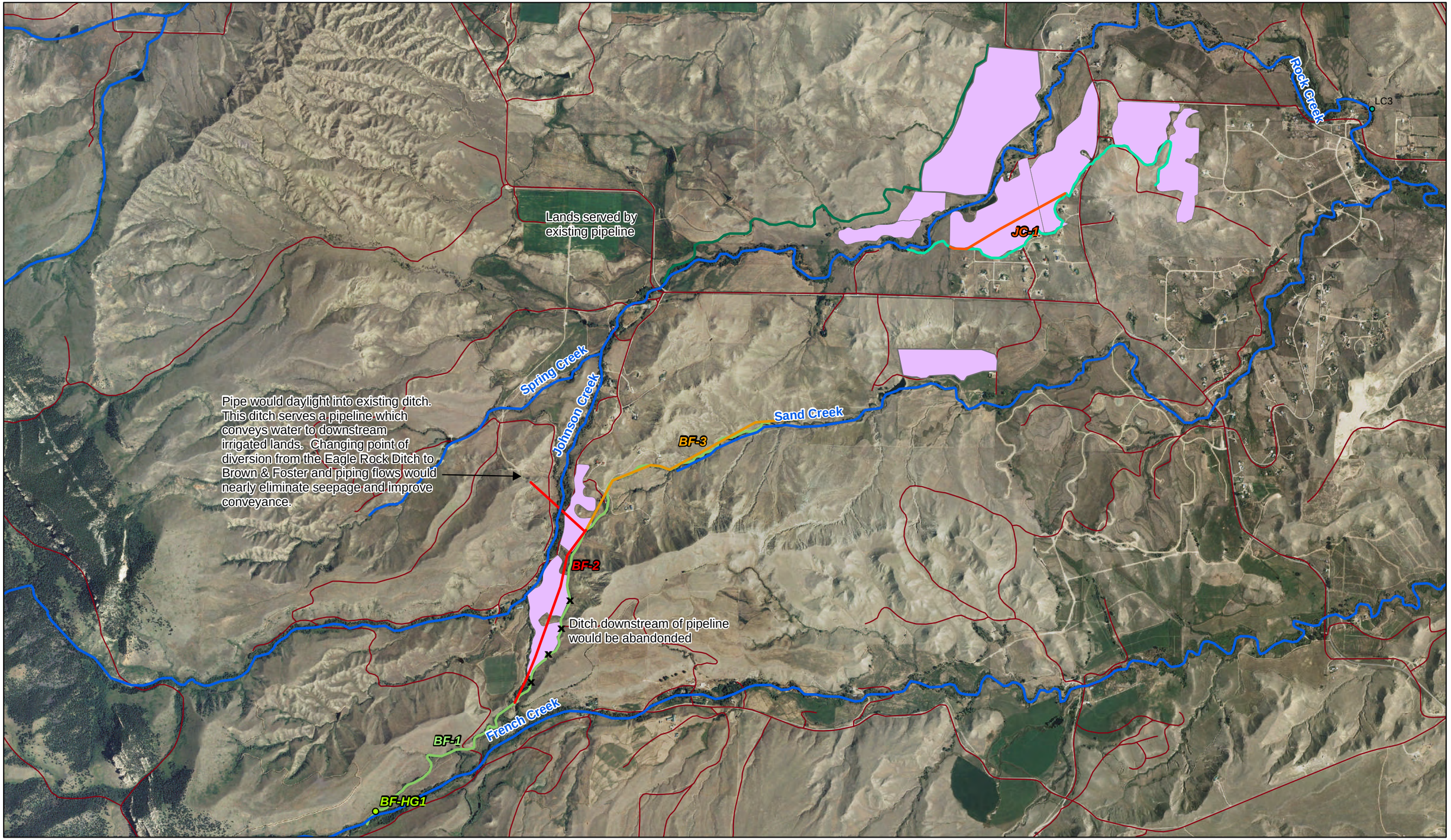
5.1.3.5 Johnson Creek Irrigation Systems

Johnson #2 Ditch (no remediation identified)

The Johnson #2 ditch diverts out of Johnson Creek. This ditch serves approximately 200 acres and most of the fields are currently served by gated pipe. The ditch has an estimated appropriation of approximately 2.8 cfs, assuming one cfs for every 70 irrigated acres. The landowner is currently working with the NRCS on a pipeline project that would allow the acreage to be served by gravity side roll sprinklers. Because this project is already being developed, rehabilitation will not be recommended for this ditch.

Johnson Creek Ditch
Figure 5-D – 19
Structure Reports: no structure improvements identified
Canal Reports: JC-1 / JC-2, Appendix 5-E

The Johnson Ditch diverts out of Johnson Creek and originally flowed in an unlined earthen ditch approximately 2.2 miles to its termination. The ditch diverts approximately 3.6 cfs, based on the approximate appropriation of 1 cfs for every 70 acres. The ditch served approximately 250 acres at one time, but it appears there are only approximately 100 acres still operated as irrigated lands. These lands are at the tail end of the ditch. The other acreages were developed as a subdivision, which the ditch crosses through. The downstream landowner indicated that a section of the ditch is piped through the subdivision through a 36" asbestos cement pipe. He indicated that the pipe has been damaged a number of times by homeowners in the subdivision, but has been repaired. Piping the ditch across the entire subdivision could eliminate maintenance issues for the irrigator at the end of the system.



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Legend

- Evaluated Structures
- Streams
- New Pipeline
- Pipeline Rehabilitation
- Bank Instability
- Johnson Creek
- Johnson #2
- Brown & Foster
- Associated Irrigated Lands
- Roads

Figure 5-D - 19
Clear Creek Irrigation Assessment
Johnson Creek, Johnson #2 and Brown & Foster Ditches

Local Name: Brown & Foster Headgate

HKM ID:	**BF-HG1**	***BIA ID:***		***Division:***	**Clear Creek**
Canal Name:	**Brown & Foster**			***Structure Type:***	**Headgate**
UTM Zone:	**13**	***Coordinates:***	**353126.2, 4912731.2**	***Total # of Photos:***	**3**

Notes: This structure is the headgate to the Brown and Foster Ditch. The headgate is an 18" screw-type headgate on a concrete headwall. The concrete is broken up and cracked. It is recommended that the headgate be replaced. A recommendation for the canal is to incorporate the Eaglerock Ditch diversion into the Brown & Foster Ditch. The new headgate should be upsized to accommodate the approximate 7 cfs that is appropriated to the Eaglerock Ditch.

Remediation Assessment

Replacement Costs

Item Description	*Quantity*	*Units*	*Unit Cost*	*Total*
Stream Control (Small)	1.0	Each	$6,812.78	$6,812.78
CIP Concrete	3.0	CY	$1,135.47	$3,406.41
2.5-ft x 2.5-ft Slide Gate	1.0	Each	$3,072.83	$3,072.83
RCP 30" D	20.0	FT	$99.93	$1,998.60
Concrete Demo. & Disposal	2.0	CY	$209.94	$419.88
Trash Rack	10.0	SF	$34.22	$342.20
Structural Fill	5.0	CY	$36.65	$183.25
Structural Excavation	5.0	CY	$22.95	$114.75
			Total Field Cost:	$16,350.70
			Contingencies: 15%	$2,452.61
			Subtotal:	$18,803.31
			Engineering: 10%	$1,880.33
			Mobilization: 10%	$1,880.33
			Current Replacement Value (CRV):	**$22,563.97**

Facilities Condition Index (FCI):	1.00
Asset Priority Index (API):	60
Remediation Priority Index (RPI):	60

Deficiency

Category: CMDM

Rating: Serious

Cleaning/Reshaping Report

HKM ID:	**BF-1**	**Division:**	**Clear Creek**		
Canal Name:	**Brown & Foster [BF-1]**	**Length:**	**5,600 ft**	**Total # of Photos:**	**0**
Notes:	This reach of the Brown & Foster ditch represents the ditch from the headgate to the start of the recommended pipeline (BF-2). The cost assumes cleaning and expanding the ditch to accommodate additional flows that could be transferred from the Eaglerock Ditch. The cross-section is assumed to have a length of 12-feet.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	8,000.0	SY	$0.62	$4,960.00

Total Field Cost:		$4,960.00
Contingencies:	10%	$496.00
Subtotal:		$5,456.00
Engineering:	0%	$0.00
Mobilization:	10%	$545.60
Total Rehabilitation Cost:		**$6,001.60**
Average Rehabilitation Cost per Foot:		**$1.07**

Deficiency

Category: C&ODM

Rating: Minor

Pipeline Rehabilitation Report

HKM ID:	**BF-2**	**Division:**	**Clear Creek**		
Canal Name:	**Brown & Foster [BF-1]**	**Length:**	**6,900 ft**	**Total # of Photos:**	**2**
Notes:	This reach represents the proposed upper section of pipe that would convey ditch flows for the Brown & Foster Ditch. This pipe would pick up ditch flows and convey them across the Steer Head Ranch. The lower end of this section will discharge into an existing ditch. This lower ditch currently serves downstream pipe. Piping this ditch would eliminate seepage, as well as losses associated with the current Eagle Rock Ditch. Costs reflect an inlet structure, pipeline, and a dissipation structure at the outlet.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
18" Irrigation Pipe	6,900.0	FT	$29.87	$206,103.00
USBR Baffled Pipe Outlet: No. 3	1.0	Each	$7,546.95	$7,546.95
CIP Concrete	4.0	CY	$1,135.47	$4,541.88
Trash Rack	30.0	SF	$34.22	$1,026.60
Structural Fill	5.0	CY	$36.65	$183.25
Structural Excavation	5.0	CY	$22.95	$114.75

Total Field Cost:		$219,516.43
Contingencies:	10%	$21,951.64
Subtotal:		$241,468.07
Engineering:	10%	$24,146.81
Mobilization:	10%	$24,146.81
Total Rehabilitation Cost:		**$289,761.69**
Average Rehabilitation Cost per Foot:		**$41.99**

Deficiency

Category: CMDM

Rating: Minor

Bank Instability Report

HKM ID:	BF-3	Division:	Clear Creek		
Canal Name:	Brown & Foster [BF-1]	Length:	7,000 ft	Total # of Photos:	0

Notes: This section indicates a problem reach on the Brown & Foster ditch. The ditch is an unlined earthen ditch. At this section, ditch flows are dumped into a natural drainage and then diverted out downstream to serve the associated irrigated lands. This natural drainage has begun to erode and head cut, which is of concern to the landowner. A PVC pipeline is recommended to convey these ditch flows from upstream of this head cut section to the irrigated lands. Remediation costs include pressure reducing valve, to reduce pressure from the upper pipe section, a turnout valve to discharge flows into Sand Creek when irrigation water is not needed, and a second pressure reducing valve for the lower end of the pipe. It is assumed that the pipe will tie into the farmer's existing pipe system.

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
12" Irrigation Pipe	7,000.0	FT	$14.42	$100,940.00
Pressure Relieve Valve	2.0	Each	$10,000.00	$20,000.00
Turnout Valve	1.0	Each	$5,000.00	$5,000.00

Total Field Cost:		$125,940.00
Contingencies:	10%	$12,594.00
Subtotal:		$138,534.00
Engineering:	10%	$13,853.40
Mobilization:	10%	$13,853.40
Total Rehabilitation Cost:		**$166,240.80**
Average Rehabilitation Cost per Foot:		**$23.75**

Deficiency

Category: CRPci

Rating: Serious

Pipeline Rehabilitation Report

HKM ID:	JC-1	Division:	Clear Creek		
Canal Name:	Johnson Creek [JC-1]	Length:	3,480 ft	Total # of Photos:	0
Notes:	This reach represents a section of the Johnson Creek ditch that passes through a subdivision. A section of the ditch is already in pipe, but it would be beneficial to pipe the ditch through the entire subdivision. This assumes HDPE pipe and a concrete headwall at the inlet and outlet of the structure. Trash rack is also recommended.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
HDPE 18" Pipe	3,480.0	FT	$21.93	$76,316.40
CIP Concrete	1.0	CY	$1,135.47	$1,135.47
Trash Rack	10.0	SF	$34.22	$342.20
Structural Fill	2.0	CY	$36.65	$73.30
Structural Excavation	2.0	CY	$22.95	$45.90

Total Field Cost:		$77,913.27
Contingencies:	10%	$7,791.33
Subtotal:		$85,704.60
Engineering:	10%	$8,570.46
Mobilization:	10%	$8,570.46
Total Rehabilitation Cost:		**$102,845.52**
Average Rehabilitation Cost per Foot:		**$29.55**

Deficiency

Category: CMDM

Rating: Minor

Cleaning/Reshaping Report

HKM ID:	JC-2	Division:	Clear Creek		
Canal Name:	Johnson Creek [JC-1]	Length:	6,900 ft	Total # of Photos:	1
Notes:	This reach of the Johnson Creek ditch represents cleaning costs associated with the open channel portion of the ditch. JC-1 represents a recommended pipe section for the ditch. JC-2 represents the cleaning upstream and downstream of this recommended pipe section. The cross-section is assumed to be six-feet.				

Remediation Assessment

Rehabilitation Costs

Item Description	Quantity	Units	Unit Cost	Total
Canal Cleaning	4,600.0	SY	$0.62	$2,852.00

Total Field Cost:		$2,852.00
Contingencies:	10%	$285.20
Subtotal:		$3,137.20
Engineering:	0%	$0.00
Mobilization:	10%	$313.72
Total Rehabilitation Cost:		**$3,450.92**
Average Rehabilitation Cost per Foot:		**$0.50**

Deficiency

Category: C&ODM

Rating: Minor

5.1.3.6 Boxelder Creek Irrigation Systems

The Boxelder Creek drainage serves approximately 1,050 acres. Irrigation methods throughout the drainage are almost exclusively flood irrigation. Some interest in sprinkler irrigation has been shown, but, in general, irrigators in the drainage are not short of water so there is not significant motivation for conversion or improvements by all irrigators. There is evidence of sub-irrigation and seepage along the drainage. Improving conveyance losses and delivery efficiencies would prove to be beneficial and could improve productivity on the sub-irrigated lands.

Belus Ranch

Concept Improvements: Section 5.5.6

The Belus Ranch is the first irrigator on Boxelder Creek. The Belus Ranch has approximately 430 total irrigated acres, which would mean an appropriation of approximately 6 cfs, assuming 1 cfs per 70 acres. They irrigate out of three ditches. The first ditch flows from Jack Moore Reservoir and conveys flows for approximately two miles. The first 0.8 miles of conveyance has no diversions. Interest was shown in conversion to sprinkler irrigation. The water right for the entire ranch could be transferred from Jack Moore Reservoir to Lake DeSmet, and the lands could potentially be served by a pipeline that would branch off of the existing 66" pipeline between Lake DeSmet and Healy Reservoir. This would provide the ranch with a water source that could serve a sprinkler system (sideroll and center pivots) under gravity pressure. This pipeline could potentially serve all the irrigation within the Boxelder drainage. However, there typically have not been water shortages in the drainage, and there was not interest in pursuing a drainage-wide system.

The cost estimate for this system, as well as a map of the area, can be found in Section 5.5.6.

Wolbrandt Lands

Concept Improvements: Section 5.5.6

The Wolbrandt family owns lands in two locations and contacted the sponsor for involvement in the project. The first land section is off of Kumor Road, approximately 50 acres. The landowner indicated that the fields are served by the pipeline between Lake DeSmet and Healy Reservoir. They have used gated pipe in the past, and would like to explore the possibility of sprinkler irrigating these lands. The gate from the pipeline is located on the northwest side of his field. This study does not make on-farm recommendations, so no action is recommended for these lands. The second location is an area on Boxelder Creek, below the Belus Ranch. This area is approximately 280 acres. They currently do not have a water right for these lands. It is recommended that a water right be established for these rights and water pumped to sprinklers. This would be considered an on-farm improvement, so no action will be presented in this report. These lands could be benefitted by the improvements discussed in Section 5.5.6.

5.2 Irrigation System Conservation and Rehabilitation

Rehabilitation plans have been divided into two categories. The first is rehabilitation of the existing systems. This approach incorporates the use of a previously developed irrigation assessment database which contains unit costs for commonly specified irrigation project materials. This database generates planning level cost estimates for each structure and canal section evaluated throughout the project. This provides costs estimates for existing systems to remediate current issues for the given system. The second category is that of conceptual conservation/rehabilitation plans. These plans do not fit into the requirements of the database, and are more broad scale, long term recommendations that may include more than one system or ditch. An example would be combining ditches, or using existing facilities to fill proposed storage reservoirs. These plans are presented in Section 5.5.

Concern regarding conservation and efficiency improvements, as well as fish protection and screening were identified as being of particular concern to project sponsors. Care was taken to assure that these issues are addressed for both remediation costs and replacement costs.

5.2.1 Structure Evaluations

For the purposes of the evaluation of structures, it was necessary to create a unique identifier to facilitate data collection and management. The identification numbers consist of an abbreviation of the canal name and structure type followed by a number.

GPS units were used to record the location of structures, identify canal deficiencies and other site-specific observations.

The condition assessment was completed during the fall of 2009 through the early summer of 2010. The main purpose of this evaluation was to provide a condition assessment of the existing structures, as well as to develop the preliminary remediation plan for each structure and canal section, which provides the basis for the project-wide remediation cost estimate. Structure evaluations are completed by collecting detailed information for each key facility, including: general notes, photos, and a list of deficiencies and remediation needs. The notes for each structure provide a general description, as well as documentation of any operational issues indicated by landowners and irrigation personnel.

A list of deficiencies was compiled for each evaluated structure following American Concrete Institute (ACI) condition survey methods and terminology. The ACI methods are used because most irrigation structures are concrete, or have a portion of the structure that is concrete. The ACI methods provide the evaluator a standard set of definitions for most deficiencies that are seen in the field. Specific deficiencies that were identified include: concrete spalling, break-up, honeycombing, cracking, exposed reinforcing bars, corrosion, deterioration, and structural failure. Some structures also had deficiencies associated with erosion, such as undermining, scour, or bank instability. The extent of the deficiencies was documented both in the notes and through photos. In addition to identifying and documenting these deficiencies, remediation and/or replacement

quantities were also estimated and recorded in the field books. These quantities were subsequently used in the development of the remediation cost estimates for each structure. Field notes were recorded by hand during the daily field work and then transcribed digitally, serving as an immediate quality control check of the data collected.

5.2.1.1 Rehabilitation and Replacement Assessments

Cost estimates for both rehabilitation and replacement were developed for all structures. The Current Replacement Value (CRV) is the estimated cost to remove the existing structure and replace it. This value is necessary regardless of the condition of the structure, because it provides the basis for comparison to the rehabilitation cost, and a means to determine the relative condition of the structure in relation to other project facilities.

The evaluation of needed rehabilitation and replacement utilizes the data collected in the field including: general notes, sketches, photos, and the list of deficiencies for each structure to develop a budget level estimate of rehabilitation and replacement costs for each structure. Standard USBR and NRCS structure types have been selected as the basis for replacement structures where applicable. This is because each bureau offers structures that provide a reasonable and accurate typical replacement structure. The USBR structures are typically for larger canal flows, and the NRCS structures are ideal for smaller canal flows. Additionally, safety features such as handrail and walkway have been included in remediation and replacement costs, to improve the safety for irrigation personnel who operate the irrigation systems.

Methods of cost estimation and the development of unit costs for both rehabilitation and replacement items are discussed in Section 5.3.1, and are presented in Appendix 5-A.

5.2.1.2 Remediation Assessments

The evaluation of needed remediation utilizes the data collected in the field including: general notes, photos, and the list of deficiencies for each structure to develop a budget level estimate of remediation costs for each structure.

5.2.1.3 Structure Remediation

Preliminary remediation plans were developed for each structure during the condition assessments. Quantities associated with this plan were used to estimate remediation costs.

Individual cost estimates are not intended to represent final design, but to provide the basis for the development of reasonable project-wide remediation cost estimates under current operating conditions.

The various deficiencies and assumed remediation efforts are described in the following sections.

5.2.1.4 Safety Concerns

Safety concerns are addressed in the remediation and replacement costs. Safety features such as walkway and handrail are included to improve the operational safety of irrigation systems for the irrigators who manage the systems.

5.2.1.5 Concrete Deficiencies

Deficiency: Spalling
Remediation: Surface Restoration (SF)

Although this deficiency is part of the natural lifecycle of concrete weathering in the elements, spalling increases the susceptibility of the concrete to the freeze-thaw cycle, and accelerates breakup and deterioration of the structure. The assumed surface restoration required to repair this deficiency is a concrete overlay of at least two inches in thickness. Surface restoration is impractical for some structure types, such as headgates, checks, and similar small structures. In these cases, it is assumed that spalling will not be repaired. For small structures with excessive spalling which affects structural integrity or gate operation, the remediation cost is assumed to be the cost of replacement. Surface restoration to repair spalling is typically only recommended for chutes and the headwalls of large facilities.

Deficiency: Cracking
Remediation: Crack Sealer (FT)

Crack sealing is divided into two categories: less than or equal to 1/16-inch and from greater than 1/16-inch to 1/2-inch crack width. Costs for cracks less than or equal to 1/16-inch assumes a two man working crew to clean and prepare the crack for sealing, place injection ports, inject epoxy and seal ports, and remove ports. Costs for cracks greater than 1/16-inch to1/2-inch assumes a two man working crew to clean and prepare the crack, saw cutting crack for backer rod, backer rod placement, and caulking of crack to seal it. Cracks that are greater than 1/2-inch require the removal and reconstruction of that section of the structure.

Deficiency: Undermining
Remediation: Grout Filler (CF)

Typically, compaction of earthen fill to repair undercutting of drops and chutes is impractical. Remediation for this deficiency includes pumping grout beneath the structure to fill the voids. The extent of voids under structures is estimated in the field. Measurements to estimate an average depth of undermining can often be made through holes in the structure. Typically, some extent of undermining is observed for chutes, and repair costs are estimated for this deficiency, as well as any deficiency that may be causing the undermining, such as cracking at the headwall or breakup of the upstream apron.

Deficiency: Concrete Break-up
Remediation: Concrete Filler (CF) / CIP Concrete (CY)

For structures with crumbling or rotten concrete, field crews made the determination of whether the concrete could be repaired, or whether demolition and reconstruction of a portion of the structure is warranted. Concrete filler can be used to fill voids resulting from popouts, honeycombing, concrete break-up, major spalling, and large cracks.

5.2.1.6 Operational Deficiencies

Identification of operational deficiencies is dependent on input from ditch riders and other irrigation personnel. Examples of operational issues are non-functional gates, flow

constrictions in the canal, and inadequate capacity. Many of these types of deficiencies cannot immediately be identified during the field investigations, and the input of project staff was heavily relied upon in identifying these deficiencies.

5.2.1.7 Other Miscellaneous Deficiencies

Deficiency: No Check Guides
Remediation: Check Guide Replacement (FT)
It is assumed that all check openings should have guides to keep boards in place, provide a tighter seal, and promote ease of operation. Replacement check guides are assumed to be either C-channel cut to a length equal to the notch height and, preferably, installed within the check notch or, alternatively, by bolting angle-iron to the upstream face of the structure. Installation within the check notch provides a good seal, and allows for ease of operation.

Deficiency: Corrosion
Remediation: Corrosion Inhibitor (SF)
Corrosion is typical of trash racks, check guides, and many gates. Remediation costs are only estimated for large gates with excessive corrosion.

Deficiency: Flow Obstruction
Remediation: Structure Removal (EACH)
The remediation cost for abandoned structures represents the cost of removing the particular type of structure. Structure removal is recommended if the abandon structure constitutes a flow obstruction or could result in leakage from the canal, such as abandoned checks or turnouts, respectively. There is no replacement cost for structures recommended for removal.

Deficiency: Scour
Remediation: Riprap / Fill (CY)
Erosion is common at pipe outlets and downstream of check or drop structures. Fill of scour holes for pipe outlets are not estimated unless major scour is observed. Riprap armoring, however, is quantified for all scour holes. Scour below concrete check and drop structures may result in undermining of the floor slab downstream, and consequent concrete failure. In addition to riprap, fill is quantified to rehabilitate scour below these types of structures.

Deficiency: Damaged Gate
Remediation: Gate Replacement / No Action
Entire replacement is assumed for damaged gates unless only minor damage is present, which could be fixed with little effort. In these instances, no remediation cost is included.

Deficiency: Fish Passage through Headworks
Remediation: Screen Structure and Rated Screen
A particular concern of project sponsors is fish passage above and below diversions, as well as keeping fish out of canals. Remediation assumes a screening structure with a

rated screen. These have previously been used in the study area, and are an appropriate remediation. Costs assume $15,000 for the structure, and an additional $3,000 per cfs to pass through the screen.

5.2.1.8 Deficiency Categories and Ratings

The deficiencies for each structure are ranked by selection of one of the following United States Department of the Interior categories. These have been adopted for previous irrigation assessments and have proven to be a useful tool in categorizing deficiencies. The definitions provided are the official DOI definitions. Categories are listed below from highest to lowest priority. All structures have a deficiency category ranking unless the rating is "none".

Critical Health and Safety Deferred Maintenance (CHSdm). A facility deferred maintenance need that poses a significant threat to public or employee safety or health.

Critical Health and Safety Capital Improvement (CHSci). A condition that poses a significant threat to public or employee safety or health and can only be reasonably abated by the construction of some capital improvement.

Critical Resource Protection Deferred Maintenance (CRPdm). A facility deferred maintenance need that poses a serious threat to natural or cultural resources.

Critical Resource Protection Capital Improvement (CRPci). A condition that poses a serious threat to natural or cultural resources.

Critical Mission Deferred Maintenance (CMDM). A facility deferred maintenance need that poses a serious threat to irrigator's ability to carry out its assigned mission (Improving the management of land and natural resource assets by ensuring the reliability of water facilities).

Compliance and Other Deferred Maintenance (C&ODM). A facility deferred maintenance need that will improve public or employee safety, health, or accessibility; compliance with codes, standards, laws, complete unmet programmatic needs and mandated programs; protection of natural or cultural resources or to irrigator's ability to carry out its assigned mission.

In those cases where several categories are applicable to a given structure, the highest priority category is selected. The difference between deferred maintenance and a capital improvement is based on whether the purpose associated with the deficiency has historically been provided by the structure, or if remediating the deficiency would require an additional feature. For example, replacing a handrail which is broken or missing would fall under deferred maintenance, while adding the handrail to a structure where there has historically never been a handrail would be a capital improvement.

In addition to giving each structure a deficiency ranking category, they are also assigned a work severity rating of critical, serious or minor. The "none" rating should be used if

there are no deficiencies, or if removal of the structure is recommended. The highest applicable rating should be selected. Definitions of the ratings are as follows:

Critical – A critical deficiency exists if any one of the following criteria is met:

- There is a threat to the health and/or safety of the user which may occur within two years.
- There is advanced deterioration which has resulted in the failure of the feature or will result in the failure of the feature if not corrected within two years.
- There is accelerated deterioration of adjacent or related materials as a result of the feature's deficiency.
- There is failure to meet a legislated requirement.

Serious – A serious deficiency exists if any one of the following criteria is met:

- A threat to the health and/or safety of the user may occur within 2 – 5 years if the deterioration is not corrected.
- There is deterioration which, if not corrected within 2 – 5 years, will result in the failure of the feature.
- There is deterioration of adjacent or related materials and/or system as a result of the feature's deficiency.

Minor – A Minor deficiency exists if any one of the following criteria is met:

- Standard preventative maintenance practices and conservation methods have not been followed.
- There is a reduced life expectancy of affected or related materials and/or systems.
- There is a condition with long-term impact beyond five years.

As mentioned previously, the deficiencies for each structure are ranked by selection of one of the following United States Department of the Interior categories. These have been adopted for previous irrigation assessments and have proven to be a useful tool in categorizing deficiencies. The rankings are not a used as an end-all priority ranking, but they do help identify structures that may be in more immediate need of rehabilitation.

5.2.1.9 Remediation Priority Ranking

DOWL HKM has previously worked closely with the Department of Interior (DOI), and in particular, staff of BIA's Irrigation, Power, and Safety of Dams (IPSOD) program, to develop a priority ranking system for rehabilitation of irrigation structures. This system has been developed to allow ranking of structures based on several different criteria, such as: Current structure condition, importance of structure type, and the significance of structure to the irrigation project. The cumulative result of these criteria is termed the Remediation Priority Index (RPI). The RPI is based upon two additional indices, the Facilities Condition Index (FCI) and the Asset Priority Index (API).

The FCI, on a 0 – 1 scale, is the ratio of the Total Rehabilitation Cost to the Current Replacement Value. A high FCI corresponds to a larger degree of deterioration (the rehabilitation cost is a high percentage of the replacement cost).

The API, on a 1 – 100 scale, is composed of two separate parameters, weighted equally; the structure function and significance. The structure function ranks the structures based on importance by structure type over a range from 1 to 50. The second parameter, structure significance, ranks the structures by their significance to the irrigation project over a range of 1 to 50, as determined by the canal capacity. Canal capacities were determined by reviewing Project reports and files as well as through the account of project personnel. A complete list of canal flows is included in Appendix 5-C. API rating criteria for the Clear Creek Watershed irrigation assessment are summarized as follows. API Significance ratings are established to provide API distribution ratings over the full range from 1 to 50. A high API corresponds to a higher priority structure.

Example: The API ranking of a 45 cfs diversion dam would be 50 (Function) + 50 (Significance) = 100. The FCI, the ratio of the total cost of rehabilitation to the Current Replacement Value, for this structure has been estimated at 0.68. The resulting RPI is then 100 x 0.68 = 68.

Further details of the Remediation Priority Index (RPI) calculations, including the API and FCI are summarized on the following page.

Asset Priority Index (API) Rating

Rating	Function	Structure Types
50	Primary Diversion	Diversion Dams, Headworks
40	Conveyance	Siphon, Flume, Pump, Drop, Chute
30	Regulation / Fish Protection	Check, Wasteway, Fish Ladder, Fish Screen
20	Lateral Diversion / Flow Measurement	Headgate, Weir
10	Delivery	Turnout

API Significance Rating

Rating	Flow Range (cfs)	
	Minimum	Maximum
50	40	100
40	25	39
30	17	24
20	6	16
10	0	5

Calculation of Remediation Priority Index (RPI)

- Remediation Priority Index **(RPI)**
  - RPI = API x FCI

- Facilities Condition Index **(FCI)**
  - Scale (0 - 1)
  - FCI = (Repair Cost)/(Replacement Cost), unless;
    - Repair Cost > Replacement Cost: FCI = 1
    - Structure Removal Recommended: FCI=0.01
    - Structure Replacement Recommended: FCI = 1

- Asset Priority Index **(API)**
  - Scale (1 – 100)
  - Based on two parameters weighted equally;
    - Significance: Rated by irrigated acres, as determined by canal capacity. (Scale of 1 – 50)
    - Function: Rated by importance of structure type. (Scale of 0 – 50)
      - Structure Removal Recommended: Function = 0

5.2.2 Canal Evaluations

During the field evaluation the canals were evaluated for deficiencies such as seepage, bank instability, and flow capacity limitations. Additionally, estimations of representative canal cross-sections were completed. During the canal portion of the investigation, landowners and irrigation personnel were heavily relied upon to identify deficient areas, as well as to provide insight into obstacles or difficulties associated with the day-to-day operation and maintenance of the canal system, facilities, and structures. In addition, aerial photography was used to supplement field observations in identifying seepage areas.

The field crew documented deficiencies through field notes, photographs, and GPS coordinate locations. Specific deficiencies that were documented include seepage and bank instability. Seepage areas were identified through the knowledge and historical accounts of landowners and irrigation personnel, and also by observing differences in the density, color, and type of vegetation adjacent to the canal. Aerial photography was also reviewed to identify variations in vegetation resulting from seepage.

Cross-section estimates were performed, where necessary, to more accurately quantify required remediation of problem areas.

5.2.2.1 Canal System Remediation

Canal Cleaning/Reshaping

The cost to clean the evaluated ditches was estimated. Cross-section estimates were performed as previously described. These cross-sections were used to estimate remediation quantities.

Seepage Area Remediation

Several areas of canal seepage were identified during the field investigations. Seepage areas were identified primarily through the historical accounts of the landowners and irrigation personnel, but additionally by observing differences in the density, color, and type of vegetation adjacent to the canal. GPS coordinates identifying the seepage areas were recorded.

Several canal lining systems were evaluated for remediation of seepage area including: concrete, buried geomembrane, and exposed geomembrane liners. In addition, HDPE pipe was used for comparison. Concrete liners are costly, subject to cracking, and require significant sub-grade preparation. Buried geomembranes require mild side slopes of no more than approximately 2.5:1 (H:V) to keep the cover material from slumping into the canal. Previously, for similar projects, exposed geomembrane liners have been selected for remediation of seepage areas due to their ability to cover steeper side slopes, and ease of installation compared to the other lining options. Upon discussion with project sponsors, it was indicated that they typically prefer to use low-head HDPE pipe through seepage sections. This is because most of the lands are grazed, and livestock impacts need to be considered. Burying pipe eliminates these livestock issues. For this reason, seepage areas will be remediated using the sponsor preferred HDPE pipe.

Bank Instability
All areas of bank instability identified during the evaluation were a result of canal seepage and should be rehabilitated with HDPE pipe.

Erosion/Headcutting
One area of head-cutting was identified on the Pratt & Ferris #1 canal. However, this issue was remediated with a pipeline during the study.

Wasteway Headcutting
One area of head-cutting along a wasteway was identified on the Big Redman ditch.

5.3 Cost Estimates

5.3.1 Existing Irrigation System Components

As mentioned, existing systems were visited to identify current operational/structural issues and provide recommendations and planning level cost estimates. These estimates were developed using a previously developed irrigation assessment tool. It compiles common unit costs for the planning level cost estimate, and prioritizes remediation based on structure function and significance.

The unit costs used in the cost estimates were based on RSMeans "Site Work and Landscape Cost Data, 24th Edition". Additionally, recent MDT and WYDOT bid tabulation as well as contractor and manufacturer quotes were referenced to provide additional cost data and serve as a reasonableness check. Bid tabulation from previous heavy construction projects have also been used in development of unit costs. The bulk of the unit costs used in the cost estimation for the current project were compiled for previous irrigation condition assessment projects. Additional costs were added as necessary, but these previously estimated costs were perpetuated to maintain consistency. The United States Bureau of Reclamation (USBR) construction cost indices were used to project previously estimated unit costs into the current cost year. Unit costs are reported in 2011 dollars. This assumes a 3% price increase over 2010 dollars. Unit costs were reviewed to determine their appropriateness. A summary table of unit costs can be found in Appendix 5-A. Also included in this appendix are the unit cost calculations for each item. As shown in these cost calculations, several construction items may be used to develop each unit cost. For example, Corrosion Inhibitor includes costs associated with the following items: Sandblasting the surface, applying one coat of an epoxy based primer, and applying two coats of epoxy based paint.

5.3.2 Regional Cost Adjustment

Unit costs are developed for each item and represent construction costs in the vicinity of Billings, Montana, as this is where the irrigation assessment database is maintained. No regional adjustment factor was considered for the Clear Creek Irrigation Assessment.

5.4 Remediation Priority Index (RPI) Ranking

The results of the inventory, rehabilitation, costs and priority rankings are submitted in the following tables. The tables are organized into structure and canal overall rankings. Additional tables summarize the structure and canal costs per system. The rankings are based on the RPI values which were discussed in Section 5.2.1.9. The higher a given structure or canal is ranked, the more immediate the need for improving or replacing the structure. The tables provide a replacement cost as well as a rehabilitation cost. No rehab is provided if the structure was identified as needing to be replaced. This is because the structure was in too poor of condition to be able to improve it without replacing it. The Remediation Cost at the end of the tables reflects the recommended cost associated with the structure. This is either the Rehab. Cost, or the Replacement Cost (CRV) if the structure is recommended for replacement.

In the Division Remediation Cost Summary table, the estimated structure and canal costs required to rehabilitate each given system are summarized and presented as a total. This could be a useful tool to identify system-wide remediation costs.

The Division Structure Remediation Cost Summary table identifies each structure within a given system that was identified and evaluated. It summarizes structure remediation costs for each system. The Division Canal Remediation Cost Summary table provides the same function, but for canal reaches within each system. Detailed remediation reports for each evaluated structure and canal reach can be found in Appendix 5-E. These sheets provide a detailed description, photos, and cost estimate for each structure and canal reach that was evaluated.

Remediation Priority Index (RPI) Structure Ranking

(ranked by RPI value)

Clear Creek Unit / Division Structure Remediation Priority Ranking Summary

HKM ID	BIA ID	Canal	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category	Deficiency Rating	Remediation Cost	Pg #
2PF-DD1		Pratt & Ferris #2	Diversion Dam (NT)	Replace	$0.00	$398,977.97	1.00	90	90	CHSci	Critical	$398,977.97	
3PF-DD1		Pratt & Ferris #3	Diversion Dam (NT)		$411,747.44	$484,704.13	0.85	100	85	CHSdm	Critical	$411,747.44	
FOX-HG1		Fox Ditch	Headgate (NT)		$143,454.92	$166,613.36	0.86	90	77	CMDM	Serious	$143,454.92	
RC-HG1		Rock Creek & South Piney	Headgate (NT)		$99,966.75	$120,835.13	0.83	90	75	CHSci	Critical	$99,966.75	
JH-SPN1		Johnson Holt	Siphon (NT)	Replace	$0.00	$53,196.99	1.00	70	70	CMDM	Critical	$53,196.99	
1PF-DD1		Pratt & Ferris #1	Diversion Dam (NT)		$221,844.28	$264,338.02	0.84	80	67	CHSci	Serious	$221,844.28	
LP-HG1		Little Piney Ditch	Headgate (NT)		$69,441.91	$86,716.13	0.8	80	64	CMDM	Critical	$69,441.91	
LD-HG1		Leiter Ditch	Headgate (NT)		$96,335.31	$157,081.99	0.61	100	61	CMDM	Minor	$96,335.31	
BB-CH1		Big Bonanza	Wasteway (NT)	Replace	$0.00	$72,209.58	1.00	60	60	CRPci	Critical	$72,209.58	
BF-HG1		Brown & Foster	Headgate (NT)	Replace	$0.00	$22,563.97	1.00	60	60	CMDM	Serious	$22,563.97	
BB-CH2		Big Bonanza	Check (NT)	Replace	$0.00	$8,477.26	1.00	60	60	CMDM	Serious	$8,477.26	
BB-CH3		Big Bonanza	Check (NT)	Replace	$0.00	$8,477.26	1.00	60	60	CMDM	Serious	$8,477.26	
BB-CH4		Big Bonanza	Check (NT)	Replace	$0.00	$8,477.26	1.00	60	60	CMDM	Serious	$8,477.26	
CD-CH2		Crown Ditch	Check (NT)	Replace	$0.00	$8,124.04	1.00	60	60	CMDM	Serious	$8,124.04	
CD-CH1		Crown Ditch	Check (NT)	Replace	$0.00	$8,124.04	1.00	60	60	CMDM	Serious	$8,124.04	
6M-HG1		Six Mile	Headgate (NT)		$154,386.65	$255,652.22	0.6	90	54	CHSci	Serious	$154,386.65	
LX-HG1		LX Ditch	Headgate (NT)		$147,438.80	$170,602.04	0.86	60	52	CMDM	Serious	$147,438.80	
MK-HG1		Fort McKinney Ditch	Headgate (NT)		$44,027.29	$51,122.37	0.86	60	52	CMDM	Minor	$44,027.29	
ST-HG1		Sturdovant Ditch	Headgate (NT)		$140,293.27	$176,415.35	0.8	60	48	CMDM	Serious	$140,293.27	
BR-DD1		Big Redman	Diversion Dam (NT)		$157,790.69	$273,848.95	0.58	80	46	CHSci	Serious	$157,790.69	
HO-SPN		Hillyer & Onslow	Siphon (NT)		$86,508.93	$99,412.03	0.87	50	44	CMDM	Critical	$86,508.93	
6M-SPN2		Six Mile	Siphon (NT)		$72,592.09	$131,412.81	0.55	80	44	CMDM	Serious	$72,592.09	
PD-HG1		Piney Divide	Headgate (NT)		$41,597.95	$98,545.07	0.42	100	42	CMDM	Critical	$41,597.95	
SNF-CH4		Senff Ditch	Check (NT)	Replace	$0.00	$13,691.63	1.00	40	40	CMDM	Serious	$13,691.63	
SNF-CH3		Senff Ditch	Check (NT)	Replace	$0.00	$13,691.63	1.00	40	40	CMDM	Serious	$13,691.63	
SNF-CH2		Senff Ditch	Check (NT)	Replace	$0.00	$13,691.63	1.00	40	40	CMDM	Serious	$13,691.63	
SNF-CH1		Senff Ditch	Check (NT)	Replace	$0.00	$13,691.63	1.00	40	40	CMDM	Serious	$13,691.63	
SNF-CH5		Senff Ditch	Check (NT)	Replace	$0.00	$8,395.64	1.00	40	40	CMDM	Serious	$8,395.64	
BB-TO1		Big Bonanza	Turnout (NT)	Replace	$0.00	$6,189.93	1.00	40	40	CMDM	Serious	$6,189.93	
BB-TO12		Big Bonanza	Turnout (NT)	Replace	$0.00	$6,189.93	1.00	40	40	CMDM	Serious	$6,189.93	
BB-TO11		Big Bonanza	Turnout (NT)	Replace	$0.00	$6,189.93	1.00	40	40	CMDM	Serious	$6,189.93	

Clear Creek Unit / Division Structure Remediation Priority Ranking Summary

HKM ID	BIA ID	Canal	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
BB-TO2		Big Bonanza	Turnout (NT)	Replace	$0.00	$6,189.93	1.00	40	40	CMDM	Serious	$6,189.93	
BB-TO3		Big Bonanza	Turnout (NT)	Replace	$0.00	$6,189.93	1.00	40	40	CMDM	Serious	$6,189.93	
BB-TO9		Big Bonanza	Turnout (NT)	Replace	$0.00	$6,189.93	1.00	40	40	CMDM	Serious	$6,189.93	
BB-TO10		Big Bonanza	Turnout (NT)	Replace	$0.00	$6,189.93	1.00	40	40	CMDM	Serious	$6,189.93	
BB-TO7		Big Bonanza	Turnout (NT)	Replace	$0.00	$6,189.93	1.00	40	40	CMDM	Serious	$6,189.93	
BB-TO8		Big Bonanza	Turnout (NT)	Replace	$0.00	$6,189.93	1.00	40	40	CMDM	Serious	$6,189.93	
BB-TO4		Big Bonanza	Turnout (NT)	Replace	$0.00	$5,651.68	1.00	40	40	CMDM	Serious	$5,651.68	
BB-TO6		Big Bonanza	Turnout (NT)	Replace	$0.00	$5,651.68	1.00	40	40	CMDM	Serious	$5,651.68	
BB-TO5		Big Bonanza	Turnout (NT)	Replace	$0.00	$5,651.68	1.00	40	40	CMDM	Serious	$5,651.68	
JH-HG1		Johnson Holt	Headgate (NT)		$133,546.49	$297,959.59	0.45	80	36	CRPdm	Serious	$133,546.49	
SNF-HG1		Senff Ditch	Headgate (NT)		$75,217.03	$131,934.73	0.57	60	34	CMDM	Serious	$75,217.03	
WJD-HG		WJD Ditch	Headgate (NT)		$69,419.13	$122,307.21	0.57	60	34	C&ODM	Minor	$69,419.13	
LC-HG1		Last Chance	Headgate (NT)		$61,852.03	$126,773.67	0.49	70	34	CMDM	Minor	$61,852.03	
LP-WR1		Little Piney Ditch	Weir (NT)		$5,491.73	$11,227.29	0.49	60	29	C&ODM	Serious	$5,491.73	
LADD-H		Ladd Ditch	Headgate (NT)		$53,813.14	$129,341.85	0.42	60	25	CMDM	Critical	$53,813.14	
LADD-C		Ladd Ditch	Check (NT)		$8,261.71	$13,856.62	0.6	40	24	CMDM	Serious	$8,261.71	
DD-FL1		Dunlap Ditch	Flume (NT)		$29,180.80	$81,401.57	0.36	60	22	CMDM	Serious	$29,180.80	
BB-DD1		Big Bonanza	Diversion Dam (NT)		$124,846.58	$452,425.94	0.28	80	22	CHSci	Critical	$124,846.58	
HL-HG1		High Line Ditch	Headgate (NT)		$52,206.98	$177,739.50	0.29	60	17	CMDM	Serious	$52,206.98	
			Total for Project			***$4,806,722.52***						***$3,225,716.87***	

Remediation Priority Index (RPI) Canal Ranking

(ranked by RPI value)

Clear Creek Unit / Division Canal Remediation Priority Ranking Summary

HKM ID	Canal	Section Type	Length	Rehabilitation Cost Total	Rehabilitation Cost $/FT	FCI	API	RPI	Deficiency Category	Deficiency Rating	Remediation Cost	Pg #
LD-4	Leiter Ditch	Canal Constriction	1,400 ft	$750,768.09	$536.26	1	100	100	CMDM	Serious	$750,768.09	
LD-2	Leiter Ditch	Seepage Area Lining	3,250 ft	$526,683.30	$162.06	1	100	100	CMDM	Serious	$526,683.30	
3PF-2	Pratt & Ferris #3	Seepage Area Lining	3,300 ft	$440,728.82	$133.55	1	100	100	CMDM	Minor	$440,728.82	
3PF-3	Pratt & Ferris #3	Seepage Area Lining	2,250 ft	$303,003.94	$134.67	1	100	100	CMDM	Serious	$303,003.94	
LDS-2	Lake Desmet Ditch	Seepage Area Lining	6,500 ft	$258,618.32	$39.79	1	100	100	CMDM	Minor	$258,618.32	
LD-3	Leiter Ditch	Seepage Area Lining	1,100 ft	$178,262.04	$162.06	1	100	100	CMDM	Serious	$178,262.04	
LDS-1	Lake Desmet Ditch	Cleaning/Reshaping	69,300 ft	$116,281.00	$1.68	1	100	100	C&ODM	Minor	$116,281.00	
3PF-1	Pratt & Ferris #3	Cleaning/Reshaping	49,400 ft	$66,017.60	$1.34	1	100	100	C&ODM	Minor	$66,017.60	
PD-2	Piney Divide	Seepage Area Lining	600 ft	$54,491.01	$90.82	1	100	100	CMDM	Serious	$54,491.01	
LD-1	Leiter Ditch	Cleaning/Reshaping	7,000 ft	$11,703.12	$1.67	1	100	100	C&ODM	Minor	$11,703.12	
PD-1	Piney Divide	Cleaning/Reshaping	8,250 ft	$9,002.40	$1.09	1	100	100	C&ODM	Minor	$9,002.40	
RC-5	Rock Creek & South Piney	Seepage Area Lining	2,900 ft	$405,256.50	$139.74	1	80	80	CMDM	Critical	$405,256.50	
2PF-2	Pratt & Ferris #2	Seepage Area Lining	2,950 ft	$270,486.84	$91.69	1	80	80	CRPci	Serious	$270,486.84	
HAL-3	Hallie Ditch	Seepage Area Lining	3,200 ft	$216,336.21	$67.61	1	80	80	CMDM	Serious	$216,336.21	
HAL-2	Hallie Ditch	Seepage Area Lining	2,100 ft	$142,850.49	$68.02	1	80	80	CMDM	Serious	$142,850.49	
RC-4	Rock Creek & South Piney	Seepage Area Lining	900 ft	$128,104.02	$142.34	1	80	80	CMDM	Critical	$128,104.02	
2PF-1	Pratt & Ferris #2	Cleaning/Reshaping	66,750 ft	$78,020.80	$1.17	1	80	80	C&ODM	Minor	$78,020.80	
6M-1	Six Mile	Cleaning/Reshaping	55,200 ft	$64,517.20	$1.17	1	80	80	C&ODM	Minor	$64,517.20	
RC-2	Rock Creek & South Piney	Seepage Area Lining	330 ft	$46,749.78	$141.67	1	80	80	CMDM	Critical	$46,749.78	
RC-3	Rock Creek & South Piney	Seepage Area Lining	325 ft	$46,749.78	$143.85	1	80	80	CMDM	Critical	$46,749.78	
HAL-1	Hallie Ditch	Cleaning/Reshaping	32,340 ft	$32,408.64	$1.00	1	80	80	C&ODM	Minor	$32,408.64	
RC-1	Rock Creek & South Piney	Seepage Area Lining	175 ft	$24,163.92	$138.08	1	80	80	CMDM	Critical	$24,163.92	
FOX-1	Fox Ditch	Cleaning/Reshaping	13,680 ft	$12,565.85	$0.92	1	80	80	C&ODM	Minor	$12,565.85	
BB-2	Big Bonanza	Canal Liner Rehabilitation	5,700 ft	$243,967.68	$42.80	1	60	60	CMDM	Serious	$243,967.68	
LP-2	Little Piney Ditch	Seepage Area Lining	3,200 ft	$217,903.54	$68.09	1	60	60	CMDM	Serious	$217,903.54	
BR-3	Big Redman	Seepage Area Lining	3,700 ft	$188,072.24	$50.83	1	60	60	CMDM	Serious	$188,072.24	
JH-2	Johnson Holt	Sediment Deposition	1,250 ft	$69,985.57	$55.99	1	60	60	CMDM	Serious	$69,985.57	
JH-1	Johnson Holt	Cleaning/Reshaping	43,630 ft	$43,661.64	$1.00	1	60	60	C&ODM	Minor	$43,661.64	
1PF-1	Pratt & Ferris #1	Cleaning/Reshaping	36,760 ft	$42,911.44	$1.17	1	60	60	C&ODM	Minor	$42,911.44	
BB-1	Big Bonanza	Cleaning/Reshaping	28,190 ft	$28,507.60	$1.01	1	60	60	C&ODM	Minor	$28,507.60	
BR-1	Big Redman	Cleaning/Reshaping	24,500 ft	$20,480.46	$0.84	1	60	60	C&ODM	Minor	$20,480.46	
LP-1	Little Piney Ditch	Cleaning/Reshaping	15,700 ft	$17,029.54	$1.08	1	60	60	C&ODM	Minor	$17,029.54	
BR-4	Big Redman	Wasteway Headcutting	1,300 ft	$16,374.60	$12.60	1	60	60	CMDM	Serious	$16,374.60	
BR-2	Big Redman	Bank Instability	300 ft	$9,551.52	$31.84	1	60	60	CMDM	Serious	$9,551.52	
FH-2	Frank Hopkins	Seepage Area Lining	4,400 ft	$225,545.68	$51.26	1	40	40	CMDM	Serious	$225,545.68	
PA-3	Prince Albert	Seepage Area Lining	1,600 ft	$82,653.08	$51.66	1	40	40	CMDM	Serious	$82,653.08	
PA-2	Prince Albert	Seepage Area Lining	1,320 ft	$68,597.19	$51.97	1	40	40	CMDM	Serious	$68,597.19	
DD-2	Dunlap Ditch	Seepage Area Lining	550 ft	$29,943.50	$54.44	1	40	40	CMDM	Critical	$29,943.50	
PA-1	Prince Albert	Cleaning/Reshaping	22,500 ft	$22,506.00	$1.00	1	40	40	C&ODM	Minor	$22,506.00	

Clear Creek Unit / Division Canal Remediation Priority Ranking Summary

HKM ID	Canal	Section Type	Length	Rehabilitation Cost Total	Rehabilitation Cost $/FT	FCI	API	RPI	Deficiency Category	Deficiency Rating	Remediation Cost	Pg #
FH-1	Frank Hopkins	Cleaning/Reshaping	21,000 ft	$17,629.70	$0.84	1	40	40	C&ODM	Minor	$17,629.70	
LC-1	Last Chance	Cleaning/Reshaping	22,000 ft	$16,504.40	$0.75	1	40	40	C&ODM	Minor	$16,504.40	
LC-2	Last Chance	Bank Instability	215 ft	$15,780.73	$73.40	1	40	40	CMDM	Serious	$15,780.73	
DD-1	Dunlap Ditch	Cleaning/Reshaping	11,740 ft	$9,827.62	$0.84	1	40	40	C&ODM	Minor	$9,827.62	
WJD-2	WJD Ditch	Seepage Area Lining	5,200 ft	$441,417.24	$84.89	1	20	20	CMDM	Critical	$441,417.24	
BF-2	Brown & Foster	Pipeline Rehabilitation	6,900 ft	$289,761.69	$41.99	1	20	20	CMDM	Minor	$289,761.69	
BF-3	Brown & Foster	Bank Instability	7,580 ft	$177,280.75	$23.39	1	20	20	CRPci	Serious	$177,280.75	
HL-2	High Line Ditch	Seepage Area Lining	7,800 ft	$172,026.29	$22.05	1	20	20	CRPci	Critical	$172,026.29	
JC-1	Johnson Creek	Pipeline Rehabilitation	3,480 ft	$102,845.52	$29.55	1	20	20	CMDM	Minor	$102,845.52	
ST-2	Sturdovant Ditch	Seepage Area Lining	1,400 ft	$96,086.85	$68.63	1	20	20	CMDM	Serious	$96,086.85	
SNF-2	Senff Ditch	Seepage Area Lining	2,500 ft	$74,431.70	$29.77	1	20	20	CMDM	Serious	$74,431.70	
ONO-3	Ono Ditch	Seepage Area Lining	2,400 ft	$71,807.96	$29.92	1	20	20	CMDM	Serious	$71,807.96	
LX-2	LX Ditch	Canal Constriction	1,950 ft	$61,115.26	$31.34	1	20	20	CMDM	Serious	$61,115.26	
ONO-2	Ono Ditch	Seepage Area Lining	1,300 ft	$39,965.60	$30.74	1	20	20	CMDM	Serious	$39,965.60	
LX-3	LX Ditch	Seepage Area Lining	1,000 ft	$33,615.04	$33.62	1	20	20	CMDM	Serious	$33,615.04	
MK-1	Fort McKinney Ditch	Pipeline Rehabilitation	600 ft	$17,368.56	$28.95	1	20	20	CMDM	Serious	$17,368.56	
ST-1	Sturdovant Ditch	Cleaning/Reshaping	20,100 ft	$16,804.48	$0.84	1	20	20	C&ODM	Minor	$16,804.48	
WJD-1	WJD Ditch	Cleaning/Reshaping	16,100 ft	$13,503.60	$0.84	1	20	20	C&ODM	Minor	$13,503.60	
LX-1	LX Ditch	Cleaning/Reshaping	13,000 ft	$8,702.32	$0.67	1	20	20	C&ODM	Minor	$8,702.32	
LADD-1	Ladd Ditch	Cleaning/Reshaping	9,200 ft	$7,689.55	$0.84	1	20	20	C&ODM	Minor	$7,689.55	
ONO-1	Ono Ditch	Cleaning/Reshaping	8,000 ft	$6,676.78	$0.83	1	20	20	C&ODM	Minor	$6,676.78	
BF-1	Brown & Foster	Cleaning/Reshaping	5,600 ft	$6,001.60	$1.07	1	20	20	C&ODM	Minor	$6,001.60	
HO-1	Hillyer & Onslow	Cleaning/Reshaping	8,700 ft	$5,776.54	$0.66	1	20	20	C&ODM	Minor	$5,776.54	
JC-2	Johnson Creek	Cleaning/Reshaping	6,900 ft	$3,450.92	$0.50	1	20	20	C&ODM	Minor	$3,450.92	
SNF-1	Senff Ditch	Cleaning/Reshaping	4,280 ft	$2,888.27	$0.67	1	20	20	C&ODM	Minor	$2,888.27	
HL-1	High Line Ditch	Cleaning/Reshaping	3,500 ft	$2,625.70	$0.75	1	20	20	C&ODM	Minor	$2,625.70	
1PF-2	Pratt & Ferris #1	Bank Instability	500 ft	$0.00	$0.00					None	$0.00	
		Total for Unit / Division		***$7,223,045.65***							***$7,223,045.65***	

Assessment Cost Summary by Irrigation System

Clear Creek Unit / Division Remediation Cost Summary

Big Bonanza [BB-1]

Structure Cost:	$295,152.38
Canal Cost:	$272,475.28
Total Cost:	***$567,627.66***

Big Redman [BR-1]

Structure Cost:	$157,790.69
Canal Cost:	$234,478.82
Total Cost:	***$392,269.51***

Brown & Foster [BF-1]

Structure Cost:	$22,563.97
Canal Cost:	$473,044.04
Total Cost:	***$495,608.01***

Crown Ditch [CR-1]

Structure Cost:	$16,248.08
Canal Cost:	$0.00
Total Cost:	***$16,248.08***

Dunlap Ditch [DUN-1]

Structure Cost:	$29,180.80
Canal Cost:	$39,771.12
Total Cost:	***$68,951.92***

Fort McKinney Ditch [MK-1]

Structure Cost:	$44,027.29
Canal Cost:	$17,368.56
Total Cost:	***$61,395.85***

Fox Ditch [FOX-1]

Structure Cost:	$143,454.92
Canal Cost:	$12,565.85
Total Cost:	***$156,020.77***

Frank Hopkins [FH-1]

Structure Cost:	$0.00
Canal Cost:	$243,175.38
Total Cost:	***$243,175.38***

Hallie Ditch [HAL-1]

Structure Cost:	$0.00
Canal Cost:	$391,595.35
Total Cost:	***$391,595.35***

High Line Ditch [HL-1]

Structure Cost:	$52,206.98
Canal Cost:	$174,651.99
Total Cost:	***$226,858.98***

Hillyer & Onslow [HO-1]

Structure Cost:	$86,508.93
Canal Cost:	$5,776.54
Total Cost:	***$92,285.47***

Clear Creek Unit / Division Remediation Cost Summary

Johnson Creek [JC-1]

Structure Cost:	$0.00
Canal Cost:	$106,296.44
Total Cost:	***$106,296.44***

Johnson Holt [JH-1]

Structure Cost:	$186,743.48
Canal Cost:	$113,647.21
Total Cost:	***$300,390.69***

Ladd Ditch [LADD-1]

Structure Cost:	$62,074.85
Canal Cost:	$7,689.55
Total Cost:	***$69,764.40***

Lake Desmet Ditch [LDS-1]

Structure Cost:	$0.00
Canal Cost:	$374,899.32
Total Cost:	***$374,899.32***

Last Chance [LC-1]

Structure Cost:	$61,852.03
Canal Cost:	$32,285.13
Total Cost:	***$94,137.16***

Leiter Ditch [LD-1]

Structure Cost:	$96,335.31
Canal Cost:	$1,467,416.55
Total Cost:	***$1,563,751.86***

Little Piney Ditch [LP-1]

Structure Cost:	$74,933.65
Canal Cost:	$234,933.08
Total Cost:	***$309,866.73***

LX Ditch [LX-1]

Structure Cost:	$147,438.80
Canal Cost:	$103,432.62
Total Cost:	***$250,871.42***

Ono Ditch [ONO-1]

Structure Cost:	$0.00
Canal Cost:	$118,450.34
Total Cost:	***$118,450.34***

Piney Divide [PD-1]

Structure Cost:	$41,597.95
Canal Cost:	$63,493.41
Total Cost:	***$105,091.36***

Pratt & Ferris #1 [PF-1]

Structure Cost:	$221,844.28
Canal Cost:	$42,911.44
Total Cost:	***$264,755.72***

Clear Creek Unit / Division Remediation Cost Summary

Pratt & Ferris #2 [PF-2]

Structure Cost:	$398,977.97
Canal Cost:	$348,507.64
Total Cost:	***$747,485.60***

Pratt & Ferris #3 [PF-3]

Structure Cost:	$411,747.44
Canal Cost:	$809,750.36
Total Cost:	***$1,221,497.80***

Prince Albert [PA-1]

Structure Cost:	$0.00
Canal Cost:	$173,756.27
Total Cost:	***$173,756.27***

Rock Creek & South Piney Ditch [RC-1]

Structure Cost:	$99,966.75
Canal Cost:	$651,024.00
Total Cost:	***$750,990.75***

Senff Ditch [SEN-1]

Structure Cost:	$138,379.18
Canal Cost:	$77,319.97
Total Cost:	***$215,699.15***

Six Mile [6M-1]

Structure Cost:	$226,978.75
Canal Cost:	$64,517.20
Total Cost:	***$291,495.95***

Sturdovant Ditch [ST-1]

Structure Cost:	$140,293.27
Canal Cost:	$112,891.33
Total Cost:	***$253,184.61***

WJD Ditch [WJD-1]

Structure Cost:	$69,419.13
Canal Cost:	$454,920.84
Total Cost:	***$524,339.98***

Grand Total	***$10,448,762.52***

Structure Remediation Cost Summary by Irrigation System

Clear Creek Unit / Division Structure Remediation Cost Summary

Big Bonanza [BB-1]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category	/ Rating	Remediation Cost	Pg #
BB-CH1		Wasteway (NT)	Replace	$0.00	$72,209.58	1.00	60	60	CRPci	Critical	$72,209.58	
BB-CH3		Check (NT)	Replace	$0.00	$8,477.26	1.00	60	60	CMDM	Serious	$8,477.26	
BB-CH2		Check (NT)	Replace	$0.00	$8,477.26	1.00	60	60	CMDM	Serious	$8,477.26	
BB-CH4		Check (NT)	Replace	$0.00	$8,477.26	1.00	60	60	CMDM	Serious	$8,477.26	
BB-TO2		Turnout (NT)	Replace	$0.00	$6,189.93	1.00	40	40	CMDM	Serious	$6,189.93	
BB-TO12		Turnout (NT)	Replace	$0.00	$6,189.93	1.00	40	40	CMDM	Serious	$6,189.93	
BB-TO11		Turnout (NT)	Replace	$0.00	$6,189.93	1.00	40	40	CMDM	Serious	$6,189.93	
BB-TO10		Turnout (NT)	Replace	$0.00	$6,189.93	1.00	40	40	CMDM	Serious	$6,189.93	
BB-TO3		Turnout (NT)	Replace	$0.00	$6,189.93	1.00	40	40	CMDM	Serious	$6,189.93	
BB-TO8		Turnout (NT)	Replace	$0.00	$6,189.93	1.00	40	40	CMDM	Serious	$6,189.93	
BB-TO7		Turnout (NT)	Replace	$0.00	$6,189.93	1.00	40	40	CMDM	Serious	$6,189.93	
BB-TO1		Turnout (NT)	Replace	$0.00	$6,189.93	1.00	40	40	CMDM	Serious	$6,189.93	
BB-TO9		Turnout (NT)	Replace	$0.00	$6,189.93	1.00	40	40	CMDM	Serious	$6,189.93	
BB-TO4		Turnout (NT)	Replace	$0.00	$5,651.68	1.00	40	40	CMDM	Serious	$5,651.68	
BB-TO5		Turnout (NT)	Replace	$0.00	$5,651.68	1.00	40	40	CMDM	Serious	$5,651.68	
BB-TO6		Turnout (NT)	Replace	$0.00	$5,651.68	1.00	40	40	CMDM	Serious	$5,651.68	
BB-DD1		Diversion Dam (NT)		$124,846.58	$452,425.94	0.28	80	22	CHSci	Critical	$124,846.58	
		Total for Canal			***$622,731.74***						***$295,152.38***	

Big Redman [BR-1]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category	/ Rating	Remediation Cost	Pg #
BR-DD1		Diversion Dam (NT)		$157,790.69	$273,848.95	0.58	80	46	CHSci	Serious	$157,790.69	
		Total for Canal			***$273,848.95***						***$157,790.69***	

Brown & Foster [BF-1]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category	/ Rating	Remediation Cost	Pg #
BF-HG1		Headgate (NT)	Replace	$0.00	$22,563.97	1.00	60	60	CMDM	Serious	$22,563.97	
		Total for Canal			***$22,563.97***						***$22,563.97***	

Crown Ditch [CR-1]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category	/ Rating	Remediation Cost	Pg #
CD-CH1		Check (NT)	Replace	$0.00	$8,124.04	1.00	60	60	CMDM	Serious	$8,124.04	
CD-CH2		Check (NT)	Replace	$0.00	$8,124.04	1.00	60	60	CMDM	Serious	$8,124.04	
		Total for Canal			***$16,248.08***						***$16,248.08***	

Clear Creek Unit / Division Structure Remediation Cost Summary

Dunlap Ditch [DUN-1]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
DD-FL1		Flume (NT)		$29,180.80	$81,401.57	0.36	60	22	CMDM	Serious	$29,180.80	
			Total for Canal		***$81,401.57***						***$29,180.80***	

Fort McKinney Ditch [MK-1]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
MK-HG1		Headgate (NT)		$44,027.29	$51,122.37	0.86	60	52	CMDM	Minor	$44,027.29	
			Total for Canal		***$51,122.37***						***$44,027.29***	

Fox Ditch [FOX-1]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
FOX-HG1		Headgate (NT)		$143,454.92	$166,613.36	0.86	90	77	CMDM	Serious	$143,454.92	
			Total for Canal		***$166,613.36***						***$143,454.92***	

High Line Ditch [HL-1]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
HL-HG1		Headgate (NT)		$52,206.98	$177,739.50	0.29	60	17	CMDM	Serious	$52,206.98	
			Total for Canal		***$177,739.50***						***$52,206.98***	

Hillyer & Onslow [HO-1]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
HO-SPN		Siphon (NT)		$86,508.93	$99,412.03	0.87	50	44	CMDM	Critical	$86,508.93	
			Total for Canal		***$99,412.03***						***$86,508.93***	

Johnson Holt [JH-1]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
JH-SPN1		Siphon (NT)	Replace	$0.00	$53,196.99	1.00	70	70	CMDM	Critical	$53,196.99	
JH-HG1		Headgate (NT)		$133,546.49	$297,959.59	0.45	80	36	CRPdm	Serious	$133,546.49	
			Total for Canal		***$351,156.58***						***$186,743.48***	

Clear Creek Unit / Division Structure Remediation Cost Summary

Ladd Ditch [LADD-1]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
LADD-H		Headgate (NT)		$53,813.14	$129,341.85	0.42	60	25	CMDM	Critical	$53,813.14	
LADD-C		Check (NT)		$8,261.71	$13,856.62	0.6	40	24	CMDM	Serious	$8,261.71	
			Total for Canal		***$143,198.47***						***$62,074.85***	

Last Chance [LC-1]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
LC-HG1		Headgate (NT)		$61,852.03	$126,773.67	0.49	70	34	CMDM	Minor	$61,852.03	
			Total for Canal		***$126,773.67***						***$61,852.03***	

Leiter Ditch [LD-1]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
LD-HG1		Headgate (NT)		$96,335.31	$157,081.99	0.61	100	61	CMDM	Minor	$96,335.31	
			Total for Canal		***$157,081.99***						***$96,335.31***	

Little Piney Ditch [LP-1]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
LP-HG1		Headgate (NT)		$69,441.91	$86,716.13	0.8	80	64	CMDM	Critical	$69,441.91	
LP-WR1		Weir (NT)		$5,491.73	$11,227.29	0.49	60	29	C&ODM	Serious	$5,491.73	
			Total for Canal		***$97,943.42***						***$74,933.65***	

LX Ditch [LX-1]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
LX-HG1		Headgate (NT)		$147,438.80	$170,602.04	0.86	60	52	CMDM	Serious	$147,438.80	
			Total for Canal		***$170,602.04***						***$147,438.80***	

Piney Divide [PD-1]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
PD-HG1		Headgate (NT)		$41,597.95	$98,545.07	0.42	100	42	CMDM	Critical	$41,597.95	
			Total for Canal		***$98,545.07***						***$41,597.95***	

Clear Creek Unit / Division Structure Remediation Cost Summary

Pratt & Ferris #1 [PF-1]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
1PF-DD1		Diversion Dam (NT)		$221,844.28	$264,338.02	0.84	80	67	CHSci	Serious	$221,844.28	
			Total for Canal		***$264,338.02***						***$221,844.28***	

Pratt & Ferris #2 [PF-2]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
2PF-DD1		Diversion Dam (NT)	Replace	$0.00	$398,977.97	1.00	90	90	CHSci	Critical	$398,977.97	
			Total for Canal		***$398,977.97***						***$398,977.97***	

Pratt & Ferris #3 [PF-3]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
3PF-DD1		Diversion Dam (NT)		$411,747.44	$484,704.13	0.85	100	85	CHSdm	Critical	$411,747.44	
			Total for Canal		***$484,704.13***						***$411,747.44***	

Rock Creek & South Piney Ditch [RC-1]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
RC-HG1		Headgate (NT)		$99,966.75	$120,835.13	0.83	90	75	CHSci	Critical	$99,966.75	
			Total for Canal		***$120,835.13***						***$99,966.75***	

Senff Ditch [SEN-1]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
SNF-CH1		Check (NT)	Replace	$0.00	$13,691.63	1.00	40	40	CMDM	Serious	$13,691.63	
SNF-CH2		Check (NT)	Replace	$0.00	$13,691.63	1.00	40	40	CMDM	Serious	$13,691.63	
SNF-CH3		Check (NT)	Replace	$0.00	$13,691.63	1.00	40	40	CMDM	Serious	$13,691.63	
SNF-CH4		Check (NT)	Replace	$0.00	$13,691.63	1.00	40	40	CMDM	Serious	$13,691.63	
SNF-CH5		Check (NT)	Replace	$0.00	$8,395.64	1.00	40	40	CMDM	Serious	$8,395.64	
SNF-HG1		Headgate (NT)		$75,217.03	$131,934.73	0.57	60	34	CMDM	Serious	$75,217.03	
			Total for Canal		***$195,096.87***						***$138,379.18***	

Six Mile [6M-1]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
6M-HG1		Headgate (NT)		$154,386.65	$255,652.22	0.6	90	54	CHSci	Serious	$154,386.65	
6M-SPN2		Siphon (NT)		$72,592.09	$131,412.81	0.55	80	44	CMDM	Serious	$72,592.09	
			Total for Canal		***$387,065.03***						***$226,978.75***	

Clear Creek Unit / Division Structure Remediation Cost Summary

Sturdovant Ditch [ST-1]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category / Rating	Remediation Cost	Pg #
ST-HG1		Headgate (NT)		$140,293.27	$176,415.35	0.8	60	48	CMDM / Serious	$140,293.27	
			Total for Canal		***$176,415.35***					***$140,293.27***	

WJD Ditch [WJD-1]

HKM ID	BIA ID	Structure Type	Action	Rehab. Cost	CRV	FCI	API	RPI	Deficiency Category / Rating	Remediation Cost	Pg #
WJD-HG		Headgate (NT)		$69,419.13	$122,307.21	0.57	60	34	C&ODM / Minor	$69,419.13	
			Total for Canal		***$122,307.21***					***$69,419.13***	
			Total for Unit / Division		***$4,806,722.52***					***$3,225,716.87***	

Canal Remediation Cost Summary by Irrigation System

Clear Creek Unit / Division Canal Remediation Cost Summary

Big Bonanza [BB-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
BB-2	Canal Liner Rehabilitation	5,700 ft	$243,967.68	$42.80	$0.00	1	60	60	CMDM	Serious	$243,967.68	
BB-1	Cleaning/Reshaping	28,190 ft	$28,507.60	$1.01	$0.00	1	60	60	C&ODM	Minor	$28,507.60	
			Total for Canal	***$272,475.28***							***$272,475.28***	

Big Redman [BR-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
BR-3	Seepage Area Lining	3,700 ft	$188,072.24	$50.83	$0.00	1	60	60	CMDM	Serious	$188,072.24	
BR-1	Cleaning/Reshaping	24,500 ft	$20,480.46	$0.84	$0.00	1	60	60	C&ODM	Minor	$20,480.46	
BR-4	Wasteway Headcutting	1,300 ft	$16,374.60	$12.60	$0.00	1	60	60	CMDM	Serious	$16,374.60	
BR-2	Bank Instability	300 ft	$9,551.52	$31.84	$0.00	1	60	60	CMDM	Serious	$9,551.52	
			Total for Canal	***$234,478.82***							***$234,478.82***	

Brown & Foster [BF-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
BF-2	Pipeline Rehabilitation	6,900 ft	$289,761.69	$41.99	$0.00	1	20	20	CMDM	Minor	$289,761.69	
BF-3	Bank Instability	7,580 ft	$177,280.75	$23.39	$0.00	1	20	20	CRPci	Serious	$177,280.75	
BF-1	Cleaning/Reshaping	5,600 ft	$6,001.60	$1.07	$0.00	1	20	20	C&ODM	Minor	$6,001.60	
			Total for Canal	***$473,044.04***							***$473,044.04***	

Dunlap Ditch [DUN-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
DD-2	Seepage Area Lining	550 ft	$29,943.50	$54.44	$0.00	1	40	40	CMDM	Critical	$29,943.50	
DD-1	Cleaning/Reshaping	11,740 ft	$9,827.62	$0.84	$0.00	1	40	40	C&ODM	Minor	$9,827.62	
			Total for Canal	***$39,771.12***							***$39,771.12***	

Fort McKinney Ditch [MK-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
MK-1	Pipeline Rehabilitation	600 ft	$17,368.56	$28.95	$0.00	1	20	20	CMDM	Serious	$17,368.56	
			Total for Canal	***$17,368.56***							***$17,368.56***	

Fox Ditch [FOX-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
FOX-1	Cleaning/Reshaping	13,680 ft	$12,565.85	$0.92	$0.00	1	80	80	C&ODM	Minor	$12,565.85	
			Total for Canal	***$12,565.85***							***$12,565.85***	

Clear Creek Unit / Division Canal Remediation Cost Summary

Frank Hopkins [FH-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
FH-2	Seepage Area Lining	4,400 ft	$225,545.68	$51.26	$0.00	1	40	40	CMDM	Serious	$225,545.68	
FH-1	Cleaning/Reshaping	21,000 ft	$17,629.70	$0.84	$0.00	1	40	40	C&ODM	Minor	$17,629.70	
			Total for Canal	***$243,175.38***							***$243,175.38***	

Hallie Ditch [HAL-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
HAL-3	Seepage Area Lining	3,200 ft	$216,336.21	$67.61	$0.00	1	80	80	CMDM	Serious	$216,336.21	
HAL-2	Seepage Area Lining	2,100 ft	$142,850.49	$68.02	$0.00	1	80	80	CMDM	Serious	$142,850.49	
HAL-1	Cleaning/Reshaping	32,340 ft	$32,408.64	$1.00	$0.00	1	80	80	C&ODM	Minor	$32,408.64	
			Total for Canal	***$391,595.35***							***$391,595.35***	

High Line Ditch [HL-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
HL-2	Seepage Area Lining	7,800 ft	$172,026.29	$22.05	$0.00	1	20	20	CRPci	Critical	$172,026.29	
HL-1	Cleaning/Reshaping	3,500 ft	$2,625.70	$0.75	$0.00	1	20	20	C&ODM	Minor	$2,625.70	
			Total for Canal	***$174,651.99***							***$174,651.99***	

Hillyer & Onslow [HO-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
HO-1	Cleaning/Reshaping	8,700 ft	$5,776.54	$0.66	$0.00	1	20	20	C&ODM	Minor	$5,776.54	
			Total for Canal	***$5,776.54***							***$5,776.54***	

Johnson Creek [JC-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
JC-1	Pipeline Rehabilitation	3,480 ft	$102,845.52	$29.55	$0.00	1	20	20	CMDM	Minor	$102,845.52	
JC-2	Cleaning/Reshaping	6,900 ft	$3,450.92	$0.50	$0.00	1	20	20	C&ODM	Minor	$3,450.92	
			Total for Canal	***$106,296.44***							***$106,296.44***	

Johnson Holt [JH-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
JH-2	Sediment Deposition	1,250 ft	$69,985.57	$55.99	$0.00	1	60	60	CMDM	Serious	$69,985.57	
JH-1	Cleaning/Reshaping	43,630 ft	$43,661.64	$1.00	$0.00	1	60	60	C&ODM	Minor	$43,661.64	
			Total for Canal	***$113,647.21***							***$113,647.21***	

Clear Creek Unit / Division Canal Remediation Cost Summary

Ladd Ditch [LADD-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
LADD-1	Cleaning/Reshaping	9,200 ft	$7,689.55	$0.84	$0.00	1	20	20	C&ODM	Minor	$7,689.55	
			Total for Canal	***$7,689.55***							***$7,689.55***	

Lake Desmet Ditch [LDS-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
LDS-2	Seepage Area Lining	6,500 ft	$258,618.32	$39.79	$0.00	1	100	100	CMDM	Minor	$258,618.32	
LDS-1	Cleaning/Reshaping	69,300 ft	$116,281.00	$1.68	$0.00	1	100	100	C&ODM	Minor	$116,281.00	
			Total for Canal	***$374,899.32***							***$374,899.32***	

Last Chance [LC-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
LC-1	Cleaning/Reshaping	22,000 ft	$16,504.40	$0.75	$0.00	1	40	40	C&ODM	Minor	$16,504.40	
LC-2	Bank Instability	215 ft	$15,780.73	$73.40	$0.00	1	40	40	CMDM	Serious	$15,780.73	
			Total for Canal	***$32,285.13***							***$32,285.13***	

Leiter Ditch [LD-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
LD-4	Canal Constriction	1,400 ft	$750,768.09	$536.26	$0.00	1	100	100	CMDM	Serious	$750,768.09	
LD-2	Seepage Area Lining	3,250 ft	$526,683.30	$162.06	$0.00	1	100	100	CMDM	Serious	$526,683.30	
LD-3	Seepage Area Lining	1,100 ft	$178,262.04	$162.06	$0.00	1	100	100	CMDM	Serious	$178,262.04	
LD-1	Cleaning/Reshaping	7,000 ft	$11,703.12	$1.67	$0.00	1	100	100	C&ODM	Minor	$11,703.12	
			Total for Canal	***$1,467,416.55***							***$1,467,416.55***	

Little Piney Ditch [LP-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
LP-2	Seepage Area Lining	3,200 ft	$217,903.54	$68.09	$0.00	1	60	60	CMDM	Serious	$217,903.54	
LP-1	Cleaning/Reshaping	15,700 ft	$17,029.54	$1.08	$0.00	1	60	60	C&ODM	Minor	$17,029.54	
			Total for Canal	***$234,933.08***							***$234,933.08***	

LX Ditch [LX-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
LX-2	Canal Constriction	1,950 ft	$61,115.26	$31.34	$0.00	1	20	20	CMDM	Serious	$61,115.26	
LX-3	Seepage Area Lining	1,000 ft	$33,615.04	$33.62	$0.00	1	20	20	CMDM	Serious	$33,615.04	
LX-1	Cleaning/Reshaping	13,000 ft	$8,702.32	$0.67	$0.00	1	20	20	C&ODM	Minor	$8,702.32	
			Total for Canal	***$103,432.62***							***$103,432.62***	

Clear Creek Unit / Division Canal Remediation Cost Summary

Ono Ditch [ONO-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
ONO-3	Seepage Area Lining	2,400 ft	$71,807.96	$29.92	$0.00	1	20	20	CMDM	Serious	$71,807.96	
ONO-2	Seepage Area Lining	1,300 ft	$39,965.60	$30.74	$0.00	1	20	20	CMDM	Serious	$39,965.60	
ONO-1	Cleaning/Reshaping	8,000 ft	$6,676.78	$0.83	$0.00	1	20	20	C&ODM	Minor	$6,676.78	
			Total for Canal	***$118,450.34***							***$118,450.34***	

Piney Divide [PD-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
PD-2	Seepage Area Lining	600 ft	$54,491.01	$90.82	$0.00	1	100	100	CMDM	Serious	$54,491.01	
PD-1	Cleaning/Reshaping	8,250 ft	$9,002.40	$1.09	$0.00	1	100	100	C&ODM	Minor	$9,002.40	
			Total for Canal	***$63,493.41***							***$63,493.41***	

Pratt & Ferris #1 [PF-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
1PF-1	Cleaning/Reshaping	36,760 ft	$42,911.44	$1.17	$0.00	1	60	60	C&ODM	Minor	$42,911.44	
1PF-2	Bank Instability	500 ft	$0.00	$0.00						None	$0.00	
			Total for Canal	***$42,911.44***							***$42,911.44***	

Pratt & Ferris #2 [PF-2]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
2PF-2	Seepage Area Lining	2,950 ft	$270,486.84	$91.69	$0.00	1	80	80	CRPci	Serious	$270,486.84	
2PF-1	Cleaning/Reshaping	66,750 ft	$78,020.80	$1.17	$0.00	1	80	80	C&ODM	Minor	$78,020.80	
			Total for Canal	***$348,507.64***							***$348,507.64***	

Pratt & Ferris #3 [PF-3]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
3PF-2	Seepage Area Lining	3,300 ft	$440,728.82	$133.55	$0.00	1	100	100	CMDM	Minor	$440,728.82	
3PF-3	Seepage Area Lining	2,250 ft	$303,003.94	$134.67	$0.00	1	100	100	CMDM	Serious	$303,003.94	
3PF-1	Cleaning/Reshaping	49,400 ft	$66,017.60	$1.34	$0.00	1	100	100	C&ODM	Minor	$66,017.60	
			Total for Canal	***$809,750.36***							***$809,750.36***	

Clear Creek Unit / Division Canal Remediation Cost Summary

Prince Albert [PA-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
PA-3	Seepage Area Lining	1,600 ft	$82,653.08	$51.66	$0.00	1	40	40	CMDM	Serious	$82,653.08	
PA-2	Seepage Area Lining	1,320 ft	$68,597.19	$51.97	$0.00	1	40	40	CMDM	Serious	$68,597.19	
PA-1	Cleaning/Reshaping	22,500 ft	$22,506.00	$1.00	$0.00	1	40	40	C&ODM	Minor	$22,506.00	
			Total for Canal	***$173,756.27***							***$173,756.27***	

Rock Creek & South Piney Ditch [RC-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
RC-5	Seepage Area Lining	2,900 ft	$405,256.50	$139.74	$0.00	1	80	80	CMDM	Critical	$405,256.50	
RC-4	Seepage Area Lining	900 ft	$128,104.02	$142.34	$0.00	1	80	80	CMDM	Critical	$128,104.02	
RC-2	Seepage Area Lining	330 ft	$46,749.78	$141.67	$0.00	1	80	80	CMDM	Critical	$46,749.78	
RC-3	Seepage Area Lining	325 ft	$46,749.78	$143.85	$0.00	1	80	80	CMDM	Critical	$46,749.78	
RC-1	Seepage Area Lining	175 ft	$24,163.92	$138.08	$0.00	1	80	80	CMDM	Critical	$24,163.92	
			Total for Canal	***$651,024.00***							***$651,024.00***	

Senff Ditch [SEN-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
SNF-2	Seepage Area Lining	2,500 ft	$74,431.70	$29.77	$0.00	1	20	20	CMDM	Serious	$74,431.70	
SNF-1	Cleaning/Reshaping	4,280 ft	$2,888.27	$0.67	$0.00	1	20	20	C&ODM	Minor	$2,888.27	
			Total for Canal	***$77,319.97***							***$77,319.97***	

Six Mile [6M-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
6M-1	Cleaning/Reshaping	55,200 ft	$64,517.20	$1.17	$0.00	1	80	80	C&ODM	Minor	$64,517.20	
			Total for Canal	***$64,517.20***							***$64,517.20***	

Sturdovant Ditch [ST-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
ST-2	Seepage Area Lining	1,400 ft	$96,086.85	$68.63	$0.00	1	20	20	CMDM	Serious	$96,086.85	
ST-1	Cleaning/Reshaping	20,100 ft	$16,804.48	$0.84	$0.00	1	20	20	C&ODM	Minor	$16,804.48	
			Total for Canal	***$112,891.33***							***$112,891.33***	

Clear Creek Unit / Division Canal Remediation Cost Summary

WJD Ditch [WJD-1]

HKM ID	Section Type	Length	Rehab. Cost	$/FT	$/FT	FCI	API	RPI	Deficiency Category / Rating		Remediation Cost	Pg #
WJD-2	Seepage Area Lining	5,200 ft	$441,417.24	$84.89	$0.00	1	20	20	CMDM	Critical	$441,417.24	
WJD-1	Cleaning/Reshaping	16,100 ft	$13,503.60	$0.84	$0.00	1	20	20	C&ODM	Minor	$13,503.60	
			Total for Canal	***$454,920.84***							***$454,920.84***	
			Total for Unit / Division	***$7,223,045.65***							***$7,223,045.65***	

5.5 Concept Level Planning

As mentioned above, the rehabilitation efforts were divided into the existing systems rehabilitation, and conceptual rehabilitation. The following discussion identifies more broad scale projects that may incorporate more than one system. These improvements could improve irrigation efficiency and losses, as well as additional benefits that will be discussed below.

5.5.1 Johnson Holt/Six Mile/Clear Creek Ditch (Clear Creek)

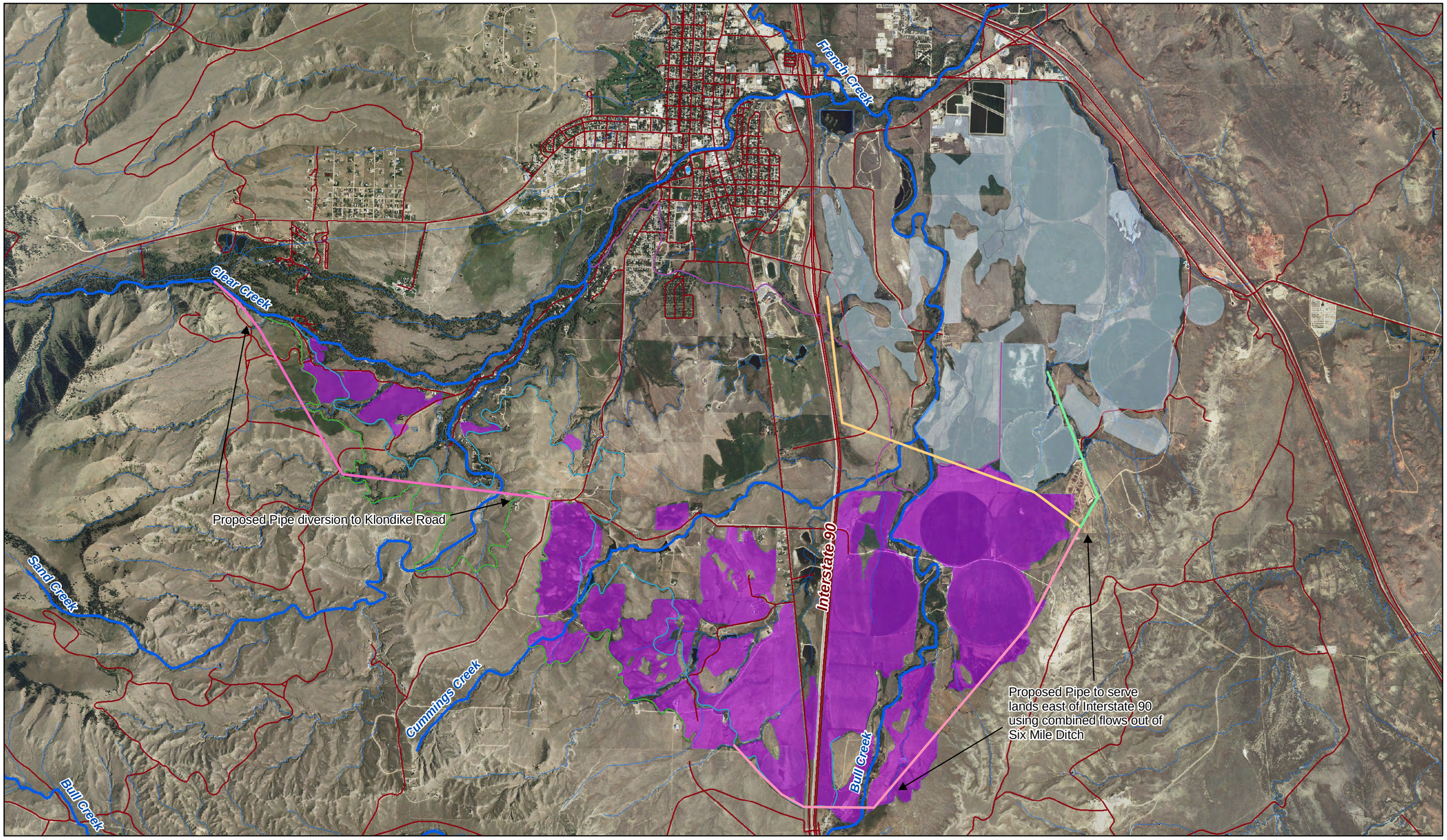
(Figure 5.5-1)

The Johnson Holt and Six Mile Ditches divert out of Clear Creek and parallel each other for the length of the Johnson Holt ditch. Both ditches convey irrigation water in open-channel, unlined ditches for significant distances before their delivery to larger appropriated lands (5 miles for Johnson Holt and 7 miles for Six Mile). The Clear Creek Ditch serves approximately 2,100 acres east of Interstate 90. It was discussed earlier that there is concern by landowners east of the interstate that the culvert piping the ditch under the high school site has no cleanout manholes, and would be extremely difficult to clean or unplug if it were to become blocked. The appropriation for the Six Mile Ditch and the Clear Creek Ditch appropriation for lands east of the interstate could be relocated upstream to share a diversion with the Johnson Holt Ditch. These ditch appropriations could then be piped to near Klondike Road, where they would daylight into the existing Johnson Holt Ditch. This would eliminate the significant length of overland flow and could significantly reduce losses associated with ditch seepage and evaporation. It would also eliminate sediment loads that build up in the ditch in areas where the ditch intercepts storm water runoff, or where the ditch passes through cut sections. The combined ditch flows could then travel to the end of the enlarged Johnson Holt Ditch. Lands irrigated by the Six Mile Ditch would be served by turnouts from the expanded ditch with the flow being piped to the existing Six Mile turnout. At the end of the ditch, flows would drop down into the existing Six Mile Ditch. Just west of the interstate, the irrigation flows would enter a pipeline that could serve all of the lands east of the interstate. A majority of these lands are already served by sprinkler delivery. This could possibly allow these lands to go to a gravity feed. In addition it would eliminate conveyance losses currently experienced in the Six Mile and Clear Creek Ditches. Table 5.5-1, on the following page, provides a cost estimate for the project.

There has been discussion regarding the possibility of serving these lands through stored water from a new reservoir. This is discussed in Section 6.6.

Table 5.5-1 – Johnson Holt / Six Mile / Clear Creek Consolidation and Pipeline

Item	Units	Estimated Quantity	Unit Cost	Cost
Diversion Structure	L.S.	--	--	$300,000
42" RCP Pipe	L.F.	15550	$171.01	$2,659,206
Unclassified Excavation	C.Y.	5000	$2.51	$12,550
30" Irrigation Pipe	L.F.	18200	$72.07	$1,311,674
18" Irrigation Pipe	L.F.	5400	$29	$156,600
12" Irrigation Pipe	L.F.	20000	$14	$280,000
Precast Turnout Box	Each	12	$650	$7,800
12" Canal Gate	Each	6	$1,200	$7,200
Turnout Valve	Each	6	$5,000	$30,000
Pressure Sustaining Valve	Each	2	$10,000	$20,000
			Total Field Costs	*$4,785,030*
			10% Engineering	$478,503
			Subtotal	*$5,263,532*
			15% Contingency	$789,530
			Construction Cost Total	$6,053,062
			Project Total	***$6,053,062***
			Report Cost	***$6,100,000***



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Miles

Legend

Existing Ditches
- Clear Creek Ditch
- Johnson-Holt Ditch
- Six Mile Ditch

Proposed Pipeline
- 42 inch RCP
- 30 inch PVC
- 18 inch PVC
- 12 inch PVC

Clear Creek Ditch Lands

Six Mile / Johnson Holt Lands

Streams

Roads

Figure 5.5-1
Clear Creek Irrigation Assessment
Johnson Holt/Six Mile/Clear Creek
Consolidation and Pipeline

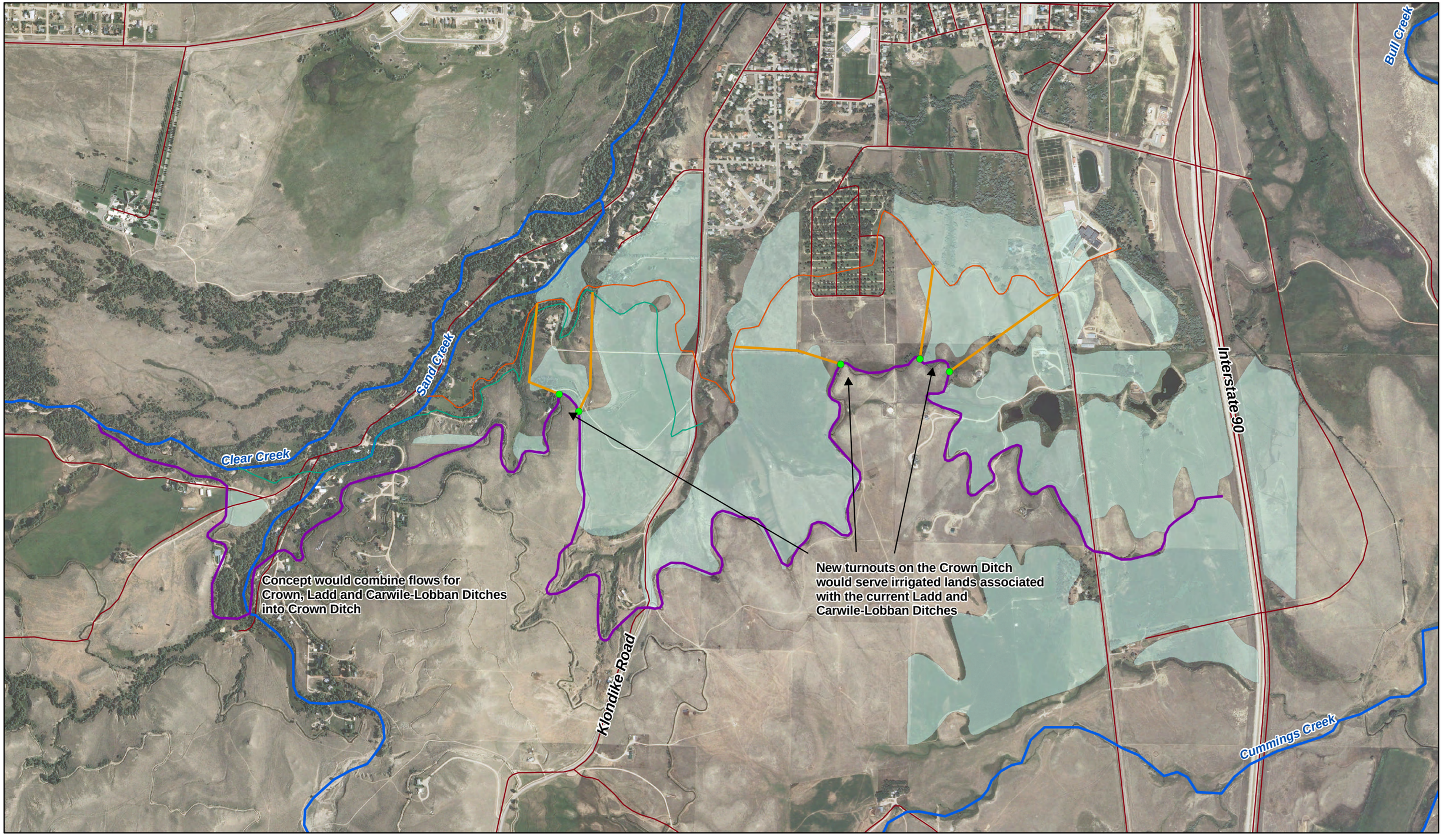
5.5.2 Crown / Ladd / Carwile-Lobban Consolidation (Clear Creek)

(Figure 5.5-2)

These four ditches divert from Clear Creek southwest of Buffalo. The Ladd Ditch, Cemetery Ditch and Carwile-Lobban Ditch are small appropriations. These ditches could be combined into the Crown Ditch to reduce losses associated with the conveyance of the three ditches. The resulting appropriation would be approximately 25 cfs. The Crown Ditch has a direct flow right of 17.8 cfs. The combined ditch would serve approximately 741 acres. Lands associated with the Ladd and Carwile-Lobban Ditches would be served by a turnout on the Crown ditch that would pipe water down to the associated lands. This would also remediate another issue. The Carwile-Lobban Ditch is piped under the new high school campus. Interviews indicated that the ditch flows are piped down to the athletic fields to a pump house, and are used to irrigate the high school practice fields. There are evidently some operational issues with this, as there are times when the ditch flows are backed up, creating a virtual reservoir at the pipe inlet. For this reason, the ditch has sediment issues, and the ditch upstream of the pipe inlet will overtop and flood out the lands below. By serving these lands from a headgate on the Crown ditch, irrigators could regulate the ditch flows more easily, and only fill the ditch when they are irrigating. This would also aid in the operational issues associated with the high school irrigation system.

Table 5.5-2 – Crown Ditch Expansion

Item	Units	Estimated Quantity	Unit Cost	Cost
Diversion Structure	L.S.	--	--	$250,000
Precast Turnout Box	Each	5	$650	$3,250
12" Canal Gate	Each	5	$1,200	$6,000
12" Irrigation Pipe	L.F.	6200	$14	$86,800
Dissipation Structure	Each	5	$7,400	$37,000
			Total Field Costs	*$383,050*
			10% Engineering	$38,305
			Subtotal	*$421,355*
			15% Contingency	$63,203
			Construction Cost Total	$484,558
				$42,136
			Project Total	***$526,694***
			Report Cost	***$530,000***



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Legend

- Proposed Turnouts
- Proposed Turnout Pipes
- Streams
- Roads

Existing Irrigation Ditches

- Ladd Ditch
- Carwile-Lobban
- Crown Ditch

Associated Lands

Figure 5.5-2
Clear Creek Irrigation Assessment
Crown/Carwile-Lobban/Ladd Ditches

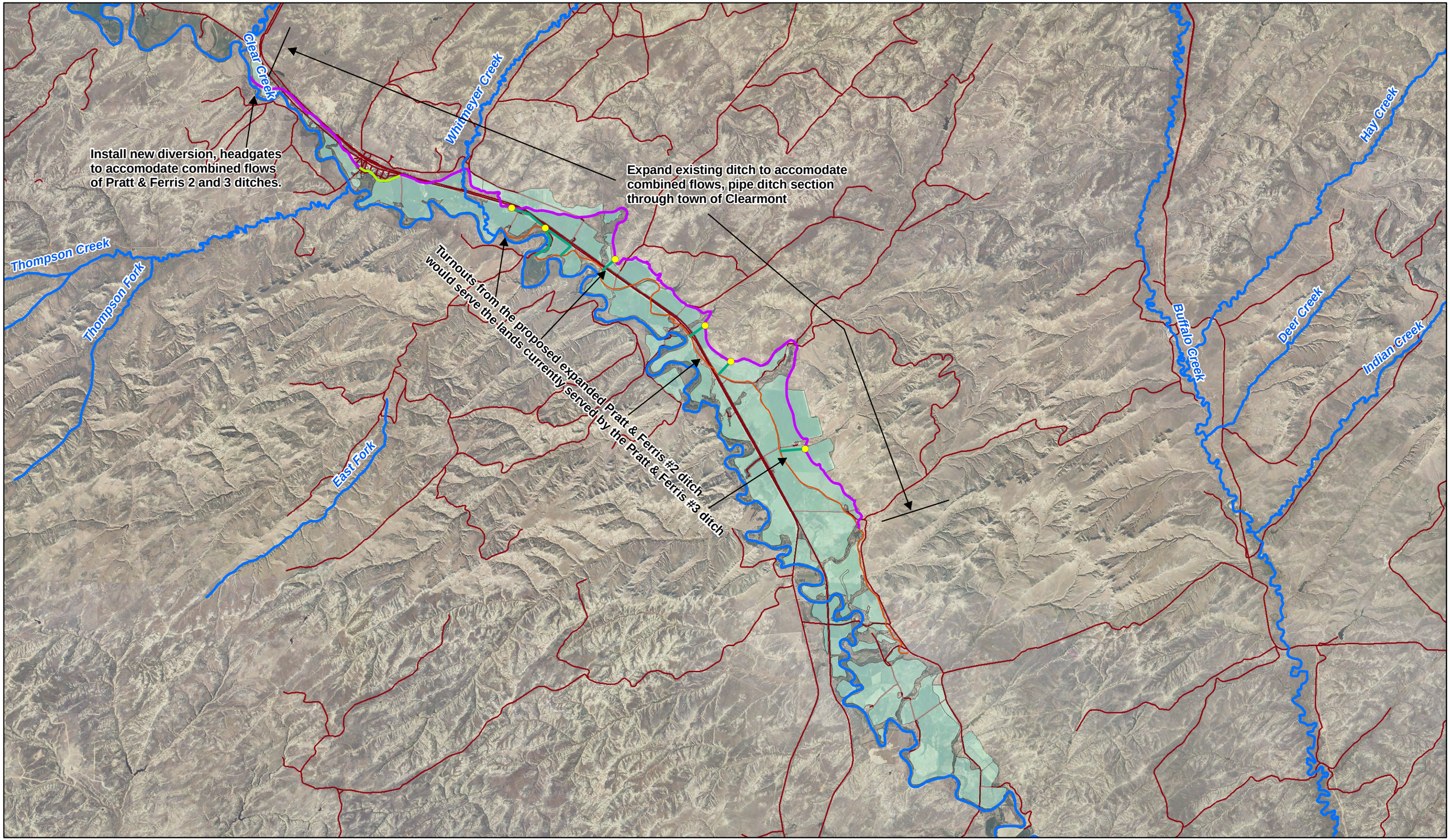
5.5.3 Pratt & Ferris #2 and #3 Combination (Clear Creek)

(Figure 5.5-3)

As evident in the structure reports in Appendix 5-E, the diversion structures for the Pratt & Ferris #2 and #3 ditches need extensive remediation. Instead of reconstructing both of these diversions, it may make sense to combine the two ditches. This would mean changing the Pratt & Ferris #3 point of diversion upstream, reconstructing the diversion to accommodate the combined ditch flows, and expanding the existing Pratt & Ferris #2 ditch. Irrigated lands currently served by the Pratt & Ferris #3 ditch would then be served by piped turnouts from the Pratt & Ferris #2 ditch. This could prove to be beneficial by reducing seepage and conveyance losses. It would benefit aquatic wildlife by eliminating two concrete ramp spillways, and replacing them with a more fish friendly rock vane.

Table 5.5-3 – Pratt & Ferris #2 and #3 Consolidation and Expansion

Item	Units	Estimated Quantity	Unit Cost	Cost
Diversion Structure	L.S.	--	--	$500,000
Demo of Pratt Ferris #3	L.S.	--	--	$75,000
Unclassified Excavation	C.Y.	30000	$2.51	$75,300
48" HDPE Pipe	L.F.	2950	$119.19	$351,611
Precast Turnout Box	Each	6	$650	$3,900
12" Canal Gate	Each	6	$1,200	$7,200
12" Irrigation Pipe	L.F.	9000	$14	$126,000
Dissipation Structure	Each	6	$7,400	$44,400
			Total Field Costs	*$1,183,411*
			10% Engineering	$118,341
			Subtotal	*$1,301,752*
			15% Contingency	$195,263
			Construction Cost Total	$1,497,014
			Project Total	***$1,497,014***
			Report Cost	***$1,500,000***



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Miles

Legend

Existing Ditches
- Pratt & Ferris #2
- Pratt & Ferris #3
- Associated Irrigated Lands
- Streams
- Roads
- Proposed Seepage Remediation
- Proposed Turnout Pipe
- Proposed Turnouts

Figure 5.5-3
Clear Creek Irrigation Assessment
Pratt & Ferris #2 & #3 Consolidation

5.5.4 Rock Creek Pipeline (Rock Creek)

(Figure 5.5-4)

A number of years ago, the Yarwood, Lilly, and Pride of the Valley Ditches were consolidated into the Fox Ditch. This has proven to reduce losses from the diversion to delivery as irrigators along the ditch are only wetting one ditch as opposed to four. There are a number of small ditches diverting out of Rock Creek from the confluence of the North and South forks to Interstate 90 that carry small appropriations. It would be beneficial to change the points of diversion for these small ditches, and consolidate them in a pipeline that could serve the valley. This could serve approximately 1,500 acres.

There are a number of concerns regarding this concept. First of all, this would most likely dry up some of the seeps and wetlands in the area, which have developed due to seepage and losses in the irrigation systems. In addition, return flows to the creek would most likely be reduced. This is due to the fact that the acreages would be served by a pipeline, and landowners would most likely prefer to change their delivery to sprinkler, as opposed to flood irrigation. A positive could be reduced flows being diverted from the creek due to the reduction of losses. It has been suggested that the existing headgates could be opened in the spring during high water, and water could be conveyed down the ditches to allow these seep and spring areas to recharge. These would be shut off once irrigation began.

The incorporation of additional lands including those served by Johnson Creek was considered; however, this would be difficult to do. The lands currently served by Johnson Creek have appropriations from Clear Creek, with typically early water rights. Changing their point of diversion to Rock Creek would give them a current year water appropriation, which would be the first to be regulated. Exchanges were discussed but this would require stored water. This too would be the latest appropriation. One possibility would be to exchange water with Lake DeSmet; however, conveyance from Lake DeSmet is a significant issue. For these reasons, only the Rock Creek appropriations are considered in this conceptual plan.

The evaluation considers consolidating seven ditches into one pipeline. The diversion would be located at the current headgate of the Kempton Ditch. Based on the 1,500 acres served, it is assumed that the diversion for the pipeline would be 21.5 cfs based on the assumption of 70 acres per 1 cfs. Table 5.5-4, on the following provides a cost estimate for the pipeline concept.

Table 5.5-4 – Rock Creek Irrigation Pipeline System

Item	Units	Estimated Quantity	Unit Cost	Cost
Diversion Structure	L.S.	--	--	$300,000
24" PVC Pipe	L.F.	9500	$47.88	$454,860
21" PVC Pipe	L.F.	8400	$38.82	$326,088
18" PVC Pipe	L.F.	2800	$29.00	$81,200
15" PVC Pipe	L.F.	1200	$19.50	$23,400
Pressure Sustaining Valve	Each	2	$10,000	$20,000
Turnout Valve	Each	6	$5,000	$30,000
			Total Field Costs	*$1,235,548*
			10% Engineering	$123,555
			Subtotal	*$1,359,103*
			15% Contingency	$203,865
			Construction Cost Total	$1,562,968
			Project Total	***$1,562,968***
			Report Cost	***$1,600,000***

Proposed systsm would relocate points of diversion to this point, with new Diversion Structure

24" PVC

21" PVC

Proposed system could provide gravity feed irrigation water to ranches along Rock Creek

18" PVC

18" PVC

15" PVC

South Rock Creek

Spring Creek

South Fork Shell Creek

Mowry Creek

Rock Creek

Red Creek

Sayles Sayles Creek

North Fork Sayles Creek

South Fork Sayles Creek

Johnson Creek

Seney Point

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Legend

- Concept Pipe
- Streams
- Roads
- Fox Ditch
- Last Chance Ditch
- Rock Creek Lands

Figure 5.5-4
Clear Creek Irrigation Assessment
Rock Creek Pipeline Concept

5.5.5 Prince Albert/Ono Ditch Consolidation (Rock Creek)

(Figure 5.5-5)

As was discussed in the Ditch Characterization section, the Prince Albert and Ono Ditches divert from the same headgate structure on Rock Creek. At the time of the field visit, the Ono headgate was shut off, and there was no water flowing into the ditch from the headgate. Just a short distance downstream of the headgate, there was water flowing in the Ono Ditch. This indicates significant seepage from Prince Albert into the Ono Ditch. In addition, the ditches parallel each other for approximately 1.4 miles. At many locations the ditches share the same ditch bank. For this reason, it is recommended that the ditches be combined into one larger ditch. In addition, it is recommended that reaches of the ditch be lined with HDPE pipe to eliminate seepage. Combining ditches would not only reduce system losses, but would also reduce maintenance and cleaning costs. Both ditches have territorial water rights. Regulation would be handled at each landowner turnout over the combined ditch section. Table 5.5-5 represents a planning level cost estimate. The cost includes cost of a new diversion; however, the current diversion was replaced only a couple years ago and is in very good condition.

Table 5.5-5 – Prince Albert / Ono Ditch Consolidation

Item	Units	Estimated Quantity	Unit Cost	Cost
Diversion Structure	L.S.	--	--	$250,000
Unclassified Excavation	C.Y.	15000	$2.51	$37,650
30" HDPE Pipe	L.F.	3850	$49.14	$189,189
30" RCP Pipe	L.F.	75	$97.02	$7,277
Precast Turnout Box	Each	6	$650	$3,900
12" Canal Gate	Each	6	$1,200	$7,200
12" RCP Pipe	L.F.	300	$61.50	$18,450
			Total Field Costs	*$513,666*
			10% Engineering	$51,367
			Subtotal	*$565,032*
			15% Contingency	$84,755
			Construction Cost Total	$649,787
			Project Total	***$649,787***
			Report Cost	***$650,000***

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Legend

- Streams
- Roads
- Associated Irrigated Lands
- Ono Ditch
- Prince Albert
- Seepage Area Lining

Figure 5.5-5
Clear Creek Irrigation Assessment
Prince Albert / Ono Ditch Consolidation

5.5.6 Boxelder Pipeline (Lake DeSmet)

(Figure 5.5-6)

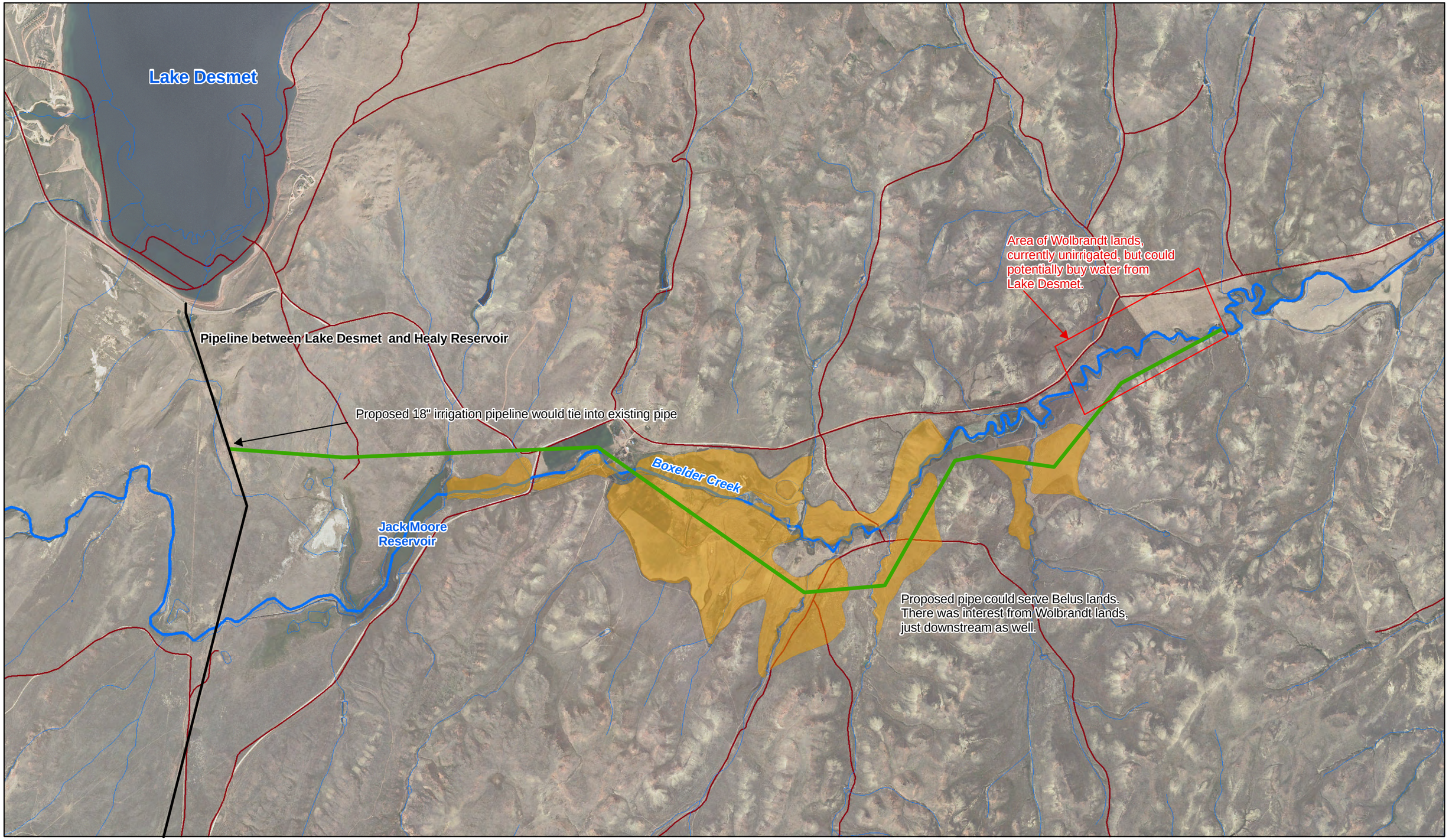
As was discussed in the Ditch Characterization section, the Boxelder Creek drainage is served by Jack Moore Reservoir. The Belus Ranch is the first water user in the drainage, and is interested in converting to sprinkler irrigation. They have significant losses in their ditches. There was interest in running an irrigation pipeline that would begin at the pipeline between Lake DeSmet and Healy Reservoir. It would then serve the Belus Ranch, and could potentially serve lands owned by the Wolbrandt family. At the time of this report, these were the two landowners interested in the concept.

This would allow the Belus Ranch to irrigate using a gravity sprinkler. It would eliminate seepage from their ditches, as they would abandon the ditches and transfer their water right from Jack Moore Reservoir to Lake DeSmet. The significant sub-irrigation issues on the lands would be helped by the sprinkler delivery. The Wolbrandt lands, downstream of the Belus Ranch, do not have water rights. However, they could buy water from Lake DeSmet and have it delivered through the proposed pipeline. This could provide the lands with a gravity feed for irrigation.

Costs assume the pipeline from the Lake DeSmet pipe, to a discharge point in Boxelder Creek, below the Wolbrandt lands. No turnout or delivery structure costs area included, as this is a conveyance project, and on farm delivery is not included in Water Development criteria. Coordination would need to be made during design/construction with the landowners to tie on-farm pipeline that would provide water to potential sprinklers into this proposed irrigation pipe.

Table 5.5-6 – Boxelder Pipeline

Item	Units	Estimated Quantity	Unit Cost	Cost
18" Irrigation Pipe	L.F.	27000	$29	$783,000
Dissipation Structure	Each	1	$7,400	$7,400
			Total Field Costs	*$790,400*
			10% Engineering	$79,040
			Subtotal	*$869,440*
			15% Contingency	$130,416
			Construction Cost Total	$999,856
			Project Total	***$999,856***
			Report Cost	***$1,000,000***



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Miles

Legend

- Potential Irrigation Pipeline
- Belus Lands
- Streams
- Roads

Figure 5.5-6
Clear Creek Irrigation Assessment
Conceptual Boxelder Pipeline

SECTION VI

WATER SUPPLY AND STORAGE OPPORTUNITIES

VI. Water Supply and Storage Opportunities

6.1 INTRODUCTION

This section of the report involved investigation and analysis of water supply issues and storage needs and opportunities in the Clear Creek Basin. This work included hydrological analysis, initial screening of storage alternatives, investigation and analysis of potential storage sites, preliminary design, cost estimates, economic analysis, permitting, and funding opportunities. The potential opportunities for water supply and storage were comparatively ranked then economic analysis was performed to determine the benefit cost ratios. Recommendations for advancement of projects were made.

The storage alternatives all have the primary purpose of supplemental agricultural irrigation water. However, economic feasibility is substantially enhanced with a multi-purpose project. The secondary purposes considered included reservoir recreation, Clear Creek instream flows, and flood control.

6.2 CLEAR CREEK BASIN HYDROLOGY

Two hydrological models were utilized for this study. A spreadsheet analysis developed in the "Powder/Tongue River Basin Plan" by HKM Engineering, Inc. dated February 2002 was utilized. Also utilized was the MODSIM model of Lake DeSmet developed for "Final Report for the City of Buffalo—Sheridan Area Water System—Lake DeSmet, Level II Study" by HKM Engineering, Inc. dated June 2008. Both models were used where applicable to evaluate project alternatives.

6.2.1 Clear Creek Models

The spreadsheet model developed for the 2002 Powder/Tongue River Basin Plan was updated and used in this study. The water availability results have been updated to include the years 2000-2009. These additional years include several significant dry years. As a result, the estimates of available flow have been reduced by 16 to 20 percent. The spreadsheet model is intended to simulate existing water use and availability under existing conditions. The model results do not reflect the impacts that operating Lake DeSmet Reservoir at its full potential would have on water availability in basin. Three models were developed, reflecting each of three hydrologic conditions: dry, normal, and wet year water supply. The spreadsheets each represent one calendar year of flows, on a monthly time step. The modelers relied on historical gage data from 1970 to 2009 to identify the hydrologic conditions for each year in the study period. Streamflow, estimated actual diversions, full supply diversions, irrigation returns, and reservoir conditions are the basic input data to the models. For all these data, average values drawn from the dry, normal, or wet subset of the study period were computed for use in the spreadsheets.

A model of the Clear Creek River basin, concentrating on Lake DeSmet, has been prepared by DOWL HKM using MODSIM. MODSIM is a river basin management decision support system originally conceived at Colorado State University (Shafer and Labadie, 1978). MODSIM is designed as a computer-aided tool for developing improved basin wide and regional strategies for short-term management, long-term operational planning, drought contingency planning, water rights analysis and resolving conflicts between urban, agricultural, and environmental concerns. The MODSIM model was setup and operated assuming full utilization of existing water rights. The model results reflect the impacts that operating Lake DeSmet Reservoir at its full potential would have on water availability in basin. MODSIM has many capabilities important for Lake DeSmet including analysis of water rights and storage contracts. Lake DeSmet receives water from many sources including Piney Creek, Little Piney Creek, Shell Creek, Rock Creek and Clear Creek. Water is stored in 13 different "accounts" within the reservoir. Each of these supply and storage permits has its own priority date.

The natural flow gage “North Fork Powder River near Hazelton, WY” (USGS 06311000) was reviewed and used to update the study period to reflect recent dry years. This streamflow gage is relatively close to Lake DeSmet and should be representative of the hydrologic conditions. The North Fork Powder River site also has a lengthy record and therefore represents long term hydrologic conditions. Extended drought periods existed from 1948 to 1961, and again from 2000 to 2007. A study period of 1945-2009 was selected because it contains both critical dry periods and because of the availability of data for this period. Missing data was filled in using regression analysis with the gage “North Fork Powder River near Hazelton”.

The complete report on the models and results are included in Appendix 6-A.

6.2.2 Available Flows

The basin model is divided into a number of reaches, each composed of several nodes, or water balance points. Reaches are typically defined by gages or confluences, and represent tributary basins or subsections of the mainstem. While simulated flow at the reach terminus indicates the estimated amount of water physically present, it does not fully reflect availability. Downstream demands relying on the water physically available at any given location must first be accounted for. These downstream demands fall into three general categories:

1. Existing irrigation, or municipal diversions
2. Instream flow constraints
3. Compact constraints

To determine how much of the physical supply is actually available in excess of existing demands, “available flow” at each reach terminus is defined as the minimum of the physically available flow at that point, and the “available flow” at all downstream reaches. Thus available flow must be defined first at the most downstream point, with upstream availability calculated in stream order. These calculations are made on a monthly basis, and annual water availability is computed as the sum of monthly values. Note that calculating annual availability in this way yields a different result than applying the same logic to annual flows for each reach. The summation of monthly values is more accurate, reflecting constraints of downstream use on a monthly basis.

The model results were utilized in conjunction with the temporary gauging results to estimate available flows at particular reservoir sites. The results of the temporary gauging are summarized in Section 3.7.2.2.

6.2.3 Shortage Estimates

The existing hydrological models previously discussed were not intended to estimate shortages for individual ditches or groups of ditches in the Clear Creek Basin. DOWL HKM reviewed the results of the water availability modeling runs to make a determination of where water shortages occur under existing conditions. The results of the modeling were further reviewed by identifying those ditches that have experienced relatively low diversions historically in comparison to other ditches. As a further crosscheck, the initial determinations of water short areas were reviewed with the SEO Division 2 Superintendent for reasonableness. It is recognized that almost every area of the planning area can be considered water short during severe dry years such as were experienced during the summer of 2001. The purpose of this investigation is to identify those areas that experience relatively high shortages in comparison to other areas in the Basin. The areas listed in Table 6.2-1 were identified as being water short in a typical year.

Table 6.2-1
Water Short Areas During Normal Hydrologic Conditions

River Basin	Stream
Clear Creek	Little Piney Cr. Rock Cr. Johnson Cr. French Cr. Clear Cr.

The shortages for individual ditches or groups of ditches were estimated by using diversion records available from the Wyoming State Engineers Office. These record total diversion flows monthly and annually for the major ditches in the basin. The shortages were estimated by comparing diversions during dry years, normal years, and wet years. The wet years were defined as the diversions for the highest 20 percent of the years of record. The dry years were defined as the diversions for the lowest 20 percent of the years of record. The remaining years comprising 60 percent of the period of record were defined as normal years.

The average shortages were estimated to be the difference between the wet years and the normal years. Maximum shortages were estimated to be the difference between the wet years and dry years.

To quantify the shortages more accurately, a more powerful hydrological model such as StateMod would have to be developed. This model would much more accurately estimate shortages for individual ditches or groups of ditches.

6.2.4 Clear Creek Instream Flows

Clear Creek through the City of Buffalo currently is nearly dewatered by irrigation diversions in late summer. There has been considerable interest expressed in incorporating instream flows through the City with a storage project. The Wyoming Game and Fish Department has evaluated this stream reach for the optimum late summer flows needed to develop a quality fishery. Minimum flows of 17 cfs through the irrigation season would meet the recommended goal. There may be benefits to maintaining the instream flow below the City of Buffalo as far as the confluence with Piney Creek. Efforts to maintain habitat for sturgeon have been made further downstream. This instream flow effort would be an additional benefit of the storage projects.

Storage alternatives located above the stream reach on the National Forest could dedicate storage for an instream flow through the City of Buffalo. This water could also be utilized for supplemental irrigation flows for ditches below the City. The regulation of these instream flows is defined by Wyoming Water Law.

The alternative reservoirs located off-channel south and southwest of the City of Buffalo could not be operated as simply as main-stem upstream storage. There are several ditches that divert upstream of the service area of the proposed reservoirs. These ditches irrigate areas north of Clear Creek. For Clear Creek instream flow purposes, three operation scenarios could be considered.

The first scenario would supply the multiple ditches south of Clear Creek from a reservoir to allow the direct diversions to shut down. However, Wyoming Water Law does not guarantee that this water flows through the City. The water becomes available to the ditches upstream. Storage from a new reservoir could be released for instream flow purpose, but the water would enter Clear Creek in the vicinity of Sand Creek. This could result in dewatering of Clear Creek upstream of Sand Creek if upstream irrigators divert available water in the creek. The junior appropriators would benefit from late season water they currently do not get. Instream flows could be provided from Sand Creek through the City of Buffalo. The water could then be used for supplemental irrigation water below the City or instream flows further downstream. The extent of the water diversion by the upstream ditches would require more detailed modeling than is available. Several of the ditches are inactive or partially active. In addition, some of the ditches and irrigated lands would be served with extension of the delivery pipeline across Clear Creek.

The second scenario would utilize the proposed reservoir only for supplemental flow for the ditches on the south side of Clear Creek. This would force late season direct flows down to the existing diversion for Clear Creek Ditch as presently occurs. The instream flow could be

released at Sand Creek which is upstream of the Clear Creek Ditch diversion. The instream flows could be routed through the City. This scenario would provide no benefits to the other upper Clear Creek ditches.

The third scenario would utilize reservoir storage to supply as many irrigated acres on the north side of Clear Creek as can be served by gravity (Snider No. 3). The proposed pipeline would be extended across Clear Creek to supply direct and supplementary flows to those lands. This scenario could also be combined with Scenario #2.

6.2.5 Water Availability

The hydrological models utilized for this study are included in Appendix 6A. The model results indicate the importance of the industrial water rights from Clear Creek to be stored in Lake DeSmet. These diversion rights are not presently utilized to deliver water. The potential effects on available flow for upper Clear Creek storage are very great.

The full utilization of the water rights would limit available flows for a new storage facility to wet years. Full utilization would assume that the yield of the water rights would be diverted and used. The actual demand of the industrial facility could be less which could increase the available flow. However, the potential for full utilization would be the most severe water supply scenario.

The most optimistic water availability scenario would be as the river currently operates with no industrial demand. For this scenario, it was assumed the 1939 Camp Comfort storage right (currently stored in Lake DeSmet) would be transferred to potential reservoir sites. The owners of the water right have not expressed interest in relinquishing the right. This potential water right transfer would be the most optimistic scenario for water supply availability for new storage reservoirs.

6.3 PRELIMINARY RESERVOIR SCREENING

The potential reservoir sites that were reviewed are shown on Figure 6.3-1. These reservoir sites were derived from previous studies, input from irrigators and sponsors, and new sites identified by the consultants to meet water shortages. These sites were preliminarily screened to eliminate sites that were not considered to be feasible. These sites were eliminated because of serious issues that involved inability to meet needs, inadequate water supply, environmental issues, land ownership issues, or extreme inefficiency, see section 6.3.1 for site specific descriptions. The summary of the reservoir sites that were eliminated from further study are presented below. Reservoir sites numbers with the "PT" prefix were sites derived from the Powder / Tongue River Basin Planning Study (HKM 2002), one and two digit site numbers were derived from other previous studies, and three digit site numbers were identified by the consultant and by input from irrigators and sponsors.

6.3.1 Potential Reservoir Sites Eliminated

PT020—Sour Dough Creek Reservoir

This reservoir site has been investigated previously and was found to have an inadequate water supply.

PT021—South Clear Creek Reservoir

This reservoir site would be redundant to the Camp Comfort Reservoir site and Tie Hack Reservoir.

PT022—Little Sour Dough Creek Reservoir

This reservoir site has been previously studied and was found to have an inadequate water supply.

PT023—Lynx Park Reservoir

This reservoir site would be redundant to Tie Hack Reservoir.

PT025—Canyon Reservoir

This reservoir site would inundate the Youth Camp, the City of Buffalo municipal water intake and pipeline, and prime fishing areas on Clear Creek.

PT026—Enlarged Negro Creek Reservoir

This reservoir site has questionable water supply and is too small.

PT027—South Rock Creek Reservoir

This reservoir site is very inefficient and is partially within the proposed wilderness area.

PT028—Triangle Park Reservoir

This reservoir site has been previously investigated and was found to inundate extensive wetlands and fens which cannot be mitigated and is partially within the proposed wilderness area.

PT029—Reynolds Shell Creek Reservoir

This reservoir site is located too far downstream on Shell Creek to serve identified irrigation needs.

PT031—Reynolds Piney Creek Reservoir

This reservoir site is redundant to Lake DeSmet and would not serve identified irrigation needs.

PT032—Boxelder Reservoir

The Boxelder Creek drainage is currently served from Lake DeSmet and a new reservoir would not serve identified needs.

PT033—Lower Clear Creek Reservoir

This reservoir site is located too far downstream on Clear Creek to serve identified needs and is redundant to Lake DeSmet.

PT034—Tex Ellis Reservoir

This reservoir site is located too far downstream on Clear Creek to serve identified needs and is redundant to Lake DeSmet.

PT035—B.C.L. Company Reservoir

This reservoir site is located too far downstream on Clear Creek to serve identified needs and is redundant to Lake DeSmet.

1—Kearny Lake Enlargement

This reservoir site is not located to meet identified needs in the Clear Creek drainage.

3—Elk Lake #1 Enlargement

This reservoir site is located in the proposed wilderness area.

4—Seven Brothers Reservoir

This reservoir site is located in a wilderness area.

10—French Creek Site #1

This reservoir site is too small (<1,000 acre-feet) and not located to meet identified needs.

11—Henry Reservoir

This site is too small to meet identified needs and could inundate portions of Interstate 25.

12—Redman Draw Reservoir

This site is too small and not located to meet identified needs.

102—Rock Creek Reservoir

This site has geotechnical issues, environmental issues, and potential land acquisition and inundated infrastructure issues (see appendix 6C and 6D).

103—Red Canyon Reservoir

This site has insufficient water supply and inefficient location.

104—Rock Creek Off Channel Reservoir

This site has insufficient water supply and inefficient location.

105—South Rock Creek Reservoir

This site is inaccessible, and located within the proposed wilderness area.

106— South Rock Creek Reservoir

This site is inaccessible, and located within the proposed wilderness area.

107— North Rock Creek Reservoir

This site is inefficient, small, and located partially within the proposed wilderness area.

113— Off-Channel Reservoir

This site is too small and inefficient to meet identified needs.

117—Lower Bull Creek Site

This reservoir site is too small to meet identified needs (<20 acre-feet), and is heavily impacted with wetlands.

118—Boot Jack

This reservoir site is too small to meet identified needs (<20 acre-feet), and is heavily impacted with wetlands.

6.3.2 Reservoir Sites Advanced to Further Analysis

PT019—Tie Hack Reservoir Enlargement

PT024—Camp Comfort Reservoir

PT030—Lake DeSmet Reservoir

2—Willow Park Reservoir Enlargement

7—French Creek Reservoir Site 3

8— French Creek Reservoir Site 8

101—North Rock Creek Reservoir

108—Lower Middle Clear Creek Reservoir

109—Upper Middle Clear Creek Reservoir

114—Sand Creek Reservoir

115—Bull Creek Reservoir

116—Bench Reservoir

The reservoir sites that were advanced for further analysis are presented in the following sections. Tables 6.3-1 and 6.3-2 display information about each potential reservoir project.

Site ID	Site Description
PT019	Tie Hack Reservoir Enlargement
PT020	Sour Dough Creek Reservoir
PT021	South Clear Creek Reservoir
PT022	Little Sour Dough Reservoir
PT023	Lynx Park Reservoir
PT024	Camp Comfort Reservoir
PT025	Canyon Reservoir
PT026	Enlarged Negro Creek Reservoir
PT027	South Rock Creek Reservoir
PT028	Triangle Park Reservoir
PT029	Reynolds Shell Creek Reservoir
PT030	Lake DeSmet and Enlargements
PT031	Reynolds Piney Creek Reservoir
PT032	Boxelder Reservoir
PT033	Lower Clear Creek Reservoir
PT034	Tex Ellis Reservoir
PT035	B.C.L. Company Reservoir

Site ID	Site Description
1	Kearny Lake Enlargement
2	Willow Park Enlargement
3	Elk Lake # 1 Enlargement
4	Seven Brothers Reservoir
5	Redundant
6	Redundant
7	French Creek Site 3
8	French Creek Site 8
10	French Creek Site 1
11	Henry Reservoir
12	Red Man Draw Reservoir
13	Redundant
14	Redundant

Site ID	Site Description
101	North Rock Creek Reservoir
102	Rock Creek Reservoir
103	Red Canyon Reservoir
104	Rock Creek Off-Channel
105	South Rock Creek Reservoir
106	South Rock Creek Reservoir
107	North Rock Creek Reservoir
108	Lower Middle Clear Creek
109	Upper Middle Clear Creek
110	Redundant
111	Redundant
112	Redundant
113	Off-Channel Reservoir
114	Sand Creek Reservoir
115	Bull Creek Reservoir
116	Bench Reservoir
117	Lower Bull Creek Site
118	Boot Jack

Sheridan
Big Horn
Johnson
Campbell
Campbell
Washakie
Hyattville
Story
Saddlestring
Leiter
Clearmont
Ucross
Buffalo
Piney Creek
South Piney Creek
Rock Creek
Boxelder Creek
Clear Creek
French Creek
Buffalo Creek
PT033
PT034
PT035
PT031
PT030
PT029
PT032
PT027
PT028
PT024
PT025
PT026
PT021
PT019
PT023
PT022
PT020

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Legend

PotentialSites
- **Eliminated**
- **Advanced to Further Analysis**

- **Cities**
- Clear Creek Watershed
- **Streams**
- **Irrigated Lands**
- Cloud Peak Wilderness
- Proposed Wilderness
- County Boundary

Figure 6.3-1
Clear Creek Basin:
Potential Reservoir Sites

Table 6.3-1 - Potential Reservoir Storage Sites Matrix

Site Name	Site PT019 - Tie Hack Reservoir Enlargement	Site PT024 - Camp Comfort Reservoir	Site PT030 - Lake DeSmet Reservoir Utilization Concept	Site 2 - Willow Park Reservoir Enlargement	Site 7 - French Creek Reservoir Site 3	Site 8 - French Creek Reservoir Site 8
Lat/Long	44.2856, -106.9214	44.3165, -106.8883	44.4503, -106.7194	44.4656, -107.0346	44.3502, -106.8645	44.3484, -106.9015
GIS Identifier	PT019	PT024	PT030	2	7	8
Location	On Channel South Clear Creek	On Channel Clear Creek	Off Channel	On Channel South Piney Creek	On Channel French Creek	On Channel Cottonwood Creek
Indirect Supply Source	NA	NA	Piney Creek, Clear Creek, Rock Creek, Shell Creek	NA	North Clear Ck	North Clear Ck
Supply Mechanism	NA	NA	Existing canal, tunnel, and pump station	NA	Enlarge Four Lakes Diversion	Enlarge Four Lakes Diversion
Storage Capacity (AF)	1,400 AF enlargement	10,400 and 6,000	80,000	4,000 AF enlargement	5500, 3000	5500, 2500
Surface Area (acres)		90		275	84, 55	87, 64
Water Surface Elevation	7467	6880	Between 4615.5 and 4590	8631.5	6230, 6190	7100, 7070
Water Availability (AF/yr)	1,400			12,000	Water year 2010: ~2,000 AF	Water year 2010: ~2,000 AF
Irrigated Acres Supplied		All acreage under Clear Creek	Upper Clear Creek basin via exchange	All acreage under Rock and Piney Creek and non trib via exchange	French Ck, Johnson Ck	French Ck, Johnson Ck
Average Annual Shortages (AF)	Irri: 4000, Fish: 1500	Irri: 4000, Fish: 1500	4,000		2,500 to 3,000	2,500 to 3,000
Average Annual Yield (AF)	1,400				3350, 1950	3310, 1630
Uses	Municipal	Ag Irri., Municipal, Environmental, Recreation	Ag Irri., Environmental	Ag Irrigation	Ag Irri., Municipal, Environmental, Recreation	Ag Irri., Municipal, Environmental, Recreation
Other Benefits		Fishery flow above and through Buffalo, flat water recreation, flood control			limited water available may preclude water delivery to Clear Ck	limited water available may preclude water delivery to Clear Ck
Dam Type	RCC	RCC	Earth embankment	Zoned embankment	Earth embankment or RCC	Earth embankment or RCC
Borrow Material Availability	Process onsite bedrock materials for RCC	Process onsite bedrock materials for RCC	NA	available on site	Rock avail, fine grain unknown	Rock avail, fine grain unknown
Dam Height (ft)	20' upstream raise	220		15 raise	230, 190	230, 200
Crest Elevation (ft)	7472	6890		8640.5	6240, 6200	7110, 7080
Crest Length (ft)		1050		6000	1000, 880	800, 700
Crest Width (ft)	37	20		20	56, 48	56, 50
Embankment Volume (1000 CY)	50	320, 240 (RCC)			3500, 2200	2400, 900
Storage Efficiency (CY/AF)	36 (RCC)	31, 40 (RCC)			636, 733	436, 360
Design Flood	PMF	PMF		PMF	PMF	PMF
Relative Peak Flood Size	Moderate	Large		Moderate	14150 cfs	9500 cfs
Avg Precip (in)		27			20	20
Drainage Area (sq-mi)		98		34.0	11.9	6.2
Potential for Flood Control	Minimal	Moderate		Minimal	Moderate	Moderate
Reservoir Supply	South Clear Creek	Clear Creek	Piney Creek, Clear Creek, Rock Creek, Shell Creek	South Piney Creek	Enlarge Four Lakes diversion and pipe existing canal	Enlarge Four Lakes diversion and pipe existing canal
Outlet Works	new multi-level intake, extend conduit	400 cfs multi level intake, conduit and control valve	Existing 66" pipeline and new 36" pipeline to Clear Creek and 18" pipeline to Redman ditch		Multilevel Intake	Multilevel Intake
Spillways	new ogee crest, extend existing chute	integral to RCC dam			Excavate around left abutment	Excavate around left abutment
Geology	enlargement would be constained by right abutment	granitic gneiss, white river formation above left abutment, wide joints identified in exposed rock, depth of suitable foundation unknown, fault in valley bottom may impact seepage control and foundation strength				Precambrian granite
Land Ownership	Forest Service	Forest Service	private	Forest Service	Forest Service	Forest Service
Irrigated Acreage Inudated (acre)	0	0	0	0	0	0
Inundated Infrastructure	-	cabins imediately up and downstream	-	none	none	French Creek cow camp (structure)
Cultural/Archaeological impacts	unknown	unknown		unknown	Mining site, historic road	French Creek cow camp (structure)
NWI Wetlands impacts (ac)	at upsteam end	~4 ac wetland or possible fen		~26 ac wetlands, possible fen in areas	<0.5	<1.0
Riparian impacts	minor woody riparian, large amount of upland forest	minor woody riparian, large amount of upland forest		very little woody riparian, large amount of upland forest	some willow riparian, large amount of upland forest	some willow riparian, large amount of upland forest
Core Sage Grouse Habibtat	No	No	No	No	No	No
Species of concern	may occur in area	may occur in area	may occur in area	may occur in area	occur in area	occur in area
Big Game impacts - crucial	none	elk	none	none	elk	elk
WDEQ Stream Class	Class 2AB	Class 2AB	-	Class 2AB	Class 2AB	Class 2AB
WGFD Stream Class	Yellow ribbon	Yellow ribbon (2.5 mi inundated)	-	Green ribbon	Green ribbon (0.7 mi inundated)	Green ribbon (1.0 mi inundated)
Access	Hwy 16	Hwy 16		4WD, Limited public access	improve existing private road or improve existing Forest Service road	improve existing Forest Service road
Project Cost ($)	$12M	$57M, $45M	$2.9M to $4.1M		$59.5M, $44.2M	$39.9M, $21.9M
Cost/AF ($/AF)	$8.6k	$5.5k, $7.5k	$0.036k to $0.051k		$10.8k, $14.7k	$7.3k, $8.8k
Cost/AF Yield ($/AF Yield)	$8.6k	$5.5k, $7.5k	$0.7k to $1.0k		$17.8k, $22.7k	$12.0k, $13.4k
Cost/CY fill ($/CY)		$178, $188	-		$17, $20	$17, $24

Favorable characteristic
Unfavorable characteristic
Probable fatal flaw or very unfavorable characteristic

Table 6.3-2 - Potential Reservoir Storage Sites Matrix						
Site Name	Site 101 - North Rock Creek Reservoir	Site 108 - Lower Middle Clear Creek Reservoir	Site 109 - Upper Middle Clear Creek Reservoir	Site 114 - Sand Creek Reservoir	Site 116 - Bench Reservoir	Site 115 - Bull Creek Reservoir
Lat/Long	44.4660, -106.9057	44.2999, -106.9780	44.3021, -106.9848	44.3107, -106.7306	44.2855, -106.6900	44.2734, -106.7152
GIS Identifier	101	108	109	114	116	115
Location	On Channel North Rock Creek	On Channel Middle Clear Creek	On Channel Middle Clear Creek	Off Channel	Off Channel	Off Channel
Indirect Supply Source	South Piney Creek	NA	NA	Clear Creek	Clear Creek	Clear Creek
Supply Mechanism	Rock Creek and South Piney Ditch Diversion	NA	NA	Enlarge existing Johnson County Farm ditch (~2mi), construct new ditch (~1.25mi). 250 cfs capacity	Enlarge existing Johnson Holt ditch (7.6mi), construct new ditch (1mi). 175 cfs capacity	Construct new supply canal (9.1 mi). 250 cfs capacity
Storage Capacity (AF)	8800, 3650	3,800	5,000	8000, 4000	3,500	9170, 4000, 2000
Surface Area (acres)	130	75	90	220, 150	160	248
Water Surface Elevation	5720, 5680	7,870	7,990	5060, 5040	4,945	5200
Water Availability (AF/yr)	12,000 in South Piney Ck					
Irrigated Acres Supplied	All acreage under Rock Creek and non trib via exchange		All acreage under Clear Creek	Johnson Holt, Six Mile, Crown, and Clear Creek ditches by pipeline	Six Mile, Crown, and Clear Creek ditches by pipeline, Johnson Holt by exchange	Johnson Holt, Six Mile, Crown, and Clear Creek ditches by pipeline
Average Annual Shortages (AF)	2500 to 3500	Irri: 4000, Fish: 1500	Irri: 4000, Fish: 1500	Irri: 3500, Fish: 2000	Irri: 3500, Fish: 2000	Irri: 3500, Fish: 2000
Average Annual Yield (AF)		approx. reservoir capacity	approx. reservoir capacity	approx. reservoir capacity	approx. reservoir capacity	approx. reservoir capacity
Uses	Ag Irrigation, Environmental	Ag Irri., Municipal, Environmental, Recreation	Ag Irri., Municipal, Environmental, Recreation	Ag Irri. Municipal, Environmental, Recreation	Ag Irri., Environmental	Ag Irri., Environmental, Recreation
Other Benefits	Flat water recreation if alternate access obtained	Fishery flow above and through Buffalo and flat water recreation, however, these would reduce water available for irrigation	Fishery flow above and through Buffalo and flat water recreation, however, these would reduce water available for irrigation	Fishery flow above and through Buffalo, reduce irrigation seepage losses, flat water recreation	limited fishery flow above and through Buffalo, reduce irrigation seepage losses	Fishery flow above and through Buffalo, reduce irrigation seepage losses, flat water recreation
Dam Type	Homogeneous or zoned earth fill	RCC	RCC	Homogeneous earth fill	Homogeneous earth fill	Homogeneous or zoned earth fill
Borrow Material Availability	likely available onsite	Process onsite bedrock materials for RCC	Process onsite bedrock materials for RCC	Fine grain likely available. Filter, riprap unknown	Fine grain likely available. Filter, riprap unknown	Fine grain and riprap likely available. Filter unknown
Dam Height (ft)	150, 110	200	200	110, 90	50	120
Crest Elevation (ft)	5730, 5690	7880	8000	5070, 5050	4955	5210
Crest Length (ft)	1,550	1150	1300	3400	7000	3250
Crest Width (ft)	20	20	20	24	20	28
Embankment Volume (1000 CY)	4000, 1800	530 (RCC)	425 (RCC)	2500, 1550	2800	1900, 1350, 700
Storage Efficiency (CY/AF)	454, 493	139 (RCC)	85 (RCC)	313, 388	800	207, 338, 350
Design Flood	PMF	PMF	PMF	PMF	PMF	PMF
Relative Peak Flood Size	Moderate	Moderate	Moderate	Minor	Minor	Minor
Avg Precip (in)	22	26	26	15	15	16
Drainage Area (sq-mi)	16	16.5	7	4	0.75	15
Potential for Flood Control	Moderate	Moderate	Moderate	Moderate - Sand Creek	Minimal	Moderate - Bull Creek
Reservoir Supply	North Rock Creek and South Piney Creek	Middle Clear Creek	Middle Clear Creek	Clear Creek	Clear Creek	Clear Creek
Outlet Works	48" outlet pipe, 200c cfs	150 cfs multi level intake, conduit and control valve	200 cfs multi level intake, conduit and control valve	36" concrete encased steel, 100c cfs. 2.65mi of 36" to 18" delivery pipeline	30" concrete encased steel, 75 cfs. 3.9mi of 30" to 18" delivery pipeline	36" concrete encased steel, 100c cfs. 4.92mi of 36" to 18" delivery pipeline
Spillways	unlined emergency spillway	integral to RCC dam	integral to RCC dam	unlined emergency spillway	unlined emergency spillway	
Geology	Cody Shale, Mesaverde Formation, Bearpaw Shale, and Lance and Fox Hills Formations. Depth of suitable foundation unknown, landslide upstream of reservoir	granitic gneiss, wide joints identified in exposed rock, depth of suitable foundation unknown	granitic gneiss, white river formation above left abutment, wide joints identified in exposed rock, depth of suitable foundation unknown	Wasatch formation, shallow ds dip, possible gypsum	Wasatch formation, possible gypsum	Wasatch formation, shallow ds dip, possible gypsum, depth of suitable foundation unknown
Land Ownership	State	Forest Service	Forest Service	State, private	Private	State, private
Irrigated Acreage Inudated (acre)	0	0	0	0	0	0
Inundated Infrastructure	none	numerous cabins downstream, no structures inundated	numerous cabins downstream, no structures inundated	portion of Johnson Holt ditch, 8" petroleum line		8" petroleum line
Cultural/Archaeological impacts	unknown	unknown	unknown	unknown	unknown	unknown
NWI Wetlands impacts (ac)	wetland fringes along stream in places, 0.06 ac wetland above stream	none on NWI, minor amount likely occur along drainage	0.05ac area not on NWI, 1.44 ac (NWI) wetland or possible fen	0.18	Minimal	none
Riparian impacts	substantial cottonwood gallery forest with understory of willow/alder riparian	very little woody riparian, large amount of upland forest	some willow riparian, some upland forest	minor	none	minor
Core Sage Grouse Habibtat	No	No	No	No	No	No
Species of concern	may occur in area	may occur in area	may occur in area	may occur in area	may occur in area	two raptor nests, sensitive species may occur in area
Big Game impacts - crucial	elk	none	none	none	none	none
WDEQ Stream Class	Class 2AB	Class 2AB	Class 2AB	NA	NA	Class 3B
WGFD Stream Class	Green ribbon	Yellow ribbon (1.5 mi inundated)	Yellow ribbon (1.1 mi inundated)	NA	NA	NA
Access	Existing private road	Existing primitive Forest Service road 2.5mi	Existing primitive Forest Service road 2.5mi	Existing county road	Existing county road 96	Existing county road (Klondike Rd)
Project Cost ($)	$60M, $32M	$80M	$68M	$39M, $27M	$33M	$41M, $32M, $23M
Cost/AF ($/AF)	$6.8k, $8.8k	$21.1k	$13.6k	$4.9k, $6.8k	$9.4k	$4.5k, $8.0k, $11.5k
Cost/AF Yield ($/AF Yield)		$21.1k	$13.6k	$4.9k, $6.8k	$9.4k	$4.5k, $8.0k, $11.5k
Cost/CY fill ($/CY)		$151.00	$160.00	$15.60, 17.40	$11.79	$21.58, $23.70, $32.86

Favorable characteristic
Unfavorable characteristic
Probable fatal flaw or very unfavorable characteristic

6.4 LAKE DESMET STORAGE WATER UTILIZATION

Lake DeSmet has been a well managed, well maintained facility. The reservoir storage has been under used due to lack of demand. The Lake DeSmet Counties Coalition Joint Powers Board sponsored a study by HKM in 2002 funded by the Wyoming Water Development Commission. This report entitled "Lake DeSmet Level II Master Plan and Reservoir Rehabilitation Plan" was completed in 2003. Primary tasks performed for the study involved potential water uses and water availability for other uses. The study concluded that substantial supplies of water were available for other uses. The coalition has expressed interest in selling water from the reservoir.

One of the goals of the Clear Creek Watershed Study was to investigate additional water supplies and potential storage for the basin. The utilization of Lake DeSmet storage was given high priority before new storage within the basin. This section of the study investigates the potential for additional utilization of Lake DeSmet storage.

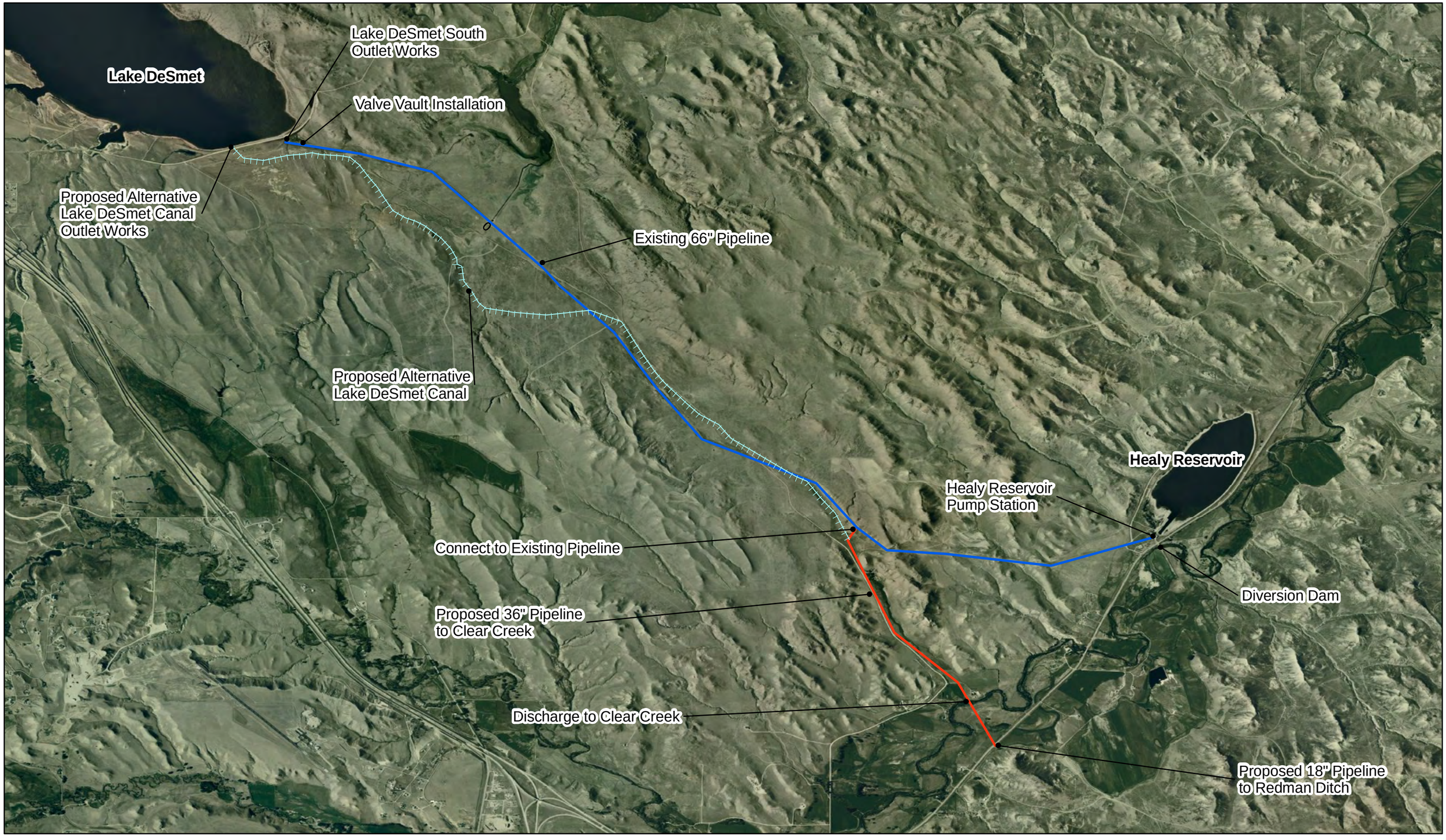
6.4.1 Lake DeSmet Storage Utilization in Clear Creek

Lake DeSmet storage water released to Clear Creek could be used to supply the diversions downstream of the City of Buffalo to the confluence with Piney Creek. These diversions have quite senior water rights and often require regulation of the upper Clear Creek basin. Release of adequate exchange water from Lake DeSmet could make the direct flow currently diverted by the lower ditches available to upper basin users.

The potential usage of Lake DeSmet water was estimated utilizing the model developed for this project and flow records. The information indicates that releases of approximately 4,000 acre-feet per year could effectively make that water available to upper basin users.

The water released from Lake DeSmet to Clear Creek could be used as exchange water for ditches upstream. Water could be purchased by individual ditches for release to satisfy the senior appropriations. By exchange, the ditches could divert equivalent water assuming that water is available in the stream. The rate of releases to Clear Creek would be a maximum of approximately 65 cfs to meet the peak demands. The Redman Ditch could be supplied with a pipeline across Clear Creek.

Lake DeSmet storage water could be delivered by gravity to Clear Creek with a canal and pipeline system as shown on Figure 6.4-1. A new outlet works from Lake DeSmet could be constructed at an approximate elevation of 4590. This elevation would allow water to be drawn from Lake DeSmet from water surface elevations higher than 4590. The reservoir storage at that elevation would be 140,000 acre-feet. With a normal maximum operation level of 4615.5', approximately 80,000 acre-feet are stored between those elevations.



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Legend

- Proposed Canal
- Proposed Pipeline
- Existing Pipeline

Figure 6.4-1
Lake DeSmet Pipeline Concept

The outlet works could release water to a canal which would carry water approximately 5.5 miles as shown. At the end of the canal, the existing drainage is quite steep and would be subject to erosion. A new pipeline could be constructed beginning at the end of the canal at a location approximately 5 miles south of the south embankment. This pipeline would be routed down an existing drainage to Clear Creek. The length of new pipeline would be approximately 1.8 miles. The new pipeline is located on private land. An easement would need to be obtained from the landowners. An energy dissipation structure would be needed at Clear Creek. An 18 inch pipeline could be used to supply the Redman Ditch on the south side of Clear Creek.

Preliminary designs and cost estimates of the systems were developed. The preliminary design is shown on Figure 6.4-1. The preliminary cost estimate is shown in Table 6.4-1. As indicated, the approximate cost would be $4.1 million. Assuming that the project would be funded using the standard WWDC funding package of two thirds grant and one third loan, the obligation to the sponsors would be $1,365,000. The WWDC loan conditions of 4 percent interest and 20 year duration would yield an annual obligation of $100,500. Based on a yield of 4,000 acre-feet, the annual cost for repayment of the loan would be approximately $25.13 per acre-foot.

Table 6.4-1
Cost Estimate-Lake DeSmet to Clear Creek Canal and Pipeline

No.	Task	Unit	Estimated Quantity	Unit Price	Total Cost
1	Mobilization	L.S.	--	--	$150,000.00
2	Lake DeSmet O.W.	L.S.	--	--	$500,000.00
3	Canal	L.F.	29,000	30	$870,000.00
5	36" Pipeline	L.F.	9,600	100	$960,000.00
6	36" Outlet	L.S.	--	--	$75,000.00
7	18" Pipeline	L.F.	2,500	40	$100,000.00
8	Creek Crossing	L.F.	100	1,000	$100,000.00
9	18" Outlet	L.S.	--	--	$25,000.00
				Construction Cost Sub-Total:	$2,780,000.00
				10% Engineering:	$278,000.00
				Sub-Total:	$3,058,000.00
				15% Contingency:	$458,700.00
				CONSTRUCTION COST TOTAL:	$3,516,700.00
				Preparation of Final Designs and Specifications:	$220,000.00
				Permitting and Mitigation:	$50,000.00
				Legal Fees:	$50,000.00
				Acquisition of Access and Rights of Way:	$220,000.00
				TOTAL PROJECT COSTS:	**$4,056,700.00**
				USE:	**$4.1 M**

Alternatively, cost savings could be realized if portions of the existing pipeline from the existing Healy Reservoir Pump Station to Lake DeSmet could be utilized. The owners of the system have not indicted interest in participation, but the cost advantages of this alternative have been presented in this report.

The Clear Creek to Lake DeSmet delivery system is comprised of several components. A major diversion dam diverts Clear Creek water to Healy Reservoir. From Healy Reservoir, water can be pumped using the Healy Pump Station through a 66 inch pipeline approximately 5 miles to Lake DeSmet. The pipeline is connected to the south outlet works located through the south embankment.

Storage water in Lake DeSmet could be discharged to Clear Creek upstream of the Healy Diversion dam as shown on Figure 6.4-1. This could be done by utilizing portions of the existing 66 inch pipeline from the Healy Pump Station to Lake DeSmet. As shown on Figure 6.4-1, a new pipeline could be constructed from a location approximately 5 miles south of the south embankment. This pipeline would be routed down an existing drainage to Clear Creek. The length of new pipeline would be approximately 1.9 miles. The new pipeline is located on private land. An easement would need to be obtained from the landowners.

This concept would allow water to be drawn from Lake DeSmet from water surface elevations higher than 4590. The reservoir storage at that elevation would be 140,000 acre-feet. With a normal maximum operation level of 4615.5', approximately 80,000 acre-feet are stored between those elevations.

Preliminary designs and cost estimates of the changes and additions to the existing piping system were developed. The preliminary design is shown on Figure 6.4-1. The major features would include modification of the piping vault immediately downstream of the south embankment and construction of a branch from the 66 inch existing pipe to the proposed 36 inch pipe to Clear Creek. A control valve and meter would be needed at that location. An energy dissipation structure would be needed at Clear Creek. An 18 inch pipeline could be used to supply the Redman Ditch on the south side of Clear Creek.

The preliminary cost estimate is shown in Table 6.4-2. As indicated, the approximate cost would be $2.9 million. Assuming that the project would be funded using the standard WWDC funding package of two thirds grant and one third loan, the obligation to the sponsors would be $966,000. The WWDC loan conditions of 4 percent interest and 20 year duration would yield an annual obligation of $71,100. Based on a yield of 4,000 acre-feet, the annual cost for repayment of the loan would be approximately $17.78 per acre-foot.

In addition to these costs, the cost of purchase of water from the Lake DeSmet coalition would be required. The selling price of this water has been $10 per acre-foot. The total cost per acre-foot under the alternative conditions would range from approximately $27.78 to $35.13. This cost is probably in excess of what irrigators in Clear Creek could pay.

The utilization of Lake DeSmet storage water to meet needs in Clear Creek could have the immediate result of better utilization of existing Clear Creek supplies. The study of new storage in the basin would lead to the fact that utilization of Lake DeSmet water could decrease the size of the new storage reservoirs. The unit cost of utilizing existing storage water in Lake DeSmet based on a yield of 4,000 acre-feet and an entirely new delivery system with an estimated project cost of $4.1 million is $1,025 per acre-foot. The partial utilization of the existing delivery system has an estimated project cost of $2.9 million for a cost of $725 per acre-foot.

As indicated in the summary section, these unit costs are lower than the most efficient new storage projects.

The potential for this project to be considered an integral part of a new storage project could qualify for a better funding package from the WWDC.

The sponsorship of this project would be most efficiently carried out by the Lake DeSmet Counties Coalition Joint Powers Board with the support and involvement of the irrigators and beneficiaries. The Board owns Lake DeSmet with the exception of the south outlet works. The Board already has the organization and personnel to operate the project.

The effects of this alternative on Lake DeSmet water levels should be evaluated using the Lake DeSmet hydrologic model. The change in operational levels of Lake DeSmet could then be determined.

Table 6.4-2
Cost Estimate - Clear Creek Pipeline

No.	Task	Unit	Estimated Quantity	Unit Price	Total Cost
1	Mobilization	L.S.	--	--	$100,000.00
2	Lake DeSmet Vault	L.S.	--	--	$500,000.00
3	66" Pipeline Rehab	L.S.	--	--	$100,000.00
4	Pipeline Connection	L.S.	--	--	$50,000.00
5	36" Pipeline	L.F.	10,000	100	$1,000,000.00
6	36" Outlet	L.S.	--	--	$75,000.00
7	18" Pipeline	L.F.	2,500	40	$100,000.00
8	Creek Crossing	L.F.	100	1,000	$100,000.00
9	18" Outlet	L.S.	--	--	$25,000.00
				Construction Cost Sub-Total:	$2,050,000.00
				10% Engineering:	$205,000.00
				Sub-Total:	$2,255,000.00
				15% Contingency:	$338,250.00
				CONSTRUCTION COST TOTAL:	$2,593,250.00
				Preparation of Final Designs and Specifications:	$150,000.00
				Permitting and Mitigation:	$50,000.00
				Legal Fees:	$25,000.00
				Acquisition of Access and Rights of Way:	$100,000.00
				TOTAL PROJECT COSTS:	**$2,918,250.00**
				USE:	**$2.9 M**

6.4.2 M&M Ranch Water Rights

The utilization of Lake DeSmet Counties Coalition Joint Powers Board storage water as an alternative source for M&M Ranch storage water should be investigated. The better utilization of Lake DeSmet storage and making more water available for storage in upper Clear Creek could be realized. An agreement for sale of coalition storage water to M&M Ranch would seem to be very much in the interests of both partners. A reasonable purchase price could bring in income for the coalition and supply water for M&M Ranch at a reduced cost and more reliability. The yield of upper basin storage would be much better and improve the feasibility of the storage projects.

If this concept is pursued, the models developed for the Lake DeSmet hydrologic analysis should be updated to reflect this operation change. The operational levels of Lake DeSmet are very important as discussed in the 2003 study. The current use of the reservoir is primarily recreation which results in a significant economic boost to the regional area. The effect on the lake levels should be analyzed.

6.5 SOUTH BUFFALO OFF-CHANNEL RESERVOIR SITES

Off channel storage sites south of Buffalo were investigated. Seven irrigation ditches are located in the area with the opportunity for combining ditches. The construction of storage in this location could reduce seepage losses, supply supplemental irrigation water, supply adequate fishery flow above and through the City of Buffalo, and create flat water recreation.

The preliminary screening identified three storage sites that were investigated. This section presents the results of that investigation. The three storage sites that were investigated were the following as shown on Figure 6.5-1:

Sand Creek Reservoir Site
Bench Reservoir Site
Bull Creek Reservoir Site

6.5.1 Water Availability

The model developed for this study was utilized to estimate available flows at the proposed diversion locations. As discussed in Section 6.2.5, it was assumed that for the most optimistic scenario, the M&M Ranch water rights from Clear Creek would not be utilized to deliver water to Lake DeSmet. For modeling purposes, the Camp Comfort water storage right currently owned by M&M Ranch for 11,640 acre-feet was assumed to be partially transferred to the proposed sites. Under these most optimistic assumptions, the water available for a new reservoir would be approximately one acre-foot of yield for one acre-foot of storage on an average annual basis. For the range of reservoir sizes analyzed, the yield would be very dependable.

6.5.2 Reservoir Purpose and Need

Irrigation shortages for the four major southside ditches, the Johnson Holt, Six Mile, Crown and Clear Creek, were estimated. The total shortages were estimated to be 3,500 acre-feet per year on an average annual basis. The direct flow rights and the supplemental storage water would be delivered to the ditches by pipeline.

Fishery flows of 17 cfs above and through the City of Buffalo would require approximately 1,500 to 2,000 acre-feet per year on an average annual basis. This water could be utilized by irrigators downstream of the city or utilized as fishery flows below the city.

Water exchanges may be possible with irrigators upstream of the project. The availability of exchange water was not evaluated due to model limitations. The fishery flows above and through the city may preclude such exchanges.

Reservoir recreational usage would be desirable to maximize public benefits of the projects. The usual range of recommended recreation pool is 25 to 30 percent of total reservoir storage.

CLEAR CREEK DITCH

CROWN DITCH

SIXMILE DITCH

SAND CREEK RESERVOIR SITE

JOHNSON HOLT DITCH

BULL CREEK RESERVOIR SITE

BENCH RESERVOIR SITE

NOTE: ALL BLUE DITCHES COULD BE CONSOLIDATED WITH A RESERVOIR PROJECT

FILE NAME: SANDCKSITE | OPERATOR: NLW | PROJECT NO.: 571
SCALE: 1"=1000' | DATE: 06/10 | TASK NO.:
LOCATION: BUFFALO, WY
PROJECT: CLEAR CREEK WATERSHED
SEND TO: VICTOR E. ANDERSON
PHONE: (307) 634-7848

REV	DESCRIPTION OF REVISION	BY	DATE
1	PRELIMINARY DESIGN	NLW	06/10

STATE LAND
BLM LAND
IRRIGATED LANDS
EXISTING IRRIGATION DITCH
PROPOSED CANAL/PIPELINE

N

SCALE 1" = 3000'

STATES WEST WATER RESOURCES CORPORATION
1904 E. 15th STREET
CHEYENNE, WYOMING 82001
(307) 634-7848
FAX: (307) 634-7851

WARNING
IF THIS BAR DOES NOT MEASURE 1/2" THEN DRAWING IS NOT TO SCALE

DESIGNED	NLW
DRAWN	NLW
CHECKED	VEA
PEER REVIEWED	VEA
PROJECT MANAGER	VEA
DATE	06/10

CLEAR CREEK WATERSHED STUDY

SOUTH BUFFALO OFF-CHANNEL RESERVOIR SITES

REVISION 1
PROJECT 571
DRAWING FIGURE 6.5-1

6.5.3 Sand Creek Reservoir Site

This potential site would be located on Sand Creek approximately 3 miles south west of the City of Buffalo as shown on Figure 6.5-2. The site could impound in excess of 10,000 acre-feet as indicated on the stage storage curve, Figure 6.5-3. The reservoir would be filled by enlargement and extension of the Johnson County Farm Ditch. The reservoir could supply the Johnson Holt, Six Mile, Crown, and Clear Creek Ditches by a pipeline as well as release water to Clear Creek. The reservoir could be utilized for late season releases which could allow the flows presently diverted above the city to flow through the City of Buffalo.

The dam and reservoir would be located primarily on State of Wyoming lands with some private land inundated as shown on Figure 6.5-2. Klondike Road passes immediately east of the proposed reservoir. Portions of the Johnson Holt Ditch would be inundated by the reservoir. The supply canal would be on private lands. The discharge pipeline would be on private lands.

6.5.3.1 Supply Canal

The canal capacity required to supply a potential reservoir of 8,000 acre-feet would be approximately 150 cfs. The direct flow rights of the ditches would also be conveyed in the canal and routed through the proposed reservoir. The total capacity of the canal would be approximately 250 cfs. The canal would follow the alignment of the Johnson County Farm Ditch for approximately 2 miles as shown on Figure 6.5-2. The canal would be extended an additional 1.25 miles to the reservoir. Portions of the canal would be lined or conveyed in a pipe to reduce seepage losses. The size of the supply systems would be reduced for smaller reservoir capacities.

6.5.3.2 Dam and Reservoir

A dam required to impound 8,000 acre-feet of storage would be a maximum of 110 feet high with a crest length of 3,400 feet as shown in Figure 6.5-4. The reservoir would inundate approximately 220 acres at full capacity. The characteristics of the site are summarized below. A range of reservoir sizes were analyzed. In addition to the 8,000 acre-feet capacity, a capacity of 4,000 acre-feet was analyzed. The project shown on the Figures are the 8,000 acre-feet capacity reservoir.

DISCHARGE TO CLEAR CREEK

DIVERSION STRUCTURE

CLEAR CREEK DITCH

JOHNSON COUNTY DITCH TO BE ENLARGED

SIPHON

DELIVERY PIPELINE

CROWN DITCH

DITCH EXTENSION

METER

OUTLET WORKS

SIX MILE DITCH

RESERVOIR DROP

PETROLEUM LINE TO BE RELOCATED

INTAKE STRUCTURE

SITE 114
SAND CREEK RESERVOIR
WATER SURFACE ELEV 5060'
TOP OF DAM 5070'
8000 AF

EMERGENCY SPILLWAY

KLONDIKE RD

JOHNSON HOLT DITCH

LEGEND

- STATE LAND
- BLM LAND
- IRRIGATED LANDS

SCALE 1" = 2000'

N

STATES WEST WATER RESOURCES CORPORATION

1904 E. 15th STREET
CHEYENNE, WYOMING 82001
(307) 634-7848
FAX: (307) 634-7851

CLEAR CREEK WATERSHED STUDY

SAND CREEK RESERVOIR SYSTEM

REVISION 1

PROJECT 571

DRAWING FIGURE 6.5-2

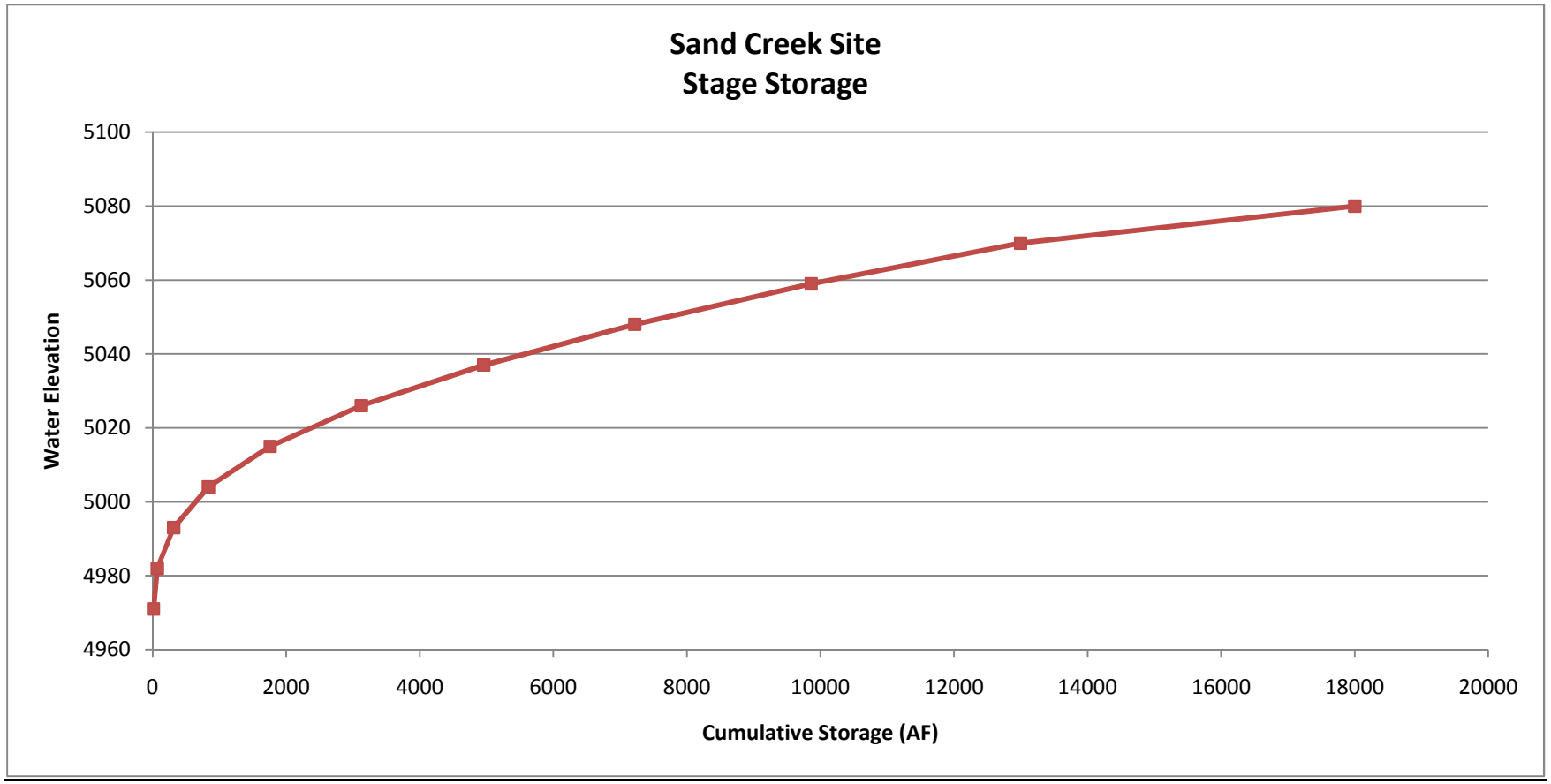
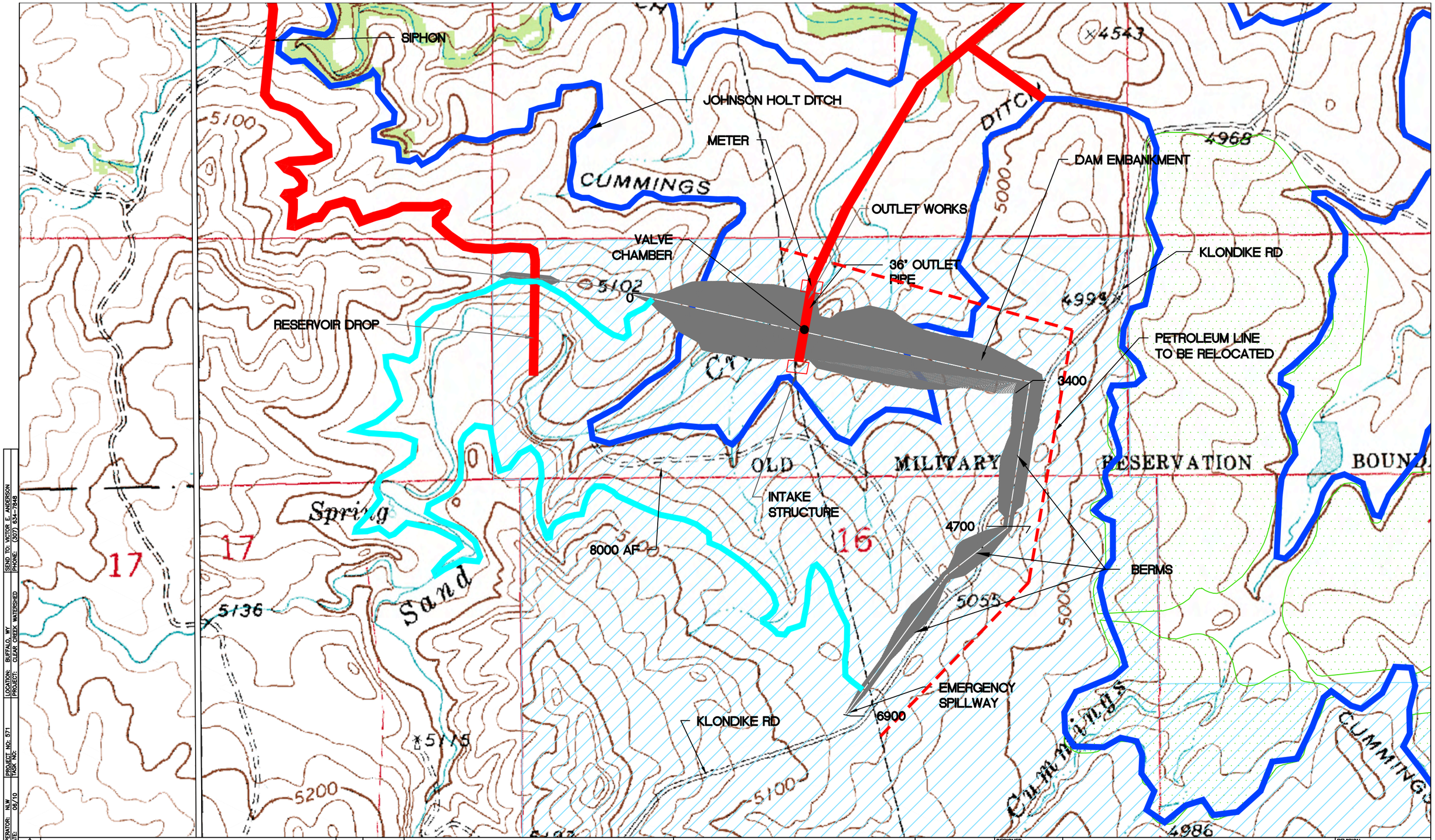


Figure 6.5-3 Sand Creek Reservoir Site Stage Storage Curve



FILE NAME: SANDCKSITE			
SCALE: 1"=750'			
OPERATOR: NLW			
DATE: 06/10			
PROJECT NO.: 571			
TASK NO.:			
LOCATION: BUFFALO, WY			
PROJECT: CLEAR CREEK WATERSHED			
SEND TO: VICTOR E. ANDERSON			
PHONE: (307) 634-7848			
REV	DESCRIPTION OF REVISION	BY	DATE
1	PRELIMINARY DESIGN	NLW	06/10

STATE LAND

IRRIGATED LANDS

SCALE 1" = 750'

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WARNING

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DESIGNED	NLW
DRAWN	NLW
CHECKED	VEA
PEER REVIEWED	VEA
PROJECT MANAGER	VEA
DATE	06/10

CLEAR CREEK WATERSHED STUDY

SAND CREEK RESERVOIR SYSTEM

REVISION 1

PROJECT 571

DRAWING FIGURE 6.5–4

6.5.3.3 Geologic/Geotechnical

The Sand Creek Reservoir site was inspected by the project geologist. The complete Geologic/Geotechnical report is included in Appendix 6-B. The specific observations and recommendations for the Sand Creek site are summarized below.

The general bedrock geology at the dam site consists of Wasatch Formation. The Wasatch Formation consists of sandstone, siltstone, shale, coal, and gypsum. Surficial soils at the site include alluvium, colluviums, and Kaycee Formation. The alluvium generally consists of gravel, sand, and silt and is reported to have a maximum thickness of about 20 feet. However, bedrock was identified in the stream bottom at about the centerline of the dam and is likely less than 10 feet deep in many locations. Colluvium and the Kaycee Formation generally consist of silt, sand, and gravel and are reported to be less than about 8 feet thick.

An appropriate dam type for the site geology would be a homogeneous earth fill dam. Geologic conditions that have the greatest potential impact to the design are:

- A suitable source for filter materials.
- A suitable source for slope protection materials.
- The ability to process bedrock materials into suitable fill materials.
- The stability of the bedrock that has a shallow downstream dip.
- If gypsum is present, there could be concerns with dissolutioning, which could affect seepage and seepage stability.

6.5.3.4 Environmental

The site is composed primarily of grassland with some small amounts of sagebrush cover. No wetlands were present on the NWI map, but two small wetlands totaling roughly 0.18 acres were observed along the channel within the inundation area. There are some mature cottonwoods within the riparian area that would be inundated, but most of these are decadent trees. Cottonwood gallery forest impacts would be relatively minor. No raptor nests were observed. No large issues with this site.

According to Wyoming Game and Fish Department data, this site is within pronghorn yearlong range, white-tailed deer yearlong range, and mule deer yearlong range.

The complete environmental report is included in Appendix 6-C.

6.5.3.5 Outlet Works

The outlet works would be constructed to discharge to a pipeline supplying the ditches and Clear Creek. A minimum capacity of 100 cfs at normal minimum pool would be required. A 36

inch outlet pipe would be constructed. The outlet works would include a reservoir intake structure, concrete encased steel outlet pipe, valve chamber and access tower, and flow meter.

6.5.3.6 Emergency Spillway

The Sand Creek Reservoir site has a drainage area of approximately 4 square miles. The reservoir would be designed to store flood flows up to the 100-year event. Very large flood flows up to the Probable Maximum Flood (PMF) would be passed through an unlined emergency spillway as shown on Figure 6.5-4. The reservoir could eliminate flooding on Sand Creek up to the 100-year flood and reduce peak flood flows of larger events.

6.5.3.7 Flood Control

The Sand Creek Reservoir would have minimal effects on Clear Creek flooding because of the limitation of the diversion capacity. The Sand Creek drainage has the potential for producing large flood peaks. The reservoir could greatly reduce flood threats to the lower portions of Sand Creek.

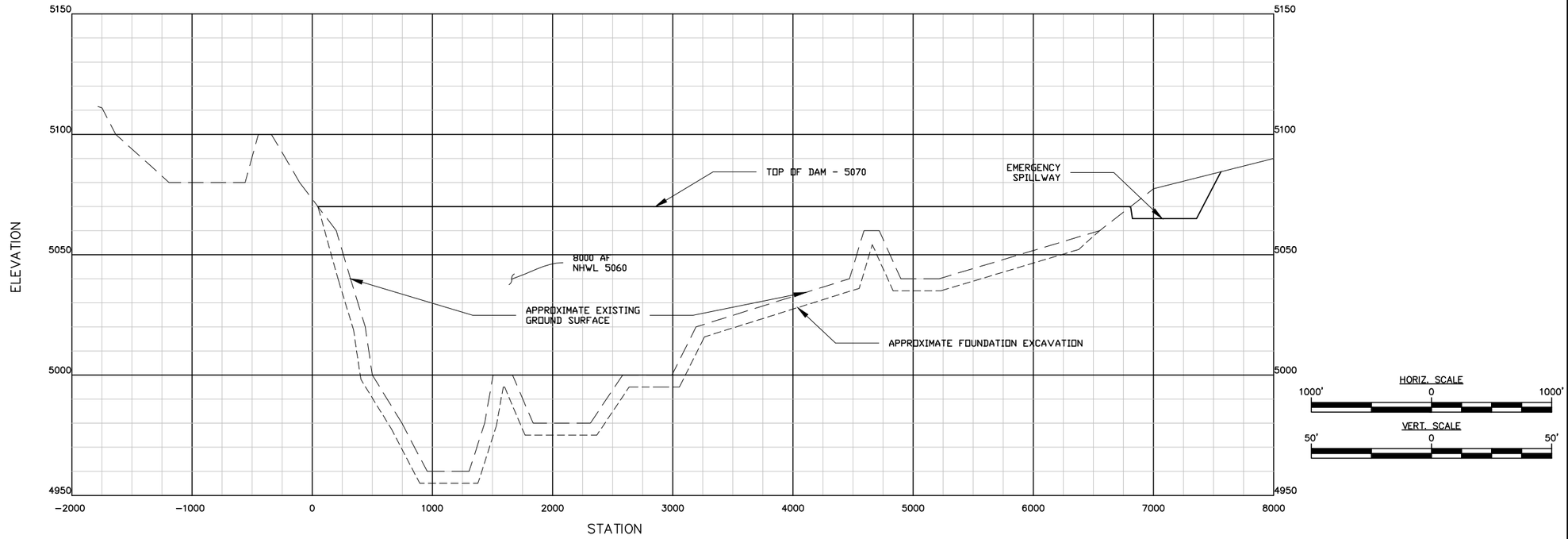
6.5.3.8 Discharge Pipeline

The pipeline from the reservoir outlet works as shown on Figure 6.5-2 would have a maximum capacity of 100 cfs. The pipeline would be decreased in size as releases are made to the ditches and Clear Creek. The pipeline sizes would range from 36 inch to 18 inch. The total pipeline length is approximately 14,000 feet (2.65 miles). The capacity would be adequate for release to the irrigation ditches and Clear Creek.

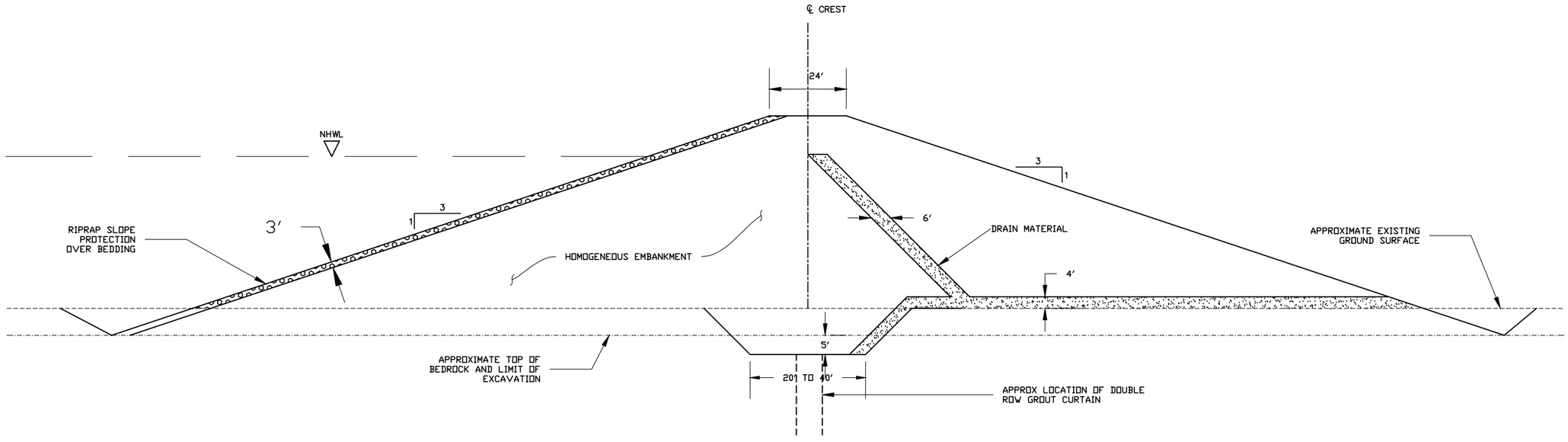
6.5.3.9 Preliminary Design and Cost Estimate

Preliminary designs and costs estimates were developed for the potential reservoir on Sand Creek. The cost estimates were developed for reservoir sizes of 4,000 acre-feet and 8,000 acre-feet. The project costs and unit costs for this size range are shown on Figure 6.5-6 and 6.5-7. The typical dam section and centerline profile are shown on Figure 6.5-5. The saddle dams on the east side of the reservoir would parallel Klondike Road.

Quantities for the dam and reservoir, supply canal, delivery pipeline, and associated items were developed. See Appendix 6-E for additional information on embankment conceptual design. The preliminary cost estimates are shown on Table 6.5-1 and 6.5-2. The estimated cost for an 8,000 acre-foot reservoir project would be $39 million. The approximate cost per acre-foot of storage is $4,875. The preliminary cost estimate for a 4,000 acre-foot reservoir would be $27 million. The approximate cost per acre-foot of this storage is $6,750.



DAM CENTERLINE PROFILE



TYPICAL HOMOGENEOUS DAM SECTION

FILE NAME: DAM SECTION | OPERATOR: NLW | LOCATION: BUFFALO, WY | PROJECT NO: 571 | SEND TO: VICTOR E. ANDERSON
SCALE: N/A | DATE: 06/10 | PROJECT: CLEAR CREEK WATERSHED | TASK NO: 001-263 | PHONE: (307) 634-7848

REV	DESCRIPTION OF REVISION	BY	DATE
1	PRELIMINARY DESIGN	NLW	06/10

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FAX: (307) 634-7851

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DESIGNED	DWW
DRAWN	NLW
CHECKED	VEA
PEER REVIEWED	VEA
PROJECT MANAGER	VEA
DATE	06/10

CLEAR CREEK WATERSHED STUDY

SAND CREEK RESERVOIR DETAILS

REVISION 1
PROJECT 571
DRAWING FIGURE 6.5-5

Table 6.5-1

Cost Estimate-Sand Creek Reservoir

Storage - 4,000 AF Top Dam Elevation - 5050

No.	Task	Unit	Estimated Quantity	Unit Price	Total Cost
1	Mobilization	L.S.	--	--	$1,000,000.00
2	Diversion Structure	L.S.	--	--	$250,000.00
3	Enlarged Canal	L.F.	13,000	45	$585,000.00
4	Lined Canal	L.F.	2,000	175	$350,000.00
5	Siphon	L.F.	1,000	300	$300,000.00
6	Outlet Structure	L.S.	--	--	$100,000.00
7	Dam Excavation	C.Y.	300,000	4	$1,200,000.00
8	Embankment	C.Y.	1,550,000	8	$12,400,000.00
9	Outlet Works	L.S.	--	--	$1,250,000.00
10	Emergency Spillway	L.S.	--	--	$250,000.00
11	30" Pipe	L.F.	6,000	90	$540,000.00
12	18" Pipe	L.F.	6,000	50	$300,000.00
13	Mitigation	L.S.	--	--	$100,000.00
14	Petro line relocate	L.S.	--	--	$250,000.00
				Construction Cost Sub-Total:	$18,875,000.00
				10% Engineering:	$1,887,500.00
				Sub-Total:	$20,762,500.00
				15% Contingency:	$3,114,375.00
				CONSTRUCTION COST TOTAL:	$23,876,875.00
				Preparation of Final Designs and Specifications:	$1,500,000.00
				Permitting and Mitigation:	$250,000.00
				Legal Fees:	$100,000.00
				Acquisition of Access and Rights of Way:	$1,250,000.00
				TOTAL PROJECT COSTS:	**$26,976,875.00**
				USE:	**$27 M**

Table 6.5-2

Cost Estimate-Sand Creek Reservoir

Storage - 8,000 AF Top Dam Elevation - 5070

No.	Task	Unit	Estimated Quantity	Unit Price	Total Cost
1	Mobilization	L.S.	--	--	$1,250,000.00
2	Diversion Structure	L.S.	--	--	$250,000.00
3	Enlarged Canal	L.F.	13,000	50	$650,000.00
4	Lined Canal	L.F.	2,000	200	$400,000.00
5	Siphon	L.F.	1,000	400	$400,000.00
6	Outlet Structure	L.S.	--	--	$100,000.00
7	Dam Excavation	C.Y.	400,000	4	$1,600,000.00
8	Embankment	C.Y.	2,500,000	8	$20,000,000.00
9	Outlet Works	L.S.	--	--	$1,500,000.00
10	Emergency Spillway	L.S.	--	--	$250,000.00
11	36" Pipe	L.F.	6,000	100	$600,000.00
12	24" Pipe	L.F.	6,000	60	$360,000.00
13	Mitigation	L.S.	--	--	$100,000.00
14	Petro line relocate	L.S.	--	--	$250,000.00
				Construction Cost Sub-Total:	$27,710,000.00
				10% Engineering:	$2,771,000.00
				Sub-Total:	$30,481,000.00
				15% Contingency:	$4,572,150.00
				CONSTRUCTION COST TOTAL:	$35,053,150.00
				Preparation of Final Designs and Specifications:	$2,000,000.00
				Permitting and Mitigation:	$250,000.00
				Legal Fees:	$100,000.00
				Acquisition of Access and Rights of Way:	$1,500,000.00
				TOTAL PROJECT COSTS:	**$38,903,150.00**
				USE:	**$39 M**

6.5.3.10 Multi-Purpose Potential

The Sand Creek Reservoir could be utilized for the purposes summarized below.

- Irrigation Supplementary Flows – The reservoir could supplement direct flow rights to meet irrigation shortages.
- Exchange Potential – There would be opportunity to benefit irrigation ditches not directly tributary by water exchange.
- Reduce Seepage Losses – Incorporation of multiple ditches into the supply canal and addressing high seepage areas would reduce losses. Delivery of water to the ditches with a pipeline would also reduce losses.
- Clear Creek Flow Improvement – The storage would facilitate increased flows above and through the City of Buffalo. The potential high quality fishery would be available for recreation purposes.
- Reservoir Recreation – Incorporation of a recreation pool would create opportunities for flat water recreation. The proximity to the City of Buffalo and year-round access would make the reservoir a valuable opportunity.
- Municipal Water Supply – The reservoir could be used directly or indirectly for additional storage for the City of Buffalo.
- Flood Control – The reservoir could provide flood control for Sand Creek.

6.5.3.11 Summary

A multi-purpose reservoir could be constructed on the Sand Creek site. The site appears to be geologically suitable for a reservoir. The site has few environmental issues. The dam and reservoir would be located primarily on State of Wyoming land with some private land inundated. The site is well situated to meet needs of the irrigation ditches.

The primary concern is the cost of the project. Preliminary costs for an 8,000 acre-foot reservoir with supply canal and delivery pipeline is approximately $39 million. The unit cost per acre-foot of storage is $4,875. The project costs and unit costs for the reservoir size range analyzed are shown on Figure 6.5-6 and 6.5-7. The unit costs indicate that the Sand Creek site is more economical at larger sizes. The smaller sizes would not meet all of the purposes of the reservoir that were previously identified.

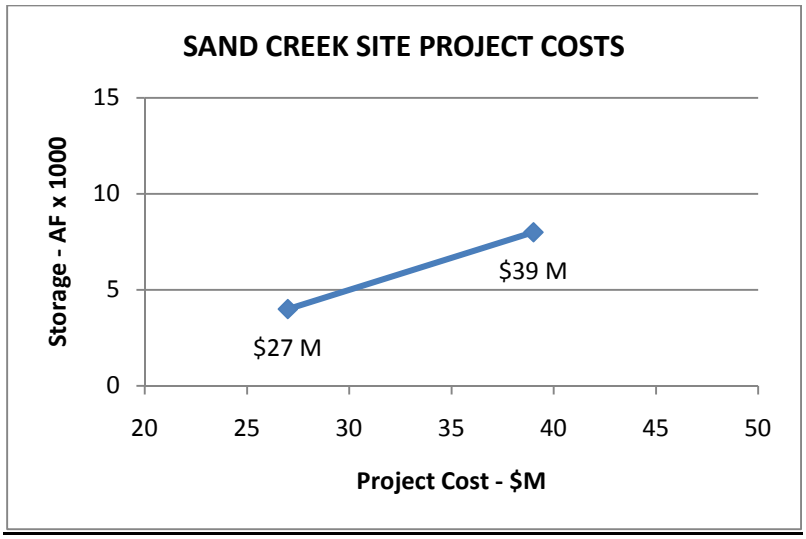


Figure 6.5-6 Sand Creek Reservoir Project Costs

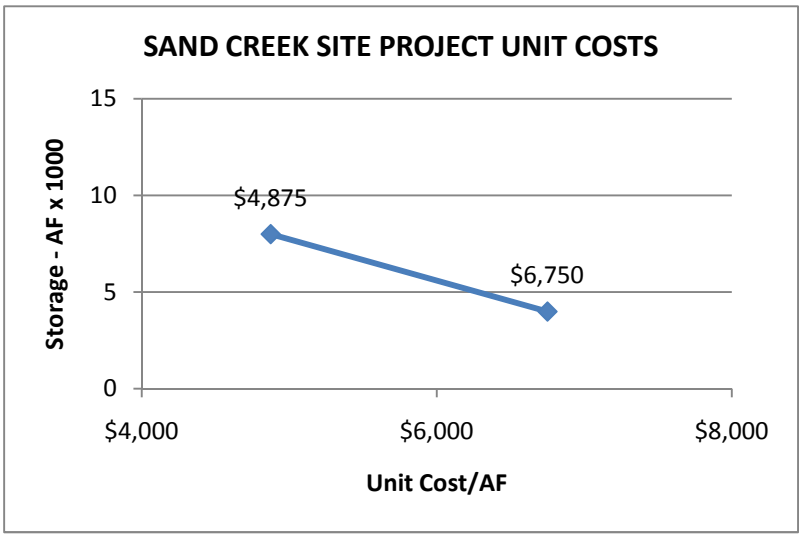


Figure 6.5-7 Sand Creek Reservoir Unit Costs

6.5.4 Bench Reservoir Site

This potential site would be located between the Johnson Holt and Six Mile ditches near I-25 approximately 4 miles south west of the City of Buffalo as shown on Figure 6.5-8. The site could impound a maximum of 3,500 acre-feet as indicated on the stage-storage curve, Figure 6.5-9. The reservoir would be filled by enlargement and extension of the Johnson Holt Ditch. The reservoir could supply the Six Mile, Crown, and Clear Creek Ditches by a pipeline. The Johnson Holt ditch, which has the most junior rights of the four ditches, could benefit by exchange. The reservoir could be utilized for late season releases which could allow the flows presently diverted to flow through the City of Buffalo.

The dam and reservoir would be located on private land. State Road 96 passes immediately east of the proposed reservoir.

6.5.4.1 Supply Canal

The canal capacity required to supply the potential 3,500 acre-feet reservoir would be approximately 75 cfs. The direct flow rights of the ditches could be conveyed in the canal and routed through the proposed reservoir. The total capacity of the canal would be approximately 175 cfs. The canal would follow the alignment of the Johnson Holt Ditch for approximately 7.6 miles as shown on Figure 6.5-8. The canal would be extended an additional 1 mile to the reservoir. Portions of the canal would be lined or conveyed in a pipe to reduce seepage losses.

6.5.4.2 Dam and Reservoir

The dam required to impound 3,500 acre-feet of storage would be a maximum of 50 feet high with a crest length of 7,000 feet. The reservoir would inundate approximately 160 acres at full capacity. Evaporation from this reservoir could be approximately 300 acre-feet per year. The characteristics of the site are summarized below.

6.5.4.3 Geologic/Geotechnical

The Bench Reservoir site was inspected by the project geologist. The complete Geologic/Geotechnical report in included in Appendix 6-B. The specific observations and recommendations for the Sand Creek site are summarized below.

The general bedrock geology at the dam site consists of Wasatch Formation. The Wasatch Formation consists of sandstone, siltstone, shale, coal, and gypsum. Surficial soils at the site include colluviums and Kaycee Formation. These soils generally consist of silt, sand, and gravel and are reported to be less than about 8 feet thick. Bedrock was identified in a small drainage at the west side of the reservoir.

DISCHARGE TO CLEAR CREEK

END PIPELINE

CLEAR CREEK DITCH

CROWN DITCH

NEW OUTLET PIPE

ENLARGED JOHNSON-HOLT DITCH

EMERGENCY SPILLWAY

RESERVOIR INLET

SITE 116
BENCH SITE
NHWL 4945'
TOP OF DAM 4955'
3500 AF

EXISTING SIX MILE DITCH

LEGEND

- STATE LAND
- BLM LAND
- IRRIGATED LANDS

SCALE 1" = 2000'

N

STATES WEST WATER RESOURCES CORPORATION

1904 E. 15th STREET
CHEYENNE, WYOMING 82001
(307) 634-7848
FAX: (307) 634-7851

CLEAR CREEK WATERSHED STUDY

BENCH RESERVOIR SYSTEM

REVISION 1

PROJECT 571

DRAWING FIGURE 6.5-8

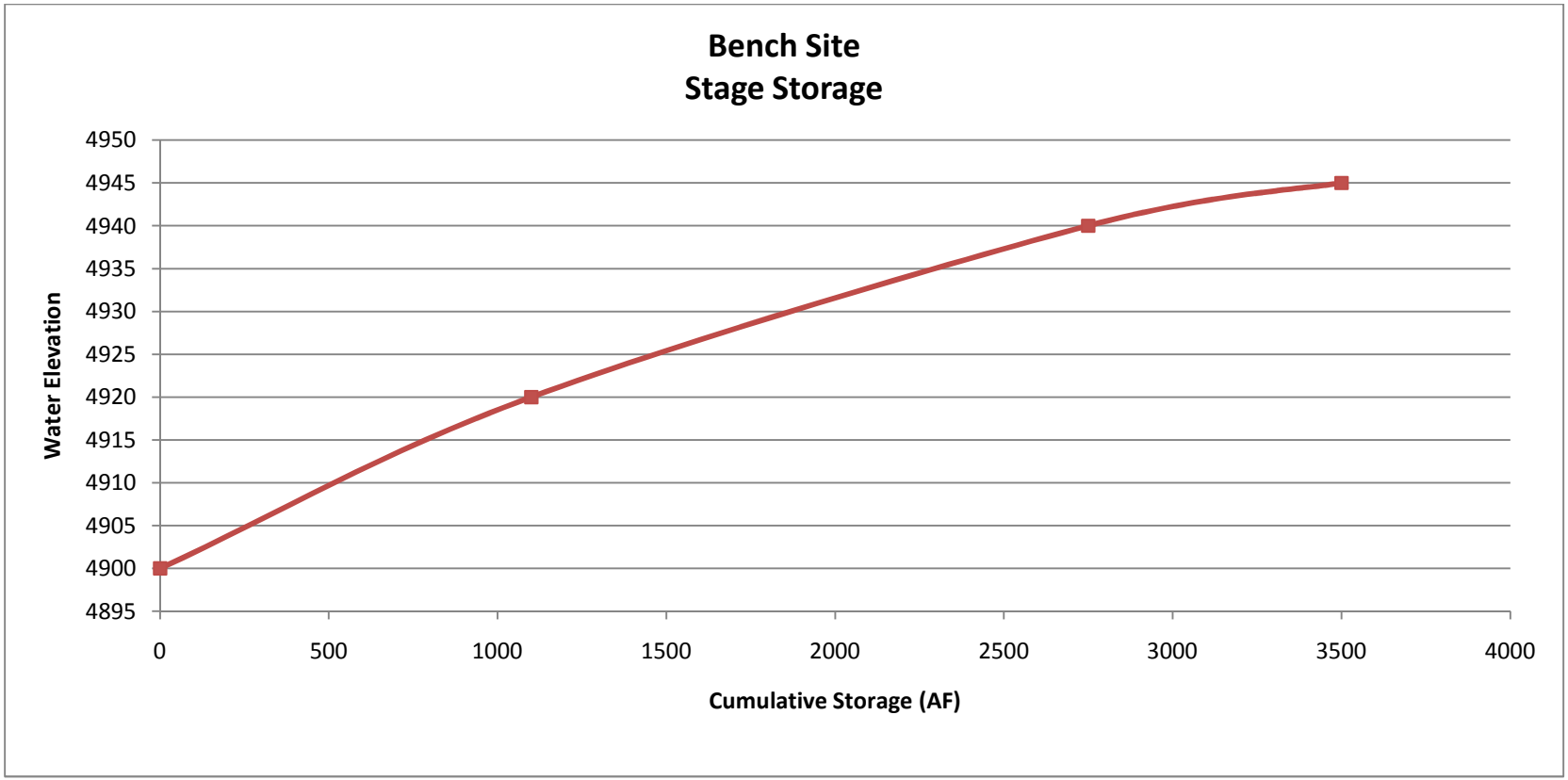


Figure 6.5-9 Bench Reservoir Stage Storage Curve

An appropriate dam type for the site geology would be a homogeneous earth fill dam. Geologic conditions that have the greatest potential impact to the design are:

- A suitable source for filter materials.
- A suitable source for slope protection materials.
- The ability to process bedrock materials into suitable fill materials.
- If gypsum is present, there could be concerns with dissolutioning, which could affect seepage and seepage stability.

6.5.4.4 Environmental

The site is composed primarily of grassland with some sparse sagebrush. It also would encompass some irrigated hay fields. There is one wetland present that appears to result from irrigation runoff. There are no large issues with this site.

According to Wyoming Game and Fish Department data, this site is within pronghorn yearlong range and mule deer yearlong range.

The complete environmental report in included in Appendix 6-C.

6.5.4.5 Outlet Works

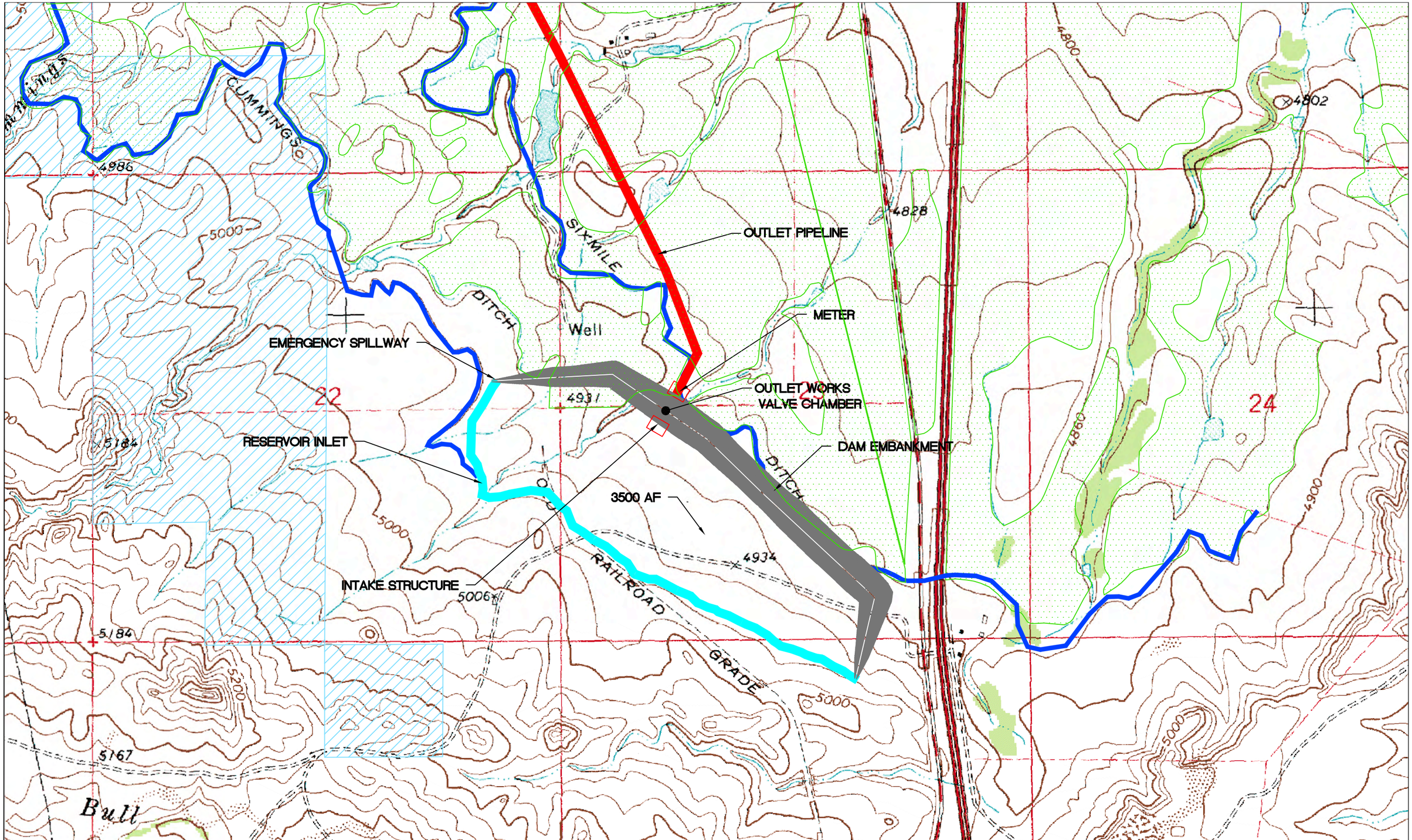
The outlet works would be constructed to discharge to a pipeline supplying the ditches. A minimum capacity of 75 cfs at normal minimum pool would be required. A 30 inch discharge pipe would be constructed. The outlet works would include a reservoir intake structure, concrete encased steel outlet pipe, valve chamber and access tower, and flow meter as shown on Figure 6.5-10.

6.5.4.6 Emergency Spillway

The Bench Reservoir site has a small drainage area of approximately 0.75 square miles. The reservoir would be designed to store flood flows up to the 100-year event. Large flood flows up to the Probable Maximum Flood (PMF) would be passed through an unlined emergency spillway as shown on Figure 6.5-11.

6.5.4.7 Discharge Pipeline

The pipeline from the reservoir outlet works would have a maximum capacity of 75 cfs. The pipeline would be decreased in size as releases are made to the ditches. The pipeline sizes would range from 30 inch to 18 inch. The pipeline length is approximately 20,750 feet (3.9 miles). This capacity would be adequate for releases to the irrigation ditches and Clear Creek.



REV	DESCRIPTION OF REVISION	BY	DATE
1	PRELIMINARY DESIGN	NLW	06/10

STATE LAND

IRRIGATED LANDS

SCALE 1" = 1000'

STATES WEST WATER RESOURCES CORPORATION

1904 E. 15th STREET
CHEYENNE, WYOMING 82001
(307) 634-7848
FAX: (307) 634-7851

WARNING

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CHECKED	VEA
PEER REVIEWED	VEA
PROJECT MANAGER	VEA
DATE	06/10

CLEAR CREEK WATERSHED STUDY

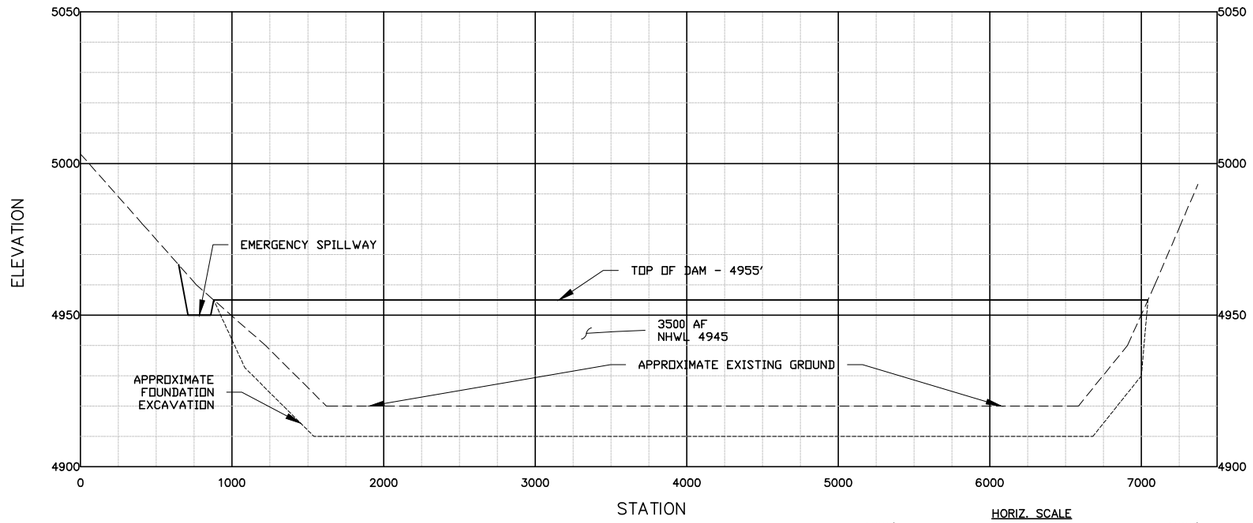
BENCH RESERVOIR SYSTEM

REVISION 1

PROJECT 571

DRAWING FIGURE 6.5-10

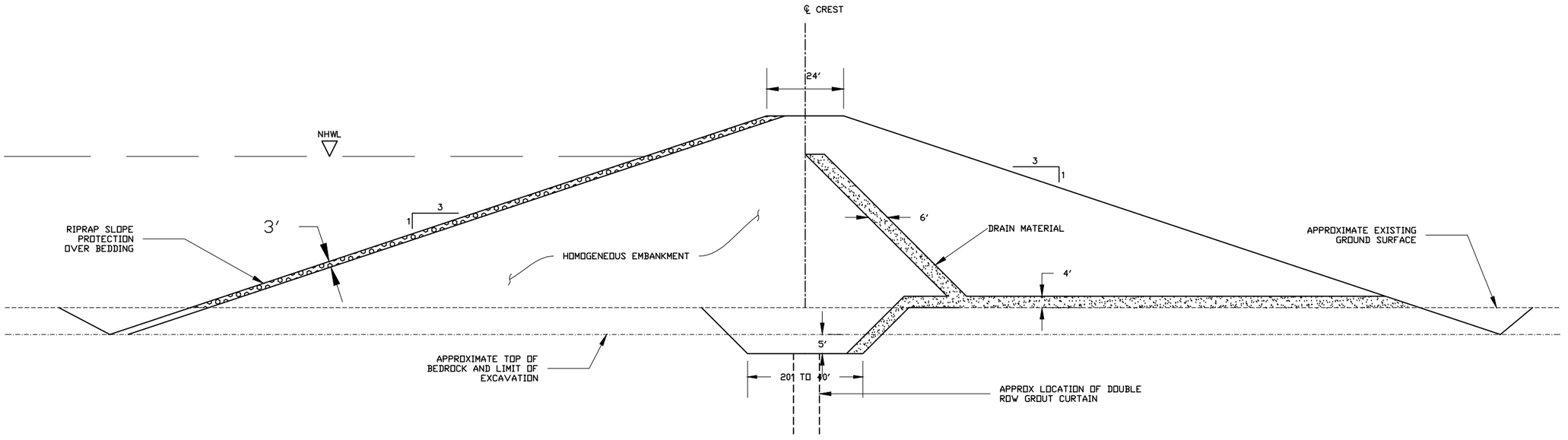
FILE NAME: SANDCKSITE
SCALE: 1"=1000'
OPERATOR: NLW
DATE: 06/10
PROJECT NO: 571
TASK NO:
LOCATION: BUFFALO, WY
PROJECT: CLEAR CREEK WATERSHED
SEND TO: VICTOR E. ANDERSON
PHONE: (307) 634-7848



DAM CENTERLINE PROFILE

HORIZ. SCALE
1000' 0 1000'

VERT. SCALE
50' 0 50'



TYPICAL HOMOGENEOUS DAM SECTION

FILE NAME: DAM SECTION | OPERATOR: NLW | PROJECT NO: 571 | LOCATION: BUFFALO, WY | SEND TO: VICTOR E. ANDERSON
SCALE: N/A | DATE: 06/10 | TASK NO: 001-263 | PROJECT: CLEAR CREEK WATERSHED | PHONE: (307) 634-7848

REV	DESCRIPTION OF REVISION	BY	DATE
1	PRELIMINARY DESIGN	NLW	06/10

STATES WEST WATER
RESOURCES CORPORATION

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DESIGNED	DWW
DRAWN	NLW
CHECKED	VEA
PEER REVIEWED	VEA
PROJECT MANAGER	VEA
DATE	06/10

CLEAR CREEK WATERSHED STUDY

BENCH RESERVOIR DETAILS

REVISION 1
PROJECT 571
DRAWING FIGURE 6.5-11

6.5.4.8 Preliminary Design and Cost Estimate

The potential 3,500 acre-feet reservoir on the Bench was preliminary designed and cost estimates developed. The typical dam section and centerline profile are shown on Figure 6.5-11.

Quantities for the dam and reservoir, supply canal, delivery pipeline, and associated items were developed. The preliminary cost estimate is shown on Table 6.5-3. The estimated cost of the reservoir project would be $33 million. The approximate cost per acre-foot of storage is $9,429.

Table 6.5-3
Cost Estimate-Bench Reservoir
Storage - 3,500 AF Top Dam Elevation - 4955

No.	Task	Unit	Estimated Quantity	Unit Price	Total Cost
1	Mobilization	L.S.	--	--	$1,250,000.00
2	Diversion Structure	L.S.	--	--	$200,000.00
3	Enlarged Canal	L.F.	42,400	50	$2,120,000.00
4	Lined Canal	L.F.	2,000	200	$400,000.00
5	Pipe	L.F.	1,000	400	$400,000.00
6	Outlet Structure	L.S.	--	--	$100,000.00
7	Dam Excavation	C.Y.	300,000	3	$900,000.00
8	Embankment	C.Y.	2,800,000	6	$16,800,000.00
9	Outlet Works	L.S.	--	--	$750,000.00
10	30" Pipe	L.F.	12,000	80	$960,000.00
11	24" Pipe	L.F.	6,500	60	$390,000.00
12	18" Pipe	L.F.	2,250	40	$90,000.00
				Construction Cost Sub-Total:	$24,360,000.00
				10% Engineering:	$2,436,000.00
				Sub-Total:	$26,796,000.00
				15% Contingency:	$4,019,400.00
				CONSTRUCTION COST TOTAL:	$30,815,400.00
				Preparation of Final Designs and Specifications:	$1,750,000.00
				Permitting:	$100,000.00
				Legal Fees:	$50,000.00
				Acquisition of Access and Rights of Way:	$500,000.00
				TOTAL PROJECT COSTS:	**$33,215,400.00**
				USE:	**$33 M**

6.5.4.9 Multi-Purpose Potential

The Bench Reservoir could be utilized for the purposes summarized below.

- Irrigation Supplementary Flows – The reservoir could supplement direct flow rights to meet the average annual irrigation shortages.
- Reduce Seepage Losses – Incorporation of multiple ditches into the supply canal and addressing high seepage areas would reduce losses. Delivery of water to the ditches with a pipeline would also reduce losses.
- Clear Creek Flow Improvement – The storage could have limited capability to increase flows above and through the City of Buffalo. There is inadequate storage available to meet the irrigation shortages as well as allow water to remain in Clear Creek by exchange.

6.5.4.10 Summary

A single purpose reservoir could be constructed on the Bench site. The site appears to be geologically suitable for a reservoir. The site has few environmental issues. The dam and reservoir would be located on private land. The site is well situated to meet needs of the irrigation ditches.

The primary concern is the cost of the project and the limited multi-purpose potential. Preliminary costs for a 3,500 acre-foot reservoir with supply canal and delivery pipeline is approximately $33 million. The unit cost per acre-foot of storage is $9,429.

6.5.5 Bull Creek Reservoir Site

This potential site would be located on Bull Creek approximately 5 miles south of the City of Buffalo as shown on Figure 6.5-12. The site could impound a maximum of approximately 9,170 acre-feet as indicated on the capacity-elevation curve, Figure 6.5-13. The reservoir would be filled by construction of a new supply canal system from Clear Creek. The reservoir could supply the Johnson Holt, Six Mile, Crown, Clear Creek Ditches and Clear Creek by a pipeline. The reservoir could be utilized for late season releases which could allow fishery flows presently diverted to flow through the City of Buffalo by an exchange.

The dam and reservoir would be located on State of Wyoming lands and private lands. Klondike Road passes immediately west of the proposed reservoir. The supply canal would be located on State of Wyoming and private lands. The delivery pipeline would be located on State of Wyoming and private lands.

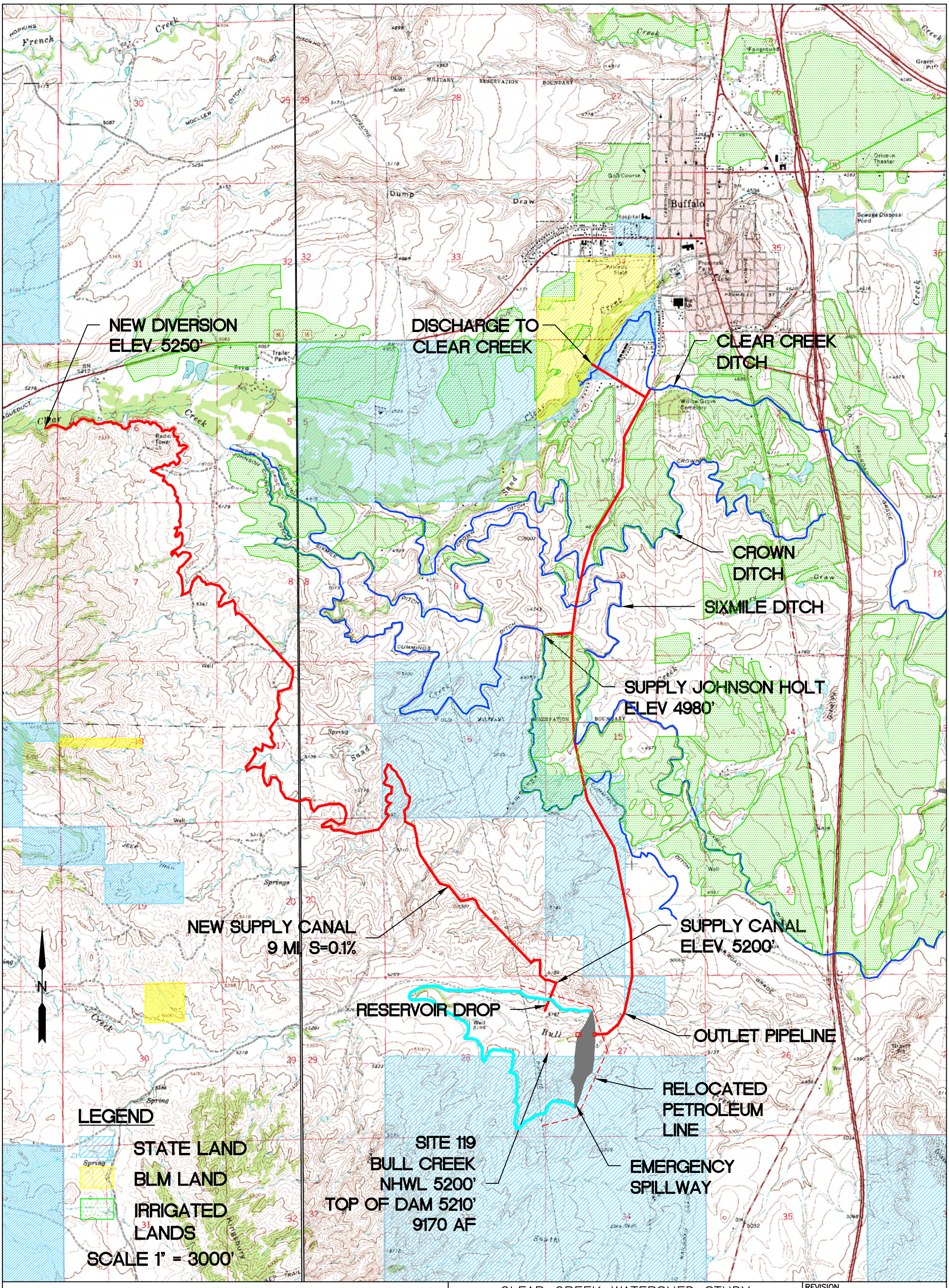
6.5.5.1 Supply Canal

The canal capacity required to supply a potential reservoir of 9,170 acre-feet would be approximately 150 cfs. The direct flow rights of the ditches would be conveyed in the canal and routed through the proposed reservoir. The total capacity of the canal would be approximately 250 cfs. The size of supply systems would be reduced for smaller reservoir capacities.

The canal would have to be located at a higher elevation than the other ditches to convey water to the reservoir site. The diversion from Clear Creek would be located at the approximate location shown on Figure 6.5-12. At this location, Clear Creek is close to steep terrain on the south side of the valley. The canal may have to be piped for the upper approximately 4,000 feet. The total length of the supply system from the diversion to the potential reservoir site is approximately 48,000 feet (9.1 miles). Most of this length would be carried in a canal. Portions of the canal route are expected to have high seepage losses. These portions of the system would be lined canal or pipe. At the reservoir, a drop structure would be constructed to discharge to the reservoir.

6.5.5.2 Dam and Reservoir

A dam required to impound 9,170 acre-feet of storage would be a maximum of 120 feet high with a crest length of 3,250 feet as shown on Figure 6.5-14. The reservoir would inundate approximately 248 acres at full capacity. A range of reservoir sizes were analyzed. In addition to the 9,170 acre-feet capacity, capacities of 4,000 acre-feet and 2,000 acre-feet were analyzed. The project shown on the Figures are the 9,170 acre-feet capacity reservoir. The characteristics of the site are summarized below.



STATES WEST WATER RESOURCES CORPORATION 1904 E. 15th STREET CHEYENNE, WYOMING 82001 (307) 634-7848 FAX: (307) 634-7851	CLEAR CREEK WATERSHED STUDY BULL CREEK RESERVOIR SYSTEM	REVISION 1 PROJECT 571 DRAWING FIGURE 6.5-12

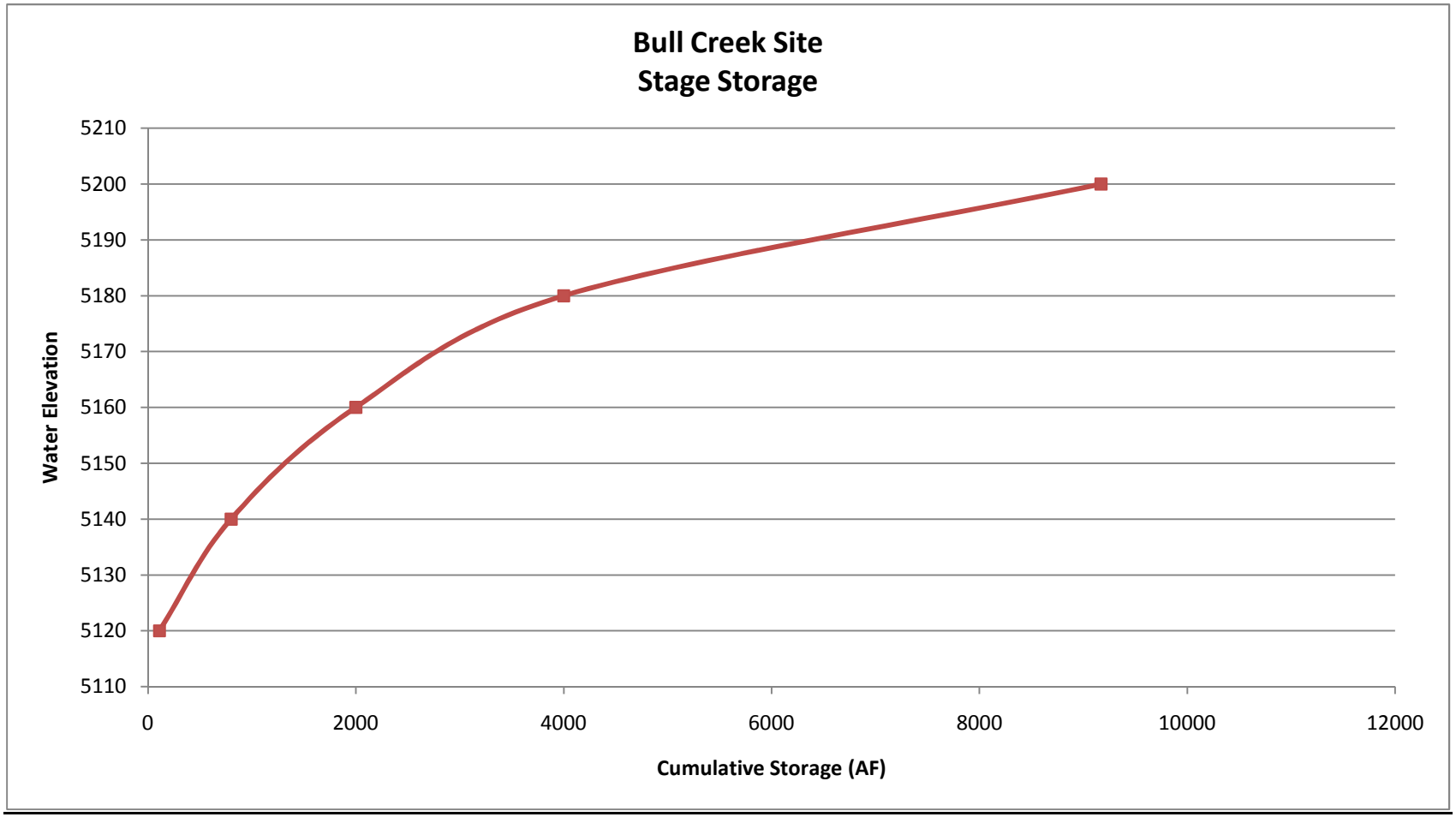
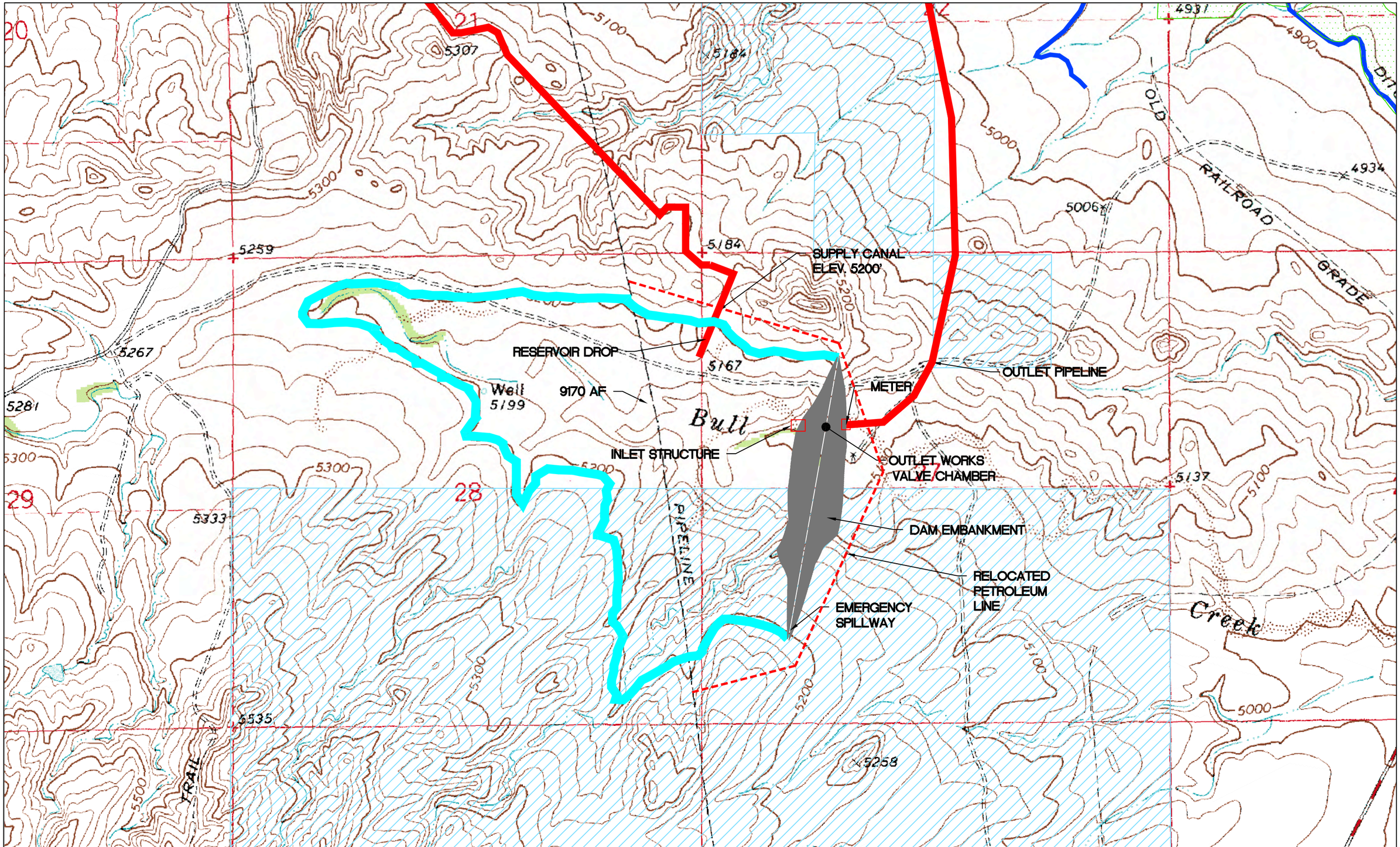


Figure 6.5-13 Bull Creek Reservoir Stage Storage Curve



REV	DESCRIPTION OF REVISION	BY	DATE
1	PRELIMINARY DESIGN	NLW	06/10

STATE LAND

SCALE 1" = 1000'

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PEER REVIEWED	VEA
PROJECT MANAGER	VEA
DATE	06/10

CLEAR CREEK WATERSHED STUDY

BULL CREEK RESERVOIR SYSTEM

REVISION 1

PROJECT 571

DRAWING FIGURE 6.5-14

FILE NAME: SANDCKSITE
SCALE: 1"=1000'
OPERATOR: NLW
DATE: 06/10
PROJECT NO: 571
TASK NO:
LOCATION: BUFFALO, WY
PROJECT: CLEAR CREEK WATERSHED
SEND TO: VICTOR E. ANDERSON
PHONE: (307) 634-7848

6.5.5.3 Geologic/Geotechnical

The Bull Creek Reservoir site was inspected by the project geologist. The complete Geologic/Geotechnical report in included in Appendix 6-B. The specific observations and recommendations for the Bull Creek site are summarized below.

The general bedrock geology at the dam site consists of Wasatch Formation. The Wasatch Formation consists of sandstone, siltstone, shale, coal, and gypsum. Surficial soils at the site include alluvium in the valley bottom and terrace deposits, and colluviums and the Kaycee Formation on the abutments. The alluvium generally consists of gravel, sand, and silt and is reported to have a maximum thickness of about 20 feet. The terrace deposits include gravel, sand, and silt with boulders up to 3 feet in size Colluvium and the Kaycee Formation generally consist of silt, sand, and gravel and are reported to be less than about 8 feet thick. The current dam alignment is located on potentially thick surficial materials that would need to be removed.

An appropriate dam type for the site geology would be a homogeneous or zoned earth fill dam. Geologic conditions that have the greatest potential impact to the design are:

- The ability to process bedrock materials into suitable fill materials.
- Shallow dipping bedrock in generally a downstream direction.
- Ability to process valley bottom alluvium for riprap bedding and filter materials.
- Depth of a suitable foundation in the valley bottom.
- If gypsum is present, there could be concerns with dissolutioning, which could affect seepage and seepage stability.

6.5.5.4 Environmental

The site is composed primarily of grassland with some small amounts of sagebrush cover. No wetlands were observed and none are on the NWI map. There are some mature cottonwoods within the riparian area that would be inundated, but most of these are decadent trees. Cottonwood gallery forest impacts would be relatively minor. One raptor nest was observed near the dam site and another was observed towards the upper end of the inundation area. No large issues with this site.

According to Wyoming Game and Fish Department data, this site is within pronghorn yearlong range and mule deer winter/yearlong range.

The complete environmental report is included in Appendix 6-C.

6.5.5.5 Outlet Works

The outlet works would be constructed to discharge to the pipeline supplying the ditches and Clear Creek. A minimum capacity of 100 cfs at normal minimum pool would be required. A 36 inch outlet pipe would be constructed. The outlet works would incorporate a multi-level intake structure to allow withdrawal of the best quality water. A flow control valve would be located in an access shaft located at the dam crest. A flow meter would be installed to measure releases.

6.5.5.6 Emergency Spillway

The Bull Creek Reservoir site has a drainage area of approximately 15 square miles. The reservoir would be designed to store flood flows up to the 100-year event. Very large flood flows up to the Probable Maximum Flood (PMF) would be passed through an unlined emergency spillway. Flood flows would cross I-25, flow down Bull Creek, and join Clear Creek west of I-80. The reservoir could eliminate flooding on Bull Creek up to the 100-year flood and reduce peak flood flows on larger events.

6.5.5.7 Flood Control

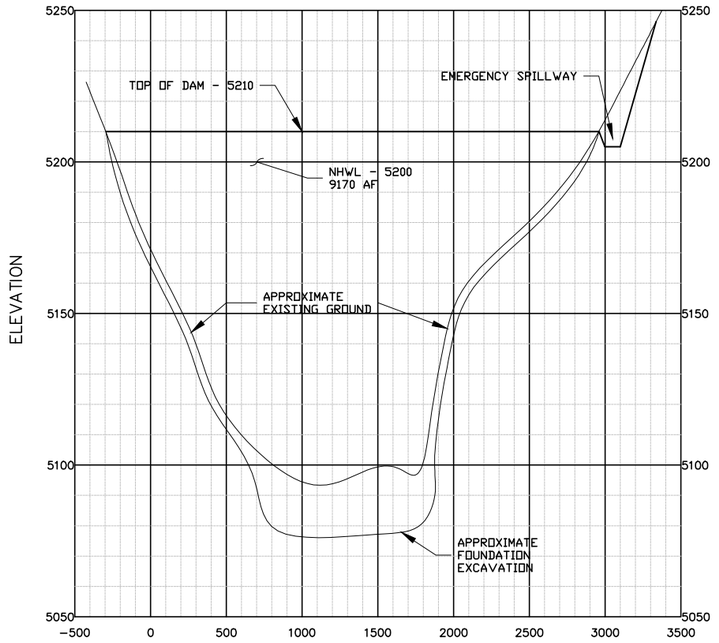
The Bull Creek Reservoir would have minimal effects on Clear Creek flooding because of the limitation of the diversion capacity. The Bull Creek drainage has the potential for producing large flood peaks. The reservoir could greatly reduce flood threats to the lower portions of Buffalo along Highway 16 between I-25 and I-90.

6.5.5.8 Discharge Pipeline

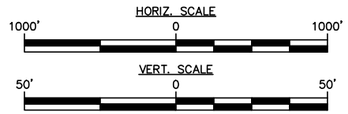
The pipeline from the reservoir outlet works would have a maximum capacity of approximately 100 cfs. This capacity would be adequate for releases to the irrigation ditches and Clear Creek. The pipeline would be decreased in size as releases are made to the ditches. The pipeline sizes would range from 36 inch to 18 inch. The water could be supplied with adequate pressure to operate sprinklers for most of the irrigated lands. The total pipeline length is approximately 26,000 feet (4.92 miles).

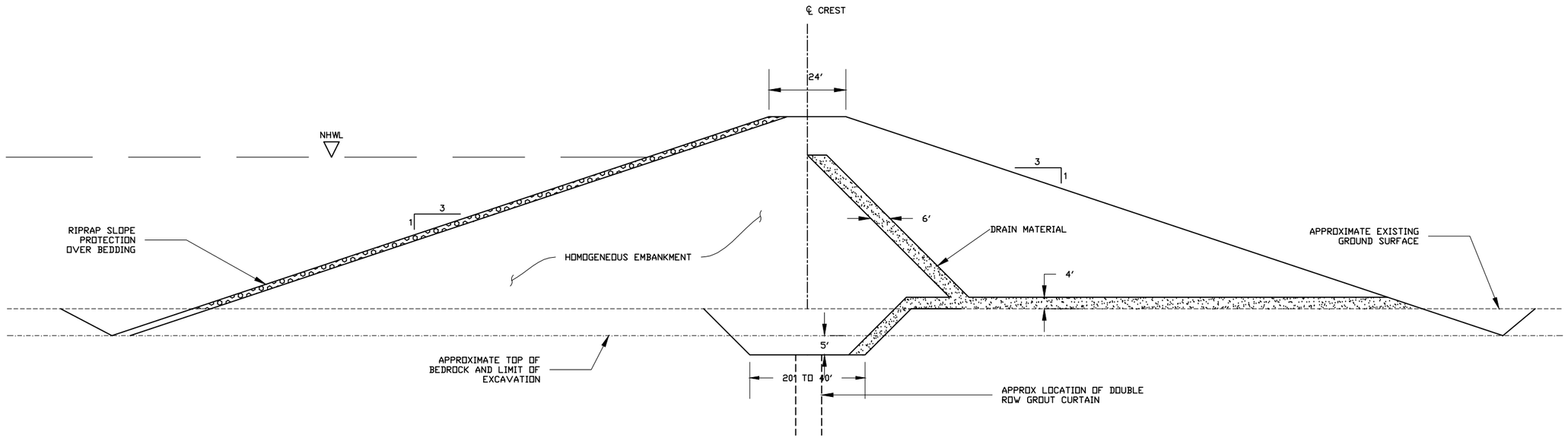
6.5.5.9 Preliminary Design and Cost Estimate

The potential reservoir on Bull Creek was preliminarily designed and cost estimates developed. The cost estimates were developed for a range of project storage size of 2,000 acre-feet, 4,000 acre-feet, and 9,170 acre-feet. The typical dam section and centerline profile are shown on Figure 6.5-15.



DAM CENTERLINE PROFILE





TYPICAL HOMOGENEOUS DAM SECTION

FILE NAME: DAM SECTION | OPERATOR: NLW | LOCATION: BUFFALO, WY | PROJECT NO: 571 | SEND TO: VICTOR E. ANDERSON
SCALE: N/A | DATE: 06/10 | PROJECT: CLEAR CREEK WATERSHED | TASK NO: 001-283 | PHONE: (307) 634-7848

REV	DESCRIPTION OF REVISION	BY	DATE
1	PRELIMINARY DESIGN	NLW	06/10

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DRAWN	NLW
CHECKED	VEA
PEER REVIEWED	VEA
PROJECT MANAGER	VEA
DATE	06/10

CLEAR CREEK WATERSHED STUDY

BULL CREEK RESERVOIR DETAILS

REVISION 1
PROJECT 571
DRAWING
FIGURE 6.5-15

Quantities for the dam and reservoir, supply canal, delivery pipeline, and associated items were developed. See Appendix 6-E for additional information on embankment conceptual design. The preliminary cost estimates are shown on Tables 6.5-4, 6.5-5 and 6.5-6. The estimated cost for a 9,170 acre-foot reservoir project would be $41 million. The approximate cost per acre-foot of storage is $4,471. The preliminary cost estimate for a 4,000 acre-foot reservoir would be $32 million. The approximate cost per acre-foot of this storage is $8,000. The preliminary cost estimate for a 2,000 acre-foot reservoir would be $23 million. The approximate cost per acre-foot of this storage is $11,500. The project costs and unit costs for the size ranges analyzed are shown on Figure 6.5-16 and 6.5-17.

Table 6.5-4

Cost Estimate-Bull Creek Reservoir

Storage - 2,000 AF Top Dam Elevation - 5170

No.	Task	Unit	Estimated Quantity	Unit Price	Total Cost
1	Mobilization	L.S.	--	--	$750,000.00
2	Diversion Structure	L.S.	--	--	$250,000.00
3	Canal	L.F.	40,000	50	$2,000,000.00
4	Lined Canal	L.F.	2,000	100	$200,000.00
5	Pipe	L.F.	6,000	200	$1,200,000.00
6	Outlet Structure	L.S.	--	--	$100,000.00
7	Dam Excavation	C.Y.	150,000	4	$600,000.00
8	Embankment	C.Y.	700,000	8	$5,600,000.00
9	Outlet Works	L.S.	--	--	$1,250,000.00
10	Emergency Spillway	L.S.	--	--	$500,000.00
11	30" Pipe	L.F.	14,000	90	$1,260,000.00
12	18" Pipe	L.F.	12,000	50	$600,000.00
13	36" Bore	L.F.	2000	750	$1,500,000.00
14	Mitigation	L.S.	--	--	$100,000.00
15	Petro line relocated	L.S.	--	--	$250,000.00
				Construction Cost Sub-Total:	$16,160,000.00
				10% Engineering:	$1,616,000.00
				Sub-Total:	$17,776,000.00
				15% Contingency:	$2,666,400.00
				CONSTRUCTION COST TOTAL:	$20,442,400.00
				Preparation of Final Designs and Specifications:	$1,500,000.00
				Permitting and Mitigation:	$250,000.00
				Legal Fees:	$100,000.00
				Acquisition of Access and Rights of Way:	$1,250,000.00
				TOTAL PROJECT COSTS:	**$23,442,400.00**
				USE:	**$23 M**

Table 6.5-5

Cost Estimate-Bull Creek Reservoir

Storage - 4,000 AF Top Dam Elevation - 5190

No.	Task	Unit	Estimated Quantity	Unit Price	Total Cost
1	Mobilization	L.S.	--	--	$750,000.00
2	Diversion Structure	L.S.	--	--	$250,000.00
3	Canal	L.F.	40,000	60	$2,400,000.00
4	Lined Canal	L.F.	2,000	150	$300,000.00
5	Pipe	L.F.	6,000	300	$1,800,000.00
6	Outlet Structure	L.S.	--	--	$100,000.00
7	Dam Excavation	C.Y.	150,000	4	$600,000.00
8	Embankment	C.Y.	1,350,000	8	$10,800,000.00
9	Outlet Works	L.S.	--	--	$1,500,000.00
10	Emergency Spillway	L.S.	--	--	$500,000.00
11	36" Pipe	L.F.	14,000	100	$1,400,000.00
12	24" Pipe	L.F.	10,000	60	$600,000.00
13	18" Pipe	L.F.	2,100	40	$84,000.00
14	36" Bore	L.F.	1000	750	$750,000.00
15	Mitigation	L.S.	--	--	$100,000.00
16	Petro line relocate	L.S.	--	--	$250,000.00
				Construction Cost Sub-Total:	$22,184,000.00
				10% Engineering:	$2,218,400.00
				Sub-Total:	$24,402,400.00
				15% Contingency:	$3,660,360.00
				CONSTRUCTION COST TOTAL:	$28,062,760.00
				Preparation of Final Designs and Specifications:	$1,750,000.00
				Permitting and Mitigation:	$250,000.00
				Legal Fees:	$100,000.00
				Acquisition of Access and Rights of Way:	$1,500,000.00
				TOTAL PROJECT COSTS:	**$31,662,760.00**
				USE:	**$32 M**

Table 6.5-6
Cost Estimate-Bull Creek Reservoir
Storage - 9,170 AF Top Dam Elevation - 5210

No.	Task	Unit	Estimated Quantity	Unit Price	Total Cost
1	Mobilization	L.S.	--	--	$1,250,000.00
2	Diversion Structure	L.S.	--	--	$250,000.00
3	Canal	L.F.	40,000	75	$3,000,000.00
4	Lined Canal	L.F.	2,000	200	$400,000.00
5	Pipe	L.F.	6,000	400	$2,400,000.00
6	Outlet Structure	L.S.	--	--	$100,000.00
7	Dam Excavation	C.Y.	200,000	4	$800,000.00
8	Embankment	C.Y.	1,900,000	8	$15,200,000.00
9	Outlet Works	L.S.	--	--	$1,750,000.00
10	Emergency Spillway	L.S.	--	--	$500,000.00
11	36" Pipe	L.F.	14,000	100	$1,400,000.00
12	24" Pipe	L.F.	10,000	60	$600,000.00
13	18" Pipe	L.F.	2,100	40	$84,000.00
13	36" Bore	L.F.	1000	750	$750,000.00
14	Mitigation	L.S.	--	--	$100,000.00
15	Petro line relocate	L.S.	--	--	$250,000.00
				Construction Cost Sub-Total:	$28,834,000.00
				10% Engineering:	$2,883,400.00
				Sub-Total:	$31,717,400.00
				15% Contingency:	$4,757,610.00
				CONSTRUCTION COST TOTAL:	$36,475,010.00
				Preparation of Final Designs and Specifications:	$2,000,000.00
				Permitting and Mitigation:	$250,000.00
				Legal Fees:	$100,000.00
				Acquisition of Access and Rights of Way:	$1,750,000.00
				TOTAL PROJECT COSTS:	**$40,575,010.00**
				USE:	**$41 M**

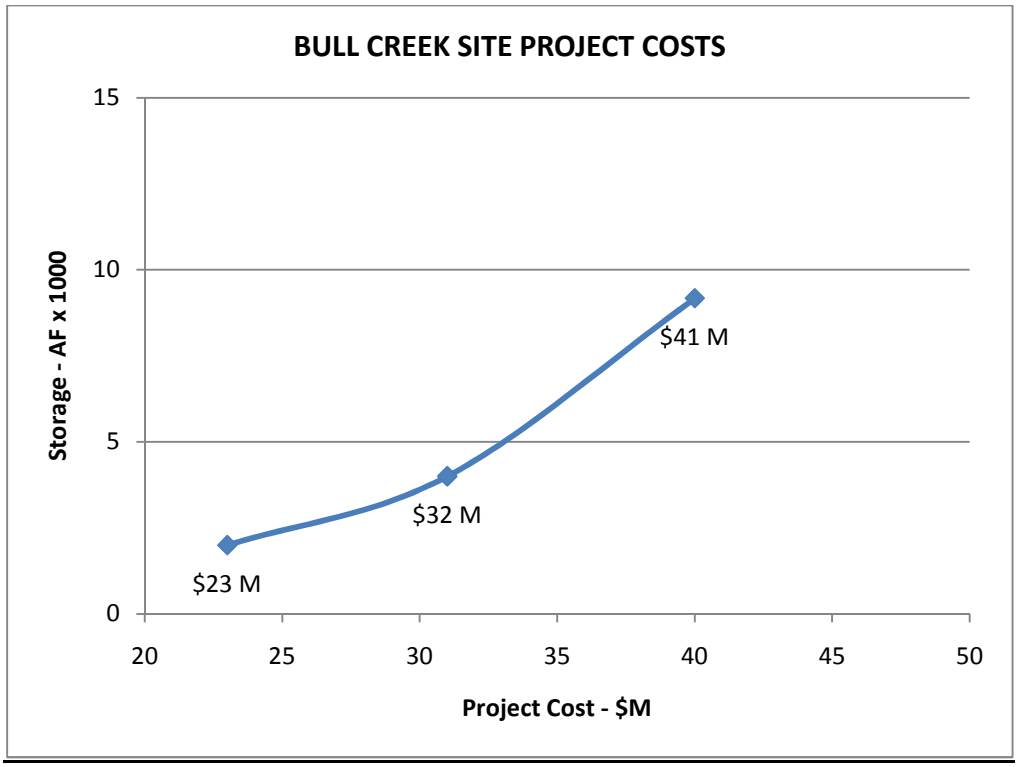


Figure 6.5-16 Bull Creek Reservoir Project Costs

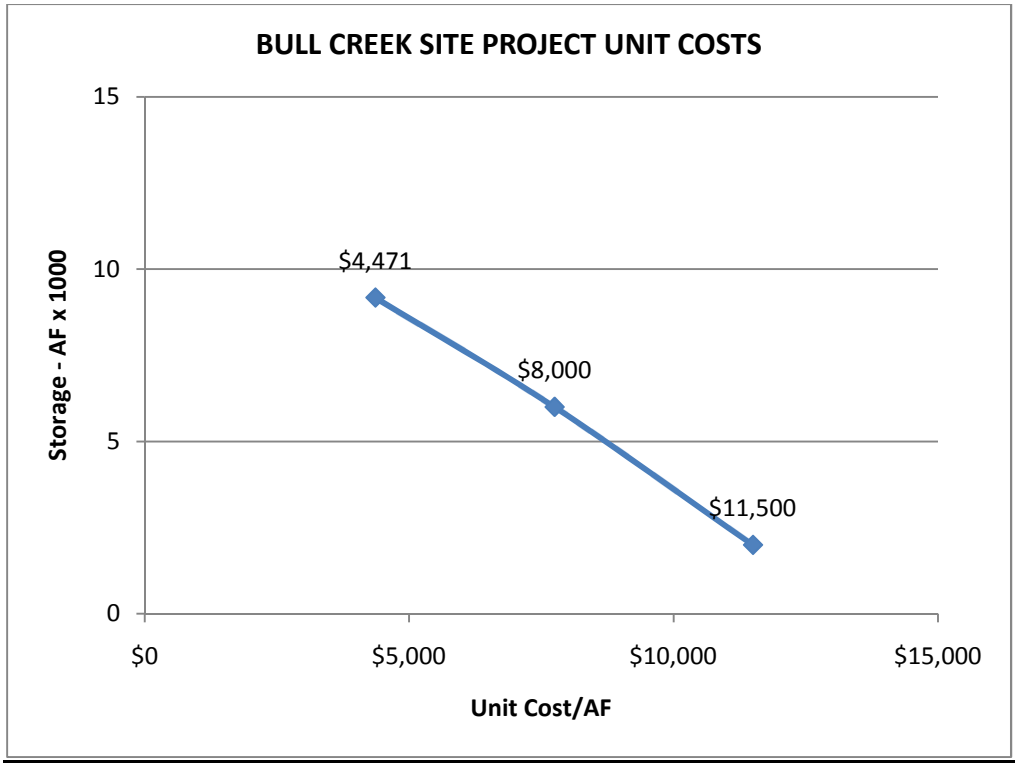


Figure 6.5-17 Bull Creek Reservoir Unit Costs

6.5.5.10 Multi-Purpose Potential

The Bull Creek Reservoir could be utilized for the purposes summarized below.

- Irrigation Supplementary Flows – The reservoir could supplement direct flow rights to meet irrigation shortages.
- Exchange Potential – There would be opportunity to benefit irrigation ditches not directly tributary by water exchange.
- Reduce Seepage Losses – Incorporation of multiple ditches into the supply canal and addressing high seepage areas would reduce losses. Delivery of water to the ditches with a pipeline would also reduce losses.
- Clear Creek Flow Improvement – The storage would facilitate increased flows above and through the City of Buffalo. The potential high quality fishery would be available for recreation purposes.
- Reservoir Recreation – Incorporation of a recreation pool would create opportunities for flat water recreation. The proximity to the City of Buffalo and year-round access would make the reservoir a valuable opportunity.
- Municipal Water Supply – The reservoir could be used directly or indirectly for additional storage for the City of Buffalo.
- Flood Control – The reservoir could provide flood control for Bull Creek.

6.5.5.11 Summary

A multi-purpose reservoir could be constructed on the Bull Creek site. The site appears to be geologically suitable for a reservoir. The site has few environmental issues. No wetlands are present, cottonwood gallery forest impacts would be minor, and two raptor nests were observed near the reservoir area. The dam and reservoir would be located on State of Wyoming lands and private land. The site is well situated to meet needs of the irrigation ditches.

The primary concerns are the cost of the project and the difficulty and cost of constructing the supply system. Preliminary costs for a 9,170 acre-foot reservoir with supply system and delivery pipeline is approximately $41 million. The unit cost per acre-foot of storage is $4,471. The project costs and unit costs for the size range analyzed are shown on Figures 6.5-16 and 6.5-17. The unit costs indicate that the Bull Creek Reservoir site is not economical at smaller sizes. This result is due to the large costs of water supply and delivery systems.

6.6 HIGH ALTITUDE CLEAR CREEK STORAGE ALTERNATIVES

High altitude storage alternatives to meet the needs in the Clear Creek basin were investigated. High altitude storage sites have the advantage of being located above all needs and have lower evaporation rates. A number of storage sites have been identified on the Big Horn National Forest in previous studies and this study. These sites were screened for potential to meet the needs of this study. That screening process resulted in four alternative reservoir sites on the Big Horn National Forest that were studied in more detail. Those sites include the following as shown on Figure 6.6-1.

Upper Middle Fork Clear Creek Reservoir site
Lower Middle Fork Clear Creek Reservoir site
Camp Comfort Reservoir Site
Tie Hack Reservoir Enlargement

The results of the investigation of these storage sites are reported in the following sections.

6.6.1 Water Availability

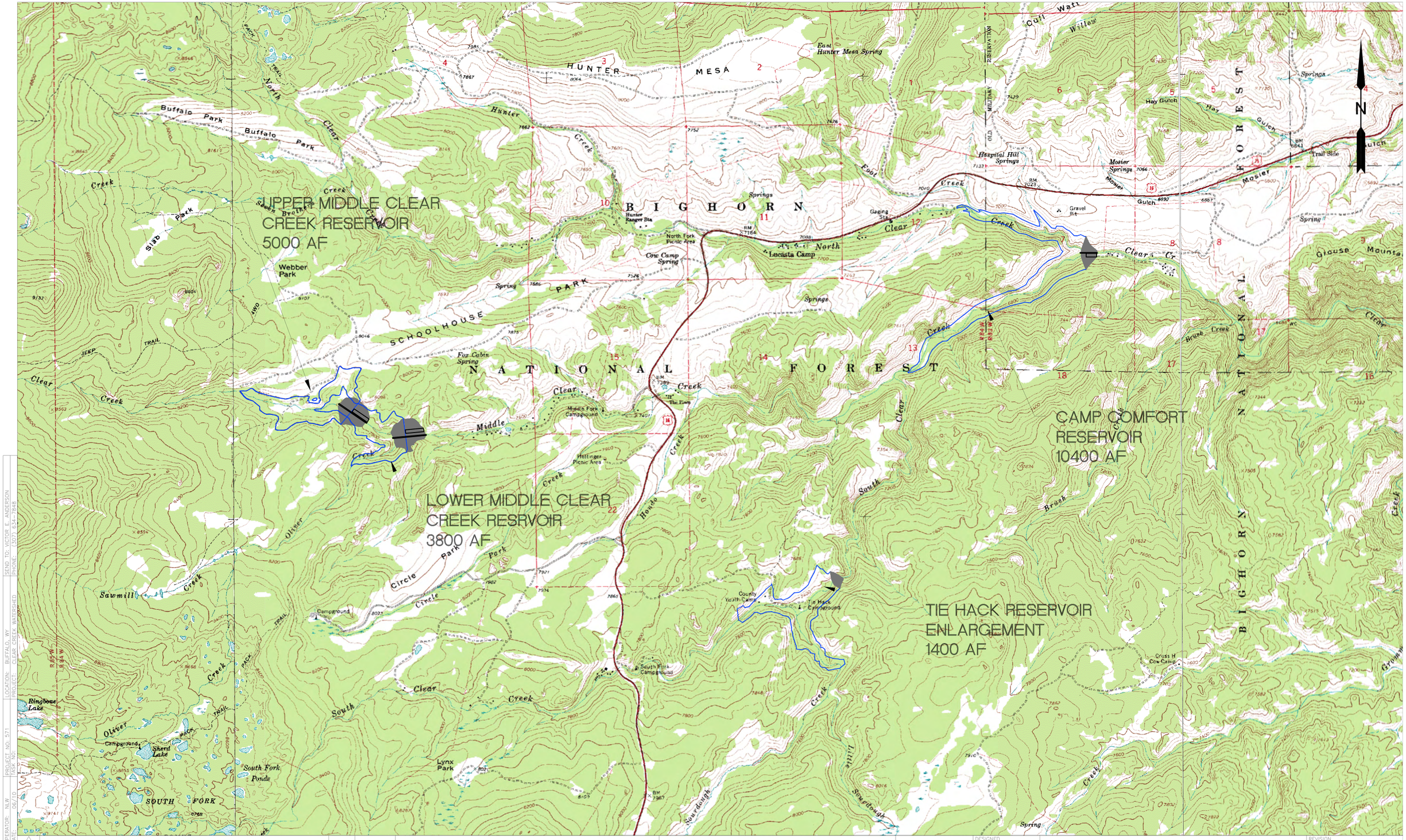
The model developed for this study and temporary gauging information was utilized to estimate available flows at the proposed reservoir locations. As discussed in Section 6.2.5, it was assumed that for the most optimistic scenario, the M&M Ranch water rights would not be utilized to deliver water to Lake DeSmet. The yield of the new reservoirs would be greatly reduced if the M&M Ranch water rights were to be utilized. For modeling purposes, the Camp Comfort water storage right for 11,640 acre-feet was assumed to be partially transferred to the proposed sites. Under these most optimistic assumptions, the water available for a new reservoir would be approximately one acre-foot of yield for one acre-foot of storage on an average annual basis. For the range of reservoir sizes analyzed, the yield would be very dependable.

6.6.2 Reservoir Purpose and Need

Irrigation shortages for the irrigation ditches above and through the City of Buffalo were estimated. The total shortages were estimated to be 4,000 acre-feet per year on an average annual basis.

Fishery flows above and through the City of Buffalo would require approximately 2,000 acre-feet per year on an average annual basis. This water could be utilized by irrigators downstream of the city or utilized as fishery flows farther downstream.

Reservoir recreational usage would be desirable to maximize public benefits of the projects. The usual range of recommended recreation pool is 25 to 30 percent of total reservoir storage.



REV	DESCRIPTION OF REVISION	BY	DATE
1	PRELIMINARY DESIGN	NLW	06/10

SCALE 1" = 3000'

STATES WEST WATER RESOURCES CORPORATION
1904 E. 15th STREET
CHEYENNE, WYOMING 82001
(307) 634-7848
FAX: (307) 634-7851

WARNING
IF THIS BAR DOES NOT MEASURE 1/2" THEN DRAWING IS NOT TO SCALE

DESIGNED	NLW
DRAWN	NLW
CHECKED	VEA
PEER REVIEWED	VEA
PROJECT MANAGER	VEA
DATE	06/10

CLEAR CREEK WATERSHED STUDY

HIGH ALTITUDE SITES

REVISION 1
PROJECT 571
DRAWING FIGURE 6.6-1

SEND TO: VICTOR E. ANDERSON PHONE: (307) 634-7848
LOCATION: BUFFALO, WY PROJECT: CLEAR CREEK WATERSHED
PROJECT NO: 571 TASK NO:
OPERATOR: NLW DATE: 06/10
FILE NAME: Forest Sites SCALE: 1"=1000'

6.6.3 Upper Middle Fork Clear Creek Reservoir Site

This potential site would be located on Middle Fork Clear Creek approximately 14.1 miles west of the City of Buffalo as shown on Figure 6.6-2. The site could impound a maximum of 5,000 acre-feet as indicated on the stage-storage curve, Figure 6.6-3.

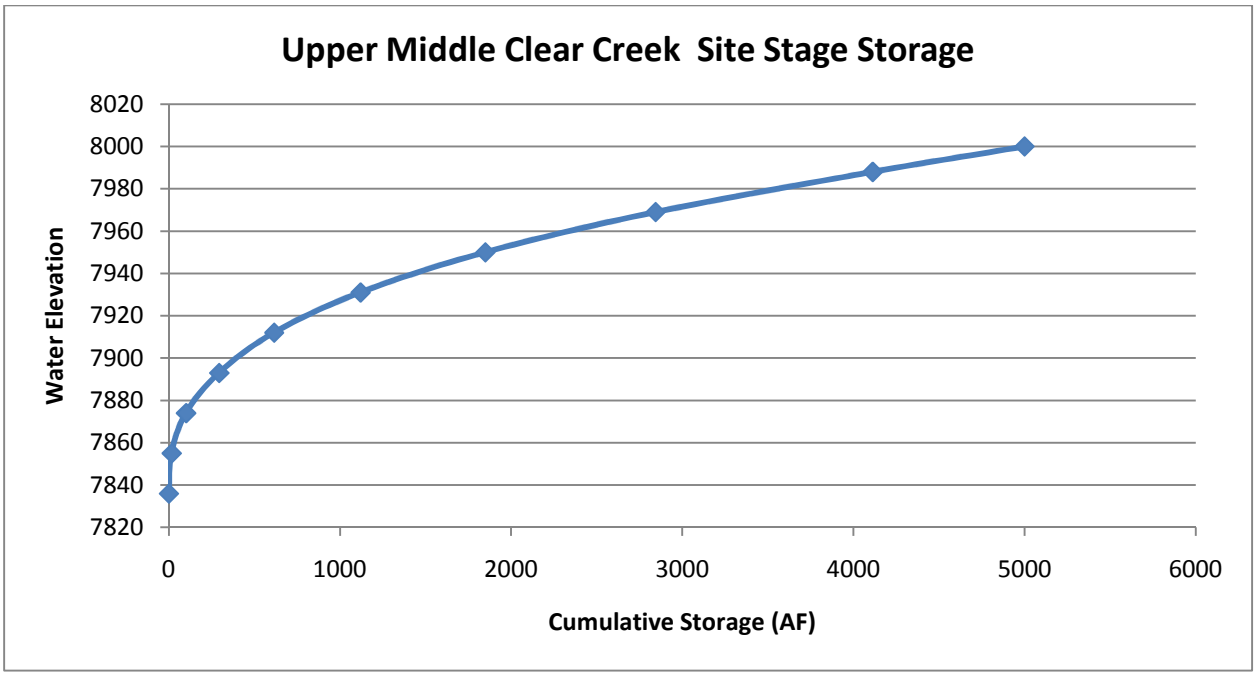


Figure 6.6-3 Upper Middle Clear Creek Reservoir Stage Storage Curve

The dam and reservoir would be located on United States Forest Service land. The site would be accessed from a primitive forest service road approximately 2.5 miles from Highway 16. There are numerous cabins located approximately one mile downstream of the dam site.

6.6.3.1 Dam and Reservoir

A roller compacted concrete (RCC) dam to impound 5,000 acre-feet of storage would be a maximum of 200 feet high with a crest length of 1,300 feet. The reservoir would inundate approximately 90 acres at full capacity. The characteristics of the site are summarized below.

6.6.3.2 Geologic/Geotechnical

The Upper Middle Fork Clear Creek Reservoir site was inspected by the project geologist. The complete Geologic/Geotechnical report is included in Appendix 6-B. The specific observations and recommendations for the Upper Middle Fork Clear Creek site are summarized below.

The general bedrock geology at the dam site consists of granitic gneiss with some thin dikes of aplite and pegmatite. The White River Formation is also located above the left abutment. The

REV	DESCRIPTION OF REVISION	BY	DATE
1	PRELIMINARY DESIGN	NLW	06/10

SCALE 1" = 1000'

N

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CHEYENNE, WYOMING 82001
(307) 634-7848
FAX: (307) 634-7851

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DESIGNED	NLW
DRAWN	NLW
CHECKED	VEA
PEER REVIEWED	VEA
PROJECT MANAGER	VEA
DATE	06/10

CLEAR CREEK WATERSHED STUDY

UPPER MIDDLE CLEAR CREEK RESERVOIR SYSTEM

REVISION 1
PROJECT 571
DRAWING FIGURE 6.6-2

FILE NAME: Upstream
SCALE: 1"=1000'
OPERATOR: NLW
DATE: 06/10
PROJECT NO: 571
TASK NO:
LOCATION: BUFFALO, WY
PROJECT: CLEAR CREEK WATERSHED
SEND TO: VICTOR E. ANDERSON
PHONE: (307) 634-7848

White River Formation consists of boulders, cobbles, and pebbles in a matrix of sandstone and bentonitic claystone. Surficial soils at the site include residuum, slopewash, and colluviums of grus. The nearest mapped fault is less than 2 miles southeast of the site.

An appropriate dam type for the site geology would be roller-compacted concrete (RCC) dam. A concrete-faced rockfill dam may also be appropriate for this site; however, it would require a large excavation through an abutment for a spillway. Geologic conditions that have the greatest potential impact to design are:

- The ability to treat the wide joints identified in exposed rock to reduce seepage.
- The ability to process onsite bedrock materials for RCC, concrete aggregate, or rockfill. The rock does appear to be suitable for RCC, concrete aggregate, or rockfill.
- The depth to suitable foundation in the valley bottom.
- Stability of abutments if joints are dipping downstream.

6.6.3.3 Environmental

This site has some, but not an expansive amount of willow riparian area. It would inundate some upland forested areas. There is one small wetland (0.05 acres) near the dam that does not show up on the NWI map. There is a relatively large wetland within the inundation area that may be a fen. A test pit was dug, but ice was encountered after about 3-4 inches. The top 3-4 inches were composed of peat, and if the peat goes deeper then this site is a fen. Further work needs to be done to determine what type of wetland this is.

According to Wyoming Game and Fish Department data, this site is within elk winter/yearlong range and mule deer spring/summer/fall range.

The complete environmental report is included in Appendix 6-C.

The Upper Middle Fork Clear Creek Reservoir site would inundate approximately 1.1 miles of the Middle Fork of Clear Creek. These segments of stream are considered important trout waters of regional importance. The fishery losses would have to be mitigated.

6.6.3.4 Emergency Spillway

The Upper Middle Fork Clear Creek Reservoir site has a drainage area of approximately 7 square miles. Flood flows up to the Probable Maximum Flood (PMF) would be passed over the spillway constructed over the proposed roller compacted concrete (RCC) dam. There are numerous cabins and buildings located approximately one mile downstream of the dam. The reservoir could be used to reduce flooding on the Middle Fork of Clear Creek. The flooding potential for the cabins downstream of the dam could be greatly reduced.

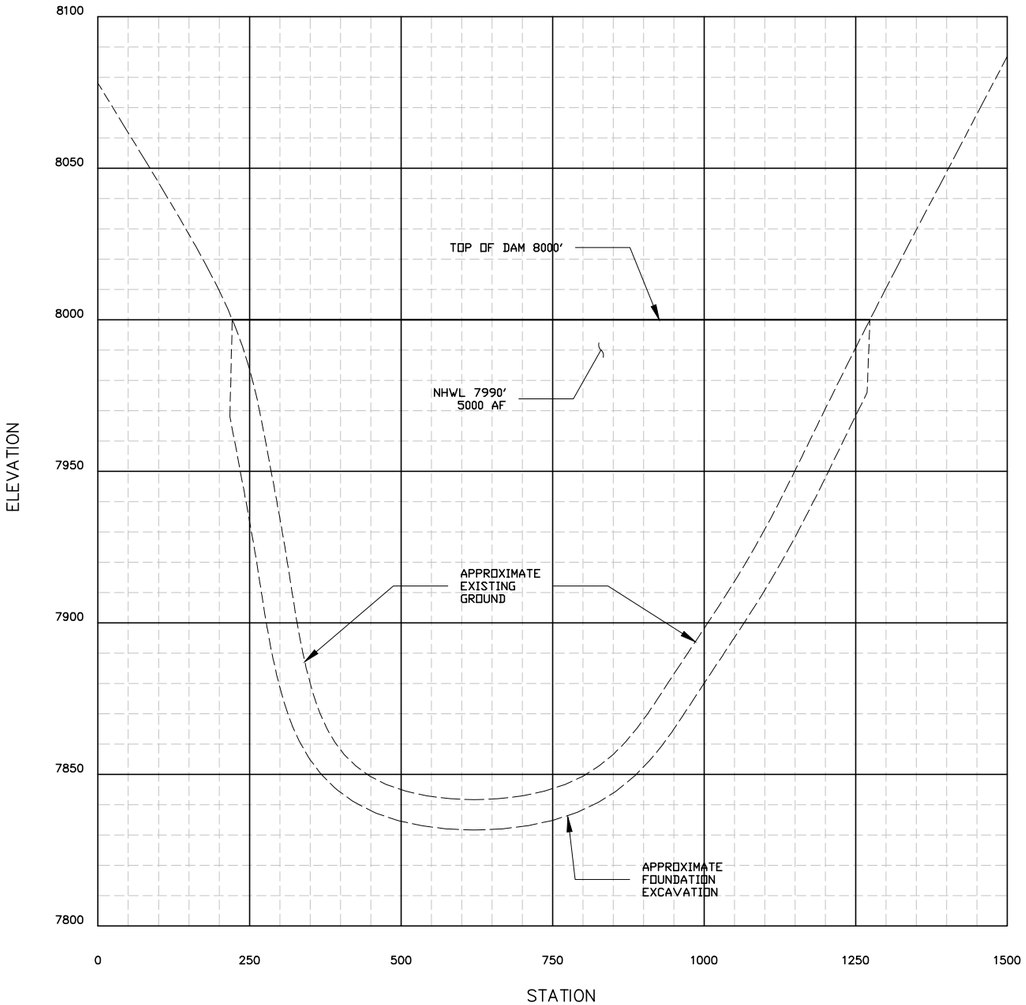
6.6.3.5 Outlet Works

The reservoir outlet works would have a maximum capacity of 200 cfs. The outlet works would consist of a multi-level intake tower, conduit through the RCC dam, and a control valve structure.

6.6.3.6 Preliminary Design and Cost Estimate

The potential 5,000 acre-feet reservoir on Upper Middle Fork Clear Creek was preliminarily designed and cost estimates developed. The typical dam section and centerline profile are shown on Figure 6.6-4.

Quantities for the 5,000 acre-foot dam and reservoir, and associated items were developed. The preliminary cost estimate is shown on Table 6.6-1. The estimated cost for a 5,000 acre-foot reservoir project would be $68 million. The approximate cost per acre-foot of storage is $13,600.



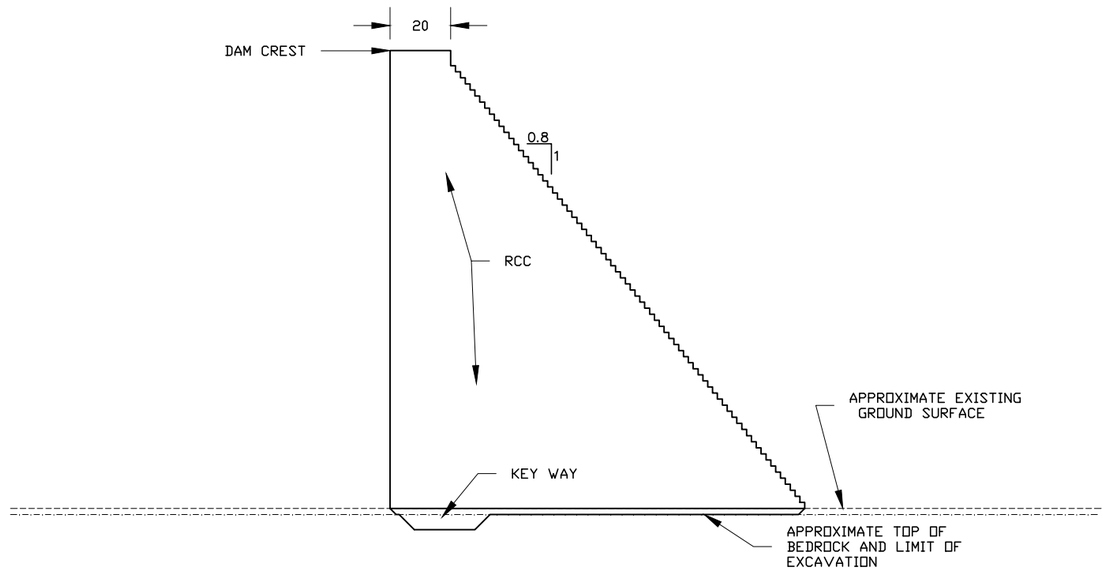
DAM CENTERLINE PROFILE

HORIZ. SCALE

250' 0 250'

VERT. SCALE

50' 0 50'



TYPICAL RCC DAM SECTION

REV	DESCRIPTION OF REVISION	BY	DATE
1	PRELIMINARY DESIGN	NLW	06/10

STATES WEST WATER RESOURCES CORPORATION

1904 E. 15th STREET
CHEYENNE, WYOMING 82001
(307) 634-7848
FAX: (307) 634-7851

WARNING

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DESIGNED	NLW
DRAWN	NLW
CHECKED	VEA
PEER REVIEWED	VEA
PROJECT MANAGER	VEA
DATE	06/10

CLEAR CREEK WATERSHED STUDY

UPPER MIDDLE FORK CLEAR CREEK RESERVOIR DETAILS

REVISION 1

PROJECT 571

DRAWING FIGURE 6.6-4

FILE NAME: CompComfort
SCALE: N/A
OPERATOR: NLW
DATE: 06/10
PROJECT NO: 571
TASK NO: 001-263
LOCATION: BUFFALO, WY
PROJECT: CLEAR CREEK WATERSHED
SEND TO: VICTOR E. ANDERSON
PHONE: (307) 634-7848

Table 6.6-1

Cost Estimate-Upper Middle Fork Clear Creek Reservoir

Storage -5,000 AF Top Dam Elevation - 8000

No.	Task	Unit	Estimated Quantity	Unit Price	Total Cost
1	Mobilization	L.S.	--	--	$2,000,000.00
2	Foundation Excavation	C.Y.	75,000	10	$750,000.00
3	RCC	C.Y.	400,000	75	$30,000,000.00
4	Grouting	L.F.	40,000	75	$3,000,000.00
5	Concrete Facing	C.Y.	25,000	400	$10,000,000.00
6	Outlet Works	L.S.	--	--	$2,000,000.00
7	Spillway	L.S.	--	--	$1,000,000.00
8	Access Road	Mi	2.5	100,000	$250,000.00
9	Wetland Mitigation	Ac	5	100,000	$500,000.00
10	Clearing	Ac	80	2,000	$160,000.00
				Construction Cost Sub-Total:	$49,660,000.00
				10% Engineering:	$4,966,000.00
				Sub-Total:	$54,626,000.00
				15% Contingency:	$8,193,900.00
				CONSTRUCTION COST TOTAL:	$62,819,900.00
				Preparation of Final Designs and Specifications:	$3,000,000.00
				Permitting:	$1,000,000.00
				Legal Fees:	$100,000.00
				Acquisition of Access and Rights of Way:	$1,000,000.00
				TOTAL PROJECT COSTS:	**$67,919,900.00**
				USE:	**$68 M**

6.6.3.7 Multi-Purpose Potential

The Upper Middle Fork Clear Creek Reservoir could be utilized for the purposes summarized below.

- Irrigation Supplementary Flows – The reservoir could supplement direct flow rights to meet irrigation shortages. This reservoir site by itself would meet all of the irrigation shortages on Clear Creek.
- Clear Creek Flow Improvement – The storage could facilitate increased flows above and through the City of Buffalo. The potential high quality fishery would be available for

recreation purposes. However, dedicated flows for increased flows above and through the City of Buffalo could reduce the water available for irrigation shortages.

- Reservoir Recreation – Incorporation of a recreation pool would create opportunities for flat water recreation. However, a dedicated recreation pool would reduce the water available for other purposes.
- Municipal Water Supply – The reservoir could be used for additional storage for the City of Buffalo.

6.6.3.8 Summary

A multi-purpose reservoir could be constructed on the Upper Middle Fork Clear Creek site. The site appears to be geologically suitable for a reservoir. The site has potentially serious environmental issues with the presence of a possible fen wetland. The dam and reservoir would be located on United States Forest Service lands. The site is well situated to meet needs of the Clear Creek basin.

The primary concerns are the cost of the project, the inability of the reservoir to meet most of the basin needs, the location on USFS lands, inundation of approximately 1.1 miles of stream, and inundation of approximately 2.0 acres of possible fen wetlands. The preliminary cost for a 5,000 acre-foot reservoir is approximately $68 million. The unit cost per acre-foot of storage is very high at $13,600.

6.6.4 Lower Middle Fork Clear Creek Reservoir Site

This potential site would be located on Middle Fork Clear Creek approximately 13.9 miles west of the City of Buffalo as shown on Figure 6.6-5. The site could impound a maximum of 3,800 acre-feet as indicated on the stage-storage curve, Figure 6.6-6.

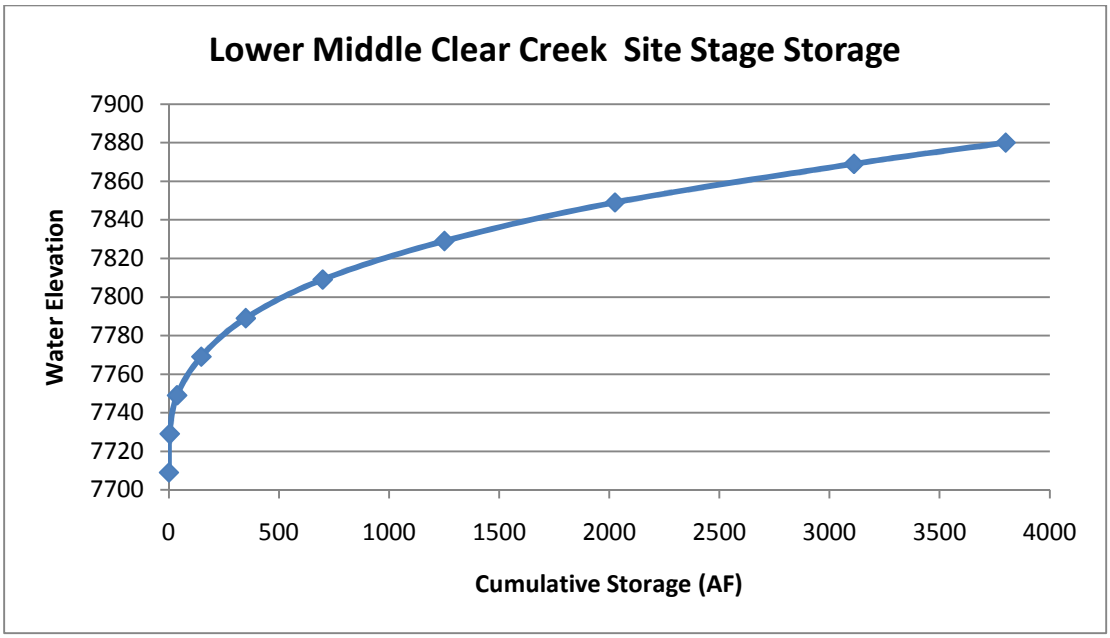


Figure 6.6-6 Lower Middle Clear Creek Reservoir Stage Storage Curve

The dam and reservoir would be located on United States Forest Service lands. The site would be accessed from a primitive forest service road approximately 2.5 miles from Highway 16. There are numerous cabins located immediately downstream of the dam site.

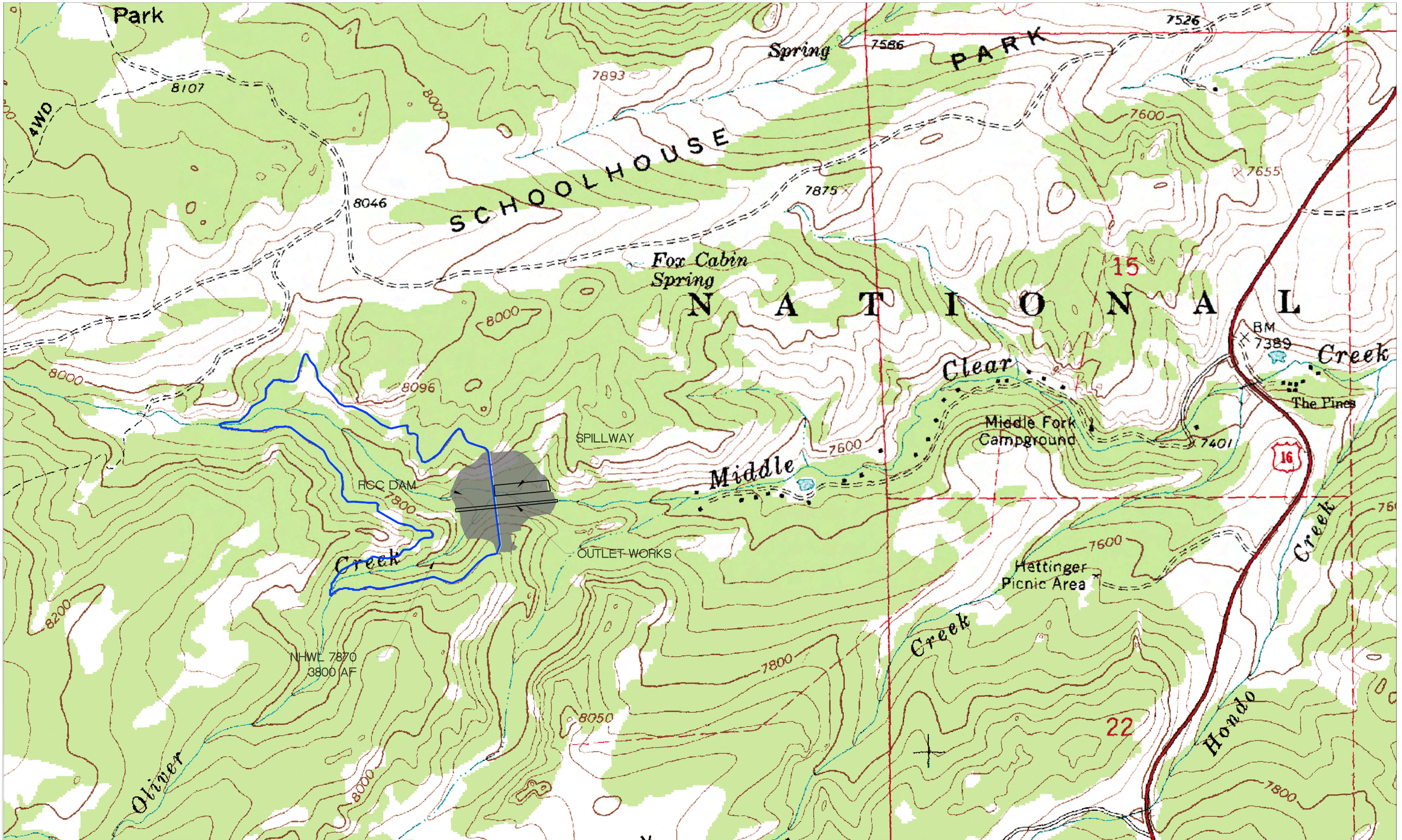
6.6.4.1 Dam and Reservoir

The dam required to impound 3,800 acre-feet of storage would be a maximum of 200 feet high with a crest length of 1,150 feet. The reservoir would inundate approximately 75 acres at full capacity. The characteristics of the site are summarized below.

6.6.4.2 Geologic/Geotechnical

The Lower Middle Fork Clear Creek Reservoir site was inspected by the project geologist. The complete Geologic/Geotechnical report in included in Appendix 6-B. The specific observations and recommendations for the Lower Middle Fork Clear Creek site are summarized below.

The general bedrock geology at the dam site consists of granitic gneiss with some thin dikes of aplite and pegmatite. Surficial soils at the site include residuum, slopewash, and colluviums of grus. The nearest mapped fault is less than 2 miles southeast of the site.



REV	DESCRIPTION OF REVISION	BY	DATE
1	PRELIMINARY DESIGN	NLW	06/10

FILE NAME: Upstream
SCALE: 1" = 1000'
OPERATOR: NLW
DATE: 06/10
TASK NO.
PROJECT NO. 571
LOCATION: BUFFALO, WY
PROJECT: CLEAR CREEK WATERSHED
SEND TO: VICTOR E. ANDERSON
PHONE: (307) 634-7848

SCALE 1" = 1000'

STATES WEST WATER RESOURCES CORPORATION
1904 E. 15th STREET
CHEYENNE, WYOMING 82001
(307) 634-7848
FAX: (307) 634-7851

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DESIGNED	NLW
DRAWN	NLW
CHECKED	VEA
PEER REVIEWED	VEA
PROJECT MANAGER	VEA
DATE	06/10

CLEAR CREEK WATERSHED STUDY

LOWER MIDDLE CLEAR CREEK RESERVOIR SYSTEM

REVISION 1
PROJECT 571
DRAWING FIGURE 6.6-5

An appropriate dam type for the site geology would be roller-compacted concrete (RCC) dam. A concrete-faced rockfill dam may also be appropriate for this site; however, it would require a large excavation through an abutment for a spillway. Geologic conditions that have the greatest potential impact to design are:

- The ability to treat the wide joints identified in exposed rock to reduce seepage.
- The ability to process onsite bedrock materials for RCC, concrete aggregate, or rockfill. The rock does appear to be suitable for RCC, concrete aggregate, or rockfill.
- The depth to suitable foundation in the valley bottom.
- Stability of abutments if joints are dipping downstream.

6.6.4.3 Environmental

This site does not have any wetlands based on NWI mapping but some minor amounts of wetlands likely occur along the drainage. It would inundate a fairly large forested area but most of this is upland forest consisting of spruce/fir, lodgepole, and some aspen on hillsides. There is very little woody riparian habitat at this site. No large issues with this site.

According to Wyoming Game and Fish Department data, this site is within elk winter/yearlong range, moose yearlong range, and mule deer spring/summer/fall range.

The complete environmental report is included in Appendix 6-C.

The Lower Middle Fork Clear Creek Reservoir site would inundate approximately 1.5 miles of the Middle Fork of Clear Creek. These segments of stream are considered important trout waters of regional importance. The fishery losses would have to be mitigated.

6.6.4.4 Emergency Spillway

The Lower Middle Fork Clear Creek Reservoir site has a drainage area of approximately 16.5 square miles. Flood flows up to the Probable Maximum Flood (PMF) would be passed through a spillway constructed over the proposed roller compacted concrete (RCC) dam. There are numerous cabins and buildings located immediately downstream of the dam. The reservoir could be used to reduce flooding on the Middle Fork of Clear Creek. The flooding potential for the cabins downstream of the dam could be greatly reduced.

6.6.4.5 Outlet Works

The reservoir outlet works would have a maximum capacity of 150 cfs. The outlet works would consist of a multi-level intake tower, conduit through the RCC dam, and a control valve structure.

6.6.4.6 Preliminary Design and Cost Estimate

The potential reservoir on Lower Middle Fork Clear Creek was preliminary designed and cost estimates developed. The typical dam section and centerline profile are shown on Figure 6.6-7.

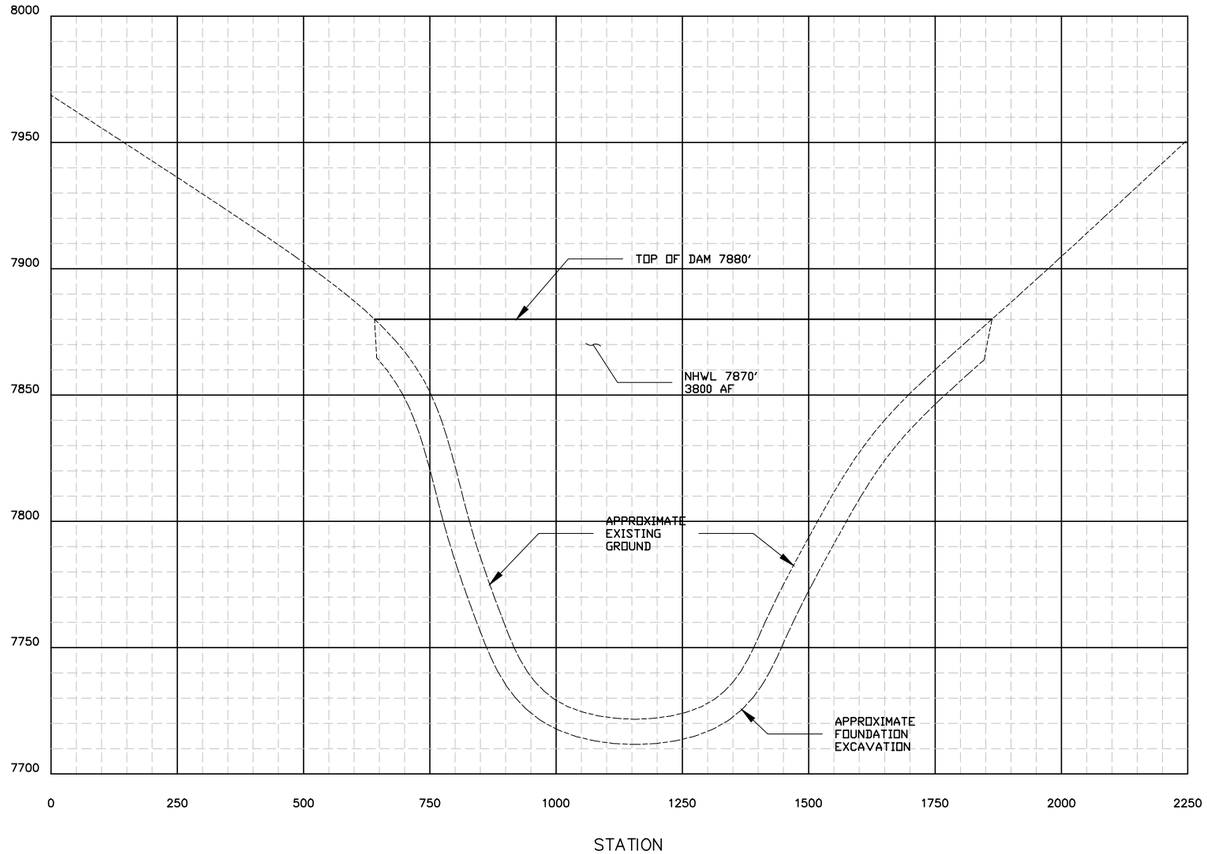
Quantities for the 3,800 acre-foot dam and reservoir, and associated items were developed. The preliminary cost estimate is shown on Table 6.6-2. The estimated cost for a 3,800 acre-foot reservoir project would be $80 million. The approximate cost per acre-foot of storage is $21,050.

Table 6.6-2

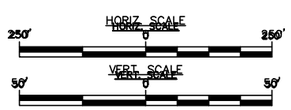
Cost Estimate-Lower Middle Fork Clear Creek Reservoir

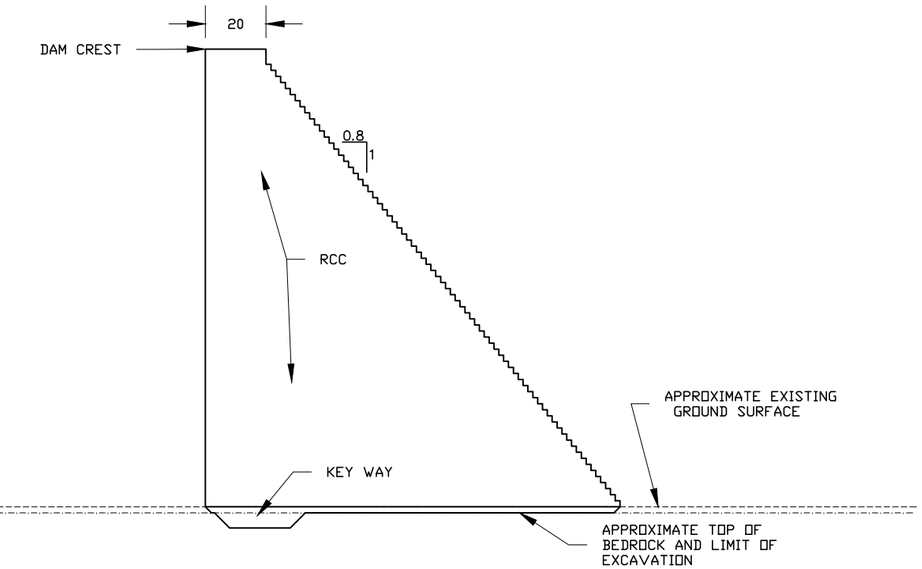
Storage - 3,800 AF Top Dam Elevation - 7880

No.	Task	Unit	Estimated Quantity	Unit Price	Total Cost
1	Mobilization	L.S.	--	--	$2,500,000.00
2	Foundation Excavation	C.Y.	75,000	10	$750,000.00
3	RCC	C.Y.	500,000	75	$37,500,000.00
4	Grouting	L.F.	40,000	75	$3,000,000.00
5	Concrete Facing	C.Y.	30,000	400	$12,000,000.00
6	Outlet Works	L.S.	--	--	$2,000,000.00
7	Spillway	L.S.	--	--	$1,000,000.00
8	Access Road	Mi	2.5	100,000	$250,000.00
9	Wetland Mitigation	Ac	2	100,000	$200,000.00
10	Clearing	Ac	70	2,000	$140,000.00
				Construction Cost Sub-Total:	$59,340,000.00
				10% Engineering:	$5,934,000.00
				Sub-Total:	$65,274,000.00
				15% Contingency:	$9,791,100.00
				CONSTRUCTION COST TOTAL:	$75,065,100.00
				Preparation of Final Designs and Specifications:	$3,000,000.00
				Permitting:	$1,000,000.00
				Legal Fees:	$100,000.00
				Acquisition of Access and Rights of Way:	$1,000,000.00
				TOTAL PROJECT COSTS:	**$80,165,100.00**
				USE:	**$80 M**



DAM CENTERLINE PROFILE





TYPICAL RCC DAM SECTION

FILE NAME: CampComfort
SCALE: N/A
OPERATOR: NLW
DATE: 06/10
PROJECT NO: 571
WORK NO: 001-263
LOCATION: BUFFALO, WY
PROJECT: CLEAR CREEK WATERSHED
SEND TO: VICTOR E. ANDERSON
PHONE: (307) 634-7848

REV	DESCRIPTION OF REVISION	BY	DATE
1	PRELIMINARY DESIGN	NLW	06/10

STATES WEST WATER
RESOURCES CORPORATION

1904 E. 15th STREET
CHEYENNE, WYOMING 82001
(307) 634-7848
FAX: (307) 634-7851

WARNING

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DRAWN	NLW
CHECKED	VEA
PEER REVIEWED	VEA
PROJECT MANAGER	VEA
DATE	06/10

CLEAR CREEK WATERSHED STUDY

LOWER MIDDLE FORK CLEAR CREEK RESERVOIR DETAILS

REVISION 1
PROJECT 571
DRAWING
FIGURE 6.6-7

6.6.4.7 Multi-Purpose Potential

The Lower Middle Fork Clear Creek Reservoir could be utilized for the purposes summarized below.

- Irrigation Supplementary Flows – The reservoir could supplement direct flow rights to meet irrigation shortages. This reservoir site by itself would not meet all of the irrigation shortages on Clear Creek.
- Clear Creek Flow Improvement – The storage could facilitate increased flows above and through the City of Buffalo. The potential high quality fishery would be available for recreation purposes. However, dedicated flows for increased flows above and through the City of Buffalo could reduce the water available for irrigation shortages.
- Reservoir Recreation – Incorporation of a recreation pool would create opportunities for flat water recreation. However, a dedicated recreation pool would reduce the water available for other purposes.
- Municipal Water Supply – The reservoir could be used for additional storage for the City of Buffalo.

6.6.4.8 Summary

A multi-purpose reservoir could be constructed on the Lower Middle Fork Clear Creek site. The site appears to be geologically suitable for a reservoir. The site has few environmental issues. The dam and reservoir would be located on USFS lands. The site is well situated to meet needs of the Clear Creek basin.

The primary concerns are the cost of the project, the inability of the reservoir to meet most the basin needs, the location on USFS lands, inundating approximately 1.5 miles of stream, and the proximity of the dam to the building development on the Middle Fork. Preliminary costs for a 3,800 acre-foot reservoir are approximately $80 million. The unit cost per acre-foot of storage is very high at $21,050.

6.6.5 Camp Comfort Reservoir Site

This potential site would be located on Clear Creek approximately 9.3 miles west of the City of Buffalo as shown on Figure 6.6-8. The site could impound a maximum of 10,400 acre-feet as indicated on the stage-storage curve, Figure 6.6-9.

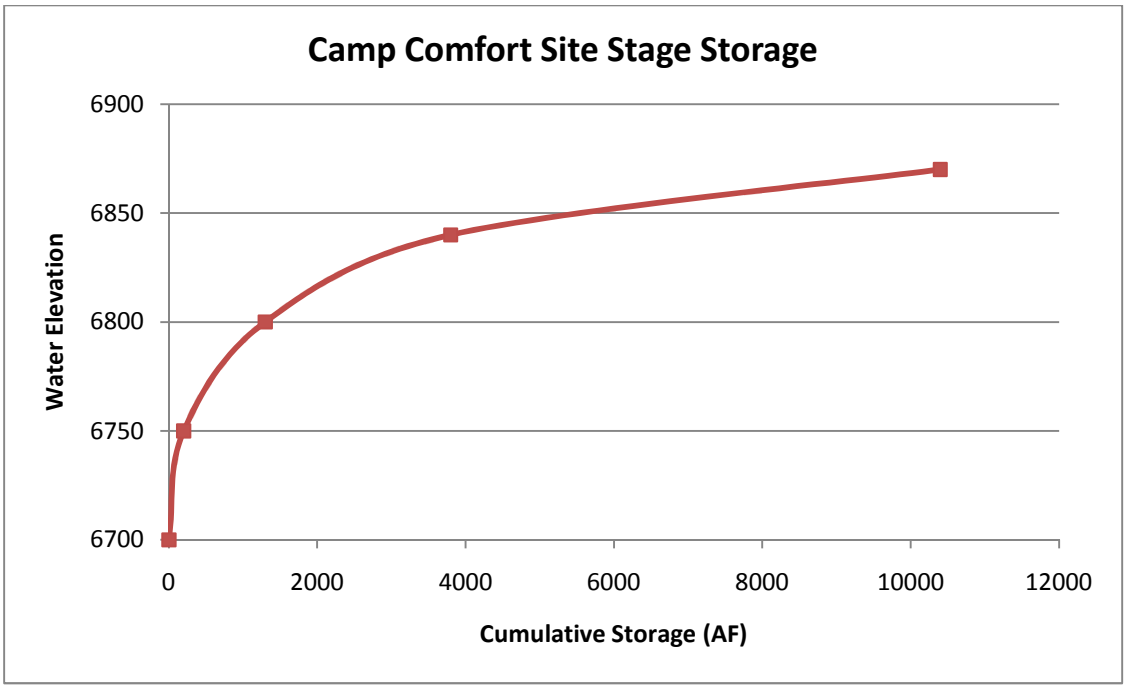


Figure 6.6-9 Camp Comfort Reservoir Stage Storage Curve

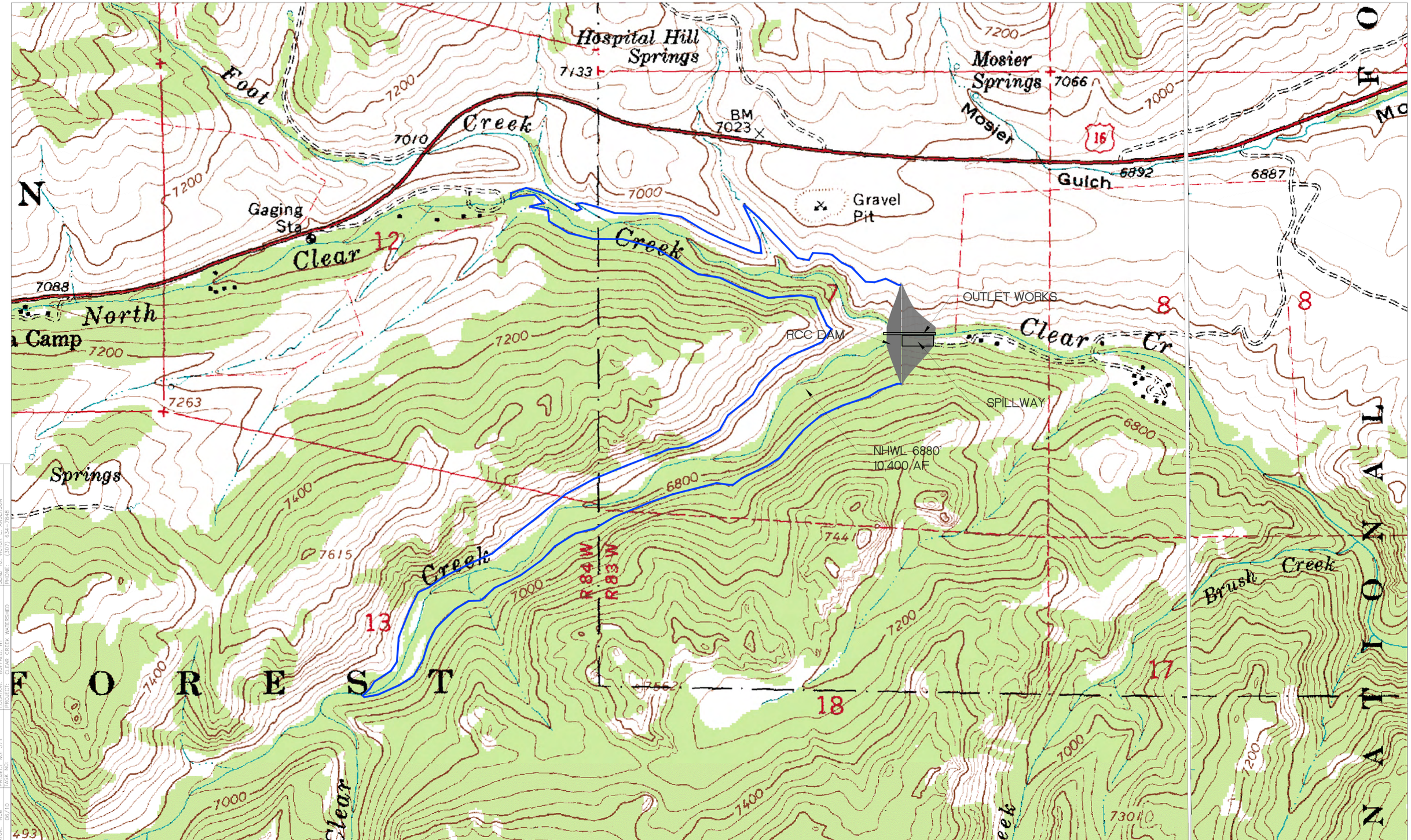
The dam and reservoir would be located primarily on United States Forest Service land. The site would be accessed from a forest service road approximately 0.5 miles from Highway 16. Private land and buildings are located immediately downstream of the dam and immediately upstream of the reservoir.

6.6.5.1 Dam and Reservoir

A roller compacted concrete (RCC) dam required to impound 10,400 acre-feet of storage would be a maximum of 220 feet high with a crest length of 1,050 feet. The reservoir would inundate approximately 90 acres at full capacity. The characteristics of the site are summarized below.

6.6.5.2 Geologic/Geotechnical

The Camp Comfort Reservoir site was inspected by the project geologist. The complete Geologic/Geotechnical report is included in Appendix 6-B. The specific observations and recommendations for the Camp Comfort site are summarized below.



REV	DESCRIPTION OF REVISION	BY	DATE
1	PRELIMINARY DESIGN	NLW	06/10

SCALE 1" = 1000'

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PEER REVIEWED	VEA
PROJECT MANAGER	VEA
DATE	06/10

CLEAR CREEK WATERSHED STUDY

CAMP COMFORT RESERVOIR SYSTEM

REVISION 1
PROJECT 571
DRAWING FIGURE 6.6-8

FILE NAME: Upstream
SCALE: 1"=1000'
OPERATOR: NLW
DATE: 06/10
PROJECT NO: 571
TASK NO:
LOCATION: BUFFALO, WY
PROJECT: CLEAR CREEK WATERSHED
SEND TO: VICTOR E. ANDERSON
PHONE: (307) 634-7848

The general bedrock geology at the dam site consists of granitic gneiss with some thin dikes of aplite and pegmatite. The White River Formation is also located above the left abutment. The White River Formation consists of boulders, cobbles, and pebbles in a matrix of sandstone and bentonitic claystone. Surficial soils at the site include residuum, slopewash, and colluviums of grus. A fault that generally follows the stream alignment has been mapped at the site. Alluvium was identified at the dam site in the valley bottom and is at least 20 to 30 feet thick.

An appropriate dam type for the site geology would be roller-compacted concrete (RCC) dam. A concrete-faced rockfill dam may also be appropriate for this site; however, it would require a large excavation through an abutment for a spillway. Geologic conditions that have the greatest potential impact to design are:

- The ability to treat the wide joints identified in exposed rock to reduce seepage.
- The ability to process onsite bedrock materials for RCC, concrete aggregate, or rockfill. The rock does appear to be suitable for RCC, concrete aggregate, or rockfill.
- The fault that generally follows the stream alignment.
- The depth to suitable foundation in the valley bottom and impacts to seepage control and foundation strength from the fault identified in the valley bottom.
- Stability of abutments if joints are dipping downstream.

6.6.5.3 Environmental

This site appears to have only a minor amount of woody riparian area, but it would inundate upland forests. There is one large wetland of approximately 4 acres present, but due to high water this wetland could not be safely accessed during the site visit. Further work should be conducted to determine if this wetland might be a fen.

According to Wyoming Game and Fish Department data, this site is within elk spring/summer/fall range, white-tailed deer yearlong range, and mule deer winter/yearlong range.

The complete environmental report is included in Appendix 6-C.

The Camp Comfort Reservoir site would inundate approximately 2.5 miles of the South Fork and North Fork of Clear Creek. These segments of stream are considered important trout waters of regional importance. The fishery losses would have to be mitigated.

6.6.5.4 Emergency Spillway

The Camp Comfort Reservoir site has a drainage area of approximately 98 square miles. Flood flows up to the Probable Maximum Flood (PMF) would be passed over a spillway constructed

over the proposed roller compacted concrete (RCC) dam. This reservoir could be utilized for flood control for the City of Buffalo and other areas bordering Clear Creek.

6.6.5.5 Outlet Works

The reservoir outlet works would have a maximum capacity of 400 cfs. The outlet works would consist of a multi-level intake tower, conduit through the RCC dam, and a control valve structure.

6.6.5.6 Preliminary Design and Cost Estimate

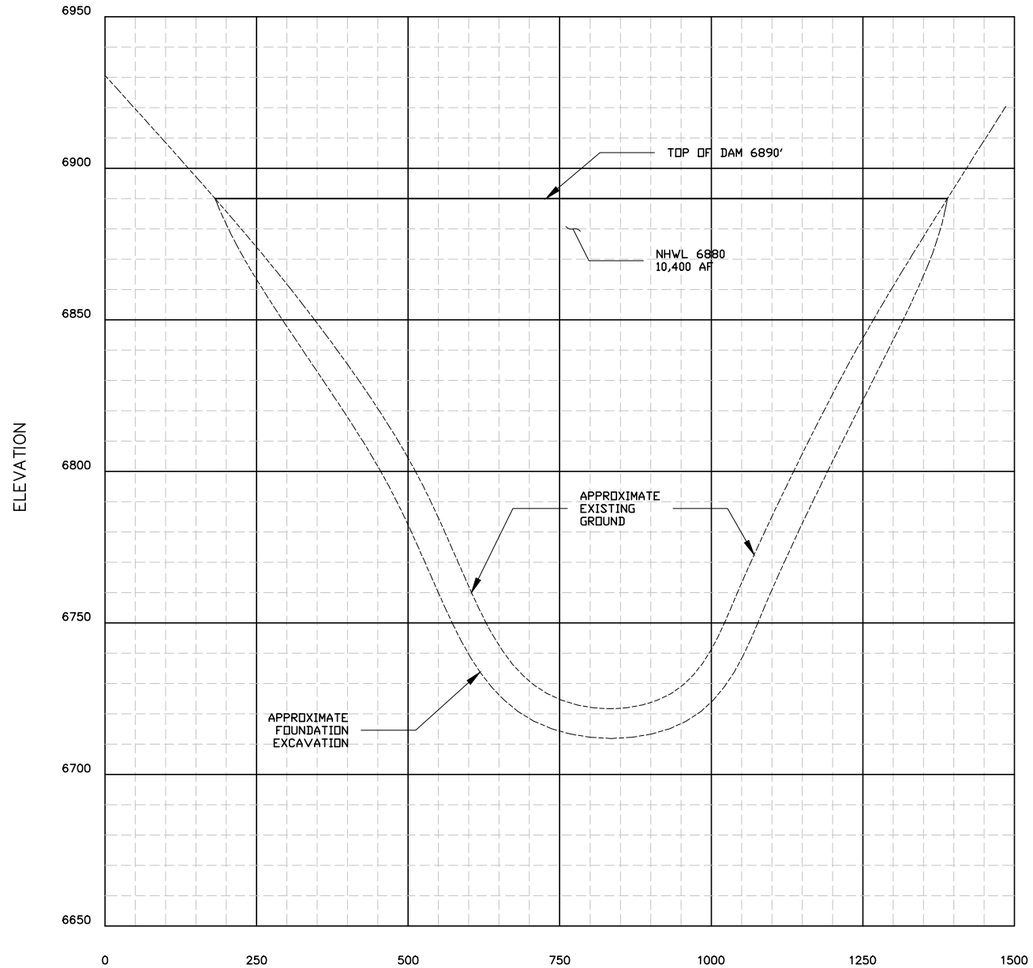
The potential reservoir at Camp Comfort was preliminary designed and cost estimates developed. The typical dam section and centerline profile are shown on Figure 6.6-10.

Quantities for 10,400 and 6,000 acre-foot dams and reservoirs, and associated items were developed. The preliminary cost estimates are shown on Table 6.6-3 and 6.6-4. The estimated cost for a 10,400 acre-foot reservoir project would be $57 million. The approximate cost per acre-foot of storage is $5,480. The estimated cost for a 6,000 area-feet reservoir project would be $45 million. The approximate cost per acre-foot of storage is $7,500. The project costs and unit costs for the size of reservoirs are shown on Figure 6.6-11 and 6.6-12.

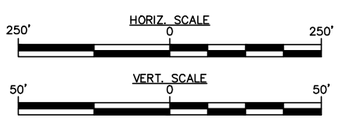
6.6.5.7 Multi-Purpose Potential

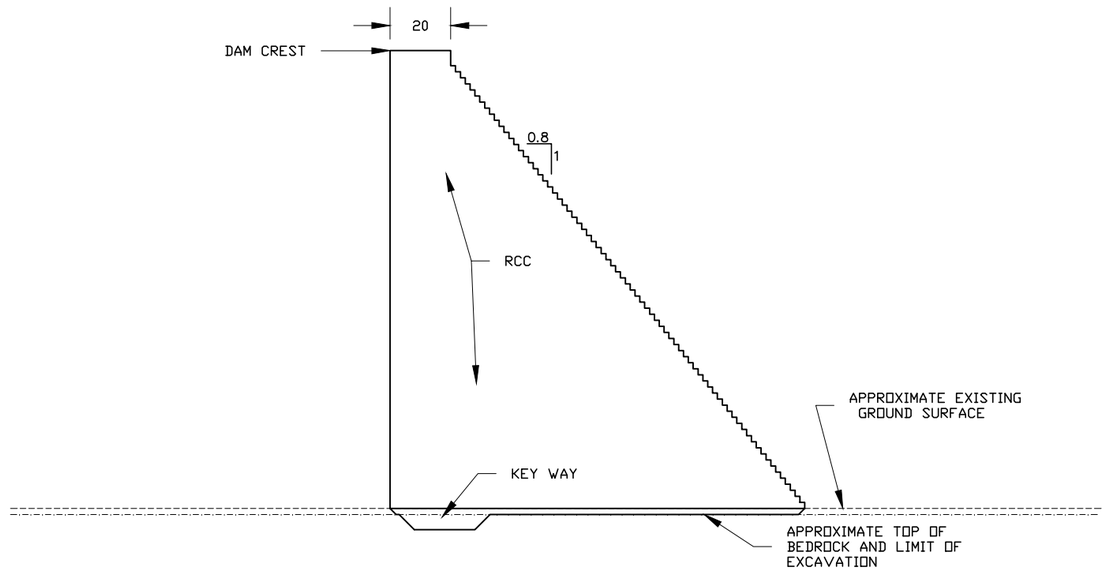
The Camp Comfort Reservoir could be utilized for the purposes summarized below.

- Irrigation Supplementary Flows – The reservoir could supplement direct flow rights to meet irrigation shortages.
- Clear Creek Flow Improvement – The storage would facilitate increased flows above and through the City of Buffalo. The potential high quality fishery would be available for recreation purposes.
- Reservoir Recreation – Incorporation of a recreation pool would create opportunities for flat water recreation.
- Municipal Water Supply – The reservoir could be used for additional storage for the City of Buffalo.
- Flood Control – The reservoir could be used to reduce flood risks for the City of Buffalo and adjoining areas.



DAM CENTERLINE PROFILE





TYPICAL RCC DAM SECTION

FILE NAME: CampComfort | OPERATOR: NLW | DATE: 06/10 | SCALE: N/A
LOCATION: BUFFALO, WY | PROJECT: CLEAR CREEK WATERSHED
PROJECT NO: 571 | HSK NO: 001-263
SEND TO: VICTOR E. ANDERSON | PHONE: (307) 634-7848

REV	DESCRIPTION OF REVISION	BY	DATE
1	PRELIMINARY DESIGN	NLW	06/10

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DESIGNED	NLW
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CHECKED	VEA
PEER REVIEWED	VEA
PROJECT MANAGER	VEA
DATE	06/10

CLEAR CREEK WATERSHED STUDY

CAMP COMFORT RESERVOIR DETAILS

REVISION 1
PROJECT 571
DRAWING FIGURE 6.6-10

Table 6.6-3

Cost Estimate-Camp Comfort Reservoir

Storage - 6000 AF Top Dam Elevation - 6870

No.	Task	Unit	Estimated Quantity	Unit Price	Total Cost
1	Mobilization	L.S.	--	--	$1,500,000.00
2	Foundation Excavation	C.Y.	80,000	10	$800,000.00
3	RCC	C.Y.	225,000	75	$16,875,000.00
4	Grouting	L.F.	40,000	75	$3,000,000.00
5	Concrete Facing	C.Y.	15,000	400	$6,000,000.00
6	Outlet Works	L.S.	--	--	$1,750,000.00
7	Spillway	L.S.	--	--	$900,000.00
8	Access Road	Mi	1.0	200,000	$200,000.00
9	Wetland Mitigation	Ac	8	100,000	$800,000.00
10	Clearing	Ac	60	2,000	$120,000.00
				Construction Cost Sub-Total:	$31,945,000.00
				10% Engineering:	$3,194,500.00
				Sub-Total:	$35,139,500.00
				15% Contingency:	$5,270,925.00
				CONSTRUCTION COST TOTAL:	$40,410,425.00
				Preparation of Final Designs and Specifications:	$2,250,000.00
				Permitting:	$1,000,000.00
				Legal Fees:	$100,000.00
				Acquisition of Access and Rights of Way:	$1,000,000.00
				TOTAL PROJECT COSTS:	**$44,760,425.00**
				USE:	**$45 M**

Table 6.6-4

Cost Estimate-Camp Comfort Reservoir

Storage - 10400 AF Top Dam Elevation - 6890

No.	Task	Unit	Estimated Quantity	Unit Price	Total Cost
1	Mobilization	L.S.	--	--	$1,750,000.00
2	Foundation Excavation	C.Y.	100,000	10	$1,000,000.00
3	RCC	C.Y.	300,000	75	$22,500,000.00
4	Grouting	L.F.	50,000	75	$3,750,000.00
5	Concrete Facing	C.Y.	20,000	400	$8,000,000.00
6	Outlet Works	L.S.	--	--	$2,000,000.00
7	Spillway	L.S.	--	--	$1,000,000.00
8	Access Road	Mi	1.0	200,000	$200,000.00
9	Wetland Mitigation	Ac	8	100,000	$800,000.00
10	Clearing	Ac	60	2,000	$120,000.00
				Construction Cost Sub-Total:	$41,120,000.00
				10% Engineering:	$4,112,000.00
				Sub-Total:	$45,232,000.00
				15% Contingency:	$6,784,800.00
				CONSTRUCTION COST TOTAL:	$52,016,800.00
				Preparation of Final Designs and Specifications:	$2,500,000.00
				Permitting:	$1,000,000.00
				Legal Fees:	$100,000.00
				Acquisition of Access and Rights of Way:	$1,000,000.00
				TOTAL PROJECT COSTS:	**$56,616,800.00**
				USE:	**$57 M**

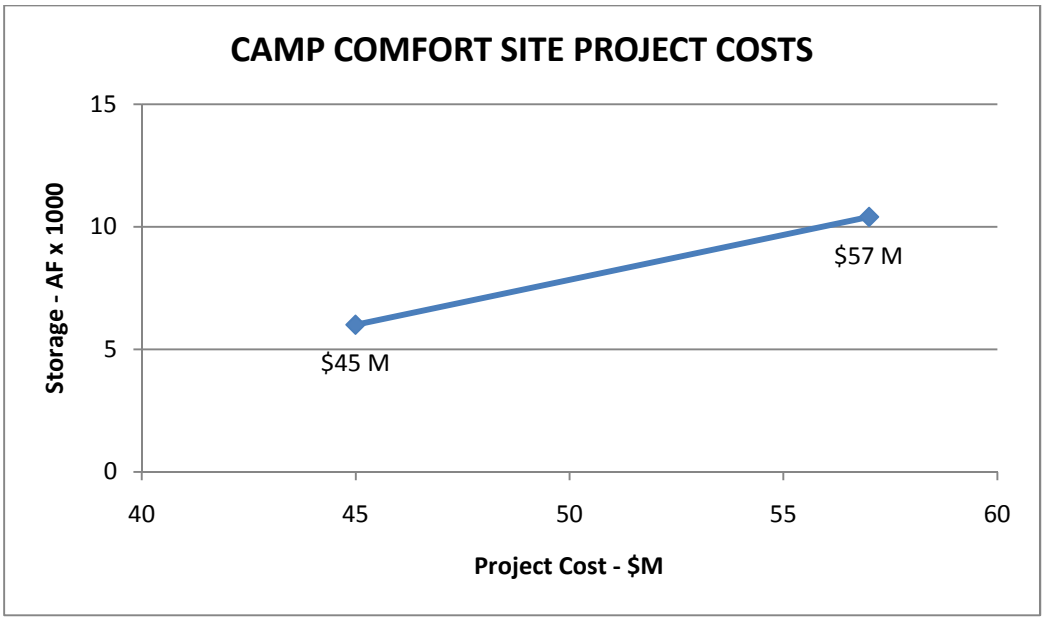

Figure 6.6-11 Camp Comfort Site Project Costs

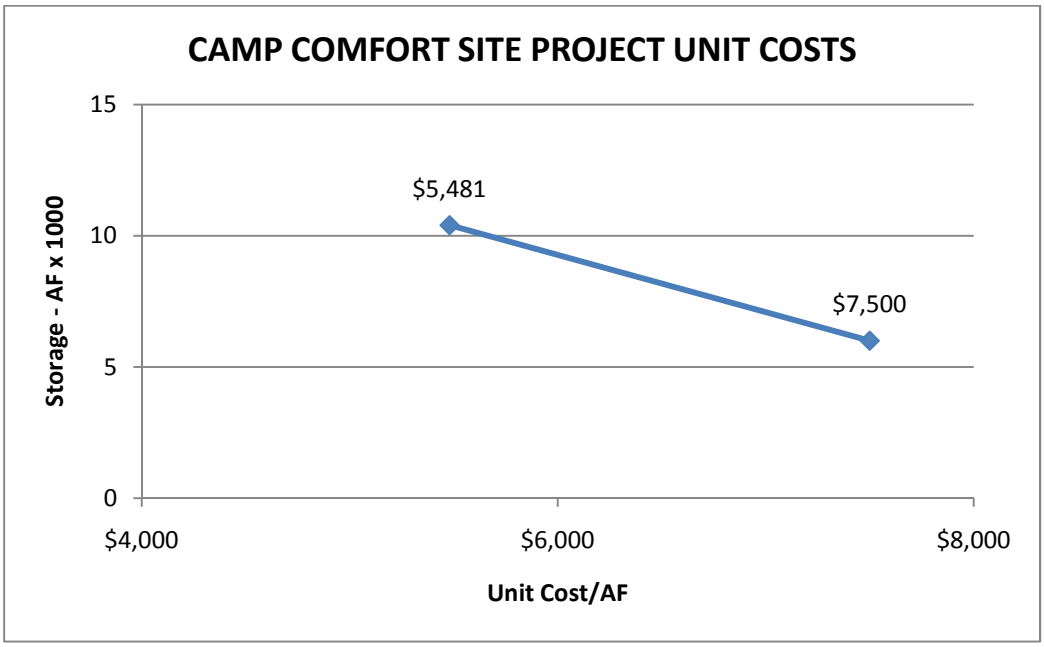

Figure 6.6-12 Camp Comfort Site Unit Costs

6.6.5.8 Summary

A multi-purpose reservoir could be constructed on the Camp Comfort site. The site appears to be geologically suitable for a reservoir. The site has several environmental issues. The dam and reservoir would be located on United States Forest Service lands. The site is well situated to meet needs of the Clear Creek basin.

The primary concerns are the cost of the project, the location on USFS lands, the close proximity to existing development, the inundation of approximately 2.5 miles of stream, and the existence of approximately 4 acres of wetlands. The preliminary cost estimate for a 10,400 acre-foot reservoir is approximately $57 million. The unit cost per acre-foot of storage is $5,480. The preliminary cost estimate for a 6,000 acre-foot reservoir is approximately $45 million. The unit cost per acre-foot of storage is $7,500.

6.6.6 Tie Hack Reservoir Enlargement

Tie Hack Reservoir is located approximately 11.5 miles west of the City of Buffalo as shown on Figure 6.6-13. It was built to a total storage of 2,425 acre-feet with 1,625 acre-feet of active storage in the late 1990s by the City of Buffalo. Studies conducted before that project construction indicated that the yield of a junior water right was not sufficiently firm to justify the cost of a larger reservoir. If the concern with the M&M water rights from Clear Creek were removed, the yield of an enlargement would be substantially better. The potential enlargement of Tie Hack Reservoir was investigated. The model results and gaging records below Tie Hack Reservoir indicate that 1,400 acre-feet per year could be available to be stored.

The existing Tie hack Reservoir land is owned by the City of Buffalo. The enlargement would require additional acquisition or easement from the U.S. Forest Service.

6.6.6.1 Dam and Reservoir

During the construction of Tie Hack Dam the right abutment alignment was changed due to unanticipated geological conditions. An enlargement of the dam would be constrained by the right abutment. The maximum dam raise feasible at the site would be approximately 20 feet. A dam raise of 20 feet would create an enlargement of 1,400 acre-feet. The enlargement would be constructed on the upstream side of the dam.

6.6.6.2 Wetland Impacts

The enlargement of the reservoir would inundate wetlands that have been established on the upper portions of the reservoir. These wetlands would have to be mitigated.

6.6.6.3 Outlet Works

The existing outlet works intake would be abandoned with the upstream raise. The conduit would be extended upstream and a new multi-level intake would be constructed. The existing control building and piping would be adequate for the 20 foot raise.

6.6.6.4 Spillway

The existing spillway would be extended 20 vertical feet to a new ogee crest as shown on Figure 6.6-14. The existing spillway chute is adequate for the enlargement.

6.6.6.5 Preliminary Design and Cost Estimates

The Tie Hack Dam could be raised with an upstream addition as shown on Figure 6.6-14. The spillway crest and dam crest would be raised by 20 feet to create the enlargement. The outlet works would be extended upstream and a new multi-level intake constructed.

FILE NAME: Upstream
SCALE: 1"=1000'
OPERATOR: NLW
DATE: 06/10
PROJECT NO. 571
TASK NO.:
LOCATION: BUFFALO, WY
PROJECT: CLEAR CREEK WATERSHED
SEND TO: VICTOR E. ANDERSON
PHONE: (307) 634-7848

REV	DESCRIPTION OF REVISION	BY	DATE
1	PRELIMINARY DESIGN	NLW	06/10

SCALE 1" = 1000'

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DESIGNED	NLW
DRAWN	NLW
CHECKED	VEA
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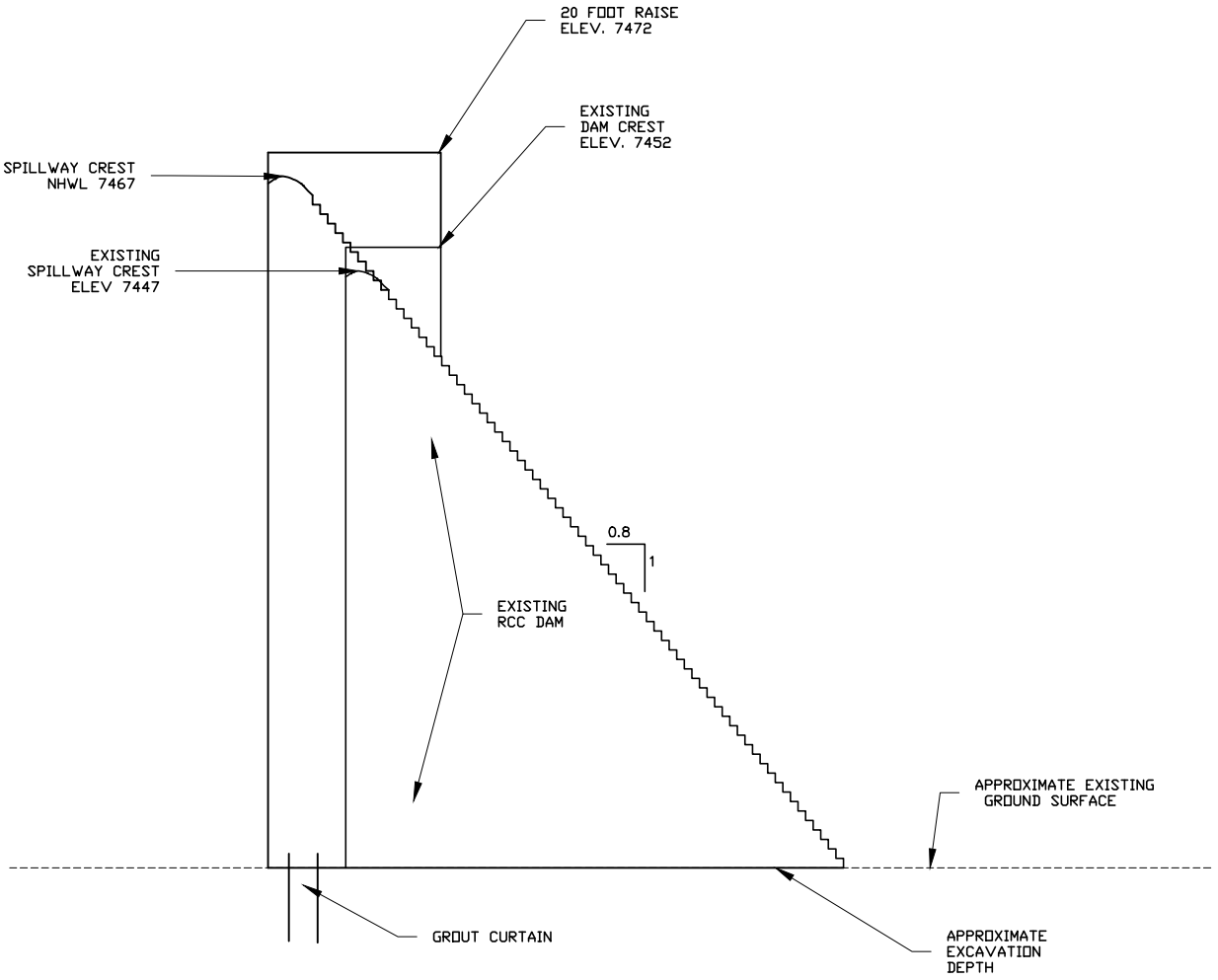
PROJECT MANAGER	VEA
DATE	06/10

CLEAR CREEK WATERSHED STUDY

TIE HACK RESRVOIR ENLARGEMENT

REVISION 1
PROJECT 571
DRAWING FIGURE 6.6-13



TYPICAL TIE HACK DAM ENLARGEMENT SECTION

SCALE 1"=40'

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CLEAR CREEK WATERSHED STUDY

TIE HACK DAM ENLARGEMENT
TYPICAL SECTION

REVISION 1

PROJECT 571

DRAWING

FIGURE 6.6-14

Cost estimates were developed for the 1,400 acre-feet enlargement as shown in Table 6.6-5. The estimated cost for the enlargement would be $12.0 million. The unit cost per acre-foot of storage for the enlargement would be $8,571 per acre-foot.

Table 6.6-5

Cost Estimate-Tie Hack Reservoir Enlargement

Enlargement Storage - 1,400 AF

No.	Task	Unit	Estimated Quantity	Unit Price	Total Cost
1	Mobilization	L.S.	--	--	$400,000.00
2	Foundation Excavation	C.Y.	10,000	20	$200,000.00
3	RCC	C.Y.	50,000	100	$5,000,000.00
4	Spillway	L.S.	--	--	$500,000.00
5	Outlet Works Mod.	L.S.	--	--	$1,000,000.00
6	Wetland Mitigation	L.S.	--	--	$250,000.00
7	Grouting	L.F.	10,000	75	$750,000.00
				Construction Cost Sub-Total:	$8,100,000.00
				10% Engineering:	$810,000.00
				Sub-Total:	$8,910,000.00
				15% Contingency:	$1,336,500.00
				CONSTRUCTION COST TOTAL:	$10,246,500.00
				Preparation of Final Designs and Specifications:	$750,000.00
				Permitting:	$500,000.00
				Legal Fees:	$100,000.00
				Acquisition of Access and Rights of Way:	$100,000.00
				TOTAL PROJECT COSTS:	**$11,696,500.00**
				USE:	**$12 M**

6.6.6.6 Summary

The increased storage and yield of a Tie Hack Reservoir enlargement is too small to address the shortages and needs of this study. The potential enlargement could be more appropriate for the future needs of the City of Buffalo.

6.7 FRENCH CREEK STORAGE ALTERNATIVES

Potential storage in French Creek was previously investigated by States West Water Resources Corp. in the report "Hopkins Producers Irrigation District Watershed/Water Storage Project, Level I Study" published in 2008. This study identified two promising potential storage sites in upper French Creek in the Big Horn National Forest as shown on Figure 6.7-1. The concern from the study was the availability of water for storage. French Creek has a relatively low yield. Water is transferred from the North Fork of Clear Creek to French Creek using the Four Lakes and French Creek Ditch Diversion.

6.7.1 Water Availability

Temporary stream gages were installed in Fall 2009 to assist in determining the water availability for French Creek Reservoirs. One gage was installed on French Creek at the US Forest Service boundary. The second gage was installed on the North Fork of Clear Creek below the Four Lakes and French Creek Ditch Diversion.

The gage information for Spring 2010 was utilized to estimate the potential available flow for a French Creek Reservoir. The information indicates that approximately 900 acre-feet of water could have been stored from the French Creek drainage. The gage information from the North Fork of Clear Creek indicated that the existing diversion capacity could have yielded approximately 1,400 acre-feet. An enlargement of the diversion could have yielded approximately 2,200 acre-feet. More years of record are needed to determine average availability of storage water. The relationship of the 2010 spring runoff to average conditions in not known. For purposes of comparison to other storage alternatives, a range of yields of 1,500 acre-feet to 3,500 acre-feet were analyzed.

6.7.2 Shortages

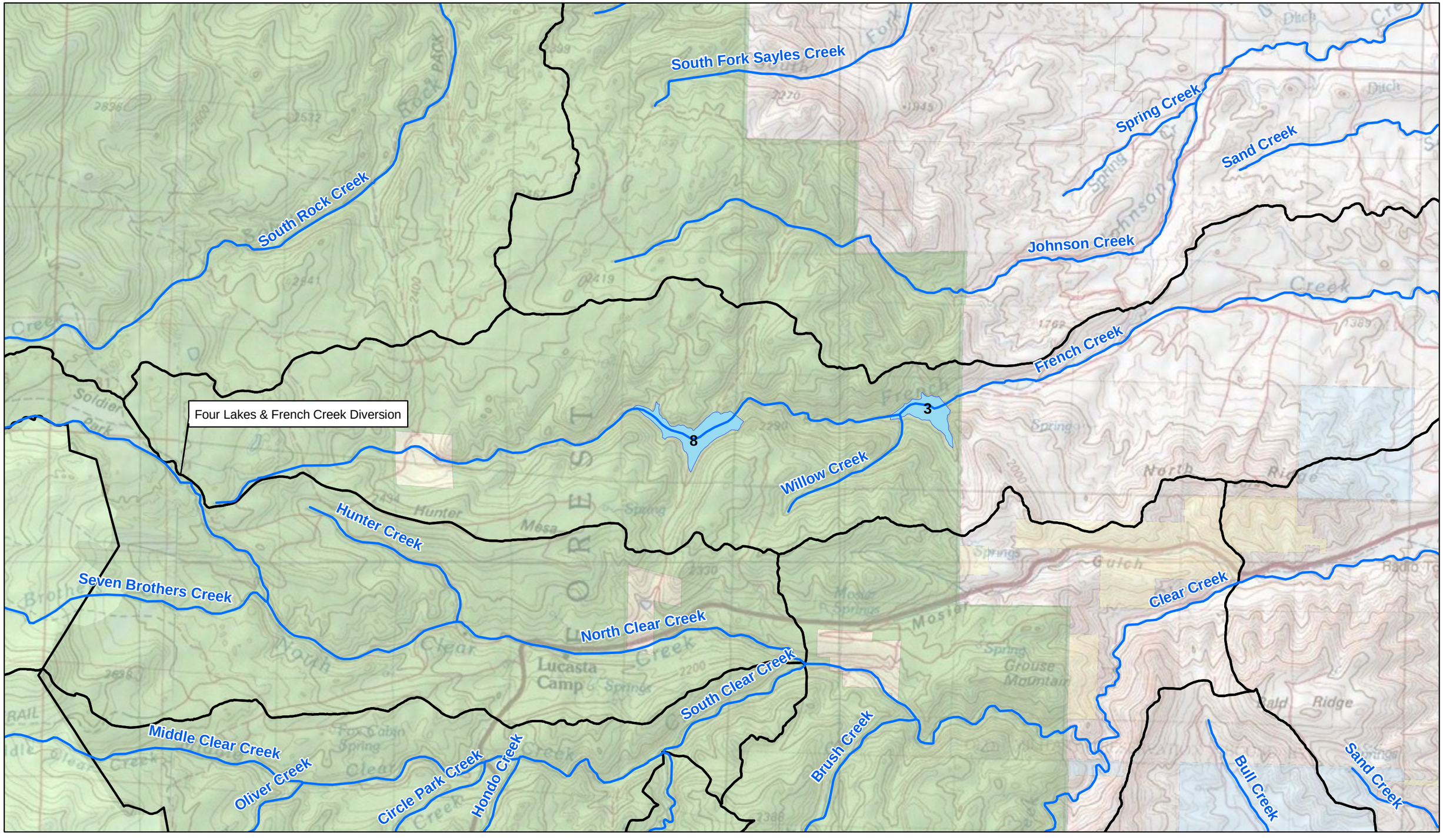
Irrigation shortages on French Creek and Johnson Creek could be met with storage on French Creek. The shortages have been estimated to be 2,500 acre-feet to 3,000 acre-feet.

6.7.3 Dams and Reservoirs Alternatives

The referenced report evaluated reservoir capacities of 2,500 acre-feet to 6,000 acre-feet for the two sites. The information on the alternative sites has been included in Appendix 6-D. The probable optimum size range of a reservoir would be 3,000 acre-feet to 4,000 acre-feet.

6.7.4 Preliminary Design and Cost Estimates

The preliminary design and cost estimates for the two sites from the French Creek report are included in Appendix 6-D. The total project costs and unit costs for the two storage sites are



N
W E
S

0 0.5 1
Miles

Legend

- Potential Site
- Streams
- Watershed Boundary

Land Ownership

- BUREAU OF LAND MANAGEMENT
- PRIVATE LANDS
- U.S.F.S. NATIONAL FOREST
- U.S.F.S. WILDERNESS AREA/SCENIC RIVER
- WYOMING STATE LAND

Figure 6.7-1
French Creek Reservoir Sites

summarized in Table 6.7-1. The information is shown graphically in Figure 6.7-2, 6.7-3, 6.7-4 and 6.7-5.

Storage in the French Creek reservoirs could be utilized for multiple purposes. Irrigation shortages on French Creek and Johnson Creek would be alleviated. A pipeline from the reservoir could deliver water to the City of Buffalo Water Treatment Plant and to Clear Creek above the city. The storage sites have high potential for recreational benefits.

Estimated project costs for reservoirs at the sites were developed in Appendix 6-D. The costs for the projects were updated to 2010 cost basis. The costs for the expected size range are summarized in Table 6.7-1.

Table 6.7-1
Cost Estimate - French Creek Potential Sites

Site 3	**Earthen Dam**	
Capacity (AF)	Total Project Cost	Unit Cost ($/AF)
3,000	$44.2 M	$14,740
5,500	$59.5 M	$10,820
Site 8	**RCC Dam**	
Capacity (AF)	Total Project Cost	Unit Cost ($/AF)
2,500	$32.1 M	$12,840
6,000	$55.2 M	$9,195
Site 8	**Earthen Dam**	
Capacity (AF)	Total Project Cost	Unit Cost ($/AF)
2,500	$21.9 M	$8,760
5,500	$39.9 M	$7,255

6.7.5 Multi-Purpose Potential

A French Creek Reservoir could be utilized for the purposes summarized below.

- Irrigation Supplemental Flows – The reservoir could supplement direct flow rights to meet irrigation shortages on French Creek and Johnson Creek.
- Reservoir Recreation – Incorporation of a recreation pool would create opportunities for flat water recreation.

6.7.6 Summary

Limited multi-purpose reservoirs could be constructed on the French Creek sites. The sites appear to be geologically suitable for reservoirs. The sites have minimal environmental issues.

The dam and reservoir would be located on United States Forest Service lands. The sites are well situated to meet needs in French Creek and Johnson Creek.

The primary concerns are the cost of the projects, the reservoir locations are on USFS lands and the inundation of approximately 0.7 miles of stream. The preliminary cost for a 5,500 acre-foot reservoir on Site 3 is approximately $59.5 million. The unit cost per acre-foot of storage would be $10,820. The preliminary cost for a 6,000 acre-foot reservoir on Site 8 is approximately $55.2 million. The unit cost per acre-foot of storage would be $9,195. The project costs and unit costs for the range of storage sizes at the two sites are shown on Figure 6.7-2 and 6.7-3.

6.7.7 Clear Creek Pipeline

Storage water from French Creek could be delivered by a pipeline to Clear Creek. The water could be delivered directly to the Buffalo Water Treatment Plant and to Clear Creek upstream of the current diversions.

The water delivery system to Clear Creek was preliminarily designed and cost estimates developed in Appendix 6-D. The estimated cost was $6 million for the pipeline project.

The availability of storage water for this purpose given the limited availability of supply is doubtful.

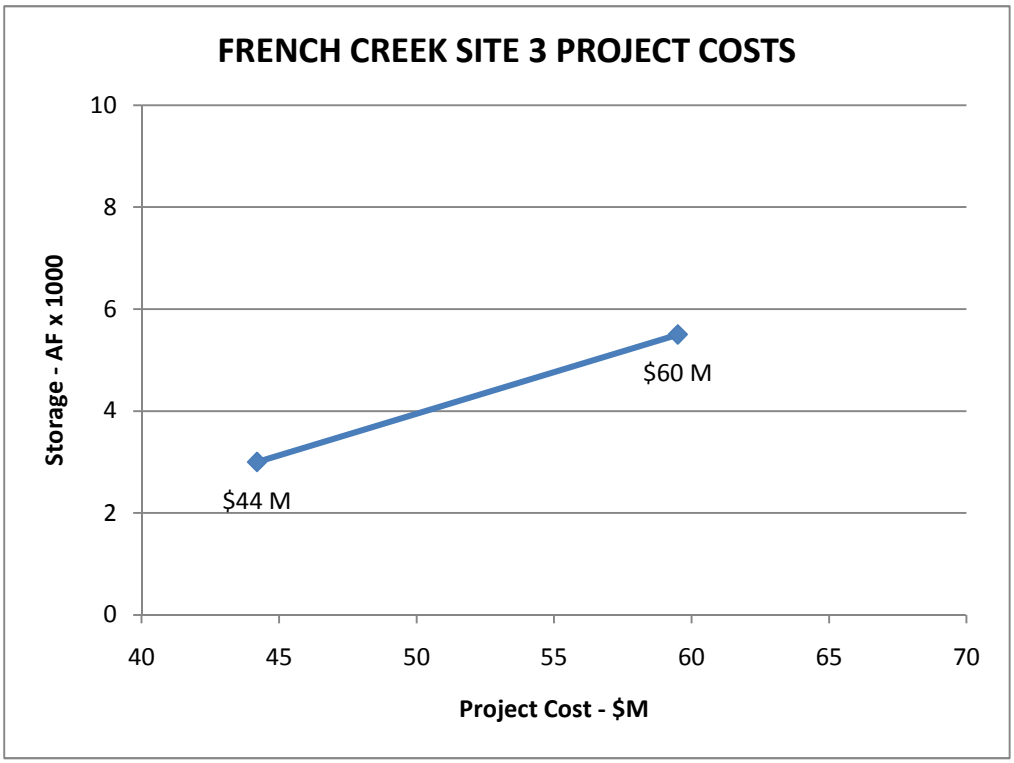


Figure 6.7-2 French Creek Site 3 Project Costs

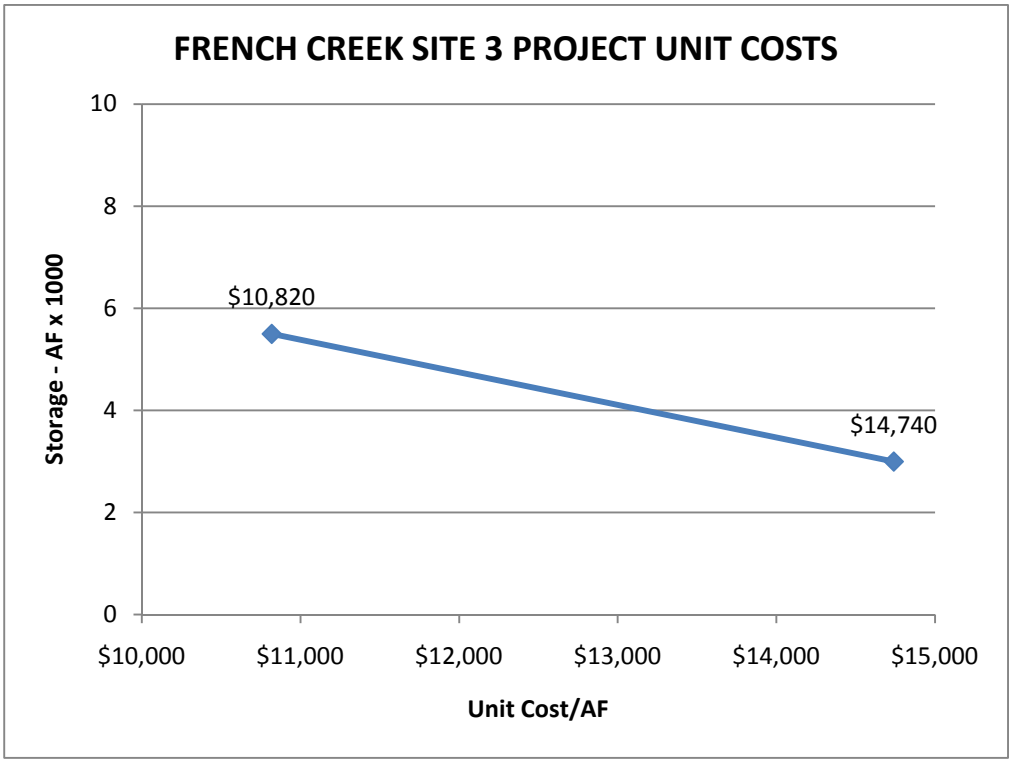


Figure 6.7-3 French Creek Site 3 Unit Costs

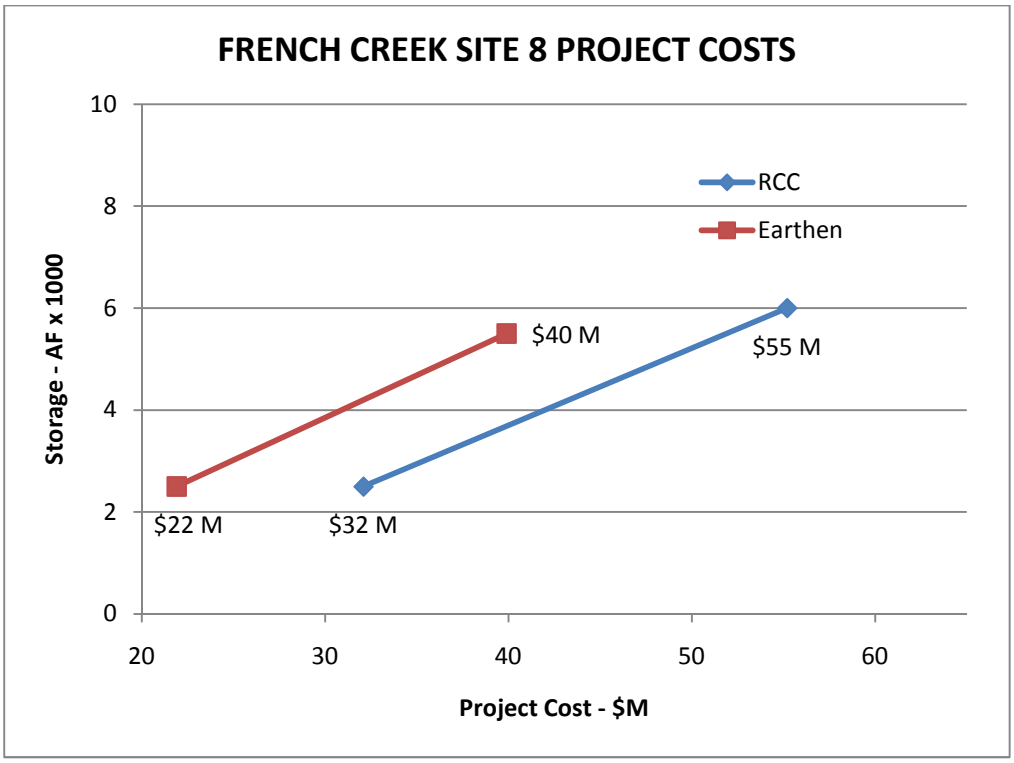


Figure 6.7-4 French Creek Site 8 Project Costs

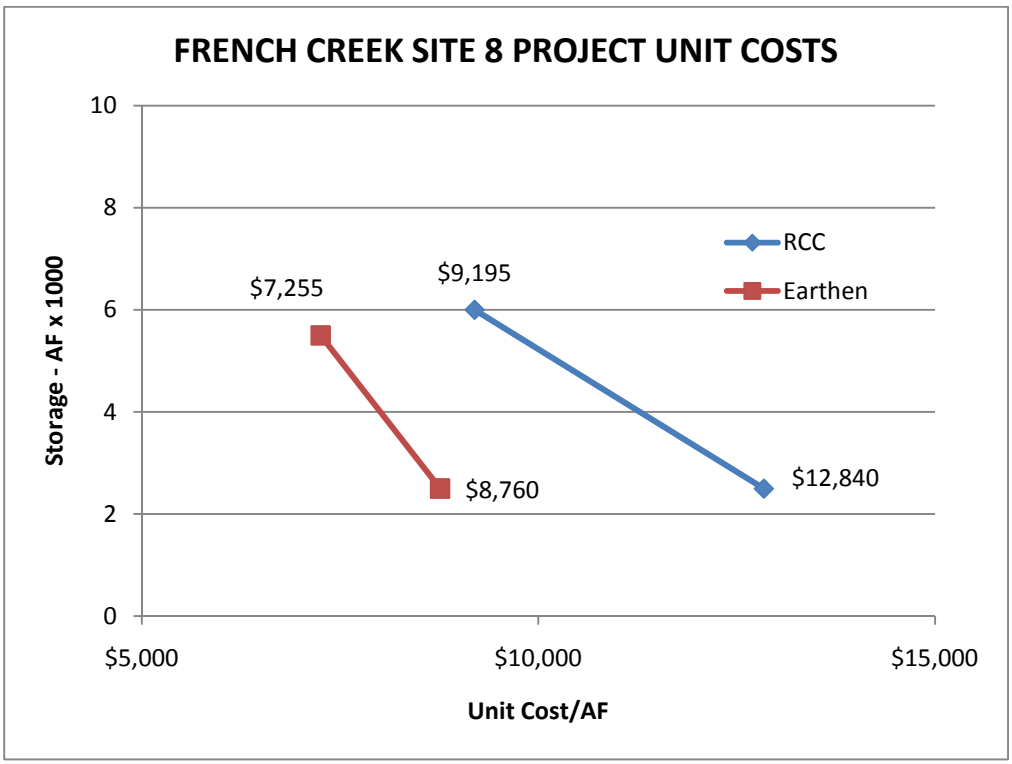


Figure 6.7-5 French Creek Site 8 Unit Costs

6.8 ROCK CREEK STORAGE AND SUPPLY ALTERNATIVES

Reservoir alternatives to meet identified needs in the Rock Creek drainage were investigated. As discussed previously, the reservoir alternatives were screened for those that would best meet the needs. The Rock Creek drainage benefits from water transfers from South Piney Creek through the Rock Creek and South Piney Ditch Diversion. This ditch transfers water from Willow Park Reservoir and Cloud Peak Reservoir.

The alternatives analyzed include the following as shown on Figure 6.8-1:

North Rock Creek Reservoir Site #101
Willow Park Reservoir Enlargement

An alternative to serve the ditches on the tributaries on the west side of Rock Creek was also analyzed.

6.8.1 Rock Creek and South Piney Ditch Diversion

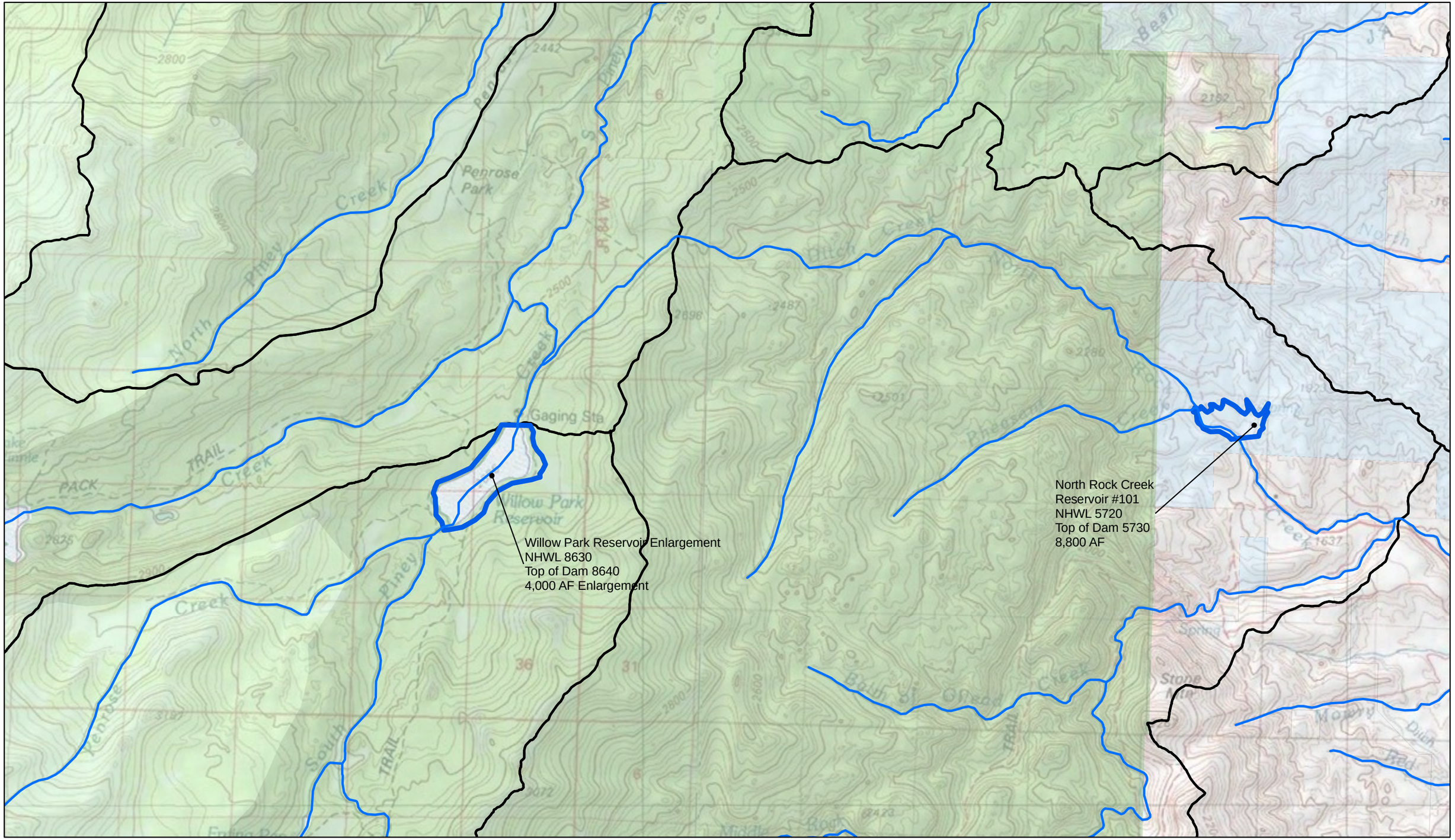
This diversion and canal is utilized to divert water from South Piney Creek into the Rock Creek basin. The system was inspected for potential rehabilitation as reported in Section 5. This system diverts approximately 5,200 acre-feet per year on the average. Losses in the system have been estimated at 25 percent or approximately 1,300 acre-feet per year. The reduction of seepage losses should be considered with any alternative for storage and supply in the Rock Creek Basin.

6.8.2 Water Availability

The storage alternatives would depend on available water in South Piney Creek. Available gaging information indicates that approximately 12,000 acre-feet of water could be available for storage.

6.8.3 Shortages

The Rock Creek basin has minimal shortages on the main stem due to the storage on South Piney Creek. The shortages are primarily on the west tributaries such as Sayles Creek, Johnson Creek, Sand Creek and French Creek. The estimated average annual shortages are 2,500 acre-feet to 3,500 acre-feet.



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Land Ownership

- BUREAU OF LAND MANAGEMENT
- PRIVATE LANDS
- U.S.F.S. NATIONAL FOREST
- U.S.F.S. WILDERNESS AREA/SCENIC RIVER
- WYOMING STATE LAND

Figure 1.2-1
Wyoming Overview:
Clear Creek Watershed

6.8.4 North rock creek reservoir site #101

This potential site would be located on North Rock Creek approximately 0.75 miles from the Big Horn National Forest Boundary on State land as shown on Figure 6.8-1. The site could impound in excess of 8,800 acre-feet as indicated on the stage storage curve, Figure 6.8-3. The reservoir would be filled by enlargement of the Rock Creek and South Piney Ditch Diversion. The reservoir could supply supplemental water to meet shortages on all of the ditches on Rock Creek.

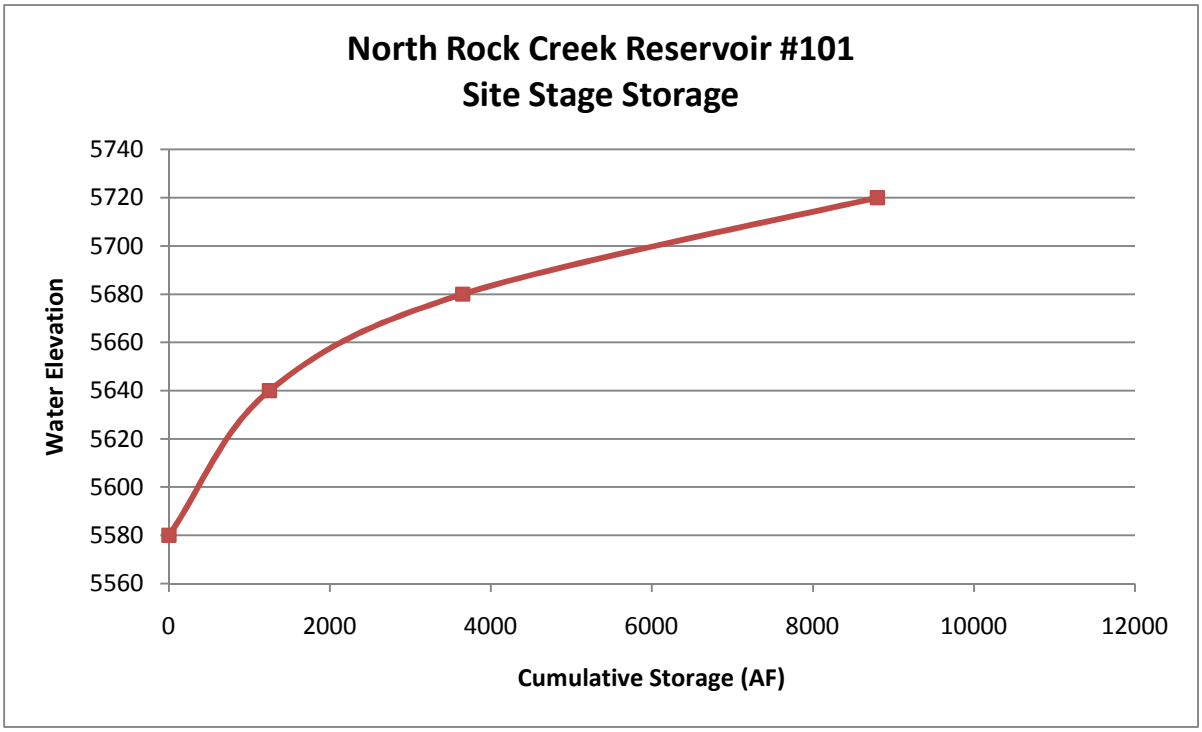


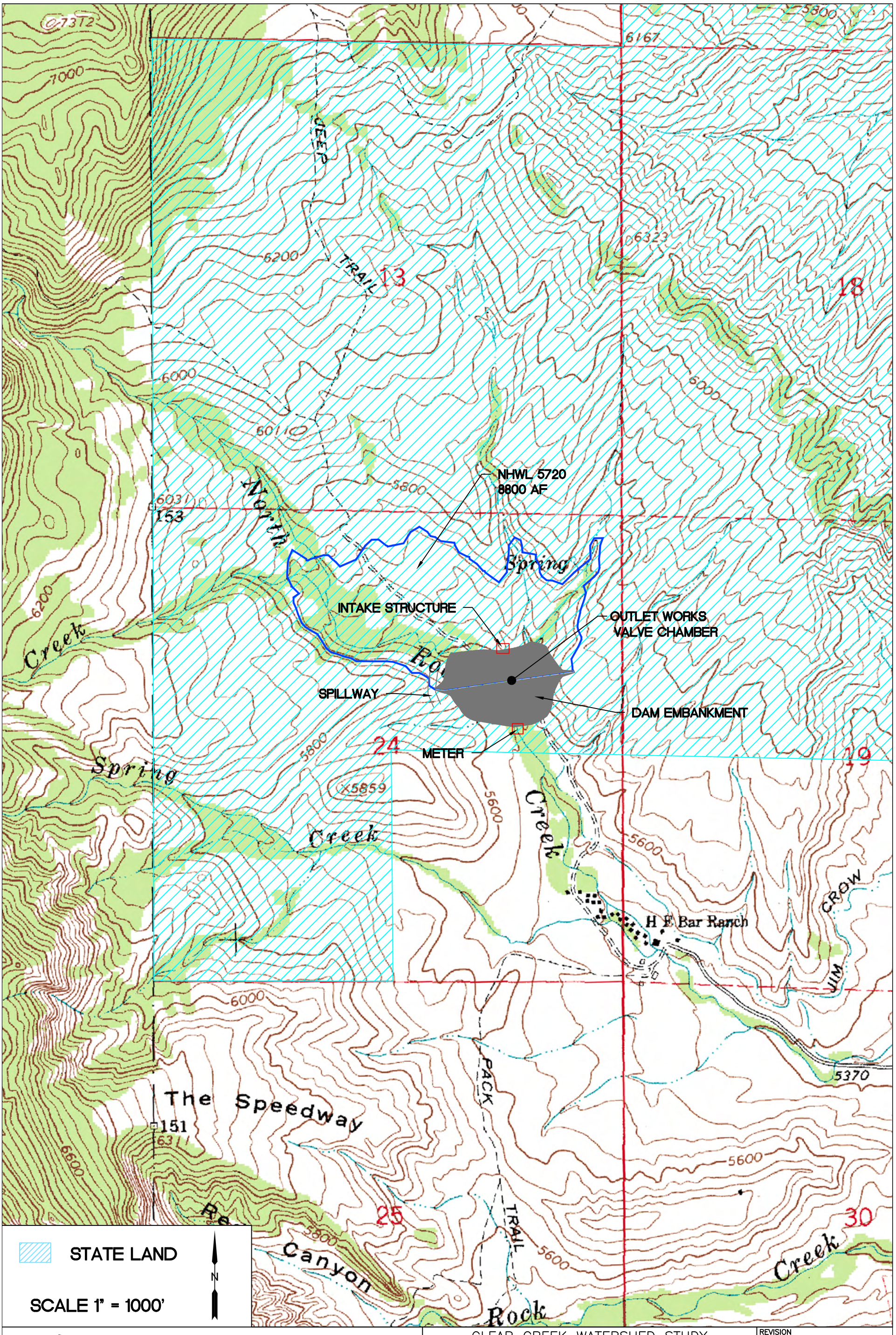
Figure 6.8-3 North Rock Creek Reservoir #101 Stage Storage Curve

6.8.4.1 Dam and Reservoir

A dam required to impound 8,800 acre-feet of storage would be a maximum of 150 feet high with a crest length of 2,200 feet as shown in Figure 6.8-2. The reservoir would inundate approximately 130 acres at full capacity. The characteristics of the site are summarized below. A range of reservoir sizes were analyzed. In addition to the 8,800 acre-feet capacity, a capacity of 3,650 acre-feet was analyzed. The project shown on the Figures are the 8,800 acre-feet capacity reservoir.

6.8.4.2 Outlet Works

The outlet works would be constructed to discharge to Rock Creek. A minimum capacity of 200 cfs at normal minimum pool would be required. A 48 inch outlet pipe would be constructed.



STATE LAND

SCALE 1" = 1000'

N

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(307) 634-7848
FAX: (307) 634-7851

CLEAR CREEK WATERSHED STUDY

NORTH ROCK CREEK RESERVOIR
SITE #101 SYSTEM

REVISION 1

PROJECT 571

DRAWING

FIGURE 6.8-2

6.8.4.3 Geologic/Geotechnical

The North Rock Creek Reservoir #101 site was inspected by the project geologist. The complete Geologic/Geotechnical report is included in Appendix 6-B. The specific observations and recommendations for the North Rock Creek Reservoir #101 site are summarized below.

Bedrock was not identified at the ground surface; however, based on published mapping the general bedrock geology at the dam site and reservoir is likely the Cody Shale, Mesaverde Formation, Bearpaw Shale, and Lance and Fox Hills Formations. The Cody Shale is likely located on the right abutment and consists of shale interbedded with sandstone and bentonite. The Mesaverde Formation is likely located within the valley bottom and consists of sandstone with interbedded siltstone and shale. Surficial soils at the site include alluvium and colluviums consisting of sand, silt, clay, and gravel. A large fault-bounded landslide is located about 0.5 miles northwest of the site. The nearest mapped faults are located within 1 mile west of the site.

An appropriate dam type for the site geology would be a homogeneous or zoned earthfill dam. Geologic conditions that have the greatest potential impact to design are:

- Depth to a suitable foundation below the entire embankment footprint.
- The stability of the landslide upstream of the reservoir.
- The ability to process large rocks present on site into riprap and riprap bedding.
- The ability to process bedrock materials into suitable fill materials.
- Thickness of terrace gravels on the right abutment and the ability to process these materials into filter and bedding materials.

6.8.4.4 Emergency Spillway

The North Rock Creek Reservoir #101 site has a drainage area of approximately 16.2 square miles. The reservoir would be designed to store flood flows up to the 100-year event. Very large flood flows up to the Probable Maximum Flood (PMF) would be passed through an unlined emergency spillway.

6.8.4.5 Environmental

The site has a fairly substantial amount of cottonwood gallery forest with an understory of willow/alder riparian area that would likely require mitigation. Although no wetlands show up on NWI maps, there are narrow wetland fringes along the stream in places and one wetland was found on a bench above the stream that is approximately 0.06 acres in size. Wetland impacts would likely be minimal.

According to Wyoming Game and Fish Department data, this site is within elk crucial winter/yearlong range and mule deer winter/yearlong range.

The complete environmental report is included in Appendix 6-C.

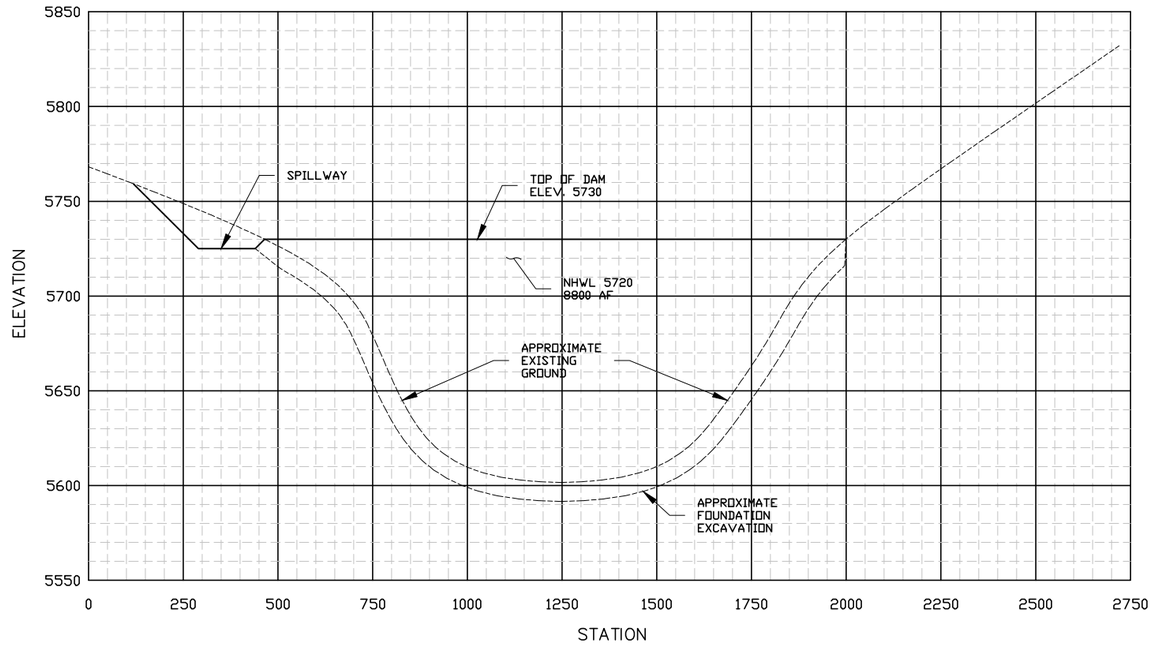
6.8.4.6 Preliminary Design and Cost Estimate

The potential reservoir on North Rock Creek was preliminary designed and cost estimates developed. The cost estimates were developed for reservoir sizes of 3,650 acre-feet and 8,800 acre-feet. The project costs and unit costs for this size range are shown on Table 6.8-1 and 6.8-2. The typical dam section and centerline profile are shown on Figure 6.8-4.

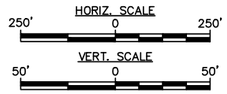
Quantities for the dam and reservoir were developed. The estimated cost for an 8,800 acre-foot reservoir project would be $60 million. The approximate cost per acre-foot of storage is $6,818. The preliminary cost estimate for a 3,650 acre-foot reservoir would be $32 million. The approximate cost per acre-foot of this storage is $8,767.

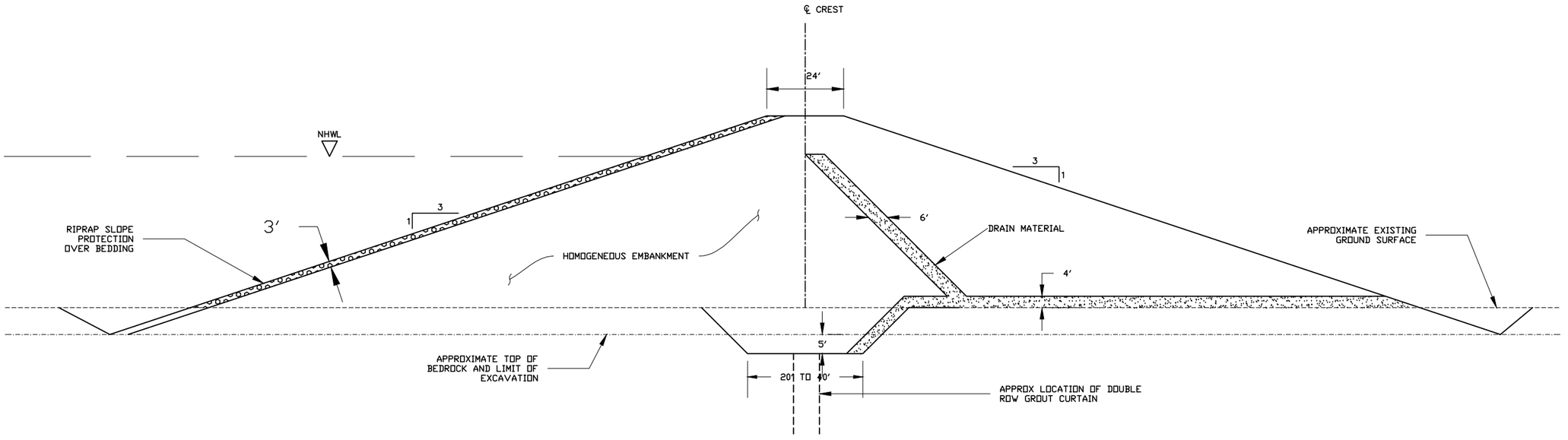
Table 6.8-1
Cost Estimate-Upper Rock Creek Reservoir #101
Storage -3,650 AF Top Dam Elevation - 5690

No.	Task	Unit	Estimated Quantity	Unit Price	Total Cost
1	Mobilization	L.S.	--	--	$1,000,000.00
2	Foundation Excavation	C.Y.	600,000	4	$2,400,000.00
3	Embankment	C.Y.	1,800,000	8	$14,400,000.00
4	Outlet Works	L.S.	--	--	$2,500,000.00
5	Spillway	L.S.	--	--	$1,500,000.00
6	Access Road	Mi	5	200,000	$1,000,000.00
				Construction Cost Sub-Total:	$22,800,000.00
				10% Engineering:	$2,280,000.00
				Sub-Total:	$25,080,000.00
				15% Contingency:	$3,762,000.00
				CONSTRUCTION COST TOTAL:	$28,842,000.00
				Preparation of Final Designs and Specifications:	$1,750,000.00
				Permitting:	$500,000.00
				Legal Fees:	$100,000.00
				Acquisition of Access and Rights of Way:	$400,000.00
				TOTAL PROJECT COSTS:	**$31,592,000.00**
				USE:	**$32 M**



DAM CENTERLINE PROFILE





TYPICAL HOMOGENEOUS DAM SECTION

FILE NAME: DAM SECTION | OPERATOR: NLW | PROJECT NO: 571 | LOCATION: BUFFALO, WY | SEND TO: VICTOR E. ANDERSON
SCALE: N/A | DATE: 06/10 | TASK NO: 001-263 | PROJECT: CLEAR CREEK WATERSHED | PHONE: (307) 634-7848

REV	DESCRIPTION OF REVISION	BY	DATE
1	PRELIMINARY DESIGN	NLW	06/10

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RESOURCES CORPORATION

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CHEYENNE, WYOMING 82001
(307) 634-7848
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WARNING

IF THIS BAR DOES NOT MEASURE 1/2" THEN DRAWING IS NOT TO SCALE

DESIGNED	NLW
DRAWN	NLW
CHECKED	VEA
PEER REVIEWED	VEA
PROJECT MANAGER	VEA
DATE	06/10

CLEAR CREEK WATERSHED STUDY

NORTH ROCK CREEK RESERVOIR #101 DETAILS

REVISION 1
PROJECT 571
DRAWING FIGURE 6.8-4

Table 6.8-2

Cost Estimate-Upper Rock Creek Reservoir #101

Storage -8,800 AF Top Dam Elevation - 5730

No.	Task	Unit	Estimated Quantity	Unit Price	Total Cost
1	Mobilization	L.S.	--	--	$2,000,000.00
2	Foundation Excavation	C.Y.	800,000	4	$3,200,000.00
3	Embankment	C.Y.	4,000,000	8	$32,000,000.00
4	Outlet Works	L.S.	--	--	$3,500,000.00
5	Spillway	L.S.	--	--	$2,500,000.00
6	Access Road	Mi	5	200,000	$1,000,000.00
				Construction Cost Sub-Total:	$44,200,000.00
				10% Engineering:	$4,420,000.00
				Sub-Total:	$48,620,000.00
				15% Contingency:	$7,293,000.00
				CONSTRUCTION COST TOTAL:	$55,913,000.00
				Preparation of Final Designs and Specifications:	$3,000,000.00
				Permitting:	$500,000.00
				Legal Fees:	$100,000.00
				Acquisition of Access and Rights of Way:	$500,000.00
				TOTAL PROJECT COSTS:	**$60,013,000.00**
				USE:	**$60 M**

6.8.4.7 Multi-Purpose Potential

The North Rock Creek Reservoir #101 could be utilized for the purposes summarized below.

- Irrigation Supplementary Flows – The reservoir could supplement direct flow rights to meet irrigation shortages.
- Exchange Potential – There would be opportunity to benefit irrigation ditches not directly tributary by water exchange.
- Reservoir Recreation – Incorporation of a recreation pool would create opportunities for flat water recreation. The proximity to the City of Buffalo and year-round access would make the reservoir a valuable opportunity.
- Flood Control – The reservoir could provide flood control for North Rock Creek.

6.8.4.8 Summary

A multi-purpose reservoir could be constructed on the North Rock Creek Reservoir #101 site. The site appears to be geologically suitable for a reservoir. The site has some environmental issues. The dam and reservoir would be located on State of Wyoming land. The site is well situated to meet needs of the Rock Creek drainage.

The primary concern is the cost of the project. Preliminary costs for an 8,800 acre-foot reservoir with supply canal and delivery pipeline is approximately $60 million. The unit cost per acre-foot of storage is $6,818. The preliminary costs for a 3,650 acre-feet reservoir is approximately $32 million. The unit cost per acre-foot of storage is $8,767. The graphical project costs and unit costs are shown on Figure 6.8-5 and 6.8-6.

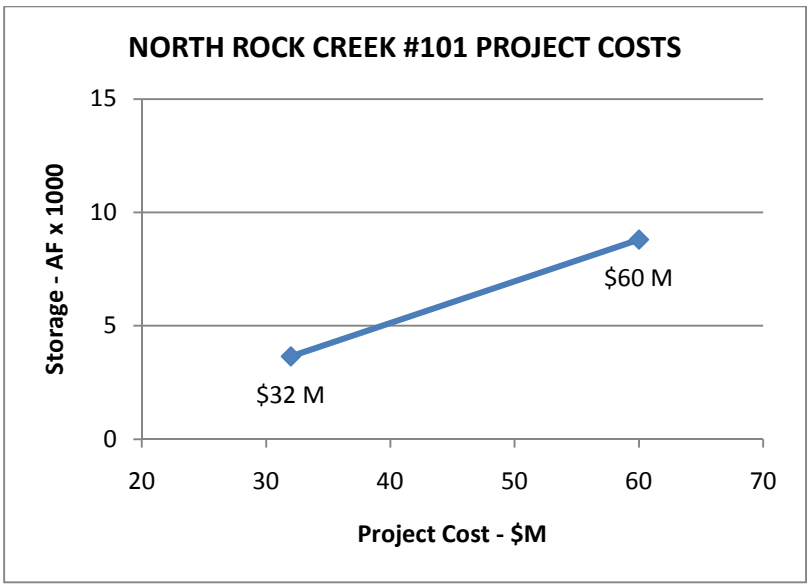


Figure 6.8-5 North Rock Creek #101 Project Costs

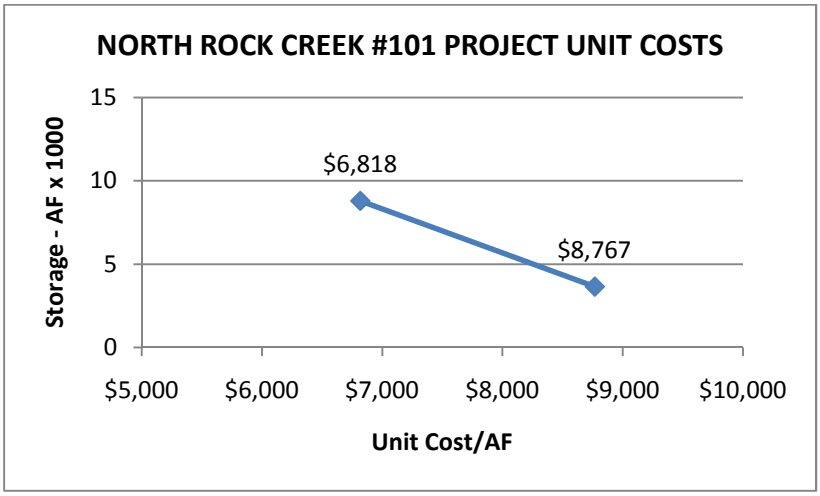


Figure 6.8-6 North Rock Creek #101 Unit Costs

6.8.5 Willow Park Reservoir Enlargement

Willow Park Reservoir is an existing reservoir for irrigation supplementary flow. The users are located such that lands are served by discharging flows through South Piney Creek and also transferred to Rock Creek by the Rock Creek and South Piney Ditch Diversion. The reservoir currently stores 4,457 acre-feet of water. The potential for enlargement of the reservoir has been investigated here in.

The reservoir is located on Big Horn National Forest lands and is accessed by a restricted Forest Service road. The current owners of the reservoir are supportive of the potential for enlargement.

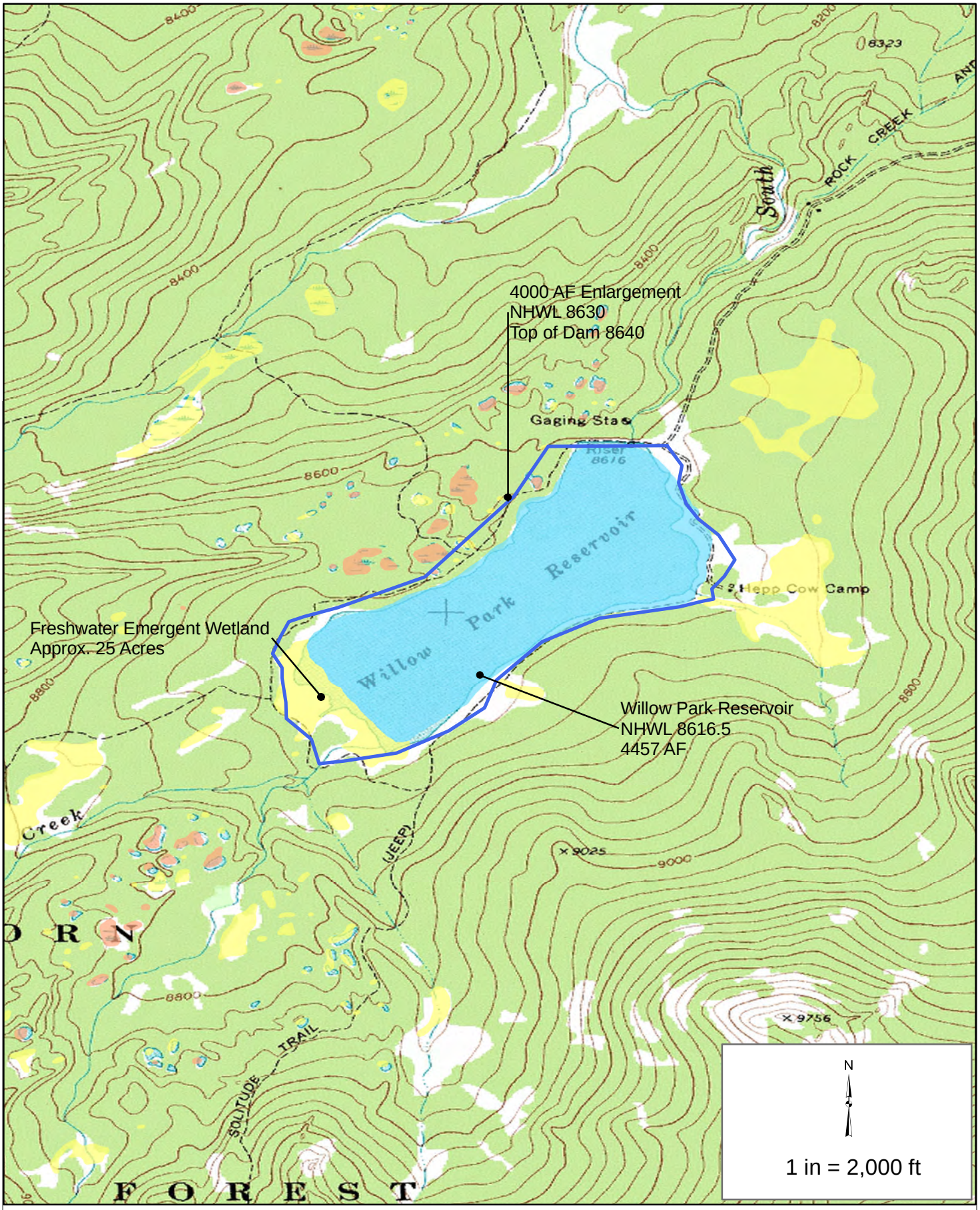
6.8.5.1 Dam and Reservoir

A dam enlargement required to impound 4,000 acre-feet of storage would be a maximum of 15 feet high with a crest length of 6,000 feet as shown in Figure 6.8-7. The reservoir would inundate approximately 275 acres at full capacity. The characteristics of the site are summarized below.

6.8.5.2 Environmental

Willow Park is a high-elevation (8700') site within the Bighorn National Forest. It is located primarily in a conifer (pine, spruce and fir) forest ecosystem. This site would entail enlarging the dam of an existing reservoir on South Piney Creek to increase storage. According to the NWI map, there are 24.88 acres of existing wetlands along the upper end of the existing reservoir , most of which would be inundated by reservoir enlargement. The presence of these wetlands was verified during a field visit to the site. In addition, several test pits were excavated to examine soils within the wetlands. Although soils varied, peat was present in the upper layer of all test pits. In some locations the peat was fairly shallow (e.g., <6 inches) and underlain by either cobble, sand or clay. However, in numerous locations the peat was as thick as the shovel (~18 inches). Therefore, much of the existing wetland would be classified as a fen. The hydrology source for these wetlands is not the existing reservoir, but comes from inflow above the reservoir in the form of seeps. In addition to the wetland area at the upper end of the reservoir, other small areas of wetland exist within the potential inundation area; however, impacts to these wetlands would be small (~1-1.5 acres).

According to the WGFD, this site is within spring/summer/fall range for mule deer and elk but there is no crucial habitat for any big game. South Piney Creek is a Green Ribbon trout steam, meaning it is a trout fishery of local importance with less than 50 lbs of trout per mile. Willow Park reservoir is also a trout fishery.



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CLEAR CREEK WATERSHED STUDY

WILLOW PARK RESERVOIR
ENLARGEMENT

REVISION 1

PROJECT 571

DRAWING

Figure 6.8-7

6.8.5.3 Summary

An enlargement of Willow Park Reservoir would not be feasible due to the large acreage of fen type wetlands that would be inundated. Fen type wetlands cannot be mitigated due to the extremely long time required to develop.

The NRCS completed a Probable Maximum Precipitation (PMP) analysis for the Willow Park Reservoir watershed. The report estimated the probable maximum flood (PMF) flow at Cloud Peak Reservoir and Willow Park Reservoir and determined that the spillways for each reservoir were not capable of passing the PMF (NRCS 2006). The report states that "if a PMP event occurs, both the Cloud Peak and Willow Park Reservoir embankments will be overtopped and most likely fail (NRCS 2006)". Increasing the capacity of the emergency spillway at Willow Park Reservoir could be accomplished by combinations of the following:

- Increasing the head on the channel by excavating the channel to a greater depth or by increasing the height of the embankment
- Improve the channel's roughness coefficient by concrete lining or other method
- Increasing the slope of the discharge channel
- Increasing the width of the discharge channel
- Incorporate an ogee crest into the spillway channel
- Construct a second emergency spillway around the left abutment

Additional analysis is required to determine the feasibility and most efficient, cost effective method of increasing the hydraulic capacity of the emergency spillway.

6.8.6 North Rock Creek Pipeline

Storage water from the North Rock Creek Reservoir or Willow Park Enlargement could be conveyed in a new pipeline to serve lands irrigated from South Rock Creek, Sayles Creek, Johnson Creek, Sand Creek and French Creek. The approximate route of the pipeline is shown on Figure 6.8-8. Water would be purchased from Willow Park Reservoir and Cloud Peak Reservoirs and conveyed in the system. The total irrigation acreage that could be served by this project is approximately 5,500 acres. The shortages for the lands that could be served was estimated to be 2,500 acre-feet to 3,500 acre-feet per year.

The capacity of the system from the North Fork diversion would be approximately 50 cfs. The capacity of the system decreases as water needs are met. The system could carry approximately 25 cfs to French Creek.

6.8.6.1 Multi-Purpose Opportunities

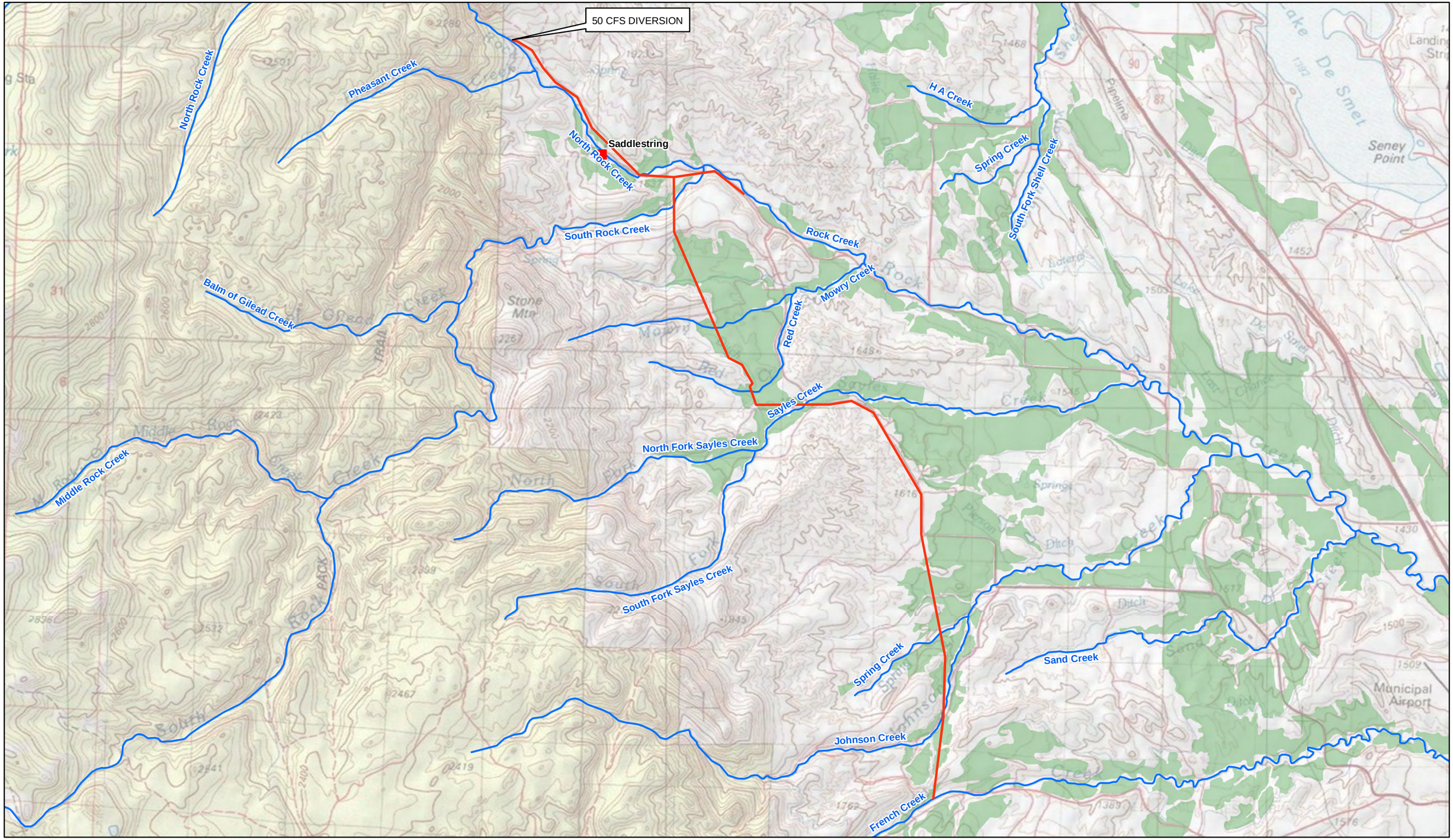
The opportunities for this alternative to benefit other purposes involve the Four Lakes and French Creek Diversion from the North Fork of Clear Creek to French Creek. Present operation involves large diversions typically starting in early June. These diversions continue until the water rights are regulated or the end of irrigation season on September 30.

French Creek has been eroded and enlarged by the peak diversion flows for a length of approximately 9 miles. Immediately below the US Forest Service boundary, flows are diverted to ditches serving French Creek, Sand Creek and Johnson Creek. When the diversion into French Creek is shut off, the flows in French Creek very rapidly decrease.

The North Fork of Clear Creek is dewatered drastically in late summer by the diversion to French Creek. The creek is substantially reduced in flow for a distance of 8 miles to where the Middle Fork of Clear Creek joins.

Availability of late season storage water for Johnson Creek and French Creek could be utilized to improve the fishery values of both drainages. Reductions in the water diverted from the North Fork of Clear Creek would improve the late season flows in Clear Creek. The regulation of the diversion in dry years leads to sudden dewatering of French Creek. The construction of storage on upper Clear Creek could eliminate the sudden flow changes due to regulation. French Creek fish habitat could be improved by stream restoration and dependable late season flows.

The opportunities are present to improve major reaches of high altitude trout fishery. The reaches are on US Forest Service lands and are fully accessible to the public.



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Legend

- Cities
- North Rock Pipeline
- Streams
- Irrigated Lands

Figure 6.8-8
North Rock Creek Pipeline

6.8.6.2 Preliminary Design and Cost Estimate

Preliminary design was prepared for the pipeline alternative and cost estimates were developed. The pipeline would serve most of the lands with sufficient pressure to operate sprinklers. The cost estimate for the alternative is $6.0 million as shown on Table 6.8-3.

Based upon the WWDC standard financing of 2/3 grant and 1/3 loan at 4 percent interest for 20 years, the annual costs would be approximately $147,000 per year. The unit costs for the pipeline system would be approximately $26.73 per irrigated acre and $49 per acre-foot of water.

Table 6.8-3
Cost Estimate- North Rock Creek Pipeline

No.	Task	Unit	Estimated Quantity	Unit Price	Total Cost
1	Mobilization	L.S.	--	--	$200,000.00
2	Diversion Structure	L.S.	--	--	$100,000.00
3	36" Pipeline	L.F.	10,500	100	$1,050,000.00
4	30" Pipeline	L.F.	18,000	75	$1,350,000.00
5	24" Pipeline	L.F.	26,500	50	$1,325,000.00
6	Structures	Ea	25	10,000	$250,000.00
				Construction Cost Sub-Total:	$4,275,000.00
				10% Engineering:	$427,500.00
				Sub-Total:	$4,702,500.00
				15% Contingency:	$705,375.00
				CONSTRUCTION COST TOTAL:	$5,407,875.00
				Preparation of Final Designs and Specifications:	$300,000.00
				Permitting:	$100,000.00
				Legal Fees:	$50,000.00
				Acquisition of Access and Rights of Way:	$150,000.00
				TOTAL PROJECT COSTS:	**$6,007,875.00**
				USE:	**$6 M**

6.8.6.3 Summary

The pipeline alternative would not be affordable for irrigators at the standard WWDC funding scenario. Additional funding assistance would be required to economically justify the project. The potential fishery enhancement on the North Fork of Clear Creek and French Creek could be the justification for better funding scenarios.

6.9 SUMMARY OF STORAGE OPPORTUNITIES

The investigation of potential storage opportunities in the Clear Creek basin resulted in conceptual analysis of eleven sites. These sites were investigated by the project team for hydrologic adequacy, geotechnical conditions, environmental effects, and suitability for the purpose and need.

6.9.1 Estimated Costs

The estimated costs for the representative sizes of reservoirs were developed. These costs are summarized in Table 6.9-1. The estimated costs are total project costs including all foreseeable items. The total project costs include supply and delivery systems for off-channel storage sites. Also included are engineering costs, land acquisition costs, environmental mitigation costs, and legal costs. The costs were developed to reflect 2011 prices. One cost which has not been included is the potential purchase of existing storage rights. The valuation of water rights is a very complex analysis and should only be done by well qualified appraisers. This analysis would normally be done in more advanced studies.

Table 6.9-1 Storage Cost Summary

Site	Size (AF)	Cost in Millions	Unit Cost
Upper Middle Clear Creek Reservoir	5,000	$68.0	$13,600
Lower Middle Clear Creek Reservoir	3,800	$80.0	$21,052
Camp Comfort Reservoir	10,400	$57.0	$5,481
Tie Hack Reservoir Enlargement	1,400	$12.0	$8,570
Sand Creek Reservoir	4,000	$27.0	$6,750
Sand Creek Reservoir	8,000	$39.0	$4,875
Bench Reservoir	3,500	$33.0	$9,429
Bull Creek Reservoir	4,000	$32.0	$8,000
Bull Creek Reservoir	9,170	$41.0	$4,471
French Creek Reservoir #3	3,000	$44.2	$14,730
French Creek Reservoir #3	5,500	$59.5	$10,820
French Creek Reservoir #8	2,500	$21.9	$8,760
French Creek Reservoir #8	5,500	$39.9	$7,255
North Rock Creek Reservoir	8,800	$60.0	$6,818
North Rock Creek Reservoir	3,650	$32.0	$8,767
Lake DeSmet Transfer – Existing pipeline	4,000	$2.9	$725
Lake DeSmet Transfer – Canal	4,000	$4.1	$1,025

6.9.2 Storage Evaluation Matrix

To evaluate the non-monetary factors for reservoir suitability, a matrix was developed as shown in Table 6.9-2. This matrix values items such as ability to meet needs, land ownership, environmental issues, geotechnical feasibility, multi-purpose potential, and ability to permit. Each of the items was assigned a weight based on the importance of the item for this project. Weights of 10 to 40 were assigned as shown in the table. Each potential reservoir site was assigned a value of 0 to 10 for each item with high values being most favorable. The value assigned to the reservoir site evaluation item was multiplied by the weighted importance of each item. The scores were then totaled to develop overall reservoir site evaluation. The factors considered for the matrix are as follows:

1. Ability to Meet Needs
   This factor considers the irrigation shortages downstream of the potential reservoir and ability of the reservoir to meet those needs. These considerations are based on the hydrologic model developed for this project.
2. Land Ownership
   This factor considers the potential difficulties of obtaining rights-of-way and acquisition or easements for lands for the dam, reservoir, and access ways.
3. Environmental Impacts
   This factor considers the potential environmental impacts of developing the dam and reservoir site. This consideration includes inundation of wetlands, riparian areas, wildlife habitat, bird nesting sites, endangered species, and other potential impacts.
4. Geotechnical Feasibility
   This factor considers the geological and geotechnical aspects of the dam and reservoir site. The initial investigation sought to find any potential "fatal flaws" that could effectively prohibit the construction of a dam and reservoir.
5. Flood Control
   This factor considers the flood control benefits of the potential reservoirs.
6. Multiple Use Potential
   This factor considers the potential for the reservoir site to be used for purposes other than irrigation water storage. This consideration includes secondary uses such as recreation, fish habitat, environmental enhancement, and hydropower production.
7. Ability to Permit
   This factor considers the regulatory potential for permitting the dam and reservoir site. Also included in this factor is consideration of potential negative public comment.
8. Cost
   This factor considers the costs to design and build the prospective dam, reservoir, and associated facilities. Included in this consideration is the unit cost of the reservoir (cost ÷ storage).

Table 6.9-2 Clear Creek Storage Evaluation Matrix

Site	Size (AF)	Ability to Meet Needs	Land Ownership	Envir. Issues	Geotechnical Feasibility	Flood Control	Multi-Purpose Potential	Ability to Permit	Relative Cost	Total Score	Comments
Weight		**40**	**20**	**30**	**20**	**20**	**40**	**40**	**20**		
Upper Middle Clear Creek Reservoir	5,000	6	2	4	6	4	6	2	2	960	Note 1
Lower Middle Clear Creek Reservoir	3,800	4	2	4	6	4	4	2	2	800	Note 1
Camp Comfort Reservoir	10,400	10	4	4	6	8	10	4	8	1,600	Note 1
Tie Hack Reservoir Enlargement	1,400	2	2	4	8	2	2	4	5	780	Note 1
Sand Creek Reservoir	8,000	8	6	8	6	4	8	10	8	1,760	Note 1
Bench Reservoir	3,500	4	10	10	6	0	2	10	6	1,380	Note 1
Bull Creek Reservoir	9,170	8	10	8	6	4	8	10	8	1,840	Note 1
French Creek Reservoir #3	5,500	8	4	6	6	4	10	4	2	1,380	Note 1
French Creek Reservoir #8	5,500	8	2	6	6	4	10	2	6	1,340	Note 1
Willow Park Enlargement	4,000									0	Fatal Flaw-Fen Wetlands
North Rock Creek Reservoir	6,600	6	4	6	4	4	6	4	2	1,100	

Note 1 - The feasibility of new storage in the Clear Creek basin is dependant on the utilization of the M&M Ranch water rights from Clear Creek. If the water rights are fully utilized, insufficient water would be available for new storage projects.

6.9.3 Summary of Results

The results of the evaluation indicated that the Bull Creek Reservoir project, the Sand Creek Reservoir project, and the Camp Comfort reservoir project are the most favorable. The unit costs of storage and the storage evaluation matrix are very close for these three projects. Preliminary designs for the Sand Creek and Bull Creek sites are included in detail in Appendix 6-E.

The water supply issue as discussed in Section 6.2.5 could have the effect of a fatal flaw for the Clear Creek storage projects. The dependable yield of storage reservoirs would be substantially reduced if the M&M Ranch water rights were fully utilized to deliver water to Lake DeSmet.

The analyses of the storage projects assumed most optimistically that the M&M Ranch Clear Creek water rights would not be utilized to transfer water to Lake DeSmet. Under that assumption, the yields of the reservoir projects analyzed would be very dependable.

6.10 RESERVOIR ECONOMIC ANALYSIS

This section of the storage investigation analyzed the economics of the storage project that was most economical and also the highest scoring project in the storage evaluation matrix. The Bull Creek site at a size of 9,170 acre-feet was used to analyze project benefits, project benefit-cost ratio, and project financing including the agricultural ability to pay.

The Bull Creek project could have additional benefits including flood control and water quality improvements which were not included in the analysis. The water utilized for instream flows through the City of Buffalo should have additional benefits downstream of the City as instream flow or supplemental irrigation water. This benefit was not evaluated because of the unknown demand. These additional potential benefits will cause the benefit cost ratio to be conservative.

6.10.1 Project Benefits

6.10.1.1 Introduction

This section generally describes the direct and indirect economic benefits that would accrue to area residents, the regional economy, and the State of Wyoming from additional storage in the project study area. The detailed analysis in this section concentrates on the Bull Creek site as representing the best alternative for a multipurpose project that would provide a wide array of benefits to area residents as well as recreational visitors. A 9,200 acre-foot reservoir at this site could provide up to 3,500 acre-feet of additional irrigation diversions for Clear Creek irrigators as well as reduce seepage losses by an estimated 2,000 acre-feet annually. Additionally, it could provide a conservation pool and also supply 17 cfs of late summer flows in a seven and one-half mile reach of the Clear Creek channel through the Town of Buffalo, which is currently often de-watered. It would also provide flat-water recreation opportunities at the reservoir site with year-round access. The economic benefits attributable to the reservoir are analyzed below.

6.10.1.2 Direct Irrigation Benefits

Direct irrigation benefits would accrue to local irrigators because the reservoir would supply additional water to supplement current supplies on existing irrigated acreage. The reservoir could make an additional 3,500 acre-feet of water available for diversion by local irrigation canals, as well as reduce canal seepage by an estimated 2,000 acre-feet annually. Thus, total irrigation canal diversions would increase by an estimated 5,500 acre-feet annually.

The direct benefits associated with this additional irrigation water consist of the increased income that would accrue to irrigators using the water. The first step in estimating that increase is to estimate how crop yields would change in response to additional irrigation water.

Such yield changes are best estimated using crop-water production functions relating crop water use (in the form of evapotranspiration, or ET) and yield. Crop water production functions are typically developed using the results of carefully monitored field experiments, and then modified to reflect differences in elevation, climate, and other variables.

Irrigated crops along Clear Creek consist primarily of alfalfa, grass hay, and pasture. Precise acreages of these crops are not known, but a rough estimate of 50 percent grass and 50 percent alfalfa acreage was used to develop the benefit estimates in this report. Crop-water production functions are the same for grass hay and grass pasture, but alfalfa production functions are different because it typically displays a higher yield response to additional water than grass.

Crop-water production functions for hay and alfalfa from two areas of Wyoming were analyzed and adapted to the project area to produce benefit estimates. The first set of production functions was developed for the North Platte River Basin in eastern Wyoming near Torrington[1] and the second set was developed for the Green River Basin in the Eden-Farson area[2]. The Eden-Farson data are probably more representative of climatic conditions and crop production practices in the Clear Creek drainage, but the Torrington data are more recent and provide a mechanism for incorporating productivity increases over time. Thus, the Torrington production functions were used to adjust the Eden-Farson data for productivity changes over time, resulting in the estimates shown below:

Grass Yield / Acre-foot ET = 1.65 tons

Alfalfa Yield / Acre-foot ET = 2.31 tons

These estimates indicate that for every acre-foot of additional water consumptively used by grass crops (ET), the resulting yield increase averages 1.65 tons. The corresponding for alfalfa crops is 2.31 tons of additional yield.

To estimate the amount of additional ET that would result from the operation of the Bull Creek site, canal seepage and field irrigation efficiency estimates are necessary. For this analysis, canal delivery efficiencies are assumed to average 80 percent, meaning that (5,500 x 0.80) = 4,400 acre-feet of additional water delivered to irrigators. Assuming 50 percent average field

[1] Watts, Gary L and David Brookshire. 2000. *An Economic Analysis of Impacts to Nebraska and Wyoming from post-1945 Changes in North Platte River Basin Water Use.* Report to the Wyoming Attorney General. February.
[2] Wyoming Water Research Center. 1987. *Development of Evapotranspiration Crop Coefficients.* Available at http:/library.wrds.uwyo.edu/wrp/87-06/ch-03.html.

irrigation efficiency means that crops would consume 2,200 acre-feet of additional water annually in the form of ET. The resulting production increase can be estimated as:

(0.5) (2,200) (1.65) + (0.5) (2,200) (2.31) = 4,360 tons

The annual value of these production increases was estimated using average hay prices in Wyoming over the last three years as reported in Wyoming Agricultural Statistics.[3] That price is $104 per ton. The market value of annual forage production increase is thus (4,360 tons) x ($104) = $453,400.

To estimate direct irrigation benefits, any marginal increase in production costs must be subtracted from the value of the increased production. Marginal cost increases can vary depending upon the type of crop (hay or alfalfa) and the way it is harvested (baled, stacked, or grazed). Marginal cost increases in this case should be small, however, because most irrigated fields would probably be harvested the same number of times with or without the additional water. For this reason, a modest marginal cost increase of five dollars per ton was assumed for this study.

The total cost increase associated with the new production is estimated to be (4,360 tons) x ($5) = $21,800. Subtracting that figure from the production value increase derived above yields an annual net benefit estimate of $431,600. That figure is an estimate of the annual direct irrigation benefits associated with the Bull Creek site. The present value of that annual benefit is $9.27 million, assuming a 50-year project life and a four percent discount rate.

6.10.1.3 Indirect Irrigation Benefits

Indirect benefits, often referred to as secondary benefits, stem from the multiplier effect of new sources of income in a regional economy. In the present case, the availability of additional irrigation water would allow irrigators to increase livestock production, thus increasing their income when livestock is sold. Much of that increased income would be spent in the region, causing income to grow in other sectors of the local economy. This indirect income growth is also benefit attributable to project construction.[4]

The Bureau of Economic Analysis of the U.S. Department of Commerce periodically produces estimates of indirect income multipliers for Wyoming's agricultural sector. These multipliers estimate the total income increase in Wyoming from a one-dollar increase in farm income. Their latest estimate of this multiplier is 2.63; meaning that for each dollar of additional farm

[3] Wyoming Agricultural Statistics Service. 2009. *Wyoming Agricultural Statistics.*

[4] Although some economists disagree with the inclusion of indirect benefits in project evaluations, it is appropriate when considering state funded projects using severance taxes on minerals exported from the state.

income, total income in Wyoming increases by $2.63.[5] The $2.63 increase consists of a one-dollar increase in farm income plus a $1.63 increase in indirect income in other economic sectors.

Applying this multiplier to the direct irrigation benefits in the previous section results in a total irrigation benefit estimate of $1.14 million annually. The present value of that benefit is $24.4 million, assuming a 50-year project life and a four percent discount rate.

6.10.1.4 Instream Flow Benefits

A seven and one-half mile stretch of Clear Creek flowing through the Town of Buffalo is often de-watered during summer months due to upstream diversions. This stretch of creek is an aesthetic asset to the community that could be greatly enhanced by continuous flows during summer months. There is public access to the creek over much of this reach and there would be significant recreation benefits to continuous flows that would support a quality trout fishery. The quality of hiking, picnicking, and other forms of streamside recreation would also be enhanced by instream flows during summer months.

Conducting an extensive site-specific analysis of instream flow values in Buffalo is beyond the scope of the current study. Numerous instream flow studies have been conducted in the U.S. over the past 30 years, however, and their results can be used to generate a ballpark estimate of instream flow values in Buffalo. These studies vary widely in terms of geographic setting, the size of stream under consideration, methods of analysis used, units used to report results, and values reported. A quick overview of the methods used and the results of previous studies is given below.

Methods

Four primary analytical methods have been used to estimate instream flow values in previous studies:

- The Travel Cost Method (TCM)
- The Contingent Valuation Method (CVM)
- The Hedonic Price Method (HPM)
- The Market Price Approach

The Travel Cost Method involves observing actual recreational behavior for streams with varying flow levels. Typically, people are willing to travel further and spend more time and

[5] U.S. Department of Commerce. 2007. *Regional Multipliers: A User Guide for the Regional Input-Output Modeling System (RIMS II).* Bureau of Economic Analysis.

money on recreation when there is sufficient stream flow to support their chosen pursuit. By analyzing this type of data statistically, economists have been able to infer the economic value of instream flows in some situations.

Contingent Valuation Method studies are based upon household surveys of stated willingness to pay for instream flows. That is, survey participants are asked how much they would pay to ensure a certain flow regime in a nearby stream. The study results are typically reported in terms of dollars per household (as a monthly or annual payment), and then multiplied by the number of households in the stream's vicinity to estimate an overall economic value. Although CVM studies can contain biases (saying you are willing to pay something is different than actually paying it), economists have learned how to minimize these biases and carefully conducted CVM studies are now widely accepted as valid benefit estimates.

The third method, the HPM, derives benefit estimates by analyzing actual prices for assets that are affected by instream flows. For example, residential home values tend to be higher along streams with consistent flows than along dry streambeds or where no stream is present. By analyzing property value differences among otherwise similar properties, it is also possible to derive estimates of instream flow values in certain settings.

Finally, some states allow water rights to be transferred to instream flow uses through limited market transactions. In such cases, the market price of the water being transferred is a useful indicator of the economic benefits associated with the transfer.

Results

In addition to using different methods, previous studies have reported instream flow value results in different ways. Some studies, for example, report average annual benefits per household for maintaining an arbitrary instream flow regime. A 1996 New Mexico statewide CVM study reported an average annual benefit of $29 per household for protecting instream flows in the Rio Grande.[6] A similar Colorado study reported statewide willingness to pay for instream flows in the Poudre, Elk, and Colorado Rivers at $40 per household.[7]

Other studies report values in terms of flows changes, as measured in acre-feet or cfs. A survey by Platt reported annual benefit estimates ranging from a low of a few cents per acre-foot to a high of over $140 per acre-foot for a high quality trout fishery.[8] Recent market price transactions in Idaho have been in the range or $75 to $100 per acre-foot annually, while in

[6] R.P. Berrens, A.K. Bohara, C.L.Silva, D. Brookshire, and M. McKee. 2000. *Contingent Values for New Mexico Instream Flows.* Journal of Environmental Management. Vol. 58.

[7] John B. Loomis. 2007. *Estimating the Public's Values for Instream Flow: Economic Techniques and Dollar Values.* Journal of the American Water Resources Association. Vol. 43.

[8] Jonathon Platt. 2001. *Economic valuation of Instream Flows.* U.S. Department of the Interior, Bureau of Reclamation. April.

2005, a conservation group in Colorado paid $162.50 per acre-foot to lease 800 acre-feet of water for summer recreational use in the Colorado River.[9]

A 1987 Hedonic Price study in New Mexico estimated the economic cost of de-watering a stretch of Ruidoso River (a stream of comparable size to Clear Creek) at $10.4 million dollars.[10]

None of these studies are directly comparable to the situation with Clear Creek in Buffalo, but they do provide some guidance. First, previous studies indicate that water to enhance trout fisheries is among the most valuable water in most of the studies. Furthermore, the first incremental amount needed to establish and maintain a trout fishery is more highly valued than additional flows in the same reach. Both of these findings indicate that instream flow benefits along Clear Creek should be valued at the higher end of the range of values found in previous studies.

Analysis

The proposed Bull Creek Reservoir site would increase flows in a seven and one-half mile long stretch of Clear Creek through Buffalo by an average of 2,000 acre-feet annually. Based upon recent market transactions and CVM studies for high quality fisheries, it seems reasonable to value that water at $150 per acre-foot annually. Total annual benefits associated with the instream flow would thus be $300,000. The present value of that benefit stream over 50 years using a four percent discount rate is $6.4 million.

As a crosscheck on this estimate, it seems reasonable to assume that the per-household benefit for households in the vicinity of the stream is $50 annually. Using the roughly 3,000 households in Buffalo as a base, and a $50 per household benefit, we get an annual benefit estimate of $150,000. This estimate understates total benefits, however, because it ignores residents of rural Johnson County and nearby Campbell and Sheridan Counties, who would also benefit from public access to a good trout fishery. So would thousands of summer tourists who visit Buffalo and surrounding areas.

Estimating benefits associated with these additional households and tourists is difficult. Assume, however, that households in Sheridan, Campbell, and rural Johnson Counties would benefit by five dollars per year from instream flows in Clear Creek. With approximately 25,000 additional households benefiting at five dollars each, the annual instream flow benefit would increase by $125,000 annually to $275,000. In addition, Buffalo hosts a large number or tourists each year. It seems reasonable to assume that tourism in Buffalo would benefit by at least $75,000 annually from instream flows through town. This assumption results in a

[9] B. Berwyn. 2005. *Water Trust Finalizes First Sale.* Summit Daily News. June 3.

[10] David S. Brookshire and Gary L. Watts. 1987. *Economic Impacts of the Proposed Rinconada Unit Diversions – Mescalero Apache Indian Reservation.* Report to the Village of Ruidoso, New Mexico. August.

$350,000 annual total benefit estimate and $7.5 million present value estimate. This estimate is in the same ballpark as the $6.4 million estimate derived using a per acre-foot approach. For purposes of this analysis, the midpoint of the two estimates, or $7.0 million, was used to estimate instream flow benefits. This estimate is still less than that derived for a similar stream reach in New Mexico using the HPM, but the local population density is somewhat higher in the New Mexico case.

6.10.1.5 Reservoir Recreation Benefits

A dam at the Bull Creek site would result in a 265 surface-acre reservoir that is 100 feet deep when full. At maximum draw down the 9,200 acre-foot reservoir would be 60 feet deep and cover 70 surface acres. With year-round access, the reservoir has the potential to provide flat-water recreational opportunities in the summer and ice fishing in the winter.

Like most small reservoirs in rural areas of Wyoming, the Bull Creek Reservoir would probably be utilized mainly by Wyoming residents. As a result, recreational activity at the reservoir would not pump a significant amount of new money into the state economy, but would increase the well-being of its recreational users. In economic jargon, this increase in well-being is called consumer surplus because consumers are not required to pay for it directly. Projecting recreational usage and multiplying by an average value of consumer surplus associated with each visit can thus provide an estimate of the economic benefits of a Bull Creek recreation site.

Projecting recreational usage is difficult because it depends on numerous variables that are not well known prior to project development, including the quality of the fishery that may develop, the level of recreational facilities to be included in the final development plan, and the uniqueness of the site relative to other sites available in the area. Also, state and federal agencies dealing with recreation seldom collect recreational activity data for smaller reservoirs in rural areas.

In spite of these difficulties, previous studies and actual visitation data from other sites in Wyoming suggest that smaller reservoirs such as Bull Creek may generate in the range of 20 to 25 visitor days of usage annually per surface acre.[11] This study uses a mid-point estimate of 22.5 activity days per surface-acre for purposes of benefit estimation. Assuming the reservoir averages 200 surface-acres during the recreation season implies an annual usage rate of 4,500 visitor days.

[11] See, for example, Gannett Fleming. 2003. *Little Snake River Dams Level II Study.* Report to the WWDC. July. Local sources also report that Lake DeSmet averages 17 visitor days per surface acre while Tie Hack Reservoir averages almost 50 visitor days per acre annually.

The value of these visitor days can be estimated from numerous studies of that topic at other recreational facilities. A study by Loomis (2005) provides average consumer surplus estimates for numerous site specific studies conducted in the intermountain region from 1967 to 2003, expressed in 2004 dollars.[12] The mean value for fishing from these studies is $49.57, while boating and water skiing are valued at $62.33 per activity day. Assuming two fishing days for each boating/water skiing day implies an average activity day value of $53.78 in 2004 dollars. Updating that value to 2010 dollars gives a current estimate of $70.69 per activity day. Multiplied by 4,500 visitor days annually, this value projects to an annual recreational benefit of $318,100. The present value of that annual stream of benefits is $6.8 million using a four percent discount rate and a 50- year project life.

This estimate is, of course, dependent upon the reservoir's ability to support a viable fishery and the development of a boat ramp and associated recreational facilities at the site, among other things.

6.10.1.6 Benefit-Cost Ratio

The estimated present value of direct and indirect irrigation benefits, instream flow benefits, and flat-water recreation benefits for the Bull Creek site is $38.2 million. When compared to an estimated construction cost of $41.0 million, the benefit-cost ratio for the project is 0.93.

6.10.2 Project Financing

6.10.2.1 Introduction

This subsection considers funding scenarios for the Bull Creek site based upon WWDC assistance and a local project sponsor. As discussed previously, the Lake DeSmet and Sheridan County Conservation Districts are not legal entities recognized by the WWDC to receive Level II, Phase III funding, so a new entity would have to be formed for that purpose. This section assumes such an entity will be formed and as such will be eligible for WWDC grants and loans. Under current guidelines, WWDC grants are available for up to 67 percent of certain projects costs, with loans available for remaining costs for up to 50 years at four percent interest.

The Bull Creek site provides some interesting financial planning challenges because its benefits would accrue to a wide group of individuals both in and out of the planning region, many of whom could not easily be assessed fees to repay project costs. For example, many people would benefit from aesthetic and recreational opportunities associated with instream flows along Clear Creek in Buffalo, but there is no easy way to assess fees for project repayment. The

[12] The Intermountain Region includes Arizona, Colorado, Idaho, Kansas, Montana, Nebraska, New Mexico, North Dakota, South Dakota, Utah, and Wyoming.

same argument applies to businesses and individuals in the area that would see their incomes increase because of the multiplier effect of increased agricultural income. Although some project costs could be repaid through recreation fees at the reservoir site, such fees are unpopular and would be costly to collect. As a result, most of the revenue to repay the local portion of project costs would have to come from irrigators who benefit from the project, as discussed below.

6.10.2.2 Agricultural Ability to Pay

This section discusses the ability of local irrigators to pay for a portion of the project's cost in return for the supplemental irrigation water that would be made available. Because the project is multipurpose, it would be unrealistic to expect irrigators to assume total financial responsibility for project costs. In fact, of the $38.2 million of potential benefits identified above, only about $9.3 million are direct irrigation benefits that would accrue to local irrigators. The other $28.9 million in benefits accrue to the public in terms of increased recreational opportunities, aesthetic improvements due to minimum stream flows in Clear Creek through Buffalo, and increased employment and earnings in the regional and state economies from the multiplier effect of increased agricultural income.

The $9.3 million in direct irrigation benefits represent an upper bound on irrigator's ability to pay for the additional water. If all of these benefits were dedicated to project cost repayment, they would cover about 23 percent of project costs. This scenario is unrealistic, however, because it would leave irrigators with no incentive to participate in the project. In fact, there would be a significant disincentive to do so because irrigators would be locked into long-term contracts that could force them to lose money in the future if conditions change.

A more realistic way of approaching the ability-to-pay issue is to look at indicators of willingness to pay for irrigation water in other settings. Most previous willingness to pay studies for the WWDC have found irrigators willing to pay in the range of $5 to $25 per acre-foot for late season irrigation water, depending upon the circumstances. The higher end of that range is associated with higher valued crops in lower elevation settings, while the lower figures are for high elevation grass hay and pasture. For the Clear Creek drainage, a willingness to pay estimate of $10 per acre-foot seems reasonable. That figure is in fact the rate set locally for irrigation storage water sales from Lake DeSmet.

Assuming that the 5,500 acre-feet of supplemental water made available by the project would be sold at $10 per acre-foot means that local revenues to repay project costs would average $55,000 annually. Under current WWDC guidelines, the sponsor's share of annual project costs would be approximately $630,500 annually. Realistically, project construction would require

the State to assume a much larger portion of project costs than specified by current WWDC guidelines.

6.10.3 Summary

The economic analysis indicates that the Bull Creek project has a conservative benefit cost ratio close to even (0.93). The ability to pay of agriculture is not sufficient to support the project at the standard WWDC grant-loan ratio. As indicated, agriculture could only afford to repay approximately 3 percent of total project cost while generating approximately 69 percent of the total benefits. The WWDC has the authorization to fund the construction of storage projects up to 100 percent if public benefits justify the expenditure. This project could be favorably viewed by the State of Wyoming for funding.

The Sand Creek storage project was the second most economical project and second highest scoring in the storage evaluation matrix. The benefit cost ratio would be approximately 0.90, and would still be quite favorable.

The French Creek Reservoir #8 project was the third most economical project and six highest scoring in the storage evaluation matrix. The benefit cost ratio would be approximately 0.74.

The Camp Comfort storage project was the fourth most economical project and third highest scoring in the storage evaluation matrix. The benefit cost ratio would be approximately 0.69.

The benefit/cost ratios of the alternative reservoir projects are summarized in Table 6.10-1.

6.10.4 Operation and Maintenance Costs

The sponsoring entity for a storage reservoir will be responsible for operation and maintenance of the facility. Estimated annual costs have been developed assuming the following conditions:

- Facility will incorporate supply canal and delivery pipelines
- Half time operator for six months
- Part time operator for six months
- Maintenance crew and equipment for two weeks

Based on these assumptions, normal operation and maintenance would be approximately $50,000 per year in 2010 costs.

Reservoir projects also require funding to be available for maintenance and replacement beyond normal annual maintenance. These potential costs are difficult to estimate and owners normally have reserves or access to reserves for these purposes. For a project of the size and

Table 6.10-1 Clear Creek Storage Benefit/Cost Ratios

Site	Size (AF)	Average Yield (AF)	Ag. Benefits $Mil	Surface Acres	Flat Water Benefits $Mil	Instream Flow Benefits $Mil	Total Benefits $Mil	Project Cost $Mil	B/C Ratio
Upper Middle Clear Creek Reservoir	5,000	2,500	$11.1	60	$4.4	$7.0	$22.5	$68.0	0.33
Lower Middle Clear Creek Reservoir	3,800	2,500	$11.1	50	$3.7	-	$14.8	$80.0	0.18
Camp Comfort Reservoir	10,400	6,000	$26.6	75	$5.5	$7.0	$39.1	$57.0	0.69
Tie Hack Reservoir Enlargement	1,400	1,000	$4.4	20	$1.5	-	$5.9	$12.0	0.49
Sand Creek Reservoir	8,000	5,000	$22.1	175	$5.8	$7.0	$34.9	$39.0	0.90
Bench Reservoir	3,500	2,000	$8.9	0	$0.0	$7.0	$15.9	$33.0	0.48
Bull Creek Reservoir	9,170	5,500	$24.4	200	$6.8	$7.0	$38.2	$41.0	0.93
French Creek Reservoir #8	2,500	1,500	$6.6	50	$5.2	-	$11.8	$21.9	0.54
French Creek Reservoir #8	5,500	3,300	$14.6	75	$7.8	$7.0	$29.4	$39.9	0.74
North Rock Creek Reservoir	3,650	2,500	$11.1	70	$5.1	-	$16.2	$32.0	0.51
Lake DeSmet Transfer - existing pipeline	4,000	4,000	$17.7	-	-	-	$17.7	$2.9	6.11
Lake DeSmet Transfer - canal	4,000	4,000	$17.7	-	-	-	$17.7	$4.1	4.32

complexity of the proposed reservoirs, a reserve fund of approximately $250,000 would be desirable. These reserve funds can be established at the beginning of the project or built up on an annual basis.

An approach that could merit consideration would be to join with the Lake DeSmet Counties Coalition Joint Powers Board. The coalition has qualified, knowledgeable operators for a dam and reservoir facility. More economical use of personnel and equipment could be possible by sharing operation and maintenance.

6.10.5 STORAGE PROJECT FUNDING POTENTIAL

The Wyoming Water Development Commission has criteria specifically directed towards the construction of new water storage projects. The guidelines are included in Appendix 6-F. The items that would be of most importance for this project are summarized below.

1. Proposed new dams with storage capacity of 2,000 acre feet or more and proposed expansions of existing dams of 1,000 acre-feet or more qualify for the Dam and Reservoir Program. Smaller storage projects qualify for funding under the New Development Program. Repairs and improvements to existing storage projects qualify for funding under the Rehabilitation Program.

2. Financial Plan – the maximum grant shall be 75% for proposed Level III projects. In order to obtain the maximum grant, the sponsor must demonstrate to the WWDC that the maximum grant is warranted due to severe financial hardship. The typical grant is 67% for proposed Level III projects. In order to obtain the typical grant, the sponsors must demonstrate to the WWDC that they have taken steps or are willing to take steps to make their water supply systems financially self supporting.

   Special Considerations for Dams and Reservoirs:

   i. The WWDC may recommend a loan/grant mix based on the sponsor's ability to pay a portion of the project costs and all the operation, maintenance, and replacement costs.
   ii. The WWDC may recommend that permitting and design costs be paid by the program thereby reducing the costs applied to the loan/grant mix.
   iii. The WWDC may recommend that the program pay for storage capacity needed to provide water for environmental mitigation and enhancement thereby reducing the costs applied to the loan/grant mix.
   iv. The WWDC may recommend any combination of the above.

3. With respect to Dams and Reservoirs, the following is a list of eligible projects in order of preference:
    1. Multipurpose Projects – W.S. 41-2-112(b) directs the program to emphasize multipurpose projects. For purposes of program implementation, multipurpose projects are hereby defined as projects which serve two or more of the following functions: agriculture, municipal, industrial, rural domestic, recreation, environmental, flood control, erosion control, and hydropower. Priority will be given to those projects that may practically serve more than one entity or purpose and whose service are encompasses a larger, more regional area.
    2. Storage Projects – Dam and reservoirs that store water during times of surplus for use later when needed shall be a program priority. These projects typically provide opportunities for many potential uses. Dams and reservoirs can also serve to re-regulate existing water supplies to meet the demands of the water users in a more efficient and effective manner. While water supply shall be emphasized in the development of operating plans, recreation, environmental enhancement, flood control, erosion control and hydropower uses should be explored as secondary purposes.
    3. Purchase of Existing Storage – This type of investment may be made under the program if the storage is uncommitted or is not being used for a specific purpose. Any such purchase shall be project specific. There should be assurances that the investment will lead to the ultimate use of the water. The potential market for the water shall be the key consideration in determining whether the purchase should be pursued. Potential secondary benefits such as recreational or environmental uses shall also be considered.

4. The project sponsor must be willing and capable of financially supporting a portion of the project development costs and all operation, maintenance, and replacement costs.

5. The state may elect to own all or a part of a project and enter into water service repayment contracts with project developers. The typical State project serves to benefit more than one entity and is multipurpose in nature. Another common characteristic of State projects is that each has a difficult permitting or political issue, which must be addressed. These issues may include developing a partnership with the Federal government, another state, and/or private industry to encourage project development; resolving endangered species, water quality, or wetland issues; or addressing resistance to the project from downstream states. The WWDC shall consider investments in State projects on a case-by-case basis. However, it should be recognized that present Federal

laws and regulations make it difficult to achieve federal clearances for projects in which there is not a clearly defined purpose and need.

The multi-purpose potential, favorable benefit cost ratio, project need, and basin support could make the preferred projects attractive to the State of Wyoming.

VII. Permitting

In the current regulation environment, permitting can become a complex and expensive process. For these reasons, this study has attempted to identify those projects that can be successfully permitted in a timely manner.

7.1 IRRIGATION SYSTEM REHABILITATION PROJECTS

For the most part, the U.S. Army Corps of Engineers will allow irrigation system rehabilitation projects to proceed with the acquisition of a Nationwide Permit. This includes canal lining, pipeline replacement for irrigation ditches, and replacement of irrigation diversion structures in the same location. The process for applying for and receiving a Nationwide Permit involves providing a project description, preliminary design documents and photos of the area involved. Once the Corps has received these documents they simply issue a letter to proceed.

7.2 NEW RESERVOIR PERMITTING

Permitting requirements will vary depending upon whether the proposed project is situated upon private, State or Federal lands. The only exception relates to Section 404 permitting through the U.S. Army Corps of Engineers. An Army Corps of Engineers Section 404 permit will be needed regardless of land ownership. A summary of new reservoir permitting is presented below.

7.3 FEDERAL PERMITTING REQUIREMENTS

7.3.1 NEPA Process for Reservoir Projects

One of the first steps in the National Environmental Policy Act (NEPA) process is to develop an accurate and defensible Purpose and Need statement for the project. The Purpose and Need statement consists of three parts: the purpose, the need, and goals and objectives. The purpose defines the problem. The need provides data to support the problem. The goals and objectives describe other issues and possible opportunities that could be realized as part of the potential solutions to the problem. The Purpose and Need statement should provide enough information to develop and support a 'reasonable range' of alternatives and guide the alternative development and screening process. The NEPA process requires analysis of the 'No Action' alternative and a reasonable range of alternatives that fully address the project's purpose and need.

7.3.2 U.S. Army Corps of Engineers Section 404 Permitting

For any new reservoir, the Applicant must submit a Section 404 permit application to the U.S. Army Corps of Engineers office. Prior to submitting the application the Applicant should

address the proposed project's Purpose and Need and any other alternatives considered and the reasons for their elimination.

For the Clear Creek projects, of the current alternatives most would be proposed "off-channel" storage options which have very few if any wetlands present. The Applicant must also be prepared to discuss the potential impact of the new diversion structure and the impacts on current flow patterns in the designated water source (Clear Creek or tributaries).

Due to the requirements of the National Environmental Policy Act (NEPA), the Corps of Engineers will require an Environmental Assessment (EA) for those projects that have minimal impacts identified. Most EA's can be completed within a year from the date of application. Those projects that have identified impacts to aquatic resources greater than 0.5 acres or have impacts to threatened or endangered (T&E) species will likely require that an Environmental Impact Statement (EIS) be prepared. The time requirements for completing an EIS can range from 2-5 years and be quite expensive. For this reason, it becomes imperative that the Applicant investigate thoroughly those projects with the least damaging impacts to area wildlife, fisheries and aquatic resources.

Once the Application package has been accepted, the Corps of Engineers (COE) will prepare a Public Notice of the pending Application and announce Public Scoping meetings to be held in the area of interest. Public notices will be sent to most local, State and Federal agencies along with all surrounding land owners. Upon the completion of Public Scoping meetings, a Scoping Document will be prepared summarizing all comments received regarding the proposed project. The COE will then finalize the Scope of Work for conducting the environmental analysis. Unlike most Federal land management agencies, the COE does not require reimbursement of their NEPA/404 participation costs.

7.3.3 Bureau of Land Management (BLM) Permitting

For those potential projects located upon BLM lands, the Bureau of Land Management will become the Lead Federal Agency and to initiate the process for permitting a new reservoir project, the Applicant must submit a Right-of-Way application. This application requires the completion of a thorough project description and a summary of alternatives investigated and the reasons for their elimination. The application also requires an explanation of all the environmental effects anticipated from the construction and operation of the proposed reservoir. As the Lead Federal Agency, the BLM will manage and direct the preparation of all environmental documentation (EA/EIS). The BLM will also manage all NEPA requirements for the proposed project. In most cases, projects on Public Lands will also include the U.S. Army Corps of Engineers as a Cooperating Federal Agency. The process for providing Public Notice and comments is nearly identical to the COE process outlined above. Upon initiating the NEPA

environmental process the Applicant will agree to pay all costs of the EA/EIS preparation and will also sign a "Cost Collection Agreement", whereby the Applicant agrees to reimburse the BLM for all their costs associated with the NEPA document preparation process.

7.3.4 United States Forest Service (USFS) Permitting

Much like the BLM, the USFS becomes the Lead Federal Agency for all projects located upon Forest Service lands. To initiate this process with the USFS, the Applicant must complete a Special Use Permit application. The application process is nearly identical to the BLM right-of-way application process. The USFS will also then be responsible for all NEPA compliance issues and the COE will become a Cooperating entity. The USFS also requires the Applicant to pay all EA/EIS preparation costs and to reimburse the Agency for all their project related NEPA compliance and document preparation expenses.

It is important to understand that although the Applicant pays all NEPA, EA/EIS and agency expenses related to Applications, this does not allow the Applicant to direct the work product of the 3rd Party consultants selected by the corresponding agency to prepare the NEPA documentation. 3rd Party environmental consultants work directly for the Federal agency involved.

7.3.5 United States Fish and Wildlife Service (USFWS)

On many projects, the Applicant is required to consult with the USFWS under Section 7 of the Endangered Species Act to make certain that the project is in compliance. The lead agency would prepare a biological assessment to determine project effects on threatened and endangered plant and animal species listed or proposed for listing under the Endangered Species Act. The USFWS would then issue an opinion on whether federal actions are likely to jeopardize the continued existence of a threatened or endangered species, or adversely modify critical habitat. The USFWS must approve the preparation of a biological assessment to comply with the Endangered Species Act in order to render its decision. If the USFWS determines that the preferred alternative would jeopardize the continued existence of a species, it may offer a reasonable and prudent alternative that would preclude jeopardy.

The Fish and Wildlife Coordination Act requires federal agencies involved in actions that will result in the control or structural modification of any natural stream or body of water for any purpose to take action to protect the fish and wildlife resources which may be affected by the action. It requires federal agencies or applicants to first consult with state and federal wildlife agencies to prevent, mitigate, and compensate for project caused losses of wildlife resources, as well as to enhance those resources. Coordination with the Wyoming Game and Fish Department is encouraged when planning and implementing water resource projects.

7.3.6 U.S. Department of Interior – Advisory Council on Historic Preservation (Section 106)

Section 106 of the National Historic Preservation Act of 1966 (NHPA) requires Federal agencies to take into account the effects of their undertakings on historic properties, and afford the Advisory Council on Historic Preservation a reasonable opportunity to comment. Laws and regulations addressing cultural resources include: the National Historic Preservation Act (NHPA) of 1966; the National Environmental Policy Act (NEPA) of 1969; the Archaeological Resources Protection Act (ARPA) of 1979; the National Park Service (NPS) procedures concerning the National Register of Historic Places (NR); the Advisory Council on Historic Preservation's Procedures for the Protection of Cultural Properties; the Treatment of Archaeological Properties of 1980: Determination of Eligibility of Inclusion in the NR; the Secretary of Interior's Standards and Guidelines for Archaeological Historical Preservation of 1983; Reservoir Salvage Act of 1960; and the 1974 Amendment to the Reservoir Salvage Act of 1960.

Section 106 is meant to protect cultural and historic resources. Section 106 functions are coordinated within Wyoming by the Wyoming State Historic Preservation Office (SHPO).

7.4 STATE OF WYOMING PERMITTING

In addition to the Federal permits outlined above, there are a host of additional permits/approvals required for any new dam construction. Outlined below are the State of Wyoming permits required for new dam construction.

7.4.1 Wyoming State Engineer's Office (WSEO) Surface Water Storage Permits

- The Applicant must obtain the necessary water rights storage permits from the WSEO for the diversion and storage of the State's surface water. If an existing ditch is utilized for reservoir supply, an enlargement permit for this ditch would be required.
- The Wyoming Dam Safety Law (W.S. 41-3) requires that any proposed dam which is greater than 20 feet high or which will impound more than 50 acre-feet of water, or a diversion system which will carry more than 50 cfs must obtain approval by the Wyoming State Engineer's Office. The Applicant must provide plans and specifications to the WSEO for a Permit to Construct through the Dam Safety office. Design, construction, and operation of jurisdictional dams must also comply with dam safety regulations pursuant to the Dam Safety Act.

7.4.2 Wyoming State Department of Environmental Quality (WDEQ) Permitting

- National Pollution Discharge Elimination System (NPDES) permit and corresponding Section 401 Certification. The NPDES permit controls the discharge of stormwater pollutants associated with construction activities. The Section 401 Certification is the State's approval to insure that the activities authorized under Section 404 (COE) meet State water quality standards and do not degrade water quality.

7.4.3 Wyoming Historic Preservation Office (SHPO) Archaeological Clearance

- SHPO coordinates with federal agencies in determining the significance of cultural resources potentially affected by ground disturbing activities.

7.4.4 Wyoming Board of Land Commissioners

- The Wyoming Board of Land Commissioners through the State Lands and Investments Board (SLIB) is responsible for regulating all activities on state lands, including granting of rights-of-way. Any facility, utility, road, ditch, or reservoir to be constructed on state or school lands must have a right-of-way, as required in the "Rules and Regulations Governing the Issuance of Rights of Way" (W.S. 36-20 and W.S. 36-202).

7.5 NEPA Process for Other Project Types

The applicability of NEPA to projects other than reservoir storage (non-stock pond) must be determined on a case-by-case basis. For example, proposed new wildlife/livestock watering developments including tank/pipeline systems that cross and/or serve federal or state land will require that an appropriate NEPA process be followed. In this case, and for many of the lesser potential impact projects (e.g., a well, stock/wildlife pond, guzzler, etc.), it is possible that an EA process will be found appropriate rather than a full EIS.

BLM

At the time of this reporting, compliance with NEPA will be guided in large part by the Approved Resource Management Plan (RMP) for Public Lands Administered by the BLM Buffalo Field Office (BLM 2001) and any subsequent new or additional guidance and/or updates. The RMP was developed on the basis of a NEPA-compliant EIS. Currently, the BLM is in the process of completing a revision to the RMP and associated EIS.

Other State/Federal Agencies

Depending on the specific circumstances of a particular project, it is possible that another state or federal agency may lead the NEPA process. For example, a project proposed within the Bighorn National Forest would presumably be led by the U.S. Forest Service, most likely from the Sheridan Regional Office. All of the relevant state and federal land management agencies

have management plans developed from NEPA-compliant processes where appropriate. As discussed above for BLM, these plans will guide these agencies' NEPA process for any applicable proposed projects.

Watershed Wide Environmental Analysis

Consideration could be given to the potential benefits of conducting a comprehensive 'watershed wide' environmental analysis for the potential wildlife/livestock water development projects and other potential water resource related improvement projects. A key benefit of this approach would be developing a single baseline characterization and impacts assessment of the relevant environmental issues associated with these types of projects rather than repetitively for similar individual projects. This could reduce the overall resources and time necessary to conduct the required environmental permitting for these projects. If necessary, the overall environmental analysis could be supplemented on a case-by-case basis for a particular issue in a focused, time and resource efficient manner.

Non-Reservoir Project Permits, Clearances, and Approvals

The permits, clearances and approvals required for projects other than dam and reservoir projects will depend on the specific nature and location of the project. The various permits and clearances discussed above in Sections 7.3 and 7.4 may also apply to other types of projects. For example, if a new groundwater well is associated with a proposed wildlife/livestock watering development, then the applicant must obtain the necessary groundwater right permits from the Wyoming State Engineer's Office (WSEO), which includes Forms U.W. 5 & 6. New wildlife/livestock watering development projects that utilize existing groundwater wells must include stock as a use in the associated water right. The specific permits and clearances necessary for a particular project should be determined early in the planning stages of the project to ensure compliance with applicable laws and regulations, and to avoid possible delays, increased costs and possible re-design during project implementation. Additionally, coordination with the Wyoming Game and Fish Department is encouraged when planning and implementing natural and water resource improvement projects.

7.6 MITIGATION

Based on prior experience, mitigation could be required at any of the identified reservoir projects or other potential projects described in Sections 4 and 5 to address impacts to wetlands, riparian vegetation, cultural resources, fish and wildlife resources, and possibly threatened or endangered species. Potential environmental impacts associated with each potential reservoir site are discussed in Section 6.

Detailed mitigation plans would need to be prepared and approved to replace any lost wetlands identified and quantified by formal wetlands delineation and riparian vegetation communities. The ratio of wetland replacement mitigation would be determined during the permitting process.

Prior to constructing a project, surveys for sensitive wildlife and plant species would likely be required. If any sensitive species are found, mitigation measures would likely be required. Mitigation of potential raptor and big game impacts would generally involve control of certain construction activities during sensitive time periods and avoidance of direct disturbance of the subject species. Impacts to crucial big game habitat will likely have more significant mitigation requirements. If any T&E species were encountered at a given site, special studies would be required to determine if appropriate mitigation could be implemented. In general, any such impacts would be avoided to the greatest extent possible by relocation of site facilities.

The greater sage-grouse has been petitioned for listing as threatened or endangered under the Endangered Species Act. The Wyoming Game and Fish Department recently revised a map showing sage grouse "Core Population Areas" within the state of Wyoming (Figure 3.3-18), and Governor Freudenthal issued an Executive Order mandating that new development within Core Population Areas should be authorized or conducted only when it can be demonstrated that the activity will not cause declines in greater sage-grouse populations. Current recommendations limit surface disturbances to 5% of suitable sage-grouse habitat per 640 acres in core areas. Given the Governor's executive order, it may be difficult to obtain state approval for projects within the core area if significant areas of sage-grouse habitat are impacted. The BLM and WGFD have developed restrictions and recommendations to help protect the species, see Appendix 7A for BLM and WGFD policy on greater sage-grouse.

Impacts to fishery resources would likely require mitigation. Impacts related to reservoir projects could potentially be mitigated through minimum reservoir release requirements and creation of a minimum pool for aquatic habitat.

Cultural and historic resource fieldwork would need to be completed to identify and document any such resources that would be impacted. This would include a class I (literature search) survey, a class II (reconnaissance inventory) survey, and if needed, a class III (intensive inventory) survey. Ultimately, a mitigation plan for cultural resources would be developed which would culminate in a Memorandum of Agreement (MOA) between the Wyoming SHPO and the lead federal agency with concurrence by the project sponsor, and possibly affected Native American tribes. The agreement would require approval from the Advisory Council on Historic Preservation.

7.7 LAND OWNERSHIP AND PROPERTY OWNERS

Where applicable, permission should be negotiated for easements/right-of-access for all construction activities associated with projects. It is important to note that the WWDC has stated that lands will NOT be 'taken' or condemned in order to construct projects recommended within this study. Representatives of the WWDO have stated that the State is not interested in condemning lands for the purpose of constructing a reservoir built with the objective of benefitting those whose lands would be used. Participation must be voluntary.

VIII. Funding Opportunities

8.1 OVERVIEW

The linchpin for setting any of the projects referenced within this document into motion is project funding. Numerous funding opportunities exist to assist with the financial burden associated with project implementation. This section briefly describes some of the programs available and provides details regarding where more information can be obtained regarding these programs. In general, most of the future watershed improvement projects can reasonably expect to tap into the funding sources identified here within.

An investigation of federal, state and local funding sources was conducted to identify potential opportunities for watershed improvement projects.

Within this section, other recent watershed studies were referenced on the behalf of the Wyoming Water Development Commission. Specifically, the Nowood River Storage/Watershed Study (Anderson Consulting Engineers, 2010) was reviewed and several sections reproduced and/or modified herein where appropriate.

The following documents provide extensive information pertaining to project funding opportunities for projects investigated within this Level I study:

- ***Water Management & Conservation Assistance Programs Directory***, ***Fourth Edition*** (WWDC, May 2009). This directory provides funding agency direct contacts to assist with potential project funding throughout the area. http://wwdc.state.wy.us/wconsprog/WtrMgntConsDirectory.html

- ***Catalog of Federal Funding Sources for Watershed Protection.*** This EPA website provides information pertaining to numerous funding sources including grants, loans, and cost sharing programs which are applicable to watershed projects. The document is available at: http://cfpub.epa.gov/fedfund/

- ***Habitat Extension Bulletin No. 50 – Fisheries and Wildlife Habitat Cost Share Programs and Grants (Wyoming Game & Fish Department, August 2007)*** The Wyoming Game & Fish department has developed this informative bulletin pertaining to financial assistance programs available for fisheries and wildlife habitat projects. http://gf.state.wy.us/habitat/ExtBulletinsCont/index.asp

As government programs frequently change according to the available budgets of the funding agencies the grants, loans, and cost share opportunities presented herein are subject to change. As such, it is recommended that additional inquires be made if interested parties wish to pursue the opportunities presented in this section.

Significant competition for funding associated with many of the opportunities presented is frequently encountered by applicants. To increase the potential for success in obtaining funding from other sources, applicants may wish to have other funds available to leverage against these opportunities. By showing the financial commitment to projects, funding agencies may look more favorably to fund specific projects that have a higher likelihood of timely implementation. Contacts for key local groups who can provide current information on funding sources relevant to watershed projects include:

- Bureau of Land Management/Buffalo Field Office (307-684-1100)
- Lake DeSmet Conservation District (307-684-2526)
- NRCS – Sheridan Office (307-672-5820)
- NRCS – Buffalo Office (307-684-2526)
- Sheridan County Conservation District (307-672-5820)
- Wyoming Water Development Office – (307-777-7626)

Information pertaining to the funding programs presented herein are discussed in the following sections and presented in Table 8.1-1.

8.2 LOCAL AGENCIES

8.2.1 Lake DeSmet and Sheridan County Conservation Districts

The Lake DeSmet and Sheridan County Conservation Districts (LDCD and SCCD) serve as the local liaisons between local landowners and resource users and state and federal government agencies. In addition to their many other roles and responsibilities, these districts can also provide funding assistance as follows:

- In-kind technical assistance as local resources, capacity and expertise allow.
- Administration of programs, projects and grants on behalf of recipients of state and federal natural resources program funding.
- Assistance in development of leveraged, partnered programs and projects.
- Facilitating work days attended by a broad base of stakeholders (e.g., Russian Olive tree cutting); and
- Assistance in preparation of grant applications

8.2.2 Johnson County/Sheridan County Weed and Pest Districts

Wyoming Weed and Pest Districts provide in-kind support to landowners and other agencies/entities including, but not necessarily limited to:

- Assistance in the identification of noxious weeds and other undesirable plants;

- Organization and/or participation in local meetings, seminars and field trips to educate local landowners and agencies on the problems and potential solutions for weed and other undesirable plant control, and
- Facilitating work days attended by a broad base of stakeholders (e.g., Russian Olive tree cutting).

8.3 STATE PROGRAMS

8.3.1 Wyoming Department of Environmental Quality

The Wyoming Department of Environmental Quality (WDEQ) provides funding for implementation of best management practices (BMPs) to address non-point sources of pollution under Section 319 of the Clean Water Act. Section 319 grant funding requires a non-federal (i.e., local) match of 40 percent from the applicant. These matching funds may be provided by landowners, a conservation district, other quasigovernmental entities (e.g., watershed improvement district, irrigation district, etc.), and/or nonprofit organizations (e.g., Trout Unlimited, Ducks Unlimited, and the Rocky Mountain Elk Foundation). Applications (proposals) conforming to a specified format are required. The proposal describes in some detail the issues to be addressed and the proposed methods/BMPs to be implemented, as well as providing all other information required to evaluate the proposed project and matching fund entity(ies). These proposals are normally due in August or September of each year.

Projects located within watersheds of streams on the 303d list are eligible for the 319 – Incremental Funds, which has historically been a larger amount. Project located within watersheds which are not listed on the 303d list, such as Clear Creek are only eligible for 319-base funds.

8.3.2 Wyoming Game and Fish Department

Wyoming Game & Fish Department funding assistance can best be summarized by the following:

> *"The Wyoming Game and Fish Department offers a funding program to help landowners, conservation groups, institutions, land managers, government agencies, industry and non-profit organizations develop and/or maintain water sources for fish and wildlife. This program also provides funding for the improvement and/or protection of riparian/wetland areas for fish and wildlife resources in Wyoming. Applications for projects are accepted any time with approval on January 1 and August 1 of each year."* (WWDC, 2005)

Current programs offered by the Wyoming Game & Fish Department include: Riparian Habitat Improvement Grant, Water Development/Maintenance Habitat Project Grant, Upland Development Grant, Fish Wyoming, and Wyoming Sage Grouse Conservation Fund. These programs are described below.

Riparian Habitat Improvement Grant
The purpose of this program is to improve or maintain riparian and wetland resources. Fencing, herding, stock water development, streambank stabilization, small damming projects and beaver transplanting are a few examples of efforts that qualify under this program. Permits, NEPA compliance, construction, maintenance, access and management planning are all grantee responsibilities. There is $10,000/project maximum available with 50% cash or in-kind contribution required from the grantee.

Water Development/Maintenance Habitat Project Grant.
The purpose of this program is to develop or maintain water for fish and wildlife. Spring development, windmills, guzzlers, water protection and pumping payments are examples of the extent of this program. Permits, NEPA compliance, maintenance, access and water rights are responsibilities of the grantee. There is a maximum of $7,500/project and 50% cash or in-kind contribution required from the grantee.

Upland Development Grant.
The purpose of this program is to develop upland wildlife habitat. Example projects include management, grazing systems, prescribed burning, and wildlife food plots such as oat, millet or corn plantings, range pitting and range seeding. Permits, NEPA compliance, maintenance, access and management planning are responsibilities of the grantee. There is a maximum of $10,000/project and 50% cash or in-kind contribution required from the grantee.

Fish Wyoming.
The purpose of this program is to develop public fishing opportunities. Examples of projects within this effort are boat ramps and fishing access. This program provides a 50% match of funding which is channeled through a private organization or municipality.

Wyoming Sage Grouse Conservation Fund.
WGFD administers the Wyoming Sage-Grouse Conservation Fund (WSGCF).

http://gf.state.wy.us

The WSGCF is a special fund established by the Wyoming State Legislature to support the efforts of Local Sage-Grouse Working Groups (LWGs). The WSGCF funding is intended to promote conservation of sage grouse populations and habitat (sagebrush ecosystems), including socio-economic and human use of the habitat.

Requests for WSGCF funding must be made on a Project Proposal Form available at:

http://gf.state.wy.us/wildlife/wildlife_management/sagegrouse/BigHornBasin/BHB%20SgConservPlanFinal.pdf

Funding is normally considered for projects ranging between $5,000 and $50,000, with priority given to those with matching funds, established partnerships, multi-species benefits, management relevance and consistency with the local sage-grouse conservation plan, highest

wildlife impact, appropriate budgets, landscape scale, and a lasting legacy of benefits. Evaluation criteria include: consistency with the local plan, likelihood of project success, project readiness, and availability of matching funds, multiple species benefits, significance at local/state/regional level, duration of benefits, and adequacy of funding. Application may be made at any time, but should be made by February 1 to receive first round consideration. Funds awarded must be expended between July 1 of the year received and September 30 of the second year after award. The funds are normally distributed as reimbursable grants (i.e., payments are made for expenses incurred and not "up-front"). Requests for funding of habitat improvement projects, including water developments, must include a livestock grazing management plan. A Project Close-out Report must also be submitted upon completion to allow tracking of expenditures and tracking of results.

8.3.3 Wyoming Office of State Lands and Investments

As the administrative advisory arm of the Board of Land Commissioners and State Loan and Investment Board, the Office of State Lands and Investments (OSLI) administers Regular Farm Loans and Small Water Development Project Loans that are applicable to potential projects identified in Sections 4 and 5.

Regular Farm Loans

These loans are made for a wide range of agricultural purposes, including as most applicable to the potential projects identified in Sections 4 and 5, purchasing, constructing or installing equipment and/or improvements necessary to maintain or improve the earning capacity of the farming operation. Eligible applicants include individuals whose primary residence is in Wyoming and legal entities with a majority of the ownership meeting the individual residency requirements. Single loans or combinations of loans cannot exceed an outstanding principal balance of $600,000. Loan rates are 8 percent for loans up to 50 percent of the appraised value of the security land and improvements and 9 percent for loans between 50 and 60 percent of the security. The term of a given loan is limited to 30 years.

Small Water Development Project Loans

These loans are authorized for projects for development and use of water upon agricultural lands for agricultural purposes. These projects may convert dry land into irrigated land or lead to more efficient use of water and/or increased crop or forage production. Eligible recipients may include court approved water districts, agencies of state and local government, persons, corporations, associations, and other legal entities recognized under state law. Individual loans up to $150,000 may be made. Interest is currently set at 6 percent and the maximum term of loan is 40 years.

8.3.4 Wyoming Water Development Commission

The mission of the Wyoming Water Development Commission (WWDC), as defined in the enabling legislation, is to:

"provide, through the commission, procedures and policies for the planning, selection, financing, construction, acquisition and operation of projects and facilities for the conservation, storage, distribution and use of water, necessary in the public interest to develop and preserve Wyoming's water and related land resources. The program shall encourage development of water facilities for irrigation...for abatement of pollution, for preservation and development of fish and wildlife resources…and shall help make available the waters of the state for all beneficial uses…" (W.S. 41-2- 112(a)).

Key aspects of the Wyoming Water Development Program and the Small Water Project Program administered by WWDC are described in the following subsections.

8.3.4.1 Wyoming Water Development Program

The main Wyoming Water Development Program encompasses new development, dams and reservoirs, rehabilitation, water resources planning and master planning. Of most relevance to the Clear Creek watershed in terms of implementing alternative projects are the New Development –Rehabilitation Programs and Dams and Reservoirs Program described below. This information was abstracted from the Operating Criteria of the Wyoming Water Development Program available at:
http://wwdc.state.wy.us/opcrit/final_opcrit.pdf

A form titled Information for New Applicants available at the following website:

http://wwdc.state.wy.us/projappl/New_Ap_Info.pdf

It is very important to ensure that the most current information on funding is reviewed prior to making an application as WWDC's policies and procedures can and do change over time in response to legislative direction and/or Commission action. Review of information available at the above websites and contact with the staff of the WWDC (307.777.7626) is recommended prior to beginning the application process.

New Development Program
The New Development Program develops presently unused and/or un-appropriated waters of Wyoming.

Rehabilitation Program
The Rehabilitation Program provides funding assistance for the improvement of water projects completed and in use for at least fifteen (15) years.

Dam and Reservoir Program
Proposed new dams with storage capacity of 2,000 acre feet or more and proposed expansions of existing dams of 1,000 acre feet or more qualify for the Dam and Reservoir Program.

Water Resource Planning

The Wyoming Water Development Commission serves as the water development planning agency for the State of Wyoming. In this capacity, the WWDC can provide assistance for both Basin Wide Plans and Master Plans. These two types of plans are further described below:

> *Basin Wide Plans*- The program serves to develop basin wide plans for each of the state's major drainage basins.
>
> *Master Plans*- The program provides a service to municipalities, districts and other entities to assist in the preparation of planning documents which serve as master plans for future water supply systems and improvements. The plans serve as a framework for the entities to establish project priorities and to perform the financial planning necessary to meet those priorities. These plans can assist entities in preparing the reports necessary to achieve federal funding assistance for water development and other water related projects.

Groundwater Grant Program

The primary purpose of the program is to inventory the available groundwater resources in the state. The program also serves to assist communities in developing efficient water supplies. Municipalities and special districts that purvey drinking water are eligible to receive up to $400,000 in grant funds if 25% of the total project costs will be paid by local matching funds.

New Development Program

This program provides technical assistance and funding to develop waters of the state that are unused and/or un-appropriated at present. It deals with a wide range of projects, including as most relevant to the Clear Creek watershed the following types of projects:

- Multiple Purpose - including among other uses two or more of the following: agriculture, recreation, and environmental;
- New Storage - dams and reservoirs less than 2,000 acre-feet;
- New Supply - diversion dams;
- Watershed Improvement - for components whose primary function or benefit is water development; and
- Recreation

These project types are listed above in the order of preference assigned by WWDC when determining what projects to pursue among all of the applications received for funding.

Rehabilitation Program

The Rehabilitation Program addresses the improvement of water projects completed and in use for at least fifteen years in order to assist in keeping existing water supplies effective and viable for the future. Relative to the Clear Creek watershed, the Rehabilitation Program can improve existing agricultural facilities and conveyance systems to insure safety, decrease operation and maintenance (O&M) costs, and increase the efficiency of agricultural water use. The types of

projects supported relevant to this watershed are essentially the same as listed above for the New Development Program.

Note that on-farm improvements (e.g., gated pipe, side rolls, center pivots and related facilities and/or equipment such as pumps, power lines) are excluded from WWDC funding under both the New Development and Rehabilitation Programs.

Dam and Reservoir Program

Proposed new dams with storage capacity of 2,000 acre feet or more and proposed expansions of existing dams of 1,000 acre feet or more qualify for the Dam and Reservoir Program. The source of revenue for the program is Water Development Account No. III [W.S. 41-2-124(a)(iii)], which has received Water Development Account No. I appropriations and budget reserve account appropriations on occasion, as approved by the legislature; the interest earnings that have accrued to the Water Development Account No. III; and a percentage (0.5%) of the revenues which accrue to the state's severance tax distribution account. Legislative approval must be granted prior to allocating funds to a particular purpose or project. Dams and reservoirs typically provide opportunities for many potential uses. While water supply shall be emphasized in the development of reservoir operating plans, recreation, environmental enhancement, flood control, erosion control and hydropower uses should be explored as secondary purposes.

Key Criteria and Procedures

An application for funding under either the New Development or Rehabilitation Programs must meet the following key criteria most applicable to potential projects as identified in Section 4 above:

> • *"The project sponsor shall be a public entity that can legally receive state funds, incur debt, generate revenues to repay a state loan, hold title and grant a minimum of a parity position mortgage on the existing water system and improvements or provide other adequate security for the anticipated state construction loan."*
>
> • *"The proposed project must serve…2,000 or more acres of irrigated cropland, or must rehabilitate watershed infrastructure, which will develop or preserve the beneficial use of water in a watershed. The watershed rehabilitation projects must possess an estimated minimum useful life span of twenty-five (25) years and demonstrate that sufficient public benefits will accrue to justify construction of the anticipated improvements..."*

Important procedures, deadlines and requirements for applications to the New Development and Rehabilitation Programs include but are not necessarily limited to the following:

- A fee of $1,000 must be submitted with initial project applications; the fee does not apply to projects advanced to the next level of study or to construction.

- A certified resolution passed by the governing body of the sponsoring entity must accompany an application for a Level II study or Level III construction. This requirement may be deferred if the applicant is in the process of forming a public entity.

- A public entity must be in place before a Level II study or Level III construction can commence, with certain exceptions discussed below.

- The due date for new project applications is August 15 of each year; the due date for applications for advancing to the next study level or construction funding is October 1 of each year.

Two important criteria that apply specifically to dam and reservoir projects are:

> • *"For projects that enlarge existing storage projects by 1,000 acre-feet or greater or for proposed new dam and reservoirs with a capacity of 2,000 acre-feet or greater, expenses associated with final engineering design and required National Environmental Policy Act reviews, including but not limited to environmental assessments and environmental impact statements, are eligible components of a Water Development Program Level II, Phase III Study Project."*
>
> • *"For dam and reservoir projects, the Commission may waive sponsor eligibility requirements through Level II, Phase II. However, the eligible entity requirements shall be met prior to initiation of Level II, Phase III activities described herein."*

Financial Plan

The current standard terms of the Wyoming Water Development Program financial plan are summarized as follows:

- Sixty-seven (67) percent grant to thirty-three (33) percent loan mix.

- Minimum four (4) percent loan interest rate (current rate is 4 percent, but legislature may increase rate).

- Maximum 50-year term of loans; term shall not exceed economic life of project.

- Payment of loan interest and principal may be deferred up to 5 years after substantial completion at WWDC's discretion under special circumstances.

In the document entitled "*Information for New Applicants"* the following additional relevant information is provided regarding financial terms:

- *"The best available project financial terms include a grant for Level I and Level II expenses, a grant of 75% of the Level III costs, a loan of 25% of the Level III costs with an interest rate of four percent (4%) and a term equal to the economic life of the*

project/improvements or fifty (50) years, whichever is less. Principal and interest payments may be deferred for five (5) years after project completion. However, these favorable terms will be granted when a project is essential and the project sponsor has a very limited ability to pay."

- *"Those sponsors who feel more favorable terms are warranted due to a limited ability to pay must make a formal presentation to the Commission documenting their case. Sponsors electing to pursue this option should be aware that the Commission is reluctant to deviate from this standard and such requests will be denied unless they are clearly documented and justified."*

The Commission will evaluate whether or not a project will be funded for Level III construction following review of the results of Level II studies. If the Commission determines that the project should not advance due to high repayment costs (as determined by an analysis of the sponsor's ability-to-pay and after other funding sources have been considered), the sponsor has the option of making a formal presentation to WWDC relative to the sponsor's ability and willingness to pay. This presentation must address the need for the project, the direct and indirect benefits of the project, and any other information the sponsor feels is relevant to the Commission's final decision.

The WWDC may waive the requirement that the project sponsor be a public entity under the following exceptions:

1. The WWDC may accept applications for Level I studies from applicants that are not public entities. This will allow the applicant to know if there is a viable project prior to becoming a public entity. However, the applicant must be a public entity before applying for a Level II study. Under these circumstances, the Level I process will have a two-year duration with the study being completed the first year and the sponsor forming a public entity the second year.

2. The WWDC may accept applications related to the construction of dams and reservoirs from applicants that are not public entities. As the evaluations of the feasibility of new dams are complex, this will allow the applicant to know if the proposed reservoir is feasible prior to becoming a public entity. However, the applicant must be a public entity before applying for Level II, Phase III funding.

Appendix 8A contains additional information pertaining to district formation and the various types of districts which can be formed.

8.3.4.2 Small Water Project Program

The Small Water Project Program (SWPP) is intended to be compatible with the conventional WWDC program described above. Small water projects are defined as providing multiple benefits where the total estimated project costs (including construction, permitting,

construction engineering, and land procurement) are less than $100,000 or where WWDC's maximum financial contribution is 50 percent of project costs or twenty-five thousand dollars ($25,000), whichever is less. SWPP funding is a "one-time" grant so that ongoing operation and maintenance costs are not included. Loans are not available under SWPP.

Eligibility
The kinds of projects eligible for SWPP funding include, but are not necessarily limited to:

- Small reservoirs and stock watering ponds (up to 20 feet high and 20 acre-feet capacity);
- Wells;
- Pipelines and conveyance facilities;
- Irrigation
- Spring developments;
- Solar platforms
- Windmills; and
- Wetland developments

Benefits associated with SWPP projects may include, but are not necessarily limited to:

- Improved water quality;
- Habitat and water for fish and wildlife
- Improved riparian habitat; and
- Increased recreational opportunities.

These projects may address environmental concerns by providing water supplies to support plant and animal species, and serve as instruments to improve range land conditions.

Funding can only be provided to eligible public entities including but not necessarily limited to conservation districts, watershed improvement districts, water conservancy districts, and irrigation districts.

Application, Evaluation and Administration
Details of the application and evaluation process and program administrative procedures are provided in the Small Water Project Program Operating Criteria available online as noted previously. Some key aspects of the process and procedures applicable to the potential projects identified in Sections 4 and 5 include the following:

1. Planning for small water projects will be generated by a WWDC watershed study or equivalent as determined by the WWDO. A watershed study will incorporate, at a minimum, available technical information describing conditions and assessments of the watershed including hydrology, geology, geomorphology, geography, soils, vegetation, water conveyance infrastructure, and stream system data. A plan outlining the site specific activities that may remediate existing impairments or

address opportunities beneficial to the watershed shall also be included. A watershed study may identify one or more projects that may qualify for SWPP funding. A professional engineer and/or geologist, as appropriate, shall certify any analysis submitted unless generated by a federal agency.

2. Applications shall be received by January 1 of each calendar year. Applications meeting criteria requirements will be considered during the regularly scheduled WWDC meeting in March. Applications shall include a project application, sponsor project referral, project location map, project cost estimates and any letters of authorization or commitment of participation that may be available from other funding sources.

3. Projects that improve watershed condition and function, provide multiple benefits, and meet the funding criteria specified in W.S. 99-3-703(j)(vii) or W.S. 99-3-704(g)(vii), as described in B.4 herein, are eligible for consideration.

4. The sponsoring entity will be required to address the WWDC and provide testimony and other additional supporting evidence that justifies SWPP funding whenever the public benefit documentation, submitted with the application, is deemed to be insufficient by the WWDO.

8.3.5 Wyoming Wildlife and Natural Resource Trust

The Wyoming Wildlife and Natural Resource Trust (WWNRT) was formed by the State legislature in 2005 to preserve and enhance Wyoming's wildlife and natural resources. Projects funded by WWNRT must provide a public benefit such as continued agricultural production to maintain open space and healthy ecosystems, enhancements to water quality, and maintenance or enhancement of wildlife habitat.

Wildlife and Natural Resource Trust funding is available for a wide variety of projects throughout the state, including natural resource programs of other agencies. Some examples include the following:

- Projects that improve or maintain existing terrestrial habitat necessary to maintain optimum wildlife populations may include grassland restoration, changes in management, prescribed fire, or treatment of invasive plants.

- Preservation of open space by purchase or acquisition of development rights contractual obligations, or other means of maintaining open space.

- Improvement and maintenance of aquatic habitats, including wetland creation or enhancement, stream restoration, water management or other methods.

- Acquisition of terrestrial or aquatic habitat when existing habitat is determined crucial / critical, or is present in minimum amounts, and acquisition presents the necessary factor in attaining or preserving desired wildlife or fish population levels.

- Mitigation of impacts detrimental to wildlife habitat, the environment and the multiple use of renewable natural resources, or mitigation of conflicts and reduction of potential for disease transmission between wildlife and domestic livestock.

Allowable projects under this program that are potentially relevant to this watershed management plan study include:

- Improvement and maintenance of existing aquatic habitat necessary to maintain optimum fish populations.

- Conservation, maintenance, protection and development of wildlife resources, the environment, and Wyoming's natural resource heritage.

- Participation in water enhancement projects to benefit aquatic habitat for fish populations and allow for other watershed enhancements that benefit wildlife.

Funding is by grant with no matching funds required. Non-profit and governmental organizations (including watershed improvement districts, conservation districts, etc.) are eligible for funding by WWNRT. Projects will be funded in July and January. Applications may be filed any time, but must be filed within 90 days of the next funding cycle to receive consideration in that cycle.

8.4 FEDERAL AGENCIES

8.4.1 Bureau of Land Management

BLM's Riparian Habitat Management Program

This program offers the opportunity to coordinate with outside interests on riparian improvement projects. The goal of BLM's riparian-wetland management is to maintain, restore, improve, protect, and expand these areas so they are in proper functioning condition for their productivity, biological diversity, and sustainability. The overall objective is to achieve an advanced ecological status, except where resource management objectives, including proper functioning condition, would require an earlier successional stage. The goal includes aggressive riparian-wetland information, inventory, training, and research programs as well as improving the partnerships and cooperative management processes.

Partnerships have been available for riparian improvement projects and for research into riparian issues. Funding is available on an annual basis subject to budget allocations from Congress. All submitted cooperative projects compete for the funds available in the riparian program. For information on the riparian habitat program within BLM, please contact Mark Gorges (307) 775-6100.

Range Improvement Planning and Development

This program is a cooperative effort not only with the livestock operator but also with other outside interests including the various environmental/conservation groups. Water development, whether it be for better livestock distribution or improved wetland habitats for wildlife, is key to healthy rangelands and biodiversity. Before actual range improvement development occurs, an approved management plan must be in place. These plans outline a management strategy for an area and identify the type of range improvements needed to accommodate that management. Examples of these plans are Coordinated Resource Plans, Allotment Management Plans, and Wildlife Habitat Management Plans.

All rangeland improvement projects on lands administered by the Bureau of Land Management require the execution of a Permit. Although there are a couple of methods for authorizing range improvements on the public lands, Cooperative Agreement for Range Improvements form 4120-6 is the method most commonly used. This applies equally to range improvement projects involving water such as reservoirs, pits, springs, and wells including any associated pipelines for distribution. The major funding source for the Bureau of Land Management's share comes from the range improvement fund which is generated from the grazing fees collected. There, too, is a limited amount of funding from the general rangeland management appropriations. If the cooperator is a livestock operator, their contributions come generally in the form of labor. There are times they also provide some of the material costs as well. Contributions from the conservation/environmental interests is monetary and often come in the form of grants. They also contribute labor on occasion. For information on the range improvement program within BLM, please contact Jim Cagney (307) 775-6194.

BLM's Watershed and Water Quality Improvement

Under this program, efforts are undertaken in a cooperative approach with the State of Wyoming, Conservation Districts, livestock operators and various conservation groups. Wyoming's BLM is partnering in the implementation of several Section 319 watershed plans state-wide.

It is anticipated that as the Wyoming Department of Environmental Quality (WDEQ) continues the inventory of waters of the State and the identification of Impaired and/or Threatened water bodies, BLM will be partnering with the WDEQ to improve water quality in water bodies on Public Lands. In the course of developing watershed plans or TMDL's for these watersheds, BLM will be routinely involved in watershed health assessments, planning, project implementation and Best Management Practice (BMP) monitoring.

Now, and in the future, the goals of cooperative watershed projects will typically be the restoration and maintenance of healthy watershed function. These goals will typically be accomplished through approved BMP's, e.g. prescribed burns, vegetation treatments, in-stream structures, too enhance vegetation cover, control accelerated soil erosion, increase water infiltration and enhance stream flows and water quality.

Currently, in response to the Clean Water and Watershed Restoration initiative and associated funding increases, BLM is expanding its efforts to address water quality and environmental concerns associated with abandoned mines. This work will also be accomplished, in cooperation with the State Abandoned Mine Lands Division, on a priority watershed basis and will employ appropriate BMP's to address identified acid mine drainage and runoff problems from mine tailings and waste rock piles.

8.4.2 Bureau of Reclamation

The Bureau of Reclamation (BOR) administers the Water 2025 Challenge Grant Program. This program provides funding on a competitive basis for projects focused on water conservation, efficiency and water marketing. Preference is given to projects that can be completed within 24 months that will help to prevent crises over water in areas identified as "hot spots" where potential for conflict is judged to be moderately to highly likely by 2025.
Because there are no existing projects within the Clear Creek watershed under jurisdiction of the BOR, funding through this program is unlikely.

8.4.3 Environmental Protection Agency

The Targeted Watershed Grants Program administered by the Environmental Protection Agency (EPA) "encourages watershed practitioners to examine local water related problems in the context of the larger watershed in which they exist, to develop solutions to those problems by creatively applying the full array of available tools, including general, state and local programs, to restore and preserve water resources through strategic planning and coordinated project management that draw in public and private sector partners..." as described in the following program website:

http://www.epa.gov/twg/2006/2006faq.html#intro

Organizations eligible for funding include nonprofits, tribes, and local governments. The assistance provided consists of grants for up to 75 percent of the total project costs. A match of at least 25 percent is required. The typical median amount awarded is $700,000 with a typical range of $300,000 to $900,000. It is important to note that application must be made by the governor, and that the competition for these grants is keen.

8.4.4 Farm Service Agency

The Farm Service Agency (FSA) administers three different programs that may be applicable to some of the alternative projects identified in Sections 4 and 5. Technical assistance for the FSA programs is provided by NRCS. Each of these three programs is briefly discussed below.

Conservation Reserve Program (CRP)
This is a voluntary program under which eligible highly erodible cropland is removed from production in return for annual rental payments and cost share assistance by FSA over a 10-15

year period. The producer is required to establish long-term conservation practices on the erodible, environmentally sensitive lands taken out of production.

Continuous Sign-Up for High Priority Conservation Practices
Under this program farmers and ranchers implement certain high-priority conservation practices on their eligible CRP lands. These practices may include: riparian buffers, filter strips, grass waterways, shelter belts, field windbreaks, living snow fences, contour grass strips, salt tolerant vegetation, and shallow water areas for wildlife.

This cost share program offers rental rates for the CRP lands based on the average value of dryland cash rent with an additional financial incentive of up to 20 percent of the soil rental rate for selected practices. Establishing permanent cover merits up to a 50 percent cost share.

Emergency Conservation Program (ECP). This program provides emergency funding and technical assistance for implementing emergency livestock watering conservation measures during periods of severe drought and rehabilitating farmland damaged during natural disasters. Cost share assistance up to 75 percent of the cost to implement the emergency measure(s) is available.

Continuous Sign-Up for High Priority Conservation Practices
Continuous sign-up provides management flexibility to farmers and ranchers to implement certain high-priority conservation practices on eligible land. Land must meet the requirements of CRP and be determined by the NRCS to be eligible and suitable for:

Riparian buffers
Living snow fences
Filter strips
Contour grass strips
Grass waterways
Salt tolerant vegetation
Shelter belts
Shallow water areas for wildlife Field windbreaks

This is a cost share program that offers rental rates based on the average value of dry-land cash rent with an additional financial incentive of up to 20% of the soil rental rate for field windbreaks, grass waterways, filter strips and riparian buffers. An additional 10% may be added if the land is located in an EPA-designated wellhead protection area. There is also a provision for cost share of up to 50% of the cost of establishing permanent cover.

8.4.5 Fish and Wildlife Service

Technical and financial assistance are available to private landowners, profit or nonprofit entities, public agencies and public-private partnerships under several programs addressing the management, conservation, restoration or enhancement of wildlife and aquatic habitat (including riparian areas, streams, wetlands and grasslands). These programs include, but are not necessarily limited to:

Partners for Wildlife Habitat

This program provides technical and financial assistance directly to private landowners through voluntary cooperative agreements called Wildlife Extension Agreements (WEA). The program targets habitats that are in need of management, restoration or enhancement such as riparian areas, streams, wetlands and grasslands. Under these Wildlife Extension Agreements, private landowners agree to maintain the restoration projects as specified in the agreement but otherwise retain full control of the land. Depending on the number of partners, the cost share may vary somewhat but is typically 75% partners and 25% landowner.

North American Wetlands Conservation Act Grant Program

This grant program promotes long-term conservation of wetlands ecosystems and the waterfowl, migratory birds, fish and wildlife that depend upon such habitat. Conservation actions supported are acquisition, enhancement and restoration of wetlands and wetlands associated habitat. This program encourages voluntary, public-private partnerships. Public or private, profit or non-profit entities or individuals establishing public-private sector partnerships are eligible. Cost-share partners must at least match grant funds with non-federal monies. *Small Grants are typically for $50,000.*

Wildlife Conservation and Appreciation Program

This program provides grants to state fish and wildlife agencies to fund projects that bring together USFWS, state agencies and private organizations and individuals. Projects include identification of significant problems that can adversely affect fish and wildlife and their habitats, actions to conserve species and their habitats, actions that will provide opportunities for the public to use and enjoy fish and wildlife through non-consumptive activities, monitoring of species and identification o f significant habitats.

Cooperative Endangered Species Conservation Fund

This program is available to states that have a cooperative agreement with the Secretary of Interior. The intent is to provide Federal assistance too any state to assist in the development of programs for the conservation of endangered and threatened species. Potential programs include animal, plant and habitat surveys, research, planning, management, land acquisition, protection and public education. Single states may receive up to 75% of program costs.

Landowner Incentive Program (Non-Tribal)

This program provides funding directly to the lead state wildlife service agency (WGFD in Wyoming) for programs addressing the issues noted previously.

8.4.6 Natural Resources Conservation Service

The Natural Resources Conservation Service (NRCS) administers a number of funding and technical assistance programs applicable to many of the alternative projects identified in Sections 5and 6. These programs are briefly described below and summarized in Table 8.1-1.

Environmental Quality Incentives Program
The Environmental Quality Incentives Program (EQIP) is a voluntary program available to agricultural producers that provides technical assistance, cost sharing and incentive payments for projects and practices that improve water quality, enhance grazing lands, and/or increase water conservation. Current priorities used by NRCS in allocating EQIP funds that are applicable to the Clear Creek watershed include reduction of nonpoint source pollution of surface waters, reduction in soil erosion and sedimentation from agricultural lands, and promotion of at-risk species habitat conservation.

Non-federal landowners (including American Indian tribes) that engage in livestock operations or agricultural production are eligible for funding. Eligible land includes cropland, rangeland, pasture, forestland, and other farm and ranch lands. Eligibility also requires that the applicant develop an EQIP plan of operations that becomes the basis of the cost-sharing agreement between NRCS and the participant.

EQIP provides payments up to 75 percent of the incurred costs and income foregone of certain conservation practices and activities. However certain historically underserved producers (Limited resource farmers/ranchers, beginning farmers/ranchers, socially disadvantaged producers) may be eligible for payments up to 90 percent of the estimated incurred costs and income foregone. Farmers and ranchers may elect to use a certified Technical Service Provider (TSP) for technical assistance needed for certain eligible activities and services. The new Farm Bill established a new payment limitation for individuals or legal entity participants who may not receive, directly or indirectly, payments that, in the aggregate, exceed $300,000 for all program contracts entered during any six year period. Projects determined as having special environmental significance may, with approval of the NRCS Chief, have the payment limitation raised to a maximum of $450,000.

Detailed information about the EQIP program is available at the following website:

http://www.nrcs.usda.gov/PROGRAMS/EQIP/

Watershed Protection and Flood Prevention Program
Also known as the “Small Watershed Program” or the “PL 566 Program,” this program provides technical and financial assistance to address resource and related economic problems on a watershed basis. Projects related to watershed protection, flood prevention, water supply, water quality, erosion and sediment control, wetland creation and restoration, fish and wildlife habitat enhancement, and public recreation are eligible for assistance. Technical and financial

assistance is also available for planning and installation of works of improvement to protect, develop, and use land and water resources in small watersheds.

Applicants eligible for funding through this program that are potentially relevant to the Clear Creek Watershed include: local or state agencies, counties, conservation districts, or other Sub-units of state government (e.g., watershed improvement, water conservancy and irrigation districts) with the authority and capacity to carry out, operate, and maintain installed works of improvement. Projects are limited to watersheds containing less than 250,000 acres.

The assistance provided consists of technical assistance and cost sharing (amount varies) for implementation of NRCS-authorized watershed plans. Technical assistance is provided on watershed surveys and planning. Although projects vary significantly in scope and complexity, projects receiving $3.5 million to $5 million in federal financial assistance are not uncommon.

Other NRCS Programs

Other programs administered through NRCS that may be relevant to certain alternative projects discussed in Sections 4 and 5 include, but are not necessarily limited to the following:

Wildlife Habitat Incentives Program (WHIP)

Through WHIP, technical and financial assistance is provided to landowners and others to develop and improve wildlife habitat on private lands.

Wetlands Reserve Program (WRP)

Eligible landowners may receive technical and financial assistance through the WRP to address wetland, wildlife habitat, soil, water and related natural resource concerns on private lands.

Grassland Reserve Program (GRP)

This program emphasizes support for grazing operations, plant and animal biodiversity, and grassland and land containing shrubs and forbs under the greatest threat of conversion.

Farm and Ranch Lands Protection Program (FRPP)

FRPP is designed to help farmers and ranchers keep their land in agriculture. It provides matching funds to State, Tribal or local governments and non-governmental organizations with existing farm and ranch land protection programs to purchase conservation easements.

Resource Conservation and Development (RC&D)

Wyoming's five RC&D areas assist communities by promoting conservation, development and use of natural resources; improving the general level of economic activity; and enhancing the environment and standard of living for residents of those communities.

Emergency Watershed Protection (ERP)

Small Watershed Rehabilitation Program

Sage Grouse Restoration Project (SGRP)

Grazing Lands Conservation Initiative (GLCI) Grants

Cooperative Conservation Partnership Initiative (CCPI)
Under CCPI, NRCS can enter into partnership agreements with eligible entities that want to enhance conservation outcomes on agricultural and nonindustrial private forest land. A primary intent of CCPI is to leverage non-Federal government resources, along with NRCS program resources (EQIP, WHIP, and CSP) to achieve greater resource conservation objectives. Both technical and financial assistance can be leveraged.

The Request for Proposals was announced in the Federal Register April 12, 2010 and includes all the information needed to submit a proposal. http://www.gpo.gov/fdsys/pkg/FR-2010-04-12/html/2010-8244.htm

This year, applicants for CCPI competed and are being selected at the national level. Proposals were due to the NRCS National office by **May 27, 2010**.

CCPI is not a grant program, and no funds are transferred to the partner through the agreement. Once the Chief approves and announces the proposals selected, agricultural producers within the approved project areas may submit an application directly to NRCS for one or more of the following programs which may be approved for the project: EQIP, CSP, or WHIP.

Agricultural Water Enhancement Program (AWEP)
The 2008 Farm Bill authorized NRCS to enter multiyear AWEP agreements with partners to provide technical and financial assistance to EQIP eligible producers for water conservation. For 2010, $20.8 million is available for new projects under AWEP and projects compete and are selected at the national level. Though no specific match is required, leveraging of funds is very important.

The Request for Proposals for the AWEP was published in the Federal Register April 2, 2010 and includes all the information needed to submit a proposal.

http://www.gpo.gov/fdsys/search/pagedetails.action?granuleId=2010-7515&packageId=FR-2010-04-02&acCode=FR

Proposals were due to the NRCS National Office by **May 17, 2010**.

AWEP is not a grant program, and no funds are transferred to the partner through the agreement. Once the Chief approves and announces the proposals selected, agricultural producers within the approved project areas may submit an application directly to NRCS for EQIP.

Information on all NRCS programs is available from the local contacts listed Table 8.1-1.

8.4.7 US Army Corps of Engineers

The Army Corps of Engineers has civil responsibilities for flood damage reduction, hydroelectric power generation and navigational improvement as well as other water and land resource problems and needs including environmental preservation and enhancement, ecosystem management and comprehensive flood plain management. The Corps is responsible for a worldwide military construction program, an extensive environmental program and a broad national civil works program.

The Corps of Engineers is authorized to provide technical assistance to local communities, States and federally recognized Indian Tribes in support of their efforts to alleviate flooding impacts, reduce erosion and otherwise plan for the wise and prudent use of the nation's water and related land resources. They also have authority to construct certain water resources related projects and respond to water resource needs.

Planning Assistance to States
This program provides for assistance in preparation of plans for the development, utilization and conservation of water and related land resources. The Corps provide technical planning assistance in all areas related to water resources development such as bank stabilization, sedimentation, water conservation, ecosystem and watershed planning and water quality. Assistance is limited to $500,000 per state and studies are cost-shared on a 50-50 basis with a non-federal sponsor such as a state, public entity or an Indian Tribe.

Flood Plain Management Services
This program provides technical services and planning guidance for support and promotion of effective flood plain management. Flood and flood plain data are developed and interpreted with assistance and guidance provided in the form of "Special Studies" on all aspects of flood plain management planning. All services are provided free of charge to local, regional, state or non-federal public agencies. Federal agencies and private entities have to cover 100% of costs.

Flood Damage Reduction Projects
This program provides structural and non-structural projects to reduce damages caused by flooding and focuses on solving local flood problems in urban areas, towns and villages. The Corps works with the project sponsor to define the flood problem, evaluate solutions, select a plan, develop the design and construct a project. A feasibility study is conducted to identify potential projects with the first $100,000 of the cost Federal. Any cost above this amount is cost-shared 50-50 with the sponsor in the form of cash and in-kind services. Construction lands, easements, rights-of-way, relocations and disposal and 5% of the projects costs are the sponsor's responsibility. Operation and maintenance and a maximum of 50% of total project cost are the sponsor's responsibility.

Project Modification for Improvement of Environment
The purpose of this program is to modify structures or operation of previously constructed water resources projects to improve environmental quality, especially fish and wildlife values. A

study, at federal expense, is initiated followed by a feasibility plan that is cost-shared 25% by the sponsor.

Aquatic Ecosystem Restoration
This effort is for restoration of historic habitat conditions to benefit fish and wildlife resources. This is primarily to provide structural or operational changes to improve the environment such river channel reconnection, wetland creation or improving water quality. Conditions are similar to the Project Modification program with sponsor cost share being 35%.

Water Resources Projects
The purpose of this program is to construct larger projects for flood damage reduction and to provide technical assistance in resolving more complex water resource problems. It is used to evaluate projects costing more than $10 million that include purposes of flood control, water supplies, water quality, environmental protection and restoration, sedimentation or recreation. This would include reservoirs, diversions, levees, channels or flood plain parks as examples. The Corps works with a non-federal sponsor to define the flood or water resource related problem or opportunity, evaluate flood control or solutions, select a plan, develop a design and construct a project. This requires special authorization and funding from Congress with a reconnaissance study being federal cost. A feasibility study to establish solutions is cost-shared 50% by the non-federal sponsor with 35 to 50% of construction cost the responsibility of the sponsor.

Support for Others Program
This program provides for environmental protection and restoration or facilities and infrastructure. This includes Environmental Planning and Compliance, Economic and Financial Analyses, Flood Plain Management, Cultural Resources and General Planning. All costs for these programs are provided by the customer agency.

Regulatory Authority/Responsibility
The Corps of Engineers has regulatory authority under the Clean Water Act and the River and Harbor Act. The purpose of these laws is to restore and maintain the chemical, physical and biological integrity of waters of the United States. Section 404 of the Clean Water Act authorizes the Corps to regulate the discharge of dredged or fill material into waters. This would include dams and dikes, levees, riprap, bank stabilization and development fill. There are three kinds of permits issued by the Corps. They are Individual, Nationwide and Regional General permits.

8.4.8 USDA Forest Service

A number of Federal laws direct or authorize watershed management on National Forest Service lands. Some of these laws provide broad authority while others deal more narrowly with specific watershed management activities.

The objectives of the Forest Service watershed management program are to protect and enhance soil productivity, water quality, water quantity and timing of water flows and to maintain favorable conditions of stream flow and continuous production of resources from National Forest System watersheds.

It is the policy of the Forest Service to implement watershed management activities on National Forest System lands in accordance with general objectives of multiple use and the specific objectives in the forest land management plans for the area involved. It is also the intent to design management activities of other resources to minimize short term impacts on soil and water resources and to maintain or enhance long term productivity, water quality and water quantity.

The Clean Water Action Plan provides broad water quality direction for the Forest Service. Specific direction for water quality is contained in the Land and Resource Management Plan for each National Forest. The forests in Wyoming are in the process of completing the Inland West Water Reconnaissance which will provide a classification of watersheds and stream reach conditions. Forest Service water quality programs are coordinated with Wyoming Department of Environmental Quality and other appropriate agencies. The Forest Service also has a water rights program that is coordinated with the Wyoming State Engineer.

The Forest Service, in conjunction with other federal, state and local agencies, provides watershed management and condition training. T-WALK and Proper Functioning Condition surveys are field methods used to assess stream reach and other water body condition.

8.4.9 Rural Utilities Service

The United States Department of Agriculture, Rural Development's utilities program is authorized to provide financial assistance for water and waste disposal facilities in rural areas and towns of up to 10,000 people. This program is intended for Non-profit corporations and public bodies such as municipalities, counties, and special purpose districts and authorities.

Funding may be obtained through Rural Development only when the applicant is unable to secure funding from other sources at reasonable rates and terms. The applicant must have legal capacity to borrow and repay loans, to pledge security for loans and to operate and maintain the facilities. The applicant must be financially sound and able to manage the facility effectively as well as have a financially sound facility based upon taxes, assessments, revenues, fees or other satisfactory sources of income to pay costs of operating, debt service and reserve. Grants are also available and are used to supplement loans to reduce debt service where necessary to achieve reasonable user rates. Assistance is also available on how to assemble information concerning engineering, financing and management of proposed improvements.

Loans and grants may be used to construct, repair, improve, expand or modify rural water supplies and distribution facilities such as reservoirs, pipelines, wells and pumping stations, waste collection, pumping, treatment or other disposal facilities. This assistance may also be

used to acquire a water supply or water right or finance facilities in conjunction with funds from other agencies or those provided by the applicant. These funds can be used to pay legal and engineering fees connected with the development of a facility or pay other costs related to development including rights-of-way or easements and relocation of roads or utilities. Loan terms are a maximum of 40 years, State Statute, or the useful life, whichever is less with interest rates based on current market yields for municipal obligations.

USDA Rural Development also guarantees loans to eligible commercial lenders to improve, develop, or finance water or waste disposal facilities in rural areas. This guarantee is a warrant to protect the lender and may cover up to 90% of the principal advanced. The guarantee fee is 1% of the loan amount multiplied by the percent of the guarantee. Interest rates will be negotiated between the lender and the borrower.

8.5 NON-PROFIT AND OTHER ORGANIZATIONS

8.5.1 Ducks Unlimited

Ducks Unlimited, Inc. (DU) is a potential funding source for wetlands and waterfowl restoration projects. Although direct grant funding is limited (to the extent that there is generally about $20,000 to $30,000 available annually statewide), in-kind assistance may be available from the local chapter of DU. Additional information on DU's funding programs and opportunities is available in the Water Management & Conservation Assistance Program Directory referenced previously.

8.5.2 National Fish and Wildlife Foundation

The National Fish and Wildlife Foundation (NFWF) is a private, non-profit, tax exempt organization chartered by Congress in 1984 to sustain, restore and enhance the Nation's fish, wildlife, plants and habitats. NFWF provides grant funding on a competitive basis through their Keystone Initiative Grants and Special Grant Program. Some of the grants/programs that may be applicable to potential projects in the Clear Creek watershed include, but are not limited to the following:

Pulling Together Initiative
Provides support on a competitive basis for the formation of local Weed Management Area (WMA) partnerships that engage federal resource agencies, state and local governments, private landowners, and other interested parties in developing long-term weed management projects within the scope of an integrated pest management strategy; minimum 1:1 nonfederal match is required.

Native Plant Conservation Initiative
This program has funding preference for "on-the-ground" projects that involve local communities and citizen volunteers in the restoration of native plant communities.

Bring Back the Natives Grant Program
This funding source can be used to restore damaged or degraded riverine habitats and their native aquatic species provided by BLM, Bureau of Reclamation, FWS, Forest Service, and NFWF; minimum 2:1 nonfederal match required.

Five-Star Restoration Program
This program provides modest financial assistance on a competitive basis to support community-based wetland, riparian, and coastal habitat restoration projects that build diverse partnerships and foster local natural resource stewardship through education, outreach and training activities; average grant is $13,000.

Information about all of these and other NFWF grants/programs is available at their website:

http://nfwf.org/

8.5.3 Trout Unlimited

The Wyoming Council of Trout Unlimited provides funding and volunteer labor for a variety of stream and watershed projects such as erosion control and fish habitat structures, willow and other riparian plantings and stream protection fencing. Embrace-A-Stream grants are available for up to $10,000 per project. Partnerships are encouraged and can include local conservation districts and state and federal agencies.

TABLE 8.1-1 POTENTIAL FUNDING SOURCES

Agency/Entity	Program Name	Project Type(s)	Internet Site	Telephoone	Email
LOCAL					
Lake DeSmet Conservation District	n/a	Liason, in-kind administrative and technical assistance, program	ttp://www.conservewy.com/wacd/districts/ lake_desmet.htr	307.684.2526	nikki.lohse@wy.nacdnet.net
Sheridan County Conservation District	n/a	Liason, in-kind administrative and technical assistance, program	http://www.sccdofwyo.org/	307.672.5820	Carrie.Rogaczewski@wy.nacdnet.net
Johnson County Weed and Pest District	n/a	Noxious weed and undesirable plant control	http://www.johnsoncountywyoming.org/Weed%20and%20Pest/weed_and_pest_home.htm	307.684.5715	jcwp@qwestoffice.net
Sheridan County Weed and Pest District	n/a	Noxious weed and undesirable plant control	http://www.sheridancounty.com/info/scwp/overview.php	307.672.3740	scwp@fiberpipe.net
State					
Wyoming Department of Environmental Quality	Nonpoint Source Implementation Grants (319 Program)	Water Quality BMP's	http://deq.state.wy.us/wqd/watershed/index.asp	307.777.7072	See WDEQ Website for contract directories
Wyoming Game and Fish Department	Riparian Habitat Improvement Grant	Stock Water Development; streambank stabilization; etc.	http://gf.state.wy.us	307.777.4565	gbutle@state.wy.us
	Water Development/Maintenance Habitat Project Grant	Water developments (springs, windmills, guzzlers, pumps, etc.)			
	Upland Development Grant	Range management; prescribed burns			
	Fish Wyoming	Public fishing opportunities			
	Wyoming Sage Grouse Conservation Fund	Sage-grouse habitat protection or improvement			
Wyoming Office of State Lands and Investments	Regular Farm Loans	Projects involving most agricultural purposes	http://slf-web.state.wy	307.777.7331	lboomg@state.wy.us
	Small Water Development Project Loans	Conversion of dry land to irrigated land and/or water use efficiency improvements			
Wyoming Water Development Commission	Wyoming Water Development Program	Planning, design, and construction of new reservoir storage and rehabilitation of existing reservoir storage projects	http://wwdc.state.wy.us/opcrit/final_opcrit.pdf	307.777.7626	jwade@state.wy.us
	Small Water Project Program	Small reservoirs and stock ponds			rvore@state.wy.us
Wyoming Wildlife and Natural Resource Trust	n/a	Aquatic and wildlife habitat improvement, including water developments, prescribed burns, invasive plant control, etc.	http://wwnrt.state.wy.us	307.856.4665	n/a
Federal					
Bureau of Land Management	Riparian Habitat Management Program	Projects to maintain, restore, improve, protect, and expand riparian/wetland areas.	http://www.blm.gov/wy/st/en.html	307.775.6092 (Rick Schuler)	Rick_Schuler@blm.gov
	Cooperative Agreement for Range Improvements	Reservoirs, pits, spring developments, wells, and associated distribution pipelines.	http://www.blm.gov/wy/st/en/field_offices/Buffalo.html	307.684.1100	Buffalo_WYMail@blm.gov
Bureau of Reclamation	Water 2025 Challenge Grant Program	Water conservation, efficiency and marketing.	http://www.doi.gov/water2025/	307.261.5671	jlawson@gp.usbr.gov
Environmental Protection Agency	Targeted Watershed Grants Program	Riparian, wetland, aquatic, and upland habitat protection and improvement.	http://www.epa.gov/owow/funding/watershedfunding.html	202.566.1730	center.water-resource@epa.gov
Farm Service Agency	Conservation Reserve Program (CRP)	Removal of highly erodible lands from production	a.gov/FSA/stateoffapp?mystate=wy&area=home&subject=lar	307.261.5081	cindy.ottel@wy.usda.gov
	Continuous Sign-Up for High Priority Conservation Practices	Riparian buffers, filter strips, grass waterways, salt tolerant vegetation, shallow water areas for wildlife, etc.			
	Emergency Conservation Program (ECO)	Emergency livestock watering conservation during severe drought.			
Fish and Wildlife Service	Partners for Wildlife Habitat Restoration	various fish and wildlife habitat restoration projects	http://ecos.fws.gov/partners/viewContent.do?viewPage=hom	307.332.8719	mark_j_hogam@mail.fws.gov
	North American Wetlands Conservation Act Program	Various wetlands conservation projects	http://www.fws.gov/birdhabitat/Grants/NAWCA/index.shtm		
	Landower Incentive Program (Non-Tribal)	Funding to WGFD to support above project types			
Natural Resources Conservation Service	Environmental Quality Incentives Program	Conservation planning, range management, irrigation rehabilitation, livestock watering, etc.	http://www.nrcs.usda.gov/PROGRAMS/EQIP	307.233.6750 (State Office) 307.684.2526 (Buffalo)	shelly.thomas@wy.usda.gov (State) allison.mckenzie@wy.usda.gov (Buffalo)
	Watershed Protection and Flood Prevention Program	Water Supply, water quality control, erosion and sediment control, wetland creation and restoration, fish and wildlife habitat enhancement, flood control, public recreation, etc.	http://www.nrcs.usda.gov/programs/watershed/index.html		
	Wildlife Habitat Incentives Program (WHIP)	See websites and/or local contacts for detailed information on these programs.	http://www.nrcs.usda.gov/programs/whip/		
	Wetlands Reserve Program (WRP)		http://www.nrcs.usda.gov/programs/wrp/		
	Grassland Reserve Program (GRP)		http://www.nrcs.usda.gov/programs/GRP/		
	Conservation Security Program (CSP)		http://www.nrcs.usda.gov/programs/csp/		
	Farm and Ranchlands Protection Program		http://www.nrcs.usda.gov/programs/frpp/		
	Emergency Watershed Protection (ERP)		http://www.nrcs.usda.gov/programs/ewp/		
	Sage Grouse Restoration Project (SGRP)		http://sgrp.usu.edu/		
	Grazing Lands Conseration Initiative (GLCI) Grants		http://www.nrcs.usda.gov/programs/glci/		
Private Groups					
Ducks Unlimited	n/a	Waterfowl, aquatic, and upland habitat protection, restoration and enhancement	http://www.ducks.org/Page1856.aspx	307.472.6980	carol.m.perry@wellsfargo.com
National Fish and Wildlife Foundation	Pulling Together Initiative	Long-term weed management projects	http://www.nfwf.org/AM/Template.cfm?Section=Grants	202.857.0166	info@nfwf.org
	Native Plant Conservation Initiative	Restoration of native plant communities			
	Bring Back the Natives Grant Program	Riverine habitat and aquatic species restoration projects			
	Five-Star Restoration Progarm	Wetland and riparian habitat restoration			
Trout Unlimited	Watershed Restoration	Erosion control, fish habitat structures, willow and other riparian plantings, etc.	ww.tu.org/conservation/watershed-restoration-home-rivers-	307.332.7700	syates@tu.org

IX. Conclusions and Recommendations

This study developed an inventory of the watershed to identify resource concerns. A Geographic Information System (GIS) was developed for a wide range of resources. The resource concerns were investigated and a watershed management plan was developed to address the issues. The following conclusions and recommendations address the watershed management plan.

9.1 CONCLUSIONS

Based on the work performed for this study, the following conclusions have been formulated. The conclusions address the watershed issues identified in the study.

9.1.1 Upland/Wildlife Watering Opportunities

1. A large percentage of the grazing lands in the watershed appear to be within one mile of a water source, however, further opportunities exist in the watershed to improve upland water supplies for livestock/wildlife.

2. A total of five potential wildlife/livestock water supply projects were identified. These projects primarily involved pipelines and tanks to provide additional watering.

9.1.2 Stream Channel Condition and Stability

1. There were limited channel reaches in the study that were identified as systemically impaired. Generally the Clear Creek system appears to have stable bank and channel characteristics. Some localized instances of stream bank erosion are evident.

2. Riparian vegetation degradation has occurred in the lower reaches of Clear Creek as little or no riparian buffer has been maintained in these areas.

3. Five potential channel stability projects were identified. These projects involved bank protection and channel management to reduce erosion.

9.1.3 Grazing Management Opportunities

1. Strategies, recommended in the state and transition models associated with NRCS descriptions of the ecological sites found within the watershed, should be adopted and employed to optimize range conditions through prescribed grazing management and best management practices.

2. Prescribed fire and other mechanical range treatments should be utilized as a tool to assist in the restoration of range health in areas benefitting by these treatments according to the state and transition models.

9.1.4 Invasive Species Treatment

1. Management efforts targeting Russian Olive and Leafy Spurge have been largely successful and continuation of these efforts is encouraged.

2. Noxious weed management programs currently being conducted by the respective weed and pest control districts of Johnson and Sheridan Counties should continue. Education opportunities for land owners and managers should continue to be made available.

9.1.5 Irrigation System Opportunities.

1. A total of 30 ditch systems were inventoried. The inventories concentrated on the primary issues identified with the systems.

2. The structures and canals in need of rehabilitation were preliminarily designed and cost estimates were developed.

3. A rehabilitation plan prioritizing needed improvements was developed.

4. The potential for combining several ditch diversions and canals into single systems was evaluated. In addition, developing piped conveyance systems and incorporation of irrigation improvements with storage concepts were evaluated. Conceptual designs and cost estimates were developed for six conceptual projects.

9.1.6 Water Supply and Storage Opportunities

Potential reservoir sites were derived from previous studies, input from irrigators and sponsors, and new sites identified by the consultants to meet needs. These sites were preliminarily screened to eliminate sites that would not be feasible. A total of eleven sites were advanced to preliminary design and analysis. Those eleven sites were investigated by the project team for hydrologic adequacy, geotechnical conditions, environmental effects, and suitability for the purpose and need. Sites matrix tables are shown previously in Section 6 (Tables 6.3-1 and 6.3-2).

Estimated Costs

The estimated costs for the representative sizes of reservoirs were developed. These costs are summarized in Table 9.1-1. The estimated costs are total project costs including all foreseeable items. The total project costs include supply and delivery systems for off-channel storage sites. Also included are engineering costs, land acquisition costs, environmental mitigation costs, and legal costs. The costs were developed to reflect 2011 prices.

Table 9.1-1 Storage Cost Summary

Site	Size (AF)	Cost in Millions	Unit Cost
Upper Middle Clear Creek Reservoir	5,000	$68.0	$13,600
Lower Middle Clear Creek Reservoir	3,800	$80.0	$21,052
Camp Comfort Reservoir	10,400	$57.0	$5,481
Tie Hack Reservoir Enlargement	1,400	$12.0	$8,570
Sand Creek Reservoir	4,000	$27.0	$6,750
Sand Creek Reservoir	8,000	$39.0	$4,875
Bench Reservoir	3,500	$33.0	$9,429
Bull Creek Reservoir	4,000	$32.0	$8,000
Bull Creek Reservoir	9,170	$41.0	$4,471
French Creek Reservoir #3	3,000	$44.2	$14,730
French Creek Reservoir #3	5,500	$59.5	$10,820
French Creek Reservoir #8	2,500	$21.9	$8,760
French Creek Reservoir #8	5,500	$39.9	$7,255
North Rock Creek Reservoir	8,800	$60.0	$6,818
North Rock Creek Reservoir	3,650	$32.0	$8,767
Lake DeSmet Transfer – Existing pipeline	4,000	$2.9	$725
Lake DeSmet Transfer – Canal	4,000	$4.1	$1,025

Storage Evaluation Matrix

To evaluate the non-monetary factors for reservoir suitability, a matrix was developed as shown in Table 9.1-2. This matrix values items such as ability to meet needs, land ownership, environmental issues, technical feasibility, multi-purpose potential, and ability to permit. Each of the items was assigned a weight based on the importance of the item for this project. Weights of 10 to 40 were assigned as shown in the table. Each potential reservoir site was assigned a value of 0 to 10 for each item with high values being most favorable. The scores were then totaled to develop overall reservoir site evaluation.

Table 9.1-2 Clear Creek Storage Evaluation Matrix

Rank	Site	Size (AF)	Ability to Meet Needs	Land Ownership	Envir. Issues	Geotechnical Feasibility	Flood Control	Multi-Purpose Potential	Ability to Permit	Relative Cost	Total Score	Comments
	Weight		**40**	**20**	**30**	**20**	**20**	**40**	**40**	**20**		
1	Bull Creek Reservoir	9,170	8	10	8	6	4	8	10	8	1,840	Note 1
2	Sand Creek Reservoir	8,000	8	6	8	6	4	8	10	8	1,760	Note 1
3	Camp Comfort Reservoir	10,400	10	4	4	6	8	10	4	8	1,600	Note 1
4	Bench Reservoir	3,500	4	10	10	6	0	2	10	6	1,380	Note 1
4	French Creek Reservoir #3	5,500	8	4	6	6	4	10	4	2	1,380	Note 1
6	French Creek Reservoir #8	5,500	8	2	6	6	4	10	2	6	1,340	Note 1
7	North Rock Creek Reservoir	6,600	6	4	6	4	4	6	4	2	1,100	
8	Upper Middle Clear Creek Reservoir	5,000	6	2	4	6	4	6	2	2	960	Note 1
9	Lower Middle Clear Creek Reservoir	3,800	4	2	4	6	4	4	2	2	800	Note 1
10	Tie Hack Reservoir Enlargement	1,400	2	2	4	8	2	2	4	5	780	Note 1
11	Willow Park Enlargement	4,000									0	Fatal Flaw-Fen Wetlands

Note 1 - The feasibility of new storage in the Clear Creek basin is dependant on the utilization of the M&M Ranch water rights from Clear Creek. If the water rights are fully utilized, insufficient water would be available for new storage projects.

9.2 RECOMMENDATIONS

Based on the information developed for this report, the following recommendations are made.

9.2.1 Upland Watershed Management Opportunities

Smaller projects involving upland watering, stream channel improvement and grazing management could be eligible for the WWDC's Small Water Project Program (SWPP). As summarized in Section 8, projects with a total project cost of less than $100,000 are eligible. Grants can be available up to 50% of the project costs or $25,000, whichever is less. Funding through this program does not require formation of a district, but does require a legal entity sponsor.

9.2.2 Irrigation System Opportunities

1. Smaller irrigation system rehabilitation projects could be eligible for the WWDC's Small Water Project Program (SWPP). As summarized in Chapter 8, projects with a total project cost of less than $100,000 are eligible. Grants can be available up to 50% of the project costs or $25,000, whichever is less. Funding through this program does not require formation of a district, but does require a legal entity sponsor.

2. Larger projects would be eligible for funding under WWDC's larger project program. This program offers two thirds grant and one third loan for rehabilitation projects. Projects in this program would require formation of a district or entity that can incur debt and has the authority under State statute to levy assessments.

3. Potential projects under both programs have been prioritized.

9.2.3 Water Supply and Storage Opportunities

The opportunities for improvement of water supply and storage in the Clear Creek basin that are most favorable have been identified. The opportunities are summarized below.

9.2.3.1 Utilization of Lake DeSmet Water in Clear Creek

The issues that must be addressed to evaluate the feasibility of this alternative include the following:

- Availability and costs of coalition storage water
- Willingness of M&M to allow use of their pipeline to deliver water
- Identification of potential users of water discharged to Clear Creek to establish demand
- Preliminary design and cost estimates of the project

- Funding opportunities for the project

9.2.3.2 Bull Creek and Sand Creek Reservoir Projects

The feasibility of construction of either the Bull Creek or Sand Creek Reservoir projects would involve the following issues:

- The hydrological studies have indicated that the water availability depends upon the potential for M&M Ranch to fully utilize their Clear Creek water rights to Lake DeSmet. The feasibility of the storage projects could depend upon the extent of usage of these water rights.
- The project would require the cooperation of the irrigation ditches directly impacted by the dam and reservoir, supply system, and discharge pipeline.
- A more rigorous hydrological model is needed to establish water availability and irrigation shortages. The WWDC has been utilizing the StateMod model for this type of study.
- The geotechnical feasibility investigation of the dam sites should be conducted. The program should include core drilling and test pit investigations.
- The optimum size of reservoir should be established. Preliminary design and updated cost estimates should be developed.
- The economic analysis should be updated to incorporate the optimum size and fully evaluate project benefits to establish the benefit-cost ratio.
- The grant-loan ratio from the WWDC should be determined to determine project feasibility.

References

B. Berwyn (2005). *Water Trust Finalizes First Sale*. Summit Daily News. June 3, 2005.

Brookshire, David S. and Watts, Gary L. (1987). Economic Impacts of the Proposed Rinconada Unit Diversions-Mescalero Apache Indian Reservation. Report to the Village of Ruidos, New Mexico. August 1987.

Bureau of Land Management Buffalo Field Office (2001). *Approved Resource Management Plan for Public Lands Administered by the Bureau of Land Management Buffalo Field Office.* April 2001.

Bureau of Land Management (2009). *Final Scoping Report: Buffalo Resource Management Plan Revision Project.*

Bureau of Land Management, 2009. *Summary of the Analysis of the Management Situation Buffalo Resource Management Plan Revision*. March 27, 2009

Clarion/Fehr & Peers/ AVI (2008). *Sheridan County Comprehensive Plan*, Prepared for Sheridan County , Adopted December 2008.

Clark, M.L. and J.P. Mason. 2007. Water-Quality Characteristics for Sites in the Tongue, Powder, Cheyenne, and Belle Fourche River Drainage Basins, Wyoming and Montana, Water Years 2001-05, with Temporal Patterns of Selected Long-Term Water_Quality Data. U.S. Department of the Interior, U.S. Geological Survey. Scientific Investigations Report 2007-5146.

Clark, M.L., Miller, K.A., and Brooks, M.H., 2001, U.S. Geological Survey monitoring of Powder River Basin stream-water quantity and quality: U.S. Geological Survey Water-Resources Investigations Report 01–4279, p.8, Rice, C.A., Ellis, M.S., and Bullock, J.H., Jr., 2000, Water co-produced with coalbed methane in the Powder River Basin, Wyoming—Preliminary compositional data: U.S. Geological Survey Open-File Report 00–372, 20 p.

Case, J.C., Arneson, C.S., and Hallberg, L.L. (1998). *Preliminary Surficial Geologic Map of Wyoming*. Wyoming Geological Survey Map HSDM 98-1.

Case, J.C., Coombs, L.A., and Larsen, L.L., 1991, *Landslide Map of the Sheridan 1x2 Quadrangle: Geological Survey of Wyoming*, Open File Report 91-2C

Dobrovolny, E. (1981). *Geologic Map of the Buffalo Quadrangle, Johnson County, Wyoming*. Unites States Geological Survey Map GQ-1552.

Feck, J. and Nibbelink, P.J. 2003. Watershed Analysis of Stream Flow Diversion Influences on Aquatic Ecosystem Health. Clear Creek Watershed. Trout Unlimited & The Nature Conservancy.

Food and Agriculture Organization of the United Nations, Rome. Reprinted 1989, 1994. Available online at http://www.fao.org/DOCREP/003/T0234E/T0234E00.htm

Ganjegunte, Girisha K., George F. Vance, and Lyle A. King. University of Wyoming, Department of Renewable Resources. 2005. "Soil Chemical Changes Resulting From Irrigation With Water Co-Produced With Coalbed Natural Gas." *Journal of Environmental Quality*. Volume Vol. 34: 2217-2227.

Gannett Fleming. 2003. *Little Snake River Dams Level II Study.* Report to the WWDC. July 2003.

Geologic Map of the Buffalo Quadrangle, Johnson County, Wyoming, Map GQ-1552, 1981, United States Geological Survey. (1:24,000 scale)

Geological Map of the Buffalo 30' x 60' Quadrangle, Johnson and Campbell Counties, Wyoming, Map Series 59, 2002, Wyoming State Geological Survey. (1:100,000 scale)

Greenwood, Larry (BLM 2004). *Multiple Use Management – Dixie Harrow Style*, Bureau of Land Management Resources Notes, No. 75, Page 1 and 2. 09/10/2004.

Hanson, B.R., Grattan, S.R., and Fulton, A., 1999, Agricultural salinity and drainage: Davis, Calif., University of California Irrigation Program, Division of Agriculture and Natural Resources Publication 3375, p. 163, Ayers, R.S. and D.W. Westcott. 1985. Water Quality for Agriculture.

HKM (2002). *Powder/Tongue River Basin Plan*. Prepared for State of Wyoming Water Development Commission. Prepared by HKM Engineering Inc., Lord Consulting, and Watts and Associates, February 2002.

Java Ground Motion Parameter Calculator, United States Geological Survey, available at http://earthquake.usgs.gov/hazards/designmaps/

Kelly, James. Natural Resources Conservation Service and Lake DeSmet Conservation District (2008). *Lake DeSmet Conservation District Portion of Clear Creek Watershed Rapid Watershed Assessment,* December 2008.

Loomis, John B. (2007). *Estimating the Public's Values of Instream Flow: Economic Techniques and Dollar Values.* Journal of the American Water Resources Association. Vol 43.

Love, J.D. and Christiansen, A.C. (1985). *Geologic Map of Wyoming*, United States Geological Survey.

Myers, Sue (2008). *Keeping ahead of Leafy Spurge, through Integrated Pest Management.* January 2008.

National Weather Service, Advanced Hydrologic Prediction Service. http://water.weather.gov/ahps2/index.php?wfo=riw

NRCS Online Soils Data Mart. http://soildatamart.nrcs.usda.gov/

Petersen Planning Consultants (2005). *Johnson County Comprehensive Land Use Plan*, Prepared for Johnson County, March 2005.

Platt, Jonathon (2001). *Economic Valuation of Instream Flows.* U.S. Department of the Interior, Bureau of Reclamation. April 2001.

Preliminary Digital Surficial Geologic Map of the Buffalo 30' x 60' Quadrangle, Johnson and Campbell Counties, Wyoming, Map HSDM 00-02, 2000, Wyoming State Geological Survey. (1:100,000 scale)

PRISM Climate Group, Oregon State University. http://www.prism.oregonstate.edu/

Rosgen, David L. (1996). *Applied River Morphology. Wildland Hydrology Books*, Pagosa Springs, Colorado

R.P. Berrens, A.K. Bohara, C.L. Silva, D. Brookshire, and M. McKee (2000). *Contingent Values of New Mexico Instream Flows.* Journal of Environmental Management. Vol. 58.

Seismicity Map of the State of Wyoming, Map MF-1798, 1985, United States Geological Survey. (1:100,000 scale)

States West (2008). *Hopkins Producers Irrigation District Watershed/Water Storage Project, Level I Study.* Prepared for State of Wyoming Water Development Commission. Prepared by States West Water Resources Corp, Hollingsworth Associates, and Western EcoSystems Technology, October 2008.

U.S. Department of Commerce (2007). *Regional Multipliers: A User Guide for the Regional Input-Output Modeling System (RIMS II).* Bureau of Economic Analysis.

United States Forest Service (2009). Allotment Management Plans (AMPs). Various AMPs associated with individual grazing allotments administered by the USFS.

United States Forest Service (2005). *Bighorn National Forest: Revised Land and Resource Management Plan*

U.S. Geological Survey (USGS) (2002). Earthquake Ground Motion Parameter Calculator, Version 5.0.9a accessed 28 September 2010. < http://earthquake.usgs.gov/hazards/designmaps/javacalc.php>.

U.S. Geological Survey (USGS) Wyoming Water Science Center. http://wy.water.usgs.gov/

Ver Ploeg, A.J. and Boyd, C.S. (2002). *Geologic Map of the Buffalo 30' x 60' Quadrangle, Johnson and Campbell Counties, Wyoming*. Wyoming Geological Survey Map Series 59.

Ver Ploeg, A.J. and Boyd, C.S. (2005). *Geologic Map of the Sheridan 30' x 60' Quadrangle, Sheridan, Johnson and Campbell Counties, Wyoming, and Southeastern Montana*. Wyoming Geological Survey Map Series 59.

Watts, Gary L and David Brookshire (2000). *An Economic Analysis of Impacts to Nebraska and Wyoming from post-1945 Changes in North Platte River Basin Water Use.* Report to the Wyoming Attorney General. February 2000.

West, T.R. (1995). *Geology Applied to Engineering*. Prentice Hall, Englewood Cliffs, New Jersey.

www.netstate.com/states/geography/wy_geography.htm

Weston Engineering. (2008). *Clearmont CBM Impact Level 1 Study*. Prepared for State of Wyoming Water Development Commission.

Wyoming Agricultural Statistics Service (2009). *Wyoming Agricultural Statistics.*

Wyoming Department of Environmental Quality (WDEQ), Water Quality Division, Surface Water Standards. 2001. Wyoming Surface Water Classification List. June 21. Available online at http://deq.state.wy.us/wqd/watershed/surfacestandards/Downloads/Standards/2-3648-doc.pdf.

Wyoming Department of Environmental Quality (WDEQ). No date. Water Quality Rules and Regulations, Chapter 1. Available on line at http://soswy.state.wy.us/Rules/RULES/6547.pdf.

Wyoming Department of Environmental Quality (WDEQ) (2010). *Wyoming Water Quality Assessment and Impaired Waters List (2010 Integrated 305(b) and 303(d) Report).* Available online at: http://**deq**.state.**wy**.us/wqd/watershed/Downloads/305b/**2010/WY2010**IR.pdf

Wyoming Game and Fish Department (1994). *Instream Flow Studies on Clear Creek*, Paul D. Dey, and Thomas C. Annear, August 1994.

Wyoming Game and Fish Department (2008). *Strategic Habitat Plan, Clear Creek Management Basin*, November 2008.

Wyoming Game and Fish Department (2010). *Wyoming State Wildlife Action Plan, Yellowstone River Basin*.

Western Regional Climate Center. Western U.S. Climate Historical Summaries. http://www.wrcc.dri.edu/

Wyoming Water Development Office (2008). Operating Criteria of the Wyoming Water Development Program, Approved June 5, 2008.

Wyoming Water Research Center (1987). *Development of Evapotranspiration Crop Coefficients.* Available at http://library.wrds.uwyo.edu/wrp/87-06/ch-03.html.

Yochum, Steve. Natural Resources Conservation Service (2006). *Willow Park Reservoir PMP Analysis, Johnson County, Wyoming.* January 2006.